SECTION 26 05 01

COMMON WORK RESULTS – ELECTRICAL

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Requirements specified within this section apply to all sections in Division 26, Electrical. This section supplements requirements of other Divisions.

1.2 CODES AND STANDARDS

A. Manitoba Building Code (MBC).

B. The Winnipeg Electrical By-law (WEB)

C. CSA C22.1 Canadian Electrical Code - Part 1 (CEC)

D. CSA C22.2 No. 0 General Requirements - Canadian Electrical Code - Part 2

E. CAN3-C235 Preferred Voltage Levels for AC Systems, 0-50,000 V

F. Electrical and Electronic Manufacturers Association of Canada (EEMAC)

G. National Electrical Manufacturers Association (NEMA)

H. Institute of the Electrical and Electronic Engineers (IEEE)

I. Insulated Cable Engineers Association (ICEA)

J. Canadian Standards Association (CSA)

K. Underwriters Laboratories Canada (ULC)

L. American National Standards Institute (ANSI)

M. National Fire Protection Agency (NFPA)

N. Comply with the most current locally enforced edition of CSA C22.1 Canadian Electrical Code - Part 1, Winnipeg Electrical By-law, Provincial Safety Electrical Authority Codes and Bulletins.

O. Comply with all laws, ordinances, rules, regulations, codes, and orders of all authorities having jurisdiction relating to this Work. Where these regulations conflict, comply with the most stringent condition.

P. Comply with latest editions of the CSA Certification Standards and Bulletins.

1.3 DRAWINGS AND SPECIFICATIONS

A. All materials, equipment, labor, work denoted on the Drawing set is to be considered as new work, to be provided by the Contractor unless specifically noted otherwise. Some of the electrical and automation Drawings show existing systems (with modifications to these systems). These Drawings specifically indicated that there are existing systems shown. Where Drawings do not specifically indicate that existing systems are depicted, the Contractor shall assume that the materials, equipment, labor, work indicated will form part of his scope, and the Contractor shall include all costs (including materials, labor, etc) to perform the work.

B. Prior to installing power and control cabling for process equipment, the Contractor shall review the equipment Shop Drawings, and to ensure that cabling requirements are understood. There may be variations in wiring requirements with process and HVAC equipment, that may require alternate wiring requirements from that shown on the Drawings. Include such wiring and connections in tender at no additional costs.

C. The electrical Drawings in some cases indicate the size of cables, breakers, conduits, etc. These sizes are based on the supply of specific sizes of equipment. For cases where the Contractor supplies equipment that varies from these assumptions it is the responsibility of the Contractor to provide the correct size of breaker, cable, etc to suit the installation, at no additional cost to the Contract.

D. The intent of the Drawings and Specifications is to indicate labor, products, and services necessary for a complete, installed, tested, commissioned and functional installation.

E. Electrical Drawings may indicate approximate route to be followed by conduits and cables and general location of electrical equipment. They do not show all structural, architectural and mechanical details. In some cases, conduit or wiring is only shown diagrammatically on the Drawings. The details on exact cable or conduit routing, and exact equipment installation location is to be determined on site and coordinated with all other trades.

F. Where circuit numbers are shown adjacent to equipment, the Electrical Contractor shall provide all wiring, conduit, supports, and any other requirements to provide power to that piece of equipment from the circuit indicated. Where circuit numbers are not shown adjacent to a piece of 575V equipment, refer to the single line drawings for connections details. Provide all wiring, conduit, supports, and any other requirements to provide power to that piece of equipment.

G. To provide sufficient detail and maximum degree of clarity on the Drawings, symbols used for various electrical devices, particularly wall mounted devices, take up more space on the Drawings than devices physically do. Locate devices with primary regard for convenience of operation, accessibility and space utilization, rather than locating devices to comply with the exact scaled locations of the electrical symbols.

H. These Specifications along with the Drawings and Specifications of all other divisions shall be considered as an integral part of the Drawing package. Any item or subject omitted from the Specifications or the Drawings but which is mentioned or reasonably specified in the Drawings or Specifications of other divisions, shall be considered as properly and sufficiently specified and shall be provided.

I. If discrepancies or omissions in the Drawings or Specifications are found, or if the intent or meaning is not clear, advise the Contract Administrator for clarification before submitting a bid.

J. Provide all minor items and work not shown or specified but which are reasonably necessary to complete the work.

K. Various package unit types of equipment are included in the work. It is the responsibility of the Contractor to familiarize himself with the requirements of the equipment vendor, and to include all materials and labor for a complete and working installation. In some cases this means that motors, valves, actuators, etc need to be wired and connected in the field. The Contractor shall include all costs to perform such services as part of his tender submittal. Coordination between the equipment vendor and the Contractor shall be performed prior to tender bid closing date, and all costs shall be included in the tender. Request for extras due to lack of coordination between the Contractor and the equipment vendors will not be accepted.

L. In some cases the plan Drawings indicate the symbol for 1 motor - for package units – when in reality, there are multiple motors, valves, dampers, solenoids, associated with the piece of equipment. It is the responsibility of the Contractor to understand the intricacies of the packaged equipment, and to perform all field connections for a complete and working system.

M. In some cases motorized dampers are shown only with one symbol on the Drawings, when in fact multiple motorized dampers are required in order to accommodate the opening size and the actuators. In these cases it is the responsibility of the Contractor to wire and connect all required actuators to allow for correct operation of the system at no additional cost.

N. Cables schedules / lists where shown do not include all cables required to perform the complete Facility installation. They shall be used as a general guide. Accurate cable lists, quantities, take-offs remain the responsibility of the Contractor. Cable schedules only show cabling where specific cable tags are available on the Drawings. Refer to the cable schedule for specific systems which are not included on the schedule, and include materials, and installation for all remaining cabling.

1.4 CARE, OPERATION AND START-UP

A. Instruct the Contract Administrator’s maintenance and operating personnel in the operation, care and maintenance of systems, system equipment and components.

B. Where services of a Manufacturer’s Factory Service Engineer is required, arrange and pay for services to supervise start-up of installation, check, adjust, balance and calibrate components and instruct operating personnel.

C. Provide factory service engineer support for such a period, and for as many visits as necessary to put equipment in operation, and ensure that operating personnel are familiar and fully trained with all aspects of its care and operation.

1.5 PERMITS, FEES AND INSPECTION

A. The Contract Administrator will submit to Electrical Inspection Department and Supply Authority necessary number of Drawings and Specifications for examination and approval prior to commencement of work.

B. The Contractor shall pay associated fees as required by the Electrical Inspections and Permitting department.

C. Notify the Contract Administrator of changes required by Electrical Inspection Department prior to making changes.

D. Furnish a Certificate of Final Inspection and approvals from inspection authority to the Contract Administrator.

1.6 DEFINITIONS

A. The following are definitions used in Division 26.
   1. Inspection Authority means agent of any authority having jurisdiction over construction and safety standards associated with any part of electrical site work.
   2. Supply Authority or Supply Utility means electrical power company or commission responsible for delivering electrical power to the project site.
   3. Electrical Code or Code means the Electrical Code in force at the project location.
   4. CEC means Canadian Electrical Code (latest edition being enforced by law).
   5. Contractor and Electrical Contractor means the entity retained to perform the work listed herein.
   6. Contract Administrator means the person with the authority to make decisions and administer the Contract on behalf of the City.
   7. Provide means to supply, install, wire, connect, test, commission and leave in complete and working order.
   8. The term “Shop Drawing” means Drawings, diagrams, illustrations, schedules, performance characteristics, brochures and other data, which are to be provided by the Contractor to illustrate details of a portion of the work.

1.7 DESIGN REQUIREMENTS

A. Design equipment, anchorage, and support systems for vertical and lateral loading in accordance with MBC.

B. Operating voltages to be within those defined in CAN3-C235.

C. Verify before energization that equipment supplied under this Contract is compatible with the site electrical power supply system.

D. All equipment, devices and installation methods (even where not specifically expressed on the Drawings) shall comply with the Manitoba Energy Code for Buildings (MECB).

1.8 ELECTRICAL COORDINATION

A. Coordinate work with all other trades to ensure that conflicts do not occur.

B. Coordinate requirement of mechanical equipment requiring electrical connection with the Mechanical Contractor. Pay specific attention to equipment full load amps, voltage, phase and breaker size.

C. Verify that all equipment ordered is compliant with the Manitoba Energy Code for Buildings.

D. Coordinate work with utilities where appropriate, including but not limited to:
   1. Incoming overhead lines,
   2. Underground buried services,
   3. Transformer(s) supplying main electrical service to the Facility,
   4. Installation of Supply Authority meter,
   5. Installation of incoming telephone / data communication service conductors or cables.

1.9 SUBMITTALS

A. Permits, Fees and Inspection:
   1. Furnish copies of all inspection reports and Certificate of Final Acceptance from Electrical Inspection Authority and any authorities having jurisdiction on completion of work to Contract Administrator and include copies in the O & M manuals.

B. Site Documentation
   1. In each electrical room, provide power distribution system single line diagrams in glazed metal frames.
   2. Provide fire alarm riser diagram, plan and building zoning in glazed metal frame at fire alarm control panel and annunciator to meet requirements of Fire Commissioner.
   3. Where work includes modification to existing power distribution or fire alarm systems, provide new single line and riser diagrams showing complete modified system. Reinstall diagram into existing frames where feasible or provide new frame and glazing.

C. Within 15 days of award of the Contract, the Contractor shall submit a completed equipment procurement schedule, which lists the Manufacturer and model of equipment, indicating the projected ordering, Shop Drawing submittal date and delivery dates of all products to meet the required construction schedule.

D. Prior to delivery of any products to the job site and sufficiently in advance of requirements to allow ample time for checking, submit Shop Drawings for review as specified in Division 01.

E. Submit Shop Drawings (including product data) for all equipment as required in each section of this Specification.

F. Prior to submitting the Shop Drawings to the Contract Administrator, the Contractor shall review, date and sign the Shop Drawings to determine that the equipment complies with the requirements of the Specifications and Drawings.

G. Shop Drawings shall indicate materials, methods of construction and attachment of support, wiring diagrams, connections, recommended installation details, explanatory notes and other information necessary for completion of the work. Where equipment is connected to other equipment, indicate that such items have been coordinated, regardless of the section under which the adjacent items will be supplied and installed. Indicate cross-references to design Drawings and Specifications. Adjustments made on Shop Drawings by the Contract Administrator are not intended to change the Contract price. If adjustments affect the value of the work, state so in writing to the Contract Administrator prior to proceeding with the work.

H. Manufacture of products shall conform to the revised Shop Drawings. Failure to supply a product based on the revised, marked up Shop Drawings may require on site product revisions or modifications, which will be at the cost of the Contractor.

I. Keep one (1) complete set of Shop Drawings at job Site during construction.

J. Prior to shipping pre-fabricated control panels, photos of completed panels shall be sent to the Contract Administrator of final review. The resolution of the photos should be such that individual wire tags can be read.

K. Shop Drawings shall have the specific equipment numbers on all pages to clearly indicate which piece of equipment the Shop Drawing refers to. In addition, the entire product part number or catalog number should be adjacent to the tag.

1.10 AS-BUILT DRAWINGS

A. Refer to Section 01 77 00, Closeout Procedures - for additional requirements for as-built drawings.

B. The Contractor shall keep one (1) complete set of white prints at the site during work, including all addenda, change orders, site instructions, clarifications, and revisions for the purpose of As-Built drawings. As the work on-site proceeds, the Contractor shall clearly record in red pencil all as-built conditions, which deviate from the original Contract Documents. As-Built drawings to include circuiting of all devices, conduit and feeder runs (complete with conductor size and number) and locations of all electrical equipment.

C. On completion of the work, minimum of four (4) weeks prior to final inspection, submit As-Built drawings to Contract Administrator for review. The Contractor shall certify, in writing signed and dated, that the As-Built drawings are complete and that they accurately indicate all electrical services, including exposed as well as concealed items.

D. Comply with all other City of Winnipeg standards and requirements.

1.11 OPERATIONS AND MAINTENANCE (O & M) MANUALS

A. Provide operation and maintenance manuals as specified herein and in accordance with the general conditions. Refer to Section 01 78 23, Operations and Maintenance Data.

B. Include in the operations and maintenance manuals a minimum of:
   1. Cover page including project name, year, name of owner and electrical consultant. Cover page shall be enclosed in a clear plastic cover.
   2. Index.
   3. List of manufacturers and supplier for all items.
   4. Names, address and phone number of all local suppliers for items included in maintenance manual.
   5. Stamped and signed Shop Drawings.
   6. Details of design elements, construction features, component function and maintenance requirements, to permit effective start-up, operation, maintenance, repair, modification, extension and expansion of portions or features of the installation.
   7. Technical data, product data, supplemented by bulletins, component illustrations, exploded views, technical descriptions of items and parts lists. Advertising or sales literature not acceptable.
   8. All test results performed. This includes, but is not limited to fire alarm V.I report, grounding system tests, battery bank test results, genset tests, switchgear tests, operation tests, cable tests, MCC tests, load balancing tests, Hi Pot tests, Megger tests, factory tests of all major systems, etc. Submit test results on COW approved test sheets.
   9. Panel schedules (hardcopy and Microsoft Excel format).
   10. Software copies of relay settings
   11. As-Built drawings.
   12. Signed and dated warranty certificate.
   13. Signed and dated approval by the local Electrical Inspections Department.
   14. All other requirements outlined in the Specifications.

C. Deliver to the Contract Administrator prior to the scheduled takeover date, five (5) sets of operation and maintenance manuals. Each operation and maintenance manual shall be contained within one or more three “D-ring” binder(s). Each binder shall be labeled directly on the front cover as well as the spine (“ELECTRICAL MAINTENANCE MANUAL – PROJECT NAME – YEAR”). Include memory sticks for required electronic media.

D. Index plastic divider tabs (with type inserts) shall be provided for each Specification section. Paper dividers, with plastic tabs and typed insertions will not be accepted.

E. Submit draft document prior to the start of Commissioning.

F. Comply with all other COW standards and requirements.

1.12 ENVIRONMENTAL CONDITIONS

A. Equipment and systems are to be rated to correctly operate in the environment in which they are to be installed.

B. Exterior devices shall be rated to operate in an exterior environment with temperature range of -40 degrees C to +40 degrees C.

1.13 QUALITY ASSURANCE

A. Qualifications
   1. For work involving specialties, including, but not limited to, the installation of high voltage switchgear, high voltage cables, overhead pole lines, sound and intercommunication systems, fire alarm systems, lightning protection systems, equipment cathodic protection, grounding systems, instrumentation, controls, electronic access, security systems, fibre optics systems, etc. employ only workers fully trained, qualified and experienced in the aspects of such work.

PART 2 PRODUCTS

2.1 ACCEPTED MATERIALS

A. Materials: approved by and bearing a CSA label. Where there is no alternative to supplying equipment or material that is not approved or certified as indicated, obtain and pay for special approvals from the Office of the Fire Commissioner, Inspection and Technical Services Manitoba.

B. Factory assemble control panels and component assemblies. Control panels to be CSA certified. Include current interrupting rating on the front panel. Shop Drawings for custom built control panels (which are not designed and sealed as part of the Issued for Construction documents) shall be signed and sealed by an engineer, registered in the Province of Manitoba.

C. Minimum enclosure type to be NEMA 12 unless otherwise specified. Refer to the Drawings and other Specification section for specific requirements.

D. Provide materials and equipment in accordance with Section 01 61 00, Common Product Requirements.

2.2 EQUIPMENT FINISH

A. Where on site finishing is required, prepare and prime surfaces as specified in Section 09 90 00, Painting and Coating.

B. Shop finish metal enclosure surfaces by application of rust resistant primer inside and outside, and at least two coats of finish enamel.

C. Paint indoor switchgear and distribution enclosures light grey to ANSI 61 grey enamel, unless otherwise specified.

2.3 EQUIPMENT IDENTIFICATION

A. Identify electrical equipment with nameplates as described below.

B. Nameplates:
   1. Lamacoid, 3 mm thick plastic nameplates, mechanically attached with self tapping stainless steel screws, white face with black lettering. Note: “Sheet Metal Screws” or other sharp pointed screws are NOT acceptable.
   2. Sizes as follows:

NAMEPLATE SIZES

Size 1	10 x 50 mm	1 line	3 mm high letters
Size 2	12 x 70 mm	1 line	5 mm high letters
Size 3	12 x 70 mm	2 lines	3 mm high letters
Size 4	20 x 90 mm	1 line	8 mm high letters
Size 5	40 x 90 mm	2 lines	8 mm high letters
Size 6	25 x 100 mm	1 line	12 mm high letters
Size 7	25 x 100 mm	2 lines	5 mm high letters
Size 8	35 x 100 mm	3 lines	5 mm high letters
Size 9	45 x 100 mm	4 lines	5 mm high letters
Size 10	75 x 160 mm	3 or 4 lines	8 mm high letters
Size 11	150 x 250 mm	3 or 4 lines	10 mm high letters

C. Wording on nameplates to be approved by Contract Administrator prior to manufacture.

D. Allow for average of fifty (50) letters per nameplate.

E. Identification to be in English.

F. Provide nameplates for the following, sizes as shown:
   1. Power, voice and data receptacles –Size 1
   2. Panelboards – Size 9
   3. Dry Type Transformer – Size 10
   4. Cabinets – Size 8
   5. Small Junction Boxes (150mm x 150mm or smaller) – Size 1
   6. Large Junction Boxes – Size 2
   7. Control panels – Size 8
   8. Contactors – Size 8
   9. Terminal / splitter cabinets – Size 8
   10. MCCs, switchgear, distribution equipment – Size 10
   11. Each cell or bucket in an MCC – Size 7
   12. Each breaker cell located within switchgear – Size 5
   13. Motor starters – Size 8
   14. Light Switches – Size 1
   15. Emergency lighting battery banks – Size 7 or Size 8
   16. Emergency lights – Size 1
   17. Exit signs – Size 3
   18. Disconnect switch – Size 8
   19. Wall mounted fire alarm devices – Size 2
   20. Ceiling mounted fire alarm devices – Size 4
   21. Oil filled padmount transformers – Size 11

2.4 WIRING IDENTIFICATION

A. Identify wiring with permanent indelible identifying markings, either numbered or coloured plastic tapes, on both ends of phase conductors of feeders and branch circuit wiring.

B. Maintain phase sequence and colour coding throughout.

C. Colour code: to CSA C22.1.

D. Use colour coded wires in communication cables, matched throughout system.

2.5 CONDUIT AND CABLE IDENTIFICATION

A. Colour code conduits, boxes and cables.

B. Code with plastic tape or paint at points where conduit or cable enters wall, ceiling, or floor, and at 5 m intervals.

C. Colours: 38 mm wide prime colour and 19 mm wide auxiliary colours.

System	**Prime Band**	**Aux. Band**
Medium Voltage (>750 V)	Orange	
347/600 V	Yellow	
120/208/240 V Power	Black	
UPS 120/208/240 V Power	Black	Green
Control Wiring (120 V)	Black	Orange
Fire Alarm	Red	
Low Voltage Communication/General	Blue	
Low Voltage Control Wiring (<50 V)	Blue	Orange
Intrinsically Safe	Blue	White
Ground	Green	
Fibre Optic	Purple	

D. Cable Identification: Supply and install lamacoid type cable identification tags for all cables. Install identification tag at both ends.

PART 3 EXECUTION

3.1 PREPARATION AND PROTECTION

A. Schedule expediting of materials and execution of work in conjunction with associated work of other trades in order to meet the required work schedule.

B. Post engraved warning signs to meet requirements of local bylaws, Inspection Authority and Contract Administrator.

C. Protect those working on or in vicinity of exposed electrically energized equipment from physical danger. Shield and mark live parts in accordance with local regulations. Indicate the appropriate voltage.

D. Arrange for installation of temporary doors, barriers and similar items for access to rooms and areas containing electrical equipment. Keep these doors locked at all times, except when under direct supervision.

E. Permanently identify with lamacoid nameplate, equipment energized from multiple power sources, noting voltages, power source locations, supply disconnect designations and grounding electrode location.

3.2 WARNING SIGNS

A. As specified and to meet the requirements of Electrical Inspection Department and the Contract Administrator.

B. Lamacoid 3 mm thick plastic engraving sheet, red face, white core, mechanically attached with self tapping screws, 20mm text.

3.3 MOUNTING HEIGHTS

A. Unless otherwise noted, or in contravention of codes and standards, mount equipment replacing existing equipment at the same height.

B. Mounting height of equipment is from finished floor to centerline of equipment unless specified or indicated otherwise.

C. If mounting height of equipment is not indicated, verify with the Contract Administrator before proceeding with the installation.

D. Mount indoor electrical distribution equipment utilizing one of the following:
1. Floor mount on 89mm (3.5”) concrete housekeeping pad
2. Surface wall mount to concrete walls (inside electrical rooms).
3. For areas of elevated humidity or moisture (or where a suitable wall is not available) – mount on modular metal support system: Unistrut, Cantruss, or similar.
4. Surface wall mount on 19mm (3/4”) thick fire retardant plywood backboard (for non-structural type of walls and to provide a level of fire retardant barrier where needed)
5. Recess mount (as indicated on the Drawings)

E. Install electrical equipment at the following heights unless indicated or directed otherwise (to bottom of the equipment):
1. Outlets above counters: 150 mm (6”); splashbacks: 100 mm (4”).
2. General receptacles & communications outlets: 400 mm (16”).
3. Receptacles in mechanical and shop areas: 1 m (40”).
4. Switches, dimmers, push buttons: 1.2 m (48”).
5. Thermostats: 1.4 m (56”).
6. Security alarm bells, horns, speakers: 2.2 m (88”).
7. Motor starters: 1675mm (66”) to top.
8. Panelboard: 2.0 m (78”) to top.
9. Control Panels: 1675mm (66”) to top.
10. Clock outlets: 2.15 m (84”).
11. Emergency lighting battery bank unit: 2.1m (82”).

12. Emergency light remote head: 150mm (6”) below ceiling, to a maximum height of 3.0m (118”).
13. Wall mount Exit signs: 2.2m (87”) or higher as required to coordinate with door height.
14. Pushbutton for power door assist: 900mm (35.4”)
15. Intrusion alarm motion detectors: 150mm (6”) below ceiling, to a maximum height of 3.0m (118”).
16. Intrusion alarm keypad: 1500mm (59”)
17. Fire alarm panel: 1650mm (65”) to top
18. End of line resistors: 1.6 m (64”),
19. Fire alarm pull stations: 1320mm (52”),
20. Fire alarm horn / strobe: a minimum of 150mm (6”) below ceiling to the top edge of the device (for low ceiling areas). Where ceilings allow, mount devices at 2400mm (94.5”) (measured to top of device) above finished floor.
21. Coordinate and confirm elevations indicated on the Architectural Drawings. Where discrepancies occur, request clarification from the Contract Administrator.
22. Mounting heights to meet all codes and regulations. Fire alarm devices to be in accordance with CAN / ULC-S524.
23. Coordinate and confirm elevations indicated on the Architectural elevations. Where discrepancies occur, request clarification from the Contract Administrator.

3.4 LOCATION OF DEVICES

A. Allow for change of location of devices at no extra cost or credit, provided that the distance does not exceed 3000mm (10’) from that shown on the Drawings, when the requirement is made known prior to installation.

3.5 CONDUIT AND CABLE INSTALLATION

A. Sleeves through concrete: schedule 40 galvanized steel pipe, sized for free passage of conduit.

B. For wall, partitions, and ceilings the sleeve ends shall be flush with the finish on both sides but for floors they shall extend 25 mm (1”) above finished floor level.

C. Fire stop opening with ULC approved assembly for the installation conditions.

D. Provide a detailed proposed conduit routing plan to the Contract Administrator prior to proceeding with the installation of conduit.

E. If possible, avoid routing conduits through hazardous area.

F. Separate cables of different voltage levels when cables are installed parallel to each other.

3.6 CUTTING, PATCHING, DRILLING

A. Provide all cutting and patching as required.

B. Return exposed surfaces to an as-found condition.

C. Exercise care where cutting/drilling holes in existing concrete elements so as not to damage existing reinforcing, or any other systems run in the concrete.
   1. Locate reinforcing and other existing systems using ground penetrating radar, X-Ray or other suitable means. Mark out on the surface of the concrete the locations of rebar and all other systems.
   2. For all holes larger than 50mm passing through reinforced concrete, mark the location of the desired hole and all embedded systems. Obtain approval from the Contract Administrator prior to cutting.

D. Firestop and seal all penetrations.

E. Ensure that water ingress will not occur.

F. Provide expansion joints for penetrations where shifting can occur.

3.7 ANCHOR INSTALLATION

A. The Contractor shall exercise care where installing anchors into existing concrete elements so as not to damage existing reinforcing. All anchors shall be installed utilizing carbide tip drill bits. The existing reinforcing shall be located utilizing a reinforcing bar locator and marked out on the surface of the concrete. The drill holes shall be advanced to the required depth for installation of the anchors. Should reinforcement be encountered while drilling the hole shall be terminated and repositioned to clear the reinforcement. Do not use core bits that can easily intercept and damage/cut the reinforcing during drilling.

3.8 FIELD QUALITY CONTROL

A. All electrical work to be carried out by qualified, licensed electricians or apprentices as per the conditions of the Provincial Act respecting manpower vocational training and qualification. Employees registered in a provincial apprentices program shall be permitted, under the direct supervision of a qualified licensed electrician, to perform specific tasks - the activities permitted shall be determined based on the level of training attained and the demonstration of ability to perform specific duties. A maximum of one apprentice is permitted per qualified electrician.

B. The work of this division to be carried out by a Contractor who holds a valid Master Electrical Contractor license as issued by the Province of Manitoba.

C. Furnish Manufacturer's certificate or letter confirming that entire installation as it pertains to each system has been installed to Manufacturer's instructions.

3.9 LOAD BALANCE

A. Drawings and Specifications indicate circuiting to electrical loads and distribution equipment.

B. Balance electrical load between phases as closely as possible on switchboards, panelboards, motor control centers, and other equipment where balancing is required.

C. When loads must be reconnected to different circuits to balance phase loads, maintain accurate record of changes made, and provide circuit panel directory that lists final circuit arrangement.

3.10 TESTS

A. Test and check electrical, instrumentation and control systems for correct operation and compliance with statutory and regulatory authority requirements.

B. Perform tests in presence of Contract Administrator. Log, tabulate, sign and include testing and Commissioning results in the O & M manuals.

C. Testing shall include, but not be limited to, the following:
   1. All items indicated in Section 26 08 05, Acceptance Testing and the testing and Commissioning requirements.
   2. Electrical power distribution systems.
   3. Wire and cable system.
   4. Lighting, emergency lighting, photocell, lighting controls and interlocks.
   5. Motors, heaters and associated control equipment including sequenced operation of systems where applicable.
   6. Communications, control and instrumentation.
   7. Fire alarm and intercom systems.
   8. Standby genset power systems.
   9. All other equipment and systems as indicated in the Drawings and Specifications.

D. Refer to appropriate Specification sections for specific system or equipment tests.

E. Supply instruments, meters, consumable parts (such as fuses) and equipment. Arrange for qualified personnel to conduct tests.

F. In cooperation with mechanical trades, take clamp-on ammeter readings with motors operating at full load. Compare values against the equipment nameplate rating. Log, tabulate and include readings in Maintenance Data and Operating Instructions.

G. Correct systems which fail any test, correct and re-do tests to ensure proper operation of the system.

3.11 CHECKOUT AND STARTUP

A. Voltage Field Test:
   1. Refer to Section 26 08 05, Acceptance Testing as applicable.
   2. Check Supply Utility voltage at point of termination of supply conductors when installation is essentially complete and is in operation.
   3. Check voltage amplitude between phases, and phase to neutral for loaded and unloaded conditions.
   4. Check voltage drop on at all distribution panels, and ensure that it is less than 2 percent in accordance with CEC requirements.
   5. Check voltage drop on equipment loads, and ensure that total voltage drop from the service to the farthest device is less than 5 percent in accordance with the CEC. Adjust transformer taps, and upsize conductors as required to meet the CEC.

6. Unbalance Corrections:
   a. Make written request to the Supply Utility to correct conditions if the service voltage unbalance exceeds 3 percent.

B. Current Field Tests:
   1. Make line current check after supply utility has made final adjustments to supply voltage.
   2. Check current balance at the service demarcation point. Adjust loads to ensure that each phase is appropriately balanced.
   3. Check line current in each phase for each piece of equipment.
   4. If the phase current for a piece of equipment is above rated nameplate current, prepare Equipment Line Phase Current Report that identifies cause of problem and corrective action taken.

3.12 TOUCH-UP PAINTING

A. Clean and touch up surfaces of shop painted equipment scratched or marred during shipment or installation, to match original paint.

B. Obtain necessary touch-up paint of original type and quality from equipment Manufacturer.

C. Clean surfaces to be painted. Feather out edges of scratch marks. Make patch inconspicuous.

D. Apply one or more coats until damaged surface has been restored to original finish condition.

E. Clean and prime exposed non galvanized hangers, racks and fastenings to prevent rusting.

F. Do not paint nameplates, tags, CSA labels, warning plates and operating instructions. Observe field painting of electrical equipment or raceways. Labels shall be visible and legible after the equipment is installed.

3.13 CLEANING

A. Clean construction debris and materials from enclosures, before final electrical tests. Vacuum the interior and exterior of enclosures to ensure all equipment is free from debris.

3.14 PROVISION FOR FUTURE EXPANSION

A. In each location where space for future equipment is indicated, leave such space clean. Install conduit, wiring and other work in such a manner that necessary connections can be made in future without dismantling existing equipment, raceways or wiring. Consult with Contract Administrator whenever necessary.

3.15 BREAKER AND RELAY SETTINGS

A. The Electrical Contractor shall field adjust and set breaker and relay settings for all breakers, relays, vfds, etc in accordance with settings provided by the Contract Administrator. Settings will be provided to the Electrical Contractor after the submission and acceptance of Shop Drawings. Shop Drawing information will be used by the Contract Administrator to calculate the appropriate settings.

3.16 TRAINING

A. Provide training of COW personnel in all aspects of maintenance, operation, and functionality for all systems.

B. Training shall be performed at the SEWPCC Facility in Winnipeg, Manitoba. Training shall involve both classroom style of training, as well as practical training with the equipment present.

3.17 UTILITY SERVICES

A. It is the responsibility of the Contractor to perform all work related to utility electrical service upgrades, and to coordinate this work with Manitoba Hydro. Coordinate the delivery of utility electrical power to the site at 66kV (2 supply feeders) with Manitoba Hydro.

B. Construct a new substation along with the required electrical infrastructure to accept the new Manitoba Hydro utility service supply feeders at 66kV. At the same time, maintain operation of the two existing Manitoba Hydro 12.47 kV utility service supply feeders.

C. The new 66 kV electrical service shall be completely operational, and the majority of the new infrastructure & facilities shall be constructed, installed and commissioned prior to the removal of the existing 12.47 kV MB Hydro utility service feeders to SGR-S701 and SGR-S702 as shown on Drawing 1-0102-ESLD-S001. In summary, construction efforts shall be completed at the Substation, Chemical / Electrical Building, the Grit & Screenings Building, the BNR area, the HRC, Admin, Secondary Clarifiers, the U.V Building, and the construction of the concrete encased duct bank (refer to Drawing 1-0102-EGAD-A001), prior to the disconnection of the two 12.47 kV MB Hydro service cables. The site is intended to run using four (4) electrical services to the site during the construction period. Two new feeders at 66 kV, and two existing feeders at 12.47 kV will run simultaneously, and feed a variety of loads. Running the plant with the redundant services will allow for a smooth and seamless transition, to the new dual service at 66kV with minimal impact to the plant with respect to down-time.

D. The existing 12.47 kV MB Hydro services currently feed SGR-S701 and SGR-S702 and are shown on Drawing 1-0102-ESLD-S001. The two new 66 kV MB Hydro electric utility services are to feed the Electrical Building SGR-C701 and SGR-C702 – refer to 1-0102-ESLD-C001, ESLD-C002, ESLD-C003).

E. Once the majority of the construction efforts have been completed, and the two new 66 kV feeders to the site are energizing the Electrical Building, the existing 12.47 kV MB Hydro service cables shall be disconnected and removed by MB Hydro. Coordinate de-energization of the 12.47 kV feeders with MB Hydro. This work shall be performed in accordance with the following general sequence (refer to 1-0102-ESLD-C001 for additional details):
   1. Install two 12.47 kV cables from the Electrical Building switchgear SGR-C701 and SGR-C702 (cables C-S701-1 and C-S702-1). Terminate lock-out breakers and terminate cabling at SGR-C701 and SGR-C702. Soft-dig excavate near transformers XFMR-S701 and XFMR-S702 without damaging systems or interrupting power the existing transformers.
   2. Assist the City electrical technicians in opening main circuit breaker MCB-S701.

3. Assist the City electrical technicians in closing tie breaker CB-S701-T.
4. Assist the City in re-energizing equipment affected by the momentary interruption as required and as direction by the City.
5. Coordinate utility outage of MB Hydro utility feeder to XFMR-S701. Ensure the correct MB Hydro feeder cable is de-energized.
6. Assist MB Hydro in removing metering equipment as applicable (and where possible).
7. Remove and replace transformer XFMR-S701 ground. Ground cabling shall be run through ground bar to X0 continuously in accordance with code requirements.
8. Remove MB Hydro service cabling from the transformer compartment.
9. Disconnect / remove 12.47 kV tie cable with the assistance of MB Hydro (ensure that the tie cable is de-energized). Isolate and make safe.
10. Install and terminate new cable C-S701-1 into transformer XFMR-S701.
11. Re-energize XFMR-S701 from the new electrical service, via SGR-C701.
12. Replace and reconnect transformer grounds if disturbed or altered.
13. Assist the City to open tie breaker CB-S701-T and close MCB-S701.
14. Perform similar work and take momentary outages to re-feed XFMR-S702 from SGR-C702.
15. The City has purchased the two 2500 kVA MB Hydro utility transformer XFMR-S701 and XFMR-S702 directly from MB Hydro. These two transformers have Manitoba Department of Labour Special Inspections Certificates.
16. MB Hydro will be responsible for removing their disconnected 12.47 kV feeder cables as applicable from the site.

F. Refer to other Contract Documents for additional scope of work and requirements, including but not limited to the Detailed Design Project Commissioning Plan, S0926-01YM-PLA-0001.

END OF SECTION

SECTION 26 05 19

WIRE AND CABLES (15 kV) – ELECTRICAL

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA C68.10 - Shielded power cable for commercial and industrial applications, 5-46 kV

1.2 SUBMITTALS

A. Submit product data in accordance with Section 01 33 00, Submittal Procedures.

B. Perform and submit pull tension and side wall bearing pressure calculations signed and sealed by a Professional Engineer as part of the Shop-Drawing submittals.

PART 2 PRODUCTS

2.1 GENERAL

A. Use armored type High Voltage (HV) TECK 90 cables for 12.47 kV cable applications.

B. All conductors (including grounds and bonds) shall be high conductivity copper.

C. Materials to be manufactured to Canadian CSA standards, approved and suitable for operation at minus 40 degrees C to plus 90 degrees C, and installation at temperatures down to minus 40 degrees C. Wires and cables shall meet the applicable CSA standard for construction and testing.

D. Insulation voltage rating: 12.47kV cable shall be rated to a minimum of 15 kV.

E. Increase conductor sizes to account for loading, cable and conductor spacing with the associated de-rating factors, voltage drop, ambient temperature, equipment termination temperature ratings, and all other requirements in accordance with CEC requirements.

F. Cabling shall be compliant with the following flame test requirements:
   1. CSA FT-4
   2. IEEE 383 (70,000 BTU/hr)
   3. UL 1581 (70,000 BTU/hr)
   4. IEEE 1202 (70,000 BTU/hr) CSA FT-4
   5. ICEA T-30-520 (70,000 BTU/hr)
   6. ICEA T-29-520 (210,000 BTU/hr)

G. Other required compliances:
   1. EPA 40 CFR, part 261 for leachable lead content per TCLP
   2. OSHA acceptable

3. RoHS Compliant
4. Meets CSA cold bend test at -40 degrees C
5. Meets CSA cold impact test at -40 degrees C

2.2 HV-TECK CABLE

A. Cables: to CSA- C68.10

B. Phase Conductors: Class B compact stranded high conductivity copper.

C. Conductor Extruded Strand Shield: Thermosetting semi-conducting polymeric strand shield extruded over the conductor.

D. Insulation Shield: A semi-conducting thermosetting layer, applied in a triple extrusion process plus a helically applied copper tape shield in contact with a bare stranded copper bonding conductor.
   1. Tape shield shall be a 3 mil annealed bare copper tape with a maximum 20 percent gap, and a minimum 10 percent overlap.

E. Bonding conductor: A bare stranded copper bonding conductor which shall be in direct contact with the copper insulation shielding tape.

F. Insulation: Tree-retardant cross-linked polyethylene (TR-XLPE).
   1. For 100 percent insulation level cables the insulation thickness shall be 175 mils (minimum), and
   2. For 133 percent insulation level cables insulation thickness shall be 220 mils (minimum).
   3. Cable insulation levels shall be as indicated on the Drawings, and Cable Schedules.

G. Inner jacket: Lead-free, flame retardant, moisture and sunlight resistant Polyvinyl Chloride (PVC), black in colour.

H. Armour: helically wound interlocked aluminum (steel armour is not accepted).

I. Outer jacket: Lead-free, Acid-flame-check flame retardant, moisture and sunlight resistant, FT4, “HL” rated polyvinyl chloride (PVC) material, suitable for direct burial, red in colour. The outer jacket shall be permanently marked (identified) in accordance with CSA C68.10, Section 12.

J. Acceptable cable Facility: General Cable, or approved equal in accordance with B8 - Substitutions.

2.3 HV-TECK CABLE CONNECTORS

A. Cable Connectors / Fittings:
   1. Weatherproof strain relief style connectors, to accommodate cable shield, as recommended by the cable Facility.

B. Acceptable Cable Connectors: Thomas and Betts type Star TECK® sized for the applicable cable complete with locknut and grounding bushing, or approved equal in accordance with B8 - Substitutions.

2.4 HV-TECK CABLE TERMINATIONS

A. Shielded Cable Conductor Terminations: Heat shrink type cable terminations appropriately sized to the conductor and insulation dimensions.
   1. For inside or weather protected applications, terminators shall be without sheds.
   2. For outdoor non weather protected installations, terminators shall be equipped with sheds.
   3. All installations for multi-conductor cables shall include conductor “breakout boots” and “rejacketing tubing”. Conductor breakout boots shall be utilized to seal the individual insulated phase conductors to the internal cable jacket to prevent water ingress to the cable.

B. Acceptable Cable Terminations: TE Raychem type HVT-Z indoor or outdoor sized for the applicable cable, c/w type CBR-6 breakout boots and type HVOT re-jacketing tubing, or approved equal in accordance with B8 – Substitutions.

PART 3 EXECUTION

3.1 INSTALLATION OF WIRES AND CABLES

A. Field Quality Control
   1. Perform tests in accordance with 26 08 05, Acceptance Testing.

B. General requirements
   1. Install wires and cables in a continuous length between termination points. Splices are not permitted, except where specifically approved by the Contract Administrator. Where splices are necessary and approved utilize the cable Facility approved and recommended kit.
   2. For outdoor or exposed installations, make all entries of cables or wires to equipment or panel from the bottom or side to minimize water entry points. Make no entries of cables or wires from the top unless specifically approved by the Contract Administrator.
   3. Do not pull conductors into conduit or cable tray until rough building construction operations have been completed.
   4. Do not embed cables or conduits in masonry or concrete without written approval from the Contract Administrator. Wiring through conduit sleeves for short, direct wall or floor penetration is accepted.
   5. Design wire and cable anchorage and support system for vertical and lateral loading in accordance with the Manitoba Building Code (MBC).

C. Installation of armored cables:
   1. Perform, and submit cable pulling and side wall bearing pressure calculations, sealed by a Professional Engineer as part of the Shop Drawing submittal.

2. Utilize conductor pulling eyes for cable pulling. Cables shall NOT be pulled by utilizing only Kellems grips or other devices which attach only to the outer jacket or interlocked armour.
3. Utilize a peak recording cable pulling dynamometer during cable pulling and record and provide a record maximum pulling tensions during pulling. Manufacturer's recommended cable pulling and sidewall bearing tensions shall not be exceeded during installation and pulling of cables.
4. Provide a cable pull plan to the Contract Administrator prior to installing cables. In some cases, such as the cable pull to the BNR Facility, cable pull may have to be done at the pull pit midway in order to minimize cable pull tension.

3.2 COLOUR CODING AND TAGGING

A. Colour code all power distribution conductors at both ends throughout Facility.

B. Same colour for same phase throughout, by insulation colour markers.

C. Conductor colour coding to be in accordance with CEC and as follows:
3 Phase - red (A), black (B), blue (C)

D. Identify all cables with the cable tag at all termination points and at all pull boxes. All cable markers must be readily visible when the device cover is open.

END OF SECTION

SECTION 26 05 21

WIRE AND CABLES (0-1000V) - ELECTRICAL

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CAN/CSA-C22.2 No. 38, Thermoset-Insulated Wires and Cables.

B. CAN/CSA-C22.2 No. 49, Flexible Cords and Cables

C. CAN/CSA-C22.2 No. 51, Armoured Cables.

D. CSA C22.2 No. 0.3, Test Methods for Electrical Wires and Cables.

E. CAN/CSA-C22.2 No. 131, Type TECK 90 Cable.

F. CAN/CSA C22.2 No. 174 Cables and Cable Glands for use in Hazardous Locations.

G. CAN/CSA C22.2 No. 230 Tray Cables.

H. CAN/CSA C21.2 300V Control Cable.

I. CAN/CSA-C22.2 No. 239, Control and Instrumentation Cables.

J. CAN/CSA-C22.2 No. 208, Fire Alarm and Signal Cable.

K. American Society for Testing and Materials (ASTM):
   1. B3, Standard Specification for Soft or Annealed Copper Wire.
   2. B8, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.

1.2 SUBMITTALS

A. Submit product data in accordance with Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 GENERAL

A. All conductors (including grounds and bonds) to be high conductivity copper.

B. Materials to be manufactured to Canadian CSA standards, approved and suitable for -40°C to +90°C operation. Wires and cables shall meet their applicable CSA standard for construction and for testing.

C. Insulation voltage rating:
   1. Conductors carrying 120/208V shall be rated 600V (except as noted otherwise for control cables).
   2. Conductors carrying 600V shall be rated 1000V.

D. Increase conductor sizes to account for loading, cable and conductor spacing with the associated de-rating factors, voltage drop, ambient temperature, equipment termination temperature ratings, and all other requirements in accordance with CEC requirements.

2.2 WIRES (POWER)

A. Conductors:
   1. Stranded for 10 AWG and larger.
   2. Minimum size, 12 AWG.

B. Copper conductors: size as indicated, with insulation of chemically cross-linked thermosetting polyethylene (XLPE) materials, RW90.

C. Wires sized 2 AWG and smaller to be factory colour coded, taping will not be accepted.

2.3 AC 90 ALUMINUM ARMOURED CABLE

A. Cable: to CAN/CSA-C22.2 No. 38 and CAN/CSA-C22.2 No. 51.

B. Insulation: chemically cross-linked thermosetting polyethylene (XLPE) type RW90, FT4 rated.

C. Armour: aluminum interlocked strip.

D. Fastenings for aluminum armoured AC-90 cables:
   1. One hole aluminum straps to secure surface cables 25 mm and smaller. Two hole aluminum straps for cables larger than 25 mm.
   2. Channel type supports for two or more cables. Space out cables, minimum 1 cable diameter.
   3. Minimum 9 mm diameter threaded rods to support suspended channels.

E. Connectors:
   1. Locknut, screw type, compression style cable connectors, sized as required.

F. Acceptable Cable Manufacturer: Nexans, General Cable, Southwire

2.4 TECK 90 CABLE

A. Cable: to CAN/CSA-C22.2 No. 131 and CAN/CSA – C22.2 No. 174

B. Insulation: chemically cross-linked thermosetting polyethylene (XLPE) type RW90.

C. Inner jacket: polyvinyl chloride (PVC), 600V or 1000V (as applicable), 100 percent insulation level.

D. Armour: interlocking aluminum.

E. Outer jacket: FT4, “HL” rated polyvinyl chloride (PVC) material, black colour.

F. Fastenings:
1. One hole aluminum straps to secure surface cables 50 mm and smaller. Two hole aluminum straps for cables larger than 50 mm.
2. Channel type or cable tray supports for two (2) or more cables.

G. Cable Connectors / Fittings:
1. Minimum requirements: Watertight, approved for TECK cable.
2. Hazardous Locations:
   a. CSA approved.
   b. Watertight type with:
      1) an elastomeric bevelled bushing.
      2) a funnel entry, splined gland nut.
      3) a non-magnetic, stainless steel grounding device with dual grounding action.
      4) a taper threaded hub.
      5) a hexagonal body and gland nut
   c. Integral seal type with metal-to-metal contact construction.
   d. Sealing of multi-conductor cable shall be accomplished with a liquid type polyurethane compound.
   e. The fitting must:
      1) Provide an environmental seal around the outer jacket of the cable and electrically bond the fitting to the cable armour prior to potting the explosion-proof seal.
      2) Allow the possibility of disconnection without disturbing the environmental seal, the electrical bonding or the explosion proof seal.
   f. All metal-clad cable fittings, for jacketed and non-jacketed interlocked armour cable, shall incorporate an easily-removable armour stop (not requiring fitting disassembly) ensuring proper positioning of the cable armour during cable termination.
3. Approved products:
   a. Teck Cable, (Non-Hazardous Locations):
      1) Approved Manufacturers: Thomas & Betts or Cooper Crouse-Hinds
      2) Thomas & Betts Star® Teck ST series, aluminum.
   b. Teck Cable, (Hazardous Locations):
      1) Shall meet the requirements of CSA C22.2 No. 174, and be marked accordingly.
      2) Approved Manufacturers: Thomas & Betts or Cooper Crouse-Hinds.
         a) Thomas & Betts, Star® Teck XP (STX) series, explosion proof aluminum, CSA certified Class I, Divisions 1 and 2, Groups A, B, C, D.

H. Acceptable Cable Manufacturer: Nexans, General Cable, Southwire.

2.5 FIRE ALARM WIRING

A. Refer to Section 28 31 02, Multiplex Fire Alarm Systems for details.

B. Low energy, 300 V, FAS 105 shielded cable: minimum #16AWG, with PVC insulation.

C. Overall aluminum /polyester foil shield, with tinned copper drain wire.

D. All fire alarm cables shall be installed in a separate, dedicated conduit system.

2.6 INSTRUMENTATION AND CONTROL WIRING

A. Armoured Control and Instrumentation Cable (ACIC) and Control and Instrumentation Cable (CIC) to: CAN/CSA-C22.2 No. 239 and CAN/CSA C21.2.

B. Conductors: minimum size, #16 AWG, stranded, annealed (7 strand minimum), tinned copper, unless otherwise specifically noted on the Drawings.

C. Insulation: chemically cross-linked thermosetting polyethylene (XLPE), rated type RW90, 300V.

D. Conductor identification: Each grouping (pair, triplet, quad) by consecutive number coding, permanently marked at regular intervals

E. Construction: twisted pair, triplet and quad grouping with staggered lay.

F. Shielding shall be in conformance with:
   1. Minimum 100 percent coverage aluminum foil or mylar tape shield with minimum 25 percent overlap.
   2. Separate drain wire, minimum size 18 AWG, bare, stranded tinned copper. Drain wire to be in direct, continuous contact with the shield.
   3. One or more twisted shielded pairs as indicated.

G. Jacket: PVC (minus 40 degrees C to plus 90 degrees C), low acid gas, minimum FT4 rated flame spread.

H. Armoured control and instrumentation cable (ACIC), to have aluminum, interlocked armour with overall PVC jacket.

I. Termination fittings: Type, configuration and gender required to connect cable directly to equipment without additional adapters or fittings.

2.7 FLEXIBLE CABLES

A. Cable: to CAN/CSA-C22.2 No. 49

B. Type SOOW, flexible, extra hard usage conductor, watertight, rubber EPDM insulation, with CPE oil resistant outer covering and incorporated ground conductor, 90 degrees C rated.

C. Instrumentation and control flexible cables, to have braided flexible shield, minimum size 16 AWG.

2.8 ARMORED VARIABLE FREQUENCY DRIVE CABLES

A. Cable to:
   1. CAN/CSA-C22.2 No. 38.
   2. CAN/CSA-C22.2 No. 174.
   3. CAN/CSA-C22.2 No. 230.

B. Conductors:
   1. Grounding conductors: Three soft bare copper, symmetrically located in continuous contact with the copper tape shield or continuous aluminum armour.
   2. Circuit conductors: copper, size as indicated.

C. Armoured cable for VFD application:
   1. Designed to reduce high frequency noise interference with data and control signals.
   2. Cross-linked polyethylene (XLPE), RW90 insulation on main conductors.
   3. Shield: Continuous copper tape shield with 50 percent overlap or continuous (non-interlocked) aluminum armour.
   4. Armored, continuously corrugated, corrosion resistant interlocking aluminum sheath.
   5. Approved for six-pulse VFD use.
   6. Overall PVC outer jacket rated FT4, and hazardous “HL” rated.
   7. Acceptable Manufacturer, Nexans DriveRx or approved equal in accordance with B8 Substitutes.

D. Fastenings:
   1. One hole aluminum straps to secure surface cables 50 mm and smaller. Two hole aluminum straps for cables larger than 50 mm.
   2. Channel type or cable tray supports for two (2) or more cables.

E. Connectors:
   1. Nexans, watertight, or hazardous rated cable connectors.

2.9 NON-ARMORED VARIABLE FREQUENCY DRIVE CABLES

A. Cable to:
   1. CAN/CSA-C22.2 No. 38.
   2. CAN/CSA-C22.2 No. 230.

B. Conductors:
   1. Grounding conductors: Three soft bare copper, symmetrically located in continuous contact with the copper tape shield or continuous aluminum armour.
   2. Circuit conductors: copper, size as indicated.

C. Cable for VFD application:
   1. Designed to reduce high frequency noise interference with data and control signals.
   2. Three bonding conductors – soft bare copper.
   3. Cross-linked polyethylene (XLPE), RW90 insulation on main conductors.
   4. Overall PVC outer jacket rated FT4.
   5. Shield: Continuous copper tape shield with minimum 50 percent overlap.
   6. Approved for six-pulse VFD use.

7. Acceptable Manufacturer, Belden VFD Cable or approved equal in accordance with B8.

D. All non-armoured VFD cables shall be run in conduit.

2.10 INSULATED GROUND CONDUCTORS

A. Insulated copper ground conductors:
   1. Size: as indicated on the Drawings, but in no case smaller than CEC required sizes.
   2. Type: soft drawn, stranded, flexible, high conductivity
   3. Shall meet the requirements of ASTM B8.
   4. Insulation: chemically cross-linked thermosetting polyethylene (XLPE) material, rated RW90
   5. Flame Test Rating:
      a. CSA FT4 (if exposed)
      b. CSA FT1 (if entirely within conduit)
   6. Insulation voltage rating: 600V
   7. Colour: green or green with yellow stripes as indicated on the Drawings.

2.11 BARE GROUND CONDUCTORS

A. Bare copper ground conductors:
   1. Size: as indicated on the Drawings, but in no case smaller than CEC required sizes.
   2. Type: soft drawn, stranded, flexible, high conductivity.
   3. Shall meet the requirements of ASTM B8.

2.12 ACCESSORIES FOR CONDUCTORS 1000 VOLTS AND BELOW

A. Wiring Accessories
   1. Splice connectors for equipment pig-tail, lighting and receptacle circuits: For wire sizes #12 and #10 AWG inclusive, twist-on compression spring type. Wing-Nut by Ideal, Marrette Type II by Marr Electric Ltd.
   2. Equipment pig-tail power circuit connections: For wire sizes #8 AWG minimum, split-bolt type, sized to suit number and size of conductors. Servit Type KS by Burndy Inc.
   3. Cable grips: To accommodate type and geometry of cable supported, single weave, variable mesh design, by Thomas and Betts Ltd., Crouse Hinds, Woodhead Canada Ltd.

B. Identification Devices:
   1. Sleeve: Permanent, PVC, white, with legible machine-printed black markings.
      a. Manufacturer and Product: Raychem; Type D-SCE or ZH-SCE.
   2. Heat Bond Marker:
      a. Transparent thermoplastic heat bonding film with acrylic pressure sensitive adhesive.
      b. Self-laminating protective shield over text.
      c. Machine printed black text.
      d. Manufacturer: 3M Co.; Type SCS-HB.
   3. Marker Plate: Nylon, with legible designations permanently hot stamped on plate.
   4. Tie-On Cable Marker Tags:
      a. Chemical resistant white tag.

b. Size: 13 mm by 51 mm.
c. Manufacturer and Product: Raychem; Type CM-SCE.

5. Grounding conductor: Permanent green heat-shrink sleeve, 51 mm minimum.

C. Cable ties:
1. Nylon, adjustable, self-locking.
2. Use nylon cable ties only in horizontal cable tray runs, to secure cables to the tray. Nylon cable ties are not to be used for cable support.
3. Manufacturer and Product: Thomas & Betts Ty-Rap.

D. Heat shrinkable insulation:
1. Thermally stabilized, crosslinked polyolefin.
2. Manufacturer and Product: Thomas & Betts Shrink-Kon.

PART 3 EXECUTION

3.1 INSTALLATION OF WIRES AND CABLES

A. Field Quality Control
1. Perform tests in accordance with 26 08 05, Acceptance Testing.
2. Perform megohmmeter testing of all cables (each conductor) for cable sizes 10 AWG and larger - with the following exceptions - megohmmeter testing is not required for: lighting circuit, 120 VAC duplex receptacle cabling. Provide test documentation for all cables tested.

B. Re-use of existing wiring
1. Except where specifically identified or approved, reuse of existing wiring is not permitted.
2. Ensure all existing wiring is tagged prior to disconnection of equipment.
3. Tag spare wires as “Spare” and indicate the location of the other end of the wire. In addition, correlate / identify both ends of each conductor.

C. General requirements
1. Wiring inside walls to drop vertically from above or come up from below. Horizontal cable runs within a wall are not permitted.
2. Branch circuit wiring for surge suppression receptacles and permanently wired computers and electronic equipment to have a dedicated neutral conductor. Do not share neutrals.
3. Conductor length for parallel feeders to be identical.
4. Install wires and cables in a continuous length between termination points. Splices are not permitted, except within junction boxes or where specifically approved by the Contract Administrator. Where splices are necessary and approved utilize the cable Manufacturer approved and recommended kit.
5. For outdoor or exposed installations, make all entries of cables or wires to equipment or panel from the bottom or side to minimize water entry points. Make no entries of cables or wires from the top unless specifically approved by the Contract Administrator.
6. For exterior wall penetrations:
a. Utilize Roxtec weatherproof sealing system.
b. Install to Manufacturer’s recommendations.

c. Install flush with exterior of the wall.
d. Prior to installation of seals, contractor to submit proof of training to the Contract Administrator. Do not install the cable seal system without equipment Manufacturer training, as work will have to be re-done. Contact Roxtec for training.
e. Prior to covering up wall penetration work, arrange for a site inspection of the work with the Contract Administrator. Proof of proper installation is required.

7. Do not pull conductors into conduit or cable tray until rough building construction operations have been completed.
8. Steel armor, steel conduit, and steel cable supports are generally not permitted in order to prevent corrosion due to H2S gas. Utilize aluminum materials in order to prevent corrosion.
9. Heat shrink insulation shall be used where additional insulation or dressing of connected cables is required. Electrical tape shall not be used for additional insulation or dressing of connected cables. The use of heat shrink tubing and electric heat gun to heat the shrink tubing is the required method.
10. Do not embed cables or conduits in masonry or concrete without written approval from the Contract Administrator. Wiring through conduit sleeves for short, direct wall or floor penetration is accepted.
11. Design wire and cable anchorage and support system for vertical and lateral loading in accordance with the Manitoba Building Code (MBC).
12. Provide non-ferrous GPO (glastic) or aluminum plates for single conductor cable entry into an enclosure. Aluminum entry plate shall be used where conductor armour is required to be bonded to the enclosure. GPO (glastic) materials shall be used where cable armour is not bonded to the enclosure.
13. In some cases the electrical conductor size may be too big to terminate on vendor supplied lugs. In these cases, the Contractor remains responsible for making all cable terminations. The Contractor shall replace the lugs or shall provide reducing compression connectors to make the termination. Alternatively the Contractor may provide appropriate junction boxes to reduce the conductors sizes as required to perform the cable termination.
14. Space out conductors and separate different systems and voltages in accordance with the CEC and the COW requirements. Refer to 26 05 36, Cable Trays for Electrical Systems for cable spacing requirements.

D. Installation of AC-90 cables:
1. To be used only in dry, non-hazardous commercial office type of occupancy.
2. Do not use AC-90 in industrial, wet well, pumping stations, or similar type of facilities.
3. Where AC-90 is permitted to be used, its use is limited as indicated:
   a. AC-90 is limited to 15A receptacle or lighting circuits only.
   b. All AC-90 cable runs must be concealed within a wall, or within a drop ceiling. Surface mounted AC-90 runs are prohibited.
   c. AC-90 drops to recessed light fixtures are permitted but shall not be run horizontally more than 6.5’ (2m) from conduit system boxes in ceiling space.
   d. AC-90 drops from conduit system in the ceiling space to feed outlets in wall stud partitions shall not run more than 6.5' (2 m) horizontally from the ceiling outlet box to the point where the AC-90 drops vertically into the partition.
   e. Where the total length of AC-90 would be greater than 2 m horizontally in the ceiling, provide conduit to a junction box closer to the drop location.

f. Cable runs to receptacles in walls shall be made from an accessible junction box. Do not use receptacles as feed through devices.
g. Do not run AC-90 horizontally within enclosed walls.

E. Installation of Teck 90 armored cables:
1. Shall be installed in industrial, hazardous, underground or wet areas and where noted on the Drawings and cable schedules.
2. Where surface mounted, cables shall be securely supported using aluminum cable clamps and cantruss supports. Space supports a maximum of 1 m apart.
3. Where multiple cables are run into an area, install cables on cable tray or on cantruss hangers.
4. Where applicable, de-rate and upsize cables in accordance with the CEC.
5. Minimum bend radius is 12 times, or larger as required by the cable Manufacturer.
6. Avoid damaging outer jacket covering the armor. In some areas, such as the chemical building, exposed armor is not desirable. Replace cables at no additional cost where outer jacket is damaged.

F. Installation of single RW90 conductors:
1. Install in conduit as per Section 26 05 34, Conduits, Conduit Fasteners and Conduit Fittings.
2. Ensure conduit is dry and clean prior to pulling conductors in. If moisture is present, thoroughly dry and clean conduits.
3. Use pulling lubricant when pulling conductors in conduit to reduce the strain on the wires. Lubricants must be polymer based, and must not adversely affect or degrade cable insulation.
4. Do not combine conductors in a common duct or conduit without regard for de-rating. De-rating is as per the CEC.

G. Installation of control cables:
1. Install control cables in conduit.
2. Ground shields at one end only. Where possible, ground shields at the end where power is supplied to the cable. Utilize shield grounding bar in panels, where present.
3. Shield drain wires, at the ungrounded end, are to be taped back to the cable. Do not cut the shield drain wire off.
4. CIC cable may not be installed in cable tray. Protection in conduit is required over the entire length.
5. ACIC cable may be installed in cable tray, provided that:
   a. The cable tray does not contain power cables, unless specifically authorized by the Contract Administrator in writing.
   b. The ACIC cable voltage rating is equal to or greater than the highest voltage contained in the cable tray.

H. Installation of fire alarm cabling:
1. Install in conduit as per Section 26 05 34, Conduits, Conduit Fasteners and Conduit Fittings.
2. Install conductors to be entirely independent of all other wiring. Do not enter raceway, boxes or enclosures occupied by other wiring except where necessary to connect to power supply, communication circuit, or ancillary devices.

3. Shields to be grounded at one end only (source end).
4. For data communication link A (DCLA) fire alarm circuits, install primary wiring circuit and alternate wiring circuit in separate conduit having a minimum separation of
   a. 300mm when installed vertically
   b. 1200mm when installed horizontally
5. For data communication link A (DCLA) fire alarm circuits, the primary wiring circuit and alternate wiring circuit may share the same conduit:
   a. For a distance of less than 3000mm where the primary and return conductors enter or exit field devices, control unit or transponder enclosures.
   b. For single conduit drops to individual field devices
   c. For single conduit drops to multiple field devices installed in a single room not exceeding 100m².

I. Installation of flexible cables:
1. Flexible, non-armored cables to be installed where plug / cord assemblies are specified and required.
2. Flexible festoon cables to be installed where specifically required for mobile equipment. Terminate both ends of festoon cables, providing cable strain relief.

J. Installation of mineral insulated cables:
1. Install cable securely supported by straps and hangers.
2. Support 2 hour fire rated cable a minimum of every 1 meter intervals (or less).
3. Make cable terminations by using cable Facility approved termination kits. Termination must be performed by personnel specifically trained by the equipment Facility.

K. VFD cable to be installed as follows:
1. VFD cable to be installed between a variable frequency drive (VFD) and the load which it serves.
2. Secure using aluminum cable clamps.
3. Route armored cable on cable tray or strapped to cantruss supports (for short runs only).
4. Non-armored VFD cable is to be run in conduit.
5. Metalic armor to be bonded to ground at both ends.
6. Supply end of the VFD cable to have the bond conductors connected to the VFD drive and connected to ground. Load end of cables to have the bond conductors connected to the motor bond/ground lug.
7. Wire and connect in accordance with the Facility's recommendations.
8. Space VFD cable as per the following minimum distances:
   a. From 120/208V wiring: 300 mm
   b. From 24 VDC instrumentation and control wiring: 300 mm
9. Avoid damaging outer jacket covering the armor. In some areas, such as the chemical building, exposed armor is not desirable. Replace cables at no additional cost where outer jacket is damaged.

3.2 COLOUR CODING AND TAGGING

A. Colour code all power distribution and control conductors at both ends throughout Facility.

B. Same colour for same phase throughout, by insulation colour or permanently applied colour banding at all distribution centres, panels and outlet boxes.

C. Colour tape shall be vinyl, 19mm wide, red, blue, white.

D. Colour coding to be in accordance with CEC and as follows:

Equipment Grounding Conductor	-	green
Neutral conductor	-	white
1 Phase, 3 wire	-	red, black and white
3 Phase	-	red (A), black (B), blue (C)
DC (positive)	-	blue
DC (negative)	-	brown

E. All control conductors shall have wire numbers at both ends of each wire using Brady heat shrink sleeves with typewritten wire numbers. Wire markers shall have a white background and black lettering. Hand written tags on adhesive tape is not acceptable. The Contractor shall adhere to the tagging scheme shown on the control Drawings.

F. All 120/208V power cables require a tag. If tag is not indicated on Drawings, reference source panel and circuit in tagging cable. Eg, Cable fed from PNL-C721, Circuit 7: C-C721-7.

G. Use wire markers in terminating all wiring, including but not limited to power, control, signal, communication and lighting wiring.

H. Identify all multi-conductor cables at all termination points with wire markers. In addition to identifying the cable, indentify each of the individual conductors at all termination points, unless it is a color coded power conductor. All cable markers must be readily visible when the device cover is open.

END OF SECTION

SECTION 26 05 22

CONDUCTORS AND TERMINATIONS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA C22.1, Canadian Electrical Code, Part 1, Safety Standard for Electrical Installations.

B. CSA C22.2 No.41, Grounding and Bonding Equipment (Tri-National Standard, with NMX-J-590ANCE and UL 467).

C. CSA C22.2 No.65, Wire connectors (Tri-National Standard, with UL 486A-486B NMX-J-543-ANCE).

1.2 SUBMITTALS

A. Submit product data in accordance with Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 CONNECTORS AND TERMINATIONS

A. Splices:
   1. Utilize cable manufacturer approved splice kits.
   2. Acceptable Manufacturer: 3M or approved equal in accordance with B8.

B. Lugs and connectors:
   1. To CSA C22.2 No.65.
   2. Provide lugs / connectors for power and ground connections where required including:
      a. Where internal lugs are not included with a piece of equipment.
      b. Ground connections.
   3. Connectors shall be fabricated to include bushings or similar devices to prevent sharp edges from being in contact with conductor insulation.
   4. Lugs for power conductors shall be tin plated copper, long barrel compression type.
   5. Rated 600 / 1000 volts of same material as conductor metal.
   6. Shall be suitable for 75 degrees C cable termination.
   7. Provide 1 hole compression lugs for conductors 1/0 AWG and smaller, 2 hole lugs for 2/0 AWG and larger conductors.
   8. Lugs for ground conductors 14 AWG and smaller, shall be ring type.
   9. Lugs for control wiring shall be spade or ring type.
   10. Hardware for bolting to cable lugs and ground lugs to ground bus shall be chrome plated Grade 5 bolts, nuts, split and flat washers.
   11. Lugs shall be compatible with the conductor size, the cable voltage rating, and the equipment connection.
   12. Acceptable Manufacturer: Burndy, Thomas & Betts.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install terminations, lugs, connectors, and splices in accordance with Manufacturer's instructions.

B. Wiring and connections should be made within junction boxes, termination cabinets, panels and devices. Use splice kits, only where absolutely necessary, and with specific approval from the Contract Administrator.

C. Splices shall only be used with specific written approval from the Contact Administrator. Otherwise, connection shall be made using suitable lugs and connectors in approved junction boxes or pull boxes.

D. Install connector bushings to prevent sharp edges from cutting or damaging conductor insulation.

END OF SECTION

SECTION 26 05 28

GROUNDING AND BONDING

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 26 05 01, Common Work Results - Electrical.

1.2 CODES AND STANDARDS

A. American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)
   1. ANSI/IEEE 837, Qualifying Permanent Connections Used in Substation Grounding.

B. Canadian Standards Association, (CSA International)

1.3 SUBMITTALS

A. Submit Shop Drawings indicating all components and equipment to be used:
   1. Manufacturer's product data sheets:
      a. Part number.
      b. Materials.
      c. Installation instructions.
      d. Certifications.

1.4 O&M MANUAL

A. Include all Shop Drawings and product submittals.

PART 2 PRODUCTS

2.1 EQUIPMENT

A. Exterior exposed grounding conductors:
   1. TWU green insulated, soft drawn, stranded copper wires shall be used for exposed, above grade grounding conductors.

B. Exterior buried or imbedded grounding conductors:
   1. Bare, soft drawn, stranded copper shall be used below grade.

C. Insulating Paint
   1. Insulating paint shall be gray Gyptal

D. Interior equipment grounding and bonding conductors:
   1. Run in conduit: RW90, green insulated, soft drawn, stranded copper shall be used inside conduits.
   2. Run in cable tray or channel: soft drawn, stranded copper in accordance with Section 26 05 36, Cable Trays for Electrical Systems shall be used for cable tray bonds.

E. Rod electrodes: copper clad steel, 19 mm diameter, minimum length of 3 m. Provide longer ground rods as indicated on the Drawings. Where multiple rods are connected, utilize a threadless compression coupling.
   1. Acceptable Manufacturers:
      a. Burndy 38-7408-02
      b. Slacan 9340
      c. Joslyn J5349
      d. Hydel 3410G
      e. T & B GR7510

F. Non-corroding accessories necessary for grounding system, type, size, material as indicated, including but not necessarily limited to:
   1. Grounding and bonding bushings.
   2. Protective type clamps.
   3. Bolted type conductor connectors.
   4. Thermit welded type conductor connectors.
   5. Bonding jumpers, straps.
   6. Pressure wire connectors.
   7. Acceptable Manufacturers:
      a. Erico
      b. Burndy
      c. or approved equal in accordance with B8 Substitutes.

G. Ground Pipe Clamp
   1. Requirements:
      a. Tinned copper or high copper alloy bronze
      b. Separate bolts for mounting on pipe and connecting wire
      c. 2/0 AWG conductor connection
      d. CSA or cUL approved.

H. Ground Wells
   1. For non-vehicular areas:
      a. Requirements:
         1) Square: minimum 304.5mm (12”) x 304.5mm (12”)
         2) Depth: minimum 304.5mm (12”)
         3) Material: high density polymer concrete body
         4) Cover: bolted in place
      b. Acceptable Manufacturer and Model:
         1) Synertech Tier 15
         2) or approved equal in accordance with B8.

2. For vehicular areas:
   a. Requirements:
      1) Equipment to be rated to handle semi-trailer traffic
      2) Rectangular: minimum 339.7mm (13-3/8”) x 508mm (20”)
      3) Depth: minimum 304.5mm (12”)
      4) Material: high density reinforced concrete body
      5) Cover: bolted in place
   b. Acceptable Manufacturer and Model:
      1) Oldcastle B1017 box, B2027-51JH cover and all other accessories as required to ensure complete and stable installation.
      2) or approved equal in accordance with B8.

I. Compression Connection – “C” Tap
   1. Requirements:
      a. Material: solid copper
      b. Type: “C” Tap
   2. Acceptable Manufacturer and Model:
      a. Burndy YGHC
      b. or approved equal in accordance with B8.

J. Compression Connection – Butt Splice
   1. Requirements:
      a. Material: solid copper
      b. Type: heavy duty splice
   2. Acceptable Manufacturer and Model:
      a. Burndy YGHS
      b. or approved equal in accordance with B8.

K. Exothermic Connection
   1. Requirements:
      a. Material: copper
   2. Acceptable Manufacturer and Model:
      a. Burndy ThermOweld or BurndyWeld product lines
      b. or approved equal in accordance with B8.

PART 3 EXECUTION

3.1 GENERAL

A. Provide a complete permanent, continuous grounding system, including electrodes, conductors, connectors and accessories.

B. Provide a complete bonding system, connected to the Facility ground. Structural steel, cladding, and all metal equipment are to be bonded to ground.

C. Install connectors in accordance with Manufacturer's instructions.

D. Protect exposed grounding conductors from mechanical injury.

E. Make buried connections and connections to electrodes, using copper welding by thermit process to ANSI/IEEE 837.

F. Obtain approval from the Contract Administrator before any conductor connections are buried.

G. Soldered joints are not permitted.

3.2 INSTALLATION

A. Conduit runs and cable trays shall be mechanically joined together and bonded to the building steel and main ground grid to ensure electrical continuity.

B. Cable tray shall be bonded in accordance with 26 05 36, Cable Trays for Electrical Systems.

C. The ground conductor in Teck 90 cable shall be bonded to ground at both ends (unless noted otherwise for single conductor runs) using compression type connectors or Manufacturer supplied grounding screws.

D. Supply and install all Teck 90 connectors complete with grounding rings to ensure adequate bonding of Teck cable armour.

E. Where cables enter a termination or junction box, all grounding conductors shall be bonded and connected to a common grounding point and to metallic box enclosures.

F. All metallic devices mounted in non-metallic enclosures shall be bonded and grounded. Manufacturer's bonding rings shall be used where available.

G. For both metallic, and non-metalic conduit system, an insulated bonding conductor shall be run inside the conduit and bonded at termination points. Using the conduit as a bonding means is not acceptable. Bonding conductors are not specifically shown on the Drawings. Provide conductors sized in accordance with Table 16 of the CEC.

H. All above grade bonding or grounding connections shall be cleaned to bare metal, treated with cleaning paste, connected to the structure or equipment, then sprayed with Gyptal.

I. All above grade ground conductors shall be continuously run and without splices where possible.

J. Ground conductors installed along beams or columns shall be run on the inside of the flange adjacent to the web, where practical. The conductor shall be supported at maximum intervals of 3 feet with one-hole conduit clamps.

K. Exposed grounding conductors shall be protected where subject to mechanical injury.

L. Exterior run grounding conductors shall be run in rigid PVC conduit where required for support or mechanical protection.

M. Use mechanical compression connectors for grounding/bonding connections to equipment provided with lugs.

N. All connections to building steel and to ground rods shall be by exothermic (cadweld) connections.

O. Compression type connectors and exothermic connections shall be installed in accordance with the Manufacturer's instructions.

P. Install conductors with a minimum of bends and without kinking. Where bends are unavoidable, make bends as smoothly as possible.

Q. Minimum bending radius for grounding conductors shall be 2 inches.

R. Install bonding conductor in cable trays installed in this Contract.

S. Grounding and bonding connection to panels shall be made on the interior of the panel.

3.3 INSPECTION

A. Do not allow or cause any work performed or installed to be covered up or enclosed by work of this Section prior to the required inspections, tests and approvals.

B. Ensure grounding lugs are torqued to the required values. Required values shall be established by the equipment Manufacturer or by CSA standards.

3.4 ELECTRODES

A. Install rod electrodes and make grounding connections as shown on the Drawings.

B. Connect multiple rod electrodes together as shown on the Drawings.

C. Use size 4/0 AWG copper conductors for connections to ground electrodes unless indicated otherwise.

D. Install a ground well at each ground rod location as shown on the Drawings.

E. Locate all existing underground services in the area prior to installation of ground electrodes. Ensure no existing underground pipes or cables are damaged during the installation of the electrodes.

F. Determine location of existing electrodes and modify Drawings to show the exact location.

G. Connect new electrodes to existing electrodes at locations shown on the Drawings.

3.5 INSULATED CONDUCTOR JOINTS

A. For joints made on insulated ground conductors, use exothermic or compression connectors. Wrap all exposed bare copper with self annealing splice tape and cover with green electrical tape.

3.6 PIPE GROUNDING

A. For pipe grounding, connect ground conductor to pipes using a pipe clamp or exothermic weld directly to the pipe. Remove enough paint from the pipe to provide a sufficient area of bare metal for the grounding connection to the pipe. After ground connection is installed, replace insulation and paint the affected pipe sections and any bare copper to match the existing pipe colour.

END OF SECTION

SECTION 26 05 29

HANGERS AND SUPPORTS

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 26 05 01, Common Work Results – Electrical

1.2 SUBMITTALS

A. Submit product data in accordance with Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 FRAMING AND SUPPORT SYSTEM

A. Materials:
   1. Conduit support structures shall employ aluminum Unistrut Framing System together with the Manufacturer's connecting components and fasteners for a complete system with exceptions indicated herein.
   2. For conduit supports in the Chemical Building, utilize 316 stainless steel Unistrut Framing System together with the Manufacturer's stainless steel connecting components and fasteners for a complete system.
   3. Acceptable Manufacturer:
      a. Unistrut P1000 series or approved equal in accordance with B8 Substitutes.

B. Finishes:
   1. Wet locations: Aluminum.
   2. Indoors, dry locations: Aluminum.
   3. Corrosive areas (Chemical Building): 316 stainless steel.
   4. Wet corrosive areas (exposed to H2S gasses): Aluminum.
   5. Nuts, bolts, machine screws: Stainless Steel.

2.2 CONCRETE AND MASONRY ANCHORS

A. Materials: 316 stainless steel inserts and anchors for corrosion resistance.

B. Components: non-drilling anchors for use in predrilled holes, sized to safely support the applied load with a minimum safety factor of four.

C. Manufacturer: Hilti (Canada) Limited or approved equal in accordance with B8.

PART 3 EXECUTION

3.1 INSTALLATION

A. Secure equipment to solid masonry, tile and plaster surfaces with anchors.

B. Secure equipment to poured concrete with expandable inserts.

C. Secure equipment to hollow masonry walls or suspended ceilings with toggle bolts.

D. Support equipment, conduit or cables using clips, spring loaded bolts, cable clamps designed as accessories to basic channel members.

E. Maximum spacing between conduit supports:
   1. As per Section 26 05 34, Conduits, Conduit Fasteners, and Conduit Fittings.

F. Fasten exposed conduit or cables to building construction or support system using straps.
   1. PVC Conduit:
      a. Two-hole straps for all sizes of conduit.

G. Suspended support systems.
   1. Support individual cable or conduit runs with 10 mm diameter threaded rods and spring clips.
   2. Support 2 or more cables or conduits on channels supported by 10 mm diameter threaded rod hangers where direct fastening to building construction is impractical.

H. For surface mounting of two or more conduits use channels, with maximum centre spacing as indicated above.

I. Provide metal brackets, frames, hangers, clamps and related types of support structures where indicated or as required to support conduit and cable runs.

J. Ensure adequate support for raceways and cables dropped vertically where there is no wall support.

K. Do not use wire lashing or perforated strap to support or secure cables.

L. Do not use supports or equipment installed for other trades for conduit or cable support except with permission of other trade and approval of the Contract Administrator.

M. Install fastenings and supports as required for each type of equipment cables and conduits, and in accordance with Manufacturer's installation recommendations.

N. Sand and file sharp edges where members were cut.

END OF SECTION

SECTION 26 05 31

SPLITTERS, JUNCTION, PULL BOXES AND CABINETS

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Materials and components for splitters, junction, pull boxes, and cabinets.

1.2 CODES AND STANDARDS

A. Canadian Standards Association (CSA International)
   1. CSA C22.2 No.76, Splitters.
   2. CSA C22.2 No. 30, Explosion-Proof Enclosures for Use in Class I hazardous Locations.
   3. CSA C22.2 No. 40, Enclosures for Electrical Equipment, Non-Environmental Considerations (Tri-National Standard, with NMX-J-235/1-ANCE-2007 and UL 50).
   4. CSA C22.2 No. 94, Special Purpose Enclosures.

1.3 SUBMITTALS

A. Submit Shop Drawings indicating the components and equipment to be used:
   1. Manufacturer’s data sheets for each type of junction box, cabinet, splitter, and pull box.
   2. Manufacturer’s Shop Drawings including:
      a. Dimensioned layout and general arrangement.
      b. CSA enclosure rating.
      c. Voltage, current rating of lugs and termination equipment.
      d. Accessories and components.
      e. Material.
      f. An indication from the Contractor in which area each type of enclosure / box will be installed.

PART 2 PRODUCTS

2.1 SPLITTERS

A. General
   1. Three sets of lugs, minimum, sized and suitable for conductor termination.
   2. Main and branch lugs to match required size and number of incoming and outgoing conductors as indicated.
   3. Provide ground bar, with a minimum of three terminals.

B. Splitters installed in dry, non-hazardous, non-corrosive locations to be constructed of sheet metal, with a hinged lockable cover, CSA enclosure type 1, 2 or 12. Use enclosure type 12 for facilities that are sprinklered.

C. Splitters for wet, exterior application to be constructed of sheet metal, CSA enclosure type 4X.

D. Do not install splitters in hazardous or corrosive areas. If required install suitable, Class I junction boxes.

2.2 JUNCTION, PULL BOXES AND CABINETS

A. Junction boxes and pull boxes installed in dry, non-hazardous, non-corrosive office type of locations:
   1. CSA enclosure type 1, 2 for dry office type areas. Use sealed, gasketted, CSA enclosure type 12 for sprinklered office areas.
   2. To be constructed of sheet metal.
   3. For boxes 100 mm square and smaller, screw-on type, flat covers.
   4. For boxes larger than 100mm square, box covers are to have a continuous piano hinge and clamps for opening.

B. Cabinets installed in dry, non-hazardous, non-corrosive process locations:
   1. To CSA C22.2 No. 94 and UL 508A
   2. CSA enclosure type 12, gasketted.
   3. To be constructed of painted, mild steel.
   4. Back-plate with offsets for installation of devices.
   5. Continuous piano hinge, door with quarter turn latch and handle.

C. Junction boxes and pull boxes for wet or corrosive locations:
   1. CSA enclosure type 4 (aluminum only) or 4X, gasketted.
   2. Constructed of cast aluminum with threaded connection.
   3. Termination of underground PVC conduit system may be made into an exterior mounted, rigid PVC CSA enclosure type 4X as applicable.
   4. Utilize 316 stainless steel bolts, washers and mounting hardware.

D. For hazardous locations:
   1. To CSA C22.2 No. 30 and UL1203.
   2. Rated for Class I, Div. 1 & 2 (or Zone 0, 1 and 2), Groups C, D locations.
   3. Constructed of cast copper free aluminum with threaded connection.
   4. Hinged, bolt-on style aluminum cover with neoprene gasket.
   5. Factory installed aluminum mounting plate for terminals, lugs and electrical devices.
   6. Factory installed threaded openings for conduit and cable connections.
   7. Utilize 316 stainless steel bolts, washers and mounting hardware.

PART 3 EXECUTION

3.1 SPLITTER INSTALLATION

A. Install splitters and mount plumb, true and square to the building lines.

B. Extend splitters full length of equipment arrangement except where indicated otherwise.

3.2 JUNCTION BOX, PULL BOXES AND CABINET INSTALLATION

A. Install pull boxes, pull boxes and cabinets in inconspicuous but accessible locations.

B. Cabinets shall have a minimum of 1 meter of clearance in front, in accordance with CEC requirements.

C. If junction boxes are required in inaccessible location, provide a suitable access panel which allows sufficient space for opening the junction box.

3.3 IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - Electrical.

B. Nameplates for cabinets and splitters, size 8 nameplates engraved as follows:
   1. Engrave with the requirements as indicated on the Drawings. If nothing is specified, the minimum is as follows:
   2. Line 1 is to be the cabinet or splitter identifier as indicated on the Drawings, for example “SPLITTER SPL-M701”.
   3. Line 2 is to be the voltage, for example “600V, 3Ø, 4W”.
   4. Line 3 is where the panel is fed from, for example “Fed From DP-M702”

C. Nameplates for junction boxes and pullboxes, size 1 or size 2 engraved with the circuit numbers in the junction box, for example “M703-2” - which corresponds to PNL-M703, circuit 2.

END OF SECTION

SECTION 26 05 32

OUTLET BOXES, CONDUIT BOXES AND FITTINGS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. UL 514A, Metalic Outlet Boxes.

B. UL 514B, Conduit, Tubing and Cable Fittings.

C. UL 1203, Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations.

D. UL 886, Outlet Boxes and Fittings for Use in Hazardous (Classified) Locations

E. CSA C22.1-2012, Canadian Electrical Code, Part 1.

F. CSA C22.2 No. 18, Non Metallic Outlet Boxes.

G. CSA C22.2 No. 30, Explosion-Proof Enclosures for Use in Class I Hazardous Locations

H. ANSI Standard C33.84, Safety Standards for Outlet Boxes and Fittings.

I. ANSI Standard C33.27, Safety Standard for Outlet Boxes and Fittings for Use in Hazardous Locations, Class I, Groups A, B, C and D, and Class II groups E, F and G.

1.2 SHOP DRAWINGS AND PRODUCT DATA

A. Submit product data in accordance with Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 OUTLET AND CONDUIT BOXES GENERAL

A. Size boxes in accordance with CSA C22.1.

B. Size outlet boxes as required to accommodate wiring devices.

C. Gang boxes where wiring devices are grouped.

D. Blank cover plates for boxes without wiring devices.

E. Knock-out covers for sealing penetration holes.

F. Combination boxes with barriers where outlets for more than one system are grouped.

2.2 SHEET METAL BOXES

A. Hot dipped galvanized steel.

B. All 100 mm square boxes shall be minimum 40 mm deep.

C. Deep boxes shall be installed where required.

D. Device boxes shall be minimum 64 mm deep

2.3 BOXES FOR RIGID METAL CONDUIT – NON-EXPLOSIONPROOF

A. General Requirements:
   1. Acceptable materials:
      a. Cast copper free aluminum
   2. Suitable for threaded rigid conduit
   3. Mounting lugs as required.
   4. Wet location, gasketted covers for all devices.
   5. To CSA 22.2 No. 18, UL 514, ANSI 33.84.

B. Conduit Junction Boxes:
   1. 100mm (4”) round, copper free cast aluminum boxes with factory-threaded hubs.
   2. Tapped conduit openings and plugs.
   3. Gasketed cover
   4. Manufacturer / Model:
      a. Crouse Hinds GRF or VXF series

C. Condulet Outlet Bodies
   1. Cast copper free aluminum condulet outlet bodies, with factory-threaded hubs for surface wiring pull points.
   2. Size outlet bodies to comply with CEC requirements.
   3. Manufacturer / Model:
      a. Crouse Hinds Form 7 series, (C, E, L, LB, LL, LR, T, TA, TB, X) to suit the application. All blank covers to be cast aluminum, wedgenut style covers.

D. Device Boxes
   1. Cast copper free aluminum boxes with factory-threaded hubs and mounting feet for surface wiring of receptacles.
   2. Single gang, 2-gang, 3-gang as required.
   3. Manufacturer / Model:
      a. Crouse Hinds FS / FD series

2.4 BOXES FOR RIGID METAL CONDUIT – EXPLOSION PROOF

A. General Requirements:
   1. Rated for Hazardous Class I, Div. 1 & 2 (or Zone 0, 1 and 2), Groups C, D Locations.
   2. Acceptable materials:
      a. Cast copper free aluminum.
   3. Suitable for threaded rigid aluminum conduit.

4. Mounting feet as required.
5. To CSA 22.2 No. 30, UL 886, ANSI C33.27.

B. Conduit Junction Boxes
1. Cast copper free aluminum boxes with factory-threaded hubs for surface wiring pull points.
2. Size boxes to comply with CEC requirements.
3. Manufacturer / Model:
   a. Crouse Hinds GUA, GUR, EAB, EAJ series.

C. Condulet Outlet Bodies
1. Cast copper free aluminum condulet outlet bodies, with factory-threaded hubs for surface wiring pull points.
2. Size outlet bodies to comply with CEC requirements.
3. Manufacturer / Model:
   a. Crouse Hinds OE series, LBH series, LBY series to suit the application.
   b. Approved equal by Appleton or Killark.

D. Device Boxes
1. Cast aluminum boxes with factory-threaded hubs and mounting feet for surface wiring of receptacles.
2. Single gang, 2-gang, 3-gang as required.
3. Manufacturer / Model:
   a. Crouse Hinds EDS or EDSCM series.

2.5 FITTINGS - GENERAL

A. Materials and type to suit the conduit type and the installation requirements.

B. Conduit outlet bodies for conduit up to 35 mm and pull boxes for larger conduits.

2.6 FITTINGS USED WITH RIGID THREADED METAL CONDUIT

A. Copper free aluminum, threaded sealing fittings for explosion proof hazardous areas.
1. Manufacturer / Model:
   a. Crouse Hinds EYS-SA, EZS-SA.
   b. Appleton type EYF-AL or EYM-AL.
   c. Killark type EY or EYS.

B. Copper free aluminum, threaded drain sealing fittings for explosion proof hazardous areas.
1. Manufacturers and Products:
   a. Crouse-Hinds type EYD-SA or EZD-SA.
   b. Appleton type EYDM-A.

C. Copper free aluminum, threaded drain / breathers for explosion proof hazardous areas.
1. Manufacturer / Model:
   a. Crouse Hinds ECD series
   b. Appleton type ECDB.

D. Sealing compound.
   1. Manufacturer / Model:
      a. Crouse Hinds Chico sealing compound or Chico speed seal.

E. Copper free aluminum, threaded unions.
   1. Manufacturer / Model:
      a. Crouse Hinds UNF, UNY series
      b. Approved equal by Appleton or Killark.

EXECUTION

2.7 INSTALLATION

A. General
   1. Provide boxes sized as required by the Canadian Electrical Code.
   2. Support boxes independently of connecting conduits.
   3. Install fittings in accordance with the Manufacturer's recommendations.
   4. Fill boxes with paper, sponges or foam or similar approved material to prevent entry of debris during construction. Remove upon completion of work.
   5. Provide correct size of openings in boxes for conduit, mineral insulated and armoured cable connections. Reducing washers are not allowed.
   6. Install all outlets surface mounted as required for the installation.
   7. Do not distort boxes during installation. If boxes are distorted, replace with new boxes.
   8. Install vapour barrier material to surround and seal all outlet boxes located on exterior walls of building. Maintain wall insulation.
   9. Extension rings shall not be utilized to accommodate conductor fill requirements.
   10. Confirm the direction of door swings on site, to confirm that outlet boxes for light switches are located on the latch side of the door.
   11. Provide lamacoid for all device boxes indicating the circuit(s) contained within.
       Example: "G10-5" - which corresponds to Panel G10, circuit 5

B. Non-hazardous, dry office areas:
   1. Install commercial series, sheet metal outlet boxes and fittings.
   2. Outlet boxes that penetrate opposite sides of a wall shall be offset to maintain the integrity of the fire separation. Boxes shall not be installed back-to-back.

C. Exterior or wet, corrosive areas:
   1. Install aluminum, threaded, gasketted, outlet boxes, conduit boxes, and fittings.

D. Hazardous areas:
   1. Install aluminum, threaded, sealing fittings, conduit boxes, outlet boxes, unions, drains, expansion fittings, flexible couplings, and all other components approved for Class I Class I, Div. 1 & 2 (or Zone 0, 1 and 2) hazardous areas.
   2. The installation shall meet the requirements of the CEC, Section 18.

END OF SECTION

SECTION 26 05 34

CONDUITS, CONDUIT FASTENERS, AND CONDUIT FITTINGS

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Requirements specified within this section apply to all sections in Division 26, Electrical. This section supplements requirements of other Divisions.

1.2 CODES AND STANDARDS

A. CAN/CSA C22.2 No. 18, Outlet Boxes, Conduit Boxes, and Fittings and Associated Hardware.

B. CSA C22.2 No. 45, Rigid Metal Conduit.

C. CSA C22.2 No. 56, Flexible Metal Conduit and Liquid-Tight Flexible Metal Conduit.

D. CSA C22.2 No. 83, Electrical Metalic Tubing.

E. CSA C22.2 No. 211.2, Rigid PVC (Unplasticized) Conduit.

F. CSA C22.2 No. 211.1, Rigid Types EB1 and DB2 / ES2 PVC Conduit

G. CAN/CSA C22.2 No. 227.3, Flexible, Non-metallic Tubing.

1.3 GENERAL CONDUIT REQUIREMENTS

A. The Drawings do not show every specific conduit run. Supply and install conduit, and support systems as required for a complete installation.

B. The materials for each conduit must meet the requirements of the area. Some areas are wet, highly corrosive; other areas have chemicals which may adversely interact with specific materials. Care must be taken in making the proper conduit selection for the particular area.

C. Design equipment anchorage and support system for vertical and lateral loading in accordance with the MBC.

1.4 SUBMITTALS

A. Submit written certification from a Professional Engineer licensed in the Province of Manitoba stating that support systems, anchorage, and equipment are structurally sound, and have been designed according to requirements of the MBC.

B. Submit Shop Drawings indicating the component and equipment to be used:
   1. Electric metallic tubing.

2. Rigid aluminum conduit.
3. Rigid PVC conduit.
4. Flexible metal, liquid tight conduit.
5. Flexible non-metallic, liquid tight conduit
6. Conduit fittings, conduit couplings.
7. Hazardous area sealing fittings, coupling and sealing compound
8. Conduit clamps and support systems.
9. Submit information on where each type of conduit will be installed, prior to installation.
10. Submit details of the ULC approved fire stop assembly for approval prior to installation.

PART 2 PRODUCTS

2.1 CONDUITS

A. Rigid aluminum conduit
   1. Meet requirements of CSA C22.2 No. 45.
   2. Materials: type 6063, copper-free aluminum alloy.

B. Rigid PVC conduit
   1. Meet requirements of C22.2 No. 211.2.
   2. FT4 rated where installed indoors.
   3. Materials: Polyvinyl Chloride (PVC).

C. Rigid DB2 PVC conduit
   1. Meet requirements of C22.2 No. 211.1.
   2. Materials: Polyvinyl Chloride (PVC).

D. HDPE conduit
   1. Meet the requirements of C22.2 No. 211.2
   2. Materials: High Density Polyethylene

E. EMT conduit
   1. Meet requirements of C22.2 No. 83.
   2. Materials: steel, electroplated outside finish, aluminum painted inside walls.

F. Flexible liquid tight, metal conduit
   1. Meet requirements of CSA C22.2 No. 56.
   2. Materials: heavy duty, liquid tight, PVC with stainless steel core.

G. Flexible non-metallic liquid tight conduit
   1. Meet requirements of CSA C22.2 No. 227.3.
   2. Materials: heavy duty, liquid tight, PVC.

H. Conduits shall be sized in accordance with CEC requirements for wire counts installed. Conductors shall be de-rated according to code requirements. Upsize conductors as required to meet CEC and voltage drop requirements. Minimum conduit size: 21 mm, unless specifically indicated otherwise on the Drawings or specifically approved by the Contract Administrator.

I. Conduits shall be EMT, rigid aluminum, liquid tight, and rigid PVC, as required to meet the requirements of the installation. Do not use steel conduit for areas where H2S gas or other corrosive gasses or liquids are present

2.2 CONDUIT FASTENINGS

A. One hole straps to secure surface conduits 50 mm and smaller. Two hole straps for conduits larger than 50 mm.

B. Beam clamps to secure conduits to exposed steel work.

C. Channel type supports for two or more conduits.

D. Strap material to match conduit material.

E. Threaded rods, minimum 10 mm diameter, to support suspended channels.

2.3 CONDUIT SPACERS

A. PVC coated malleable metal spacers, CSA approved for the purpose.

B. Aluminum channel may be utilized where conduits are grouped, however a non-metallic spacer must be provided between the aluminum channel and concrete.

2.4 CONDUIT FITTINGS

A. General:
   1. Utilize factory made elbows for 27mm and larger conduits.
   2. All components to be CSA certified for the intended area of use.
   3. Meet all requirements of the CEC with respect to hazardous area sealing fittings.
   4. Utilize insulated grounding bushings at all enclosure entries for metallic conduit.

B. Electric metallic tubing (EMT):
   1. Meet requirements of CSA C22.2 No. 45.
   2. Type: steel body and locknuts with steel or malleable iron compression nuts. Set screw and drive-on fittings not permitted.
   3. Electro zinc-plated inside and out.
   4. Raintight.
   5. Coupling Manufacturers and Products:
      a. Appleton type 95T.
      b. Crouse-Hinds.
      c. Thomas & Betts.
   6. Connector Manufacturers and Products:
      a. Appleton type 86T.
      b. Crouse-Hinds.
      c. Thomas & Betts.

C. Rigid aluminum conduit:
   1. Meet requirements of CSA C22.2 No. 45.

2. Type: threaded, copper-free aluminum. Set screw fittings not permitted.
3. Insulated bushing:
   a. Material: Cast aluminum, with integral insulated throat, rated for 150 degrees C.
   b. Manufacturer and Product: O-Z/Gedney Type AB.
4. Grounding bushing:
   a. Material: Cast aluminum with integral insulated throat, rated for 150 degrees, with solderless lugs.
   b. Manufacturer and Product: O-Z/Gedney Type ABLG.
5. Conduit hub:
   a. Material: cast aluminum, with insulated throat.
   b. ULC listed for use in wet locations.
   c. Manufacturers and Products:
      1) O-Z/Gedney Type CHA.
      2) Thomas & Betts Series 370AL.
      3) Meyers Series SA.
6. Refer to 26 05 32 for outlet boxes, conduit boxes and fittings.
7. Expansion Fitting Manufacturers and Products:
   a. Deflection/Expansion Movement:
      1) Appleton type DF.
      2) Crouse-Hinds type XD.
   b. Expansion Movement Only:
      1) Appleton type XJ.
      2) Crouse-Hinds type XJ.

D. Flexible metal, liquid-tight conduit:
   1. Meet requirements of CSA C22.2 No. 56.
   2. Metal insulated throat connectors with integral nylon or plastic bushing rated for 105 degrees C.
   3. Insulated throat and sealing O-rings.
   4. Manufacturers and Products:
      a. Thomas & Betts; Series 5331.
      b. O-Z/Gedney; Series 4Q.

E. Flexible, nonmetallic, liquid-tight conduit:
   1. Type: High strength plastic body, complete with lock nut, O-ring, threaded ferrule, sealing ring, and compression nut.
   2. Body/compression nut (gland) design to assure high mechanical pullout strength and watertight seal.
   3. Manufacturers and Products:
      a. O-Z/Gedney; Type 4Q-P.
      b. Thomas & Betts; Series 6300 or Carlon; Type LT.

F. PVC Conduit and Tubing:
   1. Meet requirements of NEMA TC-3.
   2. Type: PVC, slip-on.

G. HDPE Conduit and Tubing:
   1. Meet requirements of CSA C22.2 No. 211.2 and UL 651 for electrical cable raceway.

2. Type: Manufacturer approved

2.5 EXPANSION FITTINGS FOR RIGID CONDUIT

A. All conduits entering outlet boxes and devices that are located in walls subject to movement shall be terminated by means of liquid-tight flexible conduit, approximately 450 mm in length between the conduit and the outlet box or device which is being supplied. All conduits, bus duct, wireways, etc., passing through or across expansion joints of the building shall be installed with the use of approved expansion fittings.

B. There are structural expansion joints in the facilities – these are not specifically identified on the electrical Drawings. Review the structural Drawings and note the locations of all expansion joints. Provide expansion couplings and fittings for all conduit crossing the joints. Do not locate rigid devices (for example panels) across or on top of the expansion joints. Add expansion fittings as required to accommodate expansion joints due to temperature variations.

2.6 FISH CORD

A. Polypropylene.

2.7 CONDUIT BONDING

A. All conduits shall have a bare or insulated copper bonding conductor run within. The bonding conductor shall be sized as per the CEC, table 16. The conduit itself cannot be used as the only means of bonding. Provide bond jumpers between conduit systems, and to the bond terminals on pull boxes and junctions boxes to ensure electrical continuity of all conduit systems. Not all bond cables are shown on the Drawings or on the cables list. Provide bonds even though not explicitly indicated in other documentation.

PART 3 EXECUTION

3.1 ROUTING

A. Locate conduits containing communication and low voltage conductors away from conduits containing power wiring.

B. Run parallel or perpendicular to building lines.

C. Route conduits on suspended channels where possible.

D. Avoid routes that would interfere with any potential maintenance activities.

E. Where not specifically shown in detail on the Drawings, review proposed conduit routing with Contract Administrator prior to installation. Comply with all routing changes requested by the Contract Administrator.

F. Install conduits to conserve headroom in exposed locations and cause minimum interference in spaces through which they pass.

3.2 INSTALLATION

A. General
1. All conduits shall be cut square and reamed smooth.
2. Provide bonding conductor in all conduit systems. Verify bond continuity of all conduit systems.
3. Metal, threaded conduit to be cut with a cutting tools that provide a 19mm taper per foot.
4. Remove burrs, ream and clean metal conduit before installation of conductors, wires, or cables.
5. Threaded conduit connections shall have a minimum of 5 full threads fully engaged or greater. In general all threaded connections (for both hazardous and non-hazardous areas) shall meet or exceed the requirements set out in CEC Section 18.
6. For metallic conduits, install within a PVC sleeve for holes / penetrations through concrete walls and slabs.
7. Provide drain seal in vertical raceways where condensate may collect above sealing fitting.
8. Follow structural surface contours when installing exposed raceways. Avoid obstruction of passageways.
9. Unless otherwise indicated, install conduits surface-mounted on walls and ceilings. Conceal or embed conduits only where indicated.
10. Do not pass conduits through structural members except as specified on the Drawings, or as permitted by the Contract Administrator.
11. Install concealed, embedded, and buried raceways so that they emerge at right angles to surface and have no curved portion exposed.
12. Remove and replace blocked conduit sections. Do not use liquids to clean out conduits.
13. Install pullcords in empty conduit systems.
14. Dry conduits out before installing wire.
15. All conduits exposed in finished areas are to be free of unnecessary labels and trade marks.
16. Seal conduits with duct seal where conduits are run between heated and unheated areas.
17. Where conduits pass through walls, group and install through openings. After all required conduits are installed; close wall openings with material compatible with the wall construction. Perform fire stopping & sealing to ensure integrity of wall.
18. Do not locate conduits less than 75 mm parallel to steam or hot water lines with minimum of 25 mm space at crossovers.
19. Provide a minimum of 1 conduit diameter of space between adjacent conduit runs.
20. PVC conduit sections and fittings shall be connected using watertight PVC conduit cement.
21. Emergency lighting and exit signs shall be connected via a separate and dedicated conduit system.

B. Fire Stop Assemblies
1. Seal and firestop penetration around conduit with ULC approved fire stop assembly for the installation conditions.

3.3 CONDUIT APPLICATION

A. Interior, exposed:
   1. Rigid threaded aluminum.
   2. Rigid PVC, FT4.
   3. EMT (for office type of areas only).

B. Interior, concealed (office type of areas):
   1. EMT.

C. Connections to vibrating equipment:
   1. Liquid tight, flexible conduit.

D. Aboveground embedded in concrete walls, ceilings, or floors:
   1. Rigid PVC, FT4.

E. Direct earth burial:
   1. Rigid PVC.
   2. HDPE horizontal directional drilling conduit – Used where specifically approved by the Contract Administrator.

F. Concrete Encasement
   1. Rigid PVC, type DB2

G. Under slabs on grade:
   1. Rigid PVC.

H. Wet or Corrosive areas:
   1. Rigid threaded aluminum.
   2. Rigid PVC, FT4 rated conduit where acceptable by code and where approved on the Drawings.

I. Hazardous locations:
   1. Rigid threaded aluminum.
   2. All fittings, couplings and devices shall be rated for Hazardous Class I, Div. 1 & 2 (or Zone 0, 1 and 2), Groups C, D Locations.

3.4 SPACING AND SUPPORTS

A. WALL SPACING
   1. Group conduits wherever possible on suspended or surface mounted channels.
   2. Install spacers as required to provide a space between the conduits and the supporting surface, with a minimum space as follows:
      a. Above grade spaces not classified as CEC Category 1 or 2:
         1) Drywall / wood surfaces: no space required
         2) Masonry / concrete surfaces: 6 mm
         3) Below grade spaces: 12 mm
      b. Wet locations: 12 mm

B. Supports for Metallic Conduit
   1. Maximum spacing between supports for metallic conduit:
      a. 16mm conduit: 1.0 m
      b. 21mm conduit: 1.5 m
      c. 27mm conduit 1.5 m
      d. 35mm conduit 2.0 m
      e. 41mm conduit and larger 2.5 m

C. Supports for PVC Conduit
   1. Maximum spacing between supports for rigid PVC conduit:
      a. 21mm conduit 0.75 m
      b. 27mm conduit 0.75 m
      c. 35mm conduit 0.75 m
      d. 41mm conduit 1.2 m
      e. 53mm conduit 1.5 m
      f. 63mm conduit 1.5 m
      g. 78mm conduit 1.5 m
      h. 91mm conduit and larger 2.0 m

3.5 CONNECTIONS

A. For motors, wall or ceiling mounted fans and unit heaters, dry type transformers, electrically operated valves, instrumentation, and other equipment where flexible connection is required to minimize vibration:
   1. Wet or corrosive areas: flexible, non-metallic liquid tight conduit.
   2. Dry and non-corrosive areas: flexible, metallic liquid tight conduit.
   3. Hazardous areas: flexible liquid tight conduit, with couplings and fittings suitable for Class I, Division 1 and 2 areas.
   4. Length: 450 mm minimum, 1500 mm maximum, sufficient to allow movement and adjustment of equipment.

B. Luminaires in dry areas: flexible, metallic liquid-tight conduit or approved cabling.

C. Transition from underground or concrete embedded to exposed: rigid PVC to rigid aluminum conduit.

D. Exterior light pole foundations: rigid PVC conduit.

3.6 BENDS

A. Conduit runs shall not exceed four 90 degrees bends (for a total of 360 degrees) between pullboxes.

B. Bend conduit cold. Replace conduit if kinked or flattened more than 1/10th of its original diameter. Bends are to be symmetrical.

C. Avoid field-made bends and offsets, but where necessary, make with an acceptable bending machine. Do not heat metal raceways to facilitate bending.

D. Make bends in parallel or banked runs from same center or centerline with same radius so that bends are parallel.

E. Factory elbows may be installed in parallel or banked raceways if there is change in plane of run, and raceways are same size.

F. Use factory made elbows for conduits over 27 mm in diameter.

G. Install concealed raceways with a minimum of bends in the shortest practical distance.

H. PVC Conduit:
   1. Bends 30 degrees and larger: provide factory made elbows.
   2. Use Manufacturer's recommended method for forming bends.

I. Do not make bends that exceed allowable conductor or cable bending radius; or that significantly restrict cable pulls.

3.7 PENETRATIONS

A. Prior to coring, drilling or cutting through wall, roof or floor members: perform scan of the surface, mark the intended location, and confirm acceptability with the Contract Administrator.

B. For circular penetrations, provided steel pipe (galvanized or stainless to suit the environment). Provide 88.9mm high concrete curb around floor penetrations that are subject to regular clean up or wash down.

C. Make at right angles, unless otherwise shown.

D. Notching or penetration of structural members, including footings and beams, is not permitted unless specifically approved by the Contract Administrator.

E. Firestop openings around penetrations to maintain fire-resistance rating.

F. Apply single layer of wraparound duct band to all metallic conduit protruding through concrete floor slabs to a point 50 mm above and 50 mm below concrete surface.

G. Concrete walls, floors, or ceilings (above ground): provide non-shrink grout dry-pack, or use watertight seal device.

H. Entering Structures:
   1. General: seal raceway at the first box or outlet with oakum or expandable plastic compound to prevent the entrance of gases or liquids from one area to another.
   2. Exterior wall penetration:
      a. Utilize Roxtec weatherproof sealing system.
      b. Install to Manufacturer's recommendations.
      c. Install flush with exterior of the wall.

   d. Prior to installation of seals, Contractor to submit proof of training to the Contract Administrator. Do not install the cable seal system without equipment Manufacturer training, as work will have to be re-done. Contact Roxtec for training.
   e. Prior to covering up wall penetration work, arrange for a site inspection of the work with the Contract Administrator. Proof of proper installation is required.
3. Concrete roof or membrane waterproofed floor:
   a. Provide a watertight seal.
   b. Without concrete encasement: Install watertight entrance seal device on each side.
   c. With concrete encasement: install watertight entrance seal device on the accessible side.
   d. Securely anchor watertight entrance seal device into construction with one or more integral flanges.
   e. Secure membrane waterproofing to watertight entrance seal device in a permanent, watertight manner.
4. Heating, ventilating, and air conditioning equipment:
   a. Penetrate equipment in area established by Manufacturer.
   b. Connect equipment using liquid tight flexible conduit.
5. Corrosive sensitive Areas:
   a. Seal all conduit passing through corrosive room walls.
   b. Seal conduit entering equipment panel boards and field panels containing electrical equipment.
6. Existing or precast wall (underground): core drill wall and install a watertight entrance seal device.
7. Nonwaterproofed floor (underground, without concrete encasement):
   a. Provide watertight entrance seal device.
   b. Fill space between raceway and sleeve with expandable watertight compound or oakum and lead joint, on each side.
8. For exterior installations, conduit entry shall be from the bottom, unless approved otherwise by the Contract Administrator.

3.8 UNDERGROUND CONDUIT INSTALLATIONS

A. Minimum burial depths shall be as detailed on the Drawings, but in no case less than the requirements indicated in the CEC.

B. Conduits shall have a red plastic warning tape placed above, buried at a depth of 305mm below grade. The plastic tape is to completely cover all conduits, and overlap the width of all conduits by at least 150mm on either side. Provide mechanical protection, planking in accordance with the U.G trenching specifications.

C. All underground direct buried conduits shall be rigid PVC.

D. Provide rigid PVC conduit, type DB2 for encasement in concrete for duct banks. HDPE conduit can be used only where specifically approved by the Contract Administrator.

E. Maintain a minimum of 1200mm horizontal clearance distance from underground structures such as buildings and equipment foundations.

F. Maintain a minimum of 600mm horizontal clearance distance from underground equipment such as piping and other underground conduit runs.

G. All clearances in strict accordance with the MBC, CEC, and all other bylaws.

H. Provide Universal GPS coordinates of all underground conduit runs at every bend, and at every 6000mm intervals. Include coordinates on the As-Built drawings.

I. Provide man-holes and hand-holes as required to accommodate the conductor pull.

J. Slope conduits away from building and enclosures entry points, to provide drainage.

3.9 INSTALLATIONS IN CATEGORY 1 LOCATIONS

A. Arrange to provide drainage at frequent intervals to suitable locations.

B. Equip with approved fittings to permit the moisture to drain out of the system.

C. Install the conduit with a minimum of 12 mm space from the supporting surface.

D. Every joint, coupling and fitting to be water-tight.

E. Where conduit leaves a warm room and enters a cooler atmosphere, seal the conduit and arrange the conduit in a manner to avoid condensation accumulation at the seal.

3.10 INSTALLATIONS IN CATEGORY 2 LOCATIONS

A. Comply with all requirements of Category 1 locations.

3.11 INSTALLATIONS IN CATEGORY 2 WET LOCATIONS

A. Comply with all requirements of Category 1 locations.

3.12 INSTALLATIONS IN HAZARDOUS LOCATIONS

A. Install conduit system, complete with explosion proof conduit sealing fittings:
   1. Install cables in conduit system – maximum permitted conduit / conduit fitting fill for hazardous areas is 25 percent.
   2. Provide sealing fittings to suit the area classification, and to meet the CEC requirements.
   3. Install sealing compound following Manufacturer’s instructions.

END OF SECTION

SECTION 26 05 36

CABLE TRAYS FOR ELECTRICAL SYSTEMS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CAN/CSA C22.1 No.126.1 (latest), Metal Cable Tray Systems.

B. NEMA VE 1-2009, Metal Cable Tray Systems.

C. NEMA VE 2-2013, Cable Tray Installation Guidelines.

1.2 SUBMITTALS

A. Submit Shop Drawings indicating the components and equipment to be used:
   1. Manufacturer's product data sheets:
      a. Dimensions.
      b. Materials.
      c. Finishes.
      d. Certifications.
      e. Load rating.
      f. Fire stopping systems, including UL listings and certifications
   2. Layouts showing all cable channel and cable tray locations.
   3. Indicate cable tray structural support system:
      a. Dimensions.
      b. Materials.
      c. Finishes.
      d. Fittings.
      e. Anchor and connections details.
      f. Load rating of support system.
   4. Indicate bills of materials for the complete system, including quantities of each tray members.

1.3 O&M MANUAL

A. Include all Shop Drawings and product submittals.

PART 2 PRODUCTS

2.1 GENERAL

A. Cable tray, channel, and fittings: to NEMA VE 1 and CAN/CSA C22.1 No. 126.1.

B. Provide bonding conductors in accordance with:
   1. For tray installed in hazardous areas: green, insulated, FT4 rated jacket.

2. For trays installed in wet or corrosive areas: green, insulated, FT4 rated jacket.
3. For trays installed in dry, non-corrosive, non-hazardous areas: bare copper.

C. Exterior cable trays or channels, or where mechanical protection is required, provide tray covers.

D. Factory manufactured horizontal elbows, end plates, drop outs, vertical risers, drops, tees, wyes, expansion joints, and reducers as required. Fittings manufactured on site will not be accepted.

E. There are structural expansion joints in the Facility. Provide expansion couplings and fittings for all conduit, tray, etc crossing the joints. Do not locate rigid devices (for example panels) across or on top of the expansion joints.

2.2 CABLE TRAY

A. Cable trays shall be:
1. Aluminum ladder type in most areas. For specific locations where chemical corrosion is a concern (in the Chemical Building), use 316 Stainless steel tray.
2. CSA class loading as per the Drawings, but as a minimum, the tray must safely handle the weight of the cables installed, plus a safety factor.
3. Side rails of 152mm (6 inches) minimum.
4. Run spacing of 225mm (9 inch).
5. Widths as shown on the Drawings.
6. Horizontal supports shall be installed at maximum intervals of 2500mm in strict accordance with the Manufacturer recommendations for the loading class.
7. Minimum radii on fittings: 300mm

B. Barriers where different low voltage systems (600V and lower) are in same cable tray. Cables shall be spaced in accordance with the Electrical Design Guide, Rev 01, Table 4-8 : Segregation of Cable Systems.

Cable	**Other Cable**	**Minimum Segregation**	**Notes**
Communication - Fibre	Communication	None	
	Instrumentation / Control < 50V	None	
	Other	Separate Raceway	To reduce risk of physical damage to fibre cable.
Communication - Copper	Instrumentation / Control < 50V	50 mm	
	120 VAC, 8 AWG or smaller	100 mm	
	120 VAC, > 8 AWG	300 mm	

Cable	**Other Cable**	**Minimum Segregation**	**Notes**
	600 VAC Power	300 mm	
	VFD or other high harmonic cable	300 mm	Metallic Conduit
		600 mm	Other raceway
	Medium Voltage – 3C armoured and shielded	300 mm	May be in metallic conduit instead of armoured.
	Medium Voltage – 1C or 3C unshielded	450 mm	
Instrumentation (Analog)	Control < 50V	None	
	120 VAC, 8 AWG or smaller	100 mm	
	120 VAC, > 8 AWG	300 mm	
	600 VAC Power	300 mm	
	VFD or other high harmonic cable	300 mm	Metallic Conduit
		600 mm	Other raceway
	Medium Voltage – 3C armoured and shielded	300 mm	May be in metallic conduit instead of armoured.
	Medium Voltage – 1C or 3C unshielded	450 mm	
	Other Cable	Minimum Segregation	Notes
	120 VAC, 8 AWG or smaller	50 mm	
	120 VAC, > 8 AWG	300 mm	
	600 VAC Power	300 mm	
	VFD or other high harmonic cable	300 mm	Metallic Conduit
		450 mm	Other raceway
	Medium Voltage – 3C armoured and shielded	300 mm	May be in metallic conduit instead of armoured.
	Medium Voltage – 1C or 3C unshielded	450 mm	
	120 VAC, 8 AWG or smaller	none	
	120 VAC, > 8 AWG	Metal barrier or 150 mm	

Cable	Other Cable	Minimum Segregation	Notes
	600 VAC Power	Metal barrier or 150 mm	
	VFD or other high harmonic cable	150 mm	Metallic Conduit
		300 mm	Other raceway
	Medium Voltage – 3C armoured and shielded	300 mm	May be in metallic conduit instead of armoured.
	Medium Voltage – 1C or 3C unshielded	450 mm	
	600 VAC Power	Metal barrier	Cable Armour is acceptable
	VFD or other high harmonic cable	100 mm	Metallic Conduit
		150 mm	Other raceway
	Medium Voltage – 3C armoured and shielded	300 mm	May be in metallic conduit instead of armoured.
	Medium Voltage – 1C or 3C unshielded	450 mm	
	VFD or other high harmonic cable	100 mm	Metallic Conduit or both armoured cables
		150 mm	Other raceway
	Medium Voltage – 3C armoured and shielded	150 mm	May be in metallic conduit instead of armoured.
	Medium Voltage – 1C or 3C unshielded	300 mm	

C. For cables with voltages above 600V, run cabling on separate cable trays, grouped according to the voltage level.

D. Cable tray bonds shall be a minimum #2/0 AWG, stranded, copper conductor connected to each tray section with a Manufacturer approved grounding/bonding lug, in accordance with CEC requirements. Upsize bond conductor to account for cable ampacity in accordance with CEC table 16.

E. Covers for cable trays for all exterior run cable trays. For cable trays interior to buildings, provide covers where shown on the Drawings.

2.3 CABLE CHANNEL

A. Ventilated trough type.

B. Channel: Aluminum for process and office areas, with the exception of: use 316 stainless steel within the chemical building and for any exterior cable tray runs. Provide the required width and depth of channel to accommodate the required cabling.

C. Cable channel bonds shall be a minimum #6 AWG, stranded, copper conductor connected to each section with a Manufacturer approved grounding/bonding lug, in accordance with CEC requirements. Upsize bond conductor to account for cable ampacity in accordance with CEC table 16.

2.4 SUPPORTS

A. Provide aluminum support members for aluminum cable tray. Provide 316 Stainless steel support members for stainless steel cable tray.

B. Provide supports, clamps and accessories as required.

C. Cable tray and channel to be suspended at an elevation that will not interfere with other systems – such as lighting, mechanical systems, piping, building structure, etc.

D. Cable tray shall be supported:
   1. On trapeze style hangers constructed of minimum 41 mm x 41 mm aluminum members. Unistrut shall be supported by two 12.5 mm threaded rods. Install trapeze hangers to a maximum spacing of 2.5 metres on centre, plus located at all elbows and fittings.
   2. On wall mounted unistrut brackets.

E. Provide 45 degree risers over or under architectural, mechanical or structural systems where required.

F. Provide stiffener bars as required.

G. Supports shall be selected, designed and installed to accommodate a minimum of two times the tray loading class weight.

2.5 ACCESSORIES

A. Use stainless steel washers, bolts and fixing hardware.

B. Provide supports, clamps and accessories as required.

C. Supply and install tray manufacturer approved conduit to cable tray adapters for transitions from a conduit system onto the tray.

D. Supply and install tray manufacturer approved ground wire clamps for ground wire connection onto tray members.

E. Supply and install all other tray manufacturer approved accessories, including cantruss guide clamps, support brackets, etc.

2.6 MANUFACTURERS

A. Acceptable Manufacturers: B-Line, Thomas & Betts, or approved equal in accordance with B8.

2.7 FLOOR/WALL SEAL SYSTEMS

A. Floor/wall sealing systems shall be fire rated to suit the fire rating of the penetrations.

B. Systems to be ULC listed assemblies.

C. Provide system to allow for cable re-entry to allow for future work.

PART 3 EXECUTION

3.1 GENERAL

A. Install complete cable tray and cable channel system in accordance with NEMA VE 2.

B. The cable installation shall adhere to CEC requirements with respect to cable spacing and cable de-rating factors. De-rating shall be in accordance with CEC table 5C and 5D.

C. Do not allow or cause any work performed or installed to be covered up or enclosed prior to the required inspections, tests and approvals.

D. Design, plan and coordinate cable tray routing to avoid conflicts with other trades. Inform the Contract Administrator of any conflicts and make adjustments as determined by the Contract Administrator.

E. Provide additional offsets, bends, etc. as required to adjust cable tray routing and height to avoid conflict with ducts, pipes, beams, etc. Confirm requirements on site and include costs in tender price.

F. Install cable and channel tray in accordance with the Drawings and the Manufacturer's recommendations.

G. Install cable tray of the size and type as specified on the Drawings and as required for cable routing. The Drawings show main cable tray routes only – they do not show all required cable channel to individual pieces of equipment.

H. Provide cable channel (even though not explicitly shown on the Drawings) to route cables to specific equipment.

I. The installation shall be parallel or perpendicular to the building structure / grid lines and shall be installed straight, plumb and true.

J. Design and install the cable tray / cable channel support system suitable for the tray / channel loading class. The tray / channel loading class shall be a minimum of three times the weight of all cabling installed in the cable tray / channel.

K. The Drawings indicate general concepts, and may not show all details required for mounting or installation. Supply and install any additional items required for a complete and working installation.

L. Ensure that the cable / channel trays and supports are properly aligned with a minimum of distortion.

M. All direction changes in main runs of cable tray shall be made using standard factory made fittings.

N. Minimum cable and channel tray fitting radius shall meet or exceed the minimum bending radius of the cables installed.

O. Cable tray sections shall be saw cut as required. Cut sections shall be square, de-burred, and drilled for standard factory splice plates. Cutting by welding or burning is not permitted. Remove sharp edges. Cut ends or defaced surfaces shall be painted or as directed by the Contract Administrator.

P. Cable tray supports shall be installed in accordance with the tray Manufacturer's recommendations.

Q. Cable tray fittings, expansion joints and the like shall be supported within 600mm of both sides of such connection.

R. Locate splice plates within 600mm of a support.

S. Where a cable tray support is installed at a location greater than 1000mm from a structural column, the horizontal strut of the cable tray support shall be supported by two structural steel members.

T. Vertical cable trays shall have cable tray supports spaced at intervals not exceeding 1200mm and shall be open on one side to facilitate cable pulling.

U. Secure cables to cable tray/channel tray with approved cable clamps at intervals not exceeding 1200mm for vertical runs.

V. Expansion Joints.
   1. Install expansion joints complete with ground bond as indicated on the Drawings.
   2. Install expansion joints at intervals not exceeding 30M.

W. Install a copper bonding conductor in each tray, with insulation requirements based on the environmental conditions. Bond the conductor to the cable tray at intervals not exceeding 6000mm and at all separate joints, fittings, tray sections.

X. Repair or restore to original condition, any equipment or structure damaged during installation or before final acceptance at no additional cost.

Y. Restore to original condition any painted surfaces damaged during installation at no additional cost.

Z. Cables shall be installed uniformly across the width of the tray to minimize the number of layers and in accordance with CEC de-rating factor requirements.

AA. Provide metal cable clamps (approved for use by the tray manufacturer) bolted to the side of the tray for all cables entering or exiting the cable tray.

BB. Remove all debris and foreign material from the complete cable tray system prior to installation of cables.

CC. Construct and use approved platforms, scaffolding and rigging systems for installation and access. The use of cable trays as walkways, "ladders", or structural rigging supports is not permitted.

DD. Maintain spacing between cables of different systems and voltages in accordance with the EDG, Table 4-8. Install barriers within cable trays in accordance with the Drawings to separate systems.

EE. Install 12.47 kV cables on dedicated cable tray.

FF. Provide permanent, legible warning notice carrying the words “DANGER – 12.47 kV” on all cable trays containing 15 kV conductors. Install with a maximum spacing between warning notices of 6 meters, on both sides of trays where visible – in accordance with code requirements.

GG. Install tray so as to be accessible at all locations.

3.2 FIRE BARRIERS

A. Arrange for openings in fire rated walls, and floors for width and depth of cable tray to pass through as required.

B. Provide fire stopping, and make good, fire rating of floors and walls after cables have been installed. Fire stopping shall be made with UL listed assemblies.

3.3 CABLES IN CABLE TRAY

A. Install cables individually.

B. Lay cables into cable tray. Use rollers when necessary to pull cables.

C. Secure cables installed in horizontal trays at 4.5 m centers, with nylon ties. For vertical tray sections secure cables using Manufacturer approved metallic clamps.

3.4 CABLES IN CABLE CHANNEL

A. Install cables individually.

B. Lay cables into cable channel.

C. Secure cables installed in horizontal cable channel at 2 m centers, with nylon ties.

END OF SECTION

SECTION 26 05 44

INSTALLATION OF CABLES IN TRENCHES AND DUCTS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. Canadian Standards Association, (CSA International)

B. Insulated Cable Engineers Association, Inc. (ICEA)

1.2 SUBMITTALS

A. Submit product data in accordance with Section 01 33 00, Submittal Procedures.

B. Submittals shall include, but not be limited to the following:
   1. Precast manholes and handholes.
   2. Dimension drawings and descriptive literature.
   3. Cable pulling calculations for all cables.
   4. Proposed cable pulling methodology to ensure pulling forces are within the cable Manufacturer's limits.

PART 2 PRODUCTS

2.1 MARKERS AND PROTECTION

A. Wooden protection:
   1. 38 mm by 140 mm planks pressure treated with copper napthenate or 5 percent pentachlorophenol preservative. Creosote and some other types of wood preservatives may injure the insulation of conductors and should not be used.

B. Concrete toping protection:
   1. Concrete toping of conduit in trench, minimum 50mm thick layer of concrete, dyed red, with a 150mm overhang, past the edges of each conduit installed for the length of the trench.

C. Concrete encased duct bank:
   1. Utilize suitable duct bank spacers to relieve stress on the ducts, and maintain the required separations during concrete pour.
   2. Spacers to be installed at intervals not exceeding specified support spacing in Section 26 05 34, Conduits, Conduit Fasteners, and Conduit Fittings.
   3. Duct Bank Spacers:
      a. Type: Nonmetallic, interlocking, for multiple conduit sizes.
      b. Suitable for all types of conduit.
      c. Manufacturers:
         1) Ipex Inc.

2) Thomas & Betts Carlon.

4. Conduit to be PVC, type DB2.
5. Concrete encased duct bank, to be formed with concrete, in a rectangular or square type of arrangement, with a minimum of 50 mm thick concrete around all conduits, complete with reinforcing steel as shown on the Drawings.

D. Markers:
1. Concrete type cable markers: 600mm by 600mmbyx 100mm with words: cable, joint or conduit impressed in top surface, with arrows to indicate change in direction of cable and duct runs.
2. Cedar post type markers: 89 by 89 mm, 1.5 m long, treated with copper napthenate or 5 percent pentachlorophenol preservative, with nameplate fastened near post top, on side facing cable or conduit to indicate depth and direction of duct and cable runs.
   a. Nameplate: aluminum, anodized 89 by 125 mm, 1.5 mm thick mounted on cedar post with mylar label 0.125 mm thick with words Cable, Joint or Conduit with arrows to indicate change in direction. Fasten using stainless steel screws.

E. Warning tape:
1. Material: Polyethylene, 4-mil gauge with detectable strip.
2. Color: Red.
3. Width: Minimum 150 mm.
4. Designation: Warning on tape that electric circuit is located below tape.
5. Identifying Letters: Minimum 25 mm high permanent black lettering imprinted continuously over entire length.
6. Manufacturers and Products:
   a. Panduit; Type HTDU.
   b. Reef Industries; Terra Tape.
   c. W.H. Brady Inc.
   d. Wieland Electric Inc.

2.2 PRECAST MANHOLES

A. Manholes are referred to as pullboxes (PB-XXXX) on the Drawings, and mean the same thing.

B. Concrete Strength: refer to structural Specifications and Drawings.

C. Loading: AASHTO, HS-10 loading designed to meet or exceed ASTM C478 requirements.

D. Drainage:
1. Slope floors toward drain points, leaving no pockets or other non-draining areas.
2. Provide drainage outlet or sump at low point of floor constructed with a heavy, malleable iron, slotted or perforated hinged cover, and 100 mm minimum outlet and outlet pipe complete with back water valve and trap, all of PVC construction.

E. Handhole Frames and Covers:
1. Material: Steel, hot-dipped galvanized.
2. Cover Type: Solid, bolt-on, of checkered nonskid design.
3. Cover Loading: AASHTO HS-10.

4. Cover Designation: Burn by welder, on upper side in integral letters, minimum 50 mm in height, appropriate titles:
   a. 600 Volts and Below: ELECTRIC LV.
   b. Communication systems, including fiber: COMMUNICATIONS.

F. Manhole Frames and Covers:
1. Material: Machined malleable iron.
2. Diameter: as required of as specified on the Drawings.
3. Cover Type: Indented, solid top design, with two drop handles each.
4. Cover Loading: AASHTO HS-10.
5. Cover Designation: Cast, on upper side, in integral letters, minimum 50 mm in height, appropriate titles:
   a. Above 600 Volts: ELECTRIC MV.
   b. 600 Volts and Below: ELECTRIC LV.
   c. Communication systems, including fiber: COMMUNICATIONS.
   d. Combination of systems described above: ELECTRIC MV / COMM.

G. Cable Pull Rope:
1. Material: polypropylene pull rope, 20 kN tensile strength or higher
   a. Provide pull rope in all conduits, including spares, with a minimum of 3 meters of slack at each pull point.
   b. Coordinate maximum pull tension with the cable Manufacturer, and provide appropriate pull rope to install the required cabling.

H. Provide an accessible ground bus for bonding connection of the duct bank manholes to bonding conductor. The Contractor shall connect a 4/0 ground cable to the manhole ground bus. The manhole (or pullbox) ground bus shall be connected internally to the re-enforcing steel of the system, and to any steel members.

PART 3 EXECUTION

3.1 GENERAL

A. For cable bus systems, refer to the Drawings, and to Specifications Section 26 25 01, Cable Bus.

B. Provide Universal GPS coordinates of all underground cable or conduit runs at every bend, and at a maximum of 6000mm intervals. Include coordinates on the As-Built drawings.

C. All cable / conduit trenches shall have a red plastic warning tape placed above, buried at a depth of 305mm below grade. The plastic tape is to completely cover all conduits, and overlap the width of all conduits by at least 150mm on either side. Use multiple parallel tape runs as required.

D. Maintain a minimum of 1200mm horizontal clearance distance from underground structures such as buildings and equipment foundations.

E. Maintain a minimum of 600mm horizontal clearance distance from other underground equipment or services.

F. Clearances to be in strict accordance with the Winnipeg Electrical Bylaws (WEB), CEC, and all other applicable bylaws.

G. For underground conduits or cables, provide mechanical protection as follows:
   1. 120 V or 600V and 15A to 90A: mechanical protection using treated planks
   2. 600V and below; and 100A or greater: mechanical protection using 50 mm thick concrete toping, or concrete duct banks as directed on the Drawings.
   3. 600V to 15 kV: mechanical protection using 50 mm thick concrete toping, or concrete duct banks as directed on the Drawings

H. Backfill:
   1. Use clean backfill, free of rocks and debris. Return excavation area to the original condition.
   2. Photograph all open trenches, with cabling, conduit, supports and spacers installed.
   3. Do not backfill until inspected by Contract Administrator.

I. Prior to excavation or directional boring, perform a complete site survey to ensure that the installation will not conflict with existing systems. Repair of damages to existing systems will be at the cost of the Contractor.

J. Coordinate work with other trades to ensure that the location and route of the buried systems does not conflict with the work of other trades.

K. Refer to the Drawings for cable / trench details where applicable. Where conflict in details occurs, allow for the more onerous and costly installation method.

L. Provide a 4/0 copper bonding cable throughout the entire concrete duct bank system (run inside one of the system ducts). Make connections to all manholes with the bonding conductor. Ground the system bonding conductor to the ground grid at each Facility.

M. Employ soft dig excavation methods near and around any buried electrical system. An acceptable soft dig method is Hydrovac (water based) excavation method.

3.2 DIRECTIONAL BORING

A. Perform directional boring as directed on the Drawings, or as specifically approved by the Contract Administrator. Otherwise, use open trenching installation methods.

B. Directional boring shall utilize HDPE conduit.

3.3 DIRECT BURIAL OF CABLES

A. Perform excavation, and trenching. Provide sand bed in trench, and lay in cables, maintaining separation between cable runs. Maintain a minimum of 75 mm of clearance from each side of trench to the nearest cable. Do not pull cable into trench.

B. Provide offset for thermal action and minor earth movements. Offset 150 mm for each 60m run, maintaining minimum cable separation and bending radius requirements.

C. Make terminations and splices (splices - only where specifically approved by the Contract Administrator) leaving 0.6 m of surplus cable in each direction.
   1. Terminations and splices shall be performed with approved kits, and in accordance with the Manufacturer's instructions and with specific training.

D. Underground cable splices are not acceptable.

E. Minimum permitted radius at cable bends for rubber or plastic cables, 8 times diameter of cable; for metallic armoured cables, 12 times diameter of cables or greater in accordance with the Manufacturer's instructions.

F. Cable separation:
   1. Maintain 300 mm minimum separation between low voltage cables of different circuits.
   2. Maintain 300 mm minimum horizontal separation between low and medium voltage cables.
   3. Maintain 300 mm minimum vertical separation where low voltage and medium voltage cables cross, with the low voltage cables in the upper position.
   4. Maintain 300 mm minimum horizontal, and 300 mm minimum vertical separation between for fire alarm and control cables when crossing other cables, with the fire alarm and control cables in the upper position.
   5. Install treated planks at cable crossings, between lower and upper cables, extending 600 mm in each crossing direction.
   6. The Contractor must meet the minimum code clearance requirements when crossing of any other systems, such as mechanical or utility services.

G. Provide sand bed over cables, after the cables are laid into the trench. Minimum sand bedding below cables is 75 mm. Minimum sand bedding above cables is 75 mm. Supply and install mechanical protection of cables above sand bedding. Use clean fill, devoid of rocks or materials which can damage or deform the cable trench.

H. Repair surface to previous existing condition, or to new conditions specified on the Drawings, and in the Specifications.

I. Prior to closing up trench, and covering cables, photograph the open trench with the cables installed, and arrange for an inspection by the Contractor Administrator. Do not close up trench without approval.

J. Minimum cable burial depth shall be in accordance with the CEC, table 53, or deeper as specified on the Drawings.

3.4 CABLE INSTALLATION IN DUCTS

A. Inspect and clean ducts prior to installing cables.

B. Install cables as indicated in ducts.
   1. Do not pull spliced cables inside ducts.

C. Use CSA approved lubricants of type compatible with cable jacket to reduce pulling tension.

D. Before pulling cable into ducts and until cables are properly terminated, seal ends of cables with moisture seal tape.

E. After installation of cables, seal duct ends with duct sealing compound.

F. Avoid moisture traps where possible. When unavoidable in exposed conduit runs, provide junction box and drain fitting at conduit low point.

G. Group raceways installed in same area.

H. Install watertight fittings in outdoor, underground, or wet locations.

I. Utilize conductors that are rated for underground direct earth burial in underground ducts.

J. Provide expansion fittings that allow minimum of 100 mm of movement in vertical conduit runs from underground where exposed conduit will be fastened to or will enter building or structure.

K. Provide slack loops in cable, compatible expansion fittings.

3.5 UNDERGROUND CONCRETE ENCASED DUCTS

A. Maintain a minimum grades to allow for drainage either from one manhole, handhole, or pull box to the next, or from a high point between them, depending on surface contour.

B. Maintain a minimum of 600 mm cover above conduit and concrete encasement, unless otherwise shown.

C. Make routing changes as necessary to avoid obstructions or conflicts. Prior to making routing changes, obtain approval in writing from the Contract Administrator.

D. For multiple conduit runs, stagger coupling so that couplings in adjacent runs are not in same transverse line.

E. Union type fittings not permitted.

F. Spacers:
   1. Provide preformed, nonmetallic spacers, designed for such purpose, to secure and separate parallel conduit runs in a trench or concrete encasement.
   2. Install at intervals not greater than that specified for support of the type of conduit used indicated in Section 26 05 34, Conduits, Conduit Fasteners, and Conduit Fittings.

G. Support conduit so as to prevent bending or displacement during backfilling or concrete placement.

H. Installation with other piping systems:
   1. Crossings: Maintain minimum 300 mm vertical separation.

2. Parallel runs: Maintain minimum 300 mm separation.
3. Installation of conduits over top or below valves or couplings is not permitted.

I. Provide expansion fittings that allow minimum of 100 mm of movement in vertical conduit runs from underground where exposed conduit will be fastened to or will enter building or structure.

J. Provide deflectional/expansion fittings in conduit runs that exit building or structure below grade. Conduit from building wall to fitting shall be PVC-coated rigid steel.

K. Concrete Encasement to be installed as specified on the Drawings.

L. Provide grounding and bonding of duct bank reinforcing steel using cadweld connections. Provide cadweld connection of

M. Provide a minimum of one 4/0 copper ground conductor run inside one of the ducts, throughout the entire duct bank system. The ground cable shall be connected to the Facility ground grid at both ends of the run. This ground conductor shall be connected to the manhole concrete rebar, as well as any steel members of the manhole.

3.6 MANHOLES AND HANDHOLES

A. Perform excavation, shoring, bracing and backfill work in accordance with the Drawings and Specifications. Coordinate with other trades.

B. Do not install until final raceway grading has been determined.

C. Install such that raceways enter at right angles and as near as possible to one end of wall, unless otherwise shown.

D. Identification: Field stamp covers with manhole or handhole numbers. Stamped numbers to be 25 mm minimum height.

E. Provide cable supports within cable manholes to avoid cable sagging.

3.7 EMPTY RACEWAYS

A. Provide permanent, removable cap over each end.

B. Provide PVC plug with pull tab for underground raceways with end bells.

C. Provide nylon pull cord.

D. Identify, as specified in Article Identification Devices, with waterproof tags attached to pull cord at each end, and at intermediate pull point.

3.8 MARKERS

A. Provide cedar post type or concrete pad style markers for buried cable or conduit runs above 600V and for all concrete encased duct banks.

END OF SECTION

SECTION 26 08 05

ACCEPTANCE TESTING

PART 1 GENERAL

1.1 REFERENCES

A. NETA Acceptance Testing Specifications, 2009 (ATS-2009)

B. CSA C282, Emergency Electrical Power Supply for Buildings.

C. City of Winnipeg inspection / test forms, Appendix Y – Sample Electrical Test Forms.

1.2 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00, Submittal Procedures.

B. Submit:
   1. Test equipment to be utilized with last calibration date.
   2. Qualifications of lead electrical inspections technician.
   3. Test forms that will be utilized. These will be based on the COW test form format.

1.3 QUALIFICATION

A. Provide competent lead electrical inspection technician thoroughly familiar with all aspects of electrical testing. It is expected that the technician will have a CET, Journeyman Electrician's certificate, or other equivalent designation. The designated technician is to be on-site and lead all electrical testing.
   1. The Contract Administrator reserves right to approve the lead electrical inspection technician, and request an alternate technician if deemed to be unqualified.
   2. The Contract Administrator reserves the right to request documentation and proof from the Contractor that their lead electrical inspections technician is qualified to perform the work. The documentation and proof can include the following:
      a. A request for references from past previous projects.
      b. A request for a list of past previous projects.
      c. A request for an interview and seminar to be given by the lead electrical inspection technician demonstrating in-depth knowledge of the subject matter.
   3. In the circumstance where the Contract Administrator rejects the lead inspection technician, the Contractor will be responsible for providing a suitably qualified individual to perform the work, at no additional cost to the City of Winnipeg. Qualifications will be specifically analyzed by the Contract Administrator, based on the following:
      a. The qualified lead electrical inspection technician will have performed similar work at other similar installations.
      b. The qualified lead electrical inspection technician will be trained in using the instruments and measuring devices; and adjusting the settings or programming the devices.

c. The qualified lead electrical inspection technician will have experience in analyzing the results obtain from the instruments or measuring devices.
d. The qualified lead electrical inspection technician will have sufficient experience to immediately recognize erroneous measurements based on past work experience and expected results.
e. The qualified lead electrical inspection technician will be familiar with the settings and methodologies required to perform the work.

4. In the circumstance where the Contractor cannot provide a competent lead electrical inspection technician, the Contract Administrator reserves the right to hire a qualified individual separate from this Contract and to back charge the Contractor for services and costs performed in order to complete the work.

1.4 TESTING EQUIPMENT

A. All test equipment shall be in good mechanical and electrical condition.

B. Accuracy of metering in test equipment shall be appropriate for the test being performed.

C. Wave shape and frequency of test equipment output waveforms shall be appropriate for the test and the tested equipment.

D. The test equipment shall be calibrated as specified below:
1. The testing organization shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy for each test instrument calibrated.
2. The testing organization will have calibration certifications for test equipment, and a copy will be made available to the Contract Administrator.
3. The firm providing calibration service shall maintain up-to-date instrument calibration instructions and procedures for each test instrument calibrated.
4. Instruments shall be calibrated in accordance with the following frequency schedule:
a. Field instruments: Analog, 6 months maximum. Digital, 12 months maximum.
b. Laboratory instruments: 12 months maximum.
c. Leased specialty equipment: 12 months maximum.
d. Dated calibration labels shall be visible on all test equipment.
e. Records, which show date and results of instruments calibrated or tested, must be kept up-to-date.
f. Calibrating standard shall be of higher accuracy than that of the instrument tested.

E. Specific requirements of insulation resistance meters.
1. Must be digital units. Crank-type analog insulation resistance meters will not be acceptable.

F. Ensure suitable power supply is available for test equipment, be this 120Vac or battery powered devices. Record make, model, and calibration date of test instrument.

G. Test to be conducted with full safety requirements in force, including “barrier” of conductor ends, proper bonding, “flag-person” as necessary.

H. All test equipment to have valid calibration stickers displayed on the equipment.

I. DC High Pot (dielectric strength) Units:
   1. Test instrument to have minimum output of 60 kV dc capacity.
   2. 120Vac powered.

J. AC High Voltage (dielectric strength) Units:
   1. Use AC High voltage units for insulation tests and other tests as indicated, at voltage levels indicated, or required by Manufacturers recommendations.

K. Low Resistance Test Units (Ductor):
   1. Low resistance test units to have 10A output.
   2. Digital display and accuracy to 1 micro-ohm, with a range from 1 μΩ to 1000 Ω. Standard electrician multimeters will not be accepted.

L. Insulation Resistance Tests (Megohmmeter/Megger):
   1. Use a megger with 20,000 M-ohm resolution for megger tests.
   2. Output voltages on DC megger units to be 250V, 500V, 1000V, 2500V or other as required.
   3. Record ambient temperature and adjust the measured M-ohms to 20(C ambient.
   4. Use 2.5kV megger for 5 kV and15 kV equipment and 1000 V megger range for power equipment of 600 V and below.
   5. For 10-minute megger tests, record M-ohm values in M-ohm at 30 seconds, 60 seconds, 5 minutes and 10 minutes. Plot M-ohm against time for each connection, calculate and record the ratio of measured M-ohm as follows:
      a. 60 sec M-ohm/30 sec M-ohm = dielectric absorption.
      b. 10 min M-ohm/1 min M-ohm = polarization index.
      c. Report the 1 minute M-ohm as the insulation resistance value.
   6. Submit tabulated measure M-ohm figures for 10-minute insulation tests, submit a graph.
   7. Apply megohmmeter dc voltage in accordance with the equipment Manufacturer's recommendations or NETA ATS-2009 Table 100.1.

M. VLF Test:
   1. Use a VLF tester capable of 40 kV peak that is capable of testing 1.1uF of cable load at 0.1 Hz up to 5.5 uF at 0.2 Hz.

N. Relay Test Equipment:
   1. Relay test equipment to be designed for relay testing, secondary current injection.
   2. Current output to a minimum of 60Amps for testing of instantaneous features.
   3. Indicators to detect open signals, pick-up signals and other required signals.
   4. Timers to 1 millisecond.
   5. MultiAmp or approved equal in accordance with B8 relay test units. Specifically designed relay testers for specific relays should be used if available.
   6. For equipment required on three phase systems, have a three phase voltage and relay output test unit.
   7. For equipment required on three phase differential tests, have a six phase voltage and relay output test unit.

O. Ground Resistivity Tester:
   1. Ground resistivity tester to measure earth impedance in variable distances from the source.
   2. Unit to be capable of plotting ground resistivity from 0.1 ohms and up.

P. Other test equipment as required in order to satisfy the requirements of this section as detailed herein.

1.5 TESTING REPORT

A. Prepare an overall inspection and test report that details all investigations and tests.

B. The Contractor shall furnish five paper copies and two electronic copies on CD of each final report.
   1. The electronic copies of the report, including the test forms, shall be provided in PDF format.
   2. Sample City test forms are included for reference. The Contractor shall modify the forms, and create new forms as needed to meet all the test requirements described herein.
   3. A Microsoft Word version of the all completed test forms provided to the City shall also be included on the CDs.

C. The report shall be neat and organized. Any omissions, inconsistencies, or incomplete work identified by the Contract Administrator shall be corrected and incorporated into the report in the appropriate section, and completely resubmitted.

D. A draft of each report shall be completed and sent to the Contract Administrator for review a maximum of one month after the completion of the inspections at the Site.

E. The final report shall be submitted a maximum of two weeks after the Contractor receives the mark-up of the draft report from the Contract Administrator.

F. The report shall include the following:
   1. Summary of project.
   2. Testing Equipment.
   3. Detail the type, manufacturer, model, last calibration date and test certificate for all testing equipment used.
   4. Description of equipment tested.
   5. Description and methodology of all tests performed.
   6. Typed inspection forms including:
      a. Identification of the testing organization.
      b. Equipment identification.
      c. Humidity, temperature, and other conditions that may affect the results of the tests/calibrations.
      d. Date of inspections, tests, maintenance, and/or calibrations.
      e. Identification and signed initials of the testing technician.
      f. Indication of inspections, tests, maintenance, and/or calibrations performed and recorded, along with charts, and graphs as applicable. All measurements and readings taken shall be noted for inclusion in the report. Where repairs are made, measurements and readings before and after the repair shall be included.

g. Indication of expected results, when calibrations are to be performed.
h. Indication of “as-found” and “as-left” results, as applicable.

7. Itemized list of all repaired deficiencies which shall include:
   a. Detailed description of the deficiency.
   b. Detailed description of the deficiency repair.
8. Itemized list of all un-repaired deficiencies encountered which shall include:
   a. Detailed description of the deficiency.
   b. Recommended action to be taken to repair the deficiency.
   c. Reason for not performing the recommended repair (such as equipment or component not available).
   d. Schedule and subsequent follow up and documentation of the repair of the deficiency.

PART 2 PRODUCTS

2.1 EQUIPMENT

A. Provide all tests results with typed test reports and signed field test sheets.

B. All test sheets to include equipment nameplate data, customer identification, time and date of tests, environmental conditions during tests, and test results.

C. Provide testing equipment, lifts, man-baskets, temporary connections, cabling, lugs, leads, clips, and all other devices and equipment as required to perform the required tests and complete the required documentation.

PART 3 EXECUTION

3.1 TEST PLAN

A. Prior to performing testing, the lead electrical inspection technician shall submit written test procedures indicating details of the work to be performed to the Contract Administrator for review and approval prior to proceeding.

B. As a minimum, the test plan shall include the following:
   1. Type of tests.
   2. Equipment being used to perform the test.
   3. Equipment settings for each test.
   4. Test sheets.
   5. Safety checks and safety plan.
   6. An indication of expected results.

C. The cost of any damage to equipment due to improper test methods or procedures will be borne by the Contractor performing the tests.

3.2 SCOPE OF TESTING

A. Perform testing and Commissioning of electrical devices, in accordance with the Drawings and Specifications to suit the actual project. Scope of work for testing includes the following devices:
   1. Motor Control Centers (MCCs), including:
      a. Surge Protector
      b. Power Meter
      c. Voltage Monitor
      d. CTs
      e. PTs (if present)
      f. Main and Tie Breakers
      g. Branch Circuit Breakers
      h. Motor Starters
      i. VFDs
      j. Interlocks
      k. Kirk keys
   2. Panelboards and distribution panels, greater than 225A, including:
      a. Surge Protector
      b. Power Meter
      c. Voltage Monitor
      d. CTs
      e. PTs
      f. Branch Circuit Breakers
   3. Air circuit breakers
   4. Vacuum circuit breakers.
   5. Static Uninterruptible Power Supply (UPS)
   6. Molded case circuit breakers, greater than or equal to 250A frame.
   7. Contactors, greater than or equal to 100A.
   8. Protective relays
   9. Medium voltage and low voltage switchgear, including:
      a. Surge Protector
      b. Power Meter
      c. Voltage Monitor
      d. CTs
      e. PTs
      f. Relays
      g. Switches, pushbuttons
      h. Lock-out relays
      i. Interlocks
      j. Kirk keys
   10. Power factor correction, including:
      a. Metering
      b. Capacitors
      c. Branch Circuit Breakers
      d. Contactors
   11. Dry type transformers, 15 kVA and greater.
   12. Oil filled transformers.

13. Motors, 0.5 HP and greater.
14. Gensets.
15. Transfer switches.
16. Safety switches, greater than 200A.
17. Battery systems.
18. Surge arrestors.
19. Soft starters.
20. VFDs.
21. Cables:
    a. Test all 120 / 208 V / 240 V / 600 V power cables and wires No. 10 AWG or larger (except for lighting and 15A duplex receptacle circuits)
    b. Test all 15 kV cables
22. Grounding system.
23. Perform harmonics measurements and analysis at all main distribution panels, and at all MCCs at all available voltage levels at the Facility.

B. All equipment which fails the tests shall be replaced, repaired and corrected at no additional charge. These items are deemed to be under warrantee, and the warrantee shall not be affected or voided as a result of the testing performed.

C. The calibration, check out, testing and Commissioning activities specified in other sections, of the overall Specifications are to be considered as supplemental to the requirements of this section. Those requirements are to be completed for each particular part of the work described prior to the execution of the overall requirements described herein. Where any duplication in requirements may exist the more stringent requirement will take precedent.

D. Perform Commissioning of all systems, to ensure a complete and functional installation. Perform Commissioning work in accordance with Appendix A – Commissioning Specification and Objectives (CSO), and Appendix B – Commissioning Procedures (CP), of this document.

3.3 INPECTION, TESTING AND MAINTENANCE PROCEDURES

A. General
1. All tests are based on NETA (InterNational Electrical Testing Association) standard ATS-2009. Where Manufacturer's Specifications, tolerances, and/or published data are not available, refer to the appropriate tables in ATS-2009. Confirm with the equipment Manufacturer that the test will not damage the equipment or void the warrantee prior to proceeding with tests.
2. Torque all accessible bolted electrical connections. Additional requirements apply as specified.
3. Utilize the Drawings for reference while performing the specified electrical inspection work. Where the existing installation deviates from that shown on the Drawings, mark-up the Drawings with red pen as required to reflect the installation. Include the marked-up Drawings in the report.
4. The scope of required Drawing checks is limited to the equipment and components that are part of the electrical inspection work.

5. Any repairs made that affect the accuracy of the Drawings shall be marked up on the Drawings.
6. All inspection values, readings, corrections, and assessments shall be clearly recorded for inclusion within the report.
7. Where corrections or repairs are made, record both as found/as left test readings on the inspection sheet. If space is not provided on the inspection form, record the readings in the Note fields or on a separate sheet.

B. Inspection Forms
1. The inspection forms are to be provided, and completed by the Contractor. These shall be typewritten (in Microsoft Word or Excel format) and submitted the Contract Administrator for format approval.
2. Make appropriate print-outs of the inspection forms and utilize for entry of data and test results on site.
3. Utilizing the Microsoft Word form templates, enter the data recorded manually into the forms electronically.
4. Complete the inspection forms in their entirety and include them in the report.
5. Submit electronic PDF copies of the inspection forms.
6. The scope of work required in the Specifications is in no way limited by the inspection forms, or spaces provided. Provide additional pages, documents, and forms as required to provide a complete report.
7. The inspection forms may be updated during the by the Contract Administrator. Utilize the latest forms.
8. Perform insulation resistance temperature correction calculations utilizing the following:
   a. To correct to 20 degrees C, utilize Table 260805-1.
   b. To correct to 40 degrees C, utilize Table 260805-2.

Table 260805-1 Insulation Resistance Correction Factors (20 °C)		
Measured Temperature (°C)	**Oil Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

Table 260805-2 Insulation Resistance Correction Factors (40 °C)		
Measured Temperature (°C)	**Oil Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

C. Perform winding resistance temperature correction calculations utilizing the following:

1. $$R_C = R_M \frac{T_C + T_K}{T_M + T_K}$$

2. Where, RC = Resistance at corrected temperature.
RM = Resistance at measured temperature.
TC = Temperature to correct to in degrees C.
TM = Measured temperature in degrees C.
TK = Temperature Resistance Constant
(234.5 degrees C for copper, 226.0 degrees C for aluminum)

3.4 CABLES (ALSO FEEDERS IN CONDUIT), UP TO 600 V

A. Perform inspection and tests on cables prior to installing sealing compound in the conduit system. This applies to hazardous areas and to weatherproof penetration sealant.

B. Inspection and testing shall be comprised of the following:
1. For cables/wires 4/0 AWG or larger, inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate and correct values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Torque all accessible bolted electrical connections.
3. Inspect compression applied connectors for correct cable match and indentation.
4. Inspect grounding and cable/conduit support.
5. Verify that visible cable bends meet or exceed the minimum allowable bending radius.
6. Measure length of cable/conduit and record in meters. Record and adjust all cable lengths included in the cable schedules. Other building base building cabling such as lighting, fire alarm, public address, 15A duplex receptacles do not need to be recorded. Record cable lengths based on conductor distance markings where ever possible, for accurate lengths.
7. If cables/wires are terminated through window-type current transformers, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.
8. Perform an insulation-resistance test on each conductor. Individually test each conductor with all other conductors and shields grounded. The test duration shall be one minute. Investigate resistances less than 1 Gigohms for power cabling. The voltage applied shall be 1000 Vdc for 600 V or 1000 V rated cables.

3.5 CABLES, MEDIUM VOLTAGE (5 kV AND 15 kV)

A. Inspection and testing shall be comprised of the following:
1. Inspect exposed sections of cables for physical damage and evidence of overheating and corona.
2. Proper connections in accordance with single-line diagram.
3. Proper circuit and phase identification.
4. Inspect terminations and splices for physical damage and evidence of overheating and corona.

5. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
6. Inspect compression applied connectors for correct cable match and indentation.
7. Check for proper lug installation.
8. Confirm bolt torque levels are in accordance with Manufacturer's recommendation.
9. Inspect shield grounding and cable support.
10. Verify that visible cable bends meet or exceed the minimum allowable bending radius.
11. Measure and record the length of cable.
12. If cables are terminated through window-type current transformers, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.
13. Perform a shield-continuity test on each power cable by ohmmeter method. The shielding must exhibit continuity. Investigate resistance values in excess of 10 ohms per 1000 feet of cable.
14. Perform an insulation-resistance test on each conductor utilizing a megohm-meter:
    a. Utilize 2,500-volt megohmmeter for 5 kV, 8 kV, 15 kV conductors in accordance with NETA standards.
    b. Individually test each conductor with all other conductors and shields grounded. The test duration shall be one minute. Investigate resistances less than 5 Gig-ohms for 5 kV cable, and 15 Gig-ohms for 15 kV.
15. Perform a Very Low Frequency (VLF) ac high-potential test on cables. Adhere to all precautions and limits as specified in the applicable NEMA / ICEA Standard for the specific cable. Perform tests in accordance with IEEE Standard 400.2. Test procedure shall be as follows, and the results for each cable test shall be recorded as specified herein. The test voltage shall be sinusoidal with a frequency of 0.1 Hz, and shall not exceed cable Manufacturer's test values or IEEE 400.2 values as indicated:

Cable rating phase to phase (RMS)	Acceptance test phase to ground	Maintenance test phase to ground
5 kV RMS	10 kV RMS (14 peak)	7 kV RMS (10 peak)
15 kV RMS	20 kV RMS (28 peak)	16 kV RMS (22 peak)

    a. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the over-potential test, the test specimen is considered to have passed the test.
    b. Ensure that the input voltage to the test set is regulated.
    c. Current-sensing circuits in test equipment shall measure only the leakage current associated with the cable under test and shall not include internal leakage of the test equipment.
    d. Record wet and dry-bulb temperatures or relative humidity and temperature.
    e. Test each section of cable individually.
    f. Individually test each conductor with all other conductors grounded. Ground all shields.
    g. Terminations shall be adequately corona-suppressed by guard ring, field reduction sphere, or other suitable methods as necessary.
    h. Ensure that the maximum test voltage does not exceed the limits for terminators specified in IEEE Standard 48 or Manufacturer's Specifications.

i. Raise the conductor test voltage to the specified maximum test voltage and hold for five minutes. Record leakage current.
j. Apply grounds for a time period adequate to drain all insulation-stored charge.

16. Perform a Dissipation Factor (Tangent Delta) test on all cables.
    a. Perform tests in accordance with IEEE Standard 400.2.
    b. The test voltage applied shall be a 0.1 Hz sinusoidal waveform.
    c. The dissipation factor shall be calculated for an applied voltage of 1 Uo RMS.
        1) Test 5 kV cable to 1 Uo (1 Uo is defined as 1 x line to ground operating voltage; which is 2400V RMS for 5 kV cable, and 4.16 kV phase to phase distributions).
        2) Test 15 kV cable to 1 Uo or 7,200V RMS for 15 kV cable, and 12.47 kV phase to phase distributions.
    d. Provided that the dissipation factor does not rise significantly while raising the voltage, the dissipation factor shall also be calculated for an applied voltage 2 Uo RMS.
        1) Test 5 kV cable to 2 Uo or 4800V RMS for 5 kV cable, and 4.16 kV phase to phase distributions.
        2) Test 15 kV cable to 2 Uo or 14,400V RMS for 15 kV cable, and 12.47 kV phase to phase distributions.
17. In the event of a cable failure discovered during testing, replace the cable.

3.6 CIRCUIT BREAKERS, INSULATED-CASE/MOLDED CASE, UP TO 600 V

A. Inspection and testing shall include the following:
    1. Note the equipment nameplate data for inclusion in the report.
    2. Record all adjustable settings.
    3. Inspect physical and mechanical condition.
    4. Inspect anchorage and alignment.
    5. Clean the unit.
    6. Torque all accessible bolted power connections.
    7. Operate the circuit breaker to insure smooth operation.
    8. Test all breakers utilizing the “Push-To-Trip” button, if equipped.
    9. Move operating handle to the off and on position.
    10. Restore breaker position to original position.

B. For cables 4/0 AWG and larger, inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

C. For breakers with a frame size greater or equal to 250A, or as specified elsewhere in the Specification:
    1. Perform an insulation resistance test.
    2. Breakers rated less than 600V, test voltage is to be 500 VDC.
    3. Breakers rated at 600V, test voltage is to be 1000 VDC.

D. Perform a contact/pole-resistance test.

3.7 AIR CIRCUIT BREAKERS

A. Visual and Mechanical Inspection:
   1. Proper cell fit and element alignment.
   2. Proper operation of cubicle shutters and racking mechanism.
   3. Bolt torque level in accordance with Manufacturer's recommendations and NETA ATS-2009, Table 100.12. Where conical washers (Belleville or other) are used, consult with the Contract Administrator prior to tightening or applying pressure to connections.
   4. Proper contact condition.
   5. Perform mechanical operator and contact alignment tests on breaker and it's operating mechanism in accordance with Manufacturer's instructions.
   6. Verify primary and secondary contact wipe, gap setting, and other dimensions vital to breaker operations are correct.
   7. Ensure that maintenance devices are available for servicing and operating breaker.
   8. Check for adequate lubrication on contact, moving, and sliding parts.
   9. Check condition of brushes and limit switches on charging and lifting motors.
   10. With Breaker in TEST Position:
      a. Trip and close breaker with control switch.
      b. Trip breaker by manually operating each protective relay.
   11. Perform breaker travel and velocity analysis in accordance with Manufacturer's instructions; values shall be in accordance with Manufacturer's acceptable limits.

B. Electrical Tests:
   1. Insulation Resistance Tests:
      a. Utilize:
         1) 1,000 volt megohmmeter for 600V circuit breakers
      b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute
      c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
      d. Test values to comply with NETA ATS-2009 Table 100.1.
   2. Contact Resistance Tests:
      a. Contact resistance in microhms across each pole.
      b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
   3. Dieletric Withstand Tests:
      a. Maximum applied voltage for equipment in accordance with NETA ATS-2009, Table 100.2 and Table 100.19
      b. Each pole-to-ground with other poles grounded and contacts closed.
      c. Test results evaluated on pass/fail basis.
   4. Minimum pickup voltage tests on trip and close coils.

3.8 VACUUM CIRCUIT BREAKERS

A. Visual and Mechanical Inspection:
   1. Check for proper element alignment.
   2. Check for proper operation of cubicle shutters and racking mechanism.
   3. Bolt torque level in accordance with Manufacturer's recommendations and NETA ATS-2009, Table 100.12. Where conical washers (Belleville or other) are used, consult with the Contract Administrator prior to tightening or applying pressure to connections.

4. Perform mechanical operational tests on breaker and it's operating mechanism in accordance with Manufacturer's instructions, plus check:
   a. Pull rod adjustment.
   b. Trip latch clearance.
   c. Overtravel stops.
   d. Wipe and gap setting.
5. Perform breaker travel and velocity analysis in accordance with Manufacturer's instructions; values shall be in accordance with Manufacturer's acceptable limits.
6. Check contact erosion indicators in accordance with Manufacturer's instructions.
7. With Breaker in TEST Position:
   a. Trip and close breaker with control switch.
   b. Trip breaker by manually operating each protective relay.

B. Electrical Tests:
1. Insulation Resistance Tests:
   a. Utilize 2,500-volt dc megohmmeter for 5 kV and 15 kV circuit breakers.
   b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute
   c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
   d. Test values to comply with NETA ATS-2009, Table 100.1
2. Contact Resistance Tests:
   a. Between the line and load stab of closed contact resistance in microhms across each pole.
   b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
3. Dielectric Withstand Tests:
   a. Maximum applied voltage in accordance with NETA ATS-2009, Table 100.19.
   b. Each pole-to-ground with other poles grounded and contacts closed.
   c. Test results evaluated on pass/fail basis.
4. Minimum pickup voltage tests on trip and close coils.

3.9 CONTACTOR PANELS, UP TO 600V

A. Inspection and testing shall be comprised of the following:
1. Note the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Torque all accessible bolted power connections.
6. Inspect unit for evidence of overheating or stress.
7. Visually inspect and exercise transfer switch.

B. If power and/or control fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

C. Perform an insulation resistance tests.
1. Units rated less than 600V, test voltage is to be 500 VDC.
2. Units rated at 600V, test voltage is to be 1000 VDC.

D. Perform a contact/pole-resistance tests.

E. Perform functional testing to verify operation of unit.

3.10 CONTROL POWER TRANSFORMERS, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
   1. Record the equipment nameplate data for inclusion in the report.
   2. Inspect physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
   3. Verify that primary and secondary fuse ratings or circuit breakers match available Drawings. Where Drawings are not available, note fuses that appear to be sized incorrectly, based upon application of the Canadian Electrical Code. Mark fuse sizes and type on the Drawings, where not shown.
   4. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be:
      a. windings less than 250 V: 500 Vdc
      b. windings greater than 250 V: 1000 Vdc

3.11 CURRENT INSTRUMENT TRANSFORMERS

A. Inspection and testing shall be comprised of the following:
   1. Inspect physical and mechanical condition.
   2. Record the equipment nameplate data for inclusion in the report.
   3. Ensure that CT shorting bars are removed or installed as required.
   4. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.
   5. Perform an insulation resistance test of the current transformer primary and secondary windings, and wiring to ground at 1000 Vdc. Do not perform this test on solid-state devices. Investigate any resistance values less than 25 megohms.
   6. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
   7. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1. Note any ratio accuracies not within 0.5 percent of nameplate or Manufacturer's published data.
   8. Perform an excitation test on transformers used for protection or relaying applications in accordance with ANSI C57.13.1.

3.12 GROUNDING SYSTEM

A. Inspection and testing shall be comprised of the following:
   1. Perform resistance tests between the main grounding electrode and grounded points in the electrical distribution system located in the switchgear, transformers, and MCCs. Investigate and correct connections with a resistance greater than 0.5 milliohms.
   2. Perform resistance tests between the main grounding electrode and grounded points in the isolated ground system points in all control / PLC cabinets connected to the isolated ground system. Investigate and correct connections with a resistance greater than 0.5 milliohms.

3. Perform resistance tests between the lightning protection terminals (at roof level) and the grounding electrode. Investigate and correct connections with a resistance greater than 0.5 milliohms.

3.13 HARMONICS MEASUREMENTS

A. Testing shall be comprised of the following:
   1. Connect to existing CTs and PTs, if provided. If not provided, supply appropriate CTs and PTs as required.
   2. Test duration at each location is to be one hour.
   3. Coordinate with operations personnel to ensure the loads run during the test are representative of normal and maximum plant operation.
   4. Monitor the following for all three phases:
      a. Voltage, current, and power factor
      b. Harmonic voltage level for 1st (base) through 15th harmonics.
      c. Harmonic current level for 1st (base) through 15th harmonics, expressed in percent of current.
      d. Total harmonic distortion (THD)
      e. Total demand distortion (TDD)
   5. Record samples as one (1) minute intervals for a period of 24 hours for each required operating scenario. Included in the period, ensure all loads are running.
   6. Provide Microsoft Excel files of the test results. Provide graphical representations of levels. Provide overall systems report and analysis.
   7. Provide a summary page in the report indicating the THD, and maximum, average, and minimum for each voltage and current harmonic.
   8. Perform harmonics recording, measurements, and analysis / report for each of the following operating scenarios:
      a. On 600 VAC MCCs / 600 Switchgear
         1) Normal operation with tie breaker open
         2) Normal operation with tie breaker closed, and all systems fed from one supply.
      b. On 12.47 kV Switchgear
         1) Normal operation with tie breaker open
         2) Normal operation with tie breaker closed, and all systems fed from one supply.

3.14 PROTECTIVE RELAYS

A. Visual and Mechanical Inspection:
   1. Visually Check Each Relay For:
      a. Tight cover gasket and proper seal.
      b. Unbroken cover glass.
      c. Condition of case shorting contacts if present.
      d. Circuit wiring and connections
   2. Mechanically Check Each Relay For:
      a. Freedom of movement.
      b. Proper travel and alignment.
      c. Trip plunger mechanism.
   3. Verify That Each Relay:
      a. Complies with Contract Documents and application.

b. Is set in accordance with recommended settings.

B. Electrical Tests:
1. Tests on Nominal Recommended Setting For:
a. Perform tests to suit the type of relay and the type of protection in accordance with NETA ATS-2009.
b. Pickup parameters on each operating element.
c. Timing at three points on time-current curve.
d. Pickup target and seal-in units.
e. Special tests as required to check operation of restraint, directional, and other elements in accordance with Manufacturer's instruction manual and NETA standards.
2. Phase angle and magnitude contribution tests on differential and directional relays after energization to vectorially verify proper polarity and connections.
3. Current Injection Tests:
a. For entire current circuit in each section.
b. Secondary injection for current flow.
c. Test current at each device.
4. For Motor protection Relays and similar relays, use 3-phase current injection for unbalanced protection testing, unless recommended otherwise by the Manufacturer.
5. Use 6 phase current injection and voltage relay (3 phase line, 3 phase load) test units for differential protection relays.

3.15 METERING DEVICES, DIGITAL

A. Inspection and testing shall be comprised of the following:
1. Inspect physical and mechanical condition.
2. Torque all bolted connections.
3. Record the equipment nameplate data for inclusion in the report.
4. Verify accuracy of voltage and current at a minimum of two points each.
5. If required, calibrate meters in accordance with Manufacturer's published data.

3.16 PANELBOARDS, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
1. Note the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Clean the unit.
5. Inspect breakers and verify mechanical operation by exercising all circuit breakers.
a. Record breaker data on the inspection form.
b. Test all breakers utilizing the "Push-To-Trip" button, if equipped.
c. Move operating handle to the off and on position.
d. Restore breaker position to original position.
6. Test with current injection, main and feeder/load breakers with a frame size greater than or equal to 250A, or with long, short, or ground fault settings and complete a separate inspection form for each.

7. Torque all accessible bolted power connections including incoming, load neutral and ground connections.
8. Perform insulation-resistance tests on each bus phase with all other phases grounded.
   a. The main breaker, if present, is to be open for the test. If no main breaker is present, disconnect the supply conductors.
   b. Open all load breakers.
   c. Test voltage for all 600/347 V panelboards to be 1000 Vdc.
   d. Test voltage for all 120/208 V panelboards to be 500 Vdc.

3.17 MOTOR CONTROL, UP TO 600 V

A. Visual and Mechanical Inspection:
   1. Proper barrier and shutter installation and operation.
   2. Proper operation of indicating and monitoring devices.
   3. Proper overload protection for each motor.
   4. Improper blockage of air cooling passages.
   5. Proper operation of drawout elements.
   6. Integrity and contamination of bus insulation system.
   7. Check Door and Device Interlocking System By:
      a. Closure attempt of device when door is in OPEN position.
      b. Opening attempt of door when device is in CLOSED position.
   8. Check Key Interlocking Systems For:
      a. Key captivity when device is in CLOSED position.
      b. Key removal when device is in OPEN position.
      c. Closure attempt of device when key has been removed.
      d. Correct number of keys in relationship to number of lock cylinders.
      e. Existence of other keys capable of operating lock cylinders; destroy duplicate sets of keys.
   9. Check Nameplates for Proper Identification Of:
      a. Equipment title and tag number with latest one-line diagram.
      b. Pushbuttons.
      c. Control switches.
      d. Pilot lights.
      e. Control relays.
      f. Circuit breakers.
      g. Indicating meters.
   10. Verify that fuse and circuit breaker sizes and types conform to the Drawings.
   11. Verify that current and potential transformer ratios conform to the Drawings.
   12. Check Bus Connections for High Resistance by Low Resistance Ohmmeter, Calibrated Torque Wrench Applied to Bolted Joints and Thermographic Survey:
      a. Ohmic value to be zero.
      b. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by Manufacturer.
      c. Thermographic survey temperature gradient of 2 degrees C, or less.
   13. Check Operation and Sequencing of Electrical and Mechanical Interlock Systems By:
      a. Closure attempt for locked open devices.
      b. Opening attempt for locked closed devices.
      c. Key exchange to operate devices in OFF-NORMAL positions.

14. Verify performance of each control device and feature furnished as part of the motor control center.
15. Control Wiring:
    a. Compare wiring to local and remote control, and protective devices with elementary diagrams.
    b. Check for proper conductor lacing and bundling.
    c. Check for proper conductor identification.
    d. Check for proper conductor lugs and connections.
16. Exercise active components.
17. Inspect Contactors For:
    a. Correct mechanical operations.
    b. Correct contact gap, wipe, alignment, and pressure.
    c. Correct torque of all connections.
18. Compare overload heater rating with full-load current for proper size.
19. Compare, fuse, motor protector, and circuit breaker with motor characteristics for proper size.
20. Perform phasing check on double-ended motor control centers to ensure proper bus phasing from each source.

B. Electrical Tests:
1. For units with solid state components, follow Manufacturer's recommendations prior to performing any tests.
2. Insulation Resistance Tests:
    a. Applied megohmmeter dc voltage.
    b. Bus section phase-to-phase and phase-to-ground for 1 minute on each phase.
    c. Contactor phase-to-ground and across open contacts for 1 minute on each phase.
    d. Starter section phase-to-phase and phase-to-ground on each phase with starter contacts closed and protective devices open.
    e. Test values to comply with NETA ATS-2009, Table 100.1.
3. Current Injection Through Overload Unit at 300 Percent of Motor Full-Load Current and Monitor Trip Time:
    a. Trip time in accordance with Manufacturer's published data.
    b. Investigate values in excess of 120 seconds.
4. Control Wiring Tests:
    a. Apply secondary voltage to control power and potential circuits.
    b. Check voltage levels at each point on terminal boards and each device terminal.
5. Operational test by initiating control devices to affect proper operation.
6. Verify the correct operation of the network cabling, network switch, and associated components within Smart MCCs.
    a. Verify I/O and metering data from each Intelligent Overload.

3.18 DISTRIBUTION SWITCHBOARDS / SWITCHGEAR, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
1. Switchgear dimension verification.
2. Inspect the switchboard physical, electrical, and mechanical condition. Inspect the main bus compartment.

3. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment.
4. Inspect all doors, panels, and sections for dents, holes, fit, and missing hardware.
5. Verify that fuse and / or circuit breaker sizes and types correspond to Drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
6. Verify that current and potential transformer ratios correspond to Drawings.
7. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
9. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
10. Make key exchange with all devices included in the interlock scheme as applicable.
11. Vacuum debris from interior of switchboard. Clean off all dust and adhesive residue from switchboard.
12. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Inspect insulators for evidence of physical damage or contaminated surfaces.
14. Verify correct barrier and shutter installation and operation.
15. Operational testing of all circuit breakers (close, open, charging, racking, etc). Exercise all active components.
16. Inspect all mechanical indicating devices for correct operation.
17. Verify that filters are in place and / or vents are clear.
18. Test operation, alignment, and penetration of instrument transformer withdrawal disconnects, current-carrying and grounding contacts.
19. Perform point to point ground-resistance tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and / or derived neutral points. Investigate point-to-point resistance values which exceed 0.5 ohm.
20. Perform insulation-resistance tests each bus section, phase-to-phase and phase-to-ground.
    a. Test voltage for 600/347 V equipment to be 1000 Vdc.
    b. Test voltage for 120/208 V equipment to be 500 Vdc.
21. Inspect all surge arrestors if available.
22. Inspect control power transformers.
23. Inspect all current instrument transformers. Verify the position of any C.T shorting pins.
24. Inspect potential transformers.
25. Inspect all metering devices.
26. Inspect and test air circuit breakers.
27. Inspect and test protective relays.
28. Inspect and test all moulded case feeder breakers. Feeder breakers with a frame size less than 250A, and without long, short, or ground fault settings, may be recorded on the Switchboard inspection form. Record test results on other breakers on the appropriate inspection form.
    a. Inspect and test all capacitors.
    b. Perform a system function test to prove the correct interaction of all sensing, processing, and action devices. Perform system function tests upon completion of the maintenance tests defined, as system conditions allow.

29. Perform tests for the purpose of evaluating performance of all integral components and their functioning as a complete unit within each cell.
30. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.
31. Verify the correct operation of all sensing devices, alarms, and indicating devices.
32. Verify the correct operation of the network cabling, network switch, and associated components.

3.19 MEDIUM VOLTAGE SWITCHGEAR AND MOTOR CONTROL CENTERS (5 kV AND 15 kV)

A. Visual and Mechanical Inspection:
   1. Insulator damage and contaminated surfaces.
   2. Proper barrier and shutter installation and operation.
   3. Bolt torque level in accordance with Manufacturer's recommendations and NETA ATS-2009, Table 100.12. Where conical washers (Belleville or other) are used, consult with the Contract Administrator prior to tightening or applying pressure to connections.
   4. Proper operation of indicating devices.
   5. Proper overload protection.
   6. Blockage of air cooling passages.
   7. Proper operation of drawout elements.
   8. Integrity and contamination of bus insulation system.
   9. Check Door and Device Interlocking System By:
      a. Closure attempt of device when door is in OPEN position.
      b. Opening attempt of door when device is in CLOSED position.
   10. Check Key Interlocking Systems For:
      a. Key captivity when device is in CLOSED position.
      b. Key removal when device is in OPEN position.
      c. Closure attempt of device when key has been removed.
      d. Correct number of keys in relationship to number of lock cylinders.
      e. Existence of other keys capable at operating lock cylinders; destroy duplicate sets of keys.
   11. Check Nameplates for Proper Identification of Each:
      a. Equipment title and tag number with latest one-line diagram.
      b. Pushbutton.
      c. Control switch.
      d. Pilot light.
      e. Control relay.
      f. Circuit breaker.
      g. Indicating meter.
   12. Verify that fuse sizes and types conform to the Drawings.
   13. Check Bus Connections for High Resistance by Low Resistance Ohmmeter, Calibrated Torque Wrench Applied to Bolted Joints and Thermographic Survey:
      a. Ohmic value to be zero.
      b. Bolt torque level in accordance with Manufacturer's recommendation.
      c. Thermographic survey temperature gradient of 2 degrees C, or less.
   14. Check Operation and Sequencing of Electrical and Mechanical Interlock Systems By:
      a. Closure attempt for locked open devices.
      b. Opening attempt for locked closed devices.

c. Key exchange to operate devices in OFF-NORMAL positions.

15. Verify performance of each control device and feature furnished as part of the motor control center.
16. Control Wiring:
    a. Compare wiring to local and remote control, and protective devices with elementary diagrams.
    b. Check for proper conductor lacing and bundling.
    c. Check for proper conductor identification.
    d. Check for proper conductor lugs and connections.
17. Exercise active components.
18. Verify performance of charging mechanisms.
19. Inspect all surge arrestors if available.
20. Inspect control power transformers.
21. Inspect all current instrument transformers. Verify the position of any C.T shorting pins.
22. Inspect potential transformers.
23. Inspect all metering devices.
24. Inspect and test air circuit breakers.
25. Inspect and test protective relays.
26. For motor starters:
    a. Inspect magnetic contactors for:
        1) Correct mechanical operations.
        2) Correct contact gap, wipe, alignment, and pressure.
        3) Correct torque of connections.
    b. Perform phasing check on motor control centers to ensure proper bus phasing from each source.

B. Electrical Tests:
1. For units with solid state devices follow Manufacturer's recommendations prior to performing any tests.
2. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections
3. Insulation Resistance Tests:
    a. Applied megohmmeter dc voltage.
    b. Bus section phase-to-phase and phase-to-ground for 1 minute on each phase.
    c. Contactor phase-to-ground and across open contacts for 1 minute on each phase.
    d. Starter section phase-to-phase and phase-to-ground on each phase with starter contacts closed and protective devices open.
    e. Test values to comply with NETA ATS-2009, Table 100.1
4. Overpotential Dielectric Tests:
    a. Maximum applied voltage in accordance with NETA ATS, Table 100.19.
    b. Phase-to-phase and phase-to-ground for 1 minute for each phase of each bus section.
    c. Test results evaluated on pass/fail basis.
5. Bottle integrity test for vacuum contactors in accordance with Manufacturer's procedure.
6. Test by Primary Current Injection:
    a. Overload units at sensors using 300 percent of motor full-load current.
        1) Overload trip times to be in accordance with Manufacturer's published data.
    b. Check voltage levels at each point on terminal boards and each device terminal.

7. Control Wiring Tests:
   a. Apply secondary voltage on control power and potential circuits.
   b. Check voltage levels at each point on terminal boards and at each device terminal.
8. Test indicating and monitoring devices for proper operation.
9. Perform setup and testing of solid state relays and multifunction protective devices in accordance with Manufacturer's instructions. Relays and electronic components to be tested by means of secondary current injection test.
10. Measure Contact and Power Fuse Resistances:
    a. Contact resistance shall not exceed Manufacturer's recommended values.
    b. Resistance of power fuses not to deviate more than 15 percent between identical fuses.
11. Verify the correct operation of the network cabling, network switch, and associated components.
    a. Verify I/O, communications, metering data from relays or other solid state devices.

3.20 MOTORS, INDUCTION, AC, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
   1. Note the equipment nameplate data for inclusion in the report.
   2. Inspect physical and mechanical condition.
   3. Inspect anchorage, alignment, and grounding.
   4. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging. Air baffles and filter media should be clean. Cooling fans should operate. Slip ring wear and brushes should be within Manufacturer's tolerances for continued use. Brush rigging should be intact.
   5. Inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   6. Verify the application of appropriate lubrication and lubrication systems.
   7. Verify the absence of unusual mechanical or electrical noise or signs of overheating.
   8. Perform a rotation test to insure correct shaft direction.
   9. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43. Test voltage shall be in accordance with Manufacturer's published data or 500 Vdc.
      a. Where possible, test each winding separately. Ground all windings not under test.
      b. Ensure all cables and accessories are disconnected during the test.
      c. For motors less than or equal to 150kW (200 HP), the test duration is to be one (1) minute. Calculate the dielectric absorption ratio.
      d. For motors greater than 150kW (200 HP), the test duration is to be ten (10) minutes. Calculate the dielectric absorption ratio and polarization index.
      e. Correct test results to 40 degrees C.
      f. Investigate readings below 100 megohms. Investigate dielectric absorption ratios less than 1.4 and polarization index ratios less than 2.0 for Class B insulation and Class F insulation.
   10. Where it is not possible to perform an insulation resistance test separately on each winding, perform a winding resistance test on each winding using a low-resistance ohmmeter.

11. Measure running voltage and current and evaluate relative to load conditions and nameplate full-load amperes. Utilize a true RMS meter.
    a. Where powered by a VFD with bypass, perform test with the motor powered by the VFD and by the bypass starter.
12. Perform insulation-resistance test on insulated bearings in accordance with Manufacturer's published data, if applicable.
13. Perform resistance tests on resistance temperature detector (RTD) circuits. RTD circuits should conform to design intent and/or machine protection device Manufacturer's Specifications.

3.21 SAFETY SWITCHES, UP TO 600 V

A. Visual and Mechanical Inspection:
    1. Proper blade pressure and alignment.
    2. Proper operation of switch operating handle.
    3. Adequate mechanical support for each fuse.
    4. Proper contact-to-contact tightness between fuse clip and fuse.
    5. Cable connection bolt torque level in accordance with NETA ATS-2009, Table 100.12.
    6. Proper phase barrier material and installation.
    7. Verify that fuse sizes and types correspond to one-line diagram.
    8. Perform mechanical operational test and verify electrical and mechanical interlocking system operation and sequencing where installed.

B. Electrical Tests:
    1. Insulation Resistance Tests:
        a. Applied megohmmeter dc voltage.
        b. Phase-to-phase and phase-to-ground for 1 minute on each pole.
        c. Insulation resistance values equal to, or greater than, ohmic values established by Manufacturer.
    2. Contact Resistance Tests:
        a. Contact resistance in microhms across each switch blade and fuse holder.
        b. Investigate deviation of 50 percent or more from adjacent poles or similar switches.

3.22 MOTOR STARTERS, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
    1. Note the motor / equipment nameplate data for inclusion in the report.
    2. Record all adjustable settings, size of overload, etc.
    3. Ensure overloads are set in accordance with the motor nameplate data, and the electrical code requirements.
    4. Inspect physical and mechanical condition.
    5. Inspect anchorage, alignment, and grounding.
    6. Verify the unit is clean.
    7. Torque all accessible bolted power connections.
    8. Inspect contactors for evidence of overheating or stress.
    9. Visually inspect and exercise circuit breaker.
    10. If power fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

3.23 MOTOR STARTERS, SOFT STARTER, UP TO 600 V

A. Inspection and testing shall be comprised of the following:
   1. Note the motor / equipment nameplate data for inclusion in the report.
   2. Confirm soft starter parameters.
   3. Ensure all parameters are correct for the specific motor nameplate.
   4. Record size and setting of overload.
   5. Inspect physical and mechanical condition.
   6. Inspect anchorage, alignment, and grounding.
   7. Verify the unit is clean.
   8. Torque all accessible bolted power connections.
   9. Inspect contactors for evidence of overheating or stress.
   10. Perform resistance measurements with a low-resistance ohmmeter for each pole of the following:
      a. Bypass contactor.
      b. Capacitor contactor, if applicable.
      c. Main disconnect/circuit breaker.
      d. Main fuses.
   11. Perform power cable insulation resistance measurements. Test voltage for 208V or 240V to be 500V, 600V rated equipment is to be 1000V. Disconnect the power cables from the soft starter module and control power fuses prior to test. Test to include:
      a. Bypass contactor line and load to GND.
      b. Bypass contactor line to load with contactor open.
   12. Perform an operational inspection while starting, running, and stopping the motor at normal load. Include:
      a. Measurement of ramp up time.
      b. Measurement of motor current.
      c. Recording of soft starter, ammeter, and remote displayed current readings.
      d. Measurement of ramp down time.

3.24 VARIABLE FREQUENCY DRIVE, LOW VOLTAGE (LESS THAN 37.5 kW)

A. Inspection and testing shall be comprised of the following:
   1. Inspect physical and mechanical condition.
   2. Inspect anchorage, alignment, and grounding.
   3. Clean the unit.
   4. Check the air filters.
   5. Ensure vent path openings are free from debris and that heat transfer surfaces are not contaminated by oil, dust, or dirt.
   6. Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables.
   7. Visually inspect VFD grounding to ensure continuity.
   8. Inspect condition and connections of line reactors, and load reactors / load filter if present.
   9. Inspect DC bus capacitors for bulging and leakage.
   10. Cooling fans and heat sinks:
      a. Visually inspect and listen for any abnormal noises or vibration.
      b. Verify that fans rotate freely.
      c. Verify correct direction of airflow.

d. Clean and verify integrity of heat sinks.
e. Verify the operation of the grounding switch, if present.

11. Perform all other work in accordance with the Manufacturer's instructions.

B. Record the following VFD Parameters:
1. Motor voltage, current, frequency, nominal speed, nominal power.
2. Control mode / method.
3. Minimum and maximum control frequency.
4. Acceleration and deceleration time.
5. Compare drive overcurrent set points with motor full-load current rating to verify correct settings.

C. Power fuses:
1. Record fuse data. Confirm that the fuses are of the correct type and rating. Utilize Manufacturer's published data where available.
2. Measure fuse resistance.

D. Bolted connections:
1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Torque all bolted connections.

E. Inverter / Supply Module Power Connections:
1. Remove each power module and visually inspect the contacts.
2. Torque all cable connections.
3. Clean all contact surfaces and apply suitable joint compound as recommended by Manufacturer.

F. Operator Interface:
1. Check the display and keypad for proper operation and communication.
2. Retrieve fault history log and note any faults.

G. Grounding/Bonding measurements:
1. Measure the resistance of the ground bonding connection between the VFD and the main grounding bus in the corresponding electrical room.

H. Control Wiring:
1. Check for tightness of all accessible control wiring and torque any loose connections.

I. Perform operational tests by initiating control devices.
1. Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
2. Verify operation of drive from local start/stop and speed control signals.
3. Verify operation of all local pilot lights.
4. Verify the operation of any emergency stop switches.
5. Perform all other tests in accordance with the Manufacturer's instructions.

6. Perform all tests in accordance with the Manufacturer's recommendations and instructions.

J. Voltage and Current Testing:
   1. With the VFD under load, measure and record the following:
      a. Incoming AC voltage and currents.

K. With the VFD output in START/RUN mode, and at zero speed:
   1. Measure and record the AC output voltage. Voltages above 40 VAC should be investigated.

3.25 VARIABLE FREQUENCY DRIVE, LOW VOLTAGE (GREATER THAN 37.5 kW AND LESS THAN 150 kW)

A. Inspection and testing shall be comprised of the following:
   1. Inspect physical and mechanical condition.
   2. Inspect anchorage, alignment, and grounding.
   3. Clean the unit.
   4. Check the air filters.
   5. Ensure vent path openings are free from debris and that heat transfer surfaces are not contaminated by oil, dust, or dirt.
   6. Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables.
   7. Visually inspect VFD grounding to ensure continuity.
   8. Inspect condition and connections of line reactors, if present.
   9. Inspect condition and connections of DC Link Reactors, if present.
   10. Inspect condition and connections of load reactors or load filter, if present.
   11. Inspect condition of isolation transformers, if present.
   12. Inspect DC bus capacitors for bulging and leakage.
   13. Cooling fans and heat sinks:
      a. Visually inspect and listen for any abnormal noises or vibration.
      b. Verify that fans rotate freely.
      c. Verify correct direction of airflow.
      d. Clean and verify integrity of heat sinks.
      e. Verify the operation of the grounding switch, if present.

B. Record the following VFD Parameters:
   1. Motor voltage, current, frequency, nominal speed, nominal power.
   2. Control mode / method.
   3. Minimum and maximum control frequency.
   4. Acceleration and deceleration time.
   5. Compare drive overcurrent set points with motor full-load current rating to verify correct settings.

C. Power fuses:
   1. Record fuse data. Confirm that the fuses are of the correct type and rating. Utilize Manufacturer's published data where available.
   2. Measure fuse resistance.

D. Bolted connections:
   1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   2. Torque all bolted connections.

E. Inverter / Supply Module Power Connections:
   1. Remove each power module and visually inspect the contacts.
   2. Torque all cable connections.
   3. Clean all contact surfaces and apply suitable joint compound as recommended by Manufacturer.

F. Operator Interface:
   1. Check the display and keypad for proper operation and communication.
   2. Retrieve fault history log and note any faults.

G. Grounding/Bonding measurements:
   1. Measure the resistance of the ground bonding connection between the VFD and the main grounding bus in the corresponding electrical room.

H. Control Wiring:
   1. Check for tightness of all accessible control wiring and torque any loose connections.

I. Perform operational tests by initiating control devices.
   1. Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
   2. Verify operation of drive from local start/stop and speed control signals.
   3. Verify operation of all local pilot lights.
   4. Verify the operation of any emergency stop switches.

J. Voltage and Current Testing:
   1. With the VFD under load, measure and record the following:
      a. Measure and record incoming AC voltage and currents.
      b. Measure and record DC and AC bus voltages.
   2. Utilize a recording oscilloscope to capture the input voltage waveform and verify correct operation.
   3. Utilize a recording oscilloscope to capture the output voltage waveform and verify correct operation.
   4. Include input and output waveforms with the report.

K. With the VFD output in START/RUN mode, and at zero speed:
   1. Measure and record the AC output voltage. Voltages above 40 VAC should be investigated.

3.26 SURGE ARRESTORS, UP TO 600V

A. Inspection and testing shall be comprised of the following:
   1. Inspect physical and mechanical condition.

2. Inspect anchorage, alignment, grounding, and required clearances.
3. Clean the unit.
4. Verify that arrestors are electrically connected in their specified configuration.
5. Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Verify that stroke counter, if present, is correctly mounted and electrically connected.
8. Perform insulation-resistance tests for one minute from each phase terminal to the case.
9. Equipment rated greater than or equal to 600V, utilize a test voltage of 1000 VDC.
10. Equipment rated less than 600V, utilize a test voltage of 500 VDC.
11. Test the grounding connection. Resistance between the arrester ground terminal and the ground system should be less than 0.5 ohm.

3.27 TRANSFORMERS, DRY-TYPE, UP TO 600V

A. Inspection and testing shall be comprised of the following:
   1. Note the equipment nameplate data for inclusion in the report.
   2. Inspect physical and mechanical condition.
   3. Inspect anchorage, alignment, and grounding.
   4. Clean the unit.
   5. Torque all accessible bolted power connections.
   6. Record the tap setting.
   7. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Duration of the test is to be one minute. Calculate the dielectric absorption ratio.
      a. 600 V windings shall be tested at 1000 Vdc.
      b. 120/208 V windings shall be tested at 500 Vdc.

3.28 TRANSFORMERS, DRY-TYPE, MEDIUM VOLTAGE

A. Inspection and testing shall be comprised of the following:
   1. Note the equipment nameplate data for inclusion in the report.
   2. Inspect physical and mechanical condition.
   3. Inspect anchorage, alignment, and grounding.
   4. Clean the unit.
   5. Verify that alarm settings on temperature indicators are as specified and operate within Manufacturer's recommendations for specified settings.
   6. Inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   7. Record tap setting. Confirm the tap setting appears reasonable by measuring the voltage during normal Facility operation.
   8. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Calculate polarization index. Minimum insulation-resistance values of transformer insulation should be 1000 megohms for the 4160 V windings and 100 megohms for the

600 V windings. Values of insulation resistance less than the values stated should be investigated. The polarization index should not be less than 1.0.
   a. The test duration shall be 10 minutes for each winding.
   b. 4160 V windings shall be tested at 2500 Vdc.
   c. 600 V windings shall be tested at 1000 Vdc.
9. Perform turns-ratio tests at the designated tap position. Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.
10. Measure the resistance of each winding at the designated tap position.
11. Measure core insulation resistance at 500 Vdc if the core is insulated and if the core ground strap is removable.
12. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading. Phase-to-phase and phase-to-neutral secondary voltages should be in agreement with nameplate data.

3.29 LIQUID FILLED TRANSFORMERS

A. Inspection and testing shall be comprised of the following:
   1. Physical and insulator damage.
   2. Conduct external inspections in accordance with layout Shop Drawings. Check nameplates and vector diagrams against test results.
   3. Inspect silica gel breathers, oil gauge, temperature gauge and similar devices where fitted. For devices with settings, record the settings in use. Record actual reading of all gauges and ambient temperature.
   4. Proper winding connections.
   5. Bolt torque level in accordance Manufacturer's recommendations.
   6. Defective wiring.
   7. Proper operation of fans, indicators, and auxiliary devices.
   8. Effective core and equipment grounding. Review neutral grounding device wiring and connections (if present).
   9. Removal of shipping brackets, fixtures, or bracing.
   10. Inspect for oil leaks, correct oil level, and sign of rusting.
   11. Integrity and contamination of bus insulation system.
   12. Verify that tap-changer is set at correct ratio for rated voltage under normal operating conditions.
   13. Verify proper secondary voltage phase-to-phase and phase-to-ground after energization and prior to loading.
   14. Exercise the manual tap changer to check its functions and ease of access.
   15. Operate and simulate alarm and trip conditions of each protective device.

B. Electrical Tests:
   1. As a minimum, perform the following transformer tests:
      a. Perform high voltage AC insulation tests on high voltage windings to ground, low voltage windings to ground, high voltage windings to low voltage windings. Perform dobble test on transformer, approved equal in accordance with B8 Capacitance and Dissipation Factor tests.
      b. Inspect bushings, and measure insulation resistance with use of high voltage AC insulation test.
      c. Winding resistance measurement on all windings (standard test protocol).

d. Oil analysis and gas analysis.
e. H.V. test on oil samples from transformer tank for each transformer.
f. Voltage ratio three phase, for each tap (Transformer Tap ratio).
g. Relay and protective devices operation.

2. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage for each:
      1) Winding-to-winding.
      2) Winding-to-ground.
   b. 10-minute test duration with resistances tabulated at 30 seconds, 1 minute, and 10 minutes. Results temperature corrected in accordance with NETA ATS-2009, Table 100.14 or Tables 260805-1 and 260805-1.
   c. Temperature corrected insulation resistance values equal to, or greater than, ohmic values established by Manufacturer.
   d. Insulation resistance test results to compare within 1 percent of adjacent windings.
3. Perform tests and adjustments for fans, controls, and alarm functions as suggested by Manufacturer.

3.30 GROUNDING SYSTEMS

A. Visual and Mechanical Inspection:
   1. Equipment and circuit grounds in motor control center, panelboard, switchboard, and switchgear assemblies for proper connection and tightness.
   2. Ground bus connections in motor control center, panelboard, switchboard, and switchgear assemblies for proper termination and tightness.
   3. Effective transformer core and equipment grounding and bonding.
   4. Accessible connections to grounding electrodes for proper fit and tightness.
   5. Accessible exothermic-weld grounding connections to verify that moulds were fully filled and proper bonding was obtained.

B. Electrical Tests:
   1. Fall-Of-Potential Test:
      a. In accordance with IEEE 81, Section 8.2.1.5, perform measurements of the ground system resistance, at each Facility, and at the substation.
      b. The ground system resistance shall not exceed 0.5 ohms in summer soil conditions.
      c. Test point shall be at the North-West corner of the substation, plus at each of the individual buildings.
      d. Perform resistance testing of the connections between each ground rod and ground cabling, to ensure proper connection.

3.31 GROUND FAULT SYSTEMS

A. Inspection and Testing Limited To:
   1. Zero sequence grounding systems.
   2. Residual ground fault systems.

B. Visual and Manual Inspection:
   1. Neutral Main Bonding Connection to Assure:
      a. Zero sequence sensing system is grounded ahead of neutral disconnect link.

b. Ground strap sensing system is grounded through sensing device.
c. Neutral ground conductor is solidly grounded.
2. Verify that control power has adequate capacity for system.
3. Manually Operate Monitor Panels For:
a. Trip test.
b. No trip test.
c. Nonautomatic rest.
4. Zero sequence system for symmetrical alignment of core balance transformers about current carrying conductors.
5. Relay check for pickup and time under simulated ground fault conditions.
6. Verify nameplate identification by device operation.

3.32 AUTOMATIC TRANSFER SWITCHES

A. Visual and Mechanical Inspection:
1. Check doors and panels for proper interlocking.
2. Note the equipment nameplate data for inclusion in the report.
3. Record all adjustable settings, setpoints, delays, etc.
4. Inspect physical and mechanical condition.
5. Inspect anchorage, alignment, and grounding.
6. Verify the unit is clean.
7. Torque all accessible bolted power connections.
8. Visually inspect and exercise transfer switch.
9. Check connections for high resistance by low resistance ohmmeter and calibrated torque wrench applied to bolted joints.
10. Check positive mechanical and electrical interlock between normal and alternate sources.
11. Check for Proper Operation:
a. Manual transfer function switch.
b. Generator under load and nonload conditions.
c. Auto-exerciser of generator under load and no-load conditions.
12. Verify settings and operation of control devices.

B. Electrical Tests:
1. Insulation Resistance Tests:
a. Applied megohmmeter dc voltage for each phase with switch CLOSED in both source positions.
b. Phase-to-phase and phase-to-ground for 1 minute.
c. Test values in accordance with Manufacturer's published data.
2. Contact Resistance Test:
a. Contact resistance in microhms across each contact for both source positions.
b. Investigate values exceeding 100 microhms.
c. Investigate values deviating from adjacent pole by more than 50 percent.
3. Set and Calibrate in Accordance with Specifications:
a. Voltage and frequency sensing relays.
b. Time delay relays.
c. Engine start and shutdown relays.
4. Perform Automatic Transfer Tests By:
a. Simulating loss of normal power.

b. Return to normal power.
c. Simulating loss of alternate power.
d. Simulating single-phase conditions for normal and alternate sources.

5. Monitor and Verify Operation and Timing Of:
   a. Normal and alternate voltage sensing relays.
   b. Engine start sequence.
   c. Timing delay upon transfer and retransfer.
   d. Engine cool down and shutdown.
   e. Interlocks and limit switch functions.
   f. Engine cool down and shutdown feature.
6. If power and/or control fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

3.33 BATTERY SYSTEM

A. Visual and Mechanical Inspection:
   1. Physical damage and electrolyte leakage.
   2. Evidence of corrosion.
   3. Intercell bus link integrity.
   4. Battery cable insulation damage and contaminated surfaces.
   5. Operating conditions of ventilating equipment.
   6. Visual check of electrolyte level.

B. Electrical Tests:
   1. Measure:
      a. Bank charging voltage.
      b. Individual cell voltage.
      c. Electrolyte specific gravity in each cell.
      d. Measured test values to be in accordance with Manufacturer's published data.
   2. Verify During Recharge Mode:
      a. Charging rates from charger.
      b. Individual cell acceptance of charge.
   3. Load tests for integrity and capacity; test values in accordance with ANSI 450.

3.34 STANDBY AND EMERGENCY GENERATOR SYSTEMS

A. Perform tests and Commissioning in accordance with CSA C282 (latest) Section 10 – Initial Installation Performance Test. Tests include, but are not limited to the requirements below.

B. Visual and Mechanical Inspection:
   1. Proper grounding.
   2. Blockage of ventilating passageways.
   3. Proper operation of jack water heaters.
   4. Integrity of engine cooling and fuel supply systems.
   5. Excessive mechanical and electrical noise.
   6. Overheating of engine or generator.
   7. Proper installation of vibration isolators.
   8. Proper cooling liquid type and level.

9. Operate Engine-Generator and Check For:
    a. Excessive mechanical and electrical noise.
    b. Overheating.
    c. Correct rotation.
    d. Check resistance temperature detectors or generator inherent thermal protectors for functionability and proper operation.
    e. Excessive vibration.
10. Verify that voltage regulator and governor operation will cause unit speed and output voltage to stabilize at proper values within reasonable length of time.
11. Proper operation of meters and instruments.
12. Compare generator nameplate rating and connection with one-line diagram.
13. All other tests in accordance with the Manufacturer's recommended testing and Commissioning requirements.

C. Electrical and Mechanical Tests:
1. Alternator insulation shall be tested ("megger") in compliance with IEEE standard 43-2000 (200kW and above).
2. Ensure the engine starts (both hot and cold) within 15 seconds.
3. Cold start test by interrupting normal power source with test load consisting of connected system load to verify:
    a. Transfer switch operation.
    b. Automatic starting operation.
    c. Operating ability of engine-generator.
    d. Overcurrent devices capability to withstand inrush currents.
    e. Verify no load frequency and voltage to be as specified
4. Phase rotation tests.
5. Test Engine Protective Shutdown Features For:
    a. Low oil pressure.
    b. Overtemperature.
    c. Overspeed.
6. Vibration levels in accordance with Manufacturer's recommendations.
7. Load bank test or system load tests as required by the Contract Administrator:
    a. 25 percent applied load for 30 minutes.
    b. 50 percent applied load for 30 minutes.
    c. 75 percent applied load for 30 minutes.
    d. 100 percent applied load for 4 hours.
    e. Load test results to demonstrate ability of unit to deliver rated load for test period.
8. One-Step Rated kW Load Pickup Test:
    a. Perform test immediately after performing load bank test.
    b. Apply rated load, minus largest rated hp motor, to generator.
    c. Start largest rated hp motor and record voltage drop for 20 cycles minimum with high-speed chart recorder or digital storage oscilloscope.
    d. Compare voltage drop with maximum allowable voltage dip for specified starting situation.
9. Record the following items at first load acceptance, and at 15 minute intervals:
    a. Time delay on start.
    b. The cranking time until the engine starts and runs.
    c. The time required to come up to operating speed.

d. The time required for each life safety equipment transfer switch to be transferred to the emergency position.
e. The time required to achieve steady-state condition, with all switches transferred to the emergency position.
f. The time delay(s) for the connection of any loads arranged to be connected to the emergency supply later than the life safety equipment.
g. The voltage, frequency and amperes at start-up, at any observed change in load, and at full load.
h. The engine oil pressure, water temperature, and the battery charge rate 1 minute after start, at 5 minute intervals for the first 15 minutes, and at 15 minute intervals thereafter.
i. The time delay on retransfer for each transfer switch.
j. The time delay on engine cool-down and shutdown.

10. Cycle crank test shall be demonstrated by preventing the engine from running (any method recommended by the Manufacturer may be used). The mode selector shall then be placed in the "Manual" position to cause the engine to crank.
11. All safety shutdowns and alarms as specified in CSA C282 Table 1 shall be verified and tested.
12. Factory authorized Manufacturer's Representative shall deliver operator training to ensure that appropriately qualified personnel are trained to operate the emergency power systems.
13. The test results shall be saved for comparison with future routine scheduled analyses.
14. All other tests in accordance with the Manufacturer's testing and Commissioning requirements.

3.35 STATIC UNINTERRUPTIBLE POWER SUPPLY (UPS)

A. Testing configuration shall not interfere with the supply of power to the load ultimately supplied by the UPS.

B. Provide a complete UPS testing report in accordance with the Manufacturer's recommendations and these documents.

C. Test equipment:
1. Instruments used during testing are to have been calibrated within one year prior to the test date. Include a copy of the calibration certificate
2. Load bank for testing, adjustable to 110 percent of system rated output power.
   a. Load bank to be CSA, ULC approved or approved equal in accordance with B8.

D. Provide competent field personnel to perform test, adjustments and instruction on UPS equipment.

E. Perform a visual inspection and identify deficiencies. Inspection to include:
1. Materials, workmanship, and assembly conform with design requirements.
2. Parts are new and free of defects.
3. Accessories are present.
4. Inspect equipment for signs of damage.
5. Verify installation per Drawings.

6. Inspect cabinets for foreign objects.
7. Verify neutral and ground conductors are properly sized and configured.
8. Battery and components are not damaged.
9. Battery cells are of identical construction.
10. Inspect battery for proper polarity.
11. Confirm polarity of connections to inverter are correct.
12. Verify all printed circuit boards are configured properly.

F. Mechanical Inspection
1. Check all control wiring connections for tightness.
2. Check all power wiring.
3. Check all terminals screws, nuts, and/or spade lugs for tightness.

G. Electrical Inspection
1. Confirm input voltage and phase rotation is correct.
2. Verify control transformer connections are correct for voltages being used.
3. Verify UPS control wiring and terminations.
4. Assure connection and voltage of the battery string(s).
5. Verify neutral and ground conductors are properly landed.
6. Inspect external maintenance bypass switch for proper terminations and phasing.

H. Demonstrate System Operation:
1. System start-up and shut down.
2. Verify proper firmware control functions.
3. Verify proper firmware bypass operations.
4. System switchover to and from internal and external bypass.
5. Simulate utility power failure.
6. Verify proper charger operations.
7. Adjustable settings.

I. UPS Measurement Test:
1. Test and record all UPS internal measurements against calibrated test instruments for 50 percent and 100 percent output load. The tests shall include:
   a. Output voltage, current, frequency, and power.
   b. Battery voltage and current.
   c. Input voltage, current, and power.
   d. Bypass voltage and frequency.

J. Steady Load Test:
1. Switch system onto AC mains, start UPS and connect load bank at UPS rated load.
2. Operate system at full rated load for one (1) hour.
3. Record data, utilizing UPS display, at start of test and every 10 minutes thereafter. including:
   a. Output voltage phase to phase, phase to neutral.
   b. Output current each phase.
   c. Output frequency.
   d. Output kW.
   e. Battery voltage and current

K. Battery Testing:
   1. Charge battery to ensure cells are fully charged. When voltage reaches steady value at end of charge, record:
      a. Ambient Temperature.
      b. Temperature of each cell.
      c. Voltage of each cell.
      d. Voltage of overall battery string.
      e. Charger output voltage and current
      f. AC ripple current and voltage imposed on the battery.
      g. Internal ohmic values of each cell and battery.
      h. Measure intercell connection resistances for all cells.

L. Battery Load Test
   1. Charge battery to ensure cells are fully charged.
   2. Connect the load bank to the UPS output, configured for the UPS rated output power.
   3. Record data, utilizing UPS display, at start of test and every 5 minutes thereafter. Including:
      a. Output voltage phase to phase, phase to neutral
      b. Output current each phase.
      c. Output frequency.
      d. Output kW.
      e. Battery voltage and current.
   4. Upon the Battery Low Alarm, record:
      a. The test time expired.
      b. Battery voltage and current.
   5. Allow the UPS to automatically shutdown on low battery. Record the time of automatic shutdown

M. PLC Alarms
   1. With the assistance of City of Winnipeg personnel, test the UPS alarms transmitted to the PLC system.

N. Document, sign, and date test results. Include all documentation in the O & M manuals.

3.36 POWER FACTOR CORRECTION / HARMONICS FILTERS

A. Factory tests required
   1. Capacity testing, to ensure proper capacity, filter ratings.
   2. All other normal tests to ensure a complete and operating system

B. Visual and Mechanical Inspection:
   1. Note the equipment nameplate data for inclusion in the report.
   2. Record all adjustable settings.
   3. Inspect physical and mechanical condition.
   4. Inspect anchorage, alignment, and grounding.
   5. Torque all accessible bolted power connections.
   6. Verify capacitors are connected in proper configuration.

C. System Setup:
   1. Enter system parameters in accordance with the Manufacturer's recommended Commissioning and start-up manual. This includes but is not limited to the following
      a. Adjust and set date and time.
      b. Check the fans(s).
      c. System integrity test – inject leading and lagging vars for 15 minutes to confirm system operation and capacity.
      d. Parallel system setup (as applicable).
      e. External transformer.
      f. C.T configuration.
      g. System mode setup.
      h. Password setup.
      i. Test run.
      j. All other requirements in accordance with the Manufacturer's recommendations.

D. Electrical Tests:
   1. With the circuit breaker open perform insulation resistance testing, each pole-to-pole and pole-to-ground; values in accordance with Manufacturer's recommendation.
   2. With the circuit breaker closed, perform insulation resistance testing pole-ground only (otherwise the voltage will energize the DC buswork).
   3. Megger units rated less than 600V, test voltage is to be 500 VDC.
   4. Perform a contact/pole-resistance test.
   5. DC bus discharge time.

E. If power and/or control fuses are present, record fuse size and type. Measure the resistance of each fuse. Investigate inconsistent resistance values.

F. Perform functional testing to verify operation of unit.

G. All testing, Commissioning, shall be documented, and shall be performed in the presence of a factory trained service engineer.

3.37 THERMOGRAPHIC INSPECTION

A. Camera
   1. Minimum IR resolution:320 x 240 pixels.
   2. Minimum visible resolution: 640 x 480 pixels.

B. Thermographic inspections and photographs shall be completed in accordance with the recommendations of the Standard for Infrared Inspection of Electrical Systems and Rotating Equipment published by the Infraspection Institute.

C. Provide a thermographic survey of connections associated with incoming service conductors, bus work, and branch feeder conductors and larger at each:
   1. Medium voltage switchgear.
   2. Low voltage switchgear, greater than 225A
   3. Panelboards greater than 225A.
   4. Motor control centers
   5. Transfer switches

6. All other equipment specified herein which requires a thermographic survey.

D. Provide a thermographic survey of feeder conductors terminating at:
   1. Motors rated 50 HP and larger
   2. Transfer switches.
   3. Engine-generators.

E. Inspection and testing shall be comprised of the following:
   1. Remove all necessary covers prior to thermographic inspection.
   2. Equipment to be inspected shall include all current-carrying devices.
   3. Test Parameters:
      a. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1 degrees C at 30 degrees C.
      b. Equipment shall detect emitted radiation and convert detected radiation to a visual signal.
      c. Thermographic surveys should be performed during periods of maximum possible loading but not less than 40 percent of rated load of the electrical equipment being inspected. Coordinate with City as required.
      d. Note all temperature differences larger than 1 degrees C. Investigate all temperature differences larger than 4 degrees C.
      e. Re-inspect deficient areas with the thermographic camera following repairs and corrections, for deficient areas identified.

F. Provide a report which shall include the following:
   1. Description of the equipment tested.
   2. Discrepancies found.
   3. Temperature difference between the area of concern and the reference area.
   4. Probable cause of temperature difference.
   5. Identify any repairs made during the thermographic inspection. If no repairs were made, provide recommended action for repair.
   6. Areas inspected. Identify inaccessible and / or unobservable areas and / or equipment.
   7. Identify load conditions at time of inspection.
   8. Provide photographs and thermograms of all areas investigated, with deficient areas identified. Visible light photographs and thermograms shall align in a manner to allow for easy identification of the components shown on the thermograms.
   9. Provide thermograms of all deficient areas corrected, and identify the load conditions at the time of re-inspection.

3.38 SUPPLEMENTS

A. The Supplements listed below, following “End of Section”, are part of this Specification.
   1. Appendix A – Commissioning Specification and Objectives Figure 2 – Temporary RAS Line Modifications.
   2. Appendix B – Commissioning Procedures

END OF SECTION

APPENDIX A – Commissioning Specification and Objectives

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

15 KV SWITCHGEAR

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for 15KV switchgear. The tests are required to verify proper operation of 15KV switchgear in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct switchgear operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for switchgear manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;

10. Providing a punch list during all inspections and test;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance tests

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that switchgear is properly installed, leveled and supported;
3. Inspection and testing to verify that switchgear is properly grounded;
4. Visual and mechanical inspections;
5. Verification of correct operation of key interlocks;
6. Checking integrity of electrical connections;
7. Protective relaying system functional testing and verification (part of the system function test);
8. Electrical tests;
9. Components tests.

4.2 System functions tests

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that switchgear is ready to be energized;
2. Energizing the switchgear in a safe manner and verifying correct values to protective devices and metering;
3. Verifying the no-alarm or no-fault condition of the switchgear.

5.0 Commissioning phase activities/tests

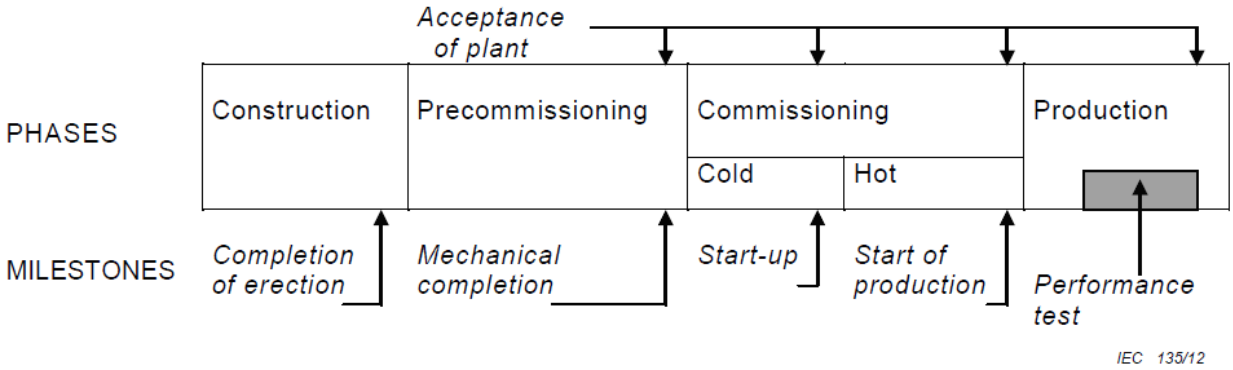
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify; acceptable condition for commissioning phase;
3. Monitoring and verifying switchgear operational values;
4. Monitoring switchgear alarms;
5. Final settings and adjustments where required;
6. Thermographic survey;
7. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

66 KV SUBSTATION

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for the 66 KV substation. The tests are required to verify proper operation of substation in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct substation operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for substation equipment manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;

10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance tests

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that substation is properly installed and grounded;
3. Visual and mechanical inspections;
4. Verification of correct operation of key interlocks;
5. Checking integrity of electrical connections;
6. Protective relaying system functional testing and verification (part of the system function test);
7. Neutral Ground Resistor (NGR) test;
8. Electrical tests;
9. Components tests.

4.2 System functions tests

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that substation is ready to be energized;
2. Energizing the substation in a safe manner and verifying correct values to protective devices and metering;
3. Verifying the no-alarm or no-fault condition of the substation.

5.0 Commissioning phase activities/tests

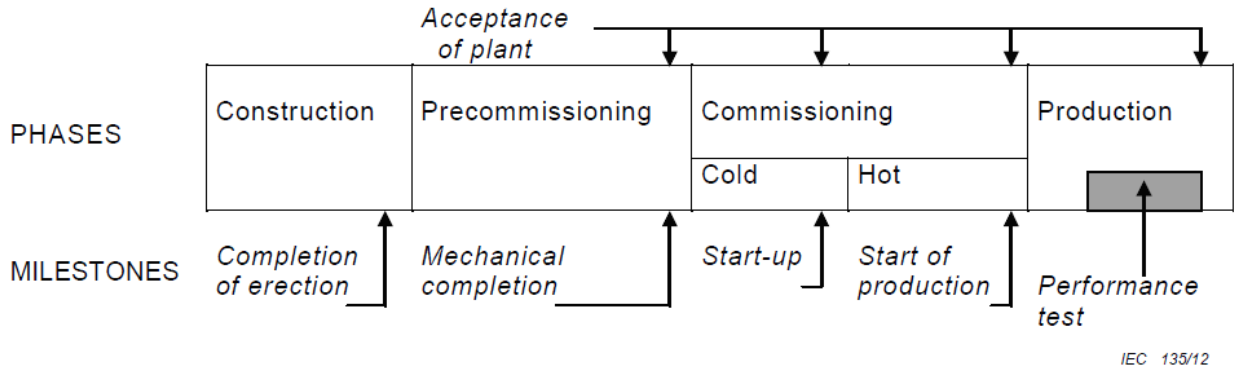
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Monitoring and verifying substation operational values;
4. Monitoring substation alarms.
5. Final settings and adjustments where required;
6. Thermographic survey;
7. Corona inspection;
8. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

600 V SWITCHGEAR

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for 600V Switchgear. The tests are required to verify proper operation of low voltage switchgears in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct switchgear operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for switchgear manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;

10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that switchgear is properly installed, leveled and supported;
3. Inspection and testing to verify that switchgear is properly grounded;
4. Visual and mechanical inspections;
5. Verification of correct operation of key interlocks;
6. Checking integrity of electrical connections;
7. Electrical tests;
8. Components tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that switchgear is ready to be energized;
2. Energizing the switchgear in a safe manner and verifying correct values to protective devices and metering;
3. Verifying the no-alarm or no-fault condition of the switchgear.

5.0 Commissioning phase activities/tests

Following activities and tests are required during commissioning phase:

4. Reviewing commissioning plan;
5. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
6. Monitoring and verifying switchgear operational values;
7. Monitoring switchgear alarms;
8. Final settings and adjustments;
9. Thermographic survey;
10. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

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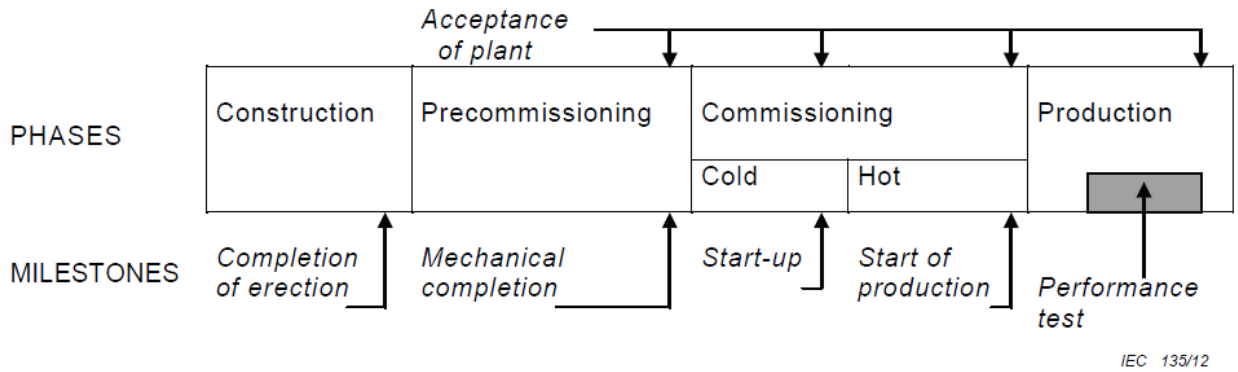


NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

ACTIVE HARMONICS FILTER (AHF)

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for active harmonics filter (AHF) system. The tests are required to verify proper operation of AHF system in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct AHF system operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for AHF manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;

10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that AHF is properly installed, leveled and supported;
3. Inspection and testing to verify that AHF system is properly grounded;
4. Visual and mechanical inspections;
5. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Function test of AHF should be performed after energization. The AHF function test should be performed after energization.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that AHF is ready to be energized;
2. Energizing AHF in a safe manner and verifying correct values of power factor and harmonic distortion;
3. Verifying the no-alarm or no-fault condition of the AHF.

5.0 Commissioning phase activities/tests

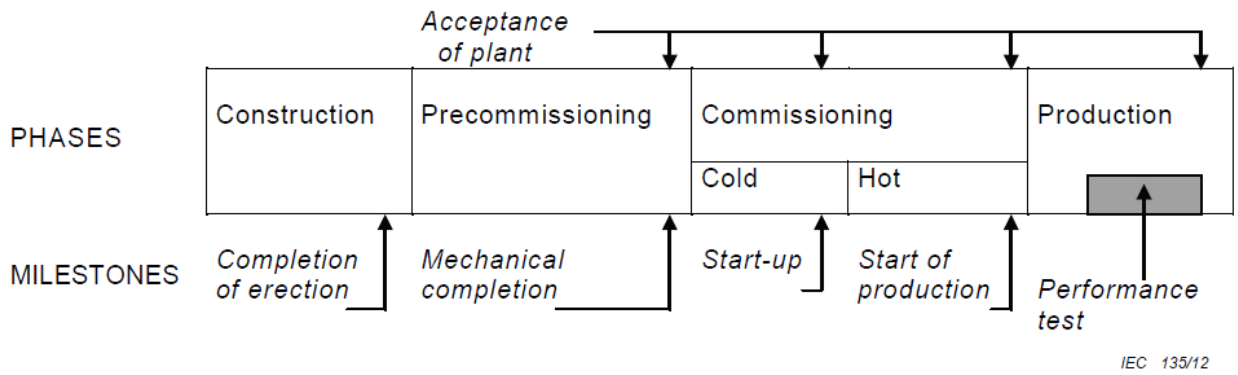
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Monitoring and verifying AHF system operational and performance values;
4. Monitoring the alarms;
5. Thermographic survey;
6. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

BATTERY SYSTEM

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for Battery Systems. The tests are required to verify proper operation of battery systems in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- ANSI/IEEE 1188, Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Stations

3.0 Commissioning objectives

1. Verifying the correct battery system operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for battery system manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;

8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;
10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that switchgear is properly installed, leveled and supported;
3. Inspection and testing to verify that battery system is properly grounded;
4. Visual and mechanical inspections;
5. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Function test of Battery system should be performed after energization.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that Battery system is ready to be energized;
2. Energizing Battery system in a safe manner and verifying correct voltage values;
3. Verifying the no-alarm or no-fault condition of the Battery system.

5.0 Commissioning phase activities/tests

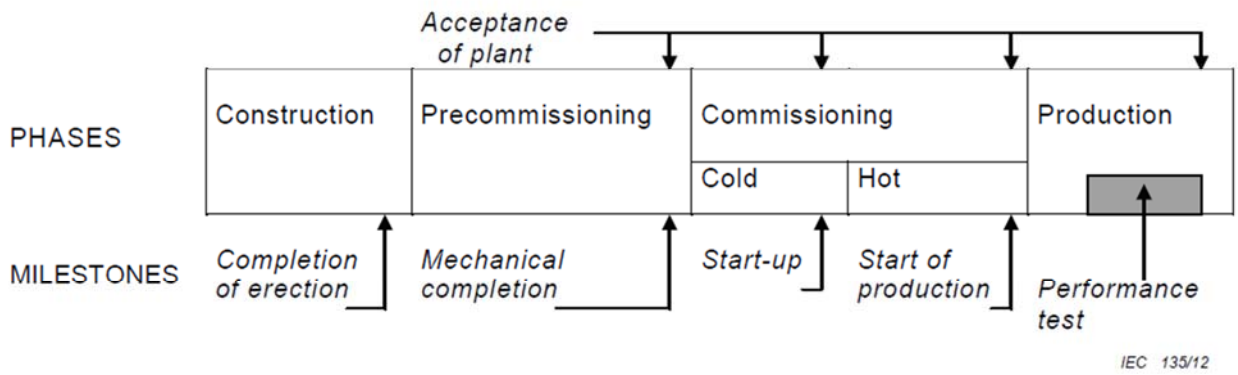
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Monitoring and verifying battery system operational values;
4. Monitoring the alarms;
5. Thermographic survey;
6. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

DIESEL ELECTRIC GENERATING UNIT

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for diesel generator. The tests are required to verify proper operation of diesel generator system in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct diesel generator system operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for diesel generator manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Obtaining local inspectors approval, where required;
8. Providing the record of corresponding test/check certificates;
9. Providing a punch list during all inspections and tests;

10. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that diesel generator system is properly installed, leveled and supported;
3. Inspection and testing to verify that diesel generator system is properly grounded;
4. Visual and mechanical inspections;
5. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

5.0 Commissioning phase activities/tests

All Diesel Generator acceptance and performance tests are completed during pre-commissioning phase.

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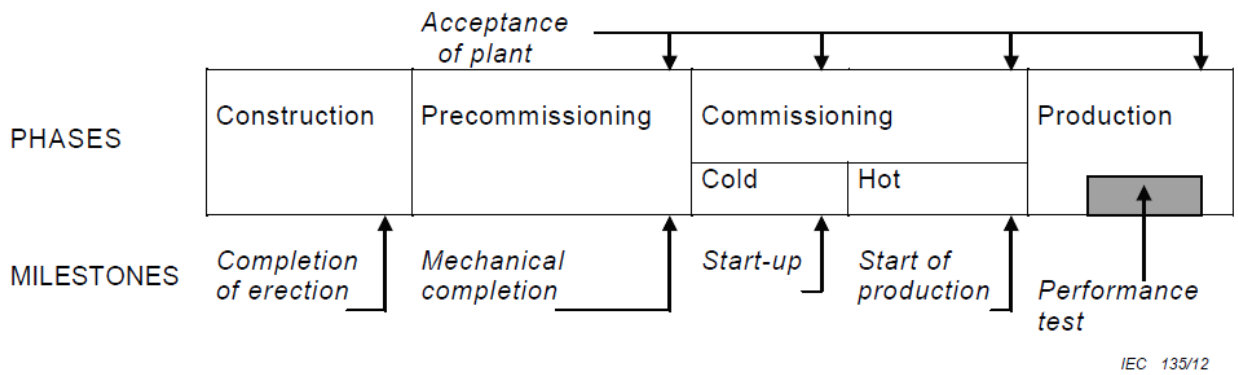
ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

GENERATOR LOAD BANK

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for the generator load bank. The tests are required to verify proper operation of the generator load bank in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct generator load bank operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for generator load bank manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Obtaining local inspectors approval, where required;
8. Providing the record of corresponding test/check certificates;
9. Providing a punch list during all inspections and tests;

10. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that generator load bank is properly installed, leveled and supported;
3. Inspection and testing to verify that generator load bank is properly grounded;
4. Visual and mechanical inspections;
5. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Function test of Battery system should be performed after energization.

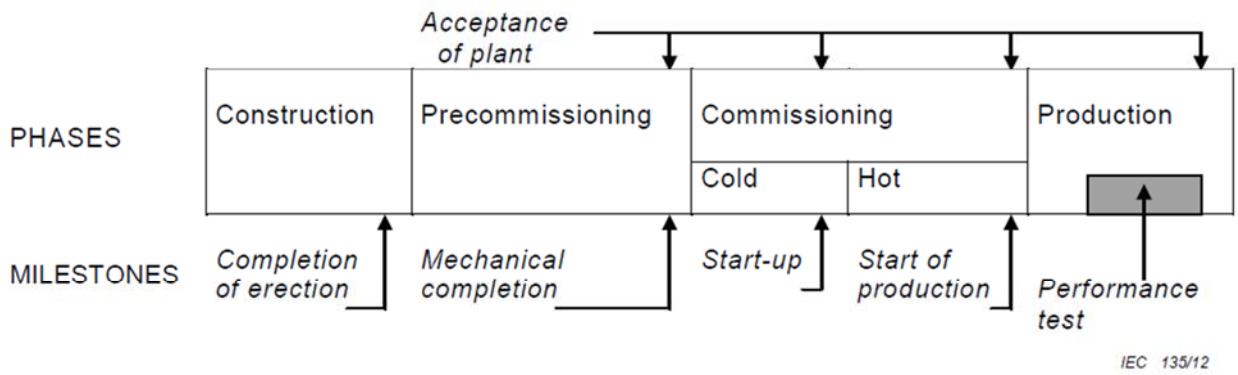
5.0 Commissioning phase activities/tests

All Generator Load Bank tests are completed during pre-commissioning phase.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

GROUND FAULT PROTECTION (LOW VOLTAGE)

1.0 General scope

This document defines pre-commissioning and commissioning tests and activities required for ground fault protection system (Low voltage).The tests are required to verify proper operation of the system in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for electrical commissioning specifications for electrical power equipment and systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for
- Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct operation of ground fault protection system in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Obtaining local inspectors approval, where required;

8. Providing the record of corresponding test/check certificates;
9. Providing a punch list during all inspections and tests;
10. Providing field acceptance and system function test reports.

4.1 Field acceptance tests

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that ground fault protection panel is properly installed, leveled and supported;
3. Inspection and testing to verify that ground fault protection panel is properly grounded;
4. Visual and mechanical inspections;
5. Verifying correct operation of all components;
6. Checking integrity of electrical connections;
7. Electrical tests;
8. Components tests.

4.2 System functions tests

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

5.0 Commissioning phase activities/tests

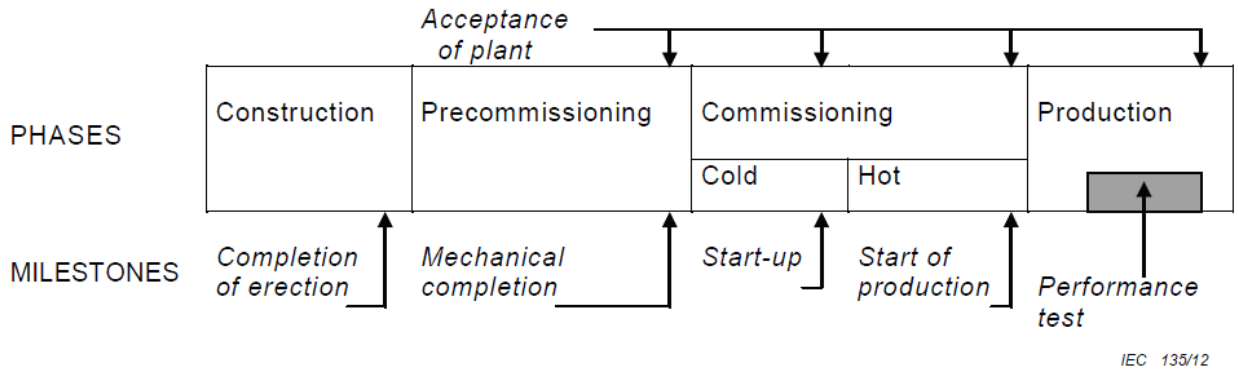
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Monitoring and verifying the operational values;
4. Monitoring the alarms;
5. Final settings and adjustments;
6. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

GROUNDING SYSTEMS

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for grounding systems. The tests are required to verify proper function of grounding systems in accordance with project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct grounding system function in accordance with design requirements and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Field acceptance tests as described in section 4.1;
2. System function tests as described in section 4.2;
3. Providing the record of corresponding test/check certificates;
4. Providing a punch list during all inspections and tests;
5. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Visual and mechanical inspections;
2. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Function test of Battery system should be performed after energization.

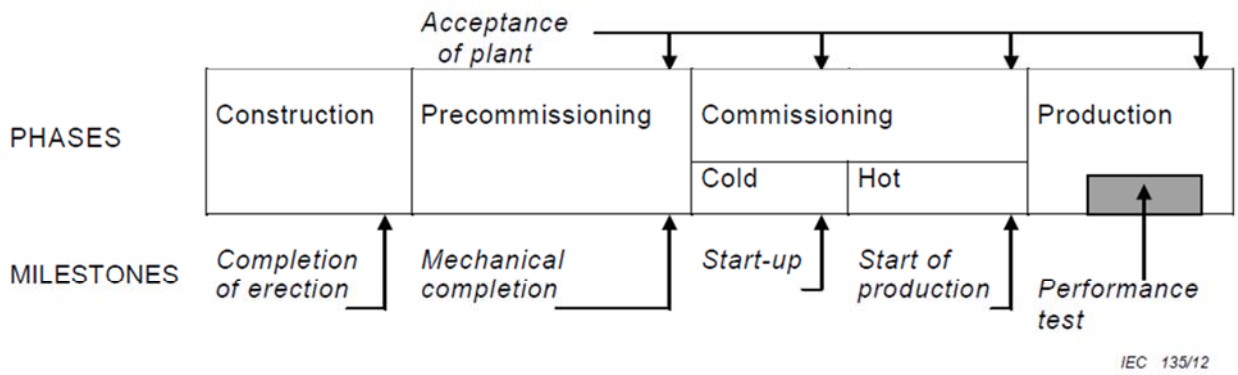
5.0 Commissioning phase activities/tests

All grounding system tests are completed during pre-commissioning phase.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

LOW VOLTAGE AC INDUCTION MOTORS

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for low voltage AC induction motors. The tests are required to verify proper operation of motors in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct motor operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for motor manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Obtaining local inspectors approval, where required;
8. Providing the record of corresponding test/check certificates;
9. Providing a punch list during all inspections and tests;

10. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that motor is properly grounded;
3. Visual and mechanical inspections;
4. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

5.0 Commissioning phase activities/tests

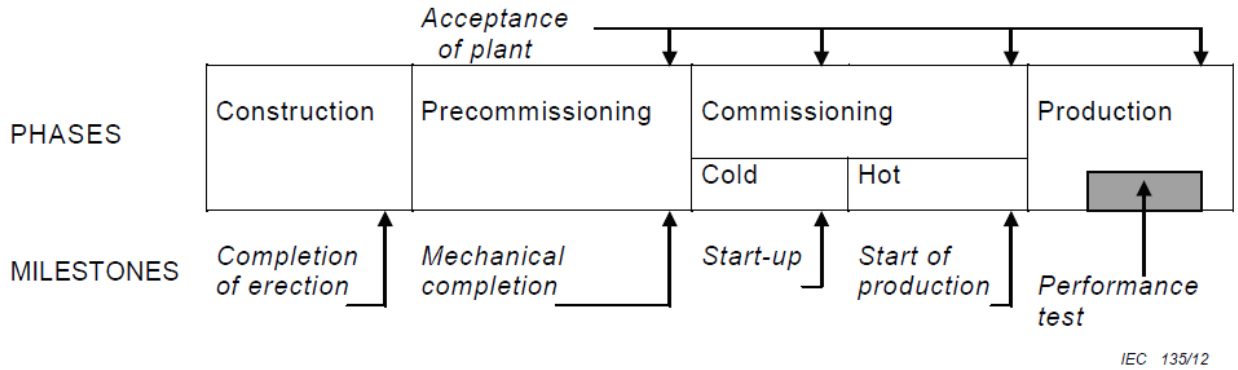
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Verifying motor loading;
4. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

DRY TYPE TRANSFORMERS, UP TO 600V PRIMARY

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for dry type transformers, up to 600V primary. The tests are required to verify proper operation of transformers in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct transformer operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for transformer manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;

9. Providing the record of corresponding test/check certificates;
10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that transformer is properly installed, leveled and supported;
3. Inspection and testing to verify that transformer is properly grounded;
4. Visual and mechanical inspections;
5. Checking integrity of electrical connections;
6. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Transformer function test should be performed after energization.

4.2 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that transformer is ready to be energized;
2. Energizing the transformer in a safe manner and verifying correct secondary voltage values;
3. Verifying the no-alarm or no-fault condition of the transformer.

5.0 Commissioning phase activities/tests

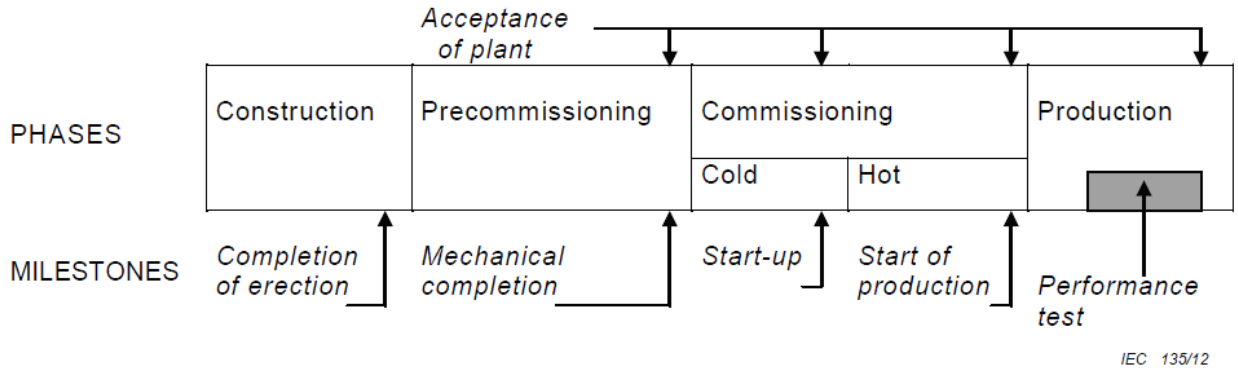
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Verifying transformer loading;
4. Thermographic survey;
5. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

MOTOR CONTROL CENTER (MCC)

1.0 General scope

This document defines pre-commissioning and commissioning tests and activities required for Motor Control Center (MCC).The tests are required to verify proper operation of MCCs in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct MCC operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for MCC manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;

10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance tests

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that MCC is properly installed, leveled and supported;
3. Inspection and testing to verify that MCC is properly grounded;
4. Visual and mechanical inspections;
5. Verifying correct operation of key interlocks;
6. Checking integrity of electrical connections;
7. Electrical tests;
8. Components tests.

4.2 System functions tests

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.
System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. MCC function test should be performed after energization.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that MCC is ready to be energized;
2. Energizing the switchgear in a safe manner and verifying correct values to protective devices and metering;
3. Verifying the no-alarm or no-fault condition of the MCC.

5.0 Commissioning phase activities/tests

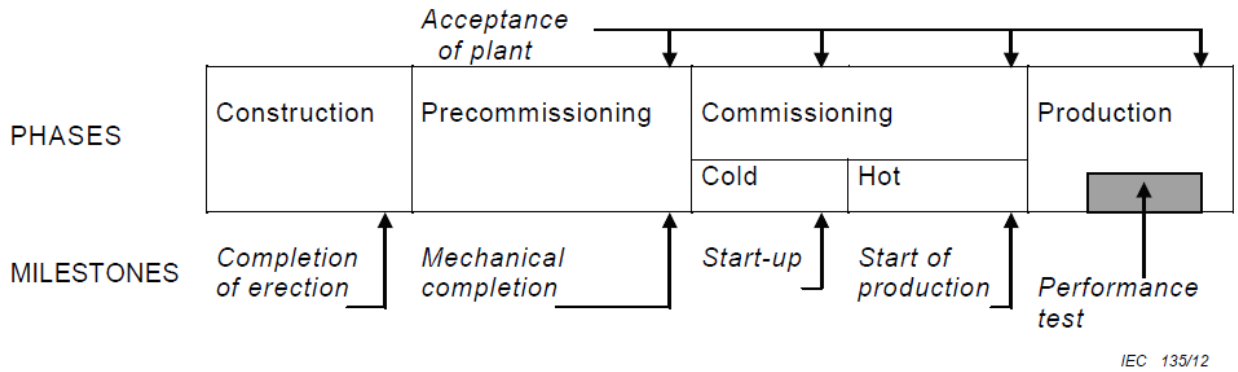
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Monitoring and verifying MCC operational values;
4. Monitoring MCC alarms;
5. Final settings and adjustments;
6. Thermographic survey;
7. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

OIL FILLED PAD MOUNTED TRANSFORMERS

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for oil filled pad mounted transformers. The tests are required to verify proper operation of transformers in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct transformer operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for transformer manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;

10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that transformer is properly installed, leveled and supported;
3. Inspection and testing to verify that transformer is properly grounded;
4. Visual and mechanical inspections;
5. Checking integrity of electrical connections;
6. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Transformer function test should be performed after energization.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that transformer is ready to be energized;
2. Energizing the transformer in a safe manner and verifying correct secondary voltage values;
3. Verifying the no-alarm or no-fault condition of the transformer.

5.0 Commissioning phase activities/tests

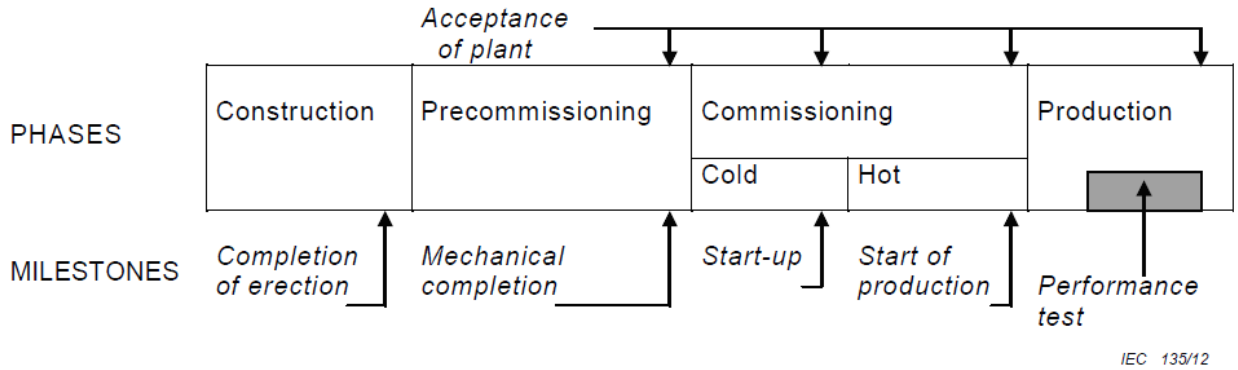
Following activities and tests are required during commissioning phase:

4. Reviewing commissioning plan;
5. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
6. Verifying transformer loading;
7. Thermographic survey;
8. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

STAND-ALONE VARIABLE FREQUENCY DRIVE (VFD)

1.0 General scope

This document defines pre-commissioning and commissioning tests and activities required for stand-alone variable speed drive (VFD). The tests are required to verify proper operation of VFD in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct VFD operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for VFD manufacturer assistance;
4. Providing manufacturer instruction files which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;
9. Providing the record of corresponding test/check certificates;

10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance tests

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that VFD is properly installed, leveled and supported;
3. Inspection and testing to verify that VFD is properly grounded;
4. Checking integrity of electrical connections;
5. Visual and mechanical inspections;
6. Electrical tests.

4.2 System functions tests

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Function test of VFD should be performed after energization.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that VFD is ready to be energized;
2. Energizing the VFD in a safe manner and performing the operational and functional tests;
3. Verifying the no-alarm or no-fault condition of the VFD.

5.0 Commissioning phase activities/tests

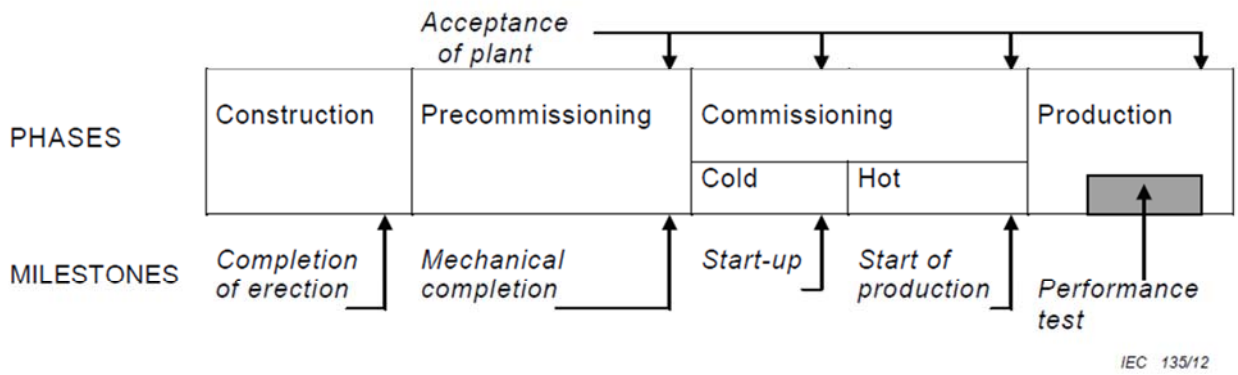
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Monitoring and verifying VFD operational values;
4. Monitoring VFD alarms;
5. Final settings and adjustments;
6. Thermographic survey;
7. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

COMMISSIONING SPECIFICATION AND OBJECTIVES (CSO)

UNINTERRUPTIBLE POWE SUPPLY (UPS)

1.0 General Scope

This document defines pre-commissioning and commissioning tests and activities required for UPS system which consists of UPS, batteries and external maintenance bypass switch cabinet. The tests are required to verify proper operation of UPS system in accordance with manufacturer's instructions, project design documents and applicable codes and standards. Detailed procedures and activities for conducting the tests are covered in the Commissioning Procedures (CP) document.

Refer to Annex 1.0 for definition of phases and milestones in the commissioning of electrical systems, according to IEC-62337 standard.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems

3.0 Commissioning objectives

1. Verifying the correct UPS system operation in accordance with design requirements, manufacturer's instructions and applicable codes and standards;
2. Contributing to the safe and reliable operation of the plant;
3. Providing baseline results for routine maintenance of the system and related components.

4.0 Pre-Commissioning phase activities/tests

Following activities and tests are required during pre- commissioning phase:

1. Reviewing factory acceptance test and the end of construction documentation to verify acceptable condition and suitability for pre-commissioning phase;
2. Reviewing Commissioning plan;
3. Planning for UPS manufacturer assistance;
4. Providing manufacturer instruction file which are readily accessible throughout the pre-commissioning and commissioning phases;
5. Field acceptance tests as described in section 4.1;
6. System function tests as described in section 4.2;
7. Energization tests/activities as described in section 4.3;
8. Obtaining local inspectors approval, where required;

9. Providing the record of corresponding test/check certificates;
10. Providing a punch list during all inspections and tests;
11. Providing field acceptance and system function test reports.

4.1 Field acceptance test

Field acceptance tests shall include the following:

1. Comparing equipment nameplate data with drawings and specifications;
2. Inspection to verify that UPS is properly installed, leveled and supported;
3. Inspection and testing to verify that UPS system is properly grounded;
4. Visual and mechanical inspections;
5. Electrical tests.

4.2 System functions test

Purpose of the system function test is to prove the correct interaction of all sensing, processing, and action devices.

System function test is required to evaluate performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data. Function test of UPS should be performed after energization.

4.3 Energization

Following activities and tests are required during energization:

1. Reviewing all test reports to verify that UPS is ready to be energized;
2. Energizing the UPS in a safe manner and verifying correct voltage values;
3. Verifying the no-alarm or no-fault condition of the Battery system.

5.0 Commissioning phase activities/tests

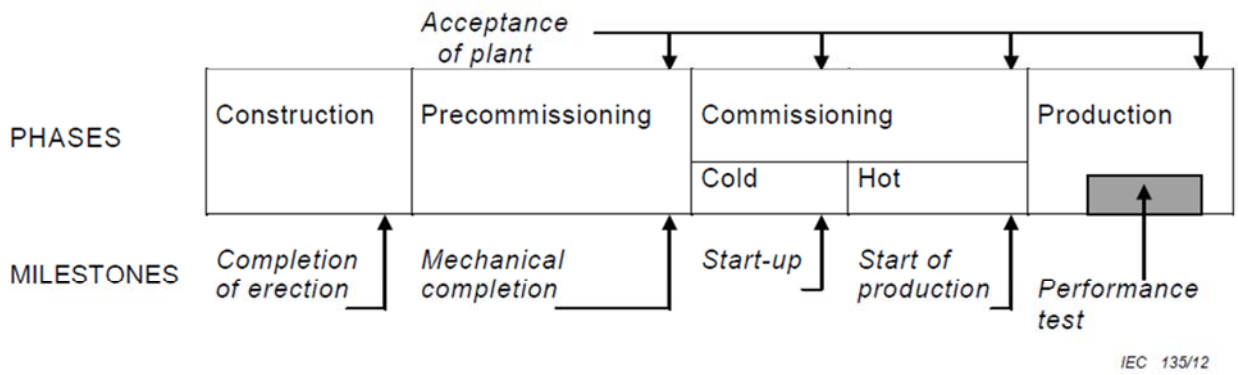
Following activities and tests are required during commissioning phase:

1. Reviewing commissioning plan;
2. Reviewing field acceptance and system function tests documentation to verify acceptable condition for commissioning phase;
3. Monitoring and verifying UPS system operational values;
4. Monitoring the alarms;
5. Thermographic survey;
6. Commissioning report.

ANNEX 1.0

Definition of phases and milestones

NOTE This standard assumes that the "acceptance-of-the-plant" milestone will occur after the performance test. If there is a reduced scope, this document should be adapted accordingly.



NOTE Construction and precommissioning activities could be overlapping.

Figure 1 – Definition of phases and milestones

mechanical completion
milestone which is achieved when the plant, or any part thereof, has been erected and tested in accordance with drawings, specifications, instructions, and applicable codes and regulations to the extent necessary to permit cold commissioning

NOTE This includes completion of all necessary electrical and instrumentation work. This is a milestone marking the end of the precommissioning activities.

cold commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using test media such as water or inert substances, prior to introducing any chemical in the system, take place

hot commissioning
phase during which the activities associated with the testing and operation of equipment or facilities using the actual process chemical, prior to making an actual production run, take place

— END OF DOCUMENT —

APPENDIX B – Commissioning Procedures

COMMISSIONING PROCEDURES (CP)

15 KV SWITCHGEAR

General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for 15KV switchgear at the pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/IEEE C57.13-2008, IEEE Standard Requirements for Instrument Transformers
- ANSI/IEEE C57.13.1-2006, IEEE Guide for Field Testing of Relaying Current Transformers
- ANSI/IEEE C57.13.3-2014, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases

Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Electronic setting files for intelligent devices;
9. Design documents including, but not limited to:
   a) Switchgear specification;

b) Switchgear layout and schedule;
c) Electrical equipment list;
d) Grounding layout;
e) Switchgear schematics;
f) Single line diagrams;
g) Network diagram;
h) Section 26 08 05, Acceptance Testing Specification;
i) Power system studies including short-circuit, coordination, arc-flash hazard and protective device setting sheets.

3.2 Commissioning phase

Following documents shall be available at the commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms;
6. Power system studies including short-circuit, coordination and arc-flash hazard;
7. Electronic setting files for intelligent devices.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. Protection trip settings for protection relays and electronic trip breakers;

5. A complete set of electrical plans and specifications, including all change orders;
6. Applicable design documents;
7. City's project requirements.

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Complete relay settings and programming
8. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks;
   i) “As left” relay setting files.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Switchgear visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean and all shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.

5. Verify that fuse and circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
6. Verify that current and voltage transformer ratios correspond to drawings.
7. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems:
   a) Attempt closure on locked-open devices. Attempt to open locked-closed devices;
   b) Make key exchange with devices operated in off-normal positions.
9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Inspect insulators for evidence of physical damage or contaminated surfaces.
11. Verify correct barrier and shutter installation and operation.
12. Exercise all active components.
13. Inspect mechanical indicating devices for correct operation.
14. Verify that filters are in place and vents are clear.
15. Perform visual and mechanical inspection of instrument transformers

8.1.2 Switchgear electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, for one minute in accordance with Table 1.0. Values of insulation resistance less than this table or manufacturer's recommendation should be investigated.
3. Perform a dielectric withstand voltage test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 10.0. The test voltage shall be applied for one minute. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application, the test is considered to have passed.
4. Perform current tests by secondary injection with magnitudes such that a minimum current of 1.0 ampere flows in secondary unit. Verify correct magnitude of current at each device in the circuit.
5. Verify operation of cubicle space heaters.
6. Perform phasing checks on dual-source switchgear to insure correct bus phasing from each source.
7. Perform vacuum circuit breakers test in accordance with section 8.1.3.
8. Perform ground-resistance test in accordance with section 8.1.4.
9. Perform instrument transformers test in accordance with Section 8.1.5 and 8.1.6.
10. Perform protective relay test in accordance with section 8.1.7.
11. Perform surge arrester test in accordance with section 8.1.8.

12. Perform power meter test in accordance with section 8.1.9.
13. Verify the correct operation of the network cabling, network switch, and associated components within switchgear.
14. Verify communication between Real Time Automation Controller and protective relays.
15. Verify all intelligent electronic devices, communication protocol, and Real Time Automation Controller system display the correct date and time.
16. Verify signal exchange with PLC.

8.1.3 Vacuum Circuit Breakers test

- **Visual and Mechanical Inspection**

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Perform all mechanical operation tests on operating mechanism in accordance with manufacturer's published data.
6. Measure critical distances such as contact gap as recommended by manufacturer.
7. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connection. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest values;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations
8. Verify cell fit and element alignment.
9. Verify racking mechanism operation.
10. Record as-found and as-left operation counter readings. .

- **Electrical tests**

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest value.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to ground with the circuit breaker closed, and across each open pole. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data use Table 1.0. Values of insulation resistance less than this table or manufacturer' published data should be investigated.
3. Perform a contact/pole-resistance test. Microhm or DC milivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
4. Perform minimum pickup voltage tests on shunt trip and close coils in accordance with manufacturer's published data. The values shall conform to the manufacturer's published data.

5. Verify correct operation of any auxiliary features such as electrical close and trip operation, trip-free, and anti-pump function.
6. Trip circuit breaker by operation of each protective device. Reset all trip logs and indicators.
7. Perform vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the breaker in the open position in strict accordance with manufacturer's published data. If no evidence of distress or insulation failure is observed, test is considered passed.
8. Perform a dielectric withstand voltage test in accordance with manufacturer's published data. If no evidence of distress or insulation failure is observed, test is considered passed.
9. Verify operation of heaters where applicable.
10. Test instrument transformers in accordance with sections 8.1.5 and 8.1.6.

8.1.4 Switchgear ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and switchgear frame.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.5 Current Transformer test

1. Inspect physical and mechanical condition.
2. Record the equipment nameplate data for inclusion in the report.
3. Ensure that CT shorting bars are removed or installed as required.
4. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.
5. Perform an insulation resistance test, according to IEEE C57.13.1 standard, of the current transformer primary and secondary windings, and wiring to ground at 1000 VDC. Do not perform this test on solid-state devices.
6. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
7. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1. Note any ratio accuracies not within 0.5% of nameplate or manufacturer's published data.
8. Perform an excitation test on transformers used for protection or relaying applications in accordance with ANSI C57.13.1.

8.1.6 Voltage Transformer test

1. Inspect physical and mechanical condition.
2. Record the equipment nameplate data for inclusion in the report.
3. Perform insulation resistance test winding-to-winding and each winding-to-ground. Test voltages shall be applied for one minute in accordance with Table 4.0. Do not perform this test on solid-state devices. Insulation resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's data, use Table 4.0.
4. Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable. Polarity results shall agree with transformer marking.
5. Perform a turns-ratio test on all tap positions. Ratio errors shall be in accordance with C57.13.
6. Measure voltage circuit burdens at transformer terminals. Measured burdens shall be compared to transformer rating.

7. Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
8. Verify that voltage transformer secondary circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. The grounding point should be located as specified by the Contract Administrator in the project drawings.

8.1.7 Protective Relays test

1. Record the equipment nameplate data for inclusion in the report.
2. Inspect physical and mechanical condition.
3. Check tightness of connections.
4. Verify that the frame is grounded in accordance with manufacturer's instructions.
5. Set the relay in accordance with the coordination study.
6. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.
7. Perform insulation-resistance tests from each circuit to the grounded frame in accordance with manufacturer's published data.
8. Apply voltage or current to all analog inputs and verify correct registration of the relay meter function.
9. Check functional operation of each element in accordance with the following:

   (24) - Volts/Hertz Element(s)
   1. Determine pickup frequency at rated voltage.
   2. Determine pickup frequency at second voltage level.
   3. Determine time delay.

   (25G) -Generator Sync Check Element(s)
   1. Determine closing zone at rated voltage.
   2. Determine maximum voltage differential that permits closing at zero degree.
   3. Determine live line, live bus, dead line, and dead bus set points
   4. Determine time delay.
   5. Verify dead bus/live line, dead line/live bus, and dead bus/dead line control functions.

   (27) - Undervoltage Element(s)
   1. Determine dropout voltage.
   2. Determine time delay.
   3. Determine time delay at second point on the timing curve for inverse time relays.

   (32) - Differential Power Element(s)
   4. Determine minimum pickup at maximum torque angle.
   5. Determine closing zone.
   6. Determine maximum torque angle.
   7. Determine time delay.
   8. Verify time delay at a second point on timing curve for inverse time relays.

   (40) - Loss of Field Element(s)
   1. Determine maximum reach.
   2. Determine maximum torque angle.
   3. Determine offset.

   (50) – Phase Instantaneous Overcurrent Element(s)
   1. Determine pickup.
   2. Determine dropout.

(51) – Phase Time Overcurrent Element(s)
1. Determine minimum pickup.
2. Determine time delays at two points on the time current curve.

(50N) – Phase Instantaneous Overcurrent Element(s)-Neutral
1. Determine pickup.
2. Determine dropout.

(51N) – Phase Time Overcurrent Element(s)-Neutral
1. Determine minimum pickup.
2. Determine time delays at two points on the time current curve.

(59) – Overvoltage Element(s)
1. Determine overvoltage pickup.
2. Determine time delay to close the contact with sudden application of 120 percent of pickup.

(59N) – Zero Sequence Overvoltage Element(s)
3. Determine overvoltage pickup.
4. Determine time delay to close the contact with sudden application of 120 percent of pickup.

(67G) - Directional Ground Current Element(s)
1. Determine directional unit minimum pickup at maximum torque angle.
2. Determine closing zone.
3. Determine overcurrent unit pickup.
4. Determine overcurrent unit time delay at two points on the time current curve.

(81) - Frequency Element(s)
1. Verify frequency set points.
2. Determine time delay.
3. Determine undervoltage cutoff.

(87) - Differential Element(s)
1. Determine operating unit pickup.
2. Determine the operation of each restraint unit.
3. Determine slope.
4. Determine harmonic restraint
5. Determine instantaneous pickup.

(REF) –Restricted Earth Fault Element(s)
1. Determine operating unit pickup.
2. Determine the operation of each restraint unit.
3. Determine instantaneous pickup.

10. Verify control function of all protective relays with the following :
    a) Check operation of all active digital inputs;
    b) Check all output contacts by operating the controlled device such as circuit breaker, auxiliary relay, or alarm.
11. Measure magnitude and phase angle of all inputs and compare to expected values.

8.1.8 Surge Arrester test

1. Compare nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding and clearances.
4. Verify arresters are clean.
5. Inspect bolted electrical connections for high resistance using the following methods:

a) Use of a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connection. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest values;
b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.

6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest value.
8. Perform insulation-resistance tests on each arrester, phase terminal-to-ground. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data use Table 1.0. Values of insulation resistance less than this table or manufacturer' published data should be investigated.
9. Perform point-to-point test to determine the resistance between the main grounding system and arrester.
10. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.9 Power Meter test

1. Compare nameplate data with drawings and specifications.
2. Inspect for any physical damage.
3. Check tightness of electrical connections.
4. Record model number, serial number, firmware version, software version and rated control voltage.
5. Verify operation of display and indicating devices.
6. Verify unit is grounded in accordance with manufacturer's instructions.
7. Verify unit is connected in accordance with manufacturer's instructions.
8. Set all required parameters in accordance with design requirements and manufacturer's instructions.
9. Set and verify the communication in accordance with manufacturer's instructions.

8.2 Switchgear system function test

1. Check and verify all internal logic functions used in the control and protection scheme, including but not limited to:
   a) Breaker trip;
   b) Close inhibit;
   c) 86 lockout test;
   d) Alarm functions.
2. Check and verify all logic functions used in all modes of operation including operation on utility power failure, diesel generator start-up and utility power restoration.
3. Verify the correct operation of all alarms and indicating devices.
4. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to switchgear during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the switchgear in a safe manner and verify correct current and voltage values to protective devices and metering.
5. Verify correct operate and restraint values to differential protection.
6. Verify correct system phase angle and sequence.
7. Verify equipment phasing.
8. Verify monitoring devices are functioning correctly.
9. Verify that protective devices have established baseline parameters and criteria.
10. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to switchgear during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Verify that protective devices have established baseline parameters and criteria.
3. Monitor switchgear loading and compare it to design criteria.
4. Monitor switchgear alarms.
5. Perform final protection device settings adjustments where required.
6. Perform final network communication settings adjustments where required.
7. Perform thermographic survey in accordance with section 9.1.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

TABLE 10.0

Switchgear Withstand Test Voltages

Type of Switchgear	Rated Maximum Voltage (kV) (rms)	Maximum Test Voltage kV	
		AC	DC
Low-Voltage Power Circuit Breaker Switchgear	.254/.508/.635	1.6	2.3
Metal-Clad Switchgear	4.76	14	20
	8.25	27	37
	15.0	27	37
	27.0	45	†
	38.0	60	†
Station-Type Cubicle Switchgear	15.5	37	†
	38.0	60	†
	72.5	120	†
Metal Enclosed Interrupter Switchgear	4.76	14	20
	8.25	19	27
	15.0	27	37
	15.5	37	52
	25.8	45	†
	38.0	60	†

Derived from ANSI/IEEE C37.20.1-1993, Paragraph 5.5, *Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear*, C37.20.2-1993, Paragraph 5.5, *Standard for Metal-Clad and Station-Type Cubicle Switchgear* and C37.20.3-1987 (R1992), Paragraph 5.5, *Standard for Metal-Enclosed Interrupter Switchgear*, and includes 0.75 multiplier with fraction rounded down.

The column headed "DC" is given as a reference only for those using dc tests to verify the integrity of connected cable installations without disconnecting the cables from the switchgear. It represents values believed to be appropriate and approximately equivalent to the corresponding power frequency withstand test values specified for voltage rating of switchgear. The presence of this column in no way implies any requirement for a dc withstand test on ac equipment or that a dc withstand test represents an acceptable alternative to the low-frequency withstand tests specified in these specifications, either for design tests, production tests, conformance tests, or field tests. When making dc tests, the voltage should be raised to the test value in discrete steps and held for a period of one minute.

† Because of the variable voltage distribution encountered when making dc withstand tests, the manufacturer should be contacted for recommendations before applying dc withstand tests to the switchgear. Voltage transformers above 34.5 kV should be disconnected when testing with dc. Refer to ANSI/IEEE C57.13-1993 (*IEEE Standard Requirements for Instrument Transformers*) paragraph 8.8.2.

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

66 KV SUBSTATION

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for 66KV substation at the pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/IEEE C57.13-2008, IEEE Standard Requirements for Instrument Transformers
- ANSI/IEEE C57.13.1-2006, IEEE Guide for Field Testing of Relaying Current Transformers
- ANSI/IEEE C57.13.3-2014, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases
- ANSI/IEEE C57.32-2015, IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
- ANSI/IEEE C57.104-2008, IEEE Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers
- ASTM D923-15, Standard Practices for Sampling Electrical Insulating Liquids
- ASTM D3612 - 02(2009), Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography
- ANSI/IEEE 81-2012, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;

2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Electronic setting files for intelligent devices;
9. Design documents including, but not limited to:
   a) High voltage power transformers specification;
   b) 66 KV Current Transformer specification;
   c) Circuit Switcher specification;
   d) Medium voltage surge arrester specification;
   e) General arrangement drawings;
   f) Grounding layout drawings;
   g) Substation schematics;
   h) Wiring diagrams;
   i) Single line diagrams;
   j) Three line diagrams;
   k) Section 26 08 05, Acceptance Testing Specification;
   l) Power system studies including short-circuit, coordination, arc-flash hazard and protective device setting sheets.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms;
6. Power system studies including short-circuit, coordination and arc-flash hazard;
7. Electronic setting files for intelligent devices.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance

tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, and protective device trip settings;
4. Factory acceptance test report;
5. A complete set of electrical plans and specifications, including all change orders
6. Applicable design documents;
7. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;

3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks;
   i) “As left” relay setting files.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Circuit Switcher test

1. Visual and Mechanical Inspection

a) Compare equipment nameplate data with drawings and specifications.
b) Inspect physical and mechanical condition
c) Inspect anchorage, alignment, and grounding.
d) Verify the bushings and insulators are clean.
e) Verify both the circuit switcher and its operating mechanism mechanically operates in accordance with manufacturer's published data.
f) Inspect bolted electrical connections for high resistance using the following methods:
   i. Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   ii. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
g) Verify operation of SF6 interrupters in accordance with manufacturer's published data.
h) Verify SF6 pressure in accordance with manufacturer's published data.
i) Verify that key interlocking system operate and sequence per system design and manufacturer's published data.
j) Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
k) Record as-found and as-left operation counter readings.

2. Electrical tests

a) Perform contact-resistance test of interrupters. Microhm or DC millivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles by more than 50 percent of the lowest value.
b) Perform insulation resistance test on each pole phase –to-ground. The values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 1.0. Investigate resistance values less than this table or manufacturer's published data.
c) Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 7.0

d) Verify correct operation of any auxiliary features such as electrical close and trip operation, trip-free, and anti-pump function where applicable. Reset all trip logs and indicators.
e) Trip circuit switcher by operation of each protective device in accordance with system design.
f) Verify correct operation of electrical trip of interrupters in accordance with system design.
g) Perform a dielectric withstand voltage test in accordance with manufacturer's published data. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the circuit switcher is considered to have passed the test.
h) Verify alarm and status signals to PLC.

8.1.2 Power Transformer test

1. Visual and mechanical inspections

a) Compare equipment nameplate data with drawings and specifications.
b) Inspect physical and mechanical conditions.
c) Inspect anchorage, alignment, and grounding.
d) Verify the presence of PCB content labeling.
e) Verify the bushings are clean.
f) Verify that alarm, control and trip settings on temperature and level indicators are accordance with manufacturer's recommendations.
g) Inspect bolted electrical connections for high resistance using the following methods:
   i. Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   ii. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
h) Verify correct liquid levels in tanks and bushings.
i) Verify that positive pressure is maintained on gas-blanketed transformers.
j) Verify presence of surge arresters.
k) Perform other inspections as recommended by manufacturer if applicable.
l) Verify de-energized tap-changer position is left in the "neutral" position.

2. Electrical tests

a) Perform insulation-resistance tests, winding-to-winding and each winding to ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 4.0. Calculate polarization index. Minimum insulation-resistance values shall be in accordance with manufacturer's published data or Table 4.0. Values less than this table or manufacturer's published data shall be investigated. The polarization index shall not be less than 1.0.

b) Perform turns-ratio tests at all tap positions. Turns-ratio test results shall not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.
c) Perform insulation power-factor or dissipation-factors tests on all windings in accordance with test equipment manufacturer's data.
Maximum winding insulation power-factor / dissipation-factor values shall be in accordance with the manufacturer's published data. In the absence of manufacturer's published data, use Table 8.0.
d) Perform insulation power-factor or dissipation-factors tests on each bushings equipped with a power-factor/capacitance tap. In the absence of a power-factor/capacitance tap, perform hot-collar tests. Investigate values that vary from nameplate values by more than ten percent. Hot-collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.
e) Perform excitation-current tests in accordance with test equipment manufacturer's data. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
f) Measure the resistance of each high-voltage winding in each de-energized tap-changer position. Measure the resistance of each low-voltage winding in each de-energized tap-changer position, if applicable. Temperature corrected winding-resistance values shall compare within one percent of previously obtained results.
g) Remove a sample of insulating liquid in accordance with ASTM D 923. Sample shall be tested for the following in accordance with relevant ASTM D series standards:
    1. Dielectric breakdown voltage;
    2. Acid neutralization number;
    3. Interfacial tension;
    4. Color;
    5. Visual condition;
    6. Dissolved-gas analysis (Evaluate results in accordance with ANSI/IEEE C57.104 standard).
h) Insulating liquid values shall be in accordance with Table 9.0.
i) Test current transformers in accordance with section 8.1.2.1.
j) Test neutral grounding resistor and monitoring relay in accordance with sections 8.1.2.3 and 8.1.2.4.
k) Test surge arrester in accordance with 8.1.2.2.

8.1.2.1 Current Transformer test

1. Inspect physical and mechanical condition.
2. Record the equipment nameplate data for inclusion in the report.
3. Ensure that CT shorting bars are removed or installed as required.
4. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.
5. Perform an insulation resistance test, according to IEEE C57.13.1 standard, of the current transformer primary and secondary windings, and wiring to ground at 1000 VDC. Do not perform this test on solid-state devices.

6. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
7. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1. Investigate any ratio accuracies not within 0.5% of nameplate or manufacturer's published data.
8. Perform an excitation test on transformers used for protection or relaying applications in accordance with ANSI C57.13.1.

8.1.2.2 Surge Arrester test

1. Compare nameplate data with drawings and specifications
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding and clearances.
4. Verify arresters are clean.
5. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connection. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest values;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest value.
8. Perform insulation-resistance tests on each arrester, phase terminal-to-ground. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data use Table 1.0. Values of insulation resistance less than this table or manufacturer' published data should be investigated.
9. Perform point-to-point test to determine the resistance between the main grounding system and arrester.
   Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.2.3 Neutral Grounding Resistor (NGR) test

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical conditions.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Inspect bolted electrical connections for high resistance using the following methods:

a) Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.

6. Perform Insulation-resistance test between resistor sections and between each resistor section and ground, in accordance with manufacturer's published data or IEEE C57.32 standard.
7. Measure the overall resistance value and investigate when the value is not within manufacturer's published data or IEEE C57.32 requirement.
8. Test NGR's current transformer in accordance with section 8.1.2.1.

8.1.2.4 Power Transformer protection and control cabinet test

1. General tests

a) Compare equipment nameplate data with drawings and specifications.
b) Inspect physical and mechanical condition.
c) Inspect anchorage, alignment, grounding, and required area clearances.
d) Verify the unit is clean and all shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.
e) Verify correct operation of the heater.
f) Verify correct operation of the GFCI receptacle.

2. Protective Relays test

a) Record the equipment nameplate data for inclusion in the report.
b) Inspect physical and mechanical condition.
c) Check tightness of connections.
d) Verify that the frame is grounded in accordance with manufacturer's instructions.
e) Set the relay in accordance with the coordination study.
f) Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.
g) Perform insulation-resistance tests from each circuit to the grounded frame in accordance with manufacturer's published data.
h) Apply voltage or current to all analog inputs and verify correct registration of the relay meter function.
i) Check functional operation of each element in accordance with the following:
   i. Transformer mounted devices:
      All testing shall be performed in accordance with manufacturer's published data. Testing shall include, but not limited to:

(49T) –Transformer Winding Temperature Relay
1. Verify setting of calibration resistor.
2. Determine alarm temperature setpoint (HI)

3. Determine alarm reset temperature value.
4. Determine trip temperature setpoint (HI HI).
5. Determine trip reset temperature value.
6. Verify alarm output (HI) to SEL-787 digital “alarm” input.
7. Verify trip output (HI HI) to SEL-787 digital “trip” input.
8. Verify trip output (HI HI) initiates 86T lockout relay operation.

(63P) – Transformer Rapid Pressure Relief Device

1. Determine relief device operating pressure.
2. Verify trip output to SEL-787 digital “trip” input.
3. Verify trip output initiates 86T lockout relay operation.

(63Q) – Transformer Sudden Pressure Relay

1. Determine rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer’s published data.
2. Verify 63Q trip circuit to seal-in relay (see 86Q below).

(71Q) – Transformer Fluid Level

1. Determine fluid level (LO) alarm setpoint.
2. Determine fluid level alarm reset point.
3. Determine fluid level (LO LO) trip setpoint.
4. Determine fluid level trip reset point.
5. Verify alarm output (LO) to SEL-787 digital “alarm” input.
6. Verify trip output (LO LO) to SEL-787 digital “trip” input.
7. Verify trip output (LO LO) initiates 86T lockout relay operation.

(71T) – Transformer Fluid Temperature (Top Oil)

1. Determine fluid temperature (HI) alarm setpoint.
2. Determine fluid temperature alarm reset point.
3. Determine fluid temperature (HI HI) trip setpoint.
4. Determine fluid temperature trip reset point.
5. Verify alarm output (HI) to SEL-787 digital “alarm” input.
6. Verify trip output (HI HI) to SEL-787 digital “trip” input.
7. Verify trip output initiates 86T lockout relay operation.

(86Q) – Transformer Sudden Pressure Seal-In Relay

1. Verify operation of the seal in circuit.
2. Verify trip output to SEL-787 digital “trip” input.
3. Verify trip output initiates 86T lockout relay operation.

ii. SEL-787 multifunction Transformer Protection Relay:
All testing shall be performed in accordance with Schweitzer Engineering Laboratories (SEL) manuals and instructions. Testing shall include, but not be limited to:

(50) – Phase Instantaneous Overcurrent Element(s) – Winding 1

1. Verify pickup setpoint.
2. Determine dropout.
3. Verify direct tripping output.

(51) – Phase Time Overcurrent Element(s) – Winding 1

1. Determine minimum pickup.
2. Determine time delays at two points on the time current curve.
3. Verify correct inverse-time curve is selected.
4. Verify direct tripping output.

(50) – Instantaneous Overcurrent Element(s) – Winding 2

1. Verify pickup setpoint.
2. Determine dropout.
3. Verify direct tripping output.

(51) – Phase Time Overcurrent Element(s) – Winding 2

1. Determine minimum pickup.
2. Determine time delays at two points on the time current curve.
3. Verify correct inverse-time curve is selected.
4. Verify direct tripping output.

(50N) – Phase Instantaneous Overcurrent Element(s) – Neutral

1. Verify pickup setpoint.
2. Determine dropout.
3. Verify direct tripping output.
4. Verify initiation of 86T lockout relay operation.

(51N) – Phase Time Overcurrent Element(s) – Neutral

1. Determine minimum pickup.
2. Determine time delays at two points on the time current curve.
3. Verify correct inverse-time curve is selected.
4. Verify direct tripping output.
5. Verify initiation of 86T lockout relay operation.

(87TG) – Restricted Earth Fault Element(s)

1. Determine pickup setpoint.
2. Verify Directional Element operation.
3. Verify Bypass Logic operation.
4. Verify direct tripping output.
5. Verify initiation of 86T lockout relay operation.

(87T) – Differential Element(s)

1. Determine operating pickup setpoint.
2. Determine the operation of each restraint unit.
3. Determine slope.
4. Determine harmonic restraint
5. Determine instantaneous pickup.
6. Verify direct tripping output.
7. Verify initiation of 86T lockout relay operation.

j) Verify control function of all protective relays with the following :
   i. Check operation of all active digital inputs
   ii. Check all output contacts by operating the controlled device such as circuit breaker, auxiliary relay, or alarm.

k) Measure magnitude and phase angle of all inputs and compare to expected values.

l) Verify proper operation of all Flexitest switches.

m) Verify alarm and status signals to PLC.

n) Verify all “transfer trip” and permissive interlocking signals to / from other equipment.

3. Neutral Grounding monitor Relay test

a) Compare equipment nameplate data with drawings and specifications.

b) Verify power supply, current transformer, sensing resistor and transformer protection relay connections.

c) Perform following tests in accordance with manufacturer's published data:

(59N) – NGR Resistor Fault
1. Resistor fault tests
2. Sensing resistor test
3. Analog output test
4. Ground fault performance test

(51G) – Ground Fault Protection
i. Ground fault trip time
ii. Ground fault trip level
iii. Neutral voltage trip level

d) Pulsed-period adjustment if applicable
e) Configuration settings
i. Resistor fault trip time
ii. Resistor fault trip level
f) Verify trip outputs to SEL-787 digital "trip" input.
g) Verify trip outputs initiate 86T lockout relay operation.
h) Verify proper operation of all Flexitest switches.

8.1.3 Substation grounding system test

1. Verify that grounding system electrical and mechanical connections are free of corrosion.
2. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
3. Perform fall of potential or alternative test in accordance with ANSI/IEEE 81 on the substation grounding system. The resistance value shall be in accordance with design requirement.
4. Perform point-to-point test to determine the resistance between the grounding system and major equipment frames and system neutral. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 Substation system function test

1. Check and verify all logic functions used in the control and protection scheme including but not limited to:
   a) Breaker trips;
   b) Close inhibit;
   c) 86 lockout test;
   d) Alarm functions.

2. Check and verify all logic functions used in all modes of operation, including operation on utility power failure, diesel generator start-up and utility power restoration.
3. Verify the correct operation of all alarms and indicating devices.
4. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to substation during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the substation in a safe manner and verify correct current and voltage values to protective devices and metering.
5. Verify correct operate and restraint values to differential protection.
6. Verify correct system phase angle and sequence.
7. Verify equipment phasing.
8. Verify monitoring devices are functioning correctly.
9. Verify that protective devices have established baseline parameters and criteria.
10. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to substation during commissioning phase.
2. Verify that protective devices have established baseline parameters and criteria.
3. Monitor substation loading and compare it to design criteria.
4. Monitor substation alarms.
5. Perform final protection device settings adjustments where required.
6. Perform thermographic survey in accordance with section 9.1.
7. Perform Corona inspection.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.

6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

600V SWITCHGEAR

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for 600V switchgear at the pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/IEEE C57.13.1-2006, IEEE Guide for Field Testing of Relaying Current Transformers
- ANSI/IEEE C57.13.3-2014, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Electronic setting files for intelligent devices;
9. Design documents including, but not limited to:
   a) Switchgear specification;
   b) Switchgear layout and schedule;

c) Electrical equipment list;
d) Grounding layout;
e) Switchgear schematics;
f) Single line diagrams;
g) Section 26 08 05, Acceptance Testing Specification;
h) Power system studies including short-circuit, coordination and arc-flash hazard.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms;
6. Power system studies including short-circuit, coordination and arc-flash hazard;
7. Electronic setting files for intelligent devices.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. Protection trip settings for protection relays and electronic trip breakers;
5. A complete set of electrical plans and specifications, including all change orders;
6. Applicable design documents;
7. City's project requirements.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. City's project requirements;
6. Designated representative(s) for the project commissioning activities.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Switchgear visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean and all shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.
5. Verify that fuse and circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker’s address for microprocessor-communication packages.
6. Verify that current and voltage transformer ratios correspond to drawings.
7. Inspect bolted electrical connections for high resistance using the following methods:

a) Use of a low-resistance ohmmeter;
b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.

8. Confirm correct operation and sequencing of electrical and mechanical interlock systems:
   a) Attempt closure on locked-open devices. Attempt to open locked-closed devices;
   b) Make key exchange with devices operated in off-normal positions.
9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Inspect insulators for evidence of physical damage or contaminated surfaces.
11. Verify correct barrier and shutter installation and operation.
12. Exercise all active components.
13. Inspect mechanical indicating devices for correct operation.
14. Verify that filters are in place and vents are clear.
15. Perform visual and mechanical inspection of instrument transformers.

8.1.2 Switchgear electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, for one minute in accordance with Table 1.0. Values of insulation resistance less than this table or manufacturer's recommendation should be investigated.
3. Perform a dielectric withstand voltage test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 10.0. The test voltage shall be applied for one minute. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application, the test is considered to have passed.
4. Perform current injection tests in each section of switchgear by secondary injection with magnitudes such that a minimum current of 1.0 ampere flows in secondary unit. Verify correct magnitude of current at each device in the circuit.
5. Verify operation of cubicle space heaters.
6. Perform phasing checks on dual-source switchgear to insure correct bus phasing from each source.
7. Perform air circuit breakers test in accordance with section 8.1.3.
8. Perform ground-resistance test in accordance with section 81.4.
9. Perform instrument transformers test in accordance with section 8.1.5.
10. Perform power meter test in accordance with section 8.1.6.

8.1.3 Air Circuit Breaker test

- **Visual and Mechanical Inspection**

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Verify the arc chutes are intact.
6. Inspect moving and stationary contacts for condition and alignment.
7. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
8. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism in accordance with manufacturer's published data.
9. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connection. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest values;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
10. Verify cell fit and element alignment.
11. Verify racking mechanism operation.
12. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Perform adjustments for final protective device settings in accordance with coordination study provided by City's representative.
14. Record as-found and as-left operation counter readings.

- **Electrical tests**

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest value.
2. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to ground with the circuit breaker closed, and across each open pole. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data use Table 1.0. Values of insulation resistance less than this table or manufacturer' published data should be investigated.
3. Perform a contact/pole-resistance test. Microhm or DC milivolt drop values shall not exceed the high levels of the normal range as indicated in the manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
4. Determine long-time pickup and delay by primary current injection where applicable.
5. Determine short-time pickup and delay by primary current injection where applicable.

6. Determine ground-fault pickup and delay by primary current injection where applicable.
7. Determine instantaneous pickup by primary current injection where applicable.
8. Perform minimum pickup voltage tests on shunt trip and close coils in accordance with manufacturer's published data. The values shall conform to the manufacturer's published data.
9. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close ant trip operation, trip-free, anti-pump function, and trip unit battery condition where applicable. Reset all trip logs and indicators.
10. Verify operation of charging mechanism.

8.1.4 Switchgear ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and switchgear frame.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.5 Current Transformer test

1. Inspect physical and mechanical condition.
2. Record the equipment nameplate data for inclusion in the report.
3. Ensure that CT shorting bars are removed or installed as required.
4. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.
5. Perform an insulation resistance test, according to IEEE C57.13.1 standard, of the current transformer primary and secondary windings, and wiring to ground at 1000 VDC. Do not perform this test on solid-state devices.
6. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
7. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1. Note any ratio accuracies not within 0.5% of nameplate or manufacturer's published data.
8. Perform an excitation test on transformers used for protection or relaying applications in accordance with ANSI C57.13.1.

8.1.6 Power Meter test

1. Compare nameplate data with drawings and specifications
2. Inspect for any physical damage.
3. Check tightness of electrical connections.
4. Record model number, serial number, firmware version, software version and rated control voltage.
5. Verify operation of display and indicating devices.
6. Verify unit is grounded in accordance with manufacturer's instructions.
7. Verify unit is connected in accordance with manufacturer's instructions.
8. Set all required parameters in accordance with design requirements and manufacturer's instructions.
9. Set and verify the communication in accordance with manufacturer's instructions.

8.2 Switchgear system function test

1. Perform Circuit Breakers operational and functional tests as part of switchgear function test.
2. Verify the correct operation of all alarms and indicating devices.
3. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to switchgear during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the switchgear in a safe manner and verify correct current and voltage values to protective devices and metering.
5. Verify correct system phase angle and sequence.
6. Verify equipment phasing.
7. Verify monitoring devices are functioning correctly.
8. Verify that protective devices have established baseline parameters and criteria.
9. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to switchgear during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Verify that protective devices have established baseline parameters and criteria.
3. Monitor switchgear loading and compare it to design criteria.
4. Monitor switchgear alarms.
5. Perform final protection device settings adjustments where required.
6. Perform thermographic survey in accordance with section 9.1.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.

7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

ACTIVE HARMONICS FILTER (AHF)

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for active harmonic filter at the pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- Schneider installation and user manuals for AccuSine active harmonic filter

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3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:
   a) Active Harmonics Filter specification;
   b) Single line diagram;
   c) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. Protection trip settings for protection relays and electronic trip breakers;
5. A complete set of electrical plans and specifications, including all change orders;
6. Applicable design documents;
7. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;

4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;

5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 AHF visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Verify the main CT connections to CT board of AHF.
6. Verify parallel communication wiring between the units.
7. Verify operation of fans.
8. Verify factory installed jumper connections in accordance with manufacturer’s published data.
9. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer’s calculation procedures and recommendations.

8.1.2 AHF electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Perform insulation-resistance tests from phase terminals to case for one minute. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 1.0.
3. Perform the equipment setup in accordance with manufacturer's published data.
4. Verify communication to plant control system.

8.1.3 AHF ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and AHF frame.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 AHF system function test

1. At least 50% of the anticipated load should be available during the function test. The total output current required for the system must be at least 10% of the unit's nameplate rating.
2. Verify THD (Total Harmonic Distortion) and power factor values.
3. Verify the correct operation of all alarms and indicating devices
4. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to AHF during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the AHF in a safe manner and perform system function test as described in section 8.2.
5. Verify correct system phase angle and sequence.
6. Verify equipment phasing.
7. Verify monitoring devices are functioning correctly.
8. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to AHF during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Monitor current, voltage, power, power factor and THD (Total Harmonic Distortion) values.
3. Check the harmonic bar graphs for loads.
4. Monitor performance of the unit.

5. Monitor alarms and fault indications.
6. Perform thermographic survey in accordance with section 9.1.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

BATTERY SYSTEM

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for Battery system (battery bank, DC station service panel and charger) at pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/IEEE 1188-2014, Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Stations

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:
   a) Battery charger and battery bank specification;
   b) Single line diagram;
   c) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;

5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning schedule;
3. Manufacturer instruction manuals and data sheets;
4. City's project requirements;
5. Designated representative(s) for the project commissioning activities.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Battery bank visual and mechanical inspections

1. Verify that battery area ventilation system is operable.
2. Verify existence of suitable eyewash equipment.
3. Compare equipment nameplate data with drawings and specifications.
4. Inspect physical and mechanical condition.
5. Inspect anchorage, alignment, grounding, and required area clearances.
6. Verify the unit is clean.
7. Verify the application of an oxide inhibitor on battery terminal connections.
8. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.

8.1.2 Battery bank electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Measure negative terminal temperature. It shall be within manufacturer's published data or IEEE 1188.
3. Measure float and equalizing voltage levels and compare with manufacturer's published data.
4. Measure each monoblock/cell voltage and total battery voltage with charger energized and in float mode of operation and compare with manufacturer's published data. .
5. Measure intercell connection resistance. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

6. Perform internal ohmic resistance test. Internal ohmic values shall not vary more than 25 percent between identical monoblock/cells in fully charged state.
7. Perform a load test in accordance with manufacturer's published data or IEEE 1188. Results shall be in accordance with manufacturer's published data or IEEE 1188.

8.1.3 Charger visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
6. Inspect filter and tank capacitors.
7. Verify operation of cooling fans and presence of filters.

8.1.4 Charger Electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Verify float voltage; equalize voltage, and high voltage shut down settings and compare with manufacturer's published data.
3. Verify current limit and compare with manufacturer's published data.
4. Verify correct load sharing.
5. Measure and record input and output voltage and current and compare with manufacturer's published data.
6. Measure and record ac ripple current and voltage imposed on the battery and compare with manufacturer's published data.
7. Verify hardwired alarms and status signals to PLC.
8. Verify Modbus/TCP communication with plant control system.

8.1.5 DC distribution panel

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Inspect bolted electrical connections for high resistance using the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be

determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.

6. Verify breaker status signals to PLC.

8.1.6 Battery system ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and battery-charger unit frame.
2. Perform point-to-point test to determine the resistance between the main grounding system and DC distribution panel frame.
3. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 Battery system function test

1. Connect the loads, one at a time, and verify correct voltage and current values.
2. Verify the correct operation of all alarms and indicating devices
3. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to Battery system during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the Battery system in a safe manner and perform system function test as described in section 8.2.
5. Verify monitoring devices are functioning correctly.
6. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to equipment during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Monitors alarms or fault indications.
3. Verify loading of the system.
4. Perform thermographic survey in accordance with section 9.1.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;

f) Identify load conditions at time of inspection;
g) Provide photographs and/or thermograms of the deficient area;
h) Recommended action.

4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

DIESEL ELECTRIC GENERATING UNIT

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for diesel electric generating unit at the pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/NFPA 110-2016, Emergency and Standby Power Systems
- CSA- C282-15, Emergency Electrical Power Supply for Buildings
- ANSI/IEEE 43-2013, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery
- ANSI/IEEE C57.13-2008, IEEE Standard Requirements for Instrument Transformers
- ANSI/IEEE C57.13.3-2014, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:

a) Diesel Electric Generating unit specification;
b) Wiring diagrams and schematics;
c) Single line diagram;
d) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning schedule;
3. Manufacturer instruction manuals and data sheets;
4. City's project requirements;
5. Designated representative(s) for the project commissioning activities.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;

d) A copy of the commissioning design review records and logs and submittal review;
e) A complete copy of the test reports;
f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
g) Analysis and recommendations;
h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Diesel Generator unit visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.

8.1.2 Diesel Generator unit electrical tests

1. Perform insulation resistance tests in accordance with IEEE standard 43. Test duration shall be ten minutes. Calculate polarization index.
   The dielectric absorption ratio or polarization shall not be less than one.
2. Verify phase rotation, phasing and synchronized operation as required.
3. Test engine shutdown for low oil pressure, overtemperature, overspeed and other protection features as applicable.
4. With the engine in a cold start condition and the emergency load at operating level, simulate normal power failure and conduct operational test in accordance with the following:

- The operational test shall be continued for 1.5 hours.
- Ensure the engine starts (both hot and cold) within 15 seconds.
- Record the following items:
  a) Time delay on start;
  b) The cranking time until the engine starts and runs;
  c) The time required to come up to operating speed;

d) The time required to achieve steady-state condition, with all switches transferred to the emergency position;
e) The voltage, frequency and amperes at first load acceptance and every 15 minutes thereafter until completion of operational test period;
f) The engine oil pressure, water temperature at first load acceptance and every 15 minutes thereafter until completion of operational test period;
g) The battery charge rate at 5 minute intervals for the first 15 minutes or until charge rate stabilization;
h) The time delay on engine cool-down and shutdown.

5. After operational test and engine cool down, perform load bank test or system load tests:
   a) 25 percent applied load for 30 minutes;
   b) 50 percent applied load for 30 minutes;
   c) 100 percent applied load for 60 minutes;
   d) Load test results to demonstrate ability of unit to deliver rated load for test period.
6. Cycle crank test shall be demonstrated by preventing the engine from running (any method recommended by the manufacturer may be used). The mode selector shall then be placed in the “Manual” position to cause the engine to crank.
7. Verify correct functioning of the governor and regulator.
8. Verify operation of alarm annunciator and operator interface (HMI).
9. Verify signal exchange with plant control system.
10. Perform any other tests in accordance with the manufacturer’s testing and commissioning requirements.

8.1.3 Diesel Generator unit ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and diesel electric generating unit.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.4 Neutral Ground Resistor (NGR) test

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical conditions.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer’s calculation procedures and recommendations.
6. Perform Insulation-resistance test between resistor sections and between each resistor section and ground, in accordance with manufacturer’s published data or IEEE C57.32 standard.

7. Measure the overall resistance value and investigate when the value is not within manufacturer's published data or IEEE C57.32 requirement.
8. Test NGR's voltage transformer in accordance with the following:
   a) Inspect physical and mechanical condition.
   b) Record the equipment nameplate data for inclusion in the report.
   c) Perform insulation resistance test winding-to-winding and each winding-to-ground. Test voltages shall be applied for one minute in accordance with Table 4.0. Do not perform this test on solid-state devices. Insulation resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's data, use Table 4.0.
   d) Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable. Polarity results shall agree with transformer marking.
   e) Perform a turns-ratio test on all tap positions. Ratio errors shall be in accordance with C57.13.
   f) Measure voltage circuit burdens at transformer terminals. Measured burdens shall be compared to transformer rating.
   g) Perform power-factor or dissipation-factor tests in accordance with test equipment manufacturer's published data. Power-factor or dissipation-factor values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.
   h) Verify that voltage transformer secondary circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. The grounding point should be located as specified by the Contract Administrator in the project drawings.

8.2 Diesel Generator unit system function test

1. Conduct performance test as described in clauses 4, 5, 6 and 7, section 8.1.2.
2. Verify generator start-up sequence logic, on utility power failure in accordance with design requirements.
3. Verify generator load sharing and paralleling functions.
4. Verify the correct operation of all alarms and indicating devices.
5. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function

9.0 Commissioning phase tests/activities

All Diesel Generator acceptance and performance tests are completed during pre-commissioning phase.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;

f) Identify load conditions at time of inspection;
g) Provide photographs and/or thermograms of the deficient area;
h) Recommended action.

4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

GENERATOR LOAD BANK

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for the generator load bank at the pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety.

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:
   a) Generator load bank specification;
   b) Single line diagram;
   c) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;

2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;

8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning schedule;
3. Manufacturer instruction manuals and data sheets;
4. City's project requirements;
5. Designated representative(s) for the project commissioning activities.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards

involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Verify operation of cooling fans.
6. Verify operation of space heaters.
7. Inspect load elements for any mechanical damage.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
9. Verify correct operation of switches on control panel.
10. Perform other inspections recommended by manufacturer.

8.1.2 Transformer Electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Perform insulation-resistance tests, winding-to-winding and each winding to ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 4.0. Calculate polarization index. Minimum insulation-resistance values shall be in accordance with manufacturer's published data or Table 4.0. Values less than this table or manufacturer's published data shall be investigated. The polarization index shall not be less than 1.0.
3. Perform power-factor or dissipation-factor test on al windings in accordance with the test equipment manufacturer's published data. C_H and C_L power-factor or dissipation-factor values will vary due to support insulators and bus work utilized on dry transformers. The C_{HL} power factors shall be 2.0 percent or less.

4. Perform turns-ratio tests at all tap positions. Turns-ratio test results shall not deviate more than one-half percent from either the adjacent coils or the calculated ratio.
5. Verify correct secondary voltage, phase-to-phase and phase-to-neutral, after energization and prior to loading.

8.1.3 Control panel electrical tests

1. Verify functionality of malfunction detection system.
2. Verify functionality of alarm annunciation system.
3. Verify manual and automatic load control functions.

8.1.4 Panel ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and load bank frame.
2. Perform point-to-point test to determine the resistance between the main grounding system and control panel frame.
3. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 System function test

1. Perform tests in accordance with section 8.1.3.
2. Refer to diesel generator commissioning procedure for performance test of generator using load banks.

9.0 Commissioning phase tests/activities

All Generator Load Bank tests are completed during pre-commissioning phase.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.

7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

GROUND FAULT PROTECTION (LOW VOLTAGE)

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for low voltage ground fault protection systems at the pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available at pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Electronic setting files for intelligent devices;
9. Design documents including, but not limited to:
   a) Fault protection system specification;
   b) Grounding layout;
   c) Fault protection system wiring diagrams;
   d) Single line diagrams;
   e) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS- 2015.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;

5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:

a) Summary of project;
b) Description of electrical system;
c) The final commissioning plan and the results of the implementation of that plan;
d) A copy of the commissioning design review records and logs and submittal review;
e) A complete copy of the test reports;
f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
g) Analysis and recommendations;
h) Resolution plan for incomplete tasks;
i) “As left” relay setting files.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Ground fault detection panel visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean and all shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.
5. Verify that ground conductor has not been routed through the measuring current transformer at any point.
6. Check for tightness of all accessible control, power and bus wirings.

8.1.2 Panel ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and ground fault detection panel frame.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.3 Residual current monitor device test

1. Verify that connected supply voltage match the information on device nameplate.
2. Verify that ground conductor has not been routed through the measuring current transformer at any point.

3. Verify that maximum permissible cable length for the measuring current transformers has been observed in accordance with manufacturer's published data.
4. Energize the device and perform all settings in accordance with manufacturer's published data, including but not limited to:
   a) Genera settings;
   b) Channel configuration;
   c) Relay mode;
   d) Data logger;
   e) Device bus address;
   f) Clock.

8.1.4 Neutral Grounding Resistor (NGR) monitor device test

1. Verify power supply, current transformer and NGR connections.
2. Set the time delay for the residual current measurement in accordance with design requirements.
3. Set the residual current response value in accordance with design requirements.
4. Set the response value for voltages across the NGR in accordance with design requirements and manufacturer's published data.
5. Verify operation of the "TEST" and "RESET" buttons
6. Set the DIP switch in accordance with manufacturer's published data.
7. Verify operation of the remote alarm unit.
8. Verify NGR alarm to PLC.

8.1.5 Ethernet Gateway test

1. Verify power supply connection.
2. Verify that bus cable is correctly connected and terminated (120 Ω).
3. Verify Ethernet cable connection.
4. Verify the network parameters and settings. Make necessary adjustments in accordance with design requirements.
5. Verify Modbus/TCP communication with plant control system.

8.2 Ground fault protection system function test

1. Simulate ground fault for each load and verify the feeder breaker trip status.
2. Simulate ground and NGR faults and verify the NGR monitor device function.
3. Verify correct operation of all functions of the alarm indicator/ test LCD panel.
4. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

9.0 Commissioning phase tests/activities

1. Restrict access to ground fault protection panel during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Verify removal of temporary protective grounding equipment where applicable.
3. Monitor alarm or fault indications.
4. Perform final settings adjustments where required.

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

GROUNDING SYSTEMs

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for grounding systems at pre-commissioning and commissioning phases.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/IEEE 81-2012, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available at pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:
   a) Grounding and bounding specification;
   b) Grounding layout drawings;
   c) Riser diagrams;
   d) Grounding details;
   e) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS- 2015.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A complete set of electrical plans and specifications, including all change orders;
4. Applicable design documents;
5. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;

7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;

c) The final commissioning plan and the results of the implementation of that plan;
d) A copy of the commissioning design review records and logs and submittal review;
e) A complete copy of the test reports;
f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
g) Analysis and recommendations;
h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Visual and mechanical inspections

1. Inspect physical and mechanical condition.
2. Insure that grounding system electrical and mechanical connections are free of corrosion.
3. Inspect anchorage.
4. Verify ground system installation is in compliance with grounding system drawings.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer’s calculation procedures and recommendations.

8.1.2 Electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2. Perform fall-of-potential or alternative test in accordance with ANSI/IEEE 81 on the main grounding system. The resistance value shall be in accordance with design criteria requirement.

8.2 System function test

1. Test grounding system in accordance with section 8.1.2.

9.0 Commissioning phase tests/activities

All grounding system tests are completed during pre-commissioning phase.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

LOW VOLTAGE AC INDUCTION MOTORS

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for low voltage AC induction motors at pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/IEEE 43-2013, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available at pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:
   a) Low voltage AC induction motors specification;
   b) Single line diagrams;
   c) Schematic diagrams;
   d) Wiring diagrams;
   e) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS- 2015.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;

4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, and protective device setting sheets;
2. Most recent version of the electronic setting files for intelligent electronic devices;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;

e) A complete copy of the test reports;
f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
g) Analysis and recommendations;
h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Inspect air baffles, filter media, cooling fans, slip rings, brushes and brush rigging.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
6. Perform special tests such as air-gap spacing and machine alignment, if applicable.
7. Verify the application of appropriate lubrication and lubrication systems.
8. Verify that resistance temperature detector (RTD) circuits conform to drawings.

8.1.2 Electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Perform insulation-resistance tests in accordance with ANSI/IEEEE standard 43:
   - For machines larger than 150 kilowatts, test duration shall be ten minutes. Calculate polarization index. Polarization index shall not be less than 1.0. The

recommended minimum insulation resistance shall be corrected to 40 °C and read 100 megohms;

- For machines 150 kilowatts and less, test duration shall be one minute. Calculate dielectric-absorption ratio. Dielectric absorption ratio shall not be less than 1.0. The recommended minimum insulation resistance shall be corrected to 40 °C and read 100 megohms.

3. Perform insulation-resistance test on insulated bearings in accordance with manufacturer's published data.
4. Perform operation of space heaters where applicable.

8.1.3 Ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and motor frame.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 Motor function test

1. Verify correct position of switches and circuit breakers.
2. Operate the motor from local and MCC.
3. Perform a rotation test to insure correct shaft direction.
4. Check for any abnormal noise or signs of overheating.
5. Measure running voltage and current and evaluate relative to load conditions and nameplate full-load amperes. Utilize a true RMS meter.

9.0 Commissioning phase tests/activities

1. Monitor alarms or fault indicators..
2. Verify motor loading.
3. Verify that protective devices have established baseline parameters.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area.
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.

6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

DRY TYPE TRANSFORMERS, UP TO 600V PRIMARY

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for low voltage dry type transformer at pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:
   a) Dry type transformers up to 600 V primary, specification;
   b) Single line diagrams;
   c) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;

2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;

8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;

d) A copy of the commissioning design review records and logs and submittal review;
e) A complete copy of the test reports;
f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
g) Analysis and recommendations;
h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Transformer test

- **Visual and mechanical inspections**

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical conditions.
3. Inspect anchorage, alignment, and grounding.
4. Verify that resilient mounts are free and that any shipping brackets have been removed.
5. Verify the unit is clean.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer’s calculation procedures and recommendations.
7. Verify that as-left tap connections are as specified.

- **Electrical tests**

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2. Perform insulation resistance tests winding-to-winding and each winding to ground. Apply voltage in accordance with manufacturer's published data or in the absence of manufacturer's published data, use Table 4.0. Values of insulation resistance less than this table or manufacturer's recommendation should be investigated. Calculate polarization index. The polarization index shall not be less than 1.0.

8.1.2 Transformer ground resistance test

Perform point-to-point test to determine the resistance between the Equipment Grounding System and transformer ground terminal. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 Transformer function test

Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

8.3 Energization

1. Restrict access to transformer during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the transformer in a safe manner and perform system function test as described in 8.2.
5. Verify correct system phase angle and sequence.
6. Verify equipment phasing.
7. Verify monitoring devices are functioning correctly.
8. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to transformer during commissioning phase.
2. Verify transformer loading.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.

4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

MOTOR CONTROL CENTERS (MCC)

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for MCC at pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ANSI/NEMA AB 4-2009, Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Application
- ANSI/IEEE C57.13.1-2006, IEEE Guide for Field Testing of Relaying Current Transformers
- ANSI/IEEE C57.13.3-2014, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available at pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Electronic setting files for intelligent devices;
9. Design documents including, but not limited to:

a) MCC specification;
b) MCC layout and schedule;
c) Electrical equipment list;
d) Grounding layout;
e) MCC schematics;
f) Single line diagrams;
g) Network diagrams;
h) Section 26 08 05, Acceptance Testing Specification;
i) Power system studies including short-circuit, coordination and arc-flash hazard.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms;
6. Power system studies including short-circuit, coordination and arc-flash hazard;
7. Electronic setting files for intelligent devices.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS- 2015.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;

5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks;
   i) “As left” relay setting files.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 MCC visual and mechanical inspections

1. Verify proper barrier and shutter installation and operation.
2. Verify proper operation of indicating and monitoring devices.
3. Verify proper overload protection for each motor.
4. Inspect air cooling passages.

5. Verify proper operation of draw-out elements.
6. Inspect and verify integrity and contamination of bus insulation system.
7. Check door and device interlocking system by:
   a) Closure attempt of device when door is in OPEN position;
   b) Opening attempt of door when device is in CLOSED position.
8. Check key interlocking systems for:
   a) Key captivity when device is in CLOSED position;
   b) Key removal when device is in OPEN position;
   c) Closure attempt of device when key has been removed;
   d) Correct number of keys in relationship to number of locks cylinders;
   e) Existences of other keys capable of operating lock cylinders; destroy duplicate sets of keys.
9. Check nameplates for proper identification of:
   a) Equipment title and tag number with latest one-line diagram;
   b) Pushbuttons;
   c) Control switches;
   d) Pilot lights;
   e) Control relays;
   f) Circuit breakers;
   g) Indicating meters.
10. Verify that fuse and circuit breaker sizes and types conform to the drawings.
11. Verify that current and potential transformer ratios conform to the drawings.
12. Check bolted electrical connections for high resistance by using one or more of the following methods:
    a) Low resistance ohmmeter;
    b) Calibrated torque wrench applied to the bolted Joints. Bolt torque level in accordance with Table 6.0, unless otherwise specified by manufacturer. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
13. Check operation and sequencing of electrical and mechanical interlock systems by:
    a) Closure attempt for locked open devices;
    b) Opening attempt for locked closed devices;
    c) Key exchange to operate devices in OFF-NORMAL positions.
14. Control Wiring:
    a) Compare wiring to local and remote control, and protective devices with elementary diagrams;
    b) Check for proper conductor lacing and bundling;
    c) Check for proper conductor identification;
    d) Check for proper conductor lugs and connections.
15. Exercise active components.
16. Inspect contactors for:
    a) Correct mechanical operations;
    b) Correct contact gap, wipe, alignment, and pressure;
    c) Correct torque of all connections.
17. Compare overload relay with full-load current for proper size.
18. Compare, fuse, motor protector, and circuit breaker with motor characteristics for proper size.

8.1.2 MCC electrical tests

1. For units with solid state components, follow manufacturer's recommendations prior to performing any tests.
2. Insulation resistance tests:
   a) Applied test voltage shall be in accordance with manufacturer's published data or Table 1.0;
   b) Bus section phase-to-phase and phase-to-ground for 1 minute on each phase;
   c) Contactor phase-to-ground and across open contacts for 1 minute on each phase;
   d) Starter section phase-to-phase and phase-to-ground on each phase with starter contacts closed and protective devices open;
   e) In the absence of manufacturer's published data, test values to comply with Table 1.0.
3. Current injection through overload unit at 300 percent of motor full-load current and monitoring trip time:
   a) Trip time in accordance with manufacturer's published data;
   b) Investigate values in excess of 120 seconds.
4. Control Wiring Tests:
   a) Apply secondary voltage to control power and potential circuits;
   b) Check voltage levels at each point on terminal boards and each device terminal.
5. Perform circuit breaker test in accordance with section 8.1.3.
6. Perform ground resistance test in accordance with section 8.1.4.
7. Perform current transformer test in accordance with section 8.1.5.
8. Perform power meter test in accordance with section 8.1.6.
9. Perform variable speed drive test in accordance with section 8.1.7.
10. Perform operational test by initiating control devices. Control devices shall perform in accordance with system design requirements.
11. Verify I/O, metering and diagnostic data from each intelligent motor management relay and variable speed drive.
12. Verify all intelligent electronic devices, communication protocol, and plant control system display the correct date and time.

8.1.3 Molded Case Circuit Breaker test

1. Inspection and testing shall include the following:
   a) Note the equipment nameplate data for inclusion in the report;
   b) Record all adjustable settings;
   c) Inspect physical and mechanical condition;
   d) Inspect anchorage and alignment;
   e) Clean the unit;
   f) Torque all accessible bolted power connections;
   g) Operate the circuit breaker to insure smooth operation;
   h) Test all breakers utilizing the "Push-To-Trip" button, if equipped;
   i) Move operating handle to the off and on position;
   j) Restore breaker position to original position;
   k) Perform adjustments for final protective device settings in accordance with the coordination study.

2. For cables 4/0 AWG and larger, inspect bolted electrical connections for high resistance using a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
3. For breakers with a frame size greater or equal to 250A Perform an insulation resistance test:
   a) Breakers rated less than 600V, test voltage is to be 500 VDC;
   b) Breakers rated at 600V, test voltage is to be 1000 VDC.
4. Insulation-resistance values shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 1.0. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
5. Perform contact/pole resistance test. Microhm or dc milivolt drop values shall not exceed the high levels of the normal range as indicated in manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
6. Determine long-time pickup and delay by primary current injection where applicable.
7. Determine short-time pickup and delay by primary current injection where applicable.
8. Determine ground-fault pickup and delay by primary current injection where applicable.
9. Determine instantaneous pickup by primary current injection where applicable
10. Perform minimum pickup voltage tests on shunt trip and close coils in accordance with manufacturer's published data where applicable. The values shall conform to the manufacturer's published data.
11. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip free, anti-pump function, and trip unit battery condition where applicable. Reset all trip logs and indicators.

8.1.4 MCC ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and MCC frame.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.5 Current Transformer test

1. Inspect physical and mechanical condition.
2. Record the equipment nameplate data for inclusion in the report.
3. Ensure that CT shorting bars are removed or installed as required.
4. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.
5. Perform an insulation resistance test, according to IEEE C57.13.1 standard, of the current transformer primary and secondary windings, and wiring to ground at 1000 VDC. Do not perform this test on solid-state devices.
6. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
7. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1. Note any ratio accuracies not within 0.5% of nameplate or manufacturer's published data.

8. Perform an excitation test on transformers used for protection or relaying applications in accordance with ANSI C57.13.1.

8.1.6 Power Meter test

1. Compare nameplate data with drawings and specifications
2. Inspect for any physical damage.
3. Check tightness of electrical connections.
4. Record model number, serial number, firmware version, software version and rated control voltage.
5. Verify operation of display and indicating devices.
6. Verify unit is grounded in accordance with manufacturer's instructions.
7. Verify unit is connected in accordance with manufacturer's instructions.
8. Set all required parameters in accordance with design requirements and manufacturer's instructions.
9. Set and verify the communication in accordance with manufacturer's instructions.

8.1.7 Variable Frequency Drive (VFD) test

1. Inspection and testing shall be comprised of the following:
   a) Inspect physical and mechanical condition;
   b) Inspect anchorage, alignment, and grounding;
   c) Clean the unit;
   d) Check the air filters;
   e) Ensure vent path openings are free from debris and that heat transfer surfaces are not contaminated by oil, dust, or dirt;
   f) Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables;
   g) Visually inspect VFD grounding to ensure continuity;
   h) Inspect condition and connections of line reactors, and load reactors / load filter if present;
   i) Inspect DC bus capacitors for bulging and leakage;
   j) Cooling fans and heat sinks:
      - Visually inspect and listen for any abnormal noises or vibration;
      - Verify that fans rotate freely;
      - Verify correct direction of airflow;
      - Clean and verify integrity of heat sinks;
      - Verify the operation of the grounding switch, if present.
   k) Perform all other work in accordance with the manufacturer's instructions.
2. Record the following VFD Parameters:
   a) Motor voltage, current, frequency, nominal speed, nominal power;
   b) Control mode / method;
   c) Minimum and maximum control frequency;
   d) Acceleration and deceleration time;
   e) Compare drive overcurrent set points with motor full-load current rating to verify correct settings.
3. Power fuses:

   a) Record the fuse data. Confirm that the fuses are of the correct type and rating. Utilize manufacturer's published data, where available;
   b) Measure the fuse resistance.
4. Bolted connections:
   a) Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
5. Inverter / supply module power connections:
   a) Remove each power module and visually inspect the contacts;
   b) Clean all contact surfaces and apply suitable joint compound as recommended by manufacturer.

6. Operator Interface:
   a) Check the display and keypad for proper operation and communication;
   b) Retrieve fault history log and note any faults.
7. Grounding/Bonding measurements:
   Measure the resistance of the ground bonding connection between the VFD and the main grounding bus in the corresponding electrical room.
8. Control Wiring:
   Check for tightness of all accessible control wiring.
9. Perform operational tests as follows:
   a) Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration;
   b) Verify operation of drive from local start/stop and speed control signals;
   c) Verify operation of all local pilot lights;
   d) Verify the operation of any emergency stop switches;
   e) Perform all other tests in accordance with the manufacturer's instructions;
   f) Perform all tests in accordance with the manufacturer's recommendations and instructions.
10. Voltage and Current Testing:
    a) With the VFD under load, measure and record the Incoming AC voltage and current;
    b) With the VFD output in START/RUN mode, and at zero speed, measure and record the AC output voltage. Voltages above 40 VAC should be investigated.
11. Set and verify the VFD communication with plant control system.

8.2 MCC system function test

1. Perform VFD and AC induction motor operational and functional tests as part of MCC function tests.
2. Verify the correct operation of all alarms and indicating devices.
3. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to MCC during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the MCC in a safe manner and verify correct current and voltage values to protective devices and metering.
5. Verify correct operate and restraint values to differential protection if applicable.
6. Verify correct system phase angle and sequence.
7. Verify equipment phasing.
8. Verify monitoring devices are functioning correctly.
9. Verify that protective devices have established baseline parameters and criteria.
10. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to MCC during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Verify no alarm or fault indications are present.
3. Verify that protective devices have established baseline parameters and criteria.
4. Monitor MCC loading and compare it to design criteria.
5. Perform final protection device settings adjustments where required.
6. Perform thermographic survey in accordance with section 9.1.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.

4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

OIL FILLED, PAD MOUNTED TRANSFORMERS

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for oil filled, pad mounted transformer at pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety
- ASTM D923-15, Standard Practices for Sampling Electrical Insulating Liquids
- ASTM D3612 - 02(2009), Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography.
- ANSI/IEEE C57.104-2008, IEEE Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers
- ANSI/IEEE C57.32-2015, IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available for the pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:

a) Oil filled pad mount transformers, specification;
b) Single line diagrams;
c) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS standard.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;

2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;

5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 Transformer test

- **Visual and mechanical inspections**

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical conditions.
3. Inspect anchorage, alignment, and grounding.
4. Verify the presence of PCB content labeling.
5. Verify the bushings are clean.
6. Verify that alarm, control and trip settings on temperature and level indicators are as specified.
7. Verify the cooling fans and pumps operate correctly and have appropriate overcurrent protection.
8. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 6.0.

Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.

9. Verify correct liquid levels in tanks and bushings.
10. Verify that positive pressure is maintained on gas-blanketed transformers.
11. Verify presence of surge arresters.
12. Perform other inspections as recommended by manufacturer if applicable.
13. Verify de-energized tap-changer position is left as specified.

- **Electrical tests**

1. Perform insulation-resistance tests, winding-to-winding and each winding to ground. Apply in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 4.0. Calculate polarization index. Minimum insulation-resistance values shall be in accordance with manufacturer's published data or Table 4.0. Values less than this table or manufacturer's published data shall be investigated. The polarization index shall not be less than 1.0.
2. Perform turns-ratio tests at all tap positions. Turns-ratio test results shall not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.
3. Perform insulation power-factor or dissipation-factors tests on all windings in accordance with test equipment manufacturer's data.
   Maximum winding insulation power-factor / dissipation-factor values shall be in accordance with the manufacturer's published data. In the absence of manufacturer's published data, use Table 8.0.
4. Perform insulation power-factor or dissipation-factors tests on each bushings equipped with a power-factor/capacitance tap. In the absence of a power-factor/capacitance tap, perform hot-collar tests. Investigate values that vary from nameplate values by more than ten percent. Hot-collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.
5. Perform excitation-current tests in accordance with test equipment manufacturer's data. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
6. Measure the resistance of each high-voltage winding in each de-energized tap-changer position. Measure the resistance of each low-voltage winding in each de-energized tap-changer position, if applicable. Temperature corrected winding-resistance values shall compare within one percent of previously obtained results.
7. Remove a sample of insulating liquid in accordance with ASTM D 923. Sample shall be tested for the following in accordance with relevant ASTM D series standards:
   a) Dielectric breakdown voltage;
   b) Acid neutralization number;
   c) Interfacial tension;
   d) Color;
   e) Visual condition;
   f) Dissolved-gas analysis (Evaluate results in accordance with ANSI/IEEE C57.104 standard).
8. Insulating liquid values shall be in accordance with Table 9.0.
9. Test neutral grounding resistor in accordance with sections 8.1.1.1.
10. Test surge arrester in accordance with 8.1.1.2.

8.1.1.1 Neutral Grounding Resistor test

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical conditions.
3. Inspect anchorage, alignment, and grounding.
4. Verify the unit is clean.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter. Compare the resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
6. Perform Insulation-resistance test between resistor sections and between each resistor section and ground, in accordance with manufacturer's published data or IEEE C57.32 standard.
7. Measure the overall resistance value and investigate when the value is not within manufacturer's published data or IEEE C57.32 requirement.

8.1.1.2 Surge Arrester test

1. Compare nameplate data with drawings and specifications
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding and clearances.
4. Verify arresters are clean.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connection. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest values;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
6. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
7. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of lowest value.
8. Perform insulation-resistance tests on each arrester, phase terminal-to-ground. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data use Table 1.0. Values of insulation resistance less than this table or manufacturer' published data should be investigated.
9. Perform point-to-point test to determine the resistance between the main grounding system and arrester.
   Investigate point-to-point resistance values that exceed 0.5 ohm.

8.1.1.3 Transformer ground resistance test

Perform point-to-point test to determine the resistance between the Equipment Grounding System and transformer ground terminal. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 Transformer function test

Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

8.3 Energization

1. Restrict access to transformer during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the transformer in a safe manner and perform system function test as described in 8.2.
5. Verify correct system phase angle and sequence.
6. Verify equipment phasing.
7. Verify monitoring devices are functioning correctly.
8. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to transformer during commissioning phase.
2. Verify transformer loading.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.

7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

STAND-ALONE VARIABLE FREQUENCY DRIVE (VFD)

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for stand-alone variable frequency drive at pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available at pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Electronic setting files for intelligent devices;
9. Design documents including, but not limited to:
   a) VFD specification;
   b) Electrical equipment list;
   c) Grounding layout;
   d) VFD schematics;
   e) Single line diagrams;
   f) Network diagrams;

g) Section 26 08 05, Acceptance Testing Specification;
h) Power system studies including short-circuit, coordination and arc-flash hazard.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;
2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms;
6. Power system studies including short-circuit, coordination and arc-flash hazard;
7. Electronic setting files for intelligent devices.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS- 2015.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;

2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;
8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Guidelines and requirements for VFD settings;
4. Commissioning plan;
5. Commissioning schedule;
6. Manufacturer instruction manuals and data sheets;
7. City's project requirements;
8. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings/ guidelines provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;

4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;
   d) A copy of the commissioning design review records and logs and submittal review;
   e) A complete copy of the test reports;
   f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
   g) Analysis and recommendations;
   h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 VFD visual and mechanical inspections

1. Inspections shall be comprised of the following:
   a) Inspect physical and mechanical condition;
   b) Inspect anchorage, alignment, and grounding;
   c) Clean the unit;
   d) Check the air filters;
   e) Ensure vent path openings are free from debris and that heat transfer surfaces are not contaminated by oil, dust, or dirt;
   f) Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables;
   g) Visually inspect VFD grounding to ensure continuity;
   h) Inspect condition and connections of line reactors, if present;
   i) Inspect condition and connections of DC Link Reactors, if present;
   j) Inspect condition and connections of load reactors or load filter, if present;
   k) Inspect condition of isolation transformers, if present;
   l) Inspect DC bus capacitors for bulging and leakage;
   m) Cooling fans and heat sinks:

- Visually inspect and listen for any abnormal noises or vibration;
- Verify that fans rotate freely;
- Verify correct direction of airflow;
- Clean and verify integrity of heat sinks;
- Verify the operation of the grounding switch, if present.

2. Record the following VFD Parameters:
   a) Motor voltage, current, frequency, nominal speed, nominal power;
   b) Control mode / method;
   c) Minimum and maximum control frequency;
   d) Acceleration and deceleration time;
   e) Compare drive overcurrent set points with motor full-load current rating to verify correct settings.

3. Power fuses:
   Record the fuse data. Confirm that the fuses are of the correct type and rating. Utilize manufacturer's published data where available.
4. Bolted connections:
   a) Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
5. Inverter / Supply Module Power Connections:
   a) Remove each power module and visually inspect the contacts;
   b) Clean all contact surfaces and apply suitable joint compound as recommended by manufacturer.
6. Control Wiring:
   Check for tightness of all accessible control wiring.

8.1.2 VFD electrical tests

1. Power fuses:
   Measure the fuse resistance.
2. Operator Interface:
   a) Check the display and keypad for proper operation and communication;
   b) Retrieve fault history log and note any faults.
3. Grounding/Bonding measurements:
   Measure the resistance of the ground bonding connection between the VFD and the main grounding bus in the corresponding electrical room.
4. Bolted connections:
   a) Perform resistance measurements through bolted connections with a low-resistance ohmmeter. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value;
   b) Torque all bolted connections.

5. Perform operational tests as follows:
   a) Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration;
   b) Verify operation of drive from local start/stop and speed control signals;
   c) Verify operation of all local pilot lights;
   d) Verify the operation of any emergency stop switches.
6. Voltage and Current Testing:
   a) With the VFD under load, measure and record the following:
      - Measure and record incoming AC voltage and currents;
      - Measure and record DC and AC bus voltages.
   b) Utilize a recording oscilloscope to capture the input voltage waveform and verify correct operation;
   c) Utilize a recording oscilloscope to capture the output voltage waveform and verify correct operation;
   d) Include input and output waveforms with the report.
7. With the VFD output in START/RUN mode, and at zero speed:
   Measure and record the AC output voltage. Voltages above 40 VAC should be investigated.
8. Set and verify the VFD communication with plant control system.

8.1.3 VFD ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and VFD frame.
2. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 VFD function test

1. Conduct the tests as described in clauses 5, 6 and 7, section 8.1.2.
2. Verify the correct operation of all alarms and indicating devices.
3. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to VFD during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the VFD in a safe manner and perform function test as described in 8.2.
5. Verify correct system phase angle and sequence.
6. Verify equipment phasing.
7. Verify monitoring devices are functioning correctly.
8. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to VFD during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Verify VFD loading.

3. Monitor alarms and fault indications
4. Verify that protective devices have established baseline parameters.
5. Perform final VFD settings adjustments where required.
6. Perform thermographic survey in accordance with section 9.1.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.
4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

COMMISSIONING PROCEDURES (CP)

UNINTERRUPTIBLE POWER SUPPLY (UPS)

1.0 General scope

This document provides detailed information to support completion of activities and tests described in Commissioning Specification and Objectives (CSO) document for UPS at pre-commissioning and commissioning phases.

Factory Acceptance Test (FAT) procedure is not covered in this document.

Refer to Commissioning Specification and Objectives (CSO) document for definition of phases that are used in this document.

2.0 References

- IEC 62337, Edition 2.0-2012, Commissioning of electrical, instrumentation and control systems in the process industry-Specific phases and milestones
- ANSI/NETA ECS-2015, Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems
- ANSI/NETA ATS-2013, Standard for Acceptance Testing Specification for Electrical Power Equipment and Systems
- CSA-Z462-15, Workplace electrical safety

3.0 Documentation

3.1 Pre-Commissioning phase

Following documents shall be available at pre-commissioning phase:

1. Commissioning plan;
2. Commissioning procedure (this document);
3. Factory acceptance test report;
4. Inspection and test forms;
5. Manufacturer instruction/operating manuals;
6. Manufacturer data sheets;
7. Manufacturer instruction files;
8. Design documents including, but not limited to:
   a) UPS specification;
   b) Single line diagrams;
   c) Section 26 08 05, Acceptance Testing Specification.

3.2 Commissioning phase

Following documents shall be available at commissioning phase:

1. Commissioning plan and schedule;

2. Commissioning procedure (this document);
3. Field acceptance and function tests reports;
4. Field acceptance and function tests punch lists;
5. Inspection and test forms.

4.0 Testing equipment

Testing equipment shall comply with the requirements of ANSI/NETA ATS standard and Section 26 08 05, Acceptance Testing Specification.

5.0 Qualification of personnel

The personnel performing the electrical field tests and commissioning shall be experienced and thoroughly familiar with the apparatus and systems being tested and commissioned. They shall be capable of conducting the tests and commissioning activities in a safe manner, analyze the test data and make a decision on operability of specific equipment and system. Qualification of personnel responsible for acceptance tests and commissioning shall be in accordance with Section 26 08 05, Acceptance Test Specification and ANSI/ATS ECS- 2015.

6.0 Division of responsibility

6.1 Pre-Commissioning phase

Contract Administrator shall provide the testing organization (Contractor) with the following:

1. Commissioning plan;
2. Commissioning Procedure (this document);
3. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
4. A complete set of electrical plans and specifications, including all change orders;
5. Applicable design documents;
6. City's project requirements;

The testing organization (Contractor) shall provide the following:

1. Review of factory acceptance, end of construction documents and punch lists to identify any remaining work which has to be completed before the pre-commissioning phase;
2. Review the commissioning plan document and provide a test schedule and plan for field acceptance and system function tests;
3. Planning for manufacturer assistance based on test schedule;
4. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform the required tests and inspections;
5. Inspection and test data forms;
6. Specific power requirements for test equipment;
7. Timely notification to the Contract Administrator prior to commencement of any testing;

8. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests;
9. A written record of all tests and test results/data;
10. Manufacturer instruction manuals and data sheets;
11. Factory acceptance test report;
12. Factory acceptance test report;
13. Field acceptance and system function tests reports which shall comply with the requirements of ANSI/NETA ATS-2013 standard and Section 26 08 05, Acceptance Testing Specification.

6.2 Commissioning phase

The Contract Administrator shall provide the commissioning organization (Contractor) with the following:

1. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, power factor and harmonic analysis;
2. Protection trip settings for protection relays and electronic trip breakers;
3. Commissioning plan;
4. Commissioning schedule;
5. Manufacturer instruction manuals and data sheets;
6. City's project requirements;
7. Designated representative(s) for the project commissioning activities.

Protective device and breaker trip settings provided will define partial requirements for equipment operation. Contractor/Manufacturer representative is required to provide all other equipment settings necessary to ensure that equipment operates in accordance with manufacturer requirements and design intent. Contractor is required to perform setting adjustments as might be necessary to facilitate successful system commissioning and startup.

The commissioning organization (Contractor) shall provide the following:

1. Review of outstanding deficiencies from the pre-commissioning phase and verify that systems and equipment are in acceptable condition for commencement of the commissioning phase;
2. Review the commissioning plan document and provide the schedule for commissioning phase accordingly;
3. All necessary services and technical expertise to conduct electrical commissioning;
4. Timely notification to the Contract Administrator prior to commencement of any testing;
5. Timely notification of deficiencies based on the results of the commissioning activities;
6. Written record of all electrical commissioning activities;
7. Commissioning report which shall include:
   a) Summary of project;
   b) Description of electrical system;
   c) The final commissioning plan and the results of the implementation of that plan;

d) A copy of the commissioning design review records and logs and submittal review;
e) A complete copy of the test reports;
f) Identification of systems or assemblies that do not meet the City's project requirements where applicable;
g) Analysis and recommendations;
h) Resolution plan for incomplete tasks.

7.0 Hazard and safety

All parties involved in pre-commissioning and commissioning activities must be familiar with standard safety practices and shall have complete knowledge of the hazards involved. Safety representative shall be designated to supervise operations with respect to safety.

Safety practices shall include but not limited to the following requirements:

a) The City's (The City of Winnipeg) safety practices;
b) CSA-Z462-15, Workplace electrical safety.

8.0 Pre-Commissioning phase tests/activities

8.1 Field acceptance tests

8.1.1 UPS visual and mechanical inspections

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Test all electrical and mechanical interlock systems for correct operation and sequencing.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer’s calculation procedures and recommendations.
7. Verify operation of forced ventilation.
8. Verify that filters are in place and vents are clear.

8.1.2 UPS electrical tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. Compare bolted connection values to values of similar connections .Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Test UPS performance in accordance with section 8.2.

3. Verify Modbus/TCP communication with plant control system.

8.1.3 External maintenance bypass switch test

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   a) Use of a low-resistance ohmmeter;
   b) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 6.0. Where Bellville spring washers are utilized, the bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
6. Perform electrical tests for circuit breakers in accordance with Commissioning Procedures for MCC, section 8.1.3.
7. Perform electrical tests for power supply transformer in accordance with Commissioning Procedures for low voltage transformers, section 8.1.1.
8. Perform grounding tests for power supply transformer in accordance with Commissioning Procedures for low voltage transformers, section 8.1.2.
9. Perform function test for power supply transformer in accordance with Commissioning Procedures for low voltage transformers, section 8.2.

8.1.4 Ground resistance test

1. Perform point-to-point test to determine the resistance between the main grounding system and UPS frame.
2. Perform point-to-point test to determine the resistance between the main grounding system and external maintenance bypass switch enclosure frame.
3. Investigate point-to-point resistance values that exceed 0.5 ohm.

8.2 UPS system function test

1. Test performance of the UPS in accordance with the following:

- Operational test:
  a) Verify switchover to and from internal and external bypass;
  b) Simulate utility power failure and verify proper charger operation;
  c) Simulate UPS fault and test static transfer from inverter to bypass and back. Use UPS rated load.

- UPS measurement test:
  Test and record all UPS internal measurements against calibrated test instruments for 50% and 100% output load. The tests shall include:
  a) Output voltage, current, frequency, and power;
  b) Battery voltage and current;

c) Input voltage, current, and power;
d) Bypass voltage and frequency.

- Steady load test:
  a) Switch system onto AC mains and connect load bank at UPS rated load;
  b) Operate system at full rated load for one (1) hour;
  c) Record following data, utilizing UPS display, at start of test and every 10 minutes thereafter:
     - Output voltage phase to phase, phase to neutral;
     - Output current each phase;
     - Output frequency;
     - Output kW;
     - Battery voltage and current.

- Battery load test:
  a) Charge battery to ensure cells are fully charged;
  b) Connect the load bank to the UPS output, configured for the UPS rated output power;
  c) Record following data, utilizing UPS display, at start of test and every 5 minutes thereafter:
     - Output voltage phase to phase, phase to neutral;
     - Output current each phase;
     - Output frequency;
     - Output kW;
     - Battery voltage and current.
  d) Upon the battery low alarm, record:
     - The test time expired;
     - Battery voltage and current.
  e) Allow the UPS to automatically shutdown on low battery. Record the time of automatic shutdown.

2. Verify the correct operation of all alarms and indicating devices.
3. Verify the correct operation of all interlock safety devices for fail-safe function in addition to design function.

8.3 Energization

1. Restrict access to UPS during energization.
2. Verify removal of temporary protective grounding equipment if applicable.
3. Verify correct position of switches and circuit breakers.
4. Energize the UPS in a safe manner and perform system function test as described in section 8.2.
5. Verify monitoring devices are functioning correctly.
6. Verify no alarms or fault indications are present.

9.0 Commissioning phase tests/activities

1. Restrict access to UPS during commissioning phase. Verify emergency exits are correctly secured to prevent the entrance of an unauthorized person from outside, while allowing free escape from inside.
2. Verify that UPS system is free of alarm and is in the specified operating mode.
3. Perform thermographic survey in accordance with section 9.1.

9.1 Thermographic survey

1. Perform thermographic survey when load is applied to the system.
2. Remove all necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment.
3. Provide a report which includes the following:
   a) Description of equipment to be tested;
   b) Discrepancies;
   c) Temperature difference between the area of concern and the reference area;
   d) Probable cause of temperature difference;
   e) Areas inspected. Identify inaccessible and unobservable areas and equipment;
   f) Identify load conditions at time of inspection;
   g) Provide photographs and/or thermograms of the deficient area;
   h) Recommended action.

4. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
5. Equipment shall detect emitted radiation and convert detected radiation to visual signal.
6. Thermographic surveys should be performed during periods of maximum possible loading.
7. Suggested actions based on temperature rise can be found in Table 5.0.

10.0 Tables

TABLE 1.0

Insulation Resistance Test values Electrical Apparatus and Systems		
Nominal Rating of Equipment in Volts	**Minimum Test Voltage (DC)**	**Recommended Minimum Insulation Resistance in Megohms**
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
≥ 34,500	15,000	100,000

-See tables 2.0 and 3.0 for temperature correction factors.

TABLE 2.0

Insulation Resistance Correction Factors (20°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.125	0.25
-5	0.18	0.32
0	0.25	0.40
5	0.36	0.50
10	0.50	0.63
15	0.75	0.81
16	0.80	0.85
17	0.85	0.89
18	0.90	0.92
19	0.95	0.96
20	1.00	1.00
21	1.08	1.05
22	1.16	1.10
23	1.24	1.15
24	1.32	1.20
25	1.40	1.25
30	1.98	1.58
35	2.80	2.00
40	3.95	2.50
45	5.60	3.15
50	7.85	3.98
55	11.20	5.00
60	15.85	6.30

TABLE 3.0

Insulation Resistance Correction Factors (40°C)		
Measured Temperature (°C)	**Liquid Immersed Insulation**	**Solid Insulation**
-10	0.03	0.10
-5	0.04	0.13
0	0.06	0.16
5	0.09	0.20
10	0.13	0.25
15	0.18	0.31
16	0.19	0.33
17	0.21	0.34
18	0.22	0.36
19	0.24	0.38
20	0.25	0.40
21	0.27	0.42
22	0.29	0.44
23	0.31	0.46
24	0.33	0.48
25	0.35	0.50
30	0.50	0.63
35	0.71	0.79
40	1.00	1.00
45	1.41	1.26
50	2.00	1.59
55	2.83	2.00
60	4.00	2.52

TABLE 4.0

Transformer Insulation Resistance Acceptance Testing			
Transformer Coil Rating Type in Volts	**Minimum DC Test Voltage**	**Recommended Minimum Insulation Resistance in Megohms**	
		Liquid Filled	**Dry**
0-600	1000	100	500
601-5000	2500	1000	5000
Greater than 5000	5000	5000	25000

TABLE 5.0

Thermographic Survey Suggested Actions Based on Temperature Rise		
Temperature difference based on comparison between similar components under similar loading	**Temperature difference based on comparison between similar component and ambient air temperature**	**Recommended Action**
1ºC - 3ºC	1ºC - 10ºC	Possible deficiency, warrants investigation
4ºC - 15ºC	11ºC - 20ºC	Indicates probable deficiency, repair as time permits
------	21ºC - 40ºC	Monitor until corrective measures can be accomplished
>15ºC	>40ºC	Major discrepancy, repair immediately

TABLE 6.0

Bolt-Torque Values for Electrical Connections

US Standard Fasteners [a]
Heat-Treated Steel – Cadmium or Zinc Plated [b]

Grade	SAE 1&2	SAE 5	SAE 7	SAE 8
Head Marking				
Minimum Tensile (Strength) (lbf/in^2)	64K	105K	133K	150K
Bolt Diameter (Inches)	**Torque (Pound-Feet)**			
1/4	4	6	8	8
5/16	7	11	15	18
3/8	12	20	27	30
7/16	19	32	44	48
1/2	30	48	68	74
9/16	42	70	96	105
5/8	59	96	135	145
3/4	96	160	225	235
7/8	150	240	350	380
1.0	225	370	530	570

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

US Standard Fasteners [a]
Silicon Bronze Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

a. Consult manufacturer for equipment supplied with metric fasteners.

b. Table is based on national coarse thread pitch.

c. This table is based on bronze alloy bolts having a minimum tensile strength of 70,000 pounds per square inch.

TABLE 6.0 (CONTINUED)

US Standard Fasteners [a]
Stainless Steel Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Uncoated
5/16	15
3/8	20
1/2	40
5/8	55
3/4	70

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is to be used for the following hardware types:
Bolts, cap screws, nuts, flat washers, locknuts (18-8 alloy)
Belleville washers (302 alloy).

US Standard Fasteners [a]
Aluminum Alloy Fasteners [b c]
Torque (Pound-Feet)

Bolt Diameter (Inches)	Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

a. Consult manufacturer for equipment supplied with metric fasteners.
b. Table is based on national coarse thread pitch.
c. This table is based on aluminum alloy bolts having a minimum tensile strength of 55,000 pounds per square inch.

TABLE 7.0

Rated Control Voltages and their Ranges for Circuit Breakers

Operating mechanisms are designed for rated control voltages listed with operational capability throughout the indicated voltage ranges to accommodate variations in source regulation, coupled with low charge levels, as well as high charge levels maintained with floating charges. The maximum voltage is measured at the point of user connection to the circuit breaker [see notes (12) and (13)] with no operating current flowing, and the minimum voltage is measured with maximum operating current flowing.

100.20.1 Rated Control Voltages and their Ranges for Circuit Breakers					
	Direct Current Voltage Ranges (1)(2)(3)(5) Volts, dc (8)(9)				Alternating Current Voltage Ranges (1)(2)(3)(4)(8)
	Closing and Auxiliary Functions			Rated Control Voltage (60 Hz)	Closing, Tripping, and Auxiliary Functions
(11) Rated Control Voltage	Indoor Circuit Breakers	Outdoor Circuit Breakers	Opening Functions All Types	Single Phase	Single Phase
24 (6)	---	---	14–28	120	104–127 (7)
48 (6)	38–56	36–56	28–56	240	208–254 (7)
125	100–140	90–140	70–140		
250	200–280	180–280	140–280	Polyphase	Polyphase
---	---	---	---	208Y/120	180Y/104–220Y/127
---	---	---	---	240	208–254

Derived from Table 8, ANSI C37.06-2000, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis — Preferred Ratings and Related Required Capabilities.*

Notes:

(1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the table as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.

(2) Relays, motors, or other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.

(3) Circuit breaker devices, in some applications, may be exposed to control voltages exceeding those specified here due to abnormal conditions such as abrupt changes in line loading. Such applications require specific study, and the manufacturer should be consulted. Also, application of switchgear devices containing solid-state control, exposed continuously to control voltages approaching the upper limits of ranges specified herein, require specific attention and the manufacturer should be consulted before application is made.

(4) Includes supply for pump or compressor motors. Note that rated voltages for motors and their operating ranges are covered by ANSI/NEMA MG-1-1978.

(5) It is recommended that the coils of closing, auxiliary, and tripping devices that are connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.

(6) 24-volt or 48-volt tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to ensure the adequacy of conductors between battery and control terminals. 24-volt closing is not recommended.

(7) Includes heater circuits

TABLE 7.0 (CONTINUED)

Rated Control Voltages and their Ranges for Circuit Breakers

(8) Voltage ranges apply to all closing and auxiliary devices when cold. Breakers utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.

(9) Direct current control voltage sources, such as those derived from rectified alternating current, may contain sufficient inherent ripple to modify the operation of control devices to the extent that they may not function over the entire specified voltage ranges

(10) This table also applies for circuit breakers in gas insulated substation installations.

(11) In cases where other operational ratings are a function of the specific control voltage applied, tests in C37.09 may refer to the "Rated Control Voltage." In these cases, tests shall be performed at the levels in this column.

(12) For an outdoor circuit breaker, the point of user connection to the circuit breaker is the secondary terminal block point at which the wires from the circuit breaker operating mechanism components are connected to the user's control circuit wiring.

(13) For an indoor circuit breaker, the point of user connection to the circuit breaker is either the secondary disconnecting contact (where the control power is connected from the stationary housing to the removable circuit breaker) or the terminal block point in the housing nearest to the secondary disconnecting contact.

100.20.2 Rated Control Voltages and their Ranges for Circuit Breakers Solenoid-Operated Devices	
Rated Voltage	**Closing Voltage Ranges for Power Supply**
125 dc	90 - 115 or 105 - 130
250 dc	180 - 230 or 210 - 260
230 ac	190 - 230 or 210 - 260

Some solenoid operating mechanisms are not capable of satisfactory performance over the range of voltage specified in the standard; moreover, two ranges of voltage may be required for such mechanisms to achieve an acceptable standard of performance.

The preferred method of obtaining the double range of closing voltage is by use of tapped coils. Otherwise it will be necessary to designate one of the two closing voltage ranges listed above as representing the condition existing at the device location due to battery or lead voltage drop or control power transformer regulation. Also, caution should be exercised to ensure that the maximum voltage of the range used is not exceeded.

TABLE 8.0

Recommended Dissipation Factor/Power Factor at 20° C Liquid-Filled Transformers, Regulators, and Reactors Acceptance Test Values

Oil, Silicone, and Less-Flammable Hydrocarbon Maximum Value (Percent)	
New Power Transformers and Reactors	0.5%
New Distribution Transformers and Regulators	1.0%
Remanufactured Power Transformers and Reactors	1.0%
Remanufactured Distribution Transformers and Regulators	1.5%

In the absence of consensus standards dealing with transformer dissipation-factor or power-factor values, the NETA Standards Review Council suggests the above representative values.

TABLE 9.0

Insulating Fluid Limits

Table 100.4.3
Typical Values for Less-Flammable Hydrocarbon Insulating Liquid Received in New Equipment

ASTM Method	Test	Results		
		Minimum		Maximum
D1816	Dielectric breakdown voltage for 0.08 in gap, kV	40	34.5 kV class and below	-----
		50	Above 34.5 kV class	
		60	Desirable	
D1816	Dielectric breakdown voltage for 0.04 in gap kV	20	34.5 kV class and below	-----
		25	Above 34.5 kV class	
		30	Desirable	
D974	Neutralization number, mg KOH/g	-----		0.03
D877	Dielectric breakdown voltage Kv	30		-----
D924	AC loss characteristic (dissipation factor), % 25° C 100° C	 ----- -----		 0.1 1
D1533B	Water content, ppm	-----		25
D1524	Condition-visual	Clear		
D92	Flash point (° C)	275		-----
D92	Fire point (° C)	300[a]		-----
D971	Interfacial tension, mN/m, 25° C	38		-----
D445	Kinematic viscosity, mm^2/s, (cSt), 40° C	1.0×10^2 (100)		1.3×10^2 (130)
D1500	Color	-----		L2.5

ANSI/IEEE C57.121-1998, *IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers,* Table 3.

The test limits shown in this table apply to less-flammable hydrocarbon fluids as a class. Specific typical values for each brand of fluid should be obtained from each fluid manufacturer.

a. If the purpose of the HMWH installation is to comply with the NFPA 70 *National Electrical Code*, this value is the minimum for compliance with NEC Article 450.23.

TABLE 9.0 (CONTINUED)

Insulating Fluid Limits

Table 100.4.1 Test Limits for New Insulating Oil Received in New Equipment					
Mineral Oil					
Test	ASTM Method	≤ 69 kV and Below	>69 kV - < 230 kV	≥230 kV - < 345 kV	≥345 kV and Above
Dielectric breakdown, kV minimum	D877	30	30	30	
Dielectric breakdown, kV minimum @ 1mm (0.04") gap	D1816	25	30	32	35
Dielectric breakdown, kV minimum @ 2 mm (0.08") gap	D1816	45	52	55	60
Interfacial tension mN/m minimum	D971 or D2285	38	38	38	38
Neutralization number, mg KOH/g maximum	D974	0.015	0.015	0.015	0.015
Water content, ppm maximum	D1533	20	10	10	10
Power factor at 25° C, %	D924	0.05	0.05	0.05	0.05
Power factor at 100° C, %	D924	0.40	0.40	0.30	0.30
Color	D1500	1.0	1.0	1.0	0.5
Visual condition	D1524	Bright and clear	Bright and clear	Bright and clear	Bright and clear

ANSI/IEEE C57.106-2002, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*, Tables 1, 2, and 3.

Table 100.4.2 Test Limits for Silicone Insulating Liquid in New Transformers		
Test	ASTM Method	Acceptable Values
Dielectric breakdown, kV minimum	D877	30
Visual	D2129	clear, free of particles
Water content, ppm maximum	D1533	50
Dissipation/power factor, 60 hertz, % max. @ 25° C	D924	0.1
Viscosity, cSt @ 25° C	D445	47.5 – 52.5
Fire point, ° C, minimum	D92	340
Neutralization number, mg KOH/g max.	D974	0.01

ANSI/IEEE C57.111-1989 (R1995), *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*, Table 2

— END OF DOCUMENT —

SECTION 26 12 11

66KV CIRCUIT SWITCHER WITH INTEGRAL HV DISCONNECT

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Requirements specified in this section apply to all sections in Division 26 for the 66 kV Substation. This section supplements the requirements of other Divisions.

B. Specific reference is made to the following sections:
   1. Section 01 33 00, Submittal Procedures
   2. Section 26 05 01, Common Work Results – Electrical
   3. Section 26 08 05, Acceptance Testing – Electrical

1.2 SCOPE

A. Provide design, supply, manufacturing, factory testing, delivery to Site, installation, Site testing and Commissioning of two (2) 66kV 1200A SF6 circuit switchers with integral disconnect switch for the new 66/12.47kV distribution substation.

B. Refer to the following Drawings for the general arrangement and elevation for the circuit switcher mounting configuration.
   1. 66 kV Substation General Arrangement,
      Drawing No.: 1-0102-EGAD-Y001 Sheet 001
   2. 66 kV Substation Section A
      Drawing No.: 1-0102-EGAD-Y004 Sheet 001
   3. 66 kV Substation Section B
      Drawing No.: 1-0102-EGAD-Y005 Sheet 001
   4. 66 kV Substation A-Frame Mounted Equipment Details
      Drawing No.: 1-0102-EGAD-Y006 Sheet 001

1.3 CODES AND STANDARDS

A. General:
   1. Primary Standards:
      a. CSA C22.1-15, Canadian Electrical Code, Part I - Safety Standard for Electrical Installations
      b. City of Winnipeg, Electrical Bylaw No. 104
      c. CAN/CSA C22.3 NO. 1-15, Overhead Systems
      d. C22.2 NO. 41-13, Grounding and bonding equipment (Tri-national standard, with NMX-J-590-ANCE and UL 467)
      e. CSA-W59, Welded Steel Construction
   2. Reference Standards:
      a. IEEE 80-2013, IEEE Guide for Safety in AC Substation Grounding

B. Circuit Switcher:
   1. Primary Standards:
      a. IEEE C37.016-2006, IEEE Standard for AC High Voltage Circuit Switcher Rated 15.5 kV Through 245 kV
      b. ANSI/IEEE C37.09 (R2007), IEEE Standard Test Procedure for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis (Section 5)
   2. Reference Standards:
      a. IEEE C37.30-1997, IEEE Standard Requirements for High Voltage Switches
      b. IEEE C37.35, IEEE Guide for the Application, Installation, Operation and Maintenance of High Voltage Air Disconnecting and Load Interrupter Switches

1.4 APPROVED MANUFACTURERS AND STANDARD OF ACCEPTANCE

A. Approved Equipment Manufacturer: Southern States LLC, or approved equal in accordance with B8

NOTE: The equipment layouts, details, wiring, and dimensions depicted on the Drawings are based upon specific equipment types and Manufacturers that are defined on the Drawings and in the Specification.

Use of alternative equipment other than the "Standard of Acceptance" defined in this Specification is permitted. However, use of alternative equipment by the Contractor is subject to the Contractor having received formal " approved equal" status for the equipment in question from the Contract Administrator. Any changes to layouts, details, wiring and dimensions including all associated costs arising from the use of "Approved Equal" materials and equipment is and are the sole responsibility of the Contractor. Use of "Approved Equal" equipment shall result in a fully functional installation in accordance with the requirements and intent of the design documents.

B. Standard of Acceptance:
   1. Southern States LLC series CSH-B Horizontal Interrupter Circuit Switcher with integral vertical break switch and type CM-4AE motor operator, or approved equal in accordance with B8.
   2. Circuit switcher shall be rated as indicated in this Specification and as shown on the Drawings.

1.5 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, Specifications and datasheet and include product characteristics, performance criteria, and limitations.

C. Submit information and Drawings as listed below:
   1. Approval Drawings:
      a. The required approval drawings to be submitted shall include but not limited to the following:

1) Nameplate data and technical datasheet
2) Circuit switcher assembly, mounting details, bill of materials, dimension and weight
3) Layout and mounting details for the control cabinet
4) Schematics and connection diagrams for the circuit switcher operating mechanism, auxiliary supply and control cabinet

b. Drawings for approval shall be submitted within six (6) weeks after award of Contract in the the quantities and formats required by Section 01 33 00, Submittal Procedures.

2. A detailed circuit switcher manufacturing schedule shall be submitted within four (4) weeks after award of Contract. The Schedule shall detail each activity with start and finish dates, duration, etc. for each step of the design, manufacturing, factory and witness testing, delivery, site assembly, testing, and Commissioning of the circuit switcher.
3. Testing
   a. Provide a complete factory inspection and test plan for review and approval within eight (8) weeks after award of Contract.
   b. Provide notification in advance of all tests and inspections. Provide fourteen (14) days notice advance notice for tests and inspections during manufacturing, and twenty-one (21) days for final witness testing.
   c. Test data and reports shall be submitted within seven (7) days after completion of tests.
   d. Submit final test reports for acceptance prior to the units being shipped.
4. "As-Manufactured" drawings shall be submitted a minimum of fourteen (14) days prior to the scheduled shipping date. Final "As-Manufactured" package shall be submitted in the quantities and formats required by Section 01 33 00, Submittal Procedures.

D. Closeout Submittals:
   1. Provide submittals in accordance to Section 01 77 00, Closeout Procedures.
   2. Operation and Maintenance (O&M) manual shall be provided in six (6) sets of hardcopy binders and one (1) set on CD. The O&M manual shall include, but not limited to, the following:
      a. Test data and reports
      b. Shop Drawings
      c. Product submittals

1.6 SPARE PARTS

A. Provide a recommended tools and spare parts list as required by Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 DESIGN REQUIREMENTS

A. Service Conditions:
   1. Circuit switcher shall be suitable for outdoor installation with an ambient temperature range of plus or minus 40 degrees C.

2. Site elevation is < 1000 meters.
3. Radial ice thickness of 12.5 mm
4. Wind loading (horizontal) at 400 N/m^2.

B. Utility Available Fault Levels:
1. In Service Values (Current):
   a. Line L8 Normal Operation (St. Vital):
      1) Three Phase = 3.4 kA
      2) Single Line to Ground = 2.3 kA
   b. Line L33 Normal Operation (Laverendrye):
      1) Three Phase = 2.6 kA
      2) Single Line to Ground = 0.9 kA
   c. Line L14 Normal Operation (St. Vital):
      1) Three Phase = 3.9 kA
      2) Single Line to Ground = 2.8 kA
2. 40/50 Year Horizon Values:
   a. Line L8 Normal Operation (St. Vital):
      1) Three Phase = 5.3 kA
      2) Single Line to Ground = 1.6 kA
   b. Line L33 Normal Operation (Laverendrye):
      1) Three Phase = 2.8 kA
      2) Single Line to Ground = 1.8 kA
   c. Line L14 Normal Operation (St. Vital):
      1) Three Phase = 6.8 kA
      2) Single Line to Ground = 1.8 kA
   d. Networked Operation of Lines L8, L14 and L33:
      1) Three Phase = 12.1 kA
      2) Single Line to Ground = 3.2 kA

C. Circuit Switcher Electrical Rating:
1. Maximum Voltage: 72.5 kV
2. Basic Insulation Level: 350 kV (interrupter heads)
3. Basic Insulation Level: 350 kV (disconnect switch)
4. Continuous Current: 1200 A
5. Rated Interrupting Time: 5 cycles
6. Rated Duty Cycle: O-15sec-CO-15sec-CO
7. Primary RMS Interrupting Rating: 20 kA
8. Maximum Transformer Secondary Through-Fault: 4 kA
9. RMS Short Time Withstand (3 seconds): 40 kA
10. Phase-to-Phase Spacing: 2134 mm
11. Supply Voltages:
    a. 125V DC (motor and control)
    b. 120V AC (heater)

D. All control components required to operate the circuit switcher shall be mounted at a height readily accessible from ground level without the use of elevating devices.

E. The circuit switchers shall be SF6 gas filled interrupters with integral disconnect switch. Each interrupter shall be provided with a color-coded density gauge, a pressure relief device and a gas fill port.

F. The position indicator shall be provided to visually indicate the interrupter's true position at ground level.

G. The circuit switcher shall be furnished with porcelain insulator at the required Basic Insulation Level as outlined in Item 2.1.C.2.

H. The terminal pads shall be non-plated aluminum with four (4) NEMA drilling pattern.

I. The circuit switcher shall be furnished with shunt trip operating mechanism using spring stored energy for each pole and it shall be located under the rotating insulator stack.

J. A motor operating mechanism shall be provided to open and close the integral disconnect switch and to reset the opening and closing spring of the shunt trip mechanism.

K. The motor operating mechanism shall operate the circuit switcher including interrupter heads and disconnect blades from full-open position to full-close position and from full-close position to full-open position in less than 8 seconds.

L. The motor operating mechanism shall be capable of being padlocked in both the open and the closed positions. The ability to re-couple in an incorrect position shall be prevented.

M. The motor operator cabinet shall provide the following accessories in a NEMA 4 aluminum enclosure:
   1. Motor,
   2. Gearing,
   3. Open/Close pushbuttons,
   4. Anti-Pump relay,
   5. Local/Remote selector switch (cover mounted),
   6. Position indicating lights (cover mounted)
      green is closed, red is open – City of Winnipeg Indication Standard),
   7. Non-resettable Operations Counter,
   8. Minimum 5 N.O and 5 N.C auxiliary contacts including spares available for external use in accordance with the design Drawings,
   9. 120V AC cabinet heater with thermostat control,
   10. 120V AC cabinet lighting with switch,
   11. De-coupler for vertical pipe,
   12. Manual crank handle where insertion of handle shall automatically disconnect the motor circuit.

N. The disconnect switch shall be integral with the interrupter with each pole mounted on the circuit switcher base.

O. The disconnect switch contact surfaces shall be designed to provide effective contact and low contact resistance and shall be supplied with silvers of differing hardness so that galling does not occur.

P. The disconnect switch blades shall have a rotating motion upon opening to release contact pressure and upon closing to engage contact pressure, and cause wiping of the stationary jaw contacts to clean contaminants and shall be capable of operating under the specified ice build-up thickness.

Q. The disconnect switch blades shall be equipped with Arcing Whips (Quick Break Whips) to provide transformer magnetizing current breaking capability in the event that the switcher interrupting heads fail to operate on circuit switcher opening.

R. The design of the disconnect switch shall ensure the switch blades are positively held in closed position in the event of a short circuit condition.

S. The steel base of the circuit switcher with integral disconnect shall be provided with two (2) NEMA ground pads for connection of the switch bases to the substation ground grid.

2.2 TESTING

A. The circuit switcher shall be fully assembled as a three phase unit at the factory, adjusted, tested and timed as per ANSI C37.09 standard. The test shall include as a minimum but not limited to:
   1. Mechanical Operation
      a. The circuit switcher shall be opened and closed at least 50 times by its high speed operator at the factory. The timing, minimum and maximum voltages for each operation shall be recorded.
   2. Leak Test
      a. A SF6 leak test shall be performed to confirm the leak rate is less than 0.5 percent per year by volume.
   3. Resistance Test
      a. Contact Resistance Test
         1) A terminal to terminal resistance check measured in μΩ (micro-ohms) shall be performed on each interrupter using a 100A DC source. Test results shall be recorded.
      b. Heater Resistance Test
         1) The resistance of each heater shall be confirmed to be within Specifications and the values shall be recorded.
   4. Dielectric Test
      a. Control Circuit Dielectric Test
         1) The completely assembled and wired operator control circuit shall pass a dielectric test of 1500 V for 1 minute.
      b. Interrupter Dielectric Test
         1) Each interrupter shall pass a power frequency withstand test at 60 Hz for 1 minute. The required test value shall be ≥ three times the rated line-to-ground voltage.

B. Test data and reports shall submitted for review and acceptance within seven (7) days after completion of testing.

2.3 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - for Electrical.

PART 3 EXECUTION

3.1 MANUFACTURER'S INSTRUCTIONS

A. Compliance: comply with Manufacturer's written recommendations or Specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSTALLATION

A. Install the circuit switchers once the structural steel A-frame has been assembled in accordance with Manufacturer's instructions and Drawings.

B. Lift the circuit switcher poles on to the A-frame and bolt down the switch base to the structural steel.

C. Install and adjust insulators, interrupter heads, mechanisms and blades as required.

D. Check interrupter head SF_6 filling pressure. Do not operate the switch or interrupter heads if the SF_6 head pressure is not within Manufacturer's recommended limits. Operation outside of allowable pressure limits will damage the interrupter heads.

E. Install motor operator in accordance with the Drawings and Manufacturer's recommendations.

F. Assemble and adjust the switch linkages per Manufacturer's specifications.

G. Install the "key" interlocking plate and the key interlock unit (unit shall lock the blades in the "Open" position when the interlock unit plunger is extended. Wire and connect the key interlock unit limit switch to the motor operator in accordance with the Drawings.

H. Connect and install the vertical pipe to the motor operator cabinet.

I. Make required external control and power supply cable connections to the motor operator cabinet and to the external shunt trip junction boxes as per the Drawings.

J. Manually operate the switch and ensure that switch mechanisms and blades operate as a synchronized unit. Check and adjust correct engagement, seating, and rotation of disconnect blades into the stationary jaws.

K. Connect and terminate the 66kV ACSR cable to the terminal pads of the circuit switchers. Wire brush the aluminum pads on the lug and switch terminals and apply oxide inhibiting joint compound (such as Penetrox) prior to termination.

L. Connect bare copper ground conductor to the circuit switcher grounding pads, motor control cabinet, switch ground mat and any other required grounding connections to the substation ground grid system in accordance with the Drawings.

3.3 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 08 05 – Acceptance Testing – Electrical.

B. Compare equipment nameplate data with Drawings and Specifications.

C. Inspect physical and mechanical condition. Verify standoff insulators are clean.

D. Verify torque value on bolted joint connections according to Specification.

E. Verify all grounding connections are terminated per design Drawings and acceptable standard.

F. Verify correct blade alignment, blade penetration, blade rotation, travel stops and interrupter operation.

G. Verify correct operation of indication, control and interlock devices.

H. Perform testing described as a minimum but not limited to the following:
   1. Carry out following insulation tests for one minute using megger with 100,000 megohm scale and resulting insulation resistance corrected to base of 20 degrees C.
      a. Phase to phase with switch closed
      b. Phase to ground with switch closed
      c. Across each open pole
   2. Carry out insulation tests for all control wiring with respect to ground. The applied potential shall be 500V DC for one minute. Insulation resistance shall be corrected to base of 20 degrees C.
   3. Carry out the contact resistance across the disconnect switch blades and the interrupters between the bolted joint connections.

3.4 CLEANING

A. Keep workplace clean, and tidy.

B. On completion and verification of performance of installation, remove surplus materials, excess materials, rubbish, tools and equipment.

END OF SECTION

SECTION 26 12 13

LIQUID FILLED, HIGH VOLTAGE POWER TRANSFORMERS

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Requirements specified in this section apply to all sections in Division 26 for the 66 kV Substation. This section supplements the requirements of other Divisions.

B. Specific reference is made to the following sections:
   1. Section 01 33 00, Submittal Procedures
   2. Section 26 05 01, Common Work Results – Electrical
   3. Section 26 08 05, Acceptance Testing – Electrical

1.2 CODES AND STANDARDS

A. General:
   1. General:
      a. Primary Standards:
         1) CSA C22.1-15, Canadian Electrical Code, Part I - Safety Standard for Electrical Installations
         2) City of Winnipeg, Electrical Bylaw No. 104
         3) CAN/CSA C22.3 NO. 1-15, Overhead Systems
         4) C22.2 NO. 41-13, Grounding and bonding equipment (Tri-national standard, with NMX-J-590-ANCE and UL 467)
         5) CSA-W59, Welded Steel Construction
      b. Reference Standards:
         1) IEEE 80-2013, IEEE Guide for Safety in AC Substation Grounding
   2. Transformers:
      a. Primary Standards:
         1) CAN/CSA-C88-M90 (R2009), Power Transformers and Reactors
         2) IEEE Std C57.12.36-2007, IEEE Standard Requirements for Liquid-Immersed Distribution Substation Transformers
      b. Reference Standards:
         1) CAN/CSA-C88.1-96 (R2011), Power Transformer and Reactor Bushings
         2) IEEE Std C57.12.00-2010, IEEE Standard General Requirements for Liquid-immersed Distribution, Power and Regulation transformers
         3) IEEE Std C57.12.10-2010, IEEE Std C57.12.10-2010/Cor 1-2012, IEEE Std C57.12.10-2010/Cor2-2013, IEEE Standard Requirements for Liquid-Immersed Power Transformers
         4) IEEE Std C57.12.70-2011, IEEE Standard Terminal Markings and Connections for Distribution and Power Transformers
         5) IEEE Std C57.12.80-2010, IEEE Standard Terminology for Power and Distribution Transformers
         6) IEEE, C59.19.100, Guide for the Application of Power Apparatus Bushings

7) IEEE C57.19.00, General Requirements and Test Procedure for Power Apparatus Bushings
8) IEEE C57.19.01, Performance Characteristics and Dimensions for Outdoor Apparatus Bushings
9) IEEE C59.19.100, Guide for the Application of Power Apparatus Bushing
10) IEEE C57.91, Guide for Loading Mineral Oil Immersed Transformers
11) IEEE C57.98, Guide for Transformer Impulse Tests
12) IEEE C57.149-2012, IEEE Guide for the Application and Interpretation of Frequency Response Analysis for Oil-Immersed Transformers

3. Insulating Oil/Fluid:
   a. Primary Standards:
      1) CAN/CSA-C50-14, Mineral insulating oil, electrical, for transformers and switches
   b. Reference Standards:
      1) IEEE Std C57.121-1998 (R2009), IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers
      2) IEEE Std C57.147-2008, IEEE Guide for Acceptance and Maintenance of Natural Ester Fluids in Transformers
4. Instrument Transformers:
   a. Primary Standards:
      1) CAN3/CSA C13, Withdrawn, Instrument Transformers replaced by CAN/CSA C60044-1:07 (R2011)
      2) CAN/CSA-C60044-1:07 (R2011), Instrument Transformers - Part 1: Current Transformers (Adopted CEI/IEC 60044-1:1996 + A1:2000 + A2:2002, edition 1.2, 2003-02, with Canadian deviations)
   b. Reference Standards:
      1) IEEE/ANSI C57.13-2008, IEEE Standard Requirements for Instrument Transformers
      2) IEEE C57.13.2-2005 (R2010), IEEE Standard Conformance Test Procedure for Instrument Transformers
      3) IEEE C57.13.3-2005, IEEE Guide for Grounding of Instrument Transformer Secondary Circuits and Cases
      4) IEEE C57.13.1-2006, IEEE Guide for Field Testing of Relaying Current Transformers
5. Neutral Grounding Devices/Resistors (NGR):
   a. Primary Standards:
      1) CSA C22.2 NO. 295-15, Neutral grounding devices
   b. Reference Standards:
      1) ANSI/IEEE Std 32-1972 (R1997), IEEE Standard Requirements, Terminology, and Test Procedure for Neutral Grounding Device.
      2) IEEE Std. C57.32-2015 - IEEE Approved Draft Standard Requirements, Terminology, and Test Procedures for Neutral Grounding Devices.

1.3 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical. Documents shall be submitted in the quantities and formats required by Section 01 33 00, Submittal Procedures.

B. Product Data:
   1. Provide Manufacturer's printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit the following documents:
   1. Completed and signed data sheet A-0102-EDTS-Y001, Electrical Data Sheet, 66 kV - 12.47 kV Liquid Filled High Voltage Power Transformer.
   2. Preliminary drawings of transformer showing:
      a. Description and location of major accessories,
      b. Dimensions and weights including total weight and shipping weights,
      c. Quantity of insulating fluid in liters.
   3. Information for major items to be supplied with transformer (including those listed on data sheet A-0102-EDTS-Y001).
   4. Preliminary schedule for the design, approval, manufacture, test and delivery to Site.
   5. Proposed delivery plan including:
      a. Method of transport,
      b. Condition monitoring requirements (impact recorder, pressurization monitor),
      c. Transportation of insulating fluid,
      d. Listing of items to be shipped loose.

D. After Contract award, submit information and drawings as listed below:
   1. Approval Documents and Drawings
      a. Provide the following approval drawings to be submitted shall include, but not be limited to the following:
         1) Nameplate data,
         2) Confirmed Dimensions and weights,
         3) Transformer outline and shipping drawings and shipping weights,
         4) Layouts, schematics, and connection diagrams for the protection and control cabinet,
         5) Schematic and connection diagrams for the transformer auxiliary equipment,
         6) Complete technical information and supplier data sheets for major items to be supplied with the transformer (including those listed on data sheet A-0102-EDTS-Y001)
      b. Drawings for approval shall be submitted within six (6) weeks after award of Contract in the quantities and formats required by Section 01 33 00, Submittal Procedures.
   2. A detailed transformer manufacturing schedule shall be submitted within four (4) weeks after award of Contract. The Schedule shall detail each activity with start and finish dates, duration, etc. for each step of the design, manufacturing, factory and witness testing, delivery, site assembly, testing, and commissioning of the transformer.
   3. Test Plans:
      a. Provide a complete factory inspection and test plan for review and approval within eight (8) weeks after award of Contract.
      b. Provide notification in advance of all tests and inspections. Provide fourteen (14) days notice advance notice for tests and inspections during manufacturing, and twenty-one (21) days for final witness testing.
      c. Test data and reports shall be submitted within seven (7) days after completion of tests.

d. Submit final test reports for acceptance prior to the units being shipped.

4. "As-Manufactured" drawings shall be submitted a minimum of fourteen (14) days prior to the scheduled shipping date. Final "As-Manufactured" package shall be submitted in the quantities and formats required by Section 01 33 00, Submittal Requirements.

E. Closeout Submittals:
1. Provide submittals in accordance to Section 01 78 00 – Closeout Submittals.
2. Operation and Maintenance (O&M) manual(s) shall be provided the quantities and formats required by Section 01 78 23, Operation and Maintenance Data.
3. The O&M manual shall include, but not limited to, the following:
a. Production test certificates signed by Manufacturer certifying that materials comply with specified performance characteristics and physical properties,
b. Certified copies of reviewed test data and reports,
c. Certified, Signed and Approved drawings,
d. Product submittals,

1.4 MAINTENANCE

A. Provide a recommended tools and spare parts list as required by Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 TRANSFORMER CHARACTERISTICS

A. General Characteristics:
1. Type and Ratings:
a. Transformer(s) shall be 3 phase, 60 Hz, liquid-filled suitable for pad mounting. The connections, cooling, and ratings shall be as per Data Sheet A-0102-ETDS-Y001. The requirements of CSA-C88, Sections 5, 6 and 7 shall apply.
2. Temperature Rise:
a. Limits of temperature rise shall be 65 degrees C average and 80 degrees C hottest spot, above ambient as per CSA-C88, Section 9. Other provisions of that section shall also apply.
3. Impedance:
a. Impedance shall be expressed on the rated (KNAN) MVA base, and shall be as indicated on the Data Sheet(s).
4. Short Circuit Capability:
a. Transformers shall be designed in accordance with IEEE C57.12.00, with a primary short circuit level as per Table 11. An acceptable alternative is CSA-C88, Table 3A.
5. Insulation Levels:
a. Minimum insulation levels for winding and bushing shall be as specified on the Data Sheet A-0102-ETDS-Y001.
b. Neutral bushings shall have same insulation as line bushings. All other requirements shall be as per CSA-C88, Section 11.

6. Overload Capability:
   a. Transformers with 65°C temperature rise shall have overload capabilities in accordance with NEMA Publication TR98.
7. Sound Level:
   a. Sound levels shall not exceed the values in CSA-C88, Table 8.
8. Tolerances:
   a. Tolerances shall be as per CSA-C88, Table 9.

B. Specific Characteristics:
   1. See Data Sheet A-0102-EDTS-Y001 for Details.
   2. High Voltage Bushings:
      a. Bushings shall be sized, rated and mounted to provide isolation clearances to the lowest part of the exposed live high voltage metallic parts of the bushing (cap/connector) above the underside of the transformer baseplate as indicated in the Data Sheets.
   3. Secondary Cable Connection Box:
      a. The 12.47 kV secondary phase and neutral bushings shall be located in a cable connection box located on the opposite side of the HV bushings. The cable box shall be constructed to NEMA 4 standard with removable front bolt-on, gasketed cover. A pair of heavy duty handles shall be welded to the cover for ease of removal.
      b. The dimension of the overall cable connection box and cable gland plate shall provide sufficient wiring space and cable bending radius for bottom outgoing two (2) runs of 3 conductors, 350 MCM, 15kV, 133 percent insulation copper TECK90 cables.
      c. Provide a 6.35 mm thick x 50.8 mm wide copper ground bus along entire width of the bottom of the cable box for ground connections.
   4. High Voltage Arresters:
      a. Gapless metal oxide station class surge arresters shall be provided on the HV of the transformer. Refer to Data Sheet A-0102-ETDS-Y001 for arrester ratings and data.
      b. Provide required mounting brackets and standoffs on the transformer tank to mount the arresters. The brackets shall be removable.
      c. Surge arresters shall be mounted on insulated bases/ standoffs to provide clearances to the exposed live high voltage metallic parts of the arrester of 6500mm (minimum) above the underside of the transformer baseplate as indicated in the Data Sheet.
      d. Arrestors shall be mounted such that their high voltage terminals are at the same approximate vertical height as the HV bushing terminals.
      e. Provide grounding bus for the surge arresters. Grounding bus shall be mounted on standoff insulators and routed to the bottom of the transformer tank with the bus end drilled to a accommodate a NEMA standard 2 hole pattern cable lug.
      f. Grounding connections between the arrestor bases and the arrestor grounding bus shall be by the transformer Manufacturer.
      g. Grounding cable connections and cable lugs between the arrestor grounding bus and the substation ground grid shall be by the Contractor.
   5. Neutral Grounding Resistor (NGR):
      a. See Data Sheet A-0102-EDTS-Y001 for details.
      b. Rating: 7200 V line-neutral voltage, 100 A, duty rated for 10 seconds.

c. Maximum permissible temperature rise of the enclosure, components (excepting resistor elements), and discharge air shall not exceed the values shown in Table 8 of CSA C22 No. 295-2015 for “Duty Rated Assemblies”.
d. Temperature rises for resistor materials shall not exceed the values shown in Table 9 of CSA C22 No. 295-2015 for a duty of “> 10 min” and the resistor material utilized.
e. Temperature rises shall be based on an ambient of 40 degrees C.
f. The NGR shall be “isolated by elevation” by mounting it on the top of the secondary cable connection box.
g. The NGR shall be insulated for the full transformer secondary line-to-line voltage.
h. The NGR shall be labelled and marked in accordance with the requirements of CSA C22 No. 295-2015, Section 5.
i. Connections between the transformer neutral X_0 bushing and the NGR HV terminal and sensing resistor shall be by the transformer Manufacturer.
j. Grounding connection between the NGR LV terminal and the substation ground grid shall be by the Contractor. The NGR shall be connected to the substation ground grid by a separate connection.

6. Transformer Accessories:
   a. See Data Sheet A-0102-EDTS-Y001 for details.
   b. Lifting eyes and jacking pad shall be provided at appropriate location on the transformer tank.
   c. Access to internal elements in the tank shall be provided by suitably sized handholes or manholes.
   d. Liquid temperature thermometer (in Celsius) with a drag hand for maximum indicated temperature (resettable), alarm and tripping contacts.
   e. Liquid level indicator shall be a magnetic oil level gauge with alarm and tripping contacts.
   f. Winding temperature thermometer (in Celsius) with a drag hand for maximum indicated temperature (resettable), alarm and tripping contacts.
   g. Emergency pressure relief device shall be sized to prevent damage to the tank in case of an internal fault. One (1) sealed tripping contact provided to trip when the pressure relief device operates. Insulating fluid discharged from pressure relief device operation shall be directed downwards towards the oil containment and away from operational area and equipment.
   h. A Rapid Pressure relay shall be installed provided to detect a rapid pressure rise in the transformer tank. The relay shall include a seal-in relay with two (2) output contacts for tripping purposes. Seal-in relay shall be located in the protection and control panel
   i. Pressure vacuum bleeder control and indication device shall be installed on the transformer tank and located to allow readability at ground level.
   j. For liquid drain, a valve closed with a threaded plug shall be provided.
   k. For liquid sampling, a valve closed with a threaded plug shall be provided. Note that a combination liquid drain/sampling valve c/w threaded plug(s) is also acceptable.
   l. Provide top and bottom connections, closed with threaded plugs for liquid treatment connection.

m. Lockable indicator type shut-off valves shall be provided on the top and bottom radiator connection pipes if detachable radiators are provided. Radiators shall be provided with drain and vent plugs.
n. Grounding pads with 4-hole NEMA configuration, drilled and tapped for 13 mm bolt connection shall be provided on opposite sides of the transformer tank. The minimum threaded depth of the holes shall be 13mm.
o. Transformer core ground connection shall be brought out of the tank to permit core insulation testing if and when required.

7. Protection and Control Cabinet:
   a. NEMA 4 panel with a hinged door, 3 point latching system, pad-lockable handle and reinforced polycarbonate viewing window shall be provided to house the transformer auxiliary device wiring, and other control protection relays and devices as indicated on Data Sheet A-0102-ETDS-Y001. The Protection and Control cabinet shall be designed, constructed, supplied, wired, connected, and tested by the transformer Vendor.
   b. A swing out inner panel shall be provided in the cabinet to mount the transformer protection relay (SEL-787), the NGR monitor relay (SE-330), rapid pressure rise seal-in relay, lockout relay (86T) the FT1 OR FT14 test switches and the CT ratio selection terminal blocks. Refer to Item 2.8 “Protection and Control” and Data Sheets for relay and control specifications.
   c. The protection and control cabinet shall be insulated and shall be provided with thermostatically controlled heater(s), door activated panel lighting (LED based) and a 15A 120V GFCI duplex receptacle. The heater shall be sized to maintain a minimum internal cabinet temperature of at least 0 degrees C at an ambient outdoor temperature of minus 40 degrees C for proper operation of the relays and shall be thermostatically controlled.
   d. A back panel shall be installed in the cabinet for mounting terminal blocks on DIN rails, CT ratio selection terminal blocks, auxiliary relays, fuseholders, wireway and other accessories for the transformer. Wiring from the inner panel to the back panel shall be fastened in a loom and provided with sufficient slack to allow opening of the swing panel without undue stress on the wiring in the wire loom. Wire loom to the swing panel shall be designed such that the wiring flexes in “torsion” rather than in “bending” when the swing panel is opened/closed.
   e. A copper grounding bar 6.3mm thick by 50mm wide, minimum 450mm long, shall be located at the bottom of the cabinet. Both ends of the ground bar shall be drilled with a NEMA Std 2 hole bolt pattern to permit the attachment of a 4/0 AWG ground cable to the substation ground grid (the grounding cable and compression lugs required for the connection of the ground bus to the substation ground grid shall be provided and installed by the Contractor).
   f. The cabinet inner swing panel, back panel, doors, and other parts requiring bonding shall be bonded to the ground bar. All relay safety grounds shall be individually bonded to the ground bar in accordance with the relay Manufacturer’s recommendations.
   g. CT secondary wiring shall be minimum 10 AWG insulated stranded copper, ring type wire lugs shall be used for all current transformer secondary circuits.
   h. Control wiring (other than CT secondary) shall be minimum 14 AWG stranded copper.

i. Terminal blocks TB-1. TB-2, TB-3, etc. shall be Weidmuller, Entrelec or approved equal in accordance with B8. A minimum of 10 percent spare terminal blocks (including those indicated on the DC Protection Schematics shall be provided.

2.2 PROTECTION AND CONTROL
REFER TO DRAWINGS AND DATA SHEET A-0102-ETDS-Y001 FOR DETAILS AND THE "STANDARD OF ACCEPTANCE", MANUFACTURER, MODEL AND ORDERING CODES.

A. The protection and control relays for the 66 kV transformer and the associated 66 kV circuit switcher shall be located in the protection and control cabinet as indicated in Item 2.1.B.6 in this Specification and on the Data Sheet.

B. The Transformer Manufacturer/Vendor shall provide the supply, install, test, and program the protection and control system as indicated on the 66kV Single Line, Three Lines, and AC/DC schematic Drawings, the Data Sheet, and as detailed in this Specification.

C. The protection and control equipment shall be follows:
1. Transformer Differential Relay:
   a. Solid state multifunction microprocessor based transformer differential relay with protective elements/functions as indicated on the Drawings and Data Sheet.
   b. The relay power supply voltage shall be plus or minus 125V DC.
   c. The "on-transformer" protective/sensing device alarm and trip signals shall be connected to the inputs of the relay, and wired as indicated on the Drawings.
   d. Bushing CTs (primary, secondary, and neutral) shall be wired to the relay CT inputs via the CT Ratio Selection Terminal Blocks and the type FT test switches as indicated on the Drawings.
   e. The relay front panel "Open" and "Close" pushbuttons shall be programmed to provide manual open and close signals to the 66kV circuit switcher. Provide a 15 second time delay between activation of the front panel pushbutton and output of the open and close relay output contacts to the Circuit Switcher.
   f. Relay element protective set points will be provided by the Contract Administrator.
   g. The vendor shall engage the services of the relay Manufacturer's Engineering Services Division to provide relay programming services for the transformer differential protection relay.
2. Neutral Grounding Monitor Relay:
   a. The relay shall be a solid state multifunction microprocessor based NGR monitoring relay with protective elements/functions as indicated on the Drawings and Data Sheet.
   b. The relay power supply voltage shall be plus or minus 125V DC.
   c. The required sensing resistor and NGR internal CT shall be provided in conjunction with the NGR monitoring relay.
   d. The 200:5 NGR internal CT secondary shall be wired to the relay CT inputs via the CT Ratio Selection Terminal Blocks and the type FT test switches as indicated on the Drawings.
   e. Relay "dip switch" settings for the specified NGR monitoring relay shall be as indicated on the Drawings.

3. Lockout Relay:
   a. The transformer/circuit switcher lockout relay shall be an electrically tripped, manually reset, electromechanical relay with a minimum of three (3) dual contact decks in addition to those required for the disconnection of the electrical release when in the tripped state.
4. Current and DC Test Switches:
   a. Potential test switches shall be ABB type FT1 or FT14. The switch pole handles shall be color coded as indicated on the Data Sheet.
   b. Current test switches shall be shorting make-before-break for each CT input and shall be ABB type FT1 or FT14. The switch pole handles shall be color coded as indicated on the Data Sheet(s).
5. CT Ratio Selection Terminal Blocks:
   a. The CT ratio selection terminal blocks shall be 6-pole with shorting bar and shall be rated 600V AC/DC, 75A when terminated with ring type terminal. The CT Ratio Selection Terminal Blocks shall be Marathon 1500 Series or approved equal in accordance with B8.

D. The transformer Manufacturer/Vendor shall supply and install all required components, including but not limited to, fuse holders, fuses, blocking/steering diodes, wire labels, equipment tags, and other wiring accessories required for of the 66kV protection and control system. Wires shall be numbered as indicated on the Drawings. Vendor's wiring numbering scheme for equipment not detailed on the Drawings but required for a complete operational system shall comply with that shown on the Drawings. Vendor shall use 600-699 series numbers for this wiring.

E. Equipment numbering and tagging shall be as indicated on the Data Sheet(s).

2.3 FINISH

A. Transformer shall be primed and painted to ASA70 light gray.

B. Finish tank exterior in accordance with CSA-C88.

2.4 APPROVED MANUFACTURERS AND STANDARD OF ACCEPTANCE

A. Approved Equipment Manufacturer:
   1. Partner Technologies Incorporated (PTI), or Approved Equal in accordance with B8 Substitutes.

NOTE: The equipment layouts, details, wiring, and dimensions depicted on the Drawings are based upon specific equipment types and manufacturers that are defined on the Drawings, in the Specification and on the Data Sheet.

Use of alternative equipment other than the "Standard Of Acceptance" defined in this Specification is permitted. However, use of alternative equipment by the Contractor is subject to the Contractor having received formal " approved equal" status for the equipment in question from the Contract Administrator. Any changes to layouts, details, wiring and dimensions including all associated costs arizing from the use of " Approved Equal" materials and equipment is and are the sole responsibility of the Contractor. Use of " Approved Equal" equipment shall result in a fully functional installation in accordance with the requirements and intent of the design documents.

B. Standard of Acceptance:
   1. As indicated on Data Sheet A-0102-EDTS-Y001.

2.5 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01 – Common Work Results - Electrical, and as indicated on the Data Sheet(s).

B. Provide metallic (stainless steel) Transformer Nameplate (Rating Plate) in accordance with CSA-C88 on the outside of the transformer and on the inside of the transformer in the cable compartment.

C. Equipment (protective relays, transformer mounted devices, test switches, ratio selection terminal blocks, etc.), nameplates and tags shall be as indicated in the Specifications, Drawings and on Data Sheet A-0102-EDTS-Y001.

D. Nameplates and equipment tags shall be in accordance with the requirements of Section 26 05 01, sub-section 2.3. – Equipment Identification.

E. Provide a Size 11 lamacoid equipment identification on the outside of the transformer, example as follows:

XFMR-Y701 10 MVA, 66 kV-12.47kV, 3Ø, 4W FED FROM MB HYDRO LINE L8

F. Provide warning nameplates on the front of the control and protection panel which if fed by multiple sources of power. The warning lamacoids shall have white lettering on a red background. The wording shall list all AC and DC power sources including source voltage, source panel and panel circuit numbers, where control compartments are equipped with internal disconnecting fuses list fuses. Wording shall conform to the requirements of the CEC, typical example as follows:

WARNING

120VAC & 125VDC POWER PRESENT FROM MULTIPLE SOURCES

REFER TO DRAWINGS AND ISOLATE BEFORE WORKING WITHIN

POWER SOURCES

120VAC -	PANEL	C722	CCT 7
		C722	CCT 11
125VDC -	PANEL	C753	CCT 1/3

CONTROL PANEL 125VDC INTERNAL DISCONNECTING FUSES

FU1-P/FU1-N
FU2-P/FU2-N

G. Nameplates shall be attached by means of rivets, drive pins, or self-tapping screws. Note that the use of “sheet metal” or other screws having sharp points is NOT acceptable.

H. Submit a detailed list of all proposed nameplates and equipment tags for review prior to fabrication.

2.6 SOURCE QUALITY CONTROL

A. Submit to the Contract Administrator standard factory test certificates for each material in accordance with Specification Section 26 08 05, Acceptance Testing - Electrical.

B. Perform a sweep frequency test (SFRA) in accordance with IEEE C57.149-2012 on all transformer terminals at the Vendor’s factory prior to loading the transformer for shipment.
   1. The SFRA test shall be the last test performed immediately before loading on the transport truck/trailer and shipping and shall be performed with the transformer in its “transport” configuration.
   2. The SFRA test shall be the first test performed immediately upon receipt and unloading at the site. This test shall be performed with the transformer in its “transport” configuration and before any other testing or work is undertaken on the transformer.
   3. Record (for each separate test):
      a. Sweep frequency test waveforms and response waveforms,
      b. Complete test equipment data including; Manufacturer, model, serial number of the test equipment, and all test equipment,
      c. Provide details (photographs and detailed sketches or drawings) of the testing configurations, and connections.

d. Include copies of the above data (both hard copy printouts and electronic files) with the transformer at shipment, forward a separate copy to the Contractor in accordance with the requirements of Section 26 08 05, Acceptance Testing - Electrical, Section 01 33 00, Submittal Procedures, and Section 26 05 01, Common Work Results – Electrical.

4. Sweep frequency tests will be used to confirm that the transformer has not suffered damage in transport, and if necessary assist in the analysis of transport induced damage, by comparing the results of the test sets in 1. And 2. above.

PART 3 EXECUTION

3.1 MANUFACTURER'S INSTRUCTIONS

A. Compliance: comply with Manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSTALLATION

A. Inspect the transformer on receipt for evidence of damage during shipping.

B. Perform a sweep frequency test on all transformer terminals on receipt of transformer on Site in accordance with 2.6.b above. Confirm that the transformer has not suffered damage in transport by comparing the sweep frequency test waveforms taken on receipt against those taken at the Vendor’s plant prior to shipment of the transformer.

C. Install transformers in accordance with Contract Documents and Manufacturer's installation instructions, coordinate work with other trades.

D. Ensure concrete transformer pad has cured for a minimum of 28 days before installation of transformers.

E. Use spreader bars on slings when lifting transformers into place.

F. Set and secure transformer in place rigid, plumb, and square.

G. Fasten the transformer to the pad using the fixing holes provided by the transformer Manufacturer.

H. Assemble and “dress” the transformer as required in accordance with the Manufacturer’s instructions and requirements.

I. Ensure internal connections are mechanically tight.

J. Process the transformer as required in accordance with the Manufacturer's instructions. Provide all required insulating fluid processing equipment, including, but not limited to, pumps, heaters, vacuum roughing and diffusion pumps, and controls required for the proper on-site filling and vacuum degassing of a liquid filled power transformer. Insulating fluid handling hoses and equipment shall be compatible with the insulating fluid and shall be metallic and rated for full vacuum.
Engage the services of a company qualified to provide the required full-vacuum leak testing, processing, and filling of the transformer.

K. Make required external cable connections. See Cable Connection Drawings and Cable Schedule.

L. Connect transformer case grounding pads, lightning arrestor grounding bus, control and protection panel ground bar, and any other required grounding connections to the substation ground mat system in accordance with the Drawings.

M. Set the transformer Tap Switch taps to produce rated secondary voltage at no-load.
DANGER: The Transformer Tap Switch is an "**De-energized, Off-Load Device,**" and must **not be operated** unless the transformer is fully **Isolated and De-energized**. The Transformer Tap Switch shall be **padlocked at all times** excepting when the transformer is Isolated and De-Energized for the purpose of changing taps, and shall be immediately re-locked after changing taps and prior to energization.
Tap changing operations shall only be performed by trained qualified skilled workers who are familiar with these requirements and who are working under a written and approved procedure.

3.3 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 08 05, Acceptance Testing - Electrical.

B. Perform resistance measurements through bolted connections with a low-resistance ohmmeter.

C. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply voltage in accordance with Manufacturer's published data. All other connected windings shall be grounded. Calculate polarization index.

D. Perform turns-ratio tests at all tap positions.

E. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with test equipment Manufacturer's published data.

F. Perform power-factor or dissipation-factor tests on each bushing.

G. Perform excitation-current tests in accordance with the test equipment Manufacturer's published data.

H. Measure the resistance of each winding at the designated tap position.

I. Remove the core ground strap, measure and record the core insulation resistance at 500 V DC, replace the core ground strap.

J. Sample the transformer internal gas blanket. Measure and record the percentage of oxygen in the transformer inert gas blanket.

K. Remove a sample of insulating liquid in accordance with ASTM D 923. The sample shall be tested for the following:
   1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
   2. Acid neutralization number: ANSI/ASTM D 974
   3. Specific gravity: ANSI/ASTM D 1298
   4. Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285
   5. Color: ANSI/ASTM D 1500
   6. Visual Condition: ASTM D 1524
   7. Water in insulating liquids: ASTM D 1533. (Required on 25 kV or higher voltages and on all silicone-filled units.)
   8. Measure power factor or dissipation factor in accordance with ASTM D 924.

L. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.

M. Instrument Transformers (CTs):
   1. Verify that all required grounding and shorting connections provide contact.
   2. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable.
   3. Perform insulation-resistance test of each current transformer and wiring-to-ground at 1000 volts dc for one minute.
      For units with solid-state components that cannot tolerate the applied test voltage, follow the device Manufacturer's recommendations.
   4. Perform a polarity test of each current transformer in accordance with ANSI/IEEE C57.13.1.
   5. Perform a ratio-verification test using the voltage or current method in accordance with ANSI/IEEE C57.13.1.
   6. Perform an excitation test on transformers used for relaying applications in accordance with ANSI/IEEE C57.13.1.
   7. Measure current circuit burdens at transformer terminals.
   8. Measure insulation power factor or dissipation factor in accordance with test equipment Manufacturer's published data.
   9. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3. (IEEE Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases).

N. Inspect and clean bushings and insulators.

O. Check oil level and temperature indicators.

P. Check that transformer Tap Switch is set correctly to achieve the required secondary no-load voltage as specified. After the transformer is at least 20-30 percent fully loaded measure secondary voltage at the 12.47 kV main switchgear in the electrical building. If necessary adjust the tap switch to achieve the required voltage. See warning in 3.2.L above.

Q. Inspect for oil leaks and rusting.

R. Inspect oil level.

S. Check for grounding and neutral continuity between primary and secondary circuits of transformer.

3.4 CLEANING

A. Keep workspace clean and tidy

B. On completion and verification of performance of installation, remove surplus materials, excess materials, rubbish, tools and equipment.

3.5 SUPPLEMENTS

A. The items listed below form a part of this Specification.
   1. Data Sheet A-0102-EDTS-Y001.

3.6 WARRANTY

A. The Contractor shall provide a complete warrantee (covering all aspects of the installation) for all equipment, labor, materials supplied for the 66 kV Substation, 15 kV switchgear, Gensets, and Genset Load Bank, valid for a period of 4 years from the date of the completed and fully signed (by all parties) Form 104.

END OF SECTION

THE CITY OF WINNIPEG WATER AND WASTE DEPARTMENT	**ELECTRICAL DATA SHEET 66 kV - 12.47 kV LIQUID FILLED HIGH VOLTAGE POWER TRANSFORMER**	CH2MHILL SNC·LAVALIN

Data Sheet No: **A-0102-EDTS-Y001**								Revision	
Project no. **WPG/474248**	REVISIONS							**No.**	**Date**
Bid Opp. No.	Rev	Date	Description	By	Chk	App		**0**	**2017/04/05**
Project Name: **SEWPCC Upgrading/Expansion**	00	17/04/05	Issued for Construction – 976-2016	KO	CWB				
Site: **South End Water Pollution Control Center**								Page	
Specification No. **26 12 13**								**1 of 14**	

INSTRUCTIONS TO BIDDERS:

1) Data and information requested by this data sheet shall be submitted to the City of Winnipeg Contract Administrator within 30 days of the award of contract.
2) A request for equal during the bid process shall utilize this fully completed data sheet as part of the submission process.
3) Perform work in accordance with the latest (at the time of contract signing) relevant codes and standards from the regulatory agencies and organizations indicated in the referenced Specification, Drawings, or as indicated below.
4) In the event of conflict between the reference codes and standards, drawings, specifications or Data Sheets, obtain clarification before proceeding with the work.
5) All listed technical requirements below are firm requirements of the Contract. These data sheets are a required submission as part of the formal shop drawing submittal process and satisfactory completion in conformance with specification requirements will be a mandatory part of that review. Any deviations shall be subject to acceptance or rejection by the Contract Administrator.
6) Vendors shall avoid the use of ambiguous words such as **"Noted", "Confirm", "Confirmed" "Ok", check marks or the use of an "X"** in responding to data sheets.
The use of the words **"YES"**, **"NO"**, a **numerical value**, a **clarifying comment** or **a reference** is acceptable.

Row	Description	Design Requirements	Vendor Confirmation	Rev.
1	**GENERAL**			
2	TRANSFORMER EQUIPMENT NUMBERS	**XFMR-Y701 XFMR-Y702**		
3	QUANTITY REQUIRED	**2 TOTAL**		
4	VENDOR QUOTATION NUMBER	VENDOR TO SPECIFY		
5	VENDOR QUOTATION DATE	VENDOR TO SPECIFY		
6	***TRANSFORMER STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
7	***EQUIPMENT MANUFACTURER***	***PARTNER TECHNOLOGIES INCORPORATED (PTI)***		
8	**OPERATING ENVIRONMENT / PHILOSOPHY**			
9	ELEVATION ABOVE SEA LEVEL (METERS)	< 304		
10	EQUIPMENT LOCATION (INDOORS / OUTDOORS)	OUTDOORS		
11	UNUSUAL CONDITIONS (GASSES & DUSTS)	NOT APPLICABLE		
12	HAZARDOUS AREA CLASSIFICATION	UNCLASSIFIED		
13	AMBIENT DESIGN TEMPERATURE RANGE (°C)	±40		
14	SEISMIC CLASSIFICATION	0		
15	OPERATING SCHEDULE	CONTINUOUS WITH SCHEDULED MAINTENANCE		
16	**MEASUREMENT SYSTEM**			
17	METRIC / IMPERIAL	METRIC		
18	**REFERENCE SPECIFICATION**			
19	SPECIFICATION SECTION NUMBER	26 12 13 – LIQUID FILLED, HIGH VOLTAGE POWER TRANSFORMERS		
20	**APPLICABLE STANDARDS**			
21	SEE SPECIFICATON 26 12 13, SECTION 1.2	COMPLIANCE REQUIRED VENDOR TO CONFIRM		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
22	**REFERENCE DRAWINGS**	1-0102-ESLD-Y001-001 1-0102-ETLD-Y001-001 1-0102-ETLD-Y001-002 1-0102-EWDG-Y001-001 1-0102-EWDG-Y001-002 1-0102-EWDG-Y001-003 1-0102-EWDG-Y002-001 1-0102-EWDG-Y002-002 1-0102-EWDG-Y002-003 1-0102-EWDG-Y003-001 1-0102-EWDG-Y003-002 1-0102-EWDG-Y004-001 1-0102-EWDG-Y004-002		
23	**UTILITY AVAILABLE FAULT LEVELS**			
24	**IN SERVICE VALUES (CURRENT)**			
25	LINE L8 NORMAL OPERATION (ST VITAL)			
26	THREE PHASE (KA)	3.4		
27	SINGLE LINE TO GROUND (KA)	2.3		
28	LINE L33 NORMAL OPERATION (LAVERENDRYE)			
29	THREE PHASE (KA)	2.6		
30	SINGLE LINE TO GROUND (KA)	0.9		
31	LINE L14 NORMAL OPERATION (ST VITAL)			
32	THREE PHASE (KA)	3.9		
33	SINGLE LINE TO GROUND (KA)	2.8		
34	**40/50 YEAR HORIZON VALUES (FUTURE)**			
35	LINE L8 NORMAL OPERATION (ST VITAL)			
36	THREE PHASE (KA)	5.3		
37	SINGLE LINE TO GROUND (KA)	1.6		
38	LINE L33 NORMAL OPERATION (LAVERENDRYE)			
39	THREE PHASE (KA)	2.8		
40	SINGLE LINE TO GROUND (KA)	1.8		
41	LINE L14 NORMAL OPERATION (ST VITAL)			
42	THREE PHASE (KA)	6.8		
43	SINGLE LINE TO GROUND (KA)	1.8		
44	NETWORKED OPERATION OF LINES L8, L14, L33			
45	THREE PHASE (KA)	12.1		
46	SINGLE LINE TO GROUND (KA)	3.2		
47	**TRANSFORMER RATINGS**			
48	POWER (MVA KNAN)	10		
49	PHASE (SINGLE, THREE, 3 x SINGLE PHASE)	THREE PHASE		
50	PRIMARY VOLTAGE (kV)	66		
51	SECONDARY VOLTAGE (kV)	12.47		
52	FREQUENCY (Hz)	60		
53	TEMPERATURE RISE (°C)	65		
54	COOLING TYPE	KNAN		
55	PRIMARY WINDING CONNECTION	DELTA		
56	PRIMARY WINDING BIL (kV)	350		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
57	SECONDARY WINDING CONNECTION	WYE, RESISTANCE GROUNDED		
58	SECONDARY WINDING BIL (kV)	110		
59	VECTOR GROUP	Dyn1		
60	**TAPS**			
61	LOCATION	PRIMARY		
62	TYPE	DE-ENERGIZED, (SEE ALSO "**TAP SELECTOR SWITCH**" BELOW)		
63	RATING	2 @ 2½% FCAN, 2 @ 2½% FCBN		
64	DESIGN IMPEDANCE	6.5%		
65	POS. SEQ. IMPEDANCE (%), KNAN	VENDOR TO SPECIFY		
66	ZERO SEQ. IMPEDANCE (%), KNAN	VENDOR TO SPECIFY		
67	X/R RATIO	VENDOR TO SPECIFY		
68	SOUND LEVEL AT 100% LOAD KNAN (dB_a)	VENDOR TO SPECIFY		
69	LOAD LOSSES @ 85°C KNAN (kW)	VENDOR TO SPECIFY		
70	NO LOAD LOSSES @ 100% RATED VOLTAGE (kW)	VENDOR TO SPECIFY		
71	FLUX DENSITY @ 100% RATED VOLTAGE (T)	VENDOR TO SPECIFY		
72	SHORT CIRCUIT WITHSTAND	(SEE UTILITY FAULT LEVEL DATA ABOVE)		
73	MULTIPLE OF KNAN CURRENT	VENDOR TO SPECIFY		
74	MAXIMUM FAULT DURATION	VENDOR TO SPECIFY		
75	**DIMENSIONS AND WEIGHTS**			
76	**DIMENSIONS (EACH TRANSFORMER)**			
77	OVERALL LENGTH (mm)	VENDOR TO SPECIFY		
78	OVERALL WIDTH (mm)	VENDOR TO SPECIFY		
79	OVERALL HEIGHT (mm)	VENDOR TO SPECIFY		
80	**WEIGHTS (EACH TRANSFORMER)**			
81	CORE AND COILS (kg)	VENDOR TO SPECIFY		
82	TANK AND FITTINGS (kg)	VENDOR TO SPECIFY		
83	INSULATING LIQUID (kg)	VENDOR TO SPECIFY		
84	RADIATORS (kg)	VENDOR TO SPECIFY		
85	**TOTAL (kg)**	VENDOR TO SPECIFY		
86	**SHIPPING DIMENSIONS (EACH TRANSFORMER)**			
87	TRANSFORMER – L x W x H (mm)	VENDOR TO SPECIFY		
88	RADIATORS – L x W x H (mm)	VENDOR TO SPECIFY		
89	ITEMS SHIPPED LOOSE – L x W x H (mm)	VENDOR TO LIST IN DETAIL		
90	**SHIPPING WEIGHTS (EACH TRANSFORMER)**			
91	TRANSFORMER SHIPPED (FILLED WITH INSULATING FLUID/WITHOUT INSULATING FLUID)	VENDOR TO SPECIFY		
92	MAIN TRANSFORMER /w INSULATING FLUID (kg)	VENDOR TO SPECIFY		
93	MAIN TRANSFORMER /wo INSULATING FLUID (kg)	VENDOR TO SPECIFY		
94	ITEMS SHIPPED LOOSE (kg)	VENDOR TO LIST IN DETAIL		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
95	**TRANSFORMER CONSTRUCTION**			
96	LIQUID PRESERVATION	SEALED TANK		
97	PROVISIONS FOR VACUUM FILLING/PROCESSING	REQUIRED (FULL VACUUM)		
98	**INSULATING FLUID**	VEGETABLE ESTER BASED		
99	INITIAL FILL OF INSULATING FLUID	REQUIRED		
100	INSULATING LIQUID VOLUME /TRANSFOMER (Liters)	VENDOR TO SPECIFY		
101	METHOD OF INSULATING FLUID SHIPMENT (DRUMS, TANKER, TRANSFORMER SHIPPED PRE- FILLED)	VENDOR TO SPECIFY		
102	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
103	***MANUFACTURER***	***CARGILL***		
104	***TYPE***	***ENVIROTEMP FR3***		
105	**PRESSURE VACUUM BLEEDER**	REQUIRED		
106	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
107	MANUFACTURER	VENDOR TO SPECIFY		
108	CATALOGUE NUMBER	VENDOR TO SPECIFY		
109	**TRANSFORMER FILL AND DRAIN/SAMPLING VALVES**	REQUIRED		
110	FILL VALVE			
111	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
112	MANUFACTURER	VENDOR TO SPECIFY		
113	CATALOGUE NUMBER	VENDOR TO SPECIFY		
114	EQUIPPED WITH “SAFETY” PIPE PLUG	REQUIRED		
115	DRAIN / SAMAPLING VALVE			
116	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
117	MANUFACTURER	VENDOR TO SPECIFY		
118	CATALOGUE NUMBER	VENDOR TO SPECIFY		
119	EQUIPPED WITH “SAFETY” PIPE PLUGS	REQUIRED		
120	BOLT-ON COVERS FOR MANHOLES/HANDHOLES	REQUIRED		
121	TANK GROUNDING PADS (QTY 2, ON OPPOSITE CORNERS OF TRANSFORMER)	4-HOLE NEMA STD		
122	HV ARRESTER GROUND BUS	REQUIRED WITH 2-HOLE NEMA STANDARD CONNECTION		
123	GROUNDING CABLE LUGS (ARRESTOR BASES TO ARRESTOR GROUND BUS)	COPPER, LONG BARREL, DOUBLE CRIMP (BURNDY YA OR YA2N SERIES OR APPROVED EQUAL IN ACCORDANCE WITH B8)		
124	GASKET MATERIAL	VENDOR TO SPECIFY		
125	EXTERIOR FINISH	EPOXY ENAMEL		
126	EXTERIOR COLOUR	ASA 70, LIGHT GRAY		
127	INTERIOR FINISH	EPOXY ENAMEL		
128	INTERIOR COLOUR	WHITE		
129	DETACHABLE RADIATORS	VENDOR TO SPECIFY		
130	RADIATOR ISOLATION VALVES	REQUIRED IF RADIATORS DETACHABLE		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
131	TYPE	VENDOR TO SPECIFY		
132	MANUFACTURER	VENDOR TO SPECIFY		
133	LOCKABLE	REQUIRED		
134	**WINDINGS**			
135	PRIMARY WINDING - MATERIAL	COPPER		
136	PRIMARY WINDING - TYPE	DISK		
137	SECONDARY WINDING - MATERIAL	COPPER		
138	SECONDARY WINDING - TYPE	DISK		
139	SECONDARY WINDING - INSULATION	NON-GRADED		
140	**HIGH VOLTAGE PRIMARY BUSHINGS (H1, H2, H3)**			
141	LOCATION	TOP/COVER MOUNTED		
142	MANUFACTURER	VENDOR TO SPECIFY		
143	STANDARD OF CONFORMANCE (ANSI, EEMAC)	ANSI/IEEE		
144	TYPE	PORCELAIN		
145	CATALOGUE NUMBER	VENDOR TO SPECIFY		
146	VOLTAGE RATING (kV)	66 (MINIMUM)		
147	CURRENT RATING (A)	VENDOR TO SPECIFY		
148	BIL LEVEL (kV)	350 (MINIMUM)		
149	CREEPAGE DISTANCE (mm)	VENDOR TO SPECIFY		
150	VERTICAL ISOLATION OF UNGUARDED EXPOSED LIVE HIGH VOLTAGE PARTS ABOVE UNDERSIDE OF TRANSFORMER BASE	4000mm (MINIMUM) (***NOTE 2***)		
151	TERMINAL PAD	4-HOLE NEMA STD		
152	**HV SURGE ARRESTERS**			
153	LOCATION	BRACKET MOUNTED ADJACENT TO HV BUSHINGS, SEE DRAWINGS AND SPECIFICATIONS		
154	MANUFACTURER	VENDOR TO SPECIFY		
155	TYPE	STATION CLASS		
156	RECOVERY VOLTAGE MCOV (kV)	57		
157	CATALOGUE NUMBER	VENDOR TO SPECIFY		
158	VERTICAL ISOLATION OF UNGUARDED EXPOSED LIVE HIGH VOLTAGE PARTS ABOVE UNDERSIDE OF TRANSFORMER BASE	4000mm (MINIMUM), (***NOTE 3***)		
159	**HIGH VOLTAGE BUSHING CURRENT TRANSFORMERS**			
160	MANUFACTURER	VENDOR TO SPECIFY		
161	QUANTITY	3 (PER TRANSFORMER)		
162	RATIO	600:5A MULTI-RATIO		
163	ACCURACY	C200 (MINIMUM) C400 (PREFERRED), VENDOR TO SPECIFY		
164	**LOW VOLTAGE BUSHING CURRENT TRANSFORMERS**			
165	MANUFACTURER	VENDOR TO SPECIFY		
166	QUANTITY	3 (PER TRANSFORMER)		
167	RATIO	600:5A MULTI-RATIO		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
168	ACCURACY	C200 (MINIMUM) C400 (PREFERRED), VENDOR TO SPECIFY		
169	**NEUTRAL BUSHING CURRENT TRANSFORMER**			
170	MANUFACTURER	VENDOR TO SPECIFY		
171	QUANTITY	1 (PER TRANSFORMER)		
172	RATIO	600:5A MULTI-RATIO		
173	ACCURACY	C200 (MINIMUM) C400 (PREFERRED), VENDOR TO SPECIFY		
174	**NEUTRAL BUSHING CURRENT TRANSFORMER**			
175	MANUFACTURER	VENDOR TO SPECIFY		
176	QUANTITY	1 (PER TRANSFORMER)		
177	RATIO	600:5A MULTI-RATIO		
178	ACCURACY	C200 (MINIMUM) C400 (PREFERRED), VENDOR TO SPECIFY		
179	**NEUTRAL GROUNDING RESISTOR (NGR)**			
180	LOCATION	MOUNTED ON TOP OF SECONDARY TERMINAL BOX, SEE DRAWINGS AND SPECIFICATIONS		
181	MANUFACTURER	VENDOR TO SPECIFY		
182	RATING, L-N (V)	7200		
183	SHORT TIME CURRENT RATING	100A FOR 10 SECONDS		
184	RESISTOR MATERIAL	STAINLESS STEEL		
185	ENCLOSURE	NEMA 3R, VENTILATED		
186	ENCLOSURE MATERIAL	STAINLESS STEEL		
187	X_0 BUSHING TO NGR CABLE	15KV INSULATED RW90 CONDUCTOR, BY TRANSFORMER VENDOR		
188	SENSING RESISTOR TO X_0 BUSHING CABLE	15KV INSULATED RW90 CONDUCTOR BY TRANSFORMER VENDOR		
189	NGR GROUND CABLE	4/0 AWG BARE GROUNDING CABLE (DIRECT TO GROUND MAT), BY CONTRACTOR		
190	**NGR CURRENT TRANSFORMER**			
191	LOCATION	IN NGR ENCLOSURE		
192	MANUFACTURER	VENDOR TO SPECIFY		
193	CT RATIO	200:5A		
194	CT ACCURACY	C200		
195	**NGR SENSING RESISTOR**			
196	LOCATION	IN NGR ENCLOSURE		
197	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
198	***MANUFACTURER***	***LITTELFUSE STARTCO***		
199	***PART NO***	***ER-15KV***		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
200	**TRANSFORMER SECONDARY TERMINAL BOX**			
201	TYPE	NEMA 4		
202	LOCATION	SIDE MOUNTED ON OPPOSITE SIDE OF TRANSFORMER FROM PRIMARY BUSHINGS		
203	SECONDARY AND NEUTRAL BUSHING ENTRANCE	SIDE, THROAT FED		
204	SPACE REQUIRED FOR PHASE X_1, X_2, X_3 AND NEUTRAL X_0 CABLE 15 KV TERMINATIONS	REQUIRED, MINIMUM 838 mm BUSHINGS TO BOTTOM OF ENCLOSURE		
205	NEUTRAL X_0 BUSHING TO NGR AND X_0 BUSHING TO SENSING RESISTOR CONDUCTOR LOCATION	SIDE OR BACK, (**TOP EXIT NOT ACCEPTABLE**) VENDOR TO SPECIFY		
206	X_0 BUSHING TO NGR AND X_0 BUSHING TO SENSING RESISTOR CONDUCTORS TYPE & SIZE	1c #1 AWG, 15kV, BY TRANSFORMER VENDOR, VENDOR TO SPECIFY		
207	TERMINATION COMPARTMENT ACCESS PROVISIONS	CONTINUOUS HINGE, BOLTED, GASKETED DOOR(S) c/w PADLOCKABLE 3 POINT LATCHES (SPLIT DOORS PREFERRED). BOLTS TO BE TAMPERPROOF (PENTAHEAD)		
208	INTERNAL GROUND BAR	REQUIRED, 6.35 x 50.8 mm, FULL WIDTH, TAPPED FOR WIRE LUGS, DRILLED FOR NEMA STD 2-HOLE LUG @ BOTH ENDS		
209	**MEDIUM VOLTAGE SECONDARY BUSHINGS (X1, X2, X3)**			
210	LOCATION	SIDE MOUNTED IN NEMA 3R SECONDARY TERMINAL BOX (SEE SPECIFICATION)		
211	MANUFACTURER	VENDOR TO SPECIFY		
212	STANDARD OF CONFORMANCE (ANSI, EEMAC)	ANSI/IEEE		
213	TYPE	PORCELAIN		
214	CATALOGUE NUMBER	VENDOR TO SPECIFY		
215	VOLTAGE RATING (kV)	12.47 (MINIMUM)		
216	CURRENT RATING (A)	VENDOR TO SPECIFY		
217	BIL LEVEL (kV)	110 (MINIMUM)		
218	CREEPAGE DISTANCE (mm)	VENDOR TO SPECIFY		
219	TERMINAL PAD	4-HOLE NEMA STD		
220	**MEDIUM VOLTAGE NEUTRAL BUSHING (X0)**			
221	LOCATION	SIDE MOUNTED IN NEMA 3R SECONDARY TERMINAL BOX (SEE SPECIFICATION)		
222	MANUFACTURER	VENDOR TO SPECIFY		
223	STANDARD OF CONFORMANCE (ANSI, EEMAC)	ANSI/IEEE		
224	TYPE	PORCELAIN, FULLY RATED		
225	CATALOGUE NUMBER	VENDOR TO SPECIFY		
226	VOLTAGE RATING (kV)	12.47 (MINIMUM)		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
227	CURRENT RATING (A)	VENDOR TO SPECIFY		
228	BIL LEVEL (kV)	110 (MINIMUM)		
229	CREEP DISTANCE (mm)	VENDOR TO SPECIFY		
230	TERMINAL PAD	4-HOLE NEMA STD		
231	**OUTGOING PHASE CABLES**			
232	EXIT LOCATION	BOTTOM		
233	X_1, X_2, X_3 OUTGOING PHASE CABLE TYPE & SIZE	SEE DRAWINGS, SPPLIED AND INSTALLED BY CONTRACTOR		
234	X_1, X_2, X_3 OUTGOING PHASE CABLE LUGS	COPPER, LONG BARREL, DOUBLE CRIMP (BURNDY YA2N SERIES) OR EQUAL, BY CONTRACTOR		
235	REMOVABLE OUTGOING PHASE CABLE GLAND PLATE	REQUIRED, FULL SIZE OF BOTTOM OF TERMINATION BOX		
236	**INFRARED VIEWING/SCANNING WINDOWS**	REQUIRED		
237	LOCATION	SIZED AND LOCATED TO PERMIT SCANNING OF CABLE TERMINATIONS AT SECONDARY BUSHINGS, SEE SPECIFICATIONS		
238	TYPE	REINFORCED POLYMER IR/VISIBLE WINDOW TYPE c/w INTEGRAL COVER		
239	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
240	***MANUFACTURER***	***IRISS***		
241	***SERIES***	***CAP-ENV*** (PREFERRED), OR ***VPFR*** (ACCEPTABLE)		
242	MINIMUM SIZES (OPTIC WINDOW SIZE)	CAP-ENV-4 (96.8 x 96.8 mm), VPFR-75 (76 mm Ø)		
243	**CONTROL & RELAYING CABINET (CONTROL PANEL)**			
244	TYPE	NEMA 4		
245	LOCATION	SIDE MOUNTED ON TRANSFORMER (SEE DRAWINGS)		
246	CONTROL PANEL DOOR	CONTINUOUS HINGE, GASKETED DOOR c/w PADLOCKABLE 3 POINT LATCH		
247	DOOR VIEWING WINDOW	REQUIRED, REINFORCED LEXAN, SIZED AND LOCATED TO PERMIT VIEWING OF PROTECTION RELAYS WITHOUT OPENING DOOR, VENDOR TO SPECIFY		
248	CONTROL AND POWER CABLE ENTRANCE	BOTTOM		
249	WIRING/CONDUITS/CABLES TO TRANSFORMER MOUNTED DEVICES (49T, 63P, 63Q, 71Q, 71T)	SIDES OR BACK OF PANEL (TOP ENTRY NOT ACCEPTABLE), VENDOR TO SPECIFY		
250	REMOVABLE CABLE GLAND PLATE	NOT REQUIRED		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
251	THERMAL INSULATION	REQUIRED, SEE SPECIFICATIONS		
252	PANEL INTERNAL HEATING	REQUIRED, SEE SPECIFICATIONS		
253	THERMOSTATIC CONTROLS	REQUIRED, SEE SPECIFICATIONS		
254	PROTECTION RELAYS: SEL-787 (RLY-Y701-1 AND RLY-Y702-1), SE-330 (RLY-Y701-2 AND RLY-Y702-1), 86Q (RLY-Y701-3 AND RLY-Y701-3), 86T (RLY-Y701-11 AND RLY-Y702-11)	MOUNTED ON INTERNAL "SWING OUT SUB-PANEL" OR EQIVALENT, VENDOR TO SPECIFY		
255	TEST SWITCHES AC & DC	MOUNTED ON INTERNAL "SWING PANEL" OR EQIVALENT, VENDOR TO SPECIFY		
256	TERMINAL BLOCKS (INCLUDING THOSE REQUIRED FOR VENDOR'S PURPOSES	MOUNTED ON INTERIOR OF BACK OR SIDES OF CABINET, VENDOR TO SPECIFY		
257	CT RATIO SELECTION TERMINAL BLOCKS	MOUNTED ON INTERIOR OF BACK OR SIDES OF CABINET, VENDOR TO SPECIFY		
258	INTERIOR LIGHTING AND CONVENIENCE RECEPTACLE	REQUIRED, LIGHTING CONTROLLED BY DOOR OPERATED SWITCH, ON SINGLE CIRCUIT		
259	WIRING	SEE SPECIFICATIONS		
260	EQUIPMENT TAGS	RELAYS AND TEST SWITCHES TO BE LABELLED ON BOTH FRONT AND REAR OF SWING PANEL		
261	INTERNAL GROUND BAR	REQUIRED, TAPPED FOR WIRE LUGS, DRILLED FOR NEMA STD 2-HOLE LUG @ BOTH ENDS, SEE SPECIFICATIONS		
262	**TRANSFORMER AUXILIARY EQUIPMENT**			
263	**TOP INSULATING FLUID TEMPERATURE (ANSI DEVICE 71T)**	REQUIRED		
264	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
265	MANUFACTURER	VENDOR TO SPECIFY		
266	CATALOGUE NUMBER	VENDOR TO SPECIFY		
267	ALARM CONTACT (HI)	1 (N.O.)		
268	ALARM SETPOINT (°C)	VENDOR TO SPECIFY		
269	TRIP CONTACT (HI-HI)	1 (N.O.)		
270	TRIP SETPOINT (°C)	VENDOR TO SPECIFY		
271	**WINDING TEMPERATURE (ANSI DEVICE 49T)**	REQUIRED		
272	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
273	MANUFACTURER	VENDOR TO SPECIFY		
274	CATALOGUE NUMBER	VENDOR TO SPECIFY		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
275	ALARM CONTACT (HI)	1 (N.O.)		
276	ALARM SETPOINT (°C)	VENDOR TO SPECIFY		
277	TRIP CONTACT (HI-HI)	1 (N.O.)		
278	TRIP SETPOINT (°C)	VENDOR TO SPECIFY		
279	**OIL LEVEL INDICATOR (ANSI DEVICE 71Q)**	REQUIRED		
280	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
281	MANUFACTURER	VENDOR TO SPECIFY		
282	CATALOGUE NUMBER	VENDOR TO SPECIFY		
283	ALARM CONTACT (LO)	1 (N.O.)		
284	ALARM SETPOINT	VENDOR TO SPECIFY		
285	TRIP CONTACT (LO-LO)	1 (N.O.)		
286	TRIP SETPOINT	VENDOR TO SPECIFY		
287	**PRESSURE RELIEF DEVICE (ANSI DEVICE 63P)**	REQUIRED		
288	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
289	MANUFACTURER	QUALITROL		
290	CATALOGUE NUMBER	VENDOR TO SPECIFY		
291	OUTPUT CONTACT	1 (N.O.)		
292	**RAPID PRESSURE RISE RELAY (ANSI DEVICE 63Q)**	REQUIRED		
293	LOCATION	ON TRANSFORMER, VENDOR TO SPECIFY		
294	MANUFACTURER	QUALITROL		
295	CATALOGUE NUMBER	VENDOR TO SPECIFY		
296	**TAP SELECTOR SWITCH**	REQUIRED		
297	TYPE (POSITIVE DETENT, DE-ENERGIZED OPERATION w/ TAP POSITION INDICATION)	REQUIRED		
298	QUANTITY REQUIRED	1 (PER TRANSFORMER)		
299	MANUFACTURER	VENDOR TO SPECIFY		
300	CATALOGUE NUMBER	VENDOR TO SPECIFY		
301	PADLOCKABLE	REQUIRED		
302	WARNING PLATE INDICATING " **DANGER** **DO NOT OPERATE TAP SELECTOR SWITCH WITH TRANSFORMER ENERGIZED** " OR SIMILAR APPROVED WORDING	REQUIRED, MOUNT AT TAP SWITCH OPERATING HANDLE, BLACK LETTERING ON RED BACKGROUND, MINIMUM 12mm LETTERING		
303	**PROTECTION AND CONTROL EQUIPMENT**			
304	**TRANSFORMER DIFFERENTIAL RELAY (MULTIFUNCTION, ELEMENTS 50W1, 51W1, 50W2, 51W2, 50N, 51N, 87T, 87TG, 43/CS)**			
305	EQUIPEMENT TAGS	RLY-Y701-1 RLY-Y702-1 SEE DRAWINGS & SPEC.		
306	LOCATION	CONTROL PANEL		
307	QUANTITY REQUIRED	1 (PER TRANSFORMER)		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
308	**STANDARD OF ACCEPTANCE (SEE NOTE 1)**			
309	***MANUFACTURER***	***SCHWEITZER ENGINEERING LABORATORIES***		
310	***MODEL***	***SEL-787 (NO EQUALS)***		
311	***ORDERING CODE***	***07871X1ACA3AA5850401***		
312	**NGR - MONITORING RELAY (ANSI DEVICES 51G, 59N)**			
313	EQUIPMENT TAGS	RLY-Y701-2 RLY-Y702-2 SEE DRAWINGS & SPEC.		
314	LOCATION	CONTROL PANEL		
315	QUANTITY REQUIRED	1 (PER TRANSFORMER)		
316	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
317	***MANUFACTURER***	***LITTELFUSE STARTCO***		
318	***MODEL***	***SE-330 (NO EQUALS)***		
319	***ORDERING CODE***	***SE330-04-01***		
320	**RAPID PRESSURE RISE SEAL-IN RELAY (ANSI DEVICE 86Q)**			
321	SEAL-IN RELAY EQUIPMENT TAGS	RLY-Y701-3 RLY-Y702-3 SEE DRAWINGS & SPEC.		
322	LOCATION	CONTROL PANEL		
323	QUANTITY REQUIRED	1 (PER TRANSFORMER)		
324	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
325	***MANUFACTURER***	***QUALITROL***		
326	***CATALOGUE NUMBER***	***909-300-01***		
327	**LOCKOUT RELAY (ANSI DEVICE 86T)**			
328	EQUIPMENT TAG	RLY-Y701-11 RLY-Y702-11 SEE DRAWINGS & SPEC.		
329	LOCATION	CONTROL PANEL		
330	QUANTITY REQUIRED	1 (PER TRANSFORMER)		
331	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
332	***MANUFACTURER***	***ELECTROSWITCH***		
333	***CATALOGUE NUMBER***	***7803E***		
334	**AC CURRENT TEST SWITCHES**			
335	EQUIPMENT TAGS	Y701-1-ACTS1 Y702-1-ACTS1 SEE DRAWINGS & SPEC.		
336	LOCATION	CONTROL PANEL		
337	QUANTITY REQUIRED	1 (PER TRANSFORMER)		
338	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
339	***MANUFACTURER***	***ABB***		
340	***MODEL***	***FT14***		
341	TERMINALS	SCREW		
342	NO. OF CURRENT POLES	12		
343	NO. OF VOLTAGE POLES	0		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
344	STYLE NO.	N/A, ORDER BY POLE ARRANGEMENT AND HANDLE COLOR		
345	POLE ARRANGEMENT	C2-C2 C1-C1 C7-C7 X0 X0 C2-C2 C1-C1 C7-C7		
346	POLE HANDLE COLORS	R-R C-C 7-7 X X R-R C-C 7-7		
347	EQUIPMENT TAGS	Y701-2-ACTS1 Y702-2-ACTS1 SEE DRAWINGS & SPEC.		
348	LOCATION	CONTROL PANEL		
349	QUANTITY REQUIRED	1 (PER TRANSFORMER)		
350	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
351	***MANUFACTURER***	***ABB***		
352	***MODEL***	***FT1***		
353	COVER	CLEAR		
354	TERMINALS	SCREW		
355	NO. OF CURRENT POLES	4		
356	NO. OF VOLTAGE POLES	0		
357	STYLE NO.	N/A, ORDER BY POLE ARRANGEMENT AND HANDLE COLOR		
358	POLE ARRANGEMENT	X0 X0 C8-C8 X0 X0 C5-C5 X0 X0		
359	POLE HANDLE COLORS	X X 8-8 X X 5-5 X X		
360	**DC TEST SWITCHES**			
361	EQUIPMENT TAGS	Y701-1-DCTS1 Y701-1-DCTS2 Y702-1-DCTS1 Y702-1-DCTS2 SEE DRAWINGS & SPEC.		
362	LOCATION	CONTROL PANEL		
363	QUANTITY REQUIRED	1 (PER TRANSFORMER)		
364	***STANDARD OF ACCEPTANCE (SEE NOTE 1)***			
365	***MANUFACTURER***	***ABB***		
366	***MODEL***	***FT14***		
367	COVER	CLEAR		
368	TERMINALS	SCREW		
369	NO. OF CURRENT POLES	0		
370	NO. OF VOLTAGE POLES	14		
371	STYLE NO.	FT4A14T14CN4001		
372	**NAMEPLATES**			
373	TRANSFORMER RATING PLATE IN ACCORDANCE WITH CSA-C88-M90 (R2009), CLAUSE 17 – RATING PLATE	REQUIRED		
374	TRANSFORMER TAGS & NAMEPLATES	AS INDICATED ABOVE SEE SPECIFICATIONS FOR SPECIFIC REQUIREMENTS AND SIZES		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
375	EQUIPMENT TAGS & NAMEPLATES	EQUIPMENT TAGS AS INDICATED ABOVE SEE SPECIFICATIONS FOR SPECIFIC REQUIREMENTS AND SIZES		
376	**CONNECTIONS AND WIRING**			
377	WIRING	AS PER SPECIFICATIONS		
378	COMMUNICATIONS	NOT REQUIRED		
379	COMMUNICATIONS PROTOCOL	NOT REQUIRED		
380	**TESTING**			
381	TYPE TESTS	AS PER SPECIFICATIONS AND STANDARDS		
382	MANUFACTURERS ROUTING TRANSFORMER TESTING	AS PER SPECIFICATIONS AND STANDARDS		
383	WITNESS TESTING	AS PER SPECIFICATIONS AND STANDARDS		
384	**OTHER TECHNICAL REQUIREMENTS**	AS SPECIFIED		
385	PROVIDE COMPLIANCE STATEMENT TO SPECIFICATION REQUIREMENTS	VENDOR TO PROVIDE		

	ENGINEERING NOTES:	**Rev.**
386	1 ***STANDARD OF ACCEPTANCE*** THE EQUIPMENT LAYOUTS, DETAILS, WIRING, AND DIMENSIONS DEPICTED ON THE DRAWINGS ARE BASED UPON SPECIFIC EQUIPMENT TYPES AND MANUFACTURERS THAT ARE DEFINED ON THE DRAWINGS AND IN THE SPECIFICATIONS. THE USE OF ALTERNATIVE EQUIPMENT OTHER THAN THE "STANDARD OF ACCEPTANCE" DEFINED MAY BE PERMITTED, HOWEVER, USE OF ALTERNATIVE EQUIPMENT BY THE CONTRACTOR IS SUBJECT TO THE CONTRACTOR HAVING RECEIVED FORMAL "APPROVED EQUAL" STATUS FOR THE EQUIPMENT IN QUESTION FROM THE CONTRACT ADMINISTRATOR. THE PROCESS REQUIRED TO OBTAIN FORMAL "APPROVED EQUAL" STATUS IS DEFINED AND DETAILED IN THE SPECIFICATIONS. ANY CHANGES TO LAYOUTS, DETAILS, WIRING AND DIMENSIONS INCLUDING ALL ASSOCIATED COSTS ARIZING FROM THE USE OF "APPROVED EQUAL" MATERIALS AND EQUIPMENT IS AND ARE THE SOLE RESPONSIBILITY OF THE CONTRACTOR. USE OF "APPROVED EQUAL" EQUIPMENT SHALL RESULT IN A FULLY FUNCTIONAL INSTALLATION IN ACCORDANCE WITH THE REQUIREMENTS AND INTENT OF THE DESIGN DOCUMENTS.	
387	2 PROVIDE EXTRA LENGTH BUSHINGS, MOUNT MUSHINGS ON TURRETS, OR BOTH AS REQUIRED TO GIVE SPECIFIED ISOLATION DISTANCE.	
388	3 PROVIDE BASE SPACER UNDER ARRESTER AS REQUIRED TO GIVE SPECIFIED ISOLATION DISTANCE.	

Row	Description	Design Requirements	Vendor Confirmation	Rev.

SIGNATURES: (Both signatures below are required)

Authorised Representative at Quoting Agency (Vendor)

Name [PRINT]	Signature	Position	Date

Authorised Representative at Manufacturer's Works (Manufacturer)

Name [PRINT]	Signature	Position	Date

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SECTION 26 12 14

TRANSFORMER INSULATING LIQUID CONTAINMENT SYSTEMS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA C22.1-15, Canadian Electrical Code, Part I - Safety Standard for Electrical Installations

B. City of Winnipeg, Electrical Bylaw No. 104

C. CAN/CSA-C88-M90 (R2009), Power Transformers and Reactors

D. IEEE Std C57.12.36-2007, IEEE Standard Requirements for Liquid-Immersed Distribution Substation Transformers

E. CAN/CSA-C50-14, Mineral Insulating Oil, Electrical, for Transformers and Switches.

F. IEEE Std C57.121-1998 (R2009), IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers

G. IEEE Std C57.147-2008, IEEE Guide for Acceptance and Maintenance of Natural Ester Fluids in Transformers

H. IEEE 980-2013, IEEE Guide for Containment and Control of Oil Spills in Substations.

I. US/EPA SPCC, 40 CFR 112.7(C) General requirements for Spill Prevention, Control, and Countermeasure Plans.

J. CAN3/CSA Z299.3, Quality Assurance Program – Category 3

K. ISO 9000 Series, Quality System Standards

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer’s printed product literature, Specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit Shop Drawings and indicate:
   1. Manufacturer’s plan, section, layout and installation detail drawings.
   2. Manufacturer’s detailed volumetric containment capacity calculations.
   3. Weight, including oil.
   4. Installation and handling instructions.

1.3 MAINTENANCE

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

PART 2 PRODUCTS

2.1 TRANSFORMER INSULATING LIQUID CONTAINMENT SYSTEM

A. The containment system shall be a passive transformer insulating liquid containment system, not requiring instrumentation or control systems.

B. The insulating liquid containment system shall consist of an impermeable liner anchored to an excavated earthen berm and/or affixed to a concrete wall or other concrete structure(s) and a floor "Liquid Mat" attached to the liner consisting of a needle-punched non-woven geotextile mat infused with one or more layers of proprietary immobilizing material suitable for use with the insulating liquid employed in the transformer.
   1. The liner shall be impermeable to both water and the insulating liquid, and
   2. The floor (Liquid Mat) shall allow the passage of water (rain, melt-water, runoff, etc.) but shall seal and block the flow of the transformer insulating liquid in the event of an insulating liquid spill, leak, or expulsion of the insulating liquid from the transformer.

C. The Manufacturer of the oil containment system shall be a company that specializes in the manufacturing and installation/supervision of needle-punched non-woven geotextile mats for secondary insulating liquid containment with a minimum of nine (9) years of experience.

D. Materials and products shall be fabricated under strict quality control and good manufacturing practices and shall be free from defects in material and workmanship.

E. Provide and install water drainage piping as indicated on the Drawings for draining the liquid containment basin. Drainage pipe shall, if required, contain an auxiliary inline filter.

F. Materials:
   1. Liquid Mat for use with Mineral Oil based Transformer Insulating Fluids:

Trade Name -	Sorbweb™
Top layer -	Black needle-punched non-woven geotextile
Middle layer -	Copoly-005, Woven polyethylene scrim
Bottom layer -	Black needle-punched non-woven geotextile
Nominal mass -	3265 g/m^2 ASTM D5993
Nominal polymer loading -	2800 g/m^2
Peel strength -	0.7 kgf (ASTM D6496)
Grab tensile strength -	80 kgf (ASTM D4632)
Puncture Resistance-	60 kgf (ASTM D6241)
CBR puncture strength -	371.5 ±41.0 kgf (ASTM D6241)
Compressive strength-	137.3 ±13.5 kgf (ASTM D6364)

Tear strength MD -	51.3 ±4.1 kgf (ASTM D4533)
Tear strength CD -	83.0 ±13.5 kgf (ASTM D4533)
Hydraulic conductivity (@ 5 psi, 20°C) -	5x10 cm/s ASTM D5084
UV resistance -	70% @ 500 hours ASTM D4355 (applies to non-woven components only)

2. Liquid Mat for use with Vegetable Oil (Ester) based Transformer Insulating Fluids:

Trade Name –	Esterweb™
Top layer –	White needle-punched micro porous non-woven geotextile
Middle layer –	Copoly-002
Loading –	20kg/m^2

Two Geomesh Spacer

Total Mass per Unit area –	290 g/m^2 (EN ISO 9864)
Nominal Thickness –	18mm
Grab Tensile Machine Direction –	204 kgf (EN ISO 10319)
Grab Tensile Cross Direction –	122 kgf (EN ISO 10319)
Polymer 3D Core –	PA6
Polymer Density –	100 kg/m^3
Temperature Resistance –	-40°C to 80°C
Inflammability –	B2 (DIN 4102)
Structure Type –	Open
Void Ratio –	>95%
UV Resistance –	Good
Toxicity –	None

Bottom layer –	Black needle-punched non-woven geotextile

3. Liner:

Reinforced polyethylene constructed of pre-stressed high density polyethylene tapes woven into a stable network and coated in a thin film of linear low density polyethylene.

Nominal thickness -	0.61 mm (ASTM D1777)
Coating thickness -	0.061 mm (ASTM D1777)
Nominal Weight -	340 g/m2
Tensile strength MD -	1500 N (ASTM D5034)
Tensile strength CD -	1500 N (ASTM D5034)
Elongation -	15% (ASTM D751)
Low temperature bend -	55°C (ATM D2136)
Burst strength-	4480 kPa (ASTM D3786)
UV resistance -	>90% after 2000 hours (ASTM G151-00)
Heat bonded seam strength (manufacturer weld) -	21.0 N/mm (ASTM D7747) 25.4 mm strip.

G. Performance:
   1. Insulating liquid detected below the insulating liquid containment system after a spill shall be within allowable quantities determined by national and/or provincial regulations following an oil spill. Needle-punched non-woven geotextile mat shall seal upon insulating fluid coming in contact with it. System shall have a UV resistance of 70 percent or greater.

2.2 APPROVED MANUFACTURERS AND STANDARD OF ACCEPTANCE

A. Approved Equipment Manufacturer:
   1. Albarrie Geocomposites Ltd., or approved equal in accordance with B8 Substitutes.

NOTE: The design on the Drawings is based on the Albarrie Geocomposites Ltd. ESTERWEB™ transformer insulating fluid containment system for Vegetable Ester Based Transformer Insulating Liquids.

The equipment layouts, details, wiring, and dimensions depicted on the Drawings are based upon specific equipment types and manufacturers that are defined on the Drawings and in the Specifications.

Use of alternative equipment other than the "Standard Of Acceptance" defined in this Specification is permitted. However, use of alternative equipment by the Contractor is subject to the Contractor having received formal "approved equal" status for the equipment in question from the Contract Administrator. Any changes to layouts, details, wiring and dimensions including all associated costs arizing from the use of "Approved Equal" materials and equipment is and are the sole responsibility of the Contractor. Use of "approved equal" equipment shall result in a fully functional installation in accordance with the requirements and intent of the design documents.

B. Standard of Acceptance:
   1. Mineral Oil Based Transformer Insulating Liquids -
      Albarrie Geocomposites Ltd. - SORBWEB™
   2. Vegetable Ester Based Transformer Insulating Liquids (EnviroTemp FR3, etc.) -
      Albarrie Geocomposites Ltd. - ESTERWEB™

2.3 SOURCE QUALITY CONTROL

A. Submit to the Contract Administrator, standard factory test certificates for each material in accordance with Section 26 08 05, Acceptance Testing – Electrical, Section 01 33 00, Submittal Procedures, and Section 26 05 01, Common Work Results – Electrical.

PART 3 EXECUTION

3.1 MANUFACTURER'S INSTRUCTION

A. Engage the Manufacturer to provide a certified final design based on the general arrangements, sections, and details indicated on the Drawings and Specifications.

B. Comply with Manufacturer's written recommendations or Specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSPECTION

A. All other requirements per Section 26 08 05, Acceptance Testing – Electrical.

3.3 INSTALLATION

A. Install in accordance with Manufacturer’s Certified final design and installation drawings.

B. Engage Manufacturer to provide Installation Supervision, in accordance with Manufacturer’s design documents, and to maintain Manufacturer’s warranty.

3.4 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 08 05, Acceptance Testing – Electrical.

B. Submit in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical.

END OF SECTION

SECTION 26 12 17

DRY TYPE TRANSFORMER UP TO 600V PRIMARY

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Materials and components for dry type transformers up to 600 V primary, equipment identification and transformer installation.

1.2 CODES AND STANDARDS

A. Canadian Standards Association (CSA International)
   1. CAN/CSA-C22.2 No.47, Air-Cooled Transformers (Dry Type).
   2. CSA C9, Dry-Type Transformers.
   3. CSA C802.2, Minimum Efficiency Values for Dry Type Transformers

B. Manitoba Energy Code for Buildings (MECB)

C. Institute of Electrical and Electronics Engineers (IEEE): C57.96, Guide for Loading Dry Type Transformers.

D. Institute of Electrical and Electronics Engineers (IEEE): C57.12, Standard Test Code for Dry Type Distribution and Power Transformers.

E. Institute of Electrical and Electronics Engineers (IEEE): C57.110, Recommended Practice for Establishing Liquid Filled and Dry-Type Power and Distribution Transformer Capability when Supplying Non-Sinusoidal Load Currents.

F. National Electrical Manufacturers Association (NEMA):
   1. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   2. ST 20, Dry-Type Transformers for General Applications.

G. Underwriters Laboratories Inc. (UL):
   1. 486E, Standard for Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors.
   2. 1561, Standard for Dry-Type, General Purpose, and Power Transformers.

1.3 SUBMITTALS

A. Submit Shop Drawings indicating the components and equipment to be used:
   1. Descriptive information.
   2. Nameplate data.
   3. Dimensions and weight.
   4. Schematic and connection diagrams.
   5. kVA rating, % impedance.
   6. Primary and secondary voltages.

7. Frequency.
8. Phase.
9. Polarity or angular displacement.
10. Full load efficiency.
11. Regulation at unity pf.
12. BIL.
13. Insulation type and temperature rise.
14. Materials
15. Energy efficiency ratings, in compliance with the MECB.
16. Transformer damage curve information so that it can be input into SKM for modeling.

B. Informational Submittals:
1. Test Report: Sound test certification for dry type power transformers (0 to 600-volt, primary).

1.4 O&M MANUAL

A. Include all Shop Drawings and product submittals.

B. Include Manufacturer's Hi-Pot test results for each transformer. Test sheets shall correlate to the specific equipment supplied.

C. Include field test results.

PART 2 PRODUCTS

2.1 GENERAL

A. Use transformers of one manufacturer throughout project and in accordance with CAN/CSA-C22.2 No.47, CAN / CSA C9 and CSA C802.2.

B. Dry-type, self-cooled, with copper windings.

C. Units larger than 5 kVA suitable for use with 75 degrees C wire at full capacity.

D. Efficiency: Meet or exceed values in CSA C802.2 Table 1.

E. Maximum Sound Level per CSA C9, Table 8:
1. 40 decibels for 0 kVA to 9 kVA.
2. 45 decibels for 10 kVA to 50 kVA.
3. 50 decibels for 51 kVA to 150 kVA.
4. 55 decibels for 151 kVA to 300 kVA.
5. 60 decibels for 301 kVA to 500 kVA.

F. Overload capability: Short-term overload per IEEE C57.96.

G. K-Factor power transformer in accordance with IEEE C57.110

H. Refer to the Drawings for the preferred transformer mounting method.
   1. Where wall mounting is specified, provide the required Manufacturer approved wall mount kit. Ensure that wall mounts are connected to the building structure, and that the Facility is designed to handle the loads.
   2. Where floor mounting is specified, provide 3.5” thick concrete housekeeping pad below transformer, extend the pad under the footprint of the transformer, plus a minimum of 2” beyond the transformer enclosure in all direction.
   3. Other mounting methods, such as steel transformer supports to be as detailed on the Drawings or as approved by the Contract Administrator.

I. Vibration Isolators:
   1. Rated for transformer’s weight.
   2. Internal vibration isolation pads to be neoprene rubber material, to isolate the core/coil assembly from the transformer enclosure.
   3. Isolation pads to be in accordance with the Manufacturer’s recommendation.

J. Enclosure:
   1. CSA enclosure type 3R, type 4, type 4X, type 12 or other as indicated on the Drawings.
   2. Exterior mounted transformers to be a minimum of Nema 3R.
   3. Exterior finish: ANSI 61 gray.

K. Transformer Construction.
   1. Type: ANN.
   2. Single phase or three phase, kVA and voltage as indicated, rated for 60Hz.
   3. Voltage taps: offload taps with positions minus 5 percent, minus 2.5 percent, nominal voltage, plus 2.5 percent, plus5 percent, rated at full capacity.
   4. Windings: copper.
   5. Insulation: class H, 220 degrees C.
   6. Temperature rise: 115 degrees C at continuous full load.
   7. Basic Impulse Level (BIL): minimum 10 kV.
   8. Impedance at 170 degrees C: standard
   9. Nameplate to include actual transformer impedance (%Z).
   10. Finish: in accordance with Section 26 05 01, Common Work Results - Electrical.

L. Transformer Factory Tests.
   1. Perform equipment specific Hi-Pot tests for each transformer in the factory, prior to shipment, and submit test results for each unit.

M. Manufacturers:
   1. Schneider Electric, Hammond, REX
   2. All equipment shall be sourced from the local Manufacturer’s Representative, through the Manufacturer’s local approved distributors. Sourcing equipment from alternate sources will not be accepted.
   3. Physical sizes shown on the Drawings are based on Schneider Electric equipment.

2.2 K-RATED TRANSFORMER

A. Insulation: class H, 220 degrees C and temperature rise: 80 degrees C at continuous full load.

B. Core and coil: sized and configured to reduce overheating caused by harmonic components.

C. Voltage taps: offload taps with positions minus 5 percent, minus 2.5 percent, nominal voltage, plus 2.5 percent, plus 5 percent, rated at full capacity.

D. K Factor: K4, K13 or K20 as indicated on the Drawings.

E. Neutral bus and terminal: 200 percent of rated phase current.

F. Electrostatic shield.

2.3 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - Electrical.

B. Label size: 10.

C. Nameplate for each transformer, example as follows:

XFMR-R714 30 kVA, 600 - 208/120V, 3Ø, 4W FED FROM MCC-R710

PART 3 EXECUTION

3.1 INSTALLATION

A. Install transformer in accordance with the Manufacturer’s instructions.

B. Mount dry type transformers as indicated on the Drawings.

C. Review the structural Drawings and ensure that the transformers are anchored in a secure manner. Ensure that the transformers are not secured to structural members divided by building expansion joints.

D. Provide metal brackets, bolts and structural support members for wall mounted transformers.

E. Provide concrete housekeeping pads for floor mounted transformers.

F. Ensure all transformers have adequate ventilation. Ensure that equipment and transformer clearances do not impede on the transformer ventilation.

G. Install transformers in level upright position.

H. Locate floor mount style transformers a minimum of 300mm away from combustible surfaces, or 150 mm from non-combustible surfaces in accordance with CEC requirements.

I. Remove shipping supports only after transformer is installed and just before putting into service.

J. Loosen isolation pad bolts until no compression is visible.

K. Make primary and secondary connections.

L. Mount transformers to reduce direct and transmitted noise.

M. Make connections to transformers in flexible conduit, entering the enclosure below the coils.

N. Provide suitable ground and bond cables / connections to the transformer (even though this may not be explicitly shown on the Drawings) in accordance with code requirements. For 3-phase, star grounded secondary transformers:
   1. Provide a separate green insulated ground conductor to the transformer star connection. Minimum size is #6 AWG in accordance with the CEC 10-812. Run ground conductor in a separate conduit, back to the main ground. Ensure conduit is bonded to ground at both ends, and electrically continuous.
   2. Provide a separate green insulated bond conductor connected to the enclosure frame, sized in accordance with CEC table 16.

O. Energize transformers after installation is complete.

P. Adjust tap connections to give the appropriate full load voltage.

3.2 TESTING

A. Perform tests in accordance with Section 26 08 05, Acceptance Testing.

B. Measure and record the voltage on the primary and secondary of the transformer. Adjust the tap position as required. Record final tap position and voltage.

END OF SECTION

SECTION 26 12 19

PAD MOUNTED, LIQUID FILLED, MEDIUM VOLTAGE (12.47kV- 600V) TRANSFORMERS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CAN/CSA-C2.1-2006, Single-Phase and Three Phase Distribution Transformers, Types ONAN and LNAN

B. CSA C227.4-2006, Three-Phase. Dead Front Pad-Mounted Distribution Transformers.

C. ANSI/IEEE 57.12.00-2006, IEEE Standard for Standard General Requirements for Liquid-Immersed Distribution Power & Regulating Transformers.

D. ANSI/IEEE 386-1985, Separable Insulated Connector System for Power Distribution Systems above 600V.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, Specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit Shop Drawings and indicate:
   1. Anchoring method and dimensioned foundation template.
   2. Dimensioned cable entry locations.
   3. Dimensioned cable termination and pothead height.
   4. Dimensioned overall transformer enclosure.
   5. Identified internal and external component layout on assembly Drawings.
   6. Insulating liquid capacity.
   7. Insulating liquid materials.
   8. Primary and secondary fuse make, model, size and time-current characteristics.
   9. Weight, including oil.
   10. Installation and handling instruction.
   11. Transformer damage curve information so that it can be input into SKM for modeling.
   12. Fuse time current curves

1.3 MAINTENANCE

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 26 05 01, Common Work Results – Electrical.

1.4 GENERAL

A. It is the responsibility of the electrical contractor to coordinate the size/compartment/ locations on the approved Shop Drawings prior to installing duct work, cable bus, conduits and cables.

B. All transformers shall be by the same equipment vendor – no split packages are allowed.

PART 2 PRODUCTS

2.1 EQUIPMENT

A. Three-phase radial feed dead front pad mounted distribution transformers: to CSA C227.4.

B. Oil filled pad mounted distribution transformers complete with cable compartments, options and accessories to form complete factory assembled, self contained, steel fabricated unit for mounting on a concrete pad.

C. HV bushings: separable insulated (dead front) 200A bushing well connectors with bushing well inserts to ANSI/IEEE386.

D. Load break inserts for HV elbow connectors.

E. HV lightning arrestors.

F. NEMA 8-hole pad (copper) voltage terminals, suitable for a minimum of 4 cables per phase, 4 cables per neutral. Refer to the single line drawing for required cable connections.

G. Load break connectors for primary cables.

H. 2 hole long barrel copper crimp connector to secondary cable.

I. Primary fuse protection – Bay-O-Net and current limiting fuses.

J. Stays to hold compartment doors in the 110° open position.

K. Separate, high voltage and low voltage compartments, complete with separate hinged, lockable doors. NEMA 4 overall enclosure.

L. Insulated neutral X0 bushing with a removable ground strap accessible from the cable compartment to incorporate NGR installation where required. Xo should not be connected to ground that is internal to the oil-filled transformer compartment.

M. All transformers sized greater than 1000 kVA shall have an insulated neutral X0 bushing as described above.

N. Copper grounding bus.

O. Shall be suitable for termination of conductors as indicated on the Drawings.

P. Kirk Key Interlock between transformer door and upstream feeder breaker. Key is to be released via the upstream breaker rack-out mechanism.

Q. Factory installed external CSA transformer nameplate, stainless steel, engraved. Affixed using rivets.

R. Transformer shall withstand thermally and mechanically two second (or greater) short circuit at its secondary terminals.

2.2 APPROVED MANUFACTURERS

A. Approved Equipment Manufacturer: Carte, Delta Star, PTI, ABB, Cooper Power Systems or approved equal in accordance to B8. The design on the Drawings is based on Carte equipment. If any other vendor is used it will be the Contractor's responsibility to ensure that concrete work and all systems are installed in a coordinated and functioning manner.

2.3 TRANSFORMER CHARACTERISTICS

A. Type: KNAN (Oil with flash point greater than 300 degrees C, oil natural, air natural)

B. Primary Voltage: 12.47 kV, 60 Hz, delta connected, 3 phase.

C. Secondary Voltage: 600 V, 60 Hz, Wye-ground connected, 3 phase, 4 wire, insulated neutral.

D. Capacity: As shown on Drawing.

E. Windings: Copper.

F. Core: Cold rolled grain oriented steel lamination.

G. Primary basic impulse level: 95 kV/ Secondary basis impulse level: 30 kV.

H. Impedance: Per CSA C227.4, and not more than 1.5 percent above minimum levels.

I. Temperature rise: 65 degrees C.

J. Liquid: Ester Dielectric (Envirotemp FR3), PCB free, suitable for arctic conditions.

K. Sound rating: As per CSA C227.4 Table 5.
   a. Less than 750 kVA: 56 dBA
   b. 750kVA-1000kVA: 58 dBA
   c. 2500 kVA: 62 dBA

L. CSA Certified.

M. Transformer shall withstand thermally and mechanically a two second short circuit at its secondary terminals.

N. Exterior Finish: Munsell 7GY3.29/1.5 Green.

O. Neutral Grounding Resistor (where required):
   1. System Voltage: 600V.
   2. L-N Voltage: 347V.
   3. Resistor: 69.4 ohms.
   4. Amp Rating: 5 amps.
   5. Time Rating: Continuous.
   6. Enclosure: Nema 3R, stainless steel enclosure.
   7. Acceptable Manufacturer: Powerohm Resistor Inc, I-Gard or approved equal in accordance with B8 Substitutes.

2.4 VOLTAGE TAPS

A. Two 2.5 percent FCAN taps, two 2.5 percent FCBN taps for adjusting voltage.

2.5 TAP CHANGER

A. Off-load tap changer with controls located in cable compartment, with provision for padlocking.

2.6 NAMEPLATE

A. Each transformer nameplate should include the information as stated in C227.4-06, Clause 9.1.3.

2.7 ACCESSORIES

A. Liquid temperature thermometer.

B. Liquid level gauge, complete with form C alarm contact.

C. Pressure relief device.

D. Vacuum / pressure gauge

E. Winding temperature indicator with form C alarm contact. Temperature probe to be located in the center winding.

F. Drain valve / tap / accessible sampling valve.

G. Filler plug.

H. Tap changer switch. Tap changer shall be functional at minus 40 degrees C ambient.

I. Lifting lugs (minimum of 4).

J. Spare fuses (minimum 3 of each type or size)

K. Primary side surge arrestors.

2.8 GROUNDING

A. Copper grounding bus bar.

B. Connectors for grounding conductors. Provisions for connection for a minimum of five ground cables to accommodate cable sizes as per the Drawings.

C. Transformer shall be provided with stainless steel grounding pads at two diagonally opposite ends.

2.9 FINISH

A. Finish exterior of unit in accordance with Section 26 05 01 - Common Work Results - for Electrical

2.10 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 0,- Common Work Results.

B. Provide metallic (stainless steel) CSA label on the outside of the transformer and on the inside of the transformer in the cable compartment.

C. Provide size 11, hard plastic equipment identification lamacoid on the outside of the transformer, example as followS:

XFMR-Y701 10,000 kVA, 66 kV-12.47 kV, 3Ø, 4W FED FROM CS-Y701

2.11 WARNING SIGNS

A. Provide warning signs in accordance with Section 26 05 01, Common Work Results - for Electrical and in accordance with the requirements of the CEC.

B. Provide high voltage warning signs in accordance with AHJ requirements.

2.12 SOURCE QUALITY CONTROL

A. Submit to the Departmental Representative standard factory test certificates of each transformer and type test of each transformer with high voltage accessories in accordance with CSA C2 and Specification Section 26 08 05, Acceptable Testing. Include test results in the O & M Manuals.

PART 3 EXECUTION

3.1 MANUFACTURER’S INSTRUCTION

A. Compliance: comply with Manufacturer's written recommendations or Specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSPECTION

A. Check factory made connections of transformer unit for mechanical tightness and electrical continuity.

B. Check transformer insulating liquid for correct quantity and Specification according to Manufacturer's instructions.

C. Confirm that the neutral Xo terminal is insulated and not internally grounded.

D. All other requirements per Section 26 08 05, Acceptance Testing.

3.3 INSTALLATION

A. Ensure concrete pad is fully cured before transformer is installed and in accordance with local codes and standards. Concrete pad requirements should be coordinated with Manufacturer.

B. Set and secure transformer unit in place, rigid, plumb and square.

C. Make connections.

D. Set transformer taps.

E. Connect transformer unit ground bus to system ground (as applicable).

F. Install neutral grounding resistor and make connections (as applicable).

G. If no NGR is required confirm and make connection between Xo and ground.

H. Install cable and channel tray in accordance with the Drawings and the Manufacturer’s recommendations.

I. Ensure care is taken to prevent contamination of liquid and components when field filling transformer.

J. Use only metal hose when field-filling transformer with oil: do not use rubber hose.

3.4 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 08 05, Acceptance Testing.

B. Inspect primary and secondary connections for tightness and for signs of overheating.

C. Inspect and clean bushings and insulators.

D. Check oil level and temperature indicators.

E. Inspect for oil leaks and excessive rusting.

F. Inspect oil level.

G. Check for grounding and neutral continuity between primary and secondary circuits of transformer (where applicable). Check for isolation between Xo and ground bus where NGRs are installed.

END OF SECTION

SECTION 26 12 22

MEDIUM VOLTAGE LIGHTNING ARRESTER

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CAN/CSA-C233.1-87(R1999), Gapless Metal Oxide Surge Arresters for Alternating Current Systems.

B. ANSI/IEEE C62.11, Standard for Metal-Oxide Surge Arresters for Alternating Current Systems.

C. ANSI/IEEE C62.22, Guide for Application of Metal-Oxide Surge Arresters for AC Systems.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit Shop Drawings and indicate:
   1. Dimensioned layout.
   2. Identified internal and external component layout on assembly drawings.
   3. Installation and handling instruction.

1.3 MAINTENANCE

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 26 05 01, Common Work Results – Electrical.

1.4 GENERAL

A. It is the responsibility of the electrical contractor to coordinate the size/compartment/ locations on the approved Shop Drawings prior to installation.

PART 2 PRODUCTS

2.1 MATERIALS

A. Arrester components parts: to CSA C233.1

B. 15 kV Metal Oxide, heavy duty, station class.

C. System highest voltage 15kV

D. Outdoor type.

E. Housing: Polymer.

2.2 APPROVED MANUFACTURERS

A. Approved Equipment Manufacturer: Ohio Brass, Joslyn Canada Inc, ABB or approved equal in accordance with B8.

2.3 TRANSFORMER CHARACTERISTICS

A. Type: KNAN (Oil with flash point greater than 300 degrees C, oil natural, air natural)

B. Primary Voltage: 12.47 kV, 60 Hz, delta connected, 3 phase.

C. Secondary Voltage: 600 V, 60 Hz, Wye-ground connected, 3 phase, 4 wire, insulated neutral.

D. Capacity: As shown on Drawing.

E. Windings: Copper.

F. Primary basic impulse level: 95 kV/ Secondary basis impulse level: 30 kV.

G. Impedance: Per CSA C227.4, and not more than 1.5 percent above minimum levels.

H. Temperature rise: 65 degrees C.

I. Liquid: Ester Dielectric (Envirotemp FR3).

J. Sound rating: As per CSA C227.4 Table 5.
   1. Less than 750 kVA: 56 dBA
   2. 750kVA-1000kVA: 58 dBA
   3. 2500 kVA: 62 dBA

K. CSA Certified.

L. Exterior Finish: Munsell 7GY3.29/1.5 Green.

M. Neutral Grounding Resistor (where required):
   1. System Voltage: 600V.
   2. L-N Voltage: 347V.
   3. Resistor: 69.4 ohms.
   4. Amp Rating: 5 amps.
   5. Time Rating: Continuous.
   6. Acceptable Manufacturer: Powerohm Resistor Inc.

2.4 VOLTAGE TAPS

A. Two 2.5 percent FCAN taps, two 2.5 percent FCBN taps for adjusting voltage.

2.5 TAP CHANGER

A. Off-load tap changer with controls located in cable compartment, with provision for padlocking.

2.6 NAMEPLATE

A. Each transformer nameplate should include the information as stated in C227.4-06, Clause 9.1.3.

2.7 ACCESSORIES

A. Liquid temperature thermometer.

B. Liquid level gauge.

C. Pressure relief device.

D. Drain valve/ tap.

E. Filler plug

F. Tap changer switch

G. Lifting lugs (minimum of 4).

H. Spare fuses (minimum 3 of each type or size)

2.8 GROUNDING

A. Copper grounding bus bar.

B. Connectors for grounding conductors. Provisions for connection for a minimum of five ground cables to accommodate cable sizes as per the Drawings.

2.9 FINISH

A. Finish exterior of unit in accordance with Section 26 05 01, Common Work Results - for Electrical

2.10 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results.

B. Provide metallic (stainless steel) CSA label on the outside of the transformer and on the inside of the transformer in the cable compartment.

C. Provide a hard plastic equipment identification lamacoid on the outside of the transformer, example as followed:

XFMR-R701 2500 kVA, 12.47 kV-600V, 3Ø, 4W FED FROM SGR-C701

2.11 WARNING SIGNS

A. Provide warning signs in accordance with Section 26 05 01, Common Work Results - for Electrical and in accordance with the requirements of the CEC.

B. Provide high voltage warning signs in accordance with AHJ requirements.

2.12 SOURCE QUALITY CONTROL

A. Submit to the Departmental Representative standard factory test certificates of each transformer and type test of each transformer with high voltage accessories in accordance with CSA C2 and Specification Section 26 08 05, Acceptable Testing. Include test results in the O & M Manuals.

PART 3 EXECUTION

3.1 MANUFACTURER’S INSTRUCTION

A. Compliance: comply with Manufacturer's written recommendations or Specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSPECTION

A. Check factory made connections of transformer unit for mechanical tightness and electrical continuity.

B. Check transformer insulating liquid for correct quantity and specification according to Manufacturer's instructions.

C. Confirm that the neutral Xo terminal is insulated and not internally grounded.

D. All other requirements per Section 26 08 05, Acceptance Testing.

3.3 INSTALLATION

A. Ensure concrete pad is fully cured before transformer is installed and in accordance with local codes and standards. Concrete pad requirements should be coordinated with Manufacturer.

B. Set and secure transformer unit in place, rigid, plumb and square.

C. Make connections.

D. Set transformer taps.

E. Connect transformer unit ground bus to system ground (as applicable).

F. Install neutral grounding resistor and make connections (as applicable).

G. If no NGR is required confirm and make connection between Xo and ground.

H. Install cable and channel tray in accordance with the Drawings and the Manufacturer's recommendations.

I. Ensure care is taken to prevent contamination of liquid and components when field filling transformer.

J. Use only metal hose when field-filling transformer with oil: do not use rubber hose.

3.4 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 08 05, Acceptance Testing.

B. Inspect primary and secondary connections for tightness and for signs of overheating.

C. Inspect and clean bushings and insulators.

D. Check oil level and temperature indicators.

E. Inspect for oil leaks and excessive rusting.

F. Inspect oil level.

G. Check for grounding and neutral continuity between primary and secondary circuits of transformer (where applicable). Check for isolation between Xo and ground bus where NGRs are installed.

END OF SECTION

SECTION 26 13 18

PRIMARY SWITCHGEAR ASSEMBLY TO 15KV

PART 1 GENERAL

1.1 RELATED SPECIFICATION SECTIONS

A. Section 26 32 10, Diesel Electric Generating Units (Liquid Cooled)

B. Section 26 32 20, Generator Load Bank (15 kV)

1.2 CODES AND STANDARDS

A. ANSI C37.06 - Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis

B. ANSI C37.010 - Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis

C. ANSI C37.11 - Requirements for Electrical Controls for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis

D. ANSI C37.20.2 - Metal-Clad and Station-Type Cubicle Switchgear

E. IEEE C37.20.7 - IEEE Guide for Testing Metal Enclosed Switchgear rated up to 38kV for Internal Arcing faults

F. ANSI C37.23 - Metal-Enclosed Bus and Guide for calculating Losses in Isolated Phase Bus

G. CSA No. 14 – Industrial Control Equipment

H. ANSI C57.13 - Requirements for Instrument Transformers

I. CAN3/CSA C13 - Instrument Transformers

J. CSA C22.2 No. 31 - Switchgear Assemblies

K. CAN3/CSA Z299.3 - Quality Assurance Program – Category 3

L. EEMAC G 14-1 - Arc-resistant switch gear assemblies

M. CSA 22.2 No. 261 - Evaluation Methods for Arc-resistant Ratings for Enclosed Electrical Equipment.

N. CSA C22.1 - Canadian Electrical Code - part 1.

O. ANSI/IEEE C37.100, C37.20, C37.04, C37.09 37.013A.

P. ANSI/IEEE C37.09,

Q. ANSI C37.54, C37.55, NEMA SG4.

R. EEMAC G8.2 - Switch gear assemblies.

S. NFPA 110 – Standard for Emergency and Standby Power systems

T. ASTM F855 – Standard Specifications for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment

1.3 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical. Documents shall be submitted in the quantities and formats required by Section 01 33 00, Submittal Procedures.

B. Provide manufacturer's printed product literature, specifications and datasheet and include product characteristics, performance criteria, physical size, finish and limitations.

C. Provide proof of capabilities and experience for the programming services provider proposed for the configuration, logic development and programming of the protective relays and RTAC.

D. Shop Drawings and calculations are to be signed and sealed by a Professional Engineer, licensed in the Province of Manitoba.

E. Shop Drawings shall include, but not be limited to:
1. Mounting method and dimensions.
2. Enclosure construction.
3. Locations of shipping splits.
4. Lifting and supporting points.
5. Electrical single line drawings.
6. Breaker control schematics.
7. Breaker internal wiring schematics.
8. Three line diagram.
9. Wiring Diagram.
10. Elevation drawings.
11. Component layout drawings.
12. Bill of materials for all components.
13. Door details.
14. IR inspection window details.
15. Communication system schematic.
16. Controls one-line diagram
17. Conduit entry / exit locations
18. Cable terminal sizes
19. Field cabling requirements, including connections and cabling details to other switchgear assemblies, and engine-generator sets (**gensets**).
20. Equipment Electrical Ratings (Nameplates).
21. Mimic diagram layout.
22. System energization and startup procedures.

23. Torque specifications for all bolted current carrying connections. For connections (bus bar and cable) employing spring washers (Bellville washers) provide detailed torque calculations including Bellville washer part numbers, and material (signed and stamped).
24. Details of the key interlock system, including part numbers, and logic diagram / table.
25. Inspection and test plan and schedules.
26. Protection relay (SEL) programming code and relay settings sheets indicating the settings for all parameters in each relay (in Excel format).
27. Detailed logic flow diagrams for all RTAC switching sequences to indicate the Switchgear Manufacturer's/RTAC Programmer's understanding of all required switching sequences.

1.4 OPERATIONS &MAINTENANCE (O&M) MANUAL

A. Provide submittals in accordance to Section 01 77 00, Closeout Procedures and Section 26 05 01, Common Work Results – Electrical.

B. Prepare installation, operating and maintenance (O&M) manuals in the formats and quantities required by Section 01 78 23, Operation and Maintenance Data.

C. Each of the O&M Manuals shall include, at a minimum, the following:
1. All Shop Drawing information.
2. Signed and sealed equipment "As Manufactured" Drawings.
3. Certified product test reports.
4. Certificates of compliance.
5. Certified Arc-flash type test data.
6. CSA certificate of inspection for the complete switchgear lineup, or Manitoba Office of the Fire Commissioner, Inspection and Technical Services Manitoba "Special Inspection" certificate for the complete switchgear lineup.
7. Handling and installation instructions, including equipment anchorage information and provisions.
8. Operating and maintenance instructions.
9. Complete component list.
10. Recommended maintenance practices and procedures.
11. Recommended spare parts list.
12. CT curves and data sheets.
13. Equipment and component Manufacturer's detailed instructions, installation and maintenance manuals.
14. Standard cut sheets for OEM devices.
15. Component manuals for all devices/equipment/relays incorporated into the equipment.
16. Metering equipment settings and programming information.
17. Certified "as programmed" versions of the detailed logic flow diagrams for all RTAC switching sequences.
18. Site Testing & Commissioning Procedures, and recommendations and precautions for setting into operation.
19. Test plan and inspection records.
20. Certified copies of all test reports.
21. Nameplate rubbings.
22. Such additional information, instructions, data, recommendations, and procedures that the switchgear manufacturer considers to be pertinent.

23. Relay programming and relays / controller settings (6 copies of software on 6 memory sticks) as well as printed hardcopy. Include a copy of the software needed to view / read / modify the files on each memory stick.

1.5 QUALITY ASSURANCE

A. Accept equipment on site and inspect for shipping damage.

B. When long term storage (> 1 week) of switchgear is required, the switchgear shall be stored indoors in a heated environment, or shall be covered with a weather-proof heated hording. For short term storage (≤ 1 week) and during installation protect equipment from weather and moisture by covering with heavy plastic or canvas and by maintaining heat within the enclosure in accordance with Manufacturer's instructions.

PART 2 PRODUCTS

2.1 SCOPE

A. Switchgear SGR-C701, SGR-C702, and SGR-C790 shall be supplied by the generator system Manufacturer/Vendor. See also Section 26 32 10, Diesel Electric Generating Units (Liquid Cooled).

B. Switchgear SGR-C701, SGR-C702, and SGR-C790 shall all be of the same type, class, and manufacture and shall utilize the same make and type of vacuum circuit breaker.

C. The generator set Manufacturer/Vendor shall be the integrator for the Generator System, Switchgear SGR-C701, SGR-C702, SGR-C790 and Load Bank LDB-Y793 equipment into a functional and fully operational system in accordance with the Specifications and Drawings.

2.2 SWITCHGEAR ASSEMBLY

A. Switchgear shall consist of an arc resistant indoor enclosure containing circuit breakers and the necessary accessory components all factory assembled (with shipping splits as required) and tested and operationally checked. The assembly shall be self-supporting and floor mounted on a level floor or concrete housekeeping pad. The integrated switchgear assembly shall withstand the effects of closing, carrying and interrupting currents up to the assigned short circuit rating.

B. System Voltage: 12.47 kV, 3Ø, 3W, 60 Hz, resistance grounded.

C. Design Voltage Class: 15 kV.

D. Impulse Withstand (BIL): 95 kV.

E. Power Frequency Withstand: 36 kV for 1 minute.

F. Main Bus Current Rating: 1200 Amps, continuous, 100 percent rated.

G. Momentary Current Rating: Equal to (or greater than) the circuit breaker close and latch rating. Switchgear structures shall be solidly grounded.

H. The basic design shall be single and two-high indoor arc-resistant Type 2B in accordance with ANSI/IEEE C37.20.7.

I. The switchgear shall be full metal-clad construction. The enclosure shall be designed with a top mounted arc exhaust plenum. The plenum shall extend from end to end of the lineup and shall have flanged ends for easy customer coupling. Provide arc-flash vents to vent arcing products (gases) from the top of the switchgear and into a plenum. The plenum shall be vented to the outside of the building. The plenum arcing product vents shall be designed to be self closing, prevent the ingress rain, snow, and dust; prevent access by vermin, birds and rodents; and shall vent the discharge products in a horizontal direction.

J. The depth of the finished equipment shall be sufficient to allow for entrance, bending radius, installation of high voltage power cable terminations (stress cones) and connection of power cables (for size of power cables see Drawings). Internal clearances shall comply with CSA standards.

K. Provide a method and sealing for control & instrumentation cables entering/exiting the control compartment while maintaining the arc-flash resistance rating as required by IEEE C37.20.7.

L. The product shall have cUL and CSA certification labels applied.

M. The switchgear assembly shall consist of individual vertical sections housing various combinations of circuit breakers and auxiliaries, in a rigid metal-clad design. Metal side sheets shall provide grounded barriers between adjacent structures and solid removable metal barriers shall isolate the major primary sections of each circuit.

N. Each front compartment shall be provided with a formed steel hinged door with hand operated door latches. Doors shall be provided with provisions for padlocking, and a means to permit visual confirmation of the circuit breaker position from outside the door.

O. Interlocks shall be provided to prevent racking a circuit breaker into or out of a compartment with the circuit breaker compartment door in the open position. This interlock may be manually circumvented for maintenance purposes by a deliberate act on the part of the operator. This override shall require a minimum of two separate and distinct operations, neither of which is considered to be part of normal operations.

2.3 COMPONENTS

A. General

1. The switchgear shall be compartmentalized, and fabricated in sections. The sections shall be divided by metal barriers into the following separate compartments:
   a. MV Circuit breaker,
   b. Instruments,
   c. Low voltage relay and control,
   d. Main bus,
   e. Auxiliary devices, and
   f. Incoming/outgoing cable(s).
2. Each vertical section shall have one or two circuit breaker compartment(s) as indicated on the Drawings.

B. Cable Compartment / Power Connections
   1. The cable compartment shall be able to accept standard customer requirements for cable terminations, including lugs, potheads and stress cones.
   2. Bus supports shall be epoxy based standoff insulators. Provision shall be made for adding cable supports as required.
   3. Cable connection pads shall be supplied with insulating boots sized to accept the cable size indicated on the Drawings. Cable connection pads shall be drilled to NEMA standard 4-hole pattern.
   4. Cable entry shall be bottom entry for all outgoing feeders, **except for the generator circuit breakers CB-C572, and CB-C582 which shall be top entry.**
   5. Space shall be allowed for the mounting of a zero sequence CT around the cables. Include spare terminal blocks and mounting hardware.
   6. Cable entry/exit plates shall be stainless steel. Cable compartment gland plates shall be non-magnetic and removable.
   7. Inter-cell barriers shall be stainless steel.
   8. The cable compartment door shall be hinged and bolted type and shall be key interlocked to prevent opening with the circuit breaker in the "Connected" position.
   9. Provide a 25mm Ø ball grounding stud c/w removable insulating cover on each phase bus within each cable compartment. The ball ground stud shall be located and oriented to permit the easy installation of grounding cable sets using hot tools. The removable insulating cover shall be designed for removal and installation using hot tools. Ball studs shall be rated 43,000 Amps for 15 cycles and 30,000 Amps for 30 cycles.
   10. Provide Infrared (IR) inspection windows on the cable compartment doors. IR windows shall be sized and located to permit thermal (IR) scanning of the cable connection area (minimum 2 windows per cable compartment door termination area).
      a. Manufacturer: IRISS (**NO Equals or Substitutions Permitted**),
      b. Type: Reinforced polymer IR/Visible window type c/w integral cover,
      c. Series: CAP-ENV (preferred), or VPFR (acceptable),
      d. Minimum Optic Windows Size: CAP-ENV-4 (96.8 x 96.8 mm),
         VPFR-75 (76 mm Ø),
   11. Cable installation in the upper breaker cable compartment on 2-high switchgear arrangements shall be possible without the requirement to access the lower breaker cable compartment.

C. Ground Bus
   1. The ground bus shall extend through the full length of the switchgear. Ground bus supports shall be NEMA Class A-20 epoxy standoff insulators.
   2. Provide a 25mm Ø ball grounding stud c/w removable insulating cover on the ground bus within each cable compartment. The ball ground stud shall be located and oriented to permit the easy installation of grounding cable sets using hot tools. The removable insulating cover shall be designed for removal and installation using hot tools. Ball studs shall be rated 43,000 Amps for 15 cycles and 30,000 Amps for 30 cycles.
   3. The ground bus system shall be capable of carrying the rated short circuit current of any breaker in the assembly for a minimum period of two (2) seconds.
   4. Provide main ground conductor cable termination points for minimum 4/0 AWG grounding cable at opposite ends of the switchgear assembly.
   5. Ground cable attachment shall be NEMA standard spacing, 2-hole pattern, long barrel crimp type lugs.

D. Main Bus Compartment
   1. The main and vertical bus bars shall be fully rated for 1200 amps per phase, and be fully insulated for its entire length. The conductors shall be tin-plated copper and of bolted connection design.
   2. Provide station class lightning arrestors on the main bus as indicated on the Drawings. Lightning arrestors shall be 15 kV class, arrestor MCOV shall be as indicated on the Drawings.
   3. Access to this compartment shall be from the rear within the structure by removing steel barrier(s). Provide for future extension of the main bus from either end, including pre-drilling of the main bus for future extension connectors.
   4. Both the main and vertical bus bars shall be contained in their own compartment within each cell.
   5. Main bus compartment shall be further compartmentalized by means of metal barriers and track resistant, flame retardant glass polyester through insulators between adjacent compartments.
   6. Buses and joints shall be designed such that the maximum temperature rise of any part shall not exceed 60 degrees C over an ambient temperature of 30 degrees C.
   7. Bolted bus connections shall utilize four bolts minimum, and shall employ constant tension devices (Bellville washers) to ensure joint integrity. Joining bolts shall be minimum Grade 5 and shall be plated for corrosion resistance.
      Note cadmium plating is considered to be carcinogenic and cadmium plated bolts are not acceptable.
   8. Where Bellville spring washers are utilized washer size, thickness and the final bolting torques shall be determined in accordance with the Bellville washer manufacturer's calculation procedures and recommendations.
   9. Bus orientation shall be A-B-C top to bottom, front to back and left to right, when viewed from the <u>front of the equipment</u>.
   10. Bus joints and cable terminations shall be covered with form-fitting insulating boots.

E. Doors and Panels
   1. Relays, meters, flexi-test switches, control switches, indicating lights etc., shall be mounted on the formed front-hinged panel of each low voltage compartment. Control components (selector switches, control switches, lockout relays, test switches, pilot lights, etc.) shall be as per the Specifications, and as indicated on Drawings. Protective relays shall be Schweitzer Engineering Laboratories (SEL), as indicated on the Drawings.
   2. Provide front cover mimic bus, c/w plastic symbols.

F. Circuit Breaker Compartment.
   1. The Drawings are based on the use of Schneider Electric (Square D) type VR vacuum circuit breaker switchgear.
   2. Where supplied the upper circuit breaker shall be horizontal draw-out type and installed using a lift truck. The compartment design shall allow the circuit breaker to roll in and out easily.
   3. The stationary primary disconnecting contacts shall be silver-plated for wear resistance. Through-the-door circuit breaker racking shall be provided. One window suitable for viewing the position of the circuit breaker in the cell and the position of the shutters with the circuit breaker out of the cell shall be provided.

4. A mechanical interlock system shall be provided as follows:
   a. The circuit breaker compartment door cannot be opened once the breaker is in the "Connected" position.
   b. The circuit breaker compartment door cannot be opened while the breaker is "Closed" or "On".
   c. The circuit breaker compartment door can be opened only with the breaker is in the "Disconnected" or "Test" position only.
5. Entrance to the stationary primary disconnecting contacts shall be automatically covered by metal shutters when the circuit breaker is withdrawn from the connected position to the "Test" or "Disconnected" position or removed from the circuit breaker compartment.
6. Extend a ground bus into the circuit breaker compartment to automatically ground the breaker frame with high-current spring type grounding contacts located on the breaker chassis when the circuit breaker is inserted into the compartment sufficiently far that the racking drive system can be engaged, and at all times when the breaker is in the "Test", "Connected" positions and during racking.
7. Guide rails for positioning the circuit breaker and all other necessary hardware shall be an integral part of the circuit breaker compartment.
8. Blocking devices shall interlock breaker frame sizes to prevent the insertion of a breaker of a lower ampere rating or interrupting capacity into a compartment designed for a breaker of a higher rating. The blocking devices shall be permanently attached to the cell and the circuit breaker and shall be non-removable without the use of specialized tools.
9. Where indoor switchgear is directly mounted on a concrete floor without the use of a housekeeping pad it shall be possible to remove and install the lower circuit breaker into its compartment without use of a transport truck or lift device. For 2 high configurations, or where switchgear is mounted on a housekeeping pad, a lift truck or lifting device shall be used to remove and install both upper and lower circuit breakers into their compartments.

G. Medium Voltage Circuit Breakers:
1. The circuit breakers shall be rated 12.47 kV nominal, 15 kV, 60 Hz, rated with a continuous current rating of 1200 amps and a symmetrical interrupting rating of 25 kA.
2. Furnish vacuum circuit breakers with one vacuum interrupter per phase. The vacuum interrupters shall be mounted in a high strength molded glass reinforced polyester insulation support/ housing.
3. Breakers of same type and rating shall be completely interchangeable.
4. The circuit breaker shall be operated by means of a stored energy mechanism which is normally charged by a universal motor but can also be charged by the manual handle for manual emergency closing or testing. The closing speed of the moving contacts shall be independent of both the control voltage and the operator.
5. Circuit breakers shall be "tease proof".
6. Provide a full front shield on the breaker.
7. Secondary control circuits shall be connected automatically with a self-aligning, self-engaging plug and receptacle arrangement when the circuit breaker is racked into the connected position. Provision shall also be made to permit the secondary control plug to be manually connected in test position.
8. Breaker manual control handle shall be located on each cell door, and allow for full manual operation of each breaker as detailed elsewhere in this Specification.
9. The racking mechanism to move the breaker between positions shall be operable with the front door closed and position indication shall be visible with door closed.

10. Each circuit breaker shall have three, clearly-marked definite positions within its enclosure, i.e. "Connected", "Test" and "Isolated" positions.
11. Mechanical interlocks shall be provided to:
    a. Prevent inserting or withdrawing a “closed” breaker,
    b. Prevent racking a closed circuit breaker to or from any position,
    c. Prevent closing a circuit breaker unless it is in the "Connected" or "Test" positions within the switchgear, or is fully removed from the switchgear with the secondary control circuits connected by an extension cable.
    d. Automatically discharge the stored-energy operating mechanism springs upon removal or insertion of the breaker.
12. A shutter system shall automatically cover the fixed line and load bus stabs, when the circuit breaker moves to a disconnected position. The shutters/shutter operating mechanism shall be pad-lockable in closed position from the front of the cell. Pad locking attachment point shall be sized to permit the installation of lock extension devices without compromising the security of the system.
13. Provide contact wear indicator for each vacuum interrupter unit.
14. Breakers shall have a trip operation time of ≤ 3 cycles.

H. Circuit Breaker Controls
1. All circuit breaker controls, spring charging mechanism, and auxiliaries shall be designed for operation at 125 VDC.
2. Visible break two pole DC dead front fuse holders with current limiting fuses shall be provided for each circuit breaker cell in the switchgear. Fuse holders shall be “ganged” so that both positive and negative fuse holders open/close as a pair. The Circuit breaker tripping circuit shall be fed from the cell “master” fuses with separate sub-fusing from the master fuses for:
    a. The circuit breaker closing coil/charging motor circuit, and
    b. The DC protection relay circuit.
3. 125 VDC control/protection power from the 125 VDC distribution panel shall connect to the switchgear at one (1) location only for each switchgear bus section (i.e. one location for each of SGR-C701, SGR-C702, and SCG-C790). Internal distribution of the 125 VDC power within the switchgear sections shall be the responsibility of the switchgear Manufacturer.
4. The switchgear automation controller (RTAC), unmanaged Ethernet switches and the Satellite-Synchronized Clock (SSC) shall be supplied by a separate circuit from the 125 VDC distribution panel.
5. Manual circuit breaker close/trip shall be by means of a heavy duty, rotary type “pistol grip” handle breaker control switch. The breaker control switch shall be equipped with a mechanical indicator flag which shall indicate the last operated position of the switch. Indicator flag shall colour coded red – Open and
green – Close.
6. All breaker status indicating light assemblies shall be 125 VDC, low burden, high luminosity, long life, LED lamp type with coloured caps. LED lamp and colour cap shall be colour matched. LED Lamps shall be bayonet base type and shall be replaceable by removing the colour cap. Minimum status indicator requirements (plus any additional requirements shown on the Drawings) per breaker shall be as follows:
    a. Green light to indicate breaker is closed (CB CLOSED).
    b. Red light to indicate breaker is open (CB OPEN).

c. Blue light to indicate that automatic control of the circuit breaker by the Real Time Automation Controller (RTAC) or other means is permitted/active as indicated on the Drawings.

I. Breaker Auxiliary Devices:
1. Mechanical Status indicators:
   a. Mechanical status indicator to show circuit breaker main contacts "closed" or "open".
   b. Mechanical status indicator to show stored-energy operating mechanism springs ”charged” or “discharged”.
2. Non-resettable mechanical operations counter (may be electrically activated).
3. Auxiliary contacts:
   a. In addition to those contacts required internally in the switchgear for control, interlocking and indication of the circuit breaker itself, provide a minimum of four (4) NO and four (4) NC Mechanism Operated Contacts (MOCs) wired to terminal blocks as shown on the Drawings.
   b. In addition to those contacts required internally in the switchgear for control, interlocking and indication of the circuit breaker itself, provide a minimum of four (4) NO and four (4) NC Truck Operated Contacts (TOCs) wired to terminal blocks as shown on the Drawings.
4. Racking provisions:
   a. All breaker racking shall operate “through-the-door” with the breaker compartment door in the closed and latched position
   b. Provide one (1) manual cranking handle with each switchgear assembly for manually racking circuit breakers in and out of the cubicle. A minimum of two (2) handles in total shall be supplied.
   c. Provide one 120 VAC powered portable electrical racking device for each switchgear assembly. The Electrical racking device shall be as follows:
      1) Be provided with a 20 meter long power cord (12 AWG or larger as required) equipped with a CSA 5-15R pattern cord cap,
      2) Be provided with a permanently attached hand-held portable control pendant on a 15 meter long cable. Pendant control shall include (at a minimum), a “power on/off” maintained contact pushbutton (pull “on”, depress “off”), a “power on” LED type pilot light, a directional “rack-in/rack-out” selector switch, and a momentary “run/operate” push button,
      3) Securely attach to the breaker cell door by means of mechanical attachments or magnets and shall be positively located to prevent rotation of the device body in operation. The attachment and locating means shall not require any projections or protrusions on the cell or cell door,
      4) Shall be equipped with limit switches and a slip clutch to prevent over-torquing or damaging the circuit breaker racking mechanism, the circuit breaker itself, the switchgear breaker compartment door or internal switchgear components (“stabs” and auxiliary connector),
      5) Shall be specifically designed and manufactured for the make and model of the switchgear equipment.
5. All auxiliary relays used for controls shall be CSA approved, with heavy duty contacts rated for operation on 125 volts DC, with visual indication of coil energization.

J. Instrument Transformers
1. Current Transformers:
   a. Each breaker compartment shall have provision to accommodate four (4) front-accessible mounted current transformers per phase, two CTs on the bus side and two CTs on cable side of circuit breaker. Provide current transformers as indicated on the Drawings and/or the Data Sheet(s).
   b. Where the current transformers are mounted over a fully insulated fixed "stab" bottle, the current transformer assembly shall be insulated to a minimum of 600V.
   c. Where current transformers are mounted over bus or other portions of the switchgear which are not insulated for the full voltage rating of the switchgear the current transformer assembly shall be, either insulated to a minimum of 600V and "spaced" from the live parts to provide the required insulation levels, or the current transformer assembly shall be insulated for the full voltage rating of the switchgear.
   d. Current transformer wiring shall be Type SIS, minimum # 10 AWG, 600 V, 90 degrees C (minimum) and shall terminate on grounding type CT ratio selection terminal blocks (c/w removable shorting jumper(s) and ABB type "Flexitest" blocks for devices.
   e. All current transformer wiring shall utilize stud or screw connections and "ring" type crimp lugs. The use of self retaining compression type spade lugs or "push-on" blade terminals and lugs are NOT acceptable for CT wiring.
   f. Current transformers shall be ANSI standard relay class and have their accuracy established in accordance with the connected burden and ANSI C57.13 but shall be at least:
      1) 10C200, Thermal factor 130 percent for all phase CTs.
      2) 10C50, for all zero sequence CT.
      3) 10C200, for all bus bar differential CTs.
   g. Zero sequence CTs shall be Manufacturer's standard design, and shall be properly rated and tested for use in medium voltage switchgear installations.
   h. Zero sequence CTs windows shall be dimensioned to allow passage of the specified cables complete with NEMA standard 2-hole pattern long barrel double crimp type lugs and high voltage cable terminations.
   i. Zero sequence CTs shall be mounted in such a manner as to permit its easy removal for installation of cables complete with high voltage terminators and cable gland connectors.
2. Potential Transformers:
   a. The main bus potential transformers shall be rated as indicated on the Drawings and/or Data Sheet(s).
   b. The bus PTs shall be rated to withstand 15500 volts to ground on any phase, and to provide an output on healthy secondary phase windings when phase to neutral voltage increases by 173 percent on a phase to ground fault.
   c. Potential transformers shall be of the draw-out or tilt-out type protected by current limiting fuses both on primary and secondary windings. The potential transformer draw-out or tilt-out mechanism shall be designed such that the primary and secondary transformer connections and fuses shall be automatically grounded in the withdrawn position.
   d. In general potential transformers shall be as follows:
      1) Primary: 13200V,
      2) Secondary: 120V,
      3) Frequency: 60 Hz,

4) Ratio: 110:1,
5) Maximum System voltage: 15.5.KV,
6) Impulse Rating:110KV BIL
7) Thermal Rating:
   a) 1500VA at 30 degrees C ambient,
   b) 1000VA at 55 degrees C ambient,
8) Accuracy Class:
   a) 0.3 WXMYZ 1.2 ZZ at 100 percent rated voltage with 120V based ANSI burden,
   b) 0.3 WXMY, 1.2Z at 58 percent rated voltage with 69.3V based ANSI burden,
9) ANSI Group 2.

K. Control Wiring and Connections.
1. The switchgear shall be wired with the type SIS, # 14 AWG, 600 V, 90 degrees C, except where larger size wire is required by CSA standard, or specified on Drawings and/or in Data Sheet(s).
2. The switchgear shall be provided with terminal blocks for incoming and outgoing control connections.
3. All wiring shall be tagged and identified on both ends of every wire using printed heat shrink sleeve type wire markers. Hand written numbering is NOT acceptable. The wire numbering scheme shall be such that the wire numbers change only when going through a device (coil, contact, etc.). Wire numbers at both ends of the same wire shall be identical. All wires on a given terminal block position shall bear the same number, with the exception that at CT shorting type ratio selection terminal blocks, wires may have different wire numbers on opposite sides of the ratio selection CT block.
4. Wires shall be run in continuous lengths, without splices between connection points, be installed in channels or neatly tied and clamped to the panel. Self-stick/adhesive type wire/cable clamps are acceptable ONLY if additionally secured by means of screws.
5. All wiring originating from a compartment must be first routed to terminal block, except for arc flash sensors.
6. Connections to external circuits shall be brought to modular, asymmetrical DIN rail mounted snap-on construction, pressure type terminal blocks, with marking strips. Approved terminal block types are:
   a. Weidmuller Type SAK 6N (preferred), Wieland type WK 6/U (acceptable), or approved equal in accordance with B8,
   b. Weidmuller type SAK B10C (preferred), Wieland type WKN 16DS (acceptable), or approved equal in accordance with B8.
7. A minimum of 20 percent spare terminals shall be included (minimum 20 terminal block positions.
8. The terminal blocks for external connections shall be located in the low voltage compartment, grouped together and easily accessible, visible and shall be positioned near the compartment's field control cable and inter-cell wiring entry/exit points.
9. All wiring not terminated on devices shall be terminated on terminal blocks. Not more than two (2) wires shall be connected to any device terminal or at any one terminal side. Interconnecting jumpers between terminal block positions shall be counted in the above 2 wire per side limitation. General and control wiring shall utilize self retaining compression type spade lugs where wiring is terminated on hardware (relays, meters, switches, etc).

10. Spare conductors in cables shall NOT be terminated to terminal blocks, but shall be neatly trained, identified, taped, and left in the bottom of the compartment. Spare cable conductors shall be of sufficient length to reach the most remote terminal block position or equipment terminal within in the compartment.
11. Current transformer secondary circuits shall utilize insulated barrel ring type compression terminals.
12. Control circuit wiring for circuit breaker "trip" circuit shall incorporate steering/blocking diodes to ensure proper routing and isolation of trip signals from the protection relays, arc-flash system trips, and operator control devices.
13. Steering/Blocking diodes shall be NTE Electronics type 5817HC axial lead plastic encapsulated silicon rectifier, or approved equal in accordance with B8. Blocking /Steering diode characteristics shall be as follows (T_A = +25 degrees C unless otherwise specified):
    a. Maximum Recurrent Peak Reverse Voltage = 1000V,
    b. Maximum RMS Voltage = 700V,
    c. Maximum DC Blocking Voltage = 1000V,
    d. Average Forward Current (TA = +50 degrees C), IF(AV) = 10A,
    e. Peak Forward Surge Current (8.3ms, Half Sine), IFSM = 400A,
    f. Maximum Inst. Forward Voltage (IFM = 10A, TA = +25 degrees C), VF = 1.0V,
    g. Maximum DC Reverse Current at Rated DC Blocking Voltage, IR (TA = +25 degrees C) = 10µA, (TA = +100 degrees C) = 100µA,
    h. Typical Junction Capacitance (Measured at 1.0MHz, VR = 4V), CJ = 150pF,
    i. Operating Junction Temperature Range, TJ = -55 degrees to +125 degrees C,
    j. Storage Temperature Range, Tstg = -55 degrees to +150 degrees C,
    k. Typical Thermal Resistance, Junction- to-Ambient, R_{thJA} = 10K/W.
14. Where wiring between cells crosses shipping splits the Manufacturer shall supply keyed separable plug and socket type in-line insulated connector(s) to permit separating the cells at the shipping splits without having to un-terminate wiring. The connector shall be sized to accommodate the wire gauge and current carrying capacity of the inter-cell conductors, shall be of a locking design to prevent separation in service due to vibration or other causes and shall be securely screwed or clamped to the structure(s).
15. Where wiring crosses between structure sections (i.e. inter-cell connections), or where wiring (control cables) exits the switchgear to connect to other equipment it shall be landed on terminal blocks at both ends. Devices external to the cell (contacts, coils, etc.) shall not be "loop" connected but shall be wired back to terminal blocks in the switchgear cell on an individual basis.
16. Soldered connections and splices in wiring are not permitted.

L. 125 VDC Inter-Cell Power Distribution Wiring and Connections
1. The 125 VDC inter-cell power distribution wiring shall be type SIS, 600 V, 90 degrees C, and shall be sized to permit simultaneous operation of all circuit breaker spring charging motors as well as all protective relaying and controls without undue voltage drop.
2. The switchgear shall be provided with terminal blocks in each cell for inter-cell power distribution wiring. The incoming 125 VDC terminal blocks for each switchgear assembly (SGR-C701, SGR-C702, and SGR-C790) shall be sized to accommodate
3. The 125 VDC inter-cell power distribution wiring shall be tagged and identified on both ends of every wire using printed heat shrink sleeve type wire markers. Hand written numbering is **NOT** acceptable. The wire at both ends of the same wire shall be identical. All wires on a given terminal block position shall bear the same number.

4. Keyed separable plug and socket type in-line insulated connector(s) shall be provided to permit separating the cells at the shipping splits without having to un-terminate the distribution wiring crossing the shipping splits.

M. Protective Relays
1. Provide protection relays as indicated on Drawings for each circuit breaker. Protection relays shall be manufactured by Schweitzer Engineering Laboratories (SEL).
2. Protection Relays shall be as follows:

Relay ID	SEL Type No.	SEL Ordering No.	Config. Key No.	Comments
RLY-C701-1 RLY-C702-1 RLY-C790-3 RLY-C790-4	SEL-751 Feeder Protection	751201ACA1A70850220	0116	⇨ Std.+ Directional Firmware, ⇨ Std.+DNP3 Protocols, ⇨ 4 DI - 125 Vdc/Vac, 4 DO - Fast High Current, ⇨ 4 DI - 125 Vdc/Vac, 4 DO - Electromechanical, ⇨ 2 AVI/4 AFDI, V_{sync}, V_{bat} Input, Arc-Flash Inputs
Relay ID	SEL Type No.	SEL Ordering No.	Config. Key No.	Comments
RLY-C701-T RLY-C703-1 RLY-G750-1 RLY-S730-1 RLY-R701-1 RLY-S701-1 RLY-C704-1 RLY-G760-1 RLY-S740-1 RLY-R702-1 RLY-S702-1 RLY-C790-1 RLY-C790-2 RLY-C572-2 RLY-C582-2 RLY-Y793-1	SEL-751 Feeder Protection	751001ACA1A70850220	0108	⇨ Std. Firmware, ⇨ Std.+DNP3 Protocols, ⇨ 4 DI - 125 Vdc/Vac, 4 DO - Fast High Current, ⇨ 4 DI - 125 Vdc/Vac, 4 DO - Electromechanical, ⇨ 2 AVI/4 AFDI, V_{sync}, V_{bat} Input, Arc-Flash Inputs
RLY-C701-2 RLY-C702-2	SEL-587Z High Impedance Differential	0587Z0X325312XX	7635	⇨ Std. Firmware, ⇨ Std.+ Modbus RTU Protocols, ⇨ 2 Energy Limiting MOVs
RLY-C572-1 RLY-C582-1	SEL-700G1 Generator Protection	0700G11ABA0X76850220 **SUGGESTED, GENERATOR MANUFACTURER TO CONFIRM**	1639	⇨ Std. Firmware, ⇨ Std.+DNP3 Protocols, ⇨ 3 DI - 125 Vdc/Vac, 4 DO - Electromechanical, 1 AO, ⇨ 3 x I_{PH} AC, V_{sync}, V_n Inputs, 5 Amp/Ø, ⇨ 3 x I_{PH}, 1 x I_N AC, 3 x V_{PH} AC, 5 Amp/Ø, 5 Amp/N

3. All relays shall be capable of being programmed using SEL "acSELerator QuickSet" Software".
4. Include software and programming costs in the Bid Amount. It is recommended that the services of the protection relay manufacturer's Engineering Services Department be used to provide configuration, logic development and programming services.
   a. The personnel engaged to perform the protection relay configuration and programming (Programming Services Provider) shall have demonstrable experience in programming of the protection relays utilized for switchgear protection (minimum of 5 years and 3 equivalent projects),

b. The choice of Programming Services Provider shall be subject to review and approval by the Contract Administrator.

5. Breaker coordination settings curves in the form of "Settings Letters" will be supplied to the Switchgear Vendor and are incorporated into the Contract documents. All other settings are to be determined by the Switchgear Vendor.

N. Real Time Automation Controller (RTAC)

1. Provide a Real Time Automation Controller (RTAC) as indicated on the Drawings. The RTAC shall be manufactured by Schweitzer Engineering Laboratories (SEL) and shall be a SEL-3530 series automation controller in a "3U" enclosure, RTAC firmware shall be version "R135" or later.
2. The RTAC shall be capable of being programmed using SEL type SEL-5033 "acSELerator RTAC Software", version "1.18.7825.1140" or later.
3. The RTAC shall be as follows:

SEL Type No.	SEL Ordering No.	Config. Key No.	Comments
SEL-3530 Real Time Automation Controller	35303A0D1211X0XXXXXX **SUPPLIER TO CONFIRM**	5151	⇨ Horizontal panel mount – 3U, ⇨ 125/250 Vdc; 120/240 Vac power supply, ⇨ Two 10/100BASE-T rear ethernet, ⇨ 24 DI - 125 Vdc/Vac, 8 DO, ⇨ Basic HMI Run-Time License, ⇨ Client Protocols, SEL, DNP3, Modbus, C37.118 Synchrophasors, L&G 8979, CP2179, ⇨ SEL, DNP3, Modbus, L&G 8979, ⇨ Server Protocols, SES-92, IEC 60870-5-101/104, C37.118 Synchrophasors, ⇨ Peer-Peer Protocols, MIRRORED BITS®, Network Global Variable List (NGVL), ⇨ 17 EIA-232/EIA-485 Rear Serial Ports

4. The RTAC shall be installed in panel CP-C794 in the electrical building.
5. Include software and programming costs for the RTAC in the Bid Amount. It is recommended that the services of the RTAC Manufacturer's Engineering Services Department be used to provide RTAC configuration, logic development and programming services.
   a. The personnel engaged to perform the RTAC configuration (Programming Services Provider), logic development, and programming shall have demonstrable experience in programming of the RTAC (minimum of 5 years and 3 equivalent projects)
   b. The choice of programming services provider shall be subject to review and approval by the Contract Administrator.
6. EC to provide/install "CAT6" Ethernet cabling and connectors as indicated on the Drawings.
7. The RTAC system shall communicate with the Plant Process Control System (**PCS**) via Ethernet to make status and analogue metering data available to the PCS for all equipment monitored or controlled by the RTAC.
8. The Plant Process Control System (**PCS**) and the Standby Generator System Master Controller are provided with hardwired signals to and from the RTAC as indicated on Drawings 1-0102-EBDG-C002, and 1-0102-EWDG-C023-001, and 1-0101-EWDG-C025.

NOTE: The RTAC incorporates provisions for up to seventeen (17) additional hardwired 125 Vdc digital input signals (IN03, IN07 to IN12, and IN15 to IN24) from the Standby Generator Control System if they are required by the Generator System Manufacturer.
Input IN101 shall not be used for generator system inputs.
If these hardwired input signals are utilized the required 125 Vdc power shall be sourced from the RTAC panel CP-C794 and the contacts in the Generator Control System shall be in the form of isolated potential free contacts (dry contacts). The Electrical Contractor shall include the supply and installation of the required type Teck cabling in his bid pricing

O. Ethernet Switches

1. Provide three (3) Schweitzer Engineering Laboratories (SEL) type SEL-2730U Unmanaged Ethernet Switches c/w SEL-9330-A power supply unit (one switch in each of switchgear units SGR-C701, SGR-C702, and SGR-C790) as indicated on the Drawings.
2. The Unmanaged Ethernet Switches shall be as follows:

SEL Type No.	SEL Ordering No.	Config. Key No.	Comments
SEL-2730U	2730U0ARAX1111AAAAX0 **SUPPLIER TO CONFIRM**	3166	⇨ Rack Mount (Front or Rear Cabled), ⇨ 125/250 Vac/Vdc Euro-style Connector, ⇨ 16 10/100BASE-T Ports 9-24, ⇨ Conformal Coating.

3. Wire and connect the switches in accordance with Drawing 1-0102-ENET-C001.

P. Ethernet Transceivers

1. Provide two (2) SEL-9890 Ethernet to RS-232 serial transceivers, one for each of the SEL-587Z high impedance differential relays. Install as indicated on Drawing 1-0102-Enet-C001.

NOTE: The internal programming jumpers in the SEL-587Z relay must be set in accordance with the instructions in "Section 2, Installation, EIA-232 Serial Communications Port Voltage Jumper" of the 587Z manual to provide the required +5VDC (Pin 1), and ground (Pin 9) voltages on "Port 1 (rear EIA-232 Communications Port) to provide power to the transceiver module.

Q. Satellite-Synchronized Clock (SSC) System

1. Provide a Satellite-Synchronized Clock System as indicated on the Drawings.
2. Satellite-Synchronized Clock (SSC) shall be manufactured by Schweitzer Engineering Laboratories (SEL) and shall be a SEL-2404 c/w a complete antenna instillation kit including antenna (SEL-9524A GNSS antenna), 50ft LMR-400 cable, gas tube coaxial surge protector & mounting kit (SEL p/n 915900139), 25ft LMR-400 cable.
3. The SEL-9524 GNSS antenna shall be mounted on a ¾" (19mm) galvanized pipe in accordance with the Drawings. Mounting pipe to be supplied and installed by the Electrical Contractor in accordance with the Drawings.
4. Gas tube coaxial surge protector to be mounted and grounded in accordance with the Drawings and Manufacturer's instructions.

5. The Satellite-Synchronized Clock shall be installed in panel CP-C794 in the electrical building.
6. The Satellite-Synchronized Clock shall be as follows:

SEL Type No.	SEL Ordering No.	Config. Key No.	Comments
SEL-2404	24041443X **SUPPLIER TO CONFIRM**	2627	⇨ Horizontal Rack Mount, ⇨ 125 Vdc or Vac, ⇨ Four (4) BNC IRIG-B Outputs, ⇨ Complete Antenna Installation Kit w/ SEL-9524 GNSS Antenna

7. Provide inline cabling, connectors (in-line and "Tee") and "end of line terminators" in accordance with Manufacturer's requirements and as indicated on the Drawings.
8. Wire and connect the SSC system in accordance with Drawing 1-0102-ENET-C001.

2.4 ARC FLASH

A. The switchgear design shall meet and comply with the following arc-flash withstand test requirements:
   1. As specified in IEEE- C37.20.7 for TYPE-2B (Switchgear with arc- resistant designs and features at front, back and sides, with equipment meeting additional requirements of clause A2.1 and A2.2 of IEEE-C37.20.7.
   2. Tested for internal arcing short circuit current of 17.7kA (70.7 percent of 25kA) for arcing duration of 500ms.
   3. As specified in IEEE-C37.20.7 clause A2.2, Type-2B: Arcing shall not cause holes in the freely accessible front, sides and rear of the enclosure or in the walls isolating the low voltage control or instrumentation compartments.
   4. Vent all arc- flash gases and internal overpressure through the switchgear top vents.
   5. The arc-flash plenum shall be vented to the exterior of the building as indicated on the Drawings.
   6. The arc-flash plenum shall be tested with the arc-resistant switchgear. Submit a certified test report from the testing laboratory.

B. The switchgear design shall utilize point sensors and fibre optic cabling in addition to current monitoring to detect arc flash events within the switchgear as follows:
   1. Fibre optic cabling shall be installed within the bus sections. All switchgear cells or compartments with voltage levels above 125 VDC shall have sensors installed within. Tripping shall be designed to allow for proper operation either from the standby generator sources, main utility sources or tie breaker.
   2. Protective relay arc flash detection zones within switchgear SGR-C701 and SGR-C702 shall generally be as follows:
      a. Main circuit breaker protective relay detection zone shall include:
         1) Incoming cable compartment,
         2) Main circuit breaker cable and bus side "stabs",
         3) Main bus compartment,
         4) All branch circuit breaker bus side "stabs" (including the incoming generator breaker bus side "stabs"),
         5) Tie breaker bus "stabs" for the associated main bus,
         6) Main circuit breaker compartment.
      b. Incoming generator circuit breaker protective relay:
         1) Incoming generator cable compartment (from switchgear SGR-C790),
         2) Incoming generator circuit breaker cable and bus side "stabs",

3) Main bus compartment,
4) All Branch circuit breaker bus side “stabs,
5) Main circuit breaker bus side ”stabs”
6) Tie breaker bus “stabs” for the associated bus,
7) Incoming generator circuit breaker compartment.

c. Branch circuit breaker protective relays:
1) Branch circuit breaker bus and cable side “stabs”,
2) Branch circuit breaker compartment,
3) Branch circuit breaker outgoing cable compartment.

d. Tie circuit breaker protective relay:
1) Zone 1 – Switchgear SGR-C701, main bus, all C701 circuit breaker bus side “stabs” and the tie breaker compartment,
2) Zone 2 – Switchgear SGR-C702, main bus, all C702 circuit breaker bus side “stabs” and the tie breaker compartment,

NOTE: Tie breaker arc flash zones shall only be active when the tie breaker is “racked-in” and the active zone (1 or 2) shall depend on which switchgear bus is being fed by the tie breaker, the other zone shall be deactivated.

3. Protective relay arc flash detection zones within switchgear SGR-C790 shall generally be as follows:
a. Generator circuit breakers CB-C572 and CB-C582 protective relay detection zones shall include:
1) Incoming cable compartment,
2) Generator circuit breaker cable and bus side “stabs”,
3) Main bus compartment,
4) All branch circuit breaker bus side “stabs”,
5) Generator circuit breaker compartment.

b. Branch circuit breakers CB-C790-1, CB-C790-2, and CB-Y793 protective relay detection zones shall include:
1) Branch circuit breaker bus and cable side “stabs”,
2) Branch circuit breaker compartment,
3) Branch circuit breaker outgoing cable compartment.

2.5 METERING

A. With each main circuit breaker provide a PowerLogic ION7650 manufactured by Schneider Electric. This item is a City of Winnipeg standard requirement, **no substitutions or equals will be accepted**.

B. The Meter shall have the following characteristics:
1. Current and voltage inputs.
2. Modbus TCP communication (over Ethernet).
3. Data logging options.
4. I/O (Analog Inputs, Analog outputs, Digital Inputs, Digital Outputs)
5. Alarm setpoints.
6. Harmonics analysis

C. Where specific metering equipment is not provided at a specific breaker, program each SEL relay to display load information on the relay display, including but not limited to Amps, Voltage, VA, VAR, etc.

2.6 FABRICATION

A. Construction:
1. Each equipment bay or cell shall be a separately constructed cubicle assembled to form a rigid freestanding unit. Adjacent bays shall be securely bolted together to form an integrated rigid structure.
2. The rear doors shall be hinged and bolted closed and shall be mechanically interlocked to prevent opening when the circuit breaker is in the "connected" position.
3. Breaker compartment front doors shall be equipped with a lockable handle operated multi-point latching system and shall be mechanically interlocked to prevent opening when the circuit breaker is in the "Connected" position. The mechanical interlock shall be equipped with an over-ride provision which requires removal of a bolt or bolts and the use of tools to operate the over-ride.
4. Breaker compartment doors shall be designed and equipped for breaker racking with the door closed and latched, and shall equipped as required to accommodate the powered portable electrical racking device specified in Section 2.2.I .b. above.
5. Each individual unit shall be braced to prevent distortion.
6. Sheet steel used shall be minimum 11 gauge.
7. All pressure flaps shall be designed such that a 114 kg fully outfitted maintenance worker can step on the flaps without causing permanent deformation or subsequent failure to operate under fault conditions.
   This includes, but is not limited to, the arc flash flaps at the top of the switchgear for energy discharge into the arc flash plenum.
8. Provisions shall be included so that the switchgear lineups can be extended on either end without out requiring modification to the equipment. Closures provided for future extension shall not compromise the required equipment arc flash ratings. Closure retaining bolts or studs shall be designed such that the closure fastenings are removable only from within the equipment.

B. Dimensions:
1. Switchgear dimensions shall be as indicated on Drawing 1-0102-EGAD-C001.
2. Any proposed alternate dimensions shall be submitted to the Contract Administrator for consideration and approval in accordance with B8. Any concrete / structural impacts due to dimensional deviations from those shown on the Drawings shall be performed at no additional cost to the Contract.

C. The metal-clad switchgear shall be fully assembled, inspected, and tested at the factory prior to shipment. Large line-ups shall incorporate shipping splits split to permit normal shipping and handling as well as for ease of rejoining at the jobs site.

2.7 FACTORY FINISHING

A. Where on site finishing is required, prepare and prime surfaces as specified in Section 09 90 00, Painting and Coating.

B. Shop finish metal enclosure surfaces by application of rust resistant primer inside and outside, and at least two coats of finish enamel.

C. Paint indoor switchgear and distribution enclosures light grey to ANSI 61 grey enamel, unless otherwise specified. All steel parts shall be cleaned and an iron phosphate pre-treatment applied prior to paint application.

D. All interior panels for mounting of control and instrumentation devices shall be painted white.

2.8 MODES OF OPERATION:

A. **UTILITY RESTRICTIONS ON OPERATIONAL MODES AND SWITCHGEAR CONFIGURATIONS**

1. Manitoba Hydro (MH) requirements for this project do not permit the paralleling of MH 66 kV overhead lines L8 and L33 at any time, including transiently during switching. Thus opening/closing of the 12.47 kV tie breaker must be an "open transition" operation.
   a. MH 66 kV overhead line L8 feeds switchgear SGR-C701 via 66 kV circuit switcher CS-Y701-1 and 66 kV – 12.47 kV transformer XFMR-Y701.
   b. MH 66 kV overhead line L33 feeds switchgear SGR-C702 via 66 kV circuit switcher CS-Y702-1 and 66 kV – 12.47 kV transformer XFMR-Y702.
2. Additionally Manitoba Hydro requirements for this project do not permit connecting the plant 12.47 kV standby generator system(s) to the MH system or the backfeed of generator power into the MH system. Thus, the 12.47 kV main switchgear (SGR-C701 and SGR-C702) must be isolated by tripping the incoming breakers (SGR-C701.MCB and SGR-C702.MCB respectively) before transferring to generator power.

B. **NORMAL OPERATION**

Refer to Drawings 1-0102-ESLD- Y001, 1-0102-ESLD-C001, 1-0102-ESLD-C002, and 1-0102-C003 for the following parts of this Section.

1. KEY "RACKING PERMISSIVE" INTERLOCKING

1.a. Main breakers SGR-C701.MCB, SGR-C702.MCB, and tie breaker CB-C701-T shall be equipped with a racking permissive key interlocking system permitting only two of the three circuit breakers to be in the "Connected" position (racked-in) at any given time (see Section 2.8 A. below).

1.b. Tie breaker CB-C701-T between SGR-C701 and SGR-C702 will normally be "racked-out". No automatic operation of CB-C701-T is contemplated and thus breaker CB-C701-T will normally be "**EFFECTIVELY OPEN**".

2. BOTH SGR-C701 AND SGR-C702 SUPPLIED BY "UTILITY BASED" POWER

TABLE 1
NORMAL OPERATION,
BOTH SGR-C701 AND SGR-C702 SUPPLIED BY "UTILITY BASED" POWER

EQUIPMENT	STATUS
MH 66 kV, Overhead Line L8	Energized
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]

TABLE 1 NORMAL OPERATION, BOTH SGR-C701 AND SGR-C702 SUPPLIED BY "UTILITY BASED" POWER	
EQUIPMENT	**STATUS**
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and Closed [1,4]
SGR-C701, Bus	Energized
SGR-C701, Incoming Generator Breaker CB-C790-3	Open w/ Close BLOCKED [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701, tie breaker CB-C701-T	"Racked-Out", and EFFECTIVELY OPEN [4]
MH 66 kV, Overhead Line L33	Energized
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and Closed [2,4]
SGR-C702, Bus	Energized
SGR-C702, Incoming Generator Breaker CB-C790-4	Open w/ Close BLOCKED [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]
SGR-C790, Bus	De-Energized
Outgoing Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
Outgoing Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
Load Bank Breaker CB-Y793	Open [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

C. **FAILURE OF ONE "UTILITY BASED" ELECTRICAL POWER SUPPLY**

Refer to Drawings 1-0102-ESLD- Y001, 1-0102-ESLD-C001, 1-0102-ESLD-C002, and 1-0102-C003 for the following parts of this Section.

1. CASE C1, FAILURE OF "UTILITY BASED" POWER TO SGR-C701

TABLE 2 "UTILITY BASED" POWER TO SGR-C701 FAILED, SGR-C702 NORMAL	
EQUIPMENT	**PRE-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	L8 Out of Service, *OR* L8 Sustained Undervoltage with CS-Y701-1 closed, *OR* L8 normal with CS-Y701-1 Open/Tripped
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	De-Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and Closed [1,4]
SGR-C701, Bus	DE-ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	Open w/ Close BLOCKED [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701, tie breaker CB-C701-T	"Racked-Out", and "EFFECTIVELY OPEN" [4]
MH 66 kV, Overhead Line L33	Energized
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and Closed [2,4]
SGR-C702, Bus	Energized
SGR-C702, Incoming Generator Breaker CB-C790-4	Open w/ Close BLOCKED [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]
SGR-C790, Bus	De-Energized

TABLE 2 "UTILITY BASED" POWER TO SGR-C701 FAILED, SGR-C702 NORMAL	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

[1] Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
[2] Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
[3] Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
[4] Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

a. MANUAL SWITCHING NOTES:
   1) The following switching involves "racking" of 12.47 kV key interlocked breakers SGR-C701.MCB and CB-C701-T and is therefore a **MANUAL OPERATION**.
   2) The required switching sequence is generally as follows:
      a) Confirm loss of "Utility" power to SGR-C701 by reading the incoming 12.47 kV voltage to the switchgear on protection relay RLY-C701-1. One or more of the phase-to-phase voltages should be significantly below 12.47 kV or "0",
      b) Confirm that "Utility" power is available from switchgear SGR-C702 by reading the switchgear "bus" voltage on power meter PM-C702. All phase-to-phase "bus" voltages should read approx. 12.47 kV,
      c) Switch the "Manual/Auto" Control Selector Switch for breaker SGR-C701.MCB to "Manual" (manual disables RTAC control). Note that the "TRIP/OPEN" function on the Breaker Control Switch is always active.
      d) **Manually "OPEN"** incoming main breaker SGR-C701.MCB using the Breaker Control Switch.
      e) Confirm that the breaker is "Open". The RED status lamp (Breaker Open) should be "ON", and the GREEN status lamp (Breaker Closed) should be "OFF".
      f) Verify that SGR-C701 is de-energized by reading the switchgear "bus" voltage on power meter PM-C701. Phase-to-phase voltages should read approx. "0" on all phases.
      g) Rack breaker SGR-C701.MCB out to the "Test" or the "Disconnected" position,
      h) Unlatch and open the SGR-C701.MCB breaker compartment door,
      i) Engage the breaker racking interlock, turn and remove the interlock key,
      j) Close and latch the breaker compartment door,
      k) Unlatch and open the breaker compartment door on tie breaker CB-C701-T,
      l) Insert the interlock key in the racking interlock, turn to unlock the interlock (the interlock key is now captive), and disengage the interlock on the circuit breaker,
      m) Close and latch the breaker compartment door, and
      n) Rack tie breaker CB-C701-T into the "Connected" position.

o) **Manually "CLOSE"** tie breaker, CB-C701-T using the Breaker Control Switch.
p) Confirm breaker CB-C701-T is "Closed". The GREEN status lamp (Breaker Closed) should be "ON" and the RED status lamp (Breaker Open) should be "OFF",
q) Verify that switchgear SGR- C701 is now energized by reading the switchgear "bus" voltage on power meter PM-C701.
All phase-to-phase voltages should read approx. 12.47 kV.
r) Switch the "Manual/Auto" Control Selector Switch for breaker SGR-C701.MCB to "Auto" to permit RTAC control of the outgoing branch circuit breakers on SGR-C701 in the event of "Utility Based" power failure to SGR-C702.
s) **Switching is complete; SGR-C701 is fed from SGR-C702 via tie breaker CB-C701-T**.

TABLE 3
"UTILITY BASED" POWER TO SGR-C701 FAILED,
SGR-C701 FED FROM SGR-C702 VIA TIE BREAKER CB-C701-T

EQUIPMENT	**POST-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	L8 Out of Service, *OR* L8 Sustained Undervoltage with CS-Y701-1 Closed, *OR* L8 normal with CS-Y701-1 Open/Tripped
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	De-Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic
SGR-C701, main breaker SGR-C701.MCB	MANUALLY OPENED and "Racked-Out" [4]
SGR-C701, Bus	ENERGIZED via CB-C701-T
SGR-C701, Incoming Generator Breaker CB-C790-3	Open w/ Close BLOCKED [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701, tie breaker CB-C701-T	"Racked-In", and MANUALLY CLOSED [4]
MH 66 kV, Overhead Line L33	Energized
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In", and CLOSED [2,4]
SGR-C702, Bus	Energized
SGR-C702, Incoming Generator Breaker CB-C790-4	Open w/ Close BLOCKED [2, 4]

TABLE 3 "UTILITY BASED" POWER TO SGR-C701 FAILED, SGR-C701 FED FROM SGR-C702 VIA TIE BREAKER CB-C701-T	
EQUIPMENT	**POST-SWITCHING STATUS**
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

2. CASE C1A, RESTORATION OF 12.47 kV "UTILITY BASED" POWER TO SGR-C701

a. 2.a. See TABLE 3, "UTILITY BASED" POWER TO SGR-C701 FAILED, SGR-C701 FED FROM SGR-C702 VIA TIE BREAKER CB-C701-T" above for equipment status before switching back to "Utility Based" Power.

b. 2.b. MANUAL SWITCHING NOTES:

1) The following switching involves "racking" of 12.47 kV key interlocked breakers CB-C701-T and SGR-C701.MCB and is therefore a **MANUAL OPERATION**.

2) The required Switching Sequence is generally as follows:

a) Confirm that "Utility Based" power is available to SGR-C701 by reading the incoming 12.47 voltage on protection relay RLY-C701-1.
All phase-to-phase voltages should read approx. 12.47 kV,

b) Switch the "Manual/Auto" Control Selector Switch for breaker SGR-C701.MCB to "Manual".
Manual closing from the Breaker Control Switch is NOT available if the selector switch is in "Auto".
Note that the "TRIP/OPEN" function from the Breaker Control Switch is always active.

c) **Manually "OPEN"** 12.47 kV main switchgear tie breaker, CB-C701-T using the Breaker Control Switch. Confirm that the breaker has opened. The RED status lamp (Breaker Open) should be "ON", and the GREEN status lamp (Breaker Closed) should be "OFF".
d) Verify that SGR-C701 is de-energized by reading the switchgear " bus" voltage on power meter PM-C701. Volts should read approx. "0" on all phases.
e) Rack tie breaker CB-C701-T out to the "Test" or the "Disconnected" position,
f) Unlatch and open the breaker compartment door,
g) Engage the breaker racking interlock, turn and remove the interlock key,
h) Close and latch the breaker compartment door,
i) Unlatch and open the breaker compartment door on main breaker SGR-C701.MCB,
j) Insert the interlock key in the racking interlock, turn to unlock the interlock (the interlock key is now captive), and disengage the interlock on the circuit breaker,
k) Close and latch the breaker compartment door, and
l) Rack incoming breaker SGR-C701.MCB into the "Connected" position.
m) **Manually "CLOSE"** incoming main breaker SGR-C701.MCB using the Breaker Control Switch. Confirm that the breaker has closed.
The GREEN status lamp (Breaker Closed should be "ON" and the RED status lamp (Breaker Open) should be "OFF".
n) Confirm that switchgear SGR- C701 is now energized by reading the switchgear "bus" voltage on power meter PM-C701. All phase-to-phase voltages should read approximately 12.47 kV.
o) Return the "Manual/Auto" Control Selector Switch for breaker SGR-C701.MCB to "Auto".
SGR-C701.MCB close and open/trip is now automatically controlled by the switchgear RTAC.
Note that the "TRIP/OPEN" function on the Breaker Control Switch is always active.
p) **Switching is complete; SGR-C701 is on normal "Utility Based Power".**

TABLE 4, NORMAL OPERATION, SGR-C701 RETURNED TO "UTILITY BASED" POWER

EQUIPMENT	POST-SWITCHING STATUS
MH 66 kV, Overhead Line L8	Energized
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In", and MANUALLY CLOSED [1,4]
SGR-C701, Bus	Energized
SGR-C701, Incoming Generator Breaker CB-C790-3	Open w/ Close BLOCKED [1,4]

TABLE 4, NORMAL OPERATION, SGR-C701 RETURNED TO "UTILITY BASED" POWER	
EQUIPMENT	**POST-SWITCHING STATUS**
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-Out", and "EFFECTIVELY OPEN" [4]
MH 66 kV, Overhead Line L33	Energized
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In", and CLOSED [2,4]
SGR-C702, Bus	Energized
SGR-C702, Incoming Generator Breaker CB-C790-4	Open w/ Close BLOCKED [2.3]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

3. CASE C2, UTILITY BASED POWER TO SGR-C702 FAILED

TABLE 5 "UTILITY BASED" POWER TO SGR-C702 FAILED, SGR-C701 NORMAL	
EQUIPMENT	**PRE-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	Energized
66 kV Circuit Switcher CS-Y701-1	Closed
66 kV Transformer XFMR-Y701	Energized [4]
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In", and CLOSED [1,4]
SGR-C701, Bus	Energized
SGR-C701, Incoming Generator Breaker CB-C790-3	Open w/ Close BLOCKED [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701, tie breaker CB-C701-T	"Racked-Out", and "EFFECTIVELY OPEN"
MH 66 kV, Overhead Line L33	L33 Out of Service, *OR* L33 Sustained Undervoltage with CS-Y702-1 Closed, *OR* L33 normal with CS-Y702-1 Open/Tripped
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	De-Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In", and CLOSED [2,4]
SGR-C702, Bus	DE-ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	Open w/ Close BLOCKED [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]

TABLE 5 "UTILITY BASED" POWER TO SGR-C702 FAILED, SGR-C701 NORMAL	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

[1] Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
[2] Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
[3] Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
[4] Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

a. 3.a. MANUAL SWITCHING NOTES:

1) The following switching involves "racking" of 12.47 kV key interlocked breakers SGR-C702.MCB and CB-C701-T and is therefore a MANUAL OPERATION.

2) The required switching sequence is generally as follows:

a) Confirm loss of "Utility Based" power to SGR-C702 by reading the incoming 12.47 kV voltage to the switchgear on protection relay RLY-C702-1.
One or more of the phase-to-phase voltages should be significantly below 12.47 kV or "0",

b) Confirm that "Utility" power is available from switchgear SGR-C701 by reading the switchgear "bus" voltage on power meter PM-C701.
All phase-to-phase "bus" voltages should read approx. 12.47 kV,

c) Switch the "Manual/Auto" Control Selector Switch for breaker SGR-C702.MCB to "Manual".
Note that the "TRIP/OPEN" function on the Breaker Control Switch is always active.

d) **Manually "OPEN"** incoming main breaker SGR-C702.MCB using the Breaker Control Switch.

e) Confirm that the breaker is "Open". The RED status lamp (Breaker Open) should be "ON", and the GREEN status lamp (Breaker Closed) should be "OFF".

f) Verify that SGR-C702 is de-energized by reading the switchgear "bus" voltage on power meter PM-C702. Phase-to-phase voltages should read approximately "0" on all phases.

g) Rack breaker SGR-C702.MCB out to the "Test" or "Disconnected" position.

h) Unlatch and open the SGR-C702.MCB breaker compartment door.

i) Engage the breaker racking interlock, turn and remove the interlock key.

j) Close and latch the breaker compartment door.

k) Unlatch and open the breaker compartment door on tie breaker CB-C701-T.

l) Insert the interlock key in the racking interlock, turn to unlock the interlock (the key is now captive), and disengage the interlock on the circuit breaker.

m) Close and latch the breaker compartment door, and

n) Rack tie breaker CB-C701-T into the "Connected" position.

o) **Manually "CLOSE"** tie breaker, CB-C701-T using the Breaker Control Switch.

p) Confirm breaker CB-C701-T is "Closed". The GREEN status lamp (Breaker Closed) should be "ON", and the RED status lamp (Breaker Open) should be "OFF",

q) Verify that switchgear SGR-C702 is now energized by reading the switchgear "bus" voltage on power meter PM-C702.
All phase-to-phase voltages should read approx. 12.47 kV.

r) Return the "Manual/Auto" Control Selector Switch for breaker SGR-C702.MCB to "Auto" to permit RTAC control of the outgoing branch circuit breakers on SGR-C702 in the event of failure of "Utility Based" power to SGR-C702.

s) Switching is complete; SGR-C702 is fed from SGR-C701 via tie breaker CB-C701-T.

TABLE 6
"UTILITY BASED" POWER TO SGR-C702 FAILED,
SGR-C702 FED FROM SGR-C701 VIA TIE BREAKER CB-C701-T

EQUIPMENT	**POST-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	Energized
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In", and CLOSED [1,4]
SGR-C701, Bus	Energized
SGR-C701, Incoming Generator Breaker CB-C790-3	Open W/ Close BLOCKED [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and MANUALLY CLOSED
MH 66 kV, Overhead Line L33	L33 Out of Service, *OR* L33 Sustained Undervoltage with CS-Y702-1 Closed, *OR* L33 normal with CS-Y702-1 Open/Tripped
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	De-Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic
SGR-C702, main breaker SGR-C702.MCB	MANUALLY OPENED and "Racked-Out" [4]
SGR-C702, Bus	Energized
SGR-C702, Incoming Generator Breaker CB-C790-4	Open [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running

TABLE 6 "UTILITY BASED" POWER TO SGR-C702 FAILED, SGR-C702 FED FROM SGR-C701 VIA TIE BREAKER CB-C701-T	
EQUIPMENT	**POST-SWITCHING STATUS**
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

[1] Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
[2] Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
[3] Operation of switchgear SGR-C790 breakers outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
[4] Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

4. CASE C2A, RESTORATION OF 12.47 kV "UTILITY BASED" POWER TO SGR-C702

a. 4.a. See TABLE 6, "UTILITY BASED" POWER TO SGR-C702 — FAILED, SGR-C702 FED FROM SGR-C701 VIA TIE BREAKER CB-C701-T" above for equipment status before switching back to "Utility Based" Power.

b. 4.b. MANUAL SWITCHING NOTES:

1) The following switching involves "racking" of 12.47 kV key interlocked breakers CB-C701-T and SGR-C702.MCB and is therefore a **MANUAL OPERATION**.

2) The required Switching Sequence is generally as follows:

a) Confirm that "Utility Based" power is available to SGR-C702 by reading the incoming 12.47 voltage on protection relay RLY-C702-1. All phase-to-phase voltages should read approx. 12.47 kV,

b) Switch the "Manual/Auto" Control Selector Switch for breaker SGR-C702.MCB to "Manual".
Note that the "TRIP/OPEN" function from the Breaker Control Switch is always active.

c) **Manually "OPEN"** tie breaker, CB-C701-T using the Breaker Control Switch.

d) Confirm that the breaker has opened. The RED status lamp (Breaker Open) should be "ON", and the GREEN status lamp (Breaker Closed) should be "OFF".

e) Verify that SGR-C702 is de-energized by reading the switchgear "Bus" voltage on power meter PM-C702. Volts should read approx. "0" on all phases.

f) Rack tie breaker CB-C701-T out to the "Test" or "Disconnected" position.

g) Unlatch and open the breaker compartment door.
h) Engage the breaker racking interlock, turn and remove the interlock key.
i) Close and latch the breaker compartment door.
j) Unlatch and open the breaker compartment door on incoming main breaker SGR-C702.MCB.
k) Insert the interlock key in the racking interlock, turn to unlock the interlock (the key is now captive), and disengage the interlock on the circuit breaker.
l) Close and latch the breaker compartment door, and
m) Rack incoming main breaker SGR-C702.MCB into the "Connected" position.
n) **Manually "CLOSE"** incoming main breaker SGR-C702.MCB using the Breaker Control Switch.
o) Confirm that the breaker has closed. The GREEN status lamp (Breaker Closed) should be "ON" and the RED status lamp (Breaker Open) should be "OFF".
p) Confirm that switchgear SGR- C702 is now energized by reading the switchgear "bus" voltage on power meter PM-C702. All phase-to-phase voltages should read approximately 12.47 kV.
q) Return the "Manual/Auto" Control Selector Switch for breaker SGR-C702.MCB to "Auto".
Close and open/trip of SGR-C701.MCB is now automatically controlled by the switchgear RTAC.
Note also that the "TRIP/OPEN" function on the Breaker Control Switch is always active.
r) **Switching is complete; SGR-C702 is on normal "Utility Based Power"**.

TABLE 7
NORMAL OPERATION, SGR-C702 RETURNED TO "UTILITY BASED" POWER

EQUIPMENT	**POST-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	Energized
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and CLOSED [1,4]
SGR-C701, Bus	Energized
SGR-C701, Incoming Generator Breaker CB-C790-3	Open w/ Close BLOCKED [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	MANUALLY OPENED, and "Racked-Out"
MH 66 kV, Overhead Line L33	Energized
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	Energized

TABLE 7 NORMAL OPERATION, SGR-C702 RETURNED TO "UTILITY BASED" POWER	
EQUIPMENT	**POST-SWITCHING STATUS**
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and MANUALLY CLOSED [2,4]
SGR-C702, Bus	Energized
SGR-C702, Incoming Generator Breaker CB-C790-4	Open w/ Close BLOCKED [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

D. FAILURE OF BOTH "UTILITY BASED" ELECTRICAL POWER SUPPLIES

1. Refer to Drawings 1-0102-ESLD-Y001, 1-0102-ESLD-C001, 1-0102-ESLD-C002, and 1-0102-C003) for the following parts of this Section.
2. **General requirements for Switchgear Automation Control**:
   a. 1.a. RTAC "Close/Open" control shall only be used for switching sequence automation purposes. Protective "Trip" functions from the switchgear Protective Relays shall be hardwired into the breaker trip coil circuits and shall NOT be routed via the RTAC.

b. 1.b. **Breaker "Auto/Manual" Control Selector Switches shall provide breaker Close & Open/Trip control of circuit breakers as follows**:

TABLE 8
SGR-C701, BREAKER CONTROL AVAILABILITY

	SGR-C701.MCB Auto/Man Sel. Sw.		Breaker Control Sw. Control		Switchgear RTAC Control[1]	
	Manual	Auto	Close	Open/Trip	Close	Open
Incoming Main SGR-C701.MCB	X		YES	YES	NO	NO
		X	NO	YES	YES	YES
Incoming Generator Breaker CB-C790-3	X		NO [2]	YES	NO	NO
		X	NO [2]	YES	YES	YES
Outgoing Feeder Breakers	X		YES	YES	NO	NO
		X	YES	YES	YES	YES

1 See 1.a. above.
2 Manual "Close" from the CB-C790-3 Breaker Control Switch is available only with breaker CB-C790-3 in the "Test" position.

TABLE 9
SGR-C702, BREAKER CONTROL AVAILABILITY

	SGR-C702.MCB Auto/Man Sel. Sw.		Breaker Control Sw. Control		Switchgear RTAC Control[1]	
	Manual	Auto	Close	Open/Trip	Close	Open
Incoming Main SGR-C702.MCB	X		YES	YES	NO	NO
		X	NO	YES	YES	YES
Incoming Generator Breaker CB-C790-4	X		NO [2]	YES	NO	NO
		X	NO [2]	YES	YES	YES
Outgoing Feeder Breakers	X		YES	YES	NO	NO
		X	YES	YES	YES	YES

1 See 1.a. above.
2 Manual "Close" from the CB-C790-4 Breaker Control Switch is available only with breaker CB-C790-4 in the "Test" position.

TABLE 10
SGR-C790, BREAKER CONTROL AVAILABILITY

	Generator System Auto/Man Sel. Sws.		Breaker Control Sw. Control		Generator System Control		Switchgear RTAC Control[4]	
	Manual	Auto	Close	Open/Trip	Close	Open/Trip	Close	Open
Outgoing Feeder Breaker CB-C790-1	X		YES	YES	NO	NO	NO	NO
		X	NO	YES	NO	NO	YES	YES
Outgoing Feeder Breaker CB-C790-2	X		YES	YES	NO	NO	NO	NO
		X	NO	YES	NO	NO	YES	YES
Incoming Generator Breaker CB-C572	X		YES [2,3]	YES	NO	YES	NO	NO
		X	NO	YES	YES [2,4]	YES	NO	NO
Incoming Generator Breaker CB-C582	X		YES [2,3]	YES	NO	YES	NO	NO
		X	NO	YES	YES [2,4]	YES	NO	NO
Load Bank Feeder Breaker CB-Y793	X		YES	YES	NO	NO	NO	NO
		X	NO	YES	NO	YES	NO	NO

1 See 1.a. above.
2 "Close" for incoming generator breakers CB-C572 and CB-C582 shall have hardwired "Close Permissive" interlocking from the "synchro-check" element in the associated generator protection relay to permit manual close ONLY if the generator switchgear bus is "de-energized" or if the generator is running conditions are within the "synchro-check window".
3 Manual "Close" for incoming generator breakers CB-C572 and CB-C582 from the Breaker Control Switch is available with breaker in the "Test" position.
4 Automatic "Close/Open" control for incoming generator breakers CB-C572 and CB-C582 shall be by the generator control system.

3. CASE D1, SIMULTANEOUS FAILURE OF "UTILITY BASED" POWER TO BOTH SGR-C701 AND SGR-C702

TABLE 11
"UTILITY BASED" POWER TO SGR-C701 FAILED, SGR-C702 FAILED

EQUIPMENT	PRE-SWITCHING STATUS
MH 66 kV, Overhead Line L8	L8 Out of Service, *OR* L8 Sustained Undervoltage with CS-Y701-1 Closed, *OR* L8 normal with CS-Y701-1 Open/Tripped
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	De-Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and CLOSED [1,4]
SGR-C701, Bus	DE-ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	Open [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]

TABLE 11 "UTILITY BASED" POWER TO SGR-C701 FAILED, SGR-C702 FAILED	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-Out" EFFECTIVELY OPEN
MH 66 kV, Overhead Line L33	L33 Out of Service, *OR* L33 Sustained Undervoltage with CS-Y702-1 Closed, *OR* L33 normal with CS-Y702-1 Open/Tripped
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	De-Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and CLOSED [2,4]
SGR-C702, Bus	DE-ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	Open [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open
SGR-C790, Generator Breaker CB-C582	Open
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

1 Switching sequence "Close/Open" control of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Switching sequence "Close/Open" control of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED.**
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

a. 2.a. **OPERATIONAL SEQUENCE ON A SUSTAINED SIMULTANEOUS FAILURE OF BOTH "UTILITY BASED" 12.47kV SUPPLIES**:

1) Note that the "Manual/Auto" selector switches on both main breakers SGR-C701.MCB and SGR-C702.MCB as well as those on the Generator System must be all in "Auto" or the Automatic Generator Switching sequence will not occur.
2) Undervoltage conditions on the incoming 12.47 kV feeders to SGR-C701 and SGR-C702 shall be detected by the operation (assertion) of the 27 (undervoltage elements) in relays RLY-C701-1 and RLY-C702-1 respectively.
3) RTAC control and sensing shall be via Ethernet communications except as noted in Sections **2.3 N 6.** to **2.3 N 10.** above.
4) The switchgear automation controller (RTAC) shall generally operate as follows:
   a) On assertion of the 27 element in relay RLY-C701-1 trigger an "SGR-C701 Supply Failure Timer", de-assertion of the 27 element shall cause immediate reset of the timer. Time delay shall be user selectable (recommended adjustable time delay of 45 seconds on utility failure to permit Manitoba Hydro overhead line reclosing attempts to occur).
   b) On assertion of the 27 element in relay RLY-C702-1 trigger an "SGR-C702 Supply Failure Timer", de-assertion of the 27 element shall cause immediate reset of the timer. Time delay shall be user selectable,
   c) On assertion of both of the "Supply Failure" timer outputs, the RTAC shall perform the following sequence of actions:
      (1) Set a "Transfer to Generation Sequence" latch.

      NOTE: Once the transfer to generation latch has been set the RTAC shall ignore any further changes in undervoltage conditions on the incoming 12.47 kV feeders to SGR-C701 and SGR-C702 and shall continue the switching sequence to completion [**Step vii) k)** below], or to sequence abort [**Step vi)** below].
      The "transfer to generation sequence" latch shall be reset either by a successful sequence completion or by a "Manual RTAC Reset" after a sequence abort condition.

      (2) Store the Breaker Status (Open/Closed) condition for all of the circuit breakers in switchgear SGR-C701 and SGR-C702. The stored breaker status will be used to determine which breakers to reclose during switching
      (3) Signal the Generator System Master Controller, to begin the generator startup and synchronizing sequence – **"Generator Startup"**,
      (4) Signal the PCS that switchgear SGR-C701 and SGR-C702 are de-energized and transfer to "Generator Power" is being initiated – "**Loss of Utility Power - Generator Power Initiated**" signal,
      (5) Open switchgear SGR-C701, 12.47 kV incoming main breaker SGR-C701.MCB via protection relay RLY-C701-1,
      (6) Confirm "no voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
      (7) Open switchgear SGR-C701, 12.47 kV outgoing branch breakers CB-S701, CB-R701, CB-S730, CB-G750, and CB-C703 via their respective protection relays,
      (8) Open switchgear SGR-C702, 12.47 kV incoming main breaker SGR-C702.MCB via protection relay RLY-C702-1,

(9) Confirm "no voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
(10) Open switchgear SGR-C702, 12.47 kV outgoing branch breakers CB-S702, CB-R702, CB-S740, CB-G760, and CB-C704 via their respective protection relays,
(11) Pause and wait for a response from the Generator System Master Controller after it has completed the generator startup sequence.

d) On receipt of the momentary "Generator Startup Signal" **[Step iv.c)(3) above]**, the Generator System Master controller shall latch the signal as required and perform (at minimum) the following functions:
(1) Open load bank breaker CB-Y793 if it is not already open,
(2) Initiate start of gensets GEN-C572, and GEN-C582,
(3) Confirm genset GEN-C572 start, stable running, voltage and frequency within tolerances,
(4) Confirm genset GEN-C582 start, stable running, voltage and frequency within tolerances,
(5) The first genset meeting the criteria of Steps (c) and (d) above shall be used to energize switchgear SGR-C790 bus by closing generator breaker CB-C572, or CB-C582 as required,
(6) Confirm switchgear SGR-C790 bus voltage, frequency and phase rotation are correct,
(7) Synchronize the second genset to switchgear SGR-C790 bus and close generator breaker CB-C572, or CB-C582 as required,
(8) The generator startup sequence is now complete and the Generator System Master Controller shall signal the RTAC as follows:
(9) Both generator units have successfully started and synchronized to Generator Switchgear SGR-C790 and the generator system is ready for load application – "**Startup Sequence Complete, 2 Generators"**, or
(10) One generator unit has successfully started and connected to Generator Switchgear SGR-C790 and is ready for load application, the second generator has failed to start and synchronize – "**Startup Sequence Complete, 1 Generator"**, or
(11) Both generator units have failed to start, synchronize and connect to Generator Switchgear SGR-C790 – "**Standby Power System Failure"**.

e) On receipt of the "**Standby Power System Failure"** signal from, the generator master controller, the RTAC shall abort any further automatic switching sequence steps, and signal the PCS "**Standby Power System Failure**" has occurred.
(1) At this point, operator intervention will be required to investigate the cause of the generator system failure and perform any corrective measures necessary. After correction of the cause of the failure, the operator shall reset the generator master controller.
(2) Operator intervention will be required to close all previously operated breakers to the original starting conditions This will allow the RTAC to resume control based on the prevailing electrical conditions on the supply system.
(3) After completing the required switching, the operator shall reset the RTAC system – (Manual RTAC Reset) which will reset the "Transfer to Generation Sequence" latch.

f) On receipt of the "**Startup Sequence Complete, 2 Generators"** or the "**Startup Sequence Complete, 1 Generator"** signals from the generator master controller, the RTAC shall perform the following actions:
   (1) Close switchgear SGR-C701, 12.47 kV incoming generator breaker CB-C790-3 via protection relay RLY-C790-3,
   (2) Close switchgear SGR-C702, 12.47 kV incoming generator breaker CB-C790-4 via protection relay RLY-C790-4,
   (3) Close generator switchgear SGR-C790 breaker CB-C790-1 via relay RLY-C790-1 to apply generator power to switchgear SGR-C701, and
   (4) Close generator switchgear SGR-C790 breaker CB-C790-2 via relay RLY-C790-2 to apply generator power to switchgear SGR-C702,
   (5) Confirm "Normal Voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
   (6) Utilizing the stored circuit breaker status conditions [Step iv.c) above] close the outgoing load breakers in the next steps only if they were closed at the time of power failure,
   (7) Close switchgear SGR-C701, 12.47 kV outgoing branch breakers in the indicated order with a time delay between successive closures CB-G750, CB-C703, CB-S730, CB-R701, and CB-S701. Time delays shall be initially set at 3 seconds. Inter-breaker time delays and closing order shall be user adjustable on an individual breaker basis,
   (8) Confirm "Normal Voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
   (9) Close switchgear SGR-C702, 12.47 kV outgoing branch breakers in the indicated order with a time delay between successive closures CB-G760, CB-C704, CB-S740, CB-R702, and CB-S702. Inter-breaker time delays and closing order shall be user adjustable on an individual breaker basis,
   (10) Signal the PCS that switchgear SGR-C701 and SGR-C702 are "**Energized on Generator Power**" or "**Energized on One Generator Only**" as appropriate. The PCS will then initiate sequential loading of the generator system in accordance with the appropriate generator loading restrictions.
   (11) Reset the "Transfer to Generation Sequence" latch

g) The automatic generator start and connect sequence is now complete and switchgear SGR-C701 and SGR-C702 are now on Generator Supply.

TABLE 12 SGR-C701 AND SGR-C702 SUPPLIED BY GENERATOR POWER	
EQUIPMENT	**POST-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	L8 Out of Service, *OR* L8 Sustained Undervoltage with CS-Y701-1 Closed, *OR* L8 normal with CS-Y701-1 Open/Tripped
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	De-Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In", AUTOMATICALLY OPENED BY RTAC, w/ Close BLOCKED [1,4,5]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	AUTOMATICALLY CLOSED BY RTAC [1,4,5]
SGR-C701, Outgoing Feeder Breakers	AUTOMATICALLY CLOSED BY RTAC [1,5]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-Out", EFFECTIVELY OPEN [4]
MH 66 kV, Overhead Line L33	L33 Out of Service, *OR* L33 Sustained Undervoltage with CS-Y701-1 Closed, *OR* L33 normal with CS-Y702-1 Open/Tripped
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	De-Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In", AUTOMATICALLY OPENED BY RTAC, w/ Close BLOCKED [2,4,5]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	AUTOMATICALLY CLOSED BY RTAC [2,4,5]
SGR-C702, feeder breakers	AUTOMATICALLY CLOSED BY RTAC [2,5]
Generator Master Control "Manual/Auto" Sel. Sw.	Automatic [3]

TABLE 12 SGR-C701 AND SGR-C702 SUPPLIED BY GENERATOR POWER	
EQUIPMENT	**POST-SWITCHING STATUS**
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	RUNNING [5]
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	RUNNING [5]
SGR-C790, Generator Breaker CB-C572	AUTOMATICALLY CLOSED BY GENERATOR CONTROLS [4,5]
SGR-C790, Generator Breaker CB-C582	AUTOMATICALLY CLOSED BY GENERATOR CONTROLS [4,5]
SGR-C790, Bus	ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	AUTOMATICALLY CLOSED BY RTAC [3,4,5]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	AUTOMATICALLY CLOSED BY RTAC [3,4,5]
SGR-C790, Load Bank Breaker CB-Y793	Open w/ Close BLOCKED [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED**.
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED**.
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
5 See sequence description above.

4. CASE D1A, RETURN FROM GENERATOR POWER TO NORMAL "UTILITY BASED" POWER FOR ONE OR BOTH OF SGR-C701 AND SGR-C702

TABLE 13 SGR-C701 AND SGR-C702 SUPPLIED BY GENERATOR POWER, "UTILITY BASED" POWER SUPLY RESTORED	
EQUIPMENT	**PRE-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	ENERGIZED
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	ENERGIZED
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and OPEN [1,4]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	"Racked-In" and CLOSED [1,4]

TABLE 13 SGR-C701 AND SGR-C702 SUPPLIED BY GENERATOR POWER, "UTILITY BASED" POWER SUPLY RESTORED	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-Out" EFFECTIVELY OPEN [4]
MH 66 kV, Overhead Line L33	ENERGIZED
66 kV Circuit Switcher CS-Y702-1	CLOSED [4]
66 kV Transformer XFMR-Y702	ENERGIZED
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and OPEN [2,4]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	CLOSED [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	RUNNING
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	RUNNING
SGR-C790, Generator Breaker CB-C572	CLOSED [4]
SGR-C790, Generator Breaker CB-C582	CLOSED [4]
SGR-C790, Bus	ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	CLOSED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	CLOSED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open w/ Close BLOCKED [4]

[1] Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
[2] Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
[3] Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
[4] Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.

a. 3.a. The sequence for return to "Utility Based" power described below will occur **IF EITHER OR BOTH OF THE "UTILITY BASED" 12.47kV FEEDS ARE RESTORED**.

b. 3.b. OPERATIONAL SEQUENCE ON RETURN TO "UTILITY BASED" POWER FROM GENERATOR SUPPLIED POWER:

1) Note that the "Manual/Auto" selector switches on both main breakers SGR-C701.MCB and SGR-C702.MCB as well as those on the Generator System must be all in "Auto" or the Automatic Generator Switching sequence will not occur.
2) Return to "Normal" voltage conditions on the incoming 12.47 kV feeders to SGR-C701 and/or SGR-C702 shall be detected by the reset (de-assertion) of the 27 (undervoltage elements) in either one or both of relays RLY-C701-1 and RLY-C702-1 respectively.
3) RTAC control and sensing shall be via Ethernet communications except as noted in Sections 2.3 N 6. to 2.3 N 10. above.
4) The switchgear automation controller (RTAC) shall perform the following sequence of actions:
   a) On reset (de-assertion) of the 27 element in either of relays RLY-C701-1 or RLY-C702-1 a user settable (recommended 10 minute delay) "Supply Restoration Delay" timer shall be triggered and the "Supply Failure Timers" shall be force reset.
   b) On assertion of the "Supply Restoration Delay" timer output. The RTAC shall execute the following sequence of actions:
      (1) Signal the PCS that "**Transfer to Utility Based Power Initiated**" for SGR-C701 and SGR-C702.
      (2) Set a "Transfer to Utility Based Power Sequence" latch.

          NOTE: Once the Transfer to Utility Based Power latch has been set the RTAC shall ignore any further changes in undervoltage conditions on the incoming 12.47 kV feeders to SGR C701 and SGR-C702 and shall continue the switching sequence to completion [**Step (14)** below].
      (3) "Open" generator switchgear SGR-C790 breakers CB-C790-1 and CB-C790-2 via protection relays RLY-C790-1 and RLY-C790-2 respectively to remove generator power from switchgear SGR-C701 and SGR-C702,
      (4) Open switchgear SGR-C701, 12.47 kV incoming generator breaker CB-C790-3 via protection relay RLY-C790-3,
      (5) Open switchgear SGR-C702, 12.47 kV incoming generator breaker CB-C790-4 via protection relay RLY-C790-4,
      (6) Signal the Generator System Master Controller to open generator breakers CB-C572 and CB-582 and begin the generator cool-off and shutdown sequence "**Generator Shutdown Signal**",
      (7) Confirm "no voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
      (8) Confirm "no voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
      (9) Providing that there are no active protective trips associated with breaker SGR-C701.MCB and the breaker was "Closed" at the time the original power failure occurred, Close incoming main breaker SGR-C701.MCB via protection relay RLY-C701-1,
      (10) Confirm "Normal Voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,

(11) Providing that there are no active protective trips associated with breaker SGR-C702.MCB and the breaker was "Closed" at the time the original power failure occurred, Close incoming main breaker SGR-C702.MCB via protection relay RLY-C702-1,
(12) Confirm "Normal Voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
(13) Signal the PCS that normal power has been restored – "**Utility Based Normal Power"**. The PCS will then initiate automatic plant operating conditions.
(14) Reset the "Transfer to Utility Based Power Sequence" latch.

c) At least one of Switchgear SGR-C701 and SGR-C702 are now on "Utility Based Normal Power".

TABLE 14
"UTILITY BASED" POWER RESTORED TO AT LEAST ONE OF SGR-C701 AND SGR-C702

EQUIPMENT	POST-SWITCHING STATUS
MH 66 kV, Overhead Line L8	ENERGIZED
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	ENERGIZED
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and AUTOMATICALLY CLOSED BY RTAC [1,4,6]
SGR-C701, Bus	ENERGIZED [5]
SGR-C701, Incoming Generator Breaker CB-C790-3	AUTOMATICALLY OPENED BY RTAC [1,4,6]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation (Open/Closed status will be the same as when under Generator Supply) [1,4]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-Out" EFFECTIVELY OPEN
MH 66 kV, Overhead Line L33	Energized
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	ENERGIZED
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and AUTOMATICALLY CLOSED BY RTAC [2,4,6]
SGR-C702, Bus	ENERGIZED [5]

TABLE 14 "UTILITY BASED" POWER RESTORED TO AT LEAST ONE OF SGR-C701 AND SGR-C702	
EQUIPMENT	**POST-SWITCHING STATUS**
SGR-C702, Incoming Generator Breaker CB-C790-4	AUTOMATICALLY OPENED BY RTAC [2,4,6]
SGR-C702, feeder breakers	As required for plant operation (Open/Closed status will be the same as when under Generator Supply) [2,4]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	SHUTTING DOWN
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	SHUTTING DOWN
SGR-C790, Generator Breaker CB-C572	AUTOMATICALLY OPENED BY GENERATOR CONTROLS [4,6]
SGR-C790, Generator Breaker CB-C582	AUTOMATICALLY OPENED BY GENERATOR CONTROLS [4,6]
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	AUTOMATICALLY OPENED BY RTAC w/ Close BLOCKED [3,4,6]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	AUTOMATICALLY OPENED BY RTAC w/ Close BLOCKED [3,4,6]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
5 Energized condition depends on which "utility" source was restored (BOTH OR AL LEAST ONE SIDE).
6 See sequence description above.

5. CASE D2, FAILURE OF "UTILITY BASED" POWER TO SGR-C701 WITH TIE BREAKER CB-C701-T CLOSED AND SGR-C702 FED FROM SGR-C701

TABLE 15 "UTILITY BASED" POWER TO SGR-C701 FAILED WITH SGR-C702 FED BY SGR-C701	
EQUIPMENT	**PRE-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	L8 Out of Service, *OR* L8 Sustained Undervoltage with CS-Y701-1 Closed, *OR* L8 normal with CS-Y701-1 Open/Tripped
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	De-Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and CLOSED [1,4]
SGR-C701, Bus	DE-ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	Open [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED
MH 66 kV, Overhead Line L33	Status does not matter as SGR-C702.MCB is "Racked-Out" and SGR-C702 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-Out", EFFECTIVELY OPEN [4,5]
SGR-C702, Bus	DE-ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	Open [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]

TABLE 15 "UTILITY BASED" POWER TO SGR-C701 FAILED WITH SGR-C702 FED BY SGR-C701	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

[1] Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
[2] Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
[3] Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
[4] Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
[5] Undervoltage (27) sensing condtions from relay RLY-C702-1 will be ignored by the RTAC as main breaker SGR-C702.MCB is "Racked-Out".

a. 4.a. OPERATIONAL SEQUENCE ON A SUSTAINED FAILURE OF "UTILITY BASED" SUPPLY TO SGR-C701 WITH SGR-C702 FED BY TIE BREAKER CB-C701-T:

1) Note that the "Manual/Auto" selector switches on both main breakers SGR-C701.MCB and SGR-C702.MCB as well as those on the Generator System must be all in "Auto" or the Automatic Generator Switching sequence will not occur.
2) Undervoltage conditions on the incoming 12.47 kV feeders to SGR-C701 shall be detected by the operation (assertion) of the 27 (undervoltage element) in relay RLY-C701-1.
3) RTAC control and sensing shall be via Ethernet communications except as noted in Sections 2.3 N 6. to 2.3 N 10. above..
4) The switchgear automation controller (RTAC) shall operate as follows:
   a) On assertion of the 27 element in relay RLY-C701-1 trigger an "SGR-C701 Supply Failure Timer", de-assertion of the 27 element shall cause immediate reset of the timer. Time delay shall be user selectable (recommended adjustable time delay of 45 seconds on utility failure to permit Manitoba Hydro overhead line reclosing attempts to occur).

      NOTE: Undervoltage (27) sensing condtions from relay RLY-C702-1 will be ignored by the RTAC as main breaker SGR-C702.MCB is "Racked-Out" and tie breaker CB-C701-T is "Racked-In and Closed".

   b) On assertion of the "SGR-C701 Supply Failure Timer" output [a) above] perform the following sequence of actions:
      (1) Set a "Transfer to Generation Sequence" latch.

NOTE: Once the transfer to generation latch has been set the RTAC shall ignore any further changes in undervoltage conditions on the incoming 12.47 kV feeders to SGR-C701 and SGR-C702 and shall continue the switching sequence to completion [**Step vii) i)** below], or to sequence abort [**Step vi)** below].
The "transfer to generation sequence" latch shall be reset either by a successful sequence completion or by a "Manual RTAC Reset" after a sequence abort condition.

(2) Store the Breaker Status (Open/Closed) condition for all of the circuit breakers in switchgear SGR-C701 and SGR-C702. The stored breaker status will be used to determine which breakers to reclose during switching
(3) Signal the Generator System Master Controller, to begin the generator startup and synchronizing sequence – "**Generator Startup Signal**",
(4) Signal the PCS that switchgear SGR-C701 and SGR-C702 are de-energized and transfer to "Generator Power" is being initiated – "**Loss of Utility Power - Generator Power Initiated**" signal,
(5) Open switchgear SGR-C701, 12.47 kV incoming main breaker SGR-C701.MCB via protection relay RLY-C701-1,
(6) Confirm "no voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
(7) Open switchgear SGR-C701, 12.47 kV outgoing branch breakers CB-S701, CB-R701, CB-S730, CB-G750, and CB-C703 via their respective protection relays,
(8) Confirm "no voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
(9) Open switchgear SGR-C702, 12.47 kV outgoing branch breakers CB-S702, CB-R702, CB-S740, CB-G760, and CB-C704 via their respective protection relays,
(10) Pause and wait for a response from the Generator System Master Controller after it has completed the generator startup sequence,

c) On receipt of the momentary "Generator Startup Signal" **[Step iv.b)(3) above**], the Generator System Master controller shall latch the signal as required and perform (at minimum) the following functions:
(1) Open load bank breaker CB-Y793 if it is not already open,
(2) Initiate start of gensets GEN-C572, and GEN-C582,
(3) Confirm genset GEN-C572 start, stable running, voltage and frequency within tolerances,
(4) Confirm genset GEN-C582 start, stable running, voltage and frequency within tolerances,
(5) The first genset meeting the criteria of Steps (c) and (d) above shall be used to energize switchgear SGR-C790 bus by closing generator breaker CB-C572, or CB-C582 as required,
(6) Confirm switchgear SGR-C790 bus voltage, frequency and phase rotation are correct,
(7) Synchronize the second genset to switchgear SGR-C790 bus and close generator breaker CB-C572, or CB-C582 as required,

(8) The generator startup sequence is now complete and the Generator System Master Controller shall signal the RTAC as follows:
   (a) Both generator units have successfully started and synchronized to Generator Switchgear SGR-C790 and the generator system is ready for load application – "**Startup Sequence Complete, 2 Generators"**, or
   (b) One generator unit has successfully started and connected to Generator Switchgear SGR-C790 and is ready for load application, the second generator has failed to start and synchronize – "**Startup Sequence Complete, 1 Generator"**, or
   (c) Both generator units have failed to start, synchronize and connect to Generator Switchgear SGR-C790 – "**Standby Power System Failure"**.

d) On receipt of the "**Standby Power System Failure"** signal from the generator master controller, the RTAC shall abort any further automatic switching sequence steps, and signal the PCS "**Standby Power System Failure**" has occurred.
   (1) At this point, operator intervention will be required to investigate the cause of the generator system failure and perform any corrective measures necessary. After correction of the cause of the failure, the operator shall reset the generator master controller.
   (2) Operator intervention will be required to close all previously operated breakers to the original starting conditions This will allow the RTAC to resume control based on the prevailing electrical conditions on the supply system.
   (3) After completing the required switching, the operator shall reset the RTAC system – (**Manual RTAC Reset**) which will reset the "Transfer to Generation Sequence" latch.

e) On receipt of the **"Startup Sequence Complete, 2 Generators"** or the "**Startup Sequence Complete, 1 Generator"** signals from the generator master controller, the RTAC shall perform the following actions:
   (1) Close switchgear SGR-C701, 12.47 kV incoming generator breaker CB-C790-3 via protection relay RLY-C790-3
   (2) Close generator switchgear SGR-C790 breaker CB-C790-1 via relay RLY-C790-1 to apply generator power to switchgear SGR-C701, and also to SGR-C701 via tie breaker CB-C701-T.
   Note that Breaker CB-C790-2 shall **NOT** be closed,
   (3) Confirm "Normal Voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
   (4) Utilizing the stored circuit breaker status conditions [Step iv.b) above] close the outgoing load breakers in the next steps **ONLY** if they were closed at the time of power failure,
   (5) Close switchgear SGR-C701, 12.47 kV outgoing branch breakers CB-G750, CB-C703, CB-S730, CB-R701, and CB-S701 in the indicated order with a time delay between successive closures. Time delays shall be initially set at 3 seconds. Inter-breaker closing time delays and closing order shall be user adjustable on an individual breaker basis,

(6) Signal the PCS that switchgear SGR-C701 is energized on "Generator Power" and the PLC may initiate restart SGR-C701 fed portions of the plant under generator loading restrictions,
(7) Confirm "Normal Voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
(8) Close switchgear SGR-C702, 12.47 kV outgoing branch breakers CB-G760, CB-C704, CB-S740, CB-R702, and CB-S702 in the order indicated with a time delay between successive closures. Inter-breaker time delays and closing order shall be user adjustable on an individual breaker basis,
(9) Signal the PCS that switchgear SGR-C702 is "**Energized on Generator Power**" or "**Energized on One Generator Only**" as appropriate. The PCS will then initiate sequential loading of the generator system in accordance with the appropriate generator loading restrictions.

f) The automatic generator start and connect sequence is now complete and switchgear SGR-C701 is now on Generator Supply with SCR-C702 fed via tie breaker CB-C701-T.

TABLE 16
SGR-C701 SUPPLIED BY GENERATOR POWER, WITH SGR-C702 SUPPLIED VIA TIE BREAKER CB-C701-T

EQUIPMENT	POST-SWITCHING STATUS
MH 66 kV, Overhead Line L8	L8 Out of Service, *OR* L8 Sustained Undervoltage with CS-Y701-1 Closed, *OR* L8 normal with CS-Y701-1 Open/Tripped
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	De-Energized
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In", AUTOMATICALLY OPENED BY RTAC [1,4,6]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	AUTOMATICALLY CLOSED BY RTAC [3,4,6]
SGR-C701, Outgoing Feeder Breakers	AUTOMATICALLY CLOSED BY RTAC [1,6]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED
MH 66 kV, Overhead Line L33	Status does not matter as SGR-C702.MCB is "Racked-Out" and SGR-C702 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]

TABLE 16
SGR-C701 SUPPLIED BY GENERATOR POWER, WITH SGR-C702 SUPPLIED VIA TIE BREAKER CB-C701-T

EQUIPMENT	POST-SWITCHING STATUS
SGR-C702, main breaker SGR-C702.MCB	"Racked-Out", EFFECTIVLEY OPEN [4,5]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	OPEN [2,3,4]
SGR-C702, feeder breakers	AUTOMATICALLY CLOSED BY RTAC [2,6]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	RUNNING [6]
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	RUNNING [6]
SGR-C790, Generator Breaker CB-C572	AUTOMATICALLY CLOSED BY GENERATOR CONTROLS [4,6]
SGR-C790, Generator Breaker CB-C582	AUTOMATICALLY CLOSED BY GENERATOR CONTROLS [4,6]
SGR-C790, Bus	ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	AUTOMATICALLY CLOSED BY RTAC [3,4,6]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	OPEN [3,4,6]
SGR-C790, Load Bank Breaker CB-Y793	AUTOMATICALLY OPENED BY GENERATOR CONTROLS w/ Close BLOCKED [4,6]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
5 Undervoltage (27) sensing condtions from relay RLY-C702-1 will be ignored by the RTAC as main breaker SGR-C702.MCB is "Racked-Out".
6 See sequence description above.

6. CASE D2A, RETURN FROM GENERATOR POWER TO NORMAL "UTILITY BASED" POWER FOR SGR-C701 WITH TIE BREAKER CB-C701-T CLOSED AND SGR-C702 FED FROM SGR-C701

TABLE 17 "UTILITY BASED" POWER RESTORED TO INPUT OF SGR-C701, SGR-C701 ON GENERATOR SUPPLIED POWER WITH SGR-C702 FED BY TIE BREAKER CB-C701-T	
EQUIPMENT	**PRE-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	ENERGIZED
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	ENERGIZED
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and OPEN [1,4]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	CLOSED [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED [4]
MH 66 kV, Overhead Line L33	Status does not matter as SGR-C702.MCB is "Racked-Out" and SGR-C702 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-Out" and EFFECTIVELY OPEN [4,5]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	OPEN
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	RUNNING
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	RUNNING
SGR-C790, Generator Breaker CB-C572	CLOSED [4]
SGR-C790, Generator Breaker CB-C582	CLOSED [4]
SGR-C790, Bus	ENERGIZED

TABLE 17 "UTILITY BASED" POWER RESTORED TO INPUT OF SGR-C701, SGR-C701 ON GENERATOR SUPPLIED POWER WITH SGR-C702 FED BY TIE BREAKER CB-C701-T	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	CLOSED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open w/ Close BLOCKED [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher
5 Undervoltage (27) sensing condtions from relay RLY-C702-1 will be ignored by the RTAC as main breaker SGR-C702.MCB is "Racked-Out".

a. 5.a. **OPERATIONAL SEQUENCE ON RETURN OF SGR-C701 TO "UTILITY BASED" POWER FROM GENERATOR SUPPLIED POWER**:

1) Note that the "Manual/Auto" selector switches on both main breakers SGR-C701.MCB and SGR-C702.MCB as well as those on the Generator System must be all in "Auto" or the Automatic Generator Switching sequence will not occur.
2) Return to "Normal" voltage conditions on the incoming 12.47 kV feeders to SGR-C701 shall be detected by the reset (de-assertion) of the 27 (undervoltage element) in relay RLY-C701-1.
3) RTAC control and sensing shall be via Ethernet communications except as noted in Sections 2.3 N 6. to 2.3 N 10. above.
4) The switchgear automation controller (RTAC) shall operate as follows:
   a) On reset (de-assertion) of the 27 element in RLY-C701-1 a user settable "Supply Restoration Delay" timer (recommended 10 minute delay) shall be triggered and the "SGR-C701 Supply Failure Timer" shall be force reset,
   b) On assertion of the "Supply Restoration Delay" timer output. The RTAC shall execute the following sequence of actions:
      (1) Signal the PCS that "**Transfer to Utility Based Power Initiated**" for SGR-C701 and SGR-C702.
      (2) Set a "Transfer to Utility Based Power Sequence" latch.

      NOTE: Once the Transfer to Utility Based Power latch has been set the RTAC shall ignore any further changes in undervoltage conditions on the incoming 12.47 kV feeders to SGR C701 and SGR-C702 and shall continue the switching sequence to completion [**Step (11)** below],
      (3) "Open" generator switchgear SGR-C790 breaker CB-C790-1 via protection relay RLY-C790-1 to remove generator power from switchgear SGR-C701 and SGR-C702 (SGR-C702 is still fed via tie breaker CB-C701-T),
      (4) Open switchgear SGR-C701, 12.47 kV incoming generator breaker CB-C790-3 via protection relay RLY-C790-3,

(5) Signal the Generator System Master Controller to open generator breakers CB-C572 and CB-C582 and begin the generator cool-off and shutdown sequence – "**Generator Shutdown Signal**",
(6) Confirm "no voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
(7) Confirm "no voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
(8) Providing that there are no active protective trips associated with breaker SGR-C701.MCB and the breaker was "Closed" at the time the power failure occurred, Close incoming main breaker SGR-C701.MCB via protection relay RLY-C701-1,
(9) Confirm "Normal Voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3
(10) Confirm "Normal Voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4
(11) Signal the PCS that normal power has been restored – "**Utility Based Normal Power"**. The PCS will then initiate automatic plant operating conditions.

c) Switchgear SGR-C701 is now on "Utility Based Normal Power" power with SCR-C702 fed via tie breaker CB-C701-T.

TABLE 18
SGR-C701 SUPPLIED BY "UTILITY BASED" POWER WITH SGR-C702 FED BY TIE BREAKER CB-C701-T

EQUIPMENT	POST-SWITCHING STATUS
MH 66 kV, Overhead Line L8	ENERGIZED
66 kV Circuit Switcher CS-Y701-1	Closed [4]
66 kV Transformer XFMR-Y701	ENERGIZED
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-In" and CLOSED BY RTAC [1,4,6]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	OPENED BY RTAC [1,4,6]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation (Open/Closed status will be the same as when under Generator Supply) [1,6]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED
MH 66 kV, Overhead Line L33	Status does not matter as SGR-C702.MCB is "Racked-Out" and SGR-C702 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]

TABLE 18
SGR-C701 SUPPLIED BY "UTILITY BASED" POWER WITH SGR-C702 FED BY TIE BREAKER CB-C701-T

EQUIPMENT	POST-SWITCHING STATUS
SGR-C702, main breaker SGR-C702.MCB	"Racked-Out" and EFFECTIVELY OPEN [4,5]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	OPEN [4,6]
SGR-C702, feeder breakers	As Required for plant operation (Open/Closed status will be the same as when under Generator Supply) [2,6]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	SHUTTING DOWN [4,6]
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	SHUTTING DOWN [4,6]
SGR-C790, Generator Breaker CB-C572	AUTOMATICALLY OPENED BY GENERATOR CONTROLS [4,6]
SGR-C790, Generator Breaker CB-C582	AUTOMATICALLY OPENED BY GENERATOR CONTROLS [4,6]
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker C790-3)	AUTOMATICALLY OPENED BY RTAC w/ Close BLOCKED [3,4,6]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
5 Undervoltage (27) sensing condtions from relay RLY-C702-1 will be ignored by the RTAC as main breaker SGR-C702.MCB is "Racked-Out".
6 See switching sequence above.

7. CASE D3, FAILURE OF "UTILITY BASED" POWER TO SGR-C702 WITH TIE BREAKER CB-C701-T CLOSED AND SGR-C701 FED FROM SGR-C702

TABLE 19 "UTILITY BASED" POWER TO SGR-C702 FAILED WITH SGR-C701 FED BY SGR-C702	
EQUIPMENT	**PRE-SWITCHING STATUS**
MH 66 kV, Overhead Line L8	Status does not matter as SGR-C702.MCB is "Racked-Out" and SGR-C702 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-Out" and EFFECTIVELY OPEN [4,5]
SGR-C701, Bus	DE-ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	Open [1,4]
SGR-C701, Outgoing Feeder Breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED
MH 66 kV, Overhead Line L33	L33 Out of Service, *OR* L33 Sustained Undervoltage with CS-Y702-1 Closed, *OR* L33 normal with CS-Y702-1 Open/Tripped
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	DE-ENERGIZED
SGR-C702.MCB, "Manual/Auto" Selector Sw	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and CLOSED [2,4]
SGR-C702, Bus	DE-ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	Open [2,4]
SGR-C702, feeder breakers	As Required for plant operation [2]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	Not Running
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	Not Running
SGR-C790, Generator Breaker CB-C572	Open [4]
SGR-C790, Generator Breaker CB-C582	Open [4]

TABLE 19 "UTILITY BASED" POWER TO SGR-C702 FAILED WITH SGR-C701 FED BY SGR-C702	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C790, Bus	DE-ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	Open w/ Close BLOCKED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

[1] Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
[2] Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
[3] Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
[4] Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
[5] Undervoltage (27) sensing condtions from relay RLY-C701-1 will be ignored by the RTAC as main breaker SGR-C701.MCB is "Racked-Out".

a. 6.a. OPERATIONAL SEQUENCE ON A SUSTAINED FAILURE OF "UTILITY BASED" SUPPLY TO SGR-C702 WITH SGR-C701 FED BY TIE BREAKER CB-C701-T:

1) Note that the "Manual/Auto" selector switches on both main breakers SGR-C701.MCB and SGR-C702.MCB as well as those on the Generator System must be all in "Auto" or the Automatic Generator Switching sequence will not occur.
2) Undervoltage conditions on the incoming 12.47 kV feeders to SGR-C702 shall be detected by the operation (assertion) of the 27 (undervoltage element) in relay RLY-C702-1.
3) RTAC control and sensing shall be via Ethernet communications except as noted in Sections 2.3 N 6. to 2.3 N 10. above.
4) The switchgear automation controller (RTAC) shall operate as follows:
   a) On assertion of the 27 element in relay RLY-C702-1 trigger an "SGR-C702 Supply Failure Timer", de-assertion of the 27 element shall cause immediate reset of the timer. Time delay shall be user selectable (recommended adjustable time delay of 45 seconds on utility failure to permit Manitoba Hydro overhead line reclosing attempts to occur).

      NOTE: Undervoltage (27) sensing condtions from relay RLY-C701-1 will be ignored by the RTAC as main breaker SGR-C701.MCB is "Racked-Out" and tie breaker CB-C701-T is "Racked-In and Closed

b) On assertion of both the "SGR-C702 Supply Failure Timer" timer output [a) above] initiate the following sequence of actions:
   (1) Set a "Transfer to Generation Sequence" latch

       NOTE: Once the transfer to generation latch has been set the RTAC shall ignore any further changes in undervoltage conditions on the incoming 12.47 kV feeders to SGR-C701 and SGR-C702 and shall continue the switching sequence to completion [**Step vii) i)** below], or to sequence abort [**Step vi)** below].
       The "transfer to generation sequence" latch shall be reset either by a successful sequence completion or by a "Manual RTAC Reset" after a sequence abort condition

   (2) Store the Breaker Status (Open/Closed) condition for all of the circuit breakers in switchgear SGR-C701 and SGR-C702. The stored breaker status will be used to determine which breakers to reclose during switching.
   (3) Signal the Generator System Master Controller, to begin the generator startup and synchronizing sequence – **"Generator Startup Signal"**,
   (4) Signal the PCS that switchgear SGR-C701 and SGR-C702 are de-energized and transfer to "Generator Power" is being initiated – "**Loss of Utility Power - Generator Power Initiated**" signal,
   (5) Open switchgear SGR-C702, 12.47 kV incoming main breaker SGR-C702.MCB via protection relay RLY-C702-1,
   (6) Confirm "no voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
   (7) Open switchgear SGR-C702, 12.47 kV outgoing branch breakers CB-S702, CB-R702, CB-S740, CB-G760, and CB-C704 via their respective protection relays,
   (8) Confirm "no voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
   (9) Open switchgear SGR-C701, 12.47 kV outgoing branch breakers CB-S701, CB-R701, CB-S730, CB-G750, and CB-C703 via their respective protection relays,
   (10) Pause and wait for a response from the Generator System Master Controller after it has completed the generator startup sequence,

c) On receipt of the momentary "Generator Startup Signal" **[Step iv.b)(3) above]**, the Generator System Master controller shall latch the signal as required and perform (at minimum) the following functions:
   (1) Open load bank breaker CB-Y793 if it is not already open,
   (2) Initiate start of gensets GEN-C572 and GEN-C582,
   (3) Confirm genset GEN-C572 start, stable running, voltage and frequency within tolerances,
   (4) Confirm genset GEN-C582 start, stable running, voltage and frequency within tolerances,
   (5) The first genset meeting the criteria of Steps (c) and (d) above shall be used to energize the switchgear SGR-C790 bus by closing generator breaker CB-C572, or CB-C582 as required,
   (6) Confirm switchgear SGR-C790 bus voltage, frequency and phase rotation are correct,

(7) Synchronize the second genset to switchgear SGR-C790 bus and close generator breaker CB-C572, or CB-C582 as required,

(8) The generator startup sequence is now complete and the Generator System Master Controller shall signal the RTAC as follows:

(a) Both generator units have successfully started and synchronized to Generator Switchgear SGR-C790 and the generator system is ready for load application – **"Startup Sequence Complete, 2 Generators"**, or

(b) One generator unit has successfully started and connected to Generator Switchgear SGR-C790 and is ready for load application, the second generator has failed to start and synchronize – **"Startup Sequence Complete, 1 Generator"**, or

(c) Both generator units have failed to start, synchronize and connect to Generator Switchgear SGR-C790 – **"Standby Power System Failure"**.

d) On receipt of the "**Standby Power System Failure"** signal from the generator master controller, the RTAC shall abort any further automatic switching sequence steps, and signal the PCS "**Standby Power System Failure**" has occurred.

(1) At this point, operator intervention will be required to investigate the cause of the generator system failure and perform any corrective measures necessary. After correction of the cause of the failure, the operator shall reset the generator master controller.

(2) Operator intervention will be required to close all previously operated breakers to the original starting conditions This will allow the RTAC to resume control based on the prevailing electrical conditions on the supply system.

(3) After completing the required switching, the operator shall reset the RTAC system – (**Manual RTAC Reset**) which will reset the "Transfer to Generation Sequence" latch.

e) On receipt of the **"Startup Sequence Complete, 2 Generators"** or the "**Startup Sequence Complete, 1 Generator"** signals from the generator master controller, the RTAC shall perform the following actions:

(1) Close switchgear SGR-C702, 12.47 kV incoming generator breaker CB-C790-4 via protection relay RLY-C790-4.

(2) Close generator switchgear SGR-C790 breaker CB-C790-2 to apply generator power to switchgear SGR-C702 and also to SGR-C701 via tie breaker CB-C701-T.
Note that breaker CB-C790-1 shall **NOT** be closed,

(3) Confirm "Normal Voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,

(4) Utilizing the circuit breaker status conditions [Step iv.b) above] close the following outgoing load breakers in the next steps **ONLY** if they were closed at the time of power failure,

(5) Close switchgear SGR-C702, 12.47 kV outgoing branch breakers CB-G760, CB-C704, CB-S740, CB-R702, and CB-S702 in the order indicated with a time delay between successive closures. Inter-breaker time delays and closing order shall be user adjustable on an individual breaker basis,

(6) Signal the PCS that switchgear SGR-C702 is energized on "Generator Power" and it may initiate restart the SGR-C702 fed portions of the plant under generator loading restrictions.
(7) Confirm "Normal Voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
(8) Close switchgear SGR-C701, 12.47 kV outgoing branch breakers CB-G750, CB-C703, CB-S730, CB-R701, and CB-S701 in the indicated order with a time delay between successive closures. Time delays shall be initially set at 3 seconds. Inter-breaker closing time delays and closing order shall be user adjustable on an individual breaker basis,
(9) Signal the PCS that switchgear SGR-C702 is "**Energized on Generator Power**" or "**Energized on One Generator Only**" as appropriate. The PCS will then initiate sequential loading of the generator system in accordance with the appropriate generator loading restrictions,

f) The automatic generator start and connect sequence is now complete and switchgear SGR-C702 is now on Generator Supply with SCR-C701 fed via tie breaker CB-C701-T.

TABLE 20
SGR-C702 SUPPLIED BY GENERATOR POWER, WITH SGR-C701 SUPPLIED VIA TIE BREAKER CB-C701-T

EQUIPMENT	POST-SWITCHING STATUS
MH 66 kV, Overhead Line L8	Status does not matter as SGR-C701.MCB is "Racked-Out" and SGR-C701 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-Out" and EFFECTIVELY OPEN [4,5]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	OPEN [1,4,6]
SGR-C701, Outgoing Feeder Breakers	AUTOMATICALLY CLOSED BY RTAC [1,6]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED
MH 66 kV, Overhead Line L33	L33 Out of Service, *OR* L33 Sustained Undervoltage with CS-Y702-1 Closed, *OR* L33 normal with CS-Y702-1 Open/Tripped
66 kV Circuit Switcher CS-Y702-1	
66 kV Transformer XFMR-Y702	De-Energized
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]

TABLE 20 SGR-C702 SUPPLIED BY GENERATOR POWER, WITH SGR-C701 SUPPLIED VIA TIE BREAKER CB-C701-T	
EQUIPMENT	**POST-SWITCHING STATUS**
SGR-C702, main breaker SGR-C702.MCB	"Racked-In", AUTOMATICALLY OPENED BY RTAC [2,4,6]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	AUTOMATICALLY CLOSED BY RTAC [2,4,6]
SGR-C702, feeder breakers	AUTOMATICALLY CLOSED BY RTAC [2,6]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	RUNNING [4]
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	RUNNING [4]
SGR-C790, Generator Breaker CB-C572	AUTOMATICALLY CLOSED BY GENERATOR CONTROLS [4,6]
SGR-C790, Generator Breaker CB-C582	AUTOMATICALLY CLOSED BY GENERATOR CONTROLS [4,6]
SGR-C790, Bus	ENERGIZED
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	OPEN [3,4,6]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	AUTOMATICALLY CLOSED BY RTAC [3,4,6]
SGR-C790, Load Bank Breaker CB-Y793	AUTOMATICALLY OPENED BY GENERATOR CONTROLS w/ Close BLOCKED [4,6]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
5 Undervoltage (27) sensing condtions from relay RLY-C701-1 will be ignored by the RTAC as main breaker SGR-C701.MCB is "Racked-Out".
6 See sequence description above.

8. CASE D3A, RETURN FROM GENERATOR POWER TO NORMAL "UTILITY BASED" POWER FOR SGR-C702 WITH TIE BREAKER CB-C701-T CLOSED AND SGR-C701 FED FROM SGR-C702

TABLE 21
"UTILITY BASED" POWER RESTORED TO INPUT OF SGR-C702, SGR-C702 ON GENERATOR SUPPLIED POWER WITH SGR-C701 FED BY TIE BREAKER CB-C701-T

EQUIPMENT	PRE-SWITCHING STATUS
MH 66 kV, Overhead Line L8	Status does not matter as SGR-C701.MCB is "Racked-Out" and SGR-C701 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	
SGR-C701.MCB, "Manual/Auto" Selector Sw.	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-Out" and EFFECTIVELY OPEN [4,5]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-4	OPEN [1.4]
SGR-C701, feeder breakers	As Required for plant operation [1]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED
MH 66 kV, Overhead Line L33	ENERGIZED
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	ENERGIZED
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and OPEN [2,4]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	CLOSED [2,4]
SGR-C702, Outgoing Feeder Breakers	As Required for plant operation [2]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic [3]
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	RUNNING
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	RUNNING
SGR-C790, Generator Breaker CB-C572	CLOSED [4]
SGR-C790, Generator Breaker CB-C582	CLOSED [4]
SGR-C790, Bus	ENERGIZED

TABLE 21 "UTILITY BASED" POWER RESTORED TO INPUT OF SGR-C702, SGR-C702 ON GENERATOR SUPPLIED POWER WITH SGR-C701 FED BY TIE BREAKER CB-C701-T	
EQUIPMENT	**PRE-SWITCHING STATUS**
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	CLOSED [3,4]
SGR-C790, Load Bank Breaker CB-Y793	Open w/ Close BLOCKED [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
5 Undervoltage (27) sensing condtions from relay RLY-C701-1 will be ignored by the RTAC as main breaker SGR-C701.MCB is "Racked-Out".

a. 7.a. **OPERATIONAL SEQUENCE ON RETURN OF SGR-C702 TO "UTILITY BASED" POWER FROM GENERATOR SUPPLIED POWER**:

1) Note that the "Manual/Auto" selector switches on both main breakers SGR-C701.MCB and SGR-C702.MCB as well as those on the Generator System must be all in "Auto" or the Automatic Generator Switching sequence will not occur.
2) Return to "Normal" voltage conditions on the incoming 12.47 kV feeders to SGR-C702 shall be detected by the reset (de-assertion) of the 27 (undervoltage element) in relay RLY-C702-1.
3) RTAC control and sensing shall be via Ethernet communications except as noted in Sections 2.3 N 6. to 2.3 N 10. above.
4) The switchgear automation controller (RTAC) shall operate as follows:
   a) On reset (de-assertion) of the 27 element in RLY-C702-1 a user settable "Supply Restoration Delay" timer (recommended 10 minute delay) shall be triggered and the "SGR-C702 Supply Failure Timer" shall be force reset,
   b) On assertion of the "Supply Restoration Delay" timer output. The RTAC shall execute the following sequence of actions:
      (1) Signal the PCS that "**Transfer to Utility Based Power Initiated**" for SGR-C702 and SGR-C701,
      (2) Set a "Transfer to Utility Based Power Sequence" latch.

      NOTE: Once the Transfer to Utility Based Power latch has been set the RTAC shall ignore any further changes in undervoltage conditions on the incoming 12.47 kV feeders to SGR C701 and SGR-C702 and shall continue the switching sequence to completion [**Step (11)** below].

      (3) "Open" generator switchgear SGR-C790 breaker CB-C790-2 via protection relay RLY-C790-2 to remove generator power from switchgear SGR-C702 and SGR-C701 (SGR-C701 is still fed via tie breaker CB-C701-T),
      (4) Open switchgear SGR-C702, 12.47 kV incoming generator breaker CB-C790-4 via protection relay RLY-C790-4,

(5) Signal the Generator System Master Controller to open generator breakers CB-C572 and CB-C582 and begin the generator cool-off and shutdown sequence – "**Generator Shutdown Signal**",
(6) Confirm "no voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
(7) Confirm "no voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3,
(8) Providing that there are no active protective trips associated with breaker SGR-C702.MCB and the breaker was "Closed" at the time the power failure occurred, Close incoming main breaker SGR-C702.MCB via protection relay RLY-C702-1,
(9) Confirm "Normal Voltage" on switchgear SGR-C702 bus via power meter PM-C702 or relay RLY-C790-4,
(10) Confirm "Normal Voltage" on switchgear SGR-C701 bus via power meter PM-C701 or relay RLY-C790-3
(11) Signal the PCS that normal power has been restored – "**Utility Based Normal Power"**. The PCS will then initiate automatic plant operating conditions.

c) Switchgear SGR-C702 is now on "Utility Based" power with SCR-C701 fed via tie breaker CB-C701-T.

TABLE 22
SGR-C702 SUPPLIED BY "UTILITY BASED" POWER WITH SGR-C701 FED BY TIE BREAKER CB-C701-T

EQUIPMENT	POST-SWITCHING STATUS
MH 66 kV, Overhead Line L8	Status does not matter as SGR-C701.MCB is "Racked-Out" and SGR-C701 is fed by tie breaker CB-C701-T
66 kV Circuit Switcher CS-Y701-1	
66 kV Transformer XFMR-Y701	
SGR-C701.MCB, "Manual/Auto" Selector Sw	Automatic [1]
SGR-C701, main breaker SGR-C701.MCB	"Racked-Out" and EFFECTIVELY OPEN [4,5]
SGR-C701, Bus	ENERGIZED
SGR-C701, Incoming Generator Breaker CB-C790-3	Open [4]
SGR-C701, feeder breakers	As Required for plant operation (Open/Closed status will be the same as when under Generator Supply) [1,6]
SGR-C701 – SGR-C702, tie breaker CB-C701-T	"Racked-In", and CLOSED
MH 66 kV, Overhead Line L33	ENERGIZED
66 kV Circuit Switcher CS-Y702-1	Closed [4]
66 kV Transformer XFMR-Y702	ENERGIZED
SGR-C702.MCB, "Manual/Auto" Selector Sw.	Automatic [2]

TABLE 22 SGR-C702 SUPPLIED BY "UTILITY BASED" POWER WITH SGR-C701 FED BY TIE BREAKER CB-C701-T	
EQUIPMENT	**POST-SWITCHING STATUS**
SGR-C702, main breaker SGR-C702.MCB	"Racked-In" and CLOSED BY RTAC [2,4,6]
SGR-C702, Bus	ENERGIZED
SGR-C702, Incoming Generator Breaker CB-C790-4	OPENED BY RTAC [2,4,6]
SGR-C702, Outgoing Feeder Breakers	As Required for plant operation (Open/Closed status will be the same as when under Generator Supply) [2,6]
Generator Master & Unit Controls "Manual/Auto" Selector Sw.	Automatic
GEN-C572 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C572	SHUTTING DOWN [4,6]
GEN-C582 Unit Controller "Off/Auto/Test" Sel. Sw.	Automatic
Generator GEN-C582	SHUTTING DOWN [4,6]
SGR-C790, Generator Breaker CB-C572	AUTOMATICALLY OPENED BY GENERATOR CONTROLS [4,6]
SGR-C790, Generator Breaker CB-C582	AUTOMATICALLY OPENED BY GENERATOR CONTROLS [4,6]
SGR-C790, Bus	DE-ENERGIZED [4]
SGR-C790, Feeder Breaker CB-C790-1 (feeds SGR-C701, breaker CB-C790-3)	Open w/ Close BLOCKED [3,4]
SGR-C790, Feeder Breaker CB-C790-2 (feeds SGR-C702, breaker CB-C790-4	AUTOMATICALLY OPENED BY RTAC w/ Close BLOCKED [3, 4,6]
SGR-C790, Load Bank Breaker CB-Y793	Open [4]

1 Operation of switchgear SGR-C701 breakers by the RTAC is **ENABLED.**
2 Operation of switchgear SGR-C702 breakers by the RTAC is **ENABLED.**
3 Operation of switchgear SGR-C790 outgoing breakers CB-C790-1 and CB-C790-2 by the RTAC is **ENABLED**.
4 Breaker has hardwired "Close Permissive Interlocks" from other breakers or devices (eg. synchronizer or synchro-check) in the switchgear or from the associated 66 KV circuit switcher.
5 Undervoltage (27) sensing condtions from relay RLY-C701-1 will be ignored by the RTAC as main breaker SGR-C701.MCB is "Racked-Out".
6 See switching sequence above.

2.9 KEY INTERLOCKING SYSTEMS

A. Provide key interlocking systems between the 66kV circuit switchers CS-Y701-1 and CS-Y702-1 and the incoming 12.47 kV cable compartments for switchgear SGR-C701 and SGR-C702 respectively, as indicated on the Drawings. The Key interlocking system shall allow access to the incoming cable compartments only with the associated circuit switcher locked in the "Open" position. Coordinate with circuit switcher supplier.

B. Provide a key interlocking system for main and tie breakers SGR-C701.MCB, SGR-C702.MCB, and CB-C701-T as indicated on the Drawings. The key interlocking system shall permit only two of the three breakers SGR-C701.MCB, SGR-C702.MCB, and CB-C701-T to be in the "Connected" position at any time.

C. Provide key interlocking systems to interlock the outgoing branch circuit breakers in switchgear SGR-C701 and SGR-C702 with their cable compartment doors and the high voltage cable/fuse compartments on downstream transformers, see Drawings. The key interlock system shall allow access to cable compartment and the transformer HV cable/fuse compartments only with the associated circuit breaker in the "Test" or "Disconnected" position. Provide locking mechanisms on all transformers, including the existing transformers XFMR-S701 and XFMR-S702.

D. Provide key interlock systems between each pair of breakers CB-C790-1/CB-C790-3 and CB-C790-2 /CB-C790-4 such that both breakers in a pair must be in the "Test" or "Disconnected" position in order to gain access to their associated cable compartments, refer to Drawings.

E. Provide key interlock systems between generator circuit breakers CB-C572 and CB-C582 and generator neutral disconnects DS-C572 and DS-C582 respectively, see Drawings. The key interlock shall allow the neutral disconnects to be opened only if the associated generator circuit breaker is in the "Test" or "Disconnected" position.

F. Key interlock systems shall satisfy all the requirements CEC Section 36, including 36-208.

2.10 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 0,- Common Work Results – Electrical.

B. Lamcoid for each switchgear to be size 11, example as follows:

SGR–C701 NORMAL & STANDBY POWER 12.47 kV, 3Ø, 3W, 1200A

C. Lamacoid for each switchgear breaker to be size 5, example as follows:

BREAKER CB-S730 XFMR-S730 & MCC-S730 SECONDARY CLARIFIERS

D. A switchgear identification nameplate for each of the switchgear line ups indicating as a minimum:
   1. Switchgear rated voltage, rated BIL, bus ampere rating.
   2. Switchgear Arc-flash withstand test rating.
   3. Switchgear fault interrupting ratings, momentary fault withstand ratings, MVA Class.
   4. Switchgear power frequency AC withstand voltage, Switchgear DC withstand voltage.
   5. Switchgear maximum design temperature rise.
   6. Manufacturer's shop reference and drawing number, contact details.
   7. CSA approval, CSA design standard.
   8. Enclosure NEMA rating.
   9. Switchgear assembly weight.

E. A lamacoid simplified mimic diagram shall be provided on the front of the switchgear.

F. A high voltage warning nameplates for the switchgear assemblies on both front and back of the switchgear,

G. Provide warning nameplates on the front of each control compartment containing multiple sources of power. The warning lamacoids shall have white lettering on a red background. The wording shall list all AC and DC power sources including source voltage, source panel and panel circuit numbers, where control compartments are equipped with internal disconnecting fuses list fuses. Wording shall conform to the requirements of the CEC, typical example as follows:

WARNING
120VAC & 125VDC POWER PRESENT FROM MULTIPLE SOURCES
REFER TO DRAWINGS AND ISOLATE BEFORE WORKING WITHIN
POWER SOURCES
120VAC PANEL C722 CCT 7
125VDC PANEL C753 CCT 1/3
COMPARTMENT 125VDC INTERNAL DISCONNECTING FUSES FU1-P/FU1-N FU2-P/FU2-N

H. Nameplates shall be attached by means of rivets, drive pins or self-tapping screws. Note that the use of “sheet metal” or other screws having sharp points is NOT acceptable.

I. Submit a detailed listing of proposed equipment nameplates for review prior to fabrication and installation.

2.11 ADDITIONAL MATERIAL/ACCESSORIES

A. Provide one (1) full box of spare control fuses for each size and rating of fuse installed.

B. For "2 high switchgear, or switchgear mounted on housekeeping pads, provide one (1) circuit breaker lifting device (lift truck) - portable, floor-supported with a roller base.

C. Provide one (1) spare vacuum circuit breaker of each frame size.

D. Provide two (2) spare current and voltage transformers of each size.

E. Provide one (1) spare SEL relay of each type, including one (1) spare RTAC controller, and one (1) spare Satelite Clock.

F. Provide four (4) spare pilot lights of each type and rating.

G. Provide two (2) spare breaker open / close switches.

H. Provide two (2) handles for manually charging the circuit breaker operating mechanisms.

I. Provide two (2) hand cranking levers for manual racking of circuit breakers. Handles shall be suitable for "through the door" racking

J. Provide two (2) sets of test plug assemblies for use with flexitest blocks.

K. Provide one (1) electrically operated portable racking device complete with a wired hand-held remote control as specified in Section 2.2.I.b. above.

L. Provide two (2) sets of circuit breaker extension rails per switchgear assembly.

M. Provide one (1) lifting device for removal of potential transformer drawer units.

N. Provide one (1) breaker auxiliary connector extension cable to permit electrical test operation of the circuit breaker while withdrawn from its cubicle.

O. Provide one (1) complete set of tools for mechanical adjustments to the switchgear.

P. Provide one (1) factory assembled "ball-stud" grounding set for each switchgear assembly (minimum 3 sets total) as follows:
   1. ASTM Type 1, Class A, Grade 3 in accordance with ASTM F855, Standard Specifications for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment,
   2. Fault current ratings: 27,000 amps for 15 cycles, 20,000 amps for 30 cycles,
   3. Suitable for installation with "hot tools" (i.e. "shotgun" type hotstick),
   4. Consisting of:
      a. One (1) three-way copper terminal block,
      b. Four (4) bronze ground clamps suitable for use with 25mm Ø ball-studs,

c. Four 1828mm lengths of # 2/0 AWG super flex copper clear jacketed ground cable with shrouded threaded-stud ferrules,
d. All of the above shall be factory assembled and tested.

2.12 APPROVED MANUFACTURER.

A. The design is based on Schneider switchgear, with Schweitzer Engineering Laboratories (SEL) relays - any deviation must be approved in writing by the Contract Administrator. In the event of approved equal status, the responsibility remains with the equipment supplier for a complete and working installation, in conjunction with the facility limitations. The Contractor is responsible for coordinating layout changes and interface connections to other work and equipment which is different than that shown on the Drawings if alternative Manufacturers are granted Approved Equal status. The Contractor will be responsible for coordinating this work and the changes will be at sole expense of the Contractor.

2.13 FACTORY TESTING

A. Provide certified factory test reports for all components.

2.14 FACTORY SYSTEM PROGRAMMING

A. Provide factory certified programming for all relays and control systems. Carry the costs associated to have the relay and RTAC Manufacturer's technical services department perform relay and RTAC systems programming and settings.

B. Note, protective relay and RTAC "Setting Letters" will be supplied to the Vendor / Manufacturer and are incorporated into the Contract Documents.

PART 3 EXECUTION

3.1 EXAMINATION

A. Visually inspect switchgear for evidence of damage and verify that surfaces are ready to receive work.

B. Visually inspect to confirm that all items and accessories are in accordance with the Specifications and Drawings.

C. Verify field measurements (i.e. voltage, current) are as indicated.

3.2 INSTALLATION

A. Install in accordance with Manufacturer's instructions, applicable requirements of the CEC and in accordance with recognized industry practices.

B. Bending of high-voltage cables should be avoided or minimized. All necessary bends should meet at least the minimum radii specified by the cable Manufacturer, or by code (whichever is greater).

C. Demonstrate that the system works as intended, and in accordance with the protection relay Setting Letters provided by the Contract Administratior.

3.3 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 05 01, Common Work Results - Electrical and Manufacturer's instructions.

B. Provide a Manufacturer’s certified field service representative for on-site field inspection and testing of switchgear.

C. Perform start-up tests in accordance with Manufacturer's instruction manual and the Commissioning Procedures.

D. Touch-up paint all chips and scratches with Manufacturer-supplied paint and leave remaining paint with Contract Administrator.

3.4 TRAINING

A. Furnish the services of a competent, factory-trained engineer or technician for two sessions (each of a minimum of 8 hours duration) instruct City of Winnipeg electrical maintenance personnel in the operation and maintenance of the equipment, on a date requested by the Contract Administrator. This item shall be specifically confirmed by the Supplier at the time of Bidding.
   1. The contents of the training session to include:
      a. Electrical manual breaker operation.
      b. Electrical automatic operation (RTAC)
      c. Breaker rack-out procedures
      d. RTAC control, access, data and programming access
      e. Operation of the portable electrically operated racking device
      f. Key interlock system
      g. Power meter use
      h. Arc flash mitigation systems
      i. Protective relay operation, diagnostic and waveform acess
      j. Network communications.
      k. Troubleshooting and maintenance, and
      l. Similar contents to the training session identified above.
      m. And operation of any other relevant systems associated with the switchgear.

3.5 FACTORY TESTING

A. All testing indicated in this section is supplemental to the requirements of Section 26 05 01, Common Work Results - Electrical and 26 08 05, Acceptance Testing - Electrical.

B. QA Requirements
   1. Submit an Inspection and Test Plan in accordance with this Specification, and NETA Acceptance Testing. This shall be submitted along with, or after acceptance of the Shop Drawings.

C. Shop Inspection And Testing
   1. Equipment will be subject to inspection at the following stages of manufacture:
      a. Prior to shop testing,
      b. Prior to packaging for shipment.
   2. Test equipment to ensure satisfactory operation prior to shipping. Provide Certification of Satisfactory performance.
   3. Test and inspect all equipment, materials, works in accordance with scope of work, Specifications, all applicable codes, standards, regulations, laws and provide Certification and Records.
   4. Provide the Contract Administrator with proper access to work, equipment, tools and facilities for carrying out such inspection, test, witness inspection or test points, surveillance or audit, whether it is in preparation or progress.
   5. Provide upon request, the following information:
      a. Non-destructive test records/results,
      b. Welding procedures and welder qualifications,

D. Factory Tests
   1. Test the equipment per applicable standards and provide test data.
   2. The Contract Administrator reserves the right to witness any or all tests.
   3. Prior to proceeding with the tests, provide in writing, a list of the tests to be performed at least two weeks before the tests are scheduled to begin, and an approximate schedule, with dates anticipated for the tests.
   4. The equipment shall be tested at the manufacturing plant prior to shipment and in accordance with the latest applicable standards.

E. Design Tests
   1. For the design tests, include the following:
      a. Dielectric tests,
      b. Power frequency voltage withstand on main contacts,
      c. Power frequency voltage withstand on auxiliary equipment and control circuits,
      d. Partial discharge,
      e. Radio interference,
      f. Temperature rise,
      g. Measurements of the main contact's resistance,
      h. Short-time and peak withstand current,
      i. Current interrupting tests.
   2. The tests classified by the standards as optional may be carried out or waived at Contract Administrator’s discretion, e.g., tests for radio interference, tests with simulated internal arcing fault, operational tests in extreme atmospheric conditions, etc.
   3. Perform the design tests in the Manufacturer’s plant or elsewhere by an internationally recognized laboratory, carried out on one complete circuit breaker.
   4. Where design type test results have been previously obtained and have been certified by an internationally recognized testing laboratory, they may be acceptable in lieu of the above specified type tests.

5. In the case of the circuit breaker, ensure these tests have been carried out on 2 circuit breakers of the same type, capacity and characteristics as specified herein.

F. Routine Tests
1. Manufacturer's routine tests shall include all tests required by the Standards for Manufactured Switchgear. Routine factory tests shall include but not be limited to the following for all of the equipment supplied:
   a. High potential tests on main circuit contacts and control wiring,
   b. Operational tests on circuit breakers, and control devices; control wiring shall be energized and electrically operated devices shall be electrically operated at normal and minimum control voltage,
   c. Remote control systems shall be tested to demonstrate proper operation under simulated conditions,
   d. Operation of key, electrical and mechanical interlock systems shall be tested. Including verification of circuit breaker racking and positional safety interlocks,
   e. Power frequency voltage dry test and partial discharge measurements,
   f. Resistance measurement of circuit breaker and switch main contacts (Ductor Tests),
   g. Mechanical testing of switching devices,
   h. Primary current injection testing to confirm CT ratios,
   i. Corona inception and extinction tests,
   j. Provide factory test certificates for tests performed on individual switchgear components and on complete switchgear assembly.

3.6 FIELD TESTING

A. All testing indicated in this section is supplemental to the requirements of Section 26 05 01, Common Work Results - Electrical and 26 08 05, Acceptance Testing – Electrical.

B. The equipment shall be field tested for its designed capacity as well as for the controllability and smoothness of operation.

C. Acceptance testing in the plant, shall include the following:
1. Switchgear dimension verification,
2. Circuit breaker ratings verification (confirmation of nameplate data),
3. PT rating verification (confirmation of nameplate data),
4. Physical inspection of switchgear, including inspection of at least one of the main bus compartments,
5. Spot confirmation of breaker contact and bus system resistances (Ductor Tests),
6. Operational testing of all circuit breakers (close, open, charging, racking, etc.),
7. Demonstration of correct operation of all circuit breaker mechanical safety interlocks.

3.7 FINAL ACCEPTANCE

A. If required by final field testing/commissioning results make adjustments/or changes such that an efficient and fully operational installation is achieved. Such adjustments or requirements shall be to the suppliers account. Final acceptance by the Contract Administrator will be conditional upon fulfillment of all requirements.

B. For equipment subject to inspection by a government ministry, department, or agency, submit original copies of the test data reports and all other documentation required for the final field inspection of the equipment by the government ministry, department or agency.

C. Following completion of the work, issue a history docket comprised of the quality certificates, inspection and test records, and any other relevant documents related to manufacture and testing for the Contract Administrator's record files.

3.8 WARRANTY

A. The Contractor shall provide a complete warrantee (covering all aspects of the installation) for all equipment, labor, materials supplied for the 66 kV Substation, 15 kV switchgear, Gensets, and Genset Load Bank, valid for a period of 4 years from the date of the completed and fully signed (by all parties) Form 104.

END OF SECTION

SECTION 26 20 00

LOW VOLTAGE AC INDUCTION MOTORS

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 26 05 01, Common Work Results - Electrical

B. Section 26 29 10, Motor Starters to 600 V

C. Section 26 29 23, Variable Frequency Drives

1.2 CODES AND STANDARDS

A. The following is a list of standards (latest edition) may be referenced in this section:
   1. CSA C22.2 No. 100, Motors and Generators.
   2. CSA C22.2 No. 145, Motors and Generators For use in Hazardous Locations.
   3. CSA C390, Test Methods, Marking Requirements, and Energy Efficiency Levels for Three-phase Induction Motors.
   4. American Bearing Manufacturers Association (ABMA):
      a. ABMA 9, Load Ratings and Fatigue Life for Ball Bearings.
      b. ABMA 11, Load Ratings and Fatigue Life for Roller Bearings.
   5. American National Standards Institute (ANSI): C50.41, Polyphase Induction Motors for Power Generating Stations.
   6. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
      a. IEEE 85, Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery.
      b. IEEE 112, Standard Test Procedures for Polyphase Induction Motors and Generators.
      c. IEEE 114, Standard Test Procedures for Single-Phase Induction Motors.
      d. IEEE 620, Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Motors.
      e. IEEE 841, Standard for Petroleum and Chemical Industry – Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors – up to and Including 500 hp.
   7. National Electrical Manufacturers Association (NEMA):
      a. NEMA MG 1, Motors and Generators.
      b. NEMA MG 13, Frame Assignments for Alternating Current Integral Horsepower Induction Motors.
      c. NEMA 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   8. Underwriters Laboratories (UL):
      a. UL 1, Flexible Metal Conduit.
      b. UL 674, Standard for Safety Electric Motors and Generators for use in Division 1 Hazardous (Classified) Locations.
      c. UL 2111, Overheating Protection for Motors.
   9. EEMAC Standard M1-6, Motors and Generators.

10. EEMAC Standard MG2, Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators.
11. Manitoba Energy Code for Buildings (MECB).

1.3 DEFINITIONS

A. CISD-TEFC: Chemical industry, severe-duty enclosure.

B. DIP: Dust-ignition-proof enclosure.

C. EXP: Explosion-proof enclosure.

D. ODP: Open drip-proof enclosure.

E. TEFC: Totally enclosed, fan cooled enclosure.

F. TENV: Totally enclosed, non-ventilated enclosure.

G. WPI: Open weather protected enclosure, Type I.

H. WPII: Open weather protected enclosure, Type II.

I. Motor Nameplate Horsepower: That rating, after any de-rating required (to allow for any issues) such as extra heating caused by the harmonic content in the voltage applied to the motor by its controller.

J. Inverter Duty Motor: Motor meeting all applicable requirements of NEMA MG 1, Section IV, Parts 30 and 31.

1.4 DESIGN REQUIREMENTS

A. Design equipment, anchorage, and support systems for vertical and lateral loading in accordance with national and local building codes. Submit written certification from a Professional Engineer licensed in the Province of Manitoba stating that support systems, anchorage, and equipment have been designed for post-disaster structures according to requirements of the NBCC with the 2011 Manitoba Amendments at the time of Shop Drawing submittals.

B. Motors to be in compliance with the requirements of the Manitoba Energy Code for Building (MECB).

C. Motor efficiencies shall comply with the latest for premium efficiency motors listed in CSA C390.

D. Motor designed for specific applications such as for VFD application and hazardous area application shall be designed and constructed in accordance with the required standards. These motors shall be marked in accordance with the City of Winnipeg Electrical By-laws, and information bulletin (2014-013-E/M). Specifically these motors must comply with CSA C22.2 No. 100 - 14 Section 13.4 and CSA C22.2 No. 145 – 11 Section 51 Markings.

1.5 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00, Submittal Procedures.

B. Shop Drawing submittals shall include the following:
1. Descriptive information.
2. Nameplate data in accordance with NEMA MG 1.
3. Additional Rating Information:
   a. Service factor.
   b. Locked rotor current.
   c. No load current.
   d. Adjustable frequency drive motor load classification (e.g., variable torque) and minimum allowable motor speed for that load classification.
   e. Guaranteed minimum full load efficiency and power factor.
   f. Motor full load amp rating.
   g. Motor power factor
4. Enclosure type and mounting (e.g. horizontal, vertical).
5. Dimensions and total weight.
6. Conduit box (termination) dimensions and usable volume as defined in NEMA MG 1. Cable termination instructions, and connection details.
7. Bearing type.
8. Bearing lubrication.
9. Bearing life.
10. Space heater voltage and watts, where applicable.
11. Description, ratings, and wiring diagram of motor thermal protection.
12. Motor sound power level in accordance with NEMA MG 1.
13. Maximum brake horsepower required by the equipment driven by the motor.
14. For Motors 447 kW and Larger:
   a. Thermal limit curves in accordance with IEEE 620.
   b. Speed torque curve.
   c. Starting time-current curve.
   d. Thermal capability during starting.
15. Description and rating of submersible motor moisture sensing system.
16. Motor markings shall be submitted, indicating full compliance with CSA C22.2 No. 100 – 14 Section 13.4 and CSA C22.2 No. 145 – 11 Section 51.

1.6 O&M MANUAL

A. Include all Shop Drawings and product submittals.
1. Factory test reports.
2. Operation and maintenance data.

PART 2 PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers:
1. GE Canada.

2. Leeson Canada.
3. Reliance Electric.
4. MagneTek.
5. Siemens Energy and Automation, Inc., Motors and Drives Division.
6. Baldor.
7. U.S. Electrical Motors.
8. TECO-Westinghouse Motor Co.
9. Toshiba International Corp., Industrial Division.
10. WEG Electric Motors Corp.

2.2 GENERAL

A. For multiple units of the same type of equipment, furnish identical motors and accessories of a single manufacturer.

B. In order to obtain single source responsibility, utilize a single supplier to provide a drive motor, its driven equipment, and specified motor accessories.

C. Meet requirements of NEMA MG 1. Motors to be premium efficiency.

D. Frame assignments in accordance with NEMA MG 1.

E. Provide motors for hazardous (classified) locations that conform to CSA Standards and have an applied CSA or cUL listing mark and associated approval number.

F. Motors shall be specifically designed for the use and conditions intended, with a NEMA design letter classification to fit the application.

G. Lifting lugs on all motors weighing 45 kg or more.

H. Operating Conditions:
1. Maximum ambient temperature not greater than 40 degrees C.
2. Motors shall be suitable for operating conditions without any reduction being required in the nameplate rated horsepower or exceeding the rated temperature rise.
3. Over-speed in either direction in accordance with NEMA MG 1.

2.3 HORSEPOWER RATING

A. As designated in motor-driven equipment Specifications.

B. Constant Speed Applications: Brake horsepower of the driven equipment at any operating condition not to exceed motor nameplate horsepower rating, excluding any service factor.

C. Adjustable Frequency and Adjustable Speed Applications (Inverter Duty Motor): Driven equipment brake horsepower at any operating condition not to exceed motor nameplate horsepower rating, excluding any service factor.

2.4 SERVICE FACTOR

A. 1.15 minimum at rated ambient temperature, unless otherwise indicated.

2.5 VOLTAGE AND FREQUENCY RATING

A. System Frequency: 60-Hz.

B. Voltage of motors shall be as shown on the Drawings. In many cases motor voltage is governed by the power supply availability in a specific area. In general, attempts shall be made to comply with the following:

Size	Voltage	Phases
Smaller than 0.37 kW	115	1
0.37 kW or larger	575	3

C. Suitable for full voltage starting and VFD operation as applicable.

D. 74 kW and larger also suitable for reduced voltage starting with 65 or 80 percent voltage tap settings on reduced inrush motor starters.

E. Suitable for accelerating the connected load with supply voltage at motor starter supply terminals dipping to 90 percent of motor rated voltage.

F. Motors rated at 575 volts, 3 phase, 60 HZ shall be suitable for operation on nominal 600 volt, 3 phase, 60 Hz systems.

G. Motors shall operate successfully with any variation in voltage or frequency as permitted in NEMA MG 1-12.44.

2.6 EFFICIENCY AND POWER FACTOR

A. For all motors except single-phase, under 0.56 kW, multispeed, short-time rated and submersible motors, or motors driving gates, valves, elevators, cranes, trolleys, and hoists:
   1. Efficiency:
      a. Tested in accordance with CSA C390.
      b. Guaranteed minimum at full load in accordance with Section 12.60 Table 12-12 of NEMA MG 1 and in accordance with CSA C390.
   2. Power Factor: Guaranteed minimum per Manufacturer’s standard.

2.7 LOCKED ROTOR RATINGS

A. Locked rotor kVA Code G or lower, if motor horsepower not covered by NEMA MG 1 tables.

B. Safe stall time 12 seconds or greater.

2.8 INSULATION SYSTEMS

A. Single-Phase, Fractional Horsepower Motors: Manufacturer's standard winding insulation system. Class F insulation with Class B (130 C) temperature rise.

B. Three-Phase and Integral Horsepower Motors: Unless otherwise indicated in motor-driven equipment Specifications, Class F at nameplate horsepower and designated operating conditions with Class B (130 C) temperature rise, except EXP and DIP motors which must be Class B with Class B rise.

2.9 ENCLOSURES

A. Enclosures to conform to NEMA MG 1.

B. TEFC and TENV: Furnish with a drain hole with porous drain/weather plug.

C. Explosion-Proof (EXP):
1. TEFC listed to meet UL 674, NFPA 70 and CSA requirements for Class I, Zone 1 or Division 1, Group C and D hazardous locations.
2. Drain holes with drain and breather fittings.
3. Integral thermostat opening on excessive motor temperature in accordance with UL 2111 and NFPA 70.
4. Terminate thermostat leads in terminal box separate from main terminal box.

D. Submersible: In accordance with the Special Motors section of this Specification, NEMA MG 1 and specifically MG 1 Part 18.

E. Chemical Industry, Severe-Duty (CISD-TEFC): In accordance with the Special Motors Section of this Specification and other relevant requirements in the listed standards.

2.10 TERMINAL (CONDUIT) BOXES

A. Oversize main terminal boxes for all motors. Nema 4 minimum. Nema 4X or hazardous rated as required to suit the area classification.

B. Diagonally split, rotatable to each of four 90-degree positions. Threaded hubs for conduit attachment.

C. Except ODP, furnish gaskets between box halves and between box and motor frame.

D. Minimum usable volume in percentage of that specified in NEMA MG 1, Section 1, Paragraph 4.19:

Terminal Box Usable Values		
Voltage	Horsepower/kW	Percentage
Below 600	15/11 through 125/93	500
Below 600	150/112 through 300/224	275
Below 600	350/261 through 600/448	225

E. Terminal for connection of equipment grounding wire in each terminal box.

2.11 BEARINGS AND LUBRICATION

A. Horizontal Motors:
   1. 0.56 kW and Smaller: Permanently lubricated and sealed ball bearings, or regreasable ball bearings in labyrinth sealed end bells with grease pressure relief units.
   2. 0.74 and above: Regreasable ball bearings in labyrinth sealed end bells with grease pressure relief units.
   3. Minimum 100,000 hours L-10 bearing life for ball and roller bearings as defined in ABMA 9 and 11.

B. Vertical Motors:
   1. Thrust Bearings:
      a. Antifriction bearing.
      b. Manufacturer’s standard lubrication; 74 kW and smaller.
      c. Oil lubricated; 93 kW and smaller.
      d. Minimum 50,000 hours L-10 bearing life.
   2. Guide Bearings:
      a. Manufacturer’s standard bearing type.
      b. Manufacturer’s standard lubrication; 149 kW and smaller.
      c. Oil lubricated; 186 kW and smaller.
      d. Minimum 100,000 hours L-10 bearing life.

C. Regreasable Antifriction Bearings:
   1. Readily accessible, grease injection fittings.
   2. Readily accessible, grease pressure relief units.

D. Oil Lubrication Systems:
   1. Oil reservoirs with sight level gauge.
   2. Oil fill and drain openings with opening plugs.
   3. Provisions for necessary oil circulation and cooling.

E. Bearing Isolation: Motors rated for inverter duty shall have electrically isolated bearings on the non-driven end to prevent stray current damage.

F. Bearing Isolator Mechanical Shaft Seals: To prevent internal motor contamination from bearing grease.

2.12 NOISE

A. Measured in accordance with IEEE 85 and NEMA MG 1.

B. Motors controlled by adjustable frequency drive systems shall not exceed sound levels of 3 dBA higher than NEMA MG 1.

2.13 BALANCE AND VIBRATION CONTROL

A. In accordance with NEMA MG 1, Part 7.

2.14 EQUIPMENT FINISH

A. Protect Motor for Service Conditions:
   1. TEFC Enclosures: Indoor industrial atmospheres.
   2. Other Enclosures: Outdoor industrial atmospheres, including moisture and direct sunlight exposure.

B. Internal Finish: Bore and end turns coated with clear polyester or epoxy varnish.

2.15 SPECIAL FEATURES AND ACCESSORIES

A. Nameplates:
   1. Raised or stamped letters on stainless steel or aluminum.
   2. Display motor data required by NEMA MG 1, paragraphs 10.39 and 10.40 in addition to bearing numbers for both bearings.
   3. Premium efficiency motor nameplates to also display NEMA nominal efficiency, guaranteed minimum efficiency, full load power factor, and maximum allowable kVAR for power factor correction capacitors.
   4. Include CSA or cUL certifications.

B. Anchor Bolts: Provide anchor bolts meeting Manufacturer’s recommendations and of sufficient size and number.

C. Where indicated on data sheets and all motors between 75 kW (100 hp) and 186 kW (250 hp), provide one thermistor per phase, inserted in the end turns of the stator winding, connected in series with leads brought out to the main termination box.

D. Where indicated on data sheets and all motors 186 kW (250 hp) and larger, provide two three wire RTD’s, 100 ohm at 0C platinum per phase, inserted in the end turns of the stator winding, with leads brought out to a separate terminal box. Identify temperature sensor terminals as to phase location. Also provide one RTD, 100 ohm 0C platinum per bearing.

E. Provide vibration accelerometers for all motors rated at 186 kW (250 hp) or larger.

F. Submersible motors shall have the following protection accessories:
   1. Motors greater than 2.2 kW (3 hp); humidity /leak detection.
   2. Motors greater than 7.5 kW (10 hp); humidity/leak detection and a winding temperature switch.
   3. Motors greater than 75 kW (100 hp); humidity/leak detection (in applicable compartments), winding temperature RTDs and bearing temperature (as noted above).
   4. Motors greater than 186 kW (250 hp); Same as 75 kW plus bearing vibration.

G. For motors at 37 kW (50 hp) and above that are subjected to high humidity and with expected periods of idle time as part of their normal utilization cycle, provide anti condensation heaters.

H. Shaft Grounding Ring. Provide shaft grounding ring integral to the motor for all VFD driven motor.

2.16 SPECIAL MOTORS

A. Requirements in this article take precedence over conflicting features specified elsewhere in this Section.

B. Severe-Duty Explosion-Proof: Meet requirements for EXP enclosures and CISD-TEFC motors.

C. Multispeed: Meet requirements for speeds, number of windings, and load torque classification indicated in the motor-driven equipment Specifications.

D. Inverter Duty Motor:
   1. Motor supplied power by adjustable voltage and adjustable frequency drives shall be inverter duty rated.
   2. Motor shall be suitable for operation over entire speed range indicated.
   3. Provide forced ventilation where speed ratio is greater than published range for motor being installed.
   4. Motor installed in Division 1 hazardous (classified) locations shall be identified as acceptable for variable speed when used in a Division 1 location.

E. Inclined Motors:
   1. Motors suitable for operation only in horizontal position not acceptable.
   2. Bearings designed for thrust imposed by driven equipment and by motor rotor when motor is in inclined position.
   3. Lubrication system designed to provide adequate bearing lubrication when motor is in inclined position.

2.17 FACTORY TESTING

A. Tests:
   1. In accordance with CSA C390 for polyphase motors and for single-phase motors.
   2. Routine (production) tests on all motors in accordance with NEMA MG 1, plus no load power at rated voltage and polyphase, rated voltage measurement of locked rotor current. Test multispeed motors at all speeds.
   3. For energy efficient motors, test efficiency at 50, 75, and 100 percent of rated horsepower:
      a. In accordance with CSA C390 or IEEE 112, Test Method B, and NEMA MG 1, paragraphs 12.59. and 12.60.
      b. For motors 373 kW and larger where facilities are not available to test by dynamometer (Test Method B), determine efficiency by CSA C390 or IEEE 112, Test Method F.
   4. Power Factor.
   5. Speed.
   6. Current at rated horsepower.
   7. kW input at rated horsepower.
   8. For motors 74 kW and smaller, furnish a certified copy of a motor efficiency test report on an identical motor.
   9. Temperature rise at rated horsepower for motors 596 kW and larger.

10. Vibration (balance).

B. Test Report Forms:
1. Routine Tests: IEEE 112, Form A-1.
2. Efficiency and power factor by CSA C390 or Test Method B, IEEE 112, Form A-2, and NEMA MG 1.
3. Efficiency and power factor by CSA C390 or Test Method F, IEEE 112, Forms F-1, F-2, and F-3.
4. Temperature Test: CSA C390 or IEEE 112, Form A-2.

PART 3 EXECUTION

3.1 INSTALLATION

A. In accordance with Manufacturer's instructions and recommendations.

B. Align motor carefully and properly with driven equipment.

C. Secure equipment to mounting surface with anchor bolts.

3.2 QUALITY CONTROL

A. Refer to other relevant sections of this Specification for commissioning requirements.

B. Test and inspect all materials and workmanship in accordance with this Specification and all applicable codes and regulations.

C. Furnish certified test documentation.

END OF SECTION

SECTION 26 23 00

LOW VOLTAGE SWITCHGEAR

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. ANSI C37.20.1 - Metal-Enclosed Low Voltage Power Circuit-Breaker Switchgear.

B. ANSI C37.51 - Testing of Metal-Enclosed Low Voltage AC Power Circuit Breaker Switchgear.

C. EEMAC G8-3 - Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear.

D. CSA 22.2 No. 31 - Switchgear Assemblies.

E. ANSI C37.13 - Low Voltage AC Power Circuit Breakers Used In Equipment.

F. ANSI C37.16 - Preferred Rating, Related Requirement And Application Recommendations For Low Voltage Power Circuit Breakers and AC Power Circuit Protectors.

G. ANSI C37.50 - Testing of Low Voltage AC Power Circuit Breakers.

H. NEMA SG-3 - Low Voltage Power Circuit Breakers.

I. NEMA SG-5 - Power Switchgear Assemblies.

J. UL1066 - Low Voltage AC and DC Power Circuit Breakers Used in Enclosures.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical.

B. Submit Shop Drawing to indicate:
   1. Mounting method and dimensions.
   2. Enclosure construction.
   3. Shipping splits.
   4. Lifting and supporting points.
   5. Electrical single line and 3-line Drawings.
   6. Breaker control schematics.
   7. Breaker wiring schematics and diagrams.
   8. Detailed Front Elevation Drawings.
   9. Component layout drawings.
   10. Bill of materials / component list indicating all components.
   11. Communication system schematic.
   12. Breaker trip curves (for every type and size of breaker).

13. Equipment Electrical Ratings (Nameplate).
14. Submit torque specification / calculation for all connections.
15. Submit an inspection and test plan schedule.
16. Details on the kirk key interlock system, including part numbers, and logic diagram / table.

C. The Manufacturer shall furnish comprehensive instruction manuals covering the installation and maintenance of the switchgear; and the operation of its various components.

1.3 O&M MANUAL

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 26 05 01, Common Work Results – Electrical.

B. Prepare installation, operating and maintenance manuals. Each of the O&M Manuals shall include, at a minimum, the following:
1. All Shop Drawing information.
2. Certified product test reports.
3. Certificates of compliance.
4. CSA certificate of inspection for the complete switchgear lineup or Manitoba "Special Inspection" certificate for the complete switchgear lineup.
5. Handling and installation instructions, including equipment anchorage information and provisions.
6. Operating and maintenance instructions.
7. Certified "as-manufactured" Drawings.
8. Recommended maintenance practices and procedures.
9. Recommended spare parts list.
10. Instruction manuals.
11. Standard cut sheets for OEM devices.
12. Component manuals for all devices/equipment/relays incorporated into the equipment.
13. Site Testing & Commissioning Procedures, and recommendations/ precautions for setting into operation.
14. Inspection records.
15. Nameplate rubbings.

1.4 QUALITY ASSURANCE

A. Accept equipment on site and inspect for shipping damage.

B. Protect equipment from weather and moisture by covering with heavy plastic or canvas and by maintaining heat within enclosure in accordance with Manufacturer's instructions.

PART 2 PRODUCTS

2.1 SWITCHGEAR ASSEMBLY

A. System Voltage: 600 V, three-phase, 60 Hz, grounded.

B. Switchgear Ampacity: As shown on the Drawings.

C. Interrupting (KAIC) Rating: As shown on the Drawings.

D. Equipment is to be complete from the incoming line connection to the outgoing feeder connections.

E. Each steel section shall contain one or more individual breakers, or instrumentation compartments, and a rear compartment for the buses and outgoing cable connections.

F. Rigid removable steel base channel shall be provided at the front and rear of each section.

G. Section widths shall be 558.8mm (22”), or wider if required. The section depths shall be 1828.8mm (72”).

H. The lineup shall provide adequate wire bending space for mains and feeders breakers using up to 750 MCM wires.

2.2 BREAKER COMPARMENT

A. Circuit Breaker
1. Each circuit breaker shall be mounted in its own barriered compartment.
2. Operational buttons on the circuit breaker as well as the trip unit and the display shall be accessible without opening the breaker compartment door.
3. Circuit breakers of like sizes and rated 1600A or less shall be interchangeable as standard. Circuit breakers of lower interruption ratings shall be mechanically prohibited from being placed in the cell.
4. Prepared spaces shall be totally complete, include the racking mechanism, bussing, and secondary contacts as necessary, so that a circuit breaker of the correct frame size can be installed with no modifications required.
5. Circuit breaker and prepared space compartments shall be “keyed” such that a breaker cannot be incorrectly installed with respect to interrupting rating, frame size, or secondary connections.
6. For circuit breakers in excess of 75 pounds, provide a floor mounted lifter to ease the installation or removal of circuit breakers.

B. Secondary Connections
1. All secondary control and communication connection shall be made from the front of the switchgear lineup.
2. A dedicated wiring area accessible from the front shall allow easy access to all control or communications terminations.
3. Dedicated conduit entry for control wires shall be provided at the top and bottom of each section, capable of landing up to three 41mm conduits and accessible from the front.
4. All interconnections between sections at shipping splits shall use locking pull- apart connectors.

C. Instrumentation
1. Where additional space is required for instrumentation, CPT’s, metering, etc., a barriered instrumentation compartment shall be used.

2. The instrumentation compartment shall not inhibit the routing of control or communication wires.
3. Individual component mounting surfaces and pans in the instrument compartments shall be painted white.

D. Ground Fault Protection
1. As indicated on Drawings, some low voltage switchgear are supplied by transformers incorporating high resistance grounding. Ensure sufficient space for ground fault current transformers in switchgear cells. Refer to the Drawings for details. Supply and install all ground fault C.Ts (including 3rd party C.Ts) in the factory.
2. For solidly grounded three phase, three-wire systems (with 1000A or greater main breaker), provide Long Time, Short Time, Instantaneous, and Ground (LSIG) trip breakers for all breakers within the switchgear.

2.3 BUSING AND CABLE COMPARTMENT

A. Busing
1. All bus bars shall be copper, with tin plating. Bus bars shall be plated along their entire length.
2. All vertical and horizontal distribution bussing shall be rated for the full ampacity of the lineup.
3. All bus joints shall consist of Grade 5 hardware and conical spring (e.g. Belleville) washers to withstand mechanical forces exerted during short circuits. All joints shall consist of a minimum of 2 bolts.
4. Busing shall be braced to withstand the instantaneous interrupting rating of the main breaker(s). Minimum withstand rating of the buswork shall be 65kA.
5. Barriers shall be installed to separate the busing and cable compartments.

B. Cable compartment
1. All incoming or outgoing power conductors shall be routed through this dedicated area.
2. Feeder breakers shall have adequate wire bending space regardless of the interrupting rating.
3. Conduit area for each section shall be a minimum of 431.8 mm (17”) wide and 863.6 (34”) deep for all sections.

2.4 TRANSIENT VOLTAGE SURGE SUPPRESSOR

A. Supply and install a Transient Voltage Surge Suppressor (TVSS) where shown on the Drawings.

B. Requirements:
1. TVSS units and all components shall be designed, manufactured, and tested in accordance with the latest applicable UL standard (ANSI/UL 1449 3rd Edition).
2. Voltage: Refer to Drawings.
3. Maximum Continuous Operating Voltage (MCOV): The MCOV shall not be less than 115 percent of the nominal system operating voltage. In cases where a neutral grounding resistor is part of the distribution, utilize minimum MCOV levels of 700V L-G and L-L. TVSS units shall be specifically designed for operation with an NGR.

4. The suppression system shall incorporate thermally protected metal-oxide varistors (MOVs) as the core surge suppression component for the service entrance and all other distribution levels. The system shall not utilize silicon avalanche diodes, selenium cells, air gaps, or other components that may crowbar the system voltage leading to system upset or create any environmental hazards.
5. Protection Modes – The TVSS must protect all modes of the electrical system being utilized. The required protection modes are:
   a. 3Ø, 3W System: L-L, and L-G
   b. 3Ø, 4W Wye System: L-L, L-N, L-G, and N-G
   c. 1Ø, 3W Wye System: L-L, L-N, L-G, and N-G
6. Nominal Discharge Current (In) – All TVSSs applied to the distribution system shall have a 20kA In rating regardless of their TVSS Type (includes Types 1 and 2) or operating voltage. TVSSs having an In less than 20kA shall be rejected.
7. ANSI/UL 1449 3rd Edition Voltage Protection Rating (VPR) – The maximum ANSI/UL 1449 3rd Edition VPR for the device shall not exceed the following:
   a. L-N, L-G, N-G:
      1) 120/208 V: 700V
      2) 347/600 V: 1500V
   b. L-L:
      3) 120/208 V: 1200V
      4) 347/600 V: 3000V

C. TVSS Design
1. Maintenance Free Design – The TVSS shall be maintenance free and shall not require any user intervention throughout its life. TVSSs containing items such as replaceable modules, replaceable fuses, or replaceable batteries shall not be accepted. TVSSs requiring any maintenance of any sort such as periodic tightening of connections shall not be accepted. TVSSs requiring user intervention to test the unit via a diagnostic test kit or similar device shall not be accepted.
2. Balanced Suppression Platform – The surge current shall be equally distributed to all MOV components to ensure equal stressing and maximum performance. The surge suppression platform must provide equal impedance paths to each matched MOV. Designs incorporating replaceable TVSS modules shall not be accepted.
3. Electrical Noise Filter – Each unit shall include a high-performance EMI/RFI noise rejection filter. Noise attenuation for electric line noise shall be up to 50 dB from 10 kHz to 100 MHz using the MIL-STD-220A insertion loss test method.
4. Internal Connections – No plug-in component modules or printed circuit boards shall be used as surge current conductors. All internal components shall utilize low impedance conductors.
5. Monitoring Diagnostics – Each TVSS shall provide the following integral monitoring options:
   a. Protection Status Indicators - Each unit shall have a green / red solid-state indicator light that reports the status of each protection mode on each phase.
6. The absence of a green light and the presence of a red light shall indicate that damage has occurred on the respective phase or mode. All protection status indicators must indicate the actual status of the protection on each phase or mode. If power is removed from any one phase, the indicator lights must continue to indicate the status of the protection on all

other phases and protection modes. Diagnostics packages that simply indicate whether power is present on a particular phase shall not be accepted.

D. Overcurrent Protection
   1. The unit shall contain thermally protected MOVs. These thermally protected MOVs shall have a thermal protection element packaged together with the MOV in order to achieve overcurrent protection of the MOV. The thermal protection element shall disconnect the MOV(s) from the system in a fail-safe manner should a condition occur that would cause them to enter a thermal runaway condition.

   E. Surge Current Capacity – The minimum surge current capacity the device is capable of withstanding shall be as shown on the Drawings, but in no case shall be less than 120 kA.

F. Installation Requirements:
   1. The TVSS shall be installed immediately following the load side of the main breaker or main switch.
   2. The switchgear shall be capable of re-energizing upon removal of the TVSS.
   3. Utilize a breaker, appropriately rated as directed by the TVSS Manufacturer, to connect the TVSS to the switchgear. The TVSS shall be located directly adjacent to the circuit breaker.
   4. The TVSS shall be included and mounted within the switchgear by the Manufacturer of the switchgear where shown on the Drawings.
      a. The complete switchgear including the TVSS shall be CSA/cUL listed.

2.5 POWER CIRCUIT BREAKERS

A. Low voltage power circuit breaker shall be Square D Masterpact.
   1. Circuit breakers shall be drawout type Masterpact with Micrologic electronic trip units.
   2. Power circuit breakers to be listed to UL 1066 and ANSI C37.
   3. Circuit breakers shall be suitable for the required instantaneous interrupting rating without the use of current limiting fuses.
   4. All circuit breakers shall have field interchangeable electrical accessories including shunt trip, spring release, electrical operator, auxiliary contacts, and trip unit.
   5. All secondary connections shall be made directly to the front of the circuit breaker cradle.
   6. Each Circuit breaker shall have built in contact temperature and contact wear sensors.
   7. Breaker trip units shall have an adjustable rating plug (range of 0.4-1 times the sensor plug value) and a field-replaceable sensor plug (available in standard amperage steps from 50 percent to 100 percent of the frame size) shall determine the ampere rating of the circuit breaker.

B. All circuit breaker operating mechanisms are to be two-step, fully- stored energy devices for quick-make, quick-break operation with a maximum of a five-cycle closing time. open-close-open (O-C-O) cycle shall be possible without recharging. Motor operator shall automatically charge when circuit breaker is closed. Actuation of the operating handle or an operation cycle of the circuit breaker motor is to charge the closing springs (step one) and operation of a local "close" button is to close the circuit breaker contact (step two). Closing the circuit breaker contacts shall automatically charge the opening springs.

C. Padlocking provisions shall be furnished to receive up to three padlocks when circuit breaker is in the disconnected position, positively preventing unauthorized closing of the circuit breaker contacts.

D. Provisions for up to two key locks shall be furnished allowing locking in the disconnected position. Provisions for locking in the connected, test and disconnected positions by padlock or key lock.

E. Located on the face of the circuit breaker shall be buttons, with a lockable clear cover, to open and close the circuit breaker and indicators to show the position of the circuit breaker contacts, status of the closing springs, and circuit breaker position in the cell. An indicator shall show “charged–not OK to close” if closing springs are charged but circuit breaker is not ready to close. Circuit breaker racking system must have positive stops at the connected, test, disconnected and withdrawn positions.

F. Circuit breaker must be equipped with an interlock to discharge the stored energy spring before the circuit breaker can be withdrawn from its cell. Circuit breaker must provide a positive ground contact check between the circuit breaker and cell when the accessory cover is removed while the circuit breaker is in the connected, test or disconnected positions.

G. Ready-to-close contact must be available to indicate remotely that the circuit breaker is "ready to close." The circuit breaker is ready to close when it is open, spring mechanism is charged, a maintained closing order is not present, a maintained opening order is not present, and the circuit breaker is in an operational position.

H. Circuit breaker shall provide long service life. The 3200 A circuit breaker frame and those of lower ratings must be certified to perform a minimum of 10,000 operations without maintenance.

I. The case of the circuit breaker shall be a polyester thermoset material providing high dielectric strength.

J. Each phase inside the circuit breaker shall be completely isolated from other phases and ground by polyester thermoset material.

K. Trip Units:
   1. Circuit breaker trip system shall be a Micrologic Type P electronic trip unit.
   2. Zone Selective Interlocking functionality.
   3. All trip units shall be removable to allow for field upgrades.
   4. Electronic trip unit is to be true RMS current sensing.
   5. Trip unit functions shall consist of adjustable long-time pickup and delay, optional short-time pickup and delay, instantaneous, optional neutral protection and optional ground-fault pickup and delay.
   6. Adjustable long-time pickup (Ir) and delay shall be available in an adjustable rating plug that is field-replaceable. Adjustable rating plug shall allow for nine long-time pickup settings from 0.4-1 times the sensor plug (In). Other adjustable rating plugs shall be available for more precise settings to match the application. Long-time delay settings shall be in nine bands from 0.5-24 seconds at six times Ir.

7. Short-time pickup shall allow for nine settings from 1.5-10 times Ir. Short-time delay shall be in nine bands from 0.1-0.4 I2t ON and 0-0.4 I2t OFF.
8. Instantaneous settings on the trip units with LSI protection shall be available in nine bands from 2-15 times In. Instantaneous setting shall also have an OFF setting.
9. All trip units shall have the capability for the adjustments to be set and read locally by rotating a switch.
10. Trip unit shall provide local trip indication and capability to indicate local and remote reason for trip, i.e., overload, short circuit or ground fault.
11. Trip units shall be available to provide additional protection by offering adjustable inverse definite minimum time lag (IDMTL). IDMTL provides optimized coordination by the adjustment of the slope of the long-time delay protection
12. Trip units shall provide real time metering. Metering functions include current, voltage, power and frequency.
13. Ethernet communication capabilities wired to common point.

2.6 ENCLOSURE

A. The enclosure shall be Type 1 located indoors unless specifically indicated otherwise on the Drawings.

B. Finish shall be gray ANSI 61, electro-deposited catalytic urethane paint applied over a rust inhibiting phosphate primer.

C. The enclosure and internal barriers shall be fabricated of steel members in accordance with NEMA and ANSI standards.

D. Steel lifting straps are to be provided with each shipping group to lift the structure from top with a crane. Supply a wooden skid to permit the use of pipe rollers for moving the switchgear to its final location in the building.

E. The lineup shall be divided into shipping splits to allow for installation in the Facility.

F. Each shipping split shall be provided with removable lifting straps.

G. All vertical sections shall be bolted together. Ventilation openings on the front of the switchgear are to be located in such a way as to preclude the possibility of metal objects being inserted through them and easily contacting energized parts. To protect the operator from escaping gases during an interruption, breakers shall be supplied with a steel front plate.

H. The equipment shall be assembled, adjusted and tested at the factory and shall be sectionalized, if required, for shipping as requested or approved.

I. The structure is to consist of three basic compartments from front to rear; the front breaker compartment, the center bus compartment, and the rear cable compartment.

2.7 COMPONENTS

A. The switchgear shall be compartmentalized, and fabricated in sections. The sections are divided by metal barriers into the following separate compartments:
   1. Circuit breaker(s), instrument, main bus, auxiliary device and cable. Each vertical section will have one or two circuit breaker compartment(s).

B. Ground Bus
   1. The ground bus shall extend through the full length of the switchgear. Bus supports to have standoff insulators.
   2. Provisions shall be made to allow for temporary grounding straps to be installed during maintenance.
   3. The ground bus system shall be capable of carrying the rated short circuit current of any breaker in the assembly for a minimum period of two (2) seconds.
   4. Provide main ground conductor cable termination points for up to 4/0 AWG grounding cable at opposite ends of the switchgear assembly.
   5. Ground cable attachment shall be NEMA standard spacing, 2 hole pattern.

C. Control Wiring and Connections.
   1. The switchgear shall be wired with the type SIS, 14 AWG, except where larger size wire is required by CSA standard, or specified. The switchgear shall be provided with terminal blocks for outgoing control connections.
   2. All wires shall be tagged and identified on both ends of every wire using heat shrink sleeve type wire markers. The wire numbering scheme shall be such that the wire numbers change only when going through a device; wire numbers at both ends of the same wire shall be identical. All wires on a given terminal block position shall bear the same number, with the exception of CT shorting type terminal blocks, which may have different wire numbers on opposite sides of the CT block.
   3. Wires shall be run in continuous lengths, without splices between connection points, installed in channels or neatly tied and clamped to the panel. Self-stick/adhesive type wire/cable clamps are acceptable only if additionally secured by means of screws.
   4. All wiring originating from a compartment must be first routed to terminal block.
   5. Connections to external circuits shall be brought to modular, asymmetrical DIN rail mounted snap-on construction, pressure type terminal blocks, with marking strips. Acceptable blocks are:
      a. Weidmuller Type SAK6N (preferred), Wieland type WK6/U.
      b. Weidmuller type SAKB10C (preferred), Wieland type 9060 APDAKAKR.
   6. A minimum of 20 percent spare terminals shall be included (minimum 20 terminal block positions.
   7. All wiring not terminated on devices shall be terminated on terminal blocks. Not more than two (2) wires shall be connected to any device terminal or at any one terminal side. Interconnecting jumpers between terminal block positions shall be counted in the above 2 wire per side limitation. General and control wiring shall utilize self retaining compression type spade connectors where wiring is terminated on hardware (relays, meters, switches, etc).
   8. Current transformer secondary circuits shall utilize insulated barrel ring type compression terminals.
   9. Where wiring between cells crosses shipping splits the Manufacturer shall supply keyed separable plug and socket type in-line insulated connectors to permit separating the cells at

the shipping splits without having to un-terminate wiring. The connector shall be sized to accommodate the wire gauge and current carrying capacity of the inter-cell conductors and shall be of a locking design to prevent separation in service due to vibration or other causes.

10. Soldered connections are not permitted.

2.8 METERING AND INSTRUMENTATION

A. Main Metering
   1. Shall use the Schneider Electric, PM8000 series power monitoring system at the switchgear main.
   2. CT's shall be appropriately sized for use at the main.
   3. Separate low voltage HMI and display shall be mounted on a separate door near the Main Circuit Breaker, and be visible from the exterior.
   4. I/O and Ethernet communication card shall be provided.

2.9 COMMUNICATION.

A. Switchgear shall include Ethernet gateway capable of accepting inputs from the micrologic trip units.

2.10 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01 - Common Work Results – Electrical.

B. Lamacoid for each switchgear to be size 10, example as followed:

SGR–R701 600 V, 3Ø, 3W, 3200A FED FROM SGR-C701

C. Lamacoid for each switchgear breaker to be size 5, example as followed:

CB-R710 FEEDS MCC-R710

D. Nameplates shall be attached by means of drive pins or self-drilling/tapping screws.

E. The Manufacturer shall submit a detailed listing of proposed equipment nameplates to the Contract Administrator for review prior to fabrication and installation.

2.11 ADDITIONAL MATERIAL/ACCESSORIES

A. Provide two (2) spare control fuses of each size installed.

B. For all switchgear with circuit breakers that weigh in excess of 75 lbs, provide one (1) circuit breaker lifting device (lift truck) per switchgear line-up. The lifting device shall be electric, plug in type (15A, 120 VAC circuit) portable, floor-supported with a roller base.

C. Provide one (1) spare circuit breaker of each frame size.

D. Provide two (2) spare current and voltage transformers of each size.

E. Provide four (4) spare pilot lights of each type / color and rating.

F. Provide two (2) spare breaker open / close switches.

G. Provide two (2) handles for manually charging the circuit breaker operating mechanisms.

H. Provide two (2) hand cranking levers for racking the circuit breaker in "connected", “test", “disconnected” positions with door closed.

I. Provide test jumpers for operating the circuit breaker.

J. Provide all other accessories to allow for full maintenance, adjustment and operation of the switchgear.

2.12 APPROVED MANUFACTURER.

A. Schneider Electric. Alternative Manufacturers will not be accepted due to this product having been selected as a standard.

B. All equipment shall be sourced from the local Manufacturer’s Representative, through the Manufacturer’s local approved distributors. Sourcing equipment from alternate sources will not be accepted.

2.13 FACTORY TESTING

A. Provide certified factory test reports for all components.

PART 3 EXECUTION

3.1 EXAMINATION

A. Visually inspect switchgear for evidence of damage and verify all systems and components are complete.

B. Check that concrete pads are level and free of irregularities, and suitable for the equipment.

C. Visually inspect to confirm that all items and accessories are in accordance with Specifications and Drawings.

D. Verify field measurements (i.e. voltage, current) are as indicated.

3.2 INSTALLATION

A. Install in accordance with manufacturer's instructions, applicable requirements of the CEC and in accordance with recognized industry practices.

B. Bending of cables should be avoided or minimized. All necessary bends should meet at least the minimum radii specified by the cable manufacturer, or by code (whichever is greater).

C. Provide relay programming and testing of the entire control system, demonstrating that the system works as intended.

D. Adjust circuit breaker settings to values indicated by the Contract Administrator.

3.3 FIELD QUALITY CONTROL

A. Provide a Manufacturer’s certified field service representative for on-site field inspection and testing of switchgear.

B. Check torque of all bolted connections, including cable terminations, by observing the bead of indicating compound to confirm that it is still intact. Perform spot checks with a torque wrench to confirm the joint is tightened to the Manufacturer's specifications.

C. Touch-up paint all chips and scratches with Manufacturer-supplied paint and leave remaining paint with Contract Administrator.

3.4 TRAINING

A. Furnish the services of a competent, factory-trained engineer or technician for two sessions of four hour duration to instruct City electrical maintenance personnel in the operation and maintenance of the equipment, on dates requested by the Contract Administrator.
   1. The contents of the training session to include:
      a. Electrical operation.
      b. Adjustment of settings, relays.
      c. Racking of breakers.
      d. Interlock systems.
      e. Power meter use.
      f. All other information deemed pertinent by the Contract Administrator.

3.5 FACTORY TESTING

A. QA Requirements
   1. Submit an Inspection and Test Plan in accordance with this Specification, and NETA Acceptance Testing. This shall be submitted along with, or after acceptance of the Shop Drawings.

B. Shop Inspection and Testing
   1. Equipment will be subject to inspection at the following stages of manufacture:
      a. Prior to shop testing,
      b. Prior to packaging for shipment.

2. Test equipment to ensure satisfactory operation prior to shipping. Provide Certification of Satisfactory performance.
3. Test and inspect all equipment, materials, works in accordance with scope of work, Specifications, all applicable codes, standards, regulations, laws and provide Certification and Records.
4. Provide the Contract Administrator with proper access to work, equipment, tools and facilities for carrying out such inspection, test, witness inspection or test points, surveillance or audit, whether it is in preparation or progress.
5. Provide upon request, the following information:
   a. Non-destructive test records/results.
   b. Welding procedures and welder qualifications.

C. Factory Tests
1. Test the equipment per applicable standards and provide test data.
2. The Contract Administrator reserves the right to witness any or all tests.
3. Prior to proceeding with the tests, provide in writing, a list of the tests to be performed at least two weeks before the tests are scheduled to begin, and an approximate schedule, with dates anticipated for the tests.
4. The equipment shall be tested at the manufacturing plant prior to shipment and in accordance with the latest applicable standards.

D. Design Tests
1. For the design tests, include the following:
   a. Dielectric tests,
   b. Power frequency voltage withstand on main contacts,
   c. Power frequency voltage withstand on auxiliary equipment and control circuits,
   d. Partial discharge,
   e. Radio interference,
   f. Temperature rise,
   g. Measurements of the main contact's resistance,
   h. Short-time and peak withstand current,
   i. Current interrupting tests.
2. The tests classified by the standards as optional may be carried out or waived at Contract Administrator’s discretion, e.g., tests for radio interference, tests with simulated internal arcing fault, operational tests in extreme atmospheric conditions, etc.
3. Perform the design tests in the Manufacturer’s plant or elsewhere by an internationally recognized laboratory, carried out on one complete circuit breaker.
4. Where design type test results have been previously obtained and have been certified by an internationally recognized testing laboratory, they may be acceptable in lieu of the above specified type tests.
5. In the case of the circuit breaker, ensure these tests have been carried out on 2 circuit breakers of the same type, capacity and characteristics as specified herein.

E. Routine Tests
1. Manufacturer’s routine tests shall include all tests required by the Standards for Manufactured Switchgear. Routine factory tests shall include but not be limited to the following for all of the equipment supplied:
   a. High potential tests on main circuit contacts and control wiring,

b. Operational tests on circuit breakers, and control devices; control wiring shall be energized and electrically operated devices shall be electrically operated at normal and minimum control voltage,
c. Remote control systems shall be tested to demonstrate proper operation under simulated conditions,
d. Operation of key, electrical and mechanical interlock systems shall be tested. Including verification of circuit breaker racking and positional safety interlocks,
e. Power frequency voltage dry test and partial discharge measurements,
f. Resistance measurement of circuit breaker and switch main contacts (Ductor Tests),
g. Mechanical testing of switching devices,
h. Primary current injection testing to confirm CT ratios,
i. Corona inception and extinction tests,
j. Provide factory test certificates for tests performed on individual switchgear components and on complete switchgear assembly.

3.6 FIELD TESTING

A. Test in accordance with Section 26 08 05, Acceptance Testing, and the Manufacturer's recommendations.

3.7 FINAL ACCEPTANCE

A. If required by final field testing/commissioning results make adjustments/or changes such that an efficient and fully operational installation is achieved. Such adjustments or requirements shall be to the suppliers account. Final acceptance by the Contract Administrator will be conditional upon fulfillment of all requirements.

B. For equipment subject to inspection by a government ministry, department, or agency, submit original copies of the test data reports and all other documentation required for the final field inspection of the equipment by the government ministry, department or agency.

C. Following completion of the work, issue a history docket comprised of the quality certificates, inspection and test records, and any other relevant documents related to manufacture and testing for the Contract Administrator's record files.

END OF SECTION

SECTION 26 24 17

PANELBOARDS

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 26 28 21, Moulded Case Circuit Breakers

1.2 CODES AND STANDARDS

A. Canadian Standards Association (CSA International) CSA C22.2 No.29, Panelboards and enclosed Panelboards.

B. Institute of Electrical and Electronics Engineers (IEEE):
1. C62.1, Surge Arresters for Alternating Current Power Circuits.
2. C62.11, Standards for Metal-Oxide Surge Arrestors for AC Power Circuits.

C. National Electrical Contractor's Association (NECA): 407, Recommended Practice for Installing and Maintaining Panelboards.

D. National Electrical Manufacturers Association (NEMA):
1. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
2. 289, Application Guide for Ground Fault Circuit Interrupters.
3. AB 1, Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures.
4. KS 1, Enclosed Switches
5. LA 1, Surge Arrestors.
6. PB 1, Panelboards.
7. PB 1.1, General Instructions for Proper Installation, Operation and Maintenance of Panelboards Rated 600 Volts or Less.

E. Underwriters Laboratories Inc. (UL):
1. 67, Standard for Panelboards.
2. 98, Standard for Enclosed and Dead-Front Switches.
3. 486E, Standard for Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors.
4. 489, Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
5. 508, Standard for Industrial Control Equipment.
6. 870, Wireways, Auxiliary Gutters and Associated Fittings.
7. 943, Standard for Ground-Fault Circuit-Interrupters.

1.3 SUBMITTALS

A. Submit Shop Drawings indicating the components and equipment to be used:
   1. Manufacturer’s data sheets for each type of panelboard, protective device, accessory item, and component.
   2. Manufacturer’s Shop Drawings including dimensioned plan, section, and elevation for each panelboard type, enclosure, and general arrangement.
   3. Details of features for each panelboard to include the following:
      a. Protective devices.
      b. Space for future protective devices.
      c. Voltage, frequency, and phase ratings.
      d. Enclosure type.
      e. Bus and terminal bar configurations and current ratings.
      f. Provisions for circuit terminations with wire range.
      g. Short circuit current rating of assembled panelboard at system voltage.
      h. Features, characteristics, ratings, and factory settings of auxiliary components.
      i. Panel schedules.
      j. Schematics / wiring diagrams for power meter and voltage monitor.
      k. Schematics / wiring diagrams for auxiliary devices
      l. Detailed panel interior and exterior layout diagram, including all dimensions.
      m. Wiring and schematic diagrams detailing control wiring, and differentiating between Manufacturer-installed and field-installed wiring.

1.4 O&M MANUAL

A. Include all Shop Drawings and product submittals.

PART 2 PRODUCTS

2.1 GENERAL

A. Panelboards: to CSA C22.2 No.29.

B. In addition to CSA requirements Manufacturer's nameplate must show fault current that the panel including breakers has been built to withstand.

C. The equipment interrupting rating listed is to be a true, independent, stand-alone interrupting rating. Achieving the listed interrupting rating using series rated equipment is not permitted.

D. Two (2) keys for each panelboard and key panelboards alike.

E. Sequence phase bussing with odd numbered breakers on left and even on right, with each breaker identified by permanent number identification as to circuit number and phase.

F. Panelboard ampacity, number of circuits, and number and size of branch circuit breakers are as indicated on the Drawings.

G. Install circuit breakers in panelboards before shipment. Circuit breaker size and position are to match the panelboard schedules.

H. The equipment size and layout shown on the electrical Drawings is based on equipment supplied in accordance with the standard of acceptance listed. Where equipment is approved as equal in accordance with B8, the approval is contingent upon the proposed equivalent equipment being of similar physical size, and able to fit within the space allocated. Equipment that does not physically fit will be replaced with suitable equipment at the cost of the Contractor.

I. Wire terminations:
   1. Panelboard assemblies, including protective devices, shall be suitable for use with 75°C or greater wire insulation systems and Canadian Electrical Code 75°C conductor ampacity.

J. Load current ratings:
   1. Unless otherwise indicated, load current ratings for panelboard assemblies, including bus and circuit breakers, are non-continuous. Continuous ratings shall be 80 percent of non-continuous rating.
   2. Where indicated “continuous” or “100 percent rated”, etc., selected components and protective devices shall be rated for continuous load current at value shown.

K. Enclosures:
   1. Provide CSA enclosure type 1, 12, 3R or 4 as specified on the Drawings. Where not specified, and installed in a clean, dry facility, use enclosure type 1.
   2. Shall be hot-dip galvanized sheet steel with reinforced steel frame.
   3. Finish: Rust inhibitor prime followed by Manufacturer’s standard gray baked enamel or lacquer.
   4. Provide sprinkler hoods for all surface mounted panelboards located in areas which are sprinklered.
   5. Provide with trim and front cover complete with concealed front bolts and hinges.

L. Bus:
   1. Material: tin plated copper, for phase bus, neutral bus, and ground bus. Full size throughout entire length. Neutral bus rating to be the same ampere rating as the phase bus (fully rated neutral).
   2. Provide for mounting of future protective devices along full length of bus regardless of number of units and spaces shown. Machine, drill, and tap as required for current and future positions.

M. Equipment ground terminal bus:
   1. Tin plated copper, full size, with suitably sized provisions for termination of ground conductors, and bonded to box.
   2. Provide individual mechanical termination points no less than the quantity of breaker pole positions.
   3. Provide individual termination points for all other grounding conductors such as feeder, grounding electrode, etc.

4. Termination points shall be bolted crimp compression lugs for conductors 6 AWG and larger.

N. Neutral terminal bus:
1. Tin plated copper full size, with suitably sized provisions for termination of neutral conductors, and isolated from box.
2. Provide removable neutral to ground jumper connection.
3. Provide individual mechanical termination points no less than the quantity of breaker pole positions.
4. Provide individual termination points for all other neutral conductors.
5. Termination points shall be bolted crimp compression lugs for conductors 6 AWG and larger.

O. Provision for future devices: equip with mounting brackets, bus connections, and necessary appurtenances for future protective device ampere ratings indicated.

P. Special features, provide the following features where indicated on the Drawings:
1. Service entrance equipment approval: listed for use as service equipment for panelboards complete with a separate, barriered, service disconnecting means.
2. Isolated equipment ground terminal bar:
   a. Provide in addition to the equipment ground terminal bar.
   b. Insulated from box.
   c. Provide individual conductor termination points equal to quantity of breaker pole positions plus all feeder, sub-feed, and feed-through isolated ground conductors.
3. Controls:
   a. Provide controls in accordance with Drawings and Specification requirements.
   b. Controls shall be 120 VAC, or as indicated.
   c. Control circuits shall be protected by fuse or circuit breaker.
4. Anti-condensation heater:
   a. Provide heater, suitable for operation (-40°C outdoor temperature) where equipment is located outdoors.
   b. Heater to be controlled by means of a thermostat located inside the enclosure.
   c. Complete with a separate breaker, and transformer (as required) to power the heater.
5. Magnetic contactor:
   a. Provide with current rating, poles, and connections (mains or between split bussing) as indicated.
   b. Contactor shall be electrically held with 120 VAC coil.
   c. Contactor shall include at least one spare NO and NC auxiliary contact.
6. Control transformer:
   a. Provide for contactor, shunt trip, or other devices as required.
   b. Capacity shall be a minimum of 125 percent of the maximum burden plus 100VA.
   c. Mount within the panelboard.
   d. Provide primary and secondary fused protection.
7. Extra gutter space: Dimensions and arrangement to suit the required field run and internal cabling.

Q. Products all from one Manufacturer. Do not submit split packages, with panelboards from multiple equipment Manufacturers.

R. Panelboards: mains, number of circuits, and number and size of branch circuit breakers as indicated on the Drawings.

S. Bus and breakers to be rated for a minimum of 10 kA (symmetrical) interrupting capacity, or higher as indicated on the Drawings and in Specification Section 26 28 21, Moulded Case Circuit Breakers.

T. Main breaker:
   1. Main breaker requirements to be as shown on the Drawings.
   2. Main breaker to be top or bottom mounted. Branch mounted main breakers are not acceptable.
   3. Barriered, separate service entrance rated where indicated on the Drawings.

U. Built-in permanent provisions for locking each breaker in the ‘Off’ position.

V. Provide individual lock-off devices for all circuit breakers in panelboard.

W. Branch and main breaker to be bolt-on style. Push on or stab-loc style breakers are not acceptable.

X. For panelboards 400A or larger, provide a hard plastic lamacoid nameplates adjacent to main breaker, and all branch breakers.

Y. Acceptable Manufacturer:
   1. Schneider Electric, or approved equal in accordance with B8 - Substitutes.
   2. All equipment shall be sourced from the local Manufacturer’s Representative, through the Manufacturer’s local approved distributors. Sourcing equipment from alternate sources will not be accepted.

2.2 BREAKERS

A. Breakers: to Section 26 28 21, Moulded Case Circuit Breakers.

2.3 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - Electrical.

B. Nameplate for each panelboard size 9, example as follows:

PNL-K711 MISC POWER 120/208V, 3Ø, 4W FED FROM MCC-K730

C. Items in the description Row 2 would be: UPS POWER, MISC POWER, GENSET POWER, LIGHTING, or other similar appropriate descriptions.

D. Provide type-written panelboard circuit directory in plastic sleeve pouch.

E. Provide hard plastic lamacoid nameplates adjacent to breakers within panelboards:
   1. For panelboards which are 400A and larger;
   2. In all panelboards, adjacent to branch breakers that are 100A and larger.

PART 3 EXECUTION

3.1 INSTALLATION

A. Locate panelboards as indicated and mount securely, plumb, true and square, to adjoining surfaces.

B. Ground fault protection: install panelboard ground fault circuit interrupter devices in accordance with installation guidelines of NEMA 289.

C. Provide filler plates in unused spaces.

D. Wiring in panel gutters: run conductors neatly in groups; bundle, and wrap with nylon wire ties.

E. Connect loads to circuits.

F. Provide typewritten circuit directory for each panelboard, affixed within each panel. Submit schedules in both AutoCAD and Microsoft Excel formats.

G. Provision for future circuits at flush (recessed) panelboards: stub four 1-inch empty conduits from panel into accessible ceiling space or space designated to be ceiling space for future use. Stub four 1-inch empty conduits into raised floor space or below slab other than slabs on grade.

H. Identify all spare breakers on breaker directory as "SPARE".

I. Loads shall be evenly balanced on all phases where possible.

J. Co-ordinate the thickness of partition walls in which panelboards are to be recessed prior to wall construction and panel rough-in. Failure to do this work shall require this Contractor to assume any costs for modifying walls, revising panels or electrical components.

3.2 WIRING IDENTIFICATION

A. Provide wiring identification in accordance with Section 26 05 01, Common Work Results - For Electrical.

3.3 TESTING

A. Test in accordance with Section 26 08 05, Acceptance Testing.

END OF SECTION

SECTION 26 24 19

MOTOR CONTROL CENTER

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 26 28 21, Moulded Case Circuit Breakers

B. Section 26 29 10, Motor Starters to 600 V

C. Section 26 29 23, Variable Frequency Drives

1.2 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00, Submittal Procedures.

B. Submit product data sheets for sills, busbars and compartments. Include product characteristics, physical size and finish.

C. Manufacturer's Instructions: provide to indicate special handling criteria, installation sequence, and cleaning procedures.

D. Submit Shop Drawings indicating the components and equipment to be used:
   1. Outline dimensions.
   2. Configuration of identified compartments.
   3. Floor anchoring method and dimensioned foundation template.
   4. Cable entry and exit locations.
   5. Dimensioned position and size of busbars and details of provision for future extension.
   6. Schematic and wiring diagrams for all systems, including VFDs, motor starters, network communication, etc.
   7. MCC riser/elevation diagram
   8. Manufacturer installation instructions, testing and Commissioning procedures
   9. Details on the kirk key interlock system, including part numbers, and logic diagram / table.

E. Closeout Submittals: provide operation and maintenance data for motor control centre for incorporation into manual specified in Section 01 77 00, Closeout Procedures.
   1. Include data for each type and style of starter.

1.3 O&M MANUAL

A. Include all Shop Drawings and product submittals.

PART 2 PRODUCTS

2.1 GENERAL CHARACTERISTICS

A. 600 V, 60Hz, wye connected, 3 phase, 3 wire or as shown on the Drawings

2.2 GENERAL DESCRIPTION

A. Compartmentalized vertical sections with common power busbars.

B. Floor mounting, free standing, enclosed dead front.

C. Indoor NEMA 1A, gasketted enclosure, front mounting.

D. Class IIS (custom, smart MCC), Type B-D and Type B-T as indicated on the Drawings.

E. Nameplates: white with black letters.

F. The MCC shall be provided with a factory wired and tested intelligent communication system.

2.3 VERTICAL SECTION CONSTRUCTION

A. Independent vertical sections fabricated from rolled flat steel sheets bolted together to form rigid, completely enclosed assembly.

B. Dimensions: 2324 mm (91.5”) high. MCC depth to be a minimum of 508 mm (20”) or larger to accommodate the motor starters and devices. Standard width to be 508 mm (20”) or larger as required in order to accommodate devices within the MCC.

C. Assembled sections into a group having a common power bus and forming an enclosure to which additional sections may be readily added. Design for all power and control connections to be made from the front. All bus and feeder bolted connections shall be accessible from the front.

D. Sections with horizontal wiring spaces top and bottom and with 102 mm full height vertical wiring spaces with cable tie supports. Insulate wireways from horizontal and vertical bus.

E. Each vertical section divided into compartment units, minimum 152 mm high, as indicated.

F. Each unit to have complete top and bottom steel plate for isolation between units.

G. Horizontal wireways, equipped with cable supports, across top and bottom, extending full width of motor control centre, isolated from busbars by steel barriers.

H. Vertical wireways c/w doors for load and control conductors extending full height of vertical sections, and equipped with cable tie supports. Installation wiring to units accessible with doors open and units in place.

I. Stab opening protection: Removable protective caps.

J. Isolation barriers between units and wireways.

K. Openings, with removable cover plates, in side of vertical sections for horizontal wiring between sections.

L. Incoming cables to enter at top and/or bottom.

M. Provision for outgoing cables to exit via top and/or bottom.

N. Removable lifting means.

O. Provision for future extension of both ends of motor control centre including busbars without need for further drilling, cutting or preparation in field.

P. Divide assembly for shipment to site, complete with hardware and instructions for re-assembly. Groupings are to allow for transport of the components into the required electrical room.

Q. Provide all spaces complete with bussing hardware and other accessories required so that additional combination starter units can be readily installed. Provide barriers to isolate the space from all buswork.

R. Provide barriers to isolate all buswork to prevent accidental contact when starter units are removed or spaced are provided. Barriers shall also provide phase-to-phase isolation of the vertical bus.

2.4 SILLS

A. Continuous channel iron floor sills for mounting bases with 19 mm diameter holes for bolts.

2.5 BUSBARS

A. Main horizontal and branch vertical, three phase high conductivity tin plated copper busbars in separate compartment bare self-cooled, extending entire width and height of motor control centre, supported on insulators and rated:
   1. Minimum main horizontal busbar size: 600 A or larger as required.
   2. Minimum branch vertical busbars: 300 A or larger as required.

B. Branch vertical busbars for distribution of power to MCC units in vertical sections.

C. Brace buswork to withstand effects of short circuit current, minimum rating of 42 kA rms symmetrical or larger as required.

D. Bus supports: with high dielectric strength, low moisture absorption, high impact material and long creepage surface designed to discourage collection of dust.

E. Location: Top

2.6 GROUND BUS

A. Tin plated copper ground bus extending entire width of motor control centre.

B. Tin plated copper vertical ground bus, full height of section, tied to horizontal ground bus, engaged by plug-in unit ground stab.

2.7 TRANSIENT VOLTAGE SURGE SUPPRESSOR

A. Supply and install a Transient Voltage Surge Suppressor (TVSS) where shown on the Drawings.

B. Requirements:
1. TVSS units and all components shall be designed, manufactured, and tested in accordance with the latest applicable UL standard (ANSI/UL 1449 3rd Edition).
2. Voltage: Refer to Drawings.
3. Maximum Continuous Operating Voltage (MCOV): The MCOV shall not be less than 115 percent of the nominal system operating voltage. In cases where a neutral grounding resistor is part of the distribution, utilize minimum MCOV levels of 700V L-G and L-L. TVSS units shall be specifically designed for operation with an NGR.
4. The suppression system shall incorporate thermally protected metal-oxide varistors (MOVs) as the core surge suppression component for the service entrance and all other distribution levels. The system shall not utilize silicon avalanche diodes, selenium cells, air gaps, or other components that may crowbar the system voltage leading to system upset or create any environmental hazards.
5. Protection Modes – The TVSS must protect all modes of the electrical system being utilized. The required protection modes are:
   a. 3Ø, 3W System: L-L, and L-G
   b. 3Ø, 4W Wye System: L-L, L-N, L-G, and N-G
   c. 1Ø, 3W Wye System: L-L, L-N, L-G, and N-G
6. Nominal Discharge Current (In) – All TVSSs applied to the distribution system shall have a 20kA In rating regardless of their TVSS Type (includes Types 1 and 2) or operating voltage. TVSSs having an In less than 20kA shall be rejected.
7. ANSI/UL 1449 3rd Edition Voltage Protection Rating (VPR) – The maximum ANSI/UL 1449 3rd Edition VPR for the device shall not exceed the following:
   a. L-N, L-G, N-G:
      1) 120/208 V: 700V
      2) 347/600 V: 1500V
   b. L-L:
      1) 120/208 V: 1200V
      2) 347/600 V: 3000V

C. TVSS Design
1. Maintenance Free Design – The TVSS shall be maintenance free and shall not require any user intervention throughout its life. TVSSs containing items such as replaceable modules, replaceable fuses, or replaceable batteries shall not be accepted. TVSSs requiring any maintenance of any sort such as periodic tightening of connections shall not

be accepted. TVSSs requiring user intervention to test the unit via a diagnostic test kit or similar device shall not be accepted.

2. Balanced Suppression Platform – The surge current shall be equally distributed to all MOV components to ensure equal stressing and maximum performance. The surge suppression platform must provide equal impedance paths to each matched MOV. Designs incorporating replaceable TVSS modules shall not be accepted.
3. Electrical Noise Filter – Each unit shall include a high-performance EMI/RFI noise rejection filter. Noise attenuation for electric line noise shall be up to 50 dB from 10 kHz to 100 MHz using the MIL-STD-220A insertion loss test method.
4. Internal Connections – No plug-in component modules or printed circuit boards shall be used as surge current conductors. All internal components shall utilize low impedance conductors.
5. Monitoring Diagnostics – Each TVSS shall provide the following integral monitoring options:
   a. Protection Status Indicators - Each unit shall have a green / red solid-state indicator light that reports the status of each protection mode on each phase.
6. The absence of a green light and the presence of a red light shall indicate that damage has occurred on the respective phase or mode. All protection status indicators must indicate the actual status of the protection on each phase or mode. If power is removed from any one phase, the indicator lights must continue to indicate the status of the protection on all other phases and protection modes. Diagnostics packages that simply indicate whether power is present on a particular phase shall not be accepted.

D. Overcurrent Protection
1. The unit shall contain thermally protected MOVs. These thermally protected MOVs shall have a thermal protection element packaged together with the MOV in order to achieve overcurrent protection of the MOV. The thermal protection element shall disconnect the MOV(s) from the system in a fail-safe manner should a condition occur that would cause them to enter a thermal runaway condition.

E. Surge Current Capacity – Refer to the Drawings for required capacity. The minimum surge current capacity the device is capable of withstanding shall be as shown:
1. 600V MCCs – Service entrance: 240 kA.
2. 600V MCCs – Not Service Entrance: 120 kA or greater.

F. Installation Requirements:
1. The TVSS shall be installed immediately following the load side of the main breaker or main switch.
2. The MCC shall be capable of re-energizing upon removal of the TVSS.
3. Utilize a breaker, appropriately rated as directed by the TVSS Manufacturer, to connect the TVSS to the MCC. The TVSS shall be located directly adjacent to the circuit breaker.
4. The TVSS shall be included and mounted within the MCC by the Manufacturer of the MCC where shown on the Drawings.
   a. The complete MCC including the TVSS shall be CSA/cUL listed.

2.8 INTELLIGENT MOTOR PROTECTION RELAYS

A. Intelligent Motor Protection Relays (IMPR's) shall be CSA and UL approved.

B. IMPR's shall be fully programmable electronic relays.

C. The IMPR shall feature a Test/Rest button.

D. I/O shall consist of six discrete logic inputs, with a minimum of three relay outputs (1 NO) and one relay output for fault signaling (1 NO + 1 NC) or greater as indicated on the Drawings.

E. Control voltage shall be 120 VAC.

F. Network, electronic and manual reset functions shall be supported.

G. The following status and monitoring functions shall be provided based on user configurable parameters:
   1. Metering
      a. Measurement:
         1) Line Currents
         2) Ground current
         3) Average Current
         4) Current Phase Imbalance
         5) Thermal capacity Level
         6) Motor Temperature Sensor
      b. Statistics:
         1) Protection Fault Counts
         2) Protection Warning counts
         3) Diagnostic fault counts
         4) Motor Control Function counts
         5) Fault History
      c. Diagnostics:
         1) Internal watchdog results
         2) Controller Internal Temperature
         3) Temperature Sensor Connections
         4) Current Connections
         5) Control Commands (start, stop, run, check back and stop check back)
         6) Control configuration checksum
         7) Communication loss
      d. Motor States:
         1) Motor control states motor starter/LO1 starts/ LO2 starts
         2) Operating time
         3) Motor starts per hour
         4) Last start max current
         5) Last start time
         6) Time to trip
         7) Time to reset

2. Fault Monitoring:
    a. Diagnostic:
        1) Run command check
        2) Stop command check
        3) Run check back
        4) Stop check back
    b. Wiring/ Configuration errors:
        1) PTC Connection
        2) CT Reversal
        3) Current Phase Reversal
        4) Phase Configuration
    c. Internal
        1) Stack Overflow
        2) Watchdog
        3) ROM Checksum
        4) EEROM
        5) CPU
        6) Internal Temperature
    d. Motor temp sensor
        1) PTC Binary
        2) PTC Analog
        3) NTC Analog
    e. Thermal overload:
        1) Definite
        2) Inverse Thermal
    f. Current:
        1) Long Start
        2) Jam
        3) Current Phase Imbalance
        4) Current Phase Loss
        5) Overcurrent
        6) Undercurrent
        7) Internal Ground Current
        8) External Ground Current
    g. Communication loss
        1) PLC to IMPR
    h. Protection:
        1) Thermal overload
    i. Current phase imbalance
    j. Current phase loss
    k. Current phase reversal
    l. Long start
    m. Jam (locked rotor during run)
    n. Undercurrent
    o. Overcurrent
    p. Ground current
    q. Motor temperature sensor
    r. Rapid cycle lockout

3. Control Functions:
    a. Motor control modes
        1) Local terminal strip
        2) Network
    b. Operating mode
        1) Overload
        2) Independent
        3) Reverser
        4) Two-step
        5) Two-speed
        6) Custom Mode
    c. Fault Management
        1) Manual reset
        2) Automatic reset
        3) Remote reset

H. Metering and Monitoring
1. The IMPR shall include accurate measurement processing functions to operate the different applications and carry out Commissioning and maintenance.
2. For measurement, the IMPR shall include Current transformers up to 100 A, for all measurements required (current, power, voltage, frequency, etc). It is not possible to use external special CTs for measurement.

I. Motor Protection Functions
1. The IMPR shall integrate all motor protection functions described above.
2. The thermal overload trip curve shall be selectable between inverse (I^2t) or definite time (Ixt) curve. The Auxiliary Fan Cooling application shall be also selectable.
3. It shall include Ground Fault Protection internally, and it shall be possible to use an external zero sequence CT to accomplish this, without the need for additional modules or devices.

J. Programming and configuration software
1. The IMPR shall use user-friendly settings and operate multi-lingual software in a Windows environment with menus and icons for fast direct access to the data required, guided navigation to go through all the data for the same function on the same screen and with file management.
2. The PC can be connected in a 1-to-1 configuration to a single controller, or in a 1-to-many configuration to multiple controllers.
3. The IMPR shall provide a “Custom Mode”, a logic customized by the end user.

K. Self-Test
1. The IMPR shall be capable of self-tests. It shall perform internal checks such as a watch-dog check and RAM check, in order to maximize availability and minimize the risk of malfunctioning.

L. Acceptable products:
   1. Schneider Electric TeSys T.

2.9 COMMUNICATION CABLING

A. The MCC shall employ a network communication cabling system to interconnect units within the MCC.

B. Network cabling shall be routed through the lower horizontal wireway to isolate the network from the horizontal bussing routed through the top.

C. A communication barrier in the full-depth vertical wireway shall serve to separate communications from power cabling and to prevent noise interference on the network cable.

D. Provisions for appropriate terminators and grounding shall be provided.

E. Addition, removal, or rearrangement of units shall not interrupt the trunk line and shall not affect the cabling of other units attached to the trunk line.

F. Cable coupler design shall include a vibration-resistant ratchet to prevent loosening.

G. The cabling is to be configured in a star configuration.

H. Cabling shall be Category 6 shielded twisted pair Ethernet cable with RJ45 connector.

I. Ethernet cable insulation rating shall be 600V minimum.

2.10 POWER METER

A. Where indicated on the Drawings, provide a microprocessor based multifunction power meter.

B. Requirements:
   1. Multifunction electrical measurement on 3 phase power systems.
   2. Accept a direct voltage input range of up to 600 Volts Line to Line.
   3. Programmable for current to any CT ratio.

C. Communications ports:
   1. 10/100 Mbps Ethernet supporting Modbus-TCP.

D. Acceptable products:
   1. Schneider Electric PM5500 or PM8000 as indicated on the single lines, front mounted, visible from outside the MCC.

2.11 NETWORK SWITCHES

A. Type: managed switch.

B. Speed: 100 mbit or gigabit as required.

C. Port quantity: as indicated on the Drawings.

D. Power supply: 24 VDC.

E. Please include in the MCC spec for the network switch power supplies that one will be fed from a control power transformer within the MCC and one fed from the UPS

F. Provide redundant power supplies for each network switch. Two 24 VDC supplies, fed from separate transformers and separate fused disconnects. One will be fed from a control power transformer within the MCC and one fed from the UPS. Each supply shall be brought into the network switches. The UPS feed shall be used to normally power the network switches. Provide dual power input network switches.

2.12 MOTOR STARTERS AND DEVICES

A. Equip the MCC with combination starters as specified and shown on the Drawings.

B. Refer to Section 26 29 10, Motor Starters to 600 V.

2.13 STARTER UNIT COMPARTMENTS

A. Units NEMA size 5 and smaller, circuit breaker units 225A and smaller, plug-in type with self-disconnect. Guide rail supports for units to ensure that stabs make positive contact with vertical bus. Provision for units to be installed or removed, off load, while buses energized.

B. Unit mounting:
   1. Engaged position - unit stabbed into vertical bus.
   2. Withdrawn position - unit isolated from vertical bus but supported by structure.
   3. Provision for positive latching in either engaged or withdrawn position and padlocking in withdrawn position.
   4. Stab-on connectors free floating tin plated clips, self-aligning, backed up with steel springs.

C. External operating handle of circuit switch interlocked with door to prevent door opening with switch in "on" position. Provision for padlock to lock operating handle in "off" position and lock door closed.

D. Hinge unit doors on same side.

E. Overload relays manually reset from front with door closed.

F. Pushbuttons and indicating lights mounted on door front.

G. Devices and components by one Manufacturer to facilitate maintenance.

H. Pull-apart terminal blocks for power and control to allow removal of starter units without removal of field wiring.

I. Control wiring shall be extended from each starter module to the control terminal section, including all auxiliary contacts. A multi unit style terminal block having screw type terminal connections shall be installed on standoff supports on back plate.

J. All terminals shall be number coded or otherwise suitably identified to indicate which section or module of the MCC they are associated with and their function.

K. Complete control wiring diagrams for each starter with conductor identification clearly shown shall be affixed to the interior cover of the starter section or provide a book of wiring diagrams for all starters in each MCC.

L. Primary and secondary high rupturing capacity (HRC) fusing shall be installed on the control transformer.

M. Equip door of each individual unit with a removable plate replaceable with similar plate complete with pushbuttons, pilot lights or selector switches as required. Use pilot lights of push-to-test type and push button of heavy-duty oil tight construction.

N. MCC cabinets with VFD drives shall have integrated keypad flush mounted on the MCC doors.

O. Ground Fault Protection
   1. As indicated on Drawings, some MCCs are supplied by transformers incorporating high resistance grounding. Ensure sufficient space for ground fault current transformers in switchgear cells. Refer to the Drawings for details. Supply and install all ground fault C.Ts (including 3rd party C.Ts, in the factory).
   2. For solidly grounded three phase, three-wire systems (with 1000A or greater main breaker), provide Long Time, Short Time, Instantaneous, and Ground (LSIG) trip breakers for all breakers within the switchgear.

2.14 WIRING IDENTIFICATION

A. Provide wiring and cable identification in accordance with Section 26 05 01, Common Work Results - For Electrical and in accordance with the Drawings.

2.15 FINISHES

A. Apply finishes in accordance with Section 26 05 01, Common Work Results - For Electrical.

B. Paint motor control centre exterior light gray and interiors white.

2.16 SOURCE QUALITY CONTROL

A. Provide Manufacturer's type test certificates including short circuit fault damage certification up to short circuit values specified under bus bracing.

B. Contract Administrator to witness standard factory testing of complete motor control centre including operation of switches, circuit breakers, starters and controls.

2.17 SPARE PARTS

A. Two (2) spare Intelligent Motor Protection Relays (overloads) of each type and size. Include two (2) spare add on modules of each type.

B. One (1) spare 120 kA TVSS unit and one (1) spare 240 kA TVSS unit.

C. One (1) spare contactor of each size.

D. One (1) spare circuit breaker of each size for breakers 150A and smaller. Breakers greater than 150A do not required spares.

E. One (1) spare Motor Circuit Protector (MCP) of each size.

F. Four (4) spare pilot lights of each type and rating.

G. Two (4) spare C.Ts of each type and size for branch feeders.

H. Two (2) spare C.Ts of each type and size for main and tie breaker C.Ts.

I. One (1) set of fuses of each type and size.

2.18 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - Electrical.

B. Mark spaces as “SPACE” and spares as “SPARE.

C. Nameplate for each MCC size 10, example as follows:

MCC-K710 NORMAL POWER 347/600V, 3Ø, 3W FED FROM SGR-K701

D. Nameplate for each MCC cell, size 8, example as follows:

P-K501 SUMP PUMP

2.19 APPROVED MANUFACTURERS

A. Schneider Electric. Alternative Manufacturers will not be accepted due to this product having been selected as a standard.

B. All equipment shall be sourced from the local Manufacturer's Representative, through the Manufacturer's local approved distributors. Sourcing equipment from alternate sources will not be accepted.

PART 3 EXECUTION

3.1 SETUP AND TESTING

A. Upon completion of assembly, all system components shall be factory-wired and tested as a system prior to shipment.

B. Each device shall be configured and addressed to correspond with software settings.

C. A read/write test shall be performed prior to shipment on all network devices including, but not limited to, Overloads, Drives, and Soft Starts.

D. Testing shall be designed to verify system operation and shall include these verifications as a minimum:
   1. I/O addressing
   2. Correct device operation by I/O address
   3. Host Communications
   4. Control Network Interface

3.2 INSTALLATION

A. Set and secure motor control centre in place on channel bases, rigid, plumb and square to building floor and wall.

B. Make field power and control connections as indicated.

C. Install and connect components in accordance with the Drawings and the Manufacturer's instructions.

3.3 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 05 01, Common Work Results - For Electrical.

B. Ensure moving and working parts are lubricated where required.

C. Include costs of having a Square D factory trained technician inspect and approve the MCC installation prior to system energization.

3.4 TRAINING

A. Furnish the services of a competent, factory-trained engineer or technician for two sessions of four hour duration to instruct City electrical maintenance personnel in the operation and maintenance of the equipment, on a date requested by the Contract Administrator.
   1. The contents of the training session to include:
      a. Electrical operation.
      b. Adjustment of overloads
      c. Racking of buckets
      d. Power meter use
      e. All other information deemed pertinent by the Contract Administrator.

B. Furnish the services of a competent, factory-trained engineer or technician for two sessions, each of two hour duration to instruct City technical maintenance personnel in the operation and maintenance of the networked equipment, on a date requested by the Contract Administrator. The contents of the training session to include:
   1. Network communications.
   2. Connection to motor starter web interface.
   3. Viewing and adjustment of parameters.
   4. Replacement of motor overload, including setting of IP address.
   5. Troubleshooting and maintenance, and
   6. Similar contents to the training session identified above.

3.5 TESTING

A. Test in accordance with Section 26 08 05, Acceptance Testing, and the Manufacturer's recommendations.

END OF SECTION

SECTION 26 25 01

CABLE BUS

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA C22.1 Canadian Electrical Code - Part 1 (CEC)

B. CSA C22.2 No. 38- Thermoset Insulated Wires and Cables.

C. CSA C68. 10-08 – Shielded power cable for commercial and industrial applications, 5-46 kV.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer’s printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

   C. Submit Shop Drawings indicating the components and equipment to be used:
   1. Manufacturer's product data sheets:
      a. Dimensions.
      b. Materials.
      c. Finishes.
      d. Certifications.
      e. Certified ampacity rating, indicating compliances with CSA standards.
      f. Exterior wall penetration seal, including UL listings and certifications.

1.3 MAINTENANCE

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 26 05 01, Common Work Results - Electrical.

PART 2 PRODUCTS

2.1 VENTILATED CABLE BUS ENCLOSURE

A. Enclosure material shall be constructed of high strength high conductivity, 6063-T6 corrosion resistant aluminum alloy meeting the requirements of CSA 22.2 No. 126.1.

B. The enclosure shall be completely enclosed on both sides, and both top and bottom of the enclosure shall be ventilated with vents that do not expose the cable bus system nor allow mechanical injury / damage.

C. Cables shall be supported within the enclosure and on each level by metal supports which shall be at least 45 mm (1.77”) in width.

D. The metal cable supports shall be repeated throughout the cable enclosure at regular intervals not exceeding 305 mm (12”).

E. Metal supports on each successive vertical cable level shall be longitudinally offset by 1/2 of the support spacing, relative to the supports in the level immediately below.

F. Cable clamps shall be clamped to the metal supports at intervals not exceeding 1143 mm (48”).

G. Cables shall be secured to a cable support by use of a one-piece non-ferrous metal clamp, of width equal to the underlying cable support, providing a trefoil cable arrangement.

H. Each clamp shall be formed to provide a sufficient number of cable ports to secure the designated number of feeder cables.

I. Shall be designed and fabricated by the system Manufacturer to meet all CEC requirements, with the ampacity requirements as indicated on the Drawings.

2.2 POWER CABLES

A. Each individual power cable shall be of a single, continuous length between terminals, and shall meet the requirements of the appropriate Standard listed in Section 1.1 above, consistent with the system design voltage.

B. Conductors:
   1. Conductors shall be of annealed uncoated Class B stranded copper, sized to meet the ampacity requirements.
   2. Spacing between conductors as indicated on Drawing.
   3. Minimum distance between conductor and inner face of the tray is 6.35 mm (0.25”).

C. Insulation:
   1. Cable insulation shall be EPR, 1000V, FT-4, tray rated, composed of a CSA approved high dielectric elastomeric insulation for system voltages of 600 volts.

D. Jackets:
   1. All cables, rated 600 volts and greater, shall be FT-4, tray rated and shall include a protective wet location listed jacket.

E. Exterior Wall Penetration
   1. Utilize Roxtec weatherproof sealing system. For cable bus, the sealing system metallic framing must be of aluminum construction (non-ferrous) so that circulating currents do not occur.
   2. Install to Manufacturer’s recommendations.
   3. Install flush with exterior portion of the wall.

4. Prior to installation of seals, Contractor to submit proof of training to the Contract Administrator. Do not install the cable seal system without equipment Manufacturer training, as work will have to be re-done. Contact Roxtec for training.
5. Prior to covering up wall penetration work, arrange for a site inspection of the work with the Contract Administrator. Proof of proper installation is required.

2.3 GROUNDING

A. The enclosure system shall be certified as a continuous bonding conductor, with provision for a ground clamp at each end of each enclosure section.

B. A bonding conductor shall be connected to the inside wall of all cable tray systems and shall be affixed to every tray member. Utilize approved bonding clamps only. A system grounding conductor, if required, shall be the responsibility of the electrical contractor.

2.4 WEATHERPROOF PLATE

A. Transformers must have a sealed base plate affixed to the transformer cable entry compartment to provide cable connector supports, and to ensure that the cable entry compartment remain dry at all times.

B. The plate shall be supplied complete by the Contractor, drilled to accommodate the number of cables and weatherproof cable connectors.

2.5 SUPPORTS

A. Electrical contractor shall provide the Cable Bus enclosure supports. Cable Bus Manufacturer to supply loading requirements.

2.6 PENETRATION FIRE SEALS

A. Where a fire separation is pierced by the enclosure system, all openings around the enclosure and around each individual cable within the enclosure shall be properly closed or sealed with an elastomeric three-hour rated sealing system, in compliance with the National Building Code of Canada.

2.7 CONCRETE ENCASEMENT (FOR BELOW GRADE INSTALLATION)

A. Provide concrete encasement, complete with steel reinforcing in accordance with the Structural Drawings and Specifications.

B. The heat dissipation and off-set vents are to be positioned in accordance with the cable bus Manufacturer’s technical requirements and the Drawings to meet the required ampacity.

C. Vents for ventilation of the concrete encasement shall have heavy duty, stainless steel vermin screens.

D. Vents shall be constructed in such a manner as to prevent the ingress of debris into the cable bus portion of the concrete encasement.

E. Provide motorized fan / ventilation of the concrete encasement where required in to meet the vent spacing limitations. Where motorized fan system is required, provide thermocouple devices to control ventilation system. The Cable Bus vendor shall provide motor starter and temperature controls as part of a complete system package.

2.8 APPROVED MANUFACTUERS

A. Cable bus ways shall be the product of United Wire & Cable (MAXIAMP), or approved equal in accordance with B8 - Substitutes.

PART 3 EXECUTION

3.1 MANUFACTURER’S INSTRUCTION

A. Compliance: comply with Manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSTALLATION

A. All installations of a cable bus feeder system shall be in complete accordance with the Manufacturer’s written installation procedure.

B. The Contractor shall ensure vents or other obstructions do not interfere with the required 3 meter clearance in front of the transformer door / access compartment. In addition, obstructions / equipment shall be a minimum of 1000mm away from other sides of the transformer in accordance with CEC requirements.

C. The Contractor shall include the services of a factory approved cable bus representative to inspect the installation and certify in writing that the system has been installed in accordance with all their requirements, and meets the required system ampacity.

D. The Drawings indicate general concepts, and may not show all details required for mounting or installation. Supply and install any additional items required for a complete and working installation.

E. Do not allow or cause any work performed or installed to be covered up or enclosed prior to the required inspections, tests and approvals.

F. The system shall be completely CSA certified (or have a special inspections certificate) by the Cable Bus vendor.

END OF SECTION

SECTION 26 27 26

WIRING DEVICES

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA-C22.2 No.42, General Use Receptacles, Attachment Plugs and Similar Devices.

B. CSA-C22.2 No.42.1, Cover Plates for Flush-Mounted Wiring Devices (Bi-national standard, with UL 514D).

C. CSA-C22.2 No.55, Special Use Switches.

D. CSA-C22.2 No.111, General-Use Snap Switches (Bi-national standard, with UL 20, twelfth edition).

E. CSA-C22.2 No. 30, Explosion-Proof Enclosures for Use in Class I Hazardous Locations.

F. UL 1203, Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations.

1.2 SHOP DRAWINGS AND PRODUCT DATA

A. Submit Shop Drawings and product data in accordance with Section 01 33 00, Submittal Procedures.

PART 2 PRODUCTS

2.1 GENERAL

A. Receptacles and switches of one Manufacturer throughout each area for the project. For instance, do not use multiple hazardous area equipment Manufacturers for similar devices in hazardous areas. Do not use multiple equipment Manufacturers for similar devices in normal areas.

B. For wiring devices in process, wet, corrosive or hazardous areas, back boxes and device coverplates to be cast aluminum.

2.2 WIRING DEVICES

A. Line Voltage Light Switches, Normal Areas
   1. CSA certified.
   2. Industrial grade, extra heavy duty, totally enclosed, AC type, with quiet tumbler switches and screw terminals suitable for No. 10 AWG.
   3. Rivet-less one-piece brass or copper alloy contact arm with silver alloy contacts.

4. Capable of controlling 100 percent tungsten filament and fluorescent lamp loads.
5. Rating: Minimum rating is 20 amps, 347 VAC. Lower rated equipment will not be accepted.
6. Color:
   a. Office areas: Ivory
   b. Other areas: brown.
7. Automatic grounding clip and integral grounding terminal on mounting strap.
8. Manufacturers and products:
   a. Brown: Hubbell; HBL18221CN (single pole)/ HBL18223CN (3-way)
   b. Ivory: Hubbell; HBL18221ICN (single pole)/ HBL18223ICN (3-way)

B. Line Voltage Light Switches, Explosion Proof
1. CSA rated, CSA C22.2 No. 30, certified for use in CEC Class 1 Div 1, Class 1 Div 2 groups C & D areas.
2. Materials: copper free aluminum
3. Electrical ratings: 20 amps, 120 or 347 volt as required.
4. Hazardous Area Ratings: NEMA 7BCD.
5. Manufacturers and Products:
   a. Crouse-Hinds; lever style EDS series c/w DSD series switches or
   b. Or approved equal in accordance with B8 - Substitutes.

C. Occupancy Sensor Light Switches (office type of non-corrosive / non-hazardous areas only, and as shown on the Drawings)
1. ULC / CSA listed.
2. Optical lens rejects white light and prevents false triggering.
3. Adjustability: 30 seconds to 30 minutes time delay.
4. Sensitivity: 20 percent to 100 percent adjustable sensitivity.
5. Auto / Off push switch for override to “Off”.
6. Suitable for LED luminaires.
7. Electrical ratings: 120 volt or as required.
8. Manufacturers and Products:
   a. Lutron: LOS-SIR-HD, heavy duty series.
   b. Or approved equal in accordance with B8 - Substitutes.

D. Occupancy Sensor – Ceiling Mount With Wall Switch (office type of non-corrosive / non-hazardous areas only, and as shown on the Drawings)
1. ULC / CSA listed system.
2. Ceiling mounted occupancy sensors to be complete with a wall mounted control station
3. Ultrasonic combined with passive infrared detection with noise immunity.
4. Non-volatile memory that saves settings during power outages
5. Adjustability: 30 seconds to 30 minutes time delay
6. Sensitivity: 20 percent to 100 percent adjustable sensitivity.
7. Auto / Off push switch for override to “Off”
8. Electrical ratings: for 347 volt luminaires as required.
9. Manufacturers and Products:
   a. Lutron: LOS-CDT Series complete with required PP series powerpack, and wall mounted SO-2BOI series switch.
   b. Or approved equal in accordance with B8 - Substitutes.

E. Receptacle, Single and Duplex:
   1. CSA certified.
   2. Heavy duty specification grade, two-pole, three-wire grounding type with screw type wire terminals suitable for No. 10 AWG.
   3. High strength, thermoplastic base color.
   4. Color:
      a. Office areas and controls rooms: white.
      b. Other areas: gray.
      c. UPS powered receptacles: red.
   5. Contact Arrangement: contact to be made on two sides of each inserted blade without detent.
   6. Rating: 125 volts, configuration 5-15R, 15 amps.
   7. One-piece mounting strap with integral ground contact, rivetless construction.
   8. Receptacles shall be of one Manufacturer throughout the project.
   9. Manufacturers and products:
      a. Arrow Hart 5262 Series.
      b. Bryant 5262 Series.
      c. Hubbell 5262 Series.

F. Receptacle, Isolated Ground Transient Voltage Surge Suppressor (TVSS):
   1. CSA rated.
   2. Heavy-duty nylon rectangular face with isolated ground identification.
   3. Light and alarm on front face.
   4. Rated for 240 joules / 15000A per mode.
   5. Ground contact isolated from mounting strap to establish a separate pure ground path.
   6. Heavy-duty, one-piece, nickel plated brass wrap-around mounting strap.
   7. Heavy-duty nylon rectangular face with isolated ground identification.
   8. Suitable for No. 10 AWG conductors back or side wiring.
   9. Break off links for use as split receptacles.
   10. Metal oxide varistor to absorb and dissipate transient surges.
   11. Heavy duty, one-piece, nickel plated brass wrap-around mounting strap.
   12. Color:
      a. Fed from a normal power circuit: blue.
      b. UPS powered receptacles: orange.
   13. Rating: 125 volts, configuration 5-15R, 15 amps.
   14. Receptacles shall be of one Manufacturer throughout the project.
   15. Manufacturers and products:
      a. Hubbell IG8262SA
      b. Or approved equal in accordance with B8 - Substitutes.

G. Receptacle, Ground Fault Circuit Interrupter (GFI or GFCI):
   1. CSA rated.
   2. Heavy duty, tamper resistant, complete with self test with red LED indicator.
   3. Duplex, listed Class A to UL Standard 943, tripping at 5 mA.
   4. Color: white.
   5. Rating: 125 volts, configuration 5-15R, 15 amps.
   6. Size: For 50 mm by 100 mm outlet boxes.
   7. Standard model: screw terminals and provisions for testing.

8. Impact resistant nylon face.
9. Receptacles shall be of one Manufacturer throughout the project.
10. Manufacturers:
    a. Arrow Hart.
    b. Bryant.

H. Receptacle, Special-Purpose:
1. Rating and number of poles as indicated or required for anticipated purpose.
2. One matching plug with cord-grip features for each special-purpose receptacle.
3. Manufacturers:
    a. Arrow Hart.
    b. Bryant.
    c. Hubbell.

I. Receptacle, Explosion Proof:
1. CSA rated, CSA C22.2 No. 30, certified for use in CEC Class 1 Div 1, Class 1 Div 2 groups C & D areas.
2. Materials: copper free aluminum
3. Dead front, interlocked, circuit breaking.
4. Electrical ratings: 125 volts, configuration 5-15R, 15 amps.
5. Hazardous Area Ratings: NEMA 7BCD.
6. Provide matching plug and strain relief with each receptacle.
7. Manufacturers and Products:
    a. Crouse-Hinds; Ark Guard 2, Series ENR, compatible with receptacles already used on site.

2.3 COVER PLATES FOR NORMAL, NON-CORROSIVE AREAS

A. Utilize normal cover plates only for the admin office area, BNR office area, non-hazardous rated electrical and controls rooms as applicable. Other process areas shall utilize coverplates for wet, corrosive areas. Hazardous areas shall have complete, certified hazardous rated equipment.

B. Cover plates for wiring devices to: CSA-C22.2 No.42.1.

C. Stainless steel, 1 mm thick cover plates for recessed wiring devices.

D. Sheet steel metal cover plates for wiring devices mounted in surface-mounted FS or FD type conduit boxes.

E. Single gang, 2-gang, 3-gang cover plates for grouped interior wiring devices.

2.4 COVER PLATES FOR WET, CORROSIVE AREAS (NON- HAZARDOUS)

A. For light switches in corrosive areas: provide weatherproof, aluminum gasketted switch cover, Cooper Crouse-Hinds DS128 (1-gang), DS1282 (2-gang), DS1283 (3-gang) or approved equal in accordance with B8 - Substitutes.

B. For receptacles in corrosive or wet areas: provide weatherproof cast aluminum or PVC cover plates, complete with gaskets for duplex receptacles located in all exterior or wet areas.

PART 3 EXECUTION

3.1 INSTALLATION

A. General:
   1. In general, the Contractor is responsible for upsizing conductors to account for voltage drop. Conductor sizes as described on the Drawings, panel schedules and elsewhere are minimum size, and are highly dependent on specific cable routing. The Contractor shall upsize wiring as required to meet the requirements herein, and in order to comply with CEC requirements.
   2. For 120 VAC, 5-15R receptacle wiring from a 1P, 15A breaker, upsize wiring in order to accommodate voltage drop (calculated based on 80 percent of the breaker rating), in accordance with the following:
      a. No. 12 AWG for runs up to a distance of 20M from the source panel.
      b. No. 10 AWG for runs between a distance of 20M and 35M from the source panel.
      c. No. 8 AWG for runs between a distance of 35M and 50M from the source panel.
      d. No. 6 AWG for runs between a distance of 50M and 75M from the source panel.
      e. Upsize further runs as required to meet the CEC.

B. Receptacles:
   1. Install receptacles in gang type outlet box when more than one receptacle is required in one location.
   2. Mount duplex receptacles vertically.
   3. Mount receptacles at height in accordance with Section 26 05 01, Common Work Results - Electrical.
   4. Affix lamacoid nameplate indicating circuit number using mechanical means.

C. Low Voltage Control Switches
   1. To be used as part of a Facility lighting control system.
   2. Install switches with the handle in the center position. Throw the handle up momentarily to turn the lights on. Momentarily throw the handle down to turn the lights off.
   3. Install switches in gang type outlet box when more than one switch is required in one location.
   4. Mount switches at height specified in Section 26 05 01, Common Work Results - Electrical or as indicated on the Drawings.

D. Line Voltage Switches:
   1. Install single throw switches with handle in "UP" position when switch closed.
   2. Install switches in gang type outlet box when more than one switch is required in one location.
   3. Mount toggle switches at height specified in Section 26 05 01, Common Work Results - Electrical or as indicated.

E. Cover plates, normal areas:
   1. Protect stainless steel cover plate finish with paper or plastic film until painting and other work is finished.
   2. Install suitable common cover plates where wiring devices are grouped.
   3. Do not use cover plates meant for flush outlet boxes on surface-mounted boxes.
   4. Affix lamacoid nameplate indicating circuit number using mechanical means.

F. Cover plates, wet, corrosive areas:
   1. Provide cast aluminum backbox. Install wiring device, and provide a gasketted, corrosion resistant weatherproof cover.
   2. Affix lamacoid nameplate indicating circuit number using adhesive in order to preserve the integrity of the enclosure.

G. Hazardous areas:
   1. Install devices, complete with sealing fittings as required to meet the CEC area classification requirements. Meet all requirements of CEC section 18.
   2. Affix nameplate using adhesive for hazardous area wiring devices, in order to preserve the integrity of the enclosure.

H. Install a permanent lamacoid for all wiring devices indicating the circuit(s) contained within.
   1. Example: “M703-2” - which corresponds to PNL-M703, circuit 2.

END OF SECTION

SECTION 26 28 14

FUSES – LOW VOLTAGE

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 01 33 00, Submittal Procedures.

B. Section 26 05 01, Common Work Results - Electrical.

C. Section 26 28 23, Disconnect Switches – Fused and Non-Fused.

1.2 CODES AND STANDARDS

A. CSA, Canadian Standards Association.
   1. CSA C22.2 No. 248 – Low Voltage Fuses.

1.3 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, Specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit Shop Drawing to indicate:
   1. Time-current curves for all fuse types and sizes.

PART 2 PRODUCTS

2.1 FUSES – VFD DRIVES

A. CSA approved

B. Size as indicated on Drawing.

C. Class J, Fast Acting.

D. Interrupting rating: at least 200 KAIC.

E. Approved Manufacturer: As recommended by the VFD Manufacturer, provide Ferraz Shawmut Class J fast acting fuses.

2.2 FUSES – FUSED DISCONNECTS

A. As required, provide fused disconnects when the interrupting rating at disconnect switches is required to exceed 10 kA (higher fault level applications).

B. CSA approved.

C. Size as indicated on Drawing

D. Class J, time delay fuses, Class R fuses, or other types as required.

E. Interrupting rating: at least 200 KAIC

2.3 FUSES – CONTROL CIRCUITS

A. CSA approved

B. Size as indicated on Drawing

C. Provide Class CC, time delay or fast acting, as indicated on the Drawings.

D. Interrupting rating. At least 200 KAIC.

2.4 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results – Electrical.

2.5 SPARE PARTS

A. Provide spare fuses for each size and type required in accordance with the following:
   1. Where there are up to 10 fuses of a specific type and size installed, provide 3 spares.
   2. Where there are up between 11 and 50 fuses of a specific type and size installed, provide 6 spares.
   3. Where there are 51 and greater quantity of a specific type and size installed, provide 10 spares.
   4. Turn over all spares to the Contract Administrator at completion of the project.

2.6 APPROVED MANUFACTURERS

A. Manufacturers:
   1. Ferraz Shawmut or approved equal in accordance with B8 - Substitutes.

PART 3 EXECUTION

3.1 INSTALLATION

A. Installation of fuses for VFD drives and motor control circuits will be done during MCC fabrication.

B. Prior to energizing, Contractor is to confirm correct fuse size and type are installed.

END OF SECTION

SECTION 26 28 18

GROUND FAULT PROTECTION

PART 1 GENERAL.

1.1 CODES AND STANDARDS

A. Canadian Standards Association (CSA International).
   1. CAN/CSA-C22.2 No. 144, Ground Fault Circuit Interrupters.
   2. C22.2 No. 14-13, Industrial control equipment

B. National Electrical Manufacturers Association (NEMA):
   1. NEMA PG 2.2, Application Guide for Ground Fault Protection Devices for Equipment.

C. Underwriters Laboratories, Inc. (UL):
   1. UL 1053, Standard for Ground Fault Sensing and Relaying Equipment.

D. IEEE:
   1. IEEE-32, Standard Requirements, Terminology and Test Procedure for Neutral Grounding Devices.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results.

B. Product Data:
   1. Submit Manufacturer's printed product literature, Specifications and datasheets and include product characteristics, performance criteria, and limitations.

1.3 QUALITY ASSURANCE

A. Prior to shipment, the Manufacturer shall perform a full Performance Test at full current and voltage to assure compliance with equipment Specification defined here-in. Provide signed and dated test certificate.

PART 2 PRODUCTS

2.1 MEDIUM VOLTAGE (12.47 kV)

A. Utilize ground fault protection incorporated into SEL protection relay.

B. Utilize SEL's recommended ground fault current transformer.

C. Utilize SEL relays to detect current through the neutral grounding resistor.

D. Ground Fault current transformer ratio: As indicated on Drawing.

E. Main 66/12.47 kV supply transformer, XFMR-C701 and XFMR-C702, shall be designed and supplied with neutral grounding resistors.

F. Locate all components such that moisture/snow will not enter into the resistor enclosure. Provide a rigid galvanized steel frame suitable for installation of the resistor.

G. Neutral Grounding Resistor:
   1. System Voltage: 12.47 kV.
   2. L-N Voltage: 7.2 kV.
   3. Resistor: 72 ohms, tolerance ±10 percent
   4. Amp Rating: 100 amps.
   5. Time Rating: 10 seconds.
   6. Operating temperature: minus 50 degrees C to plus 760 degrees C
   7. Maximum working voltage:7.2 kV
   8. Resistive Element: Stainless Steel
   9. Element Insulators: Ceramic
   10. Enclosure: Stainless Steel
   11. High Voltage Insulation: Porclein
   12. Packing: Wood Crated
   13. Acceptable Manufacturer: Powerohm Resistors Inc.

H. Utilize neutral ground resistor as indicated on the Drawings, and as recommended by the Manufacturer.

2.2 LOW VOLTAGE (600 V)

A. Solidly grounded neutral for all 12.47kV/600V transformers with a capacity lower than 1000 kVA. Ground fault protection system is not utilized for these distributions.

B. High resistance neutral grounding system on all 12.47kV/600V transformers with a capacity greater than 1000 kVA. Ground fault protection system is utilized for these distributions (New Grit Area and Bioreactor Building).

C. Locate all components such that moisture/snow will not enter into the resistor enclosure. Provide a rigid galvanized steel frame suitable for installation of the resistor.

D. Neutral Grounding Resistor characteristics:
   1. System Voltage: 600 V.
   2. L-N Voltage: 347 V.
   3. Resistor: 69.4 ohms.
   4. Amp Rating: 5 amps.
   5. Time Rating: continuous.

E. Bender W.. AB Series Current Transformer:
   1. Voltage ± 12 VDC. Require 120VAC/12 VDC power supply (Bender AN420).
   2. Used for VFD driven loads.
   3. Size as indicated on Drawing.

4. Power Consumption: ≤ 2.5 VA.
5. Located in MCC bucket/switchgear cell. Power supply located in ground fault panel.
6. Screw Mounting: M5 screws with mounting brackets.
7. Utilize Bender WXS-1000 connection cable for all W…AB series current transformers. Run the cable in conduit. This cable has a maximum distance of 10m. For situation where the distance between the current transformer and the ground fault panel is longer than 10m, use the following cable:
   a. Cable Manufacturer: LAPP
   b. 5C, 18 AWG Olflex Control TM CY Cable (maximum distance: 40m).

F. Bender W Series Current Transformer:
   1. No power required.
   2. Size as indicated on Drawing.
   3. Power Consumption: 37.5 mVA.
   4. Located in MCC bucket/switchgear cell
   5. Screw Mounting: M5 screws with mounting brackets.
   6. Utilize 18 AWG, shielded. ACIC, twisted pair, 1000V cable for W series current transformer. Cable will be routed on cable tray.
   7. Follow shielding instructions as indicated on Drawings.

G. Bender WR200x500S(P) Current Transformer.
   1. No power required.
   2. Utilized for incoming distribution cable bus systems.
   3. Power Consumption: 50 mVA.
   4. Located in MCC /switchgear cell.
   5. Screw Mounting: M5 screws with mounting brackets.

H. Bender RCM-S490 Residual Current Monitor.
   1. Located in Ground Fault Panel.
   2. Voltage: 120 VAC.
   3. 12 separate monitoring channels per monitor. Interconnect up to90 monitors per system.
   4. Selectably monitor either pure AC or AC/DC mix (VFD loads) on each channel.
   5. Digital backlit LCD display.
   6. One SPST contact for each channel.
   7. RS-485 interface.

I. Bender MK-800AF-11 Remote Alarm Indicator
   1. Display of operating status and alarm messages.
   2. Voltage: 24 VDC. Require Bender AN410 120 VAC/24 VDC power supply.
   3. Mounted on front door of ground fault panel. Power supply located in ground fault panel.
   4. RS-485 interface.

J. Bender BMS-Ethernet-Gateway, COM460IP
   1. Gateway between Bender BMS bus to Modbus/TCP protocol.
   2. Data can be view from PC via web browser using Silverlight Plugin.
   3. Voltage: 120 VAC.
   4. Located in ground fault panel.
   5. RS-485 interface.

6. Ethernet connection.

K. Ground Fault Panel
1. Nema 12 wall mount continuous hinge with clamps.
2. Refer to Drawing for layout.
3. Panel shall be fabricated by CSA certified shop. Affix CSA label to front door cover.
4. Panel construction shall meet the requirements in CSA 22.2 No. 14-13.

PART 3 EXECUTION

3.1 MANUFACTURER'S INSTRUCTION

A. Compliance: comply with Manufacturer's written recommendations or Specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSTALLATION

A. Installation shall comply with Manufacturer's instructions and recommendations.

B. Do not run ground cable through current transformers.

C. Manufacturer shall provide a certified technical service representative to review the Contractor's installation and commission the unit.

3.3 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 08 05, Common Work Results - for Electrical and Acceptance Testing.

3.4 START-UP ASSISTANCE

A. Set-up and verify all parameters and settings. Verify correct operation with loads in operation.

B. Provide formatted, typed forms indicating all settings as programmed.

3.5 TRAINING

A. Furnish the services of a competent, factory trained-engineer or technician for a period of two 8 hour sessions to instruct City personnel in the operation and maintenance of the equipment, on a date requested by the Contact Administrator.

END OF SECTION

SECTION 26 28 21

MOULDED CASE CIRCUIT BREAKERS

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Requirements specified within this section apply to all sections in Division 26, Electrical. This section supplements requirements of other Divisions.

1.2 CODES AND STANDARDS

A. Canadian Standards Association (CSA International).
   1. CSA-C22.2 No. 5, Moulded-Case Circuit Breakers, Moulded-Case Switches and Circuit-Breaker Enclosures (Tri-national standard with UL 489, tenth edition, and the second edition of NMX-J-266-ANCE).

B. ASTM (ASTM):
   1. ASTM E 329, Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction.

C. National Electrical Manufacturers Association (NEMA):
   1. NEMA AB 1, Molded Case Circuit Breakers and Molded Case Switches.

D. Underwriters Laboratories, Inc. (UL):
   1. UL 489, Standard for Molded-Case Circuit Breakers and Circuit Breaker Enclosures.
   2. UL 508, Standard for Industrial Control Equipment
   3. UL 1053, Standard for Ground Fault Sensing and Relaying Equipment.

1.3 SUBMITTALS

A. Submit Shop Drawings indicating the components and equipment to be used:
   1. Manufacturer’s data sheets for each type of breaker, protective device, accessory item, and component.
   2. Submit time-current breaker trip curves for all breakers greater than 100A.

1.4 QUALITY ASSURANCE

A. Qualifications:
   1. Manufacturer qualifications:
      a. Manufacturer shall be a firm engaged in the manufacture of molded case circuit breakers of types and sizes required, and whose products have been in satisfactory use in similar service for a minimum of 20 years.
      b. The Manufacturer shall be ISO 9001 certified and shall utilize designs compliant with internationally accepted standards.

2. Installer qualifications: Installer shall be a firm that shall have a minimum of five years of successful installation experience with projects utilizing molded case circuit breakers similar in type and scope to that required for this project.
3. Inspecting and testing agency qualifications: To qualify for acceptance, the Manufacturer or a qualified independent inspecting and testing agency hired by the Contractor or Manufacturer to test products shall demonstrate that they are qualified according to ASTM E 329 to conduct testing indicated.

PART 2 PRODUCTS

2.1 BREAKERS GENERAL

A. Circuit breakers to CSA C22.2 No. 5.

B. Circuit breakers shall be constructed using glass reinforced insulating material. Current carrying components shall be completely isolated from the handle, and the accessory mounting area.

C. Circuit breakers shall have an over center, trip free, toggle operating mechanism which shall provide quick-make, quick-break contact action. The circuit breaker shall have common tripping of all poles.

D. All breakers to be bolt-on style. Push on style, or stab-lok breakers will not be accepted.

E. Breakers to be mounted using Manufacturer approved breaker mounting accessories.

F. Common-trip breakers: with single common handle for multi-pole applications.

G. Branch circuit breakers shall have a minimum interrupting capacity as indicated on the Drawings. Breakers shall have the same interrupting rating as that indicated for the panelboard, on the panelboard schedules. Series rated breakers will not be accepted.

H. Moulded case circuit breakers shall operate automatically by means of trip element devices to provide inverse time current tripping.

I. The circuit breaker handle shall reside in a tripped position between on and off to provide local trip indication. Circuit breaker escutcheon shall be clearly marked on and off.

J. Protective devices shall be suitable for use with 75°C or greater wire insulation systems and Canadian Electrical Code 75°C conductor ampacity.

K. The maximum ampere rating, CSA standards with applicable voltage systems and corresponding interrupting ratings, shall be clearly marked on the face of the circuit breaker.

L. Circuit breakers shall be factory sealed, with an installed hologram quality mark and shall have a date code on the face of the circuit breaker.

M. All equipment and components must be supplied through a Manufacturer approved distribution channel. Equipment shall be supported, guaranteed, and traceable through the equipment Manufacturer channels. Equipment procured from an unauthorized third party will be rejected.

N. Handle Accessories:
   1. Circuit breaker handle accessories shall provide provisions for locking handle in the on and off position.

O. Breakers shall be Manufacturer approved, tested, and CSA approved for use within the panelboard or distribution equipment that it is installed within.

2.2 TRIP UNITS

A. Trip elements to be as follows:
   1. Breakers sized less than 100A shall be equipped with thermal magnetic trip elements, unless indicated otherwise on the Drawings.
   2. Breakers sized 100A and greater shall have electronic, fully adjustable trip elements, unless indicated otherwise on the Drawings.
   3. Fully adjustable, electronic LSIG, LSI, LI, are to be provided as indicated on the Drawings.
   4. Switchgear, panelboards, CDPs, MCC and motor starter breakers shall utilize breakers by Schneider Electric based on the City of Winnipeg standards, with ratings in accordance with the single line Drawings.
   5. Meet the requirements of the CEC, and the Drawings with respect to ground fault protection.

B. Electronic trip units:
   1. Trip system shall be a Micrologic electronic trip unit with true RMS sensing.
   2. Current transformers shall be used to ensure accurate measurements from low current up to high currents.
   3. Electronic trip unit shall be fitted with thermal imaging.
   4. The following monitoring functions shall be integral parts of electronic trip units:
      a. A test connector shall be installed for checks on electronic and tripping mechanism operation using an external device.
      b. LED for load indication at 105 percent.
      c. LED for load indication at 90 percent of load for applications 600A and smaller
      d. LED for visual verification of protection circuit functionality for applications 600A or smaller.
      e. LED for trip indication for applications above 600A.
   5. Micrologic trip unit functions shall consist of fully adjustable protection settings with the capability to be set and read locally by rotating a switch.
      a. Long-time pickup shall allow for adjustment to nine long-time pickup settings. This adjustment must be at least from 0.4 to 1 times the sensor plug (In), with finer adjustments available for more precise settings to match the application.
      b. Adjustable long-time delay shall be in nine bands. At six times Ir, from 0.5 to 24 seconds above 600A, and 0.5 to 16 seconds for 600A and below.
      c. Short-time pickup shall allow for nine settings from 1.5 to 10 times Ir.

d. Short-time delay shall be in nine bands from 0.1–0.4 I^2t ON and 0–0.4 I^2t OFF.
e. Instantaneous settings on the trip units with LSI protection shall be available in nine bands.
   1) Above 600A, from 2 to 15 times In
   2) 600A, from 1.5 to 11 times In
   3) 400A from 1.5 to 12 times In
   4) 250A and below, from 1.5 to 15 times In
f. Ground fault settings for circuit breaker sensor sizes 1200 amperes or below shall be in nine bands from 0.2 to 1.0 times In. The ground fault settings for circuit breakers above 1200 amperes shall be nine bands from 500 amperes to 1200 amperes.

6. 24V power supply for electronic trip breakers to be internal to panelboard.
7. Electronic components shall withstand temperatures up to 221 degrees F (105 degrees C).

C. Accessories
1. General:
   a. Circuit breakers shall be equipped with ULC listed electrical accessories as noted on the Drawings or schedules.
   b. The addition of auxiliaries shall not increase the overall mounting size of the circuit breaker.
   c. The addition of mechanisms shall not mask or block device settings.
2. Electrical auxiliaries: electrical auxiliaries, such as voltage releases (shunt and undervoltage releases) and indication switches as follows:
   a. Same field-installable auxiliary contacts for signaling different functions, such as open/ closed position, fault signal, electrical fault (including electrical leakage) signal.
   b. Electrical auxiliaries shall be separated from power circuits.
   c. Electrical auxiliaries shall be of the snap-in type and fitted with terminal blocks.
   d. Electrical auxiliary function and terminals shall be permanently engraved on the case of the circuit breaker and the auxiliary itself.

PART 3 EXECUTION

3.1 INSTALLATION

A. Preparation and installation shall be in accordance with reviewed product data, final Shop Drawings, Manufacturer’s written recommendations, and as indicated on the Drawings.

B. The Contractor to field set / program breakers in accordance with the coordination study. The breaker coordination study will be available after all Shop Drawings have been submitted and approved, as settings will depend on the specific product. Obtain breaker settings sheets from the Contract Administrator at that time.

C. Provide lamacoid labels adjacent to MCC breakers, Switchgear breakers, and any CDP style panelboard breakers.

D. Breakers located in panelboards 225A and less do not require lamacoid nameplates adjacent to circuit breakers that are smaller than 100A. Those breakers would be identified using the panel directory.

3.2 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - Electrical.

B. Lamacoid labels to be size 7, engraved as follows:
   1. Line 1 is to be the breaker load identifier as indicated on the Drawings, for example “PDC-U211”.
   2. Line 2 is to be a description of the load for example “U.V POWER DIST. CTR.”.

C. Confirm label description with the Contract Administrator prior to manufacture and installation.

3.3 ADJUSTING

A. Circuit breaker pickup level and time delay settings shall be adjusted to values indicated by the coordination study, and as instructed by the Contact Administrator.

3.4 PROTECTION

A. Provide final protection and maintain conditions in a manner acceptable that shall ensure that the molded case circuit breakers shall be without damage at time of substantial completion.

END OF SECTION

SECTION 26 28 23

DISCONNECT SWITCHES – FUSED AND NON-FUSED

PART 1 GENERAL

1.1 GENERAL

A. This section is specifically applicable to fused disconnect switch rated at 600 VAC and below. This section does not apply to high voltage disconnect switches.

1.2 RELATED SECTIONS

A. Section 01 33 00, Submittal Procedures.

B. Section 26 05 01, Common Work Results - Electrical.

C. Section 26 28 14, Fuses – Low Voltage

1.3 CODES AND STANDARDS

A. Canadian Standards Association.
   1. CSA-C22.2 No. 4-M89 (R2000), Enclosed Switches.

1.4 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, Specifications and datasheets and include product characteristics, performance criteria (including interrupting rating), enclosure rating, and limitations.

PART 2 PRODUCTS

2.1 DISCONNECT SWITCHES

A. CSA approved.

B. Size to accommodate the required loads. Minimum sizes as indicated on Drawings.

C. Disconnect switches shall be in NEMA 4 enclosures (or higher). All disconnects exposed to weather or moisture shall be NEMA 4x rated (minimum). Disconnects in hazardous areas shall be rated for the classification of the area.

D. All disconnect switches located in the Chemical Building shall be NEMA 4X, 316 stainless steel.

E. Unless otherwise indicated on the Drawings, motors in hazardous locations will not utilize disconnect switches. They will be locked out at the MCC (in order to locate disconnecting means outside of the hazardous areas).

F. For VFD driven loads provide early break contact in order to signal the VFD drive that operation of the disconnecting means is underway. The VFD drive will be wired and connected in a manner that the early break contactor will shutdown the system.

G. Any disconnect switch installed in hazardous areas shall be rated for the space they are installed in.

H. Mechanically interlocked door to prevent opening when handle in ON position.

I. Disconnects for motor loads to be heavy duty, motor rated.

J. Disconnect switches shall have the appropriate interrupting rating (kAIC). Minimum rating is 10 kAIC. For interrupting ratings greater than 10 KAIC, utilize fused disconnects. For fuses refer to Section 26 28 14, Fuses – Low Voltage.

K. Provide fuses as indicated on the Drawings. Provide 3 spare fuses for every disconnect switch.

L. Provision for padlocking in on-off switch position.

M. Switch mechanism: quick-make, quick-break action with self-wiping contacts.

N. For switches 100A and over, provide non-tracking arc shrouds.

O. Solderless pressure lugs for cable connectors.

P. All switch poles to operate together, simultaneously with a common operating bar.

Q. Highly visible ON-OFF switch position indication on switch enclosure cover.

R. For 120V non-hazardous areas, where indicated on the Drawings, provide type K manual motor disconnect switches. If not specifically indicated as type K on the Drawings, utilize, Nema, full size, fully rated heavy duty disconnect switches.

2.2 ACCESSORIES

A. Provide 2 spare disconnect switches of each size and type. Turn over to the Contract Administrator.

B. One spare handle for each type of disconnect switch. Turn over to the Contract Administrator.

C. For fused disconnects, provide spare fuses in accordance with Section 26 28 14, Fuses – Low Voltage.

2.3 APPROVED MANUTFACTURERS.

A. Schneider Electric, Eaton, Hubbell or approved equal in accordance to B8 - Substitutes.

B. All disconnect switches to be of one Manufacturer for the entire project. Split packages (multiple vendors) will be rejected.

2.4 EQUIPMENT INDENTIFICATION.

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - Electrical.

B. Nameplate to be size 8, example as followed:

DS-K501 P-K501 SUMP PUMP

PART 3 EXECUTION

3.1 INSTALLATION

A. Install disconnect switches plumb and true. Provide structural supports, including cantruss and other steel members for disconnect supports.

B. Supports to be installed rigid, affixed (bolted) to structural members.

C. Provide lamacoid labels to disconnect switch enclosure.

END OF SECTION

SECTION 26 29 10

MOTOR STARTER TO 600 V

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA, Canadian Standards Association.

B. NEMA, National Electrical Manufacturer Association.

1.2 RELATED SECTIONS.

A. Section 26 24 19, Motor Control Center.

1.3 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, specifications and datasheet and include product characteristics, performance criteria, physical size, finish and limitations.

C. Submit Shop Drawing to indicate:
   1. Mounted method and dimensions.
   2. Starter size and type.
   3. Layout and components.
   4. Enclosure type.
   5. Bill of Materials.
   6. Wiring and schematic diagram.

1.4 MAINTENANCE

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 26 05 01, Common Work Results – Electrical.

B. Submit operation and maintenance data for each type and style of motor starter for incorporation into maintenance manual.

PART 2 PRODUCTS

2.1 MANUAL MOTOR STARTERS

A. Manual starters with overloads of size and rating as required. Enclosure type as required to suit the environment. Include components as follows:
   1. Switching mechanism, quick make and break.
   2. Overload heaters, manual reset, trip indicating handle.

B. Accessories:
   1. Indicating light: LED type, green run light.
   2. Locking tab to permit padlocking in "ON" or "OFF" position.

C. Approved Manufacturers:
   1. Non-Hazardous areas: Square D, Nema Type 4, class 2510

2.2 FULL VOLTAGE MAGNETIC STARTERS

A. UL/CSA listed, NEMA size as shown on the drawings.
   1. Smallest size starter: NEMA size 1, unless otherwise indicated.
   2. IEC rated starters are not acceptable.

B. Magnetic of size, type, rating and enclosure type as indicated with components as follows:
   1. Combination style motor starter, with instantaneous overcurrent protection, starter contactor, overload protection.
   2. Smart motor starter contactor / overload protective device:
      a. Electronic overloads, manually reset from outside enclosure.
      b. Modbus TCP over Ethernet communications
   3. Wiring and schematic diagram inside starter enclosure in visible location.
   4. Identify each wire and terminal for external connections, within starter, with permanent number marking identical to diagram.
   5. Transient suppressors shall be supplied for all coils in each individual starter unit.

C. Approved Manufacturers:
   1. Schneider TeSys T

2.3 CONTROL TRANSFORMER

A. Single phase, dry type, control transformer with primary voltage as indicated and 120 V secondary, complete with primary and secondary fuses, installed in with starter as indicated on Drawings.

B. Size control transformer as indicated on Drawings.

2.4 ACCESSORIES.

A. Pushbuttons and selector switches:
   1. Heavy duty, oil tight, colour as indicated.
   2. Model: Schneider Electric Harmony XB4 series.

B. Indicating Lights:
   1. Heavy duty, oil tight, colour as indicated.
   2. LED type.
   3. Model: Schneider Electric Harmony XB4 series.

2.5 FINSHES

A. Apply finishes to enclosure in accordance with Section 26 05 01, Common Work Results - Electrical.

2.6 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results – Electrical.

B. Magnetic starter lamacoid: white plate, black letters, size 7 engraved with load identifier and load description. Example as followed:

P-K661 HOT WATER PUMP

2.7 SPARE PARTS

A. Fuses: two (2) of each type and rating.

B. Indicating lights: two (2) LED style indicating light of each type.

C. Relays: two (2) relays of each type (base not required).

PART 3 EXECUTION

3.1 INSTALLATION

A. Install starters and control devices in accordance with Manufacturer's instructions.

B. Install and wire starters and controls as indicated.

C. Ensure correct fuses installed.

D. Confirm motor nameplate and adjust overload device to suit.

3.2 FIELD QUALITY CONTROL

A. Perform tests in accordance with Section 26 05 01, Common Work Results - Electrical and Manufacturer's instructions.

B. Operate switches and contactors to verify correct functioning.

C. Perform starting and stopping sequences of contactors and relays.

D. Check that sequence controls, interlocking with other separate related starters, equipment, control devices, operate as indicated.

3.3 CONFIGURATION

A. Configure motor starter parameters as required to meet design requirements. Refer to Motor Schematics, Functional Requirements Specifications, and other Contract Documents for design requirements.

B. Provide the following configuration for all motor starters, unless shown otherwise:
   1. On loss of communication, the motor starter should stop the motor.
   2. All faults should be reset by a pushbutton on the front of the MCC bucket connected to an input on the MMC, unless otherwise noted.
   3. For starters within “Disconnect Closed” inputs, this signal is to activate the “Not Ready” status.

END OF SECTION

SECTION 26 29 23

VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA, Canadian Standards Association

B. NEMA, National Electrical Manufacturer Association

C. IEEE, The Institute of Electrical Engineers

D. Other, Local Power Utility and Telephone Utility Guidelines for Harmonic Distortion

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Submit Shop Drawings:
   1. Physical layout in MCC or layout of separate enclosure as applicable.
   2. Wiring diagram showing terminal blocks and terminal numbers.
      a. Provide AutoCAD version of the VFD Drawings upon request.
   3. Material list
   4. Front panel detail.
   5. Recommended spare component list.
   6. Recommended breaker (molded case switch) & fuse size.
   7. Cooling system and heat rejection calculations for each size / type of VFD.
   8. Completed VFD settings sheets.

C. Product Data:
   1. Submit Manufacturer’s printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

D. Settings Sheet
   1. Contractor shall provide Variable Frequency Drive Settings Sheets with the O & M manual submission for each VFD. See 1-0102-EDTS-A001 for sample document.

1.3 DESIGN REQUIRMENTS

A. Ventilation system designed for ambient temperature range of 10 degrees C to 35 degrees C. Temperature within the enclosures not to exceed 45 degrees C.

B. Ventilation system filters.

C. A number of MCC and switchgear along with VFDs are installed and fed from high resistance grounded systems (systems with NGRs). Ensure wiring and design is appropriate for the type of distribution from which the drives are fed. Isolate the RFI filters from ground in these specific applications in accordance with the Manufacturer's recommendations.

1.4 MAINTENANCE

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 26 05 01, Common Work Results - Electrical.

1.5 QUALITY ASSURANCE

A. Prior to shipment, the Manufacturer shall functionally test the AC drive. The inverter shall be tested by running at full nominal load with a motor.

B. The Manufacturer shall provide a factory certified test report along with the VFD.

PART 2 PRODUCTS

2.1 VARIABLE FREQUENCY DRIVES

A. CSA Approved.

B. 3 Phase.

C. Voltage Input: 600 VAC or other voltage as per the Drawings.

D. Variable speed controller shall be electronic and allow for the adjustment of frequency and voltage output of the unit.

E. Motors 75 kW and less to employ a minimum 6-pulse pulse width modulated (PWM) inverter system utilizing Insulated Gate Bipolar Transistors (IGBT) power switching devices.

F. Motors greater than 75 kW employ a minimum 6-pulse pulse width modulated (PWM) inverter system utilizing Insulated Gate Bipolar Transistors (IGBT) power switching devices provided that the distribution system has active harmonics filters. If the VFD is connected to a system that does not have active harmonics filtering, then provide a minimum of 12-pulse (or greater) drives.

G. VFDs to be complete with line and load reactors / load filters as indicated herein, and as shown on the Drawings.

H. Line reactors to be a minimum of 3%Z or higher as indicated on the single line drawings.

I. Be capable of re-accelerating the driven equipment, following voltage dips greater than 20 percent of the rated input power supply, of up to 5 seconds duration, without the need to

come to a complete stop. Vendor shall indicate the maximum time delay before re-acceleration begins following restoration of the supply voltage

J. Be capable to continue operation without coming to a standstill or resulting in a process shutdown, following any momentary voltage dips in the input power supply, auxiliary power supply, or both, of less than 20 percent rated voltage, which last for less than 0.5 second.

K. Designed to provide output requirements dictated by the speed/torque characteristics of motor and driven equipment over the entire speed range.

L. VFD shall convert the line input power to adjustable AC voltage and frequency output power. The output power shall be controlled such that permissible volts/Hertz ratio is not exceeded throughout the specified operating speed range, over a voltage range of plus or minus10 percent and frequency variation of plus or minus 5 percent.

M. The VFD output frequency shall not deviate more than plus or minus 1 percent of any given set point within the operating frequency range.

N. The VFD shall include radio interference suppression and limit radio interference values to within the limits of local code requirements.

O. The telephone influence factor shall be in accordance with maximum values specified by local authorities.

P. Accessories:
   1. Integral flush mounted keypad on the enclosure door (MCC cabinet or standalone enclosure) for programming, monitoring, and operating the drive, accessible through password or other acceptable security measure only.
   2. Integral selector switches and pushbuttons for control on enclosure door.
      a. Standard of acceptance, Square D Harmony XB4 series, or approved equal in accordance with B8.
   3. Selector switches and pushbutton as follows:
      a. Hand/Off/Remote three position maintained selector switch at the equipment.
      b. VFD/bypass two position maintained selector switch, if indicated on Drawings.
      c. Manual speed potentiometer, if indicated on Drawings.
      d. Local Emergency Stop button, if indicated on Drawings.
   4. Communication Card: Provide Ethernet Modbus TCP connection to all VFDs except for HVAC packaged systems. VFDs integral with packaged HVAC equipment (where a central controller has Ethernet Modbus TCP communication) do not require the communication card.

Q. Diagnostics features:
   1. Integral long life LED indicating lights on enclosure door
      a. Standard of acceptance, Square D Harmony XB4 series.
   2. Indicating lights as follows:
      a. Running (Green).
      b. VFD Fault (Amber).
      c. Overload Tripped (Amber).

R. Environmental capabilities: Drive to operate without mechanical or electrical damage under an combination of conditions as follows:
   1. Room ambient temperature: 0 degrees C - 35 degrees C.
   2. Humidity: 0 to 90 percent (non-condensing).
   3. Vibration: up to 0.5 g.
   4. Altitude: 0 to 1250 m above sea level.

S. Protective functions to be incorporated are:
   1. VFD failure.
   2. Ground fault in VFD.
   3. Ground fault on converter output.
   4. VFD overcurrent.
   5. Supply system over or under voltage.
   6. Supply system phase voltage unbalance.
   7. DC link fault.
   8. Voltage/frequency ratio incorrect.
   9. 5 percent frequency deviation from the set point.
   10. Loss of control signal.
   11. Control electronics fault.
   12. Electronics motor overload protection adjustable up to 150 percent of motor rating for 60 seconds.
   13. Motor stalled.
   14. Inverter over temperature.

2.2 CABLING

A. Provide VFD rated cabling on load side of VFD in accordance with Section 26 05 21, Wires and Cables (0-1000V).

2.3 BYPASS STARTER AND OVERLOAD

A. Provide bypass system only where indicated on Drawings. Bypass system will be utilized on VFD driven motor load that are deemed critical and do not have a system redundancy arrangement with another motor load.

B. The bypass would consist of a starter contactor and overload.

C. Bypass starter should be interlocked with VFD to ensure only one is operating at a time.

D. Overload to be resettable from enclosure door.
   1. Label as follows:

OVERLOAD RESET FOR BYPASS STARTER

2.4 LOAD REACTOR

A. VFD load reactors shall be installed for all motors greater than 37 kW (50 HP) regardless of cable length between VFD and motor.

B. VFD load reactors shall be installed for all motors where cabling between the VFD and motor exceeds 30m.

C. The equipment Manufacturer to provide standard sized load reactors unless specifically noted otherwise on the Drawings.

D. Reactor shall not exceed its temperature limit under all operation conditions.

2.5 FILTERS

A. DV/DT Filters shall be installed where power cables between the VFD and the motor exceed 150m or where recommended by the VFD vendor for the specific size and application.

B. Size filter for the given load.

2.6 FUSES

A. Fuses for branch circuit protection to be fast acting Class J or as specified on Drawings.

B. Fuses shall be installed with a molded case switch. Size accordingly based on load rating.

2.7 WIRE COLOUR CODING

A. Utilize the following wire colours for the types of voltage/signals indicated:

1.	120VAC Line:	Black
2.	120VAC Control	Orange
3.	120VAC Neutral	White
4.	24VDC Supply:	Blue
5.	24VDC Control:	Blue
6.	24VDC Common:	Blue
7.	24VAC Supply:	Blue
8.	24VAC Control:	Blue
9.	24VAC Neutral:	White
10.	10VDC Supply:	Blue
11.	0-10VDC Signal:	Blue
12.	10VDC Common:	Blue
13.	Intrinsically Safe:	Light Blue
14.	4-20mA Signal:	Blue

2.8 COOLING SYSTEM

A. The equipment Manufacturer shall perform heat load analysis to determine air-cooling requirements.

B. Air-cooled converters shall meet the following:
   1. Redundant cooling fans.
   2. Cooling fan operates when motor is started from VFD or bypass system or when enclosure reaches temperature set point.
   3. Provides adjustable the level set at the temperature switch, with minimum range 10 degrees C to 30 degrees C.
   4. All VFD components shall be rated to operate at full capacity, with full component life expectancy, at 60 degrees C at the components / circuit board level (and at 40 degrees C ambient temperature within the enclosure).
   5. The VFD cooling and heat sink system capacity shall be designed and sized to bring the ambient temperature within the VFD enclosure below 40 degrees C with all components running at full load, and with an electrical room ambient of temperature of 35 degrees C.

2.9 SPARE PARTS

A. Provide, at minimum the following spare parts:
   1. Provide three spare fuses for branch circuit protection.
   2. Control fuses. Provide a minimum of two spare fuses of each size inside each VFD section
   3. One N.O and N.C contact block for switches.
   4. One form “C” relay.

B. Provide sealed plastic bag for spare parts to be located to the side of enclosure interior.

2.10 EQUIPMENT IDENTIFICATION

A. Nameplate for each VFD cabinet to be size 9, example as followed:

VFD-K251 WASTE SLUDGE PUMP P-K251

2.11 APPROVED MANUFACTURER / EQUIPMENT

A. Schneider Electric. Alternative Manufacturers will not be accepted due to this product having been selected as a standard.

B. Provide Schneider Electric Altivar 61 drives for drives less than 800 kW with variable torque applications, and Altivar 71 drives for drives less than 630 kW and with constant torque application.

C. Provide Schneider Electric Altivar Plus drives for drives that are stand-alone mounted within a separate enclosure and are rated at 110 kW to 800 kW in a single enclosure.

D. All equipment shall be sourced from the local Manufacturer’s representative, through the Manufacturer’s local approved distributors. Sourcing equipment from alternate sources will not be accepted.

PART 3 EXECUTION

3.1 MANUFACTURER'S INSTRUCTION

A. Compliance: comply with Manufacturer's written recommendations or Specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSTALLATION

A. The minimum clearance in front of VFDs is 1 m. Installation shall comply with Manufacturer's instructions, drawings, and recommendations.

B. Manufacturer shall provide a certified technical service representative to review the Contractor's installation and commission the unit.

3.3 CONFIGURATION

A. Configure VFD parameters as required to meet design requirements. Refer to Motor Schematics, Functional Requirements Specifications, and other contract documents for design requirements.

B. Provide a setting sheet for each VFD in Microsoft Word format based on the sample document 1-0102-EDTS-A001. All settings included in the sample shall be included in each setting sheet, as well as any settings that are modified from the factory defaults.

C. Submit settings sheets for review as part of the Shop Drawing submittal process, and include in the final O & M Manual submission.

D. Provide the following configuration for all VFDs unless shown otherwise:
   1. On loss of communication, VFD to stop.
   2. For VFDs with "Disconnect Closed" inputs, when the disconnect is opened the VFD should stop. When the disconnect is closed, the VFD should automatically return to an operational state without additional operator involvement.
   3. For VFDs with "Disconnect Closed" inputs, this signal is to activate the "Not Ready" status.
   4. All VFD faults should be reset by a reset button on the VFD keypad.
   5. For VFDs powering fans with associated dampers, the VFD should send an open command to the damper when it receives a run command and wait to start until the damper closed limit switch is deactivated. The ramp up rate should be set slow enough to allow for damper opening time.

3.4 FIELD QUALITY CONTROL

A. Tested on site by the Contractor per the Manufacturer's recommendation and the requirements of Section 26 08 05, Acceptance Testing.

B. Confirm VFD capability to continue operation without coming to a standstill, following any momentary voltage dips in the input power supply, auxiliary power supply or both of less than 20 percent rated voltage, which last for less than 0.5 seconds.

C. Confirm manual transfer capability to and from by-pass, where bypass starter is provided.

D. Confirm VFD capability to automatically re-accelerate following loss of voltage for up to five seconds.

E. Field testing;
   1. Provide on-site startup, fine-tuning, commissioning, operator training, and instruction.
   2. Full-load functional test of the VFD shall be performed. The test shall prove the correct operation of all control functions, auxiliaries, protective systems, alarms and metering.
   3. Ensure shaft to ground voltages do not exceed 1.5 V at any speed or load requirement.

END OF SECTION

SECTION 26 32 10

DIESEL ELECTRIC GENERATING UNITS (LIQUID COOLED)

PART 1 GENERAL

1.1 RELATED SPECIFICATION SECTIONS

A. Section 23 11 10, Generator Fuel Oil System

B. Section 23 51 01, Generator Exhaust System and Stack

C. Section 26 13 18, Primary Switchgear Assembly to 15kV

D. Section 26 32 20, Generator Load Bank (15 kV)

1.2 CODES AND STANDARDS

A. The most recent adopted version of the following standards:
1. Cenelec EN 61000-6-4:2007 (BS EN 61000-6-4:2007+A1:2011) – Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments.
2. Cenelec EN 61000-6-2:2005 (BS EN 61000-6-2:2005) – Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments.
3. CSA C282-15 – Emergency Electrical Power Supply for Buildings.
4. CSA B139 – Installation Code for Oil Burning Equipment.
5. CAN/CSA-E61131-2-06 (R2011) – Programmable Controllers - Part 2: Equipment Requirements and Tests (Adopted IEC 61131-2:2003, second edition, 2003-02, including Corrigendum 1:2004, with Canadian deviations)
6. EEC 89/336/EEC, 91/368/EEC, 3/44/EEC, 93/68/EEC – Electromagnetic compatibility,
7. Manitoba Building Code (MBC)
8. NFPA 37 – Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines, 2015 Edition.
9. ISO 8528 – Reciprocating internal combustion engine driven alternating current generating sets
10. UL 508 – Standard for Industrial Control Panels
    23 (Note that as of Jan. 27, 2017, UL 508 will be replaced by the UL 60947 series and **UL-508 series approvals will be withdrawn**),
11. UL 60947 (series) –Low-Voltage Switchgear and Controlgear.
    Note that as of Jan. 27, 2017, the UL 508 series of Standards will be replaced by the UL 60947 series of Standards including:
    a. UL 60947-1– Low-Voltage Switchgear and Controlgear - Part 1: General rules,
    b. UL 60947-4-1A – Low-Voltage Switchgear and Controlgear - Part 4-1: Contactors and Motor-Starters - Electromechanical Contactors and Motor-Starters,
    c. UL 61131-2 – Programmable Controllers – Part 2: Equipment requirements and tests.

1.3 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Result – Electrical.

B. Submit shop drawings:
   1. Complete set of dimensioned equipment drawings showing plan and elevations of the proposed generator set and drive system including anchoring requirements
   2. Interconnecting wiring diagrams.
   3. Field wiring cable list, conduit list.
   4. Weight of all equipment.
   5. Engine mechanical data at varying loads up to full load, including heat rejection, exhaust gas flows, combustion air and ventilation air flows, noise data, fuel consumption, etc.
   6. Generator electrical data including temperature and insulation data, cooling requirements, excitation ratings, voltage regulation, voltage regulator, efficiencies, waveform distortion and telephone influence factor.
   7. Material List.
   8. Generator resistances, reactances (including transient and sub-transient), and time constants.
   9. Generator current decrement curves.
   10. Generator motor starting capability.
   11. Generator thermal damage curve.
   12. Jacket water heater connection diagram, heater wattage and voltage.
   13. Alternator space heater connection diagram, heater wattage and voltage.
   14. Control panel schematics.
   15. Generator set synchronization details and wiring diagrams
   16. Generator set controller details and wiring diagrams
   17. Control interconnection diagrams / interface with the switchgear
   18. Manufacturer's and Vendor's written warranty.
   19. Emissions data (sound and environmental).
   20. Breaker specifications, including trip unit curves.
   21. Complete list of accessories provided.

C. Product Data:
   1. Submit Manufacturer’s printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations. Specific model shall be indicated.

D. Owner’s Manual:
   1. Paper and digital copies of owner’s manual specific to the product supplied must be provided in accordance with the requirements of CSA C282. General operating instructions, preventative maintenance, wiring diagrams, schematics and parts exploded views specific to the supplied model must be included.

1.4 OPERATIONS &MAINTENANCE (O&M) MANUAL

A. Provide submittals in accordance to Section 01 77 00, Closeout Procedures and Section 26 05 01, Common Work Results – Electrical.

B. Prepare installation, operating and maintenance (O&M) manuals in the formats and quantities required by Section 01 78 23, Operation and Maintenance Data.

C. Each of the O&M Manuals shall include, at a minimum, the following:
   1. All Shop drawing information.
   2. Signed and sealed equipment "As Manufactured" drawings.
   3. Certified product test reports.
   4. Certificates of compliance.
   5. Certified Arc-flash type test data.
   6. CSA certificates of inspection for the provided equipment, or Manitoba Office of the Fire Commissioner, Inspection and Technical Services Manitoba "Special Inspection" certificate for the provided equipment.
   7. Handling and installation instructions, including equipment anchorage information and provisions.
   8. Operating and maintenance instructions.
   9. Complete component list.
   10. Recommended maintenance practices and procedures.
   11. Recommended spare parts list.
   12. CT curves and data sheets.
   13. Equipment and component Manufacturer's detailed instructions, installation and maintenance manuals.
   14. Standard cut sheets for OEM devices.
   15. Component manuals for all devices/equipment/relays incorporated into the equipment.
   16. Metering equipment settings and programming information.
   17. Site Testing & Commissioning Procedures, and recommendations and precautions for setting into operation.
   18. Test plan and inspection records.
   19. Certified copies of all test reports.
   20. Nameplate rubbings.
   21. Such additional information, instructions, data, recommendations, and procedures that the Manufacturer considers to be pertinent.

D. Relay programming settings (6 copies of software on 6 memory sticks) as well as printed hardcopy. Include a copy of the software needed to view / read / modify the files on each memory stick.

1.5 QUALITY ISSURANCE

A. Prior to shipment, the Manufacturer shall factory test the generator and associated control and protection equipment and switchgear in accordance with the requirements of clauses 2.12 – FACTORY TESTING,

B. A certified test and compliance report shall be submitted within 7 days of the successful completion of the tests.

C. Accept equipment on site and inspect for shipping damage.

D. When long term storage (> 1 week) is required, the equipment shall be stored indoors in a heated environment, or shall be covered with a weather-proof heated hording. For short term storage (≤ 1 week) and during installation protect equipment from weather and moisture by covering with heavy plastic or canvas and by maintaining heat within the enclosure in accordance with Manufacturer's instructions.

PART 2 PRODUCTS

2.1 GENERAL

A. Quality and Experience
1. All materials and parts of the generator set shall be new and unused. Each component shall be of current manufacture from a firm regularly engaged in the production of such equipment. Units and components offered under these specifications shall be covered by the Manufacturer's standard warranty on new machines, a copy of which shall be included in the submittal.

B. Torsional Vibration
1. The system shall be free of injurious torsional and bending vibrations within a speed range from 10 percent below to 10 percent above synchronous speed.

C. Guards
1. The system shall be adequately guarded both physically and electrically for protection of operating personnel.

D. Layout
1. The layout of the Generator Room is based on the generator from the first named Manufacturer listed herein and as shown on the Contract Drawings. The Contractor is responsible for coordinating layout changes and interface connections to other work and equipment which is different than that shown on the Drawings if alternative manufacturers are proposed. The Contractor will be responsible for coordinating this work and the changes will be at sole expense of the Contractor.

2.2 DIESEL ENGINE

A. The prime mover shall be a liquid cooled, diesel fueled, internal combustion engine. It shall have a minimum displacement of 69 liters.

B. The engine shall be EPA Certified for Non-Road Application (EPA Tier 2 emissions limits).

C. The unit shall operate at 1800 RPM.

D. The engine shall be water cooled with a unit mounted radiator, fan (with guard), water pump, and closed coolant recovery system providing low coolant level alarm. The radiator shall be designed for operation in plus or minus 40 degrees C ambient temperatures. The radiator fans shall be genset driven, and not require additional power or control connections.

E. Radiator duct flange shall be shipped loose by generator set Manufacturer, and shall be installed with flexible boot vibration isolator by Contractor.

F. Intake air filter(s) with replaceable element(s) c/w service indication shall be mounted on the unit.

G. The integral engine mounted fuel pump shall be capable of a suction lift of 3660 mm (minimum).

H. Full pressure lubrication shall be supplied by a positive displacement lube oil pump. The engine shall have full flow oil filter(s) with internal bypass and replaceable element(s).

I. The engine shall be equipped with a battery charging DC alternator with an integral "solid state" voltage regulator.

J. The engine shall be equipped with a unit mounted, thermostatically controlled jacket water heater to aid in quick starting. Power supply for the jacket water heater shall be from a 600 VAC, 3-phase, 15A breaker. The Genset vendor shall provide all required thermostatic controls, contactors, control transformers, inside an enclosure. The wattage shall be as recommended by the Manufacturer. The jacket water heater shall be sized to allow the genset to start at -40 degrees C ambient temperature (even though the genset room will normally be heated). The Contractor shall provide proper branch circuit from normal utility power source.

K. Sensing elements shall be located on the engine for:
   1. Low oil pressure alarm/shutdown.
   2. High coolant temperature alarm/shutdown.
   3. Low coolant level shutdown.
   4. Overspeed shutdown.
   5. Overcrank shutdown.
   6. Emergency stop shutdown.
   7. Low coolant temperature alarm.
   8. Low battery voltage alarm.
   9. High battery voltage alarm.
   10. Unit control selector switch not in auto alarm.
   11. AC battery charger failure alarm.
   12. Fuel alarms (programmable).

L. Sensors shall be connected to the control panel using a prefabricated wiring harness(es), each connectors shall be sealed to prevent corrosion and all wiring shall be run in flexible conduit(s) for protection from the environment and moving parts.

M. The following equipment is to be provided by the engine-generator set Manufacturer and shipped loose with the generator set for installation by the Contractor:
   1. Approved flexible fuel lines to connect the engine to the external diesel fuel supply and return lines.
   2. Approved isolation ball valves (Type V305 per 40 27 02 Process Valves and Operators), pressure gauge and drain connection for diesel fuel supply line as indicated on the Contract Drawings.
   3. AC Battery Charger.
   4. Vibration isolators.

N. The engine speed shall be controlled by an isochronous governor. Speed regulation during steady state operation shall be plus or minus 0.2 Hz.

O. The Generator set shall be capable of accepting a block load of 100 percent of the block load nameplate rating.

P. Generator set performance shall meet the requirements of the latest version of CSA C282-15.

Q. The engine shall be equipped with a suitably sized closed crankcase ventilation (CCV) re-breather system (Racor type CCV) to recycle oil crankcase sump fumes back to the engine air inlet and return collected oil back to the engine crankcase. The CCV unit shall be temperature rated for operation at -40 degrees C to 116 degrees C. The CCV filter unit shall be equipped with an electronic filter gauge and if required an insulation/heater kit. The electronic filter gauge shall be wired to the unit control panel to indicate that the CCV filter requires replacement or service.

R. Approved Manufacturer: Caterpillar model number 3516C or Approved Equal in accordance with B8 - Substitutes.

2.3 GENERATOR ALTERNATOR

A. The alternator shall be of the 4 pole revolving field type, 6 lead, wired for 12,470 VAC, 3Ø, 60 Hz, rated at 2000 kW, 0.8 pf with shaft mounted exciter and permanent magnet pilot exciter. Photosensitive components shall not be permitted in the rotating exciter. The alternator shall be suitable for use with a resistance grounded neutral connection.

B. The alternator rotor shall be connected to the engine by means of a gear type coupling to ensure permanent alignment.

C. The alternator shall meet temperature rise standards for Class "H" insulation; operate within Class "F" temperature rise standards for extended life. All leads shall be extended into an AC connection panel.

D. The alternator and regulator shall sustain at least 300 percent short circuit current for 10 seconds during 3 phase fault conditions.

E. The alternator shall be equipped with an internally mounted space heater. Heater supply shall be 208 VAC 1Ø fed from a common 30A breaker. The Genset vendor shall provide the appropriate fusing, disconnects, breakers, contactors, controls, control transformer, etc The

alternator heater(s) shall be automatically disconnected when the engine is running and shall have an independent means of being disconnected or switched off for maintenance.

F. Manufacturer shall state the alternator space heater wattage at the time of Bid.

G. The alternator terminal box shall be arranged for top connection of the outgoing load cable(s) and the neutral cable(s). The terminal box shall be oversized and shall include adequate space for the installation of high voltage cable terminations (stress cones), neutral current transformers (if mounted in the terminal box), cable gland connectors, and for bending and training of the load and neutral cables. Refer to Drawing 1-0102-ESLD-C003 for cable types and sizes.

2.4 CONTROLS

A. The generator unit control system shall be a fully integrated control system enabling remote diagnostics and building management integration of all generator functions. The generator controller shall provide integrated and digital control over all generator functions including: engine protection, alternator protection, speed governing, voltage regulation and critical generator operations. The generator controller shall also provide seamless digital integration with the engine's electronic management system. Generator controller shall utilize separate voltage regulators and speed governors to integrate with the engine management system.

B. The generator unit control panel shall include an "AUTO/OFF/TEST" selector switch (Unit Control Selector Switch).

C. The generator control system shall meet all requirements of CSA C282 for standby engine generators.

D. Communications shall be supported with building automation via the Modbus protocol over Ethernet.

E. The control system shall be environmentally sealed including encapsulated circuit boards and sealed automotive style plugs for all sensors and circuit board connections. The generator set control shall be tested and certified to the following environmental conditions:
   1. Minus 40 degrees C to 70 degrees C Operating Range.
   2. 95 percent humidity non-condensing, 30 degrees C to 60 degrees C.
   3. IP22 protection.
   4. 5 percent salt spray: 48 hours, 38 degrees C, 36.8 V system voltage.
   5. Sinusoidal vibration: 4.3G RMS, 24-1000 Hz.
   6. Electromagnetic Capability:
      a. 89/336/EEC, 91/368/EEC, 3/44/EEC, 93/68/EEC,
      b. BS EN 61000-6-4:2007+A1:2011,
      c. BS EN 61000-6-2:2005.
   7. Shock withstand: 15G.

F. Diagnostic capabilities shall include time-stamped event and alarm logs, ability to capture operational parameters during events, and simultaneous monitoring of all input and output parameters.

G. The Controller shall include the ability to accept six programmable digital inputs, two dedicated digital inputs, six programmable form "A" dry contacts, two programmable form "C" dry contacts, and two digital outputs. The signals shall be programmable for either high or low activation using programmable Normally Open (NO) or Normally Closed (NC) contacts.
   1. The generator set controller shall receive inputs to allow for controls from an external generator set paralleling / synchronizing control system for the control of:
      a. Generator set startup
      b. Generator set phase and synchronization
   2. The generator set controller shall have auxiliary contacts (outputs) for communications with other systems including, but not limited to, the following:
      a. Unit control "AUTO/OFF/TEST" selector switch in "AUTOMATIC"
      b. Unit control "AUTO/OFF/TEST" selector switch in "TEST"
      c. Generator set running
      d. Generator set fault

H. The control panel shall display all user pertinent generator set parameters including, but not limited to, the following:
   1. Alarm Conditions:
      a. Low oil pressure alarm,
      b. High coolant temperature alarm,
      c. High intake manifold temperature alarm,
      d. High exhaust manifold temperature alarm,
      e. High crankcase pressure alarm,
      f. Low coolant temperature alarm,
      g. CCV filter,
      h. Low battery voltage,
      i. High battery voltage,
      j. Unit control selector switch <u>not in "AUTOMATIC"</u> position alarm.
      k. AC Battery charger failure,
      l. Voltage Regulator,
      m. Loss of excitation,
      n. Instantaneous over-excitation,
      o. Time over-excitation,
   2. Shutdown Conditions:
      a. Low oil pressure,
      b. High coolant temperature,
      c. Loss of coolant,
      d. Overspeed,
      e. Overcrank,
      f. High intake manifold temperature,
      g. High exhaust manifold temperature,
      h. High crankcase pressure,
      i. Emergency stop activated,
      j. Generator shutdown.
      k. Generator over voltage.
      l. Generator under voltage.
      m. Generator over frequency.
      n. Generator under frequency.

o. Generator reverse power.
p. Generator overcurrent.
q. Voltage Regulator,
r. Loss of excitation,
s. Instantaneous over-excitation ,
t. Time over-excitation,
u. Rotating diode failure.
v. Loss of sensing.
w. Interlocked with NGR disconnect switches to prevent gensets from running if NGR disconnects are open.

I. Access to and manipulation of the internal operating set points and alarm limits shall be by password protected.

J. Provide a CSA C282 compliant alarm annunciator panel for remote indication per local and national code requirements (shipped loose). The annunciator shall be controlled using RS-485 communications from the generator controller. Annunciator panels requiring individual contacts and wires per indication point are not preferred. The alarm annunciator panel shall have an "Alarm Silence" pushbutton that when momentarily depressed silences the audible alarm, the audible alarm shall automatically re-trigger on receipt of a new or subsequent alarm. A "Test/Reset" pushbutton shall be provided to verify the indicator lights are functional and reset any alarm condition after it has cleared.

K. Control Wiring and Connections
1. Current Transformer Wiring and Connections
a. Current transformer wiring shall be Type SIS, minimum # 10 AWG, 600 V, 90 degrees C (minimum).
b. All current transformer wiring shall utilize stud or screw connections and "ring" type crimp lugs. The use of self retaining compression type spade lugs or "push-on" blade terminals and lugs are NOT acceptable for CT wiring.
c. Current transformers shall be rated as shown on the Drawings.
d. Current transformers shall be ANSI standard relay class and have their accuracy established in accordance with the connected burden and ANSI C57.13 but shall be at least:
1) 10C200, Thermal factor 130 percent for all phase CTs.
2) 10C50, for all zero sequence CTs.
e. Zero sequence CTs shall be Manufacturer's standard design, and shall be properly rated and tested for use in medium voltage switchgear installations.
f. Zero sequence CTs windows shall be dimensioned to allow passage of the specified cables complete with NEMA standard 2-hole pattern long barrel double crimp type lugs and high voltage cable terminations.
g. Zero sequence CTs shall be mounted in such a manner as to permit its easy removal for installation of cables complete with high voltage terminators and cable gland connectors.
2. Potential Transformers:
a. The main bus potential transformers shall be rated as indicated on the Drawings.

b. Potential transformers shall be designed be rated to withstand 14400 volts to ground on any phase, and to provide an output on healthy secondary phase windings when phase to neutral voltage increases by 173 percent on a phase to ground fault.
c. Potential transformers shall be rated to 95kV BIL (minimum).

3. Wiring Rules (other than engine mounted wiring except as noted)
   a. Wiring shall in general be type SIS, # 14 AWG, 600 V, 90 degrees C, except where larger size wire is required by CSA standard, or specified on the Drawings.
   b. Provide terminal blocks for incoming and outgoing control connections.
   c. All wiring (including engine mounted wiring) shall be tagged and identified on both ends of every wire using printed heat shrink sleeve type wire markers. Hand written numbering is NOT acceptable. The wire numbering scheme shall be such that the wire numbers change only when going through a device (coil, contact, etc.); wire numbers at both ends of the same wire shall be identical. All wires on a given terminal block or connector position shall bear the same number.
   d. Wires shall be run in continuous lengths, without splices between connection points, be installed in channels, ducts, or neatly tied and clamped to the supporting structure or panel. Self-stick/adhesive type wire/cable clamps are acceptable ONLY if additionally secured by means of screws.
   e. All wiring originating from a compartment must be first routed to terminal blocks.
   f. Connections to external circuits shall be brought to modular, asymmetrical DIN rail mounted snap-on construction, pressure type terminal blocks, with marking strips. Approved terminal block types are:
      1) Weidmuller Type SAK 6N (preferred), Wieland type WK 6/U, or approved equal in accordance with B8,
      2) Weidmuller type SAK B10C (preferred), Wieland type WKN 16DS, or approved equal in accordance with B8.
   g. The terminal blocks for external connections shall grouped together and easily accessible, visible and positioned near the compartment's field control cable and inter-cell wiring entry/exit points.
   h. All wiring not terminated on devices shall be terminated on terminal blocks. Not more than two (2) wires shall be connected to any device terminal or at any one terminal side. Interconnecting jumpers between terminal block positions shall be counted in the above 2 wire per side limitation. General and control wiring shall utilize self retaining compression type spade lugs where wiring is terminated on hardware (relays, meters, switches, etc).
   i. Where wiring between cells crosses shipping splits the manufacturer shall supply keyed separable plug and socket type in-line insulated connector(s) to permit separating the cells at the shipping splits without having to un-terminate wiring. The connector shall be sized to accommodate the wire gauge and current carrying capacity of the inter-cell conductors, shall be of a locking design to prevent separation in service due to vibration or other causes and shall be securely screwed or clamped to the structure(s).
   j. Where wiring crosses between structure sections (i.e. inter-cell connections), or where wiring (control cables) exits the equipment to connect to other equipment it shall be landed on terminal blocks at both ends. Devices external to the cell (contacts, coils, etc.) shall not be "loop" connected but shall be wired back to the terminal blocks in the cell or panel on an individual device basis.
   k. Soldered connections and splices in wiring are not permitted.

2.5 OPERATIONAL CHARACTERISTICS

A. Refer to Section 26 13 18, Primary Switchgear Assembly TO 15kV, Subsection 2.7 - MODES OF OPERATION for a detailed description of the switchgear and 12.47 kV generator system operation.

B. General Requirements for Generator Operation
   1. As described in Section 26 13 18, the generators are active only under the following system configurations:
      a. SGR-C701 and SGR-C702 both fed by "Utility Based" Power
         The generators will operate when there is a simultaneous failure of "Utility Based" power to SGR-C701 and SGR-C702. (See specification 26 13 18, subsection 2.8.D.2. "Case D1" for Supply Failure and 2.8.D.3. "Case D1A" for Return to Normal Supply on one or both feeders).
      b. Tie Breaker CB-C701-T CLOSED and SGR-C702 fed from SGR-C701
         The generators will operate when there is a failure of "Utility Based" power to SGR-C701. (See 26 13 18, subsection 2.8.D.4. "Case D2" for Supply Failure and 2.8.D.5. "Case D2A" for return to normal supply on SGR-C701).
      c. Tie Breaker CB-C701-T CLOSED and SGR-C701 fed from SGR-C702
         The generators will operate when there is a failure of "Utility Based" power to SGR-C702. (See Section 26 13 18, subsection 2.8.D.6. "Case D3" for Supply Failure and 2.8.D.7. "Case D3A" for return to normal supply on SGR-C702).
      d. Test Operation and Operation on Load Bank LDB-Y793
         The generators shall also be operable for "Test" to verify engine starting and operation and to permit load testing of one generator set at a time in conjunction with a 2,000 kW 12.47 kV resistive load bank LDB-Y793 via generator switchgear SGR-C790.
         (See Section 26 13 18 for details on system requirements for generator set "Test Operation").
   2. Transfer to and from generation shall be **open transition only**. The Facility will experience a total power outage during transfer to and from generation.
   3. Operations involving switching between the 12.47 kV Tie breaker CB-C701-T and main breakers SGR-C701.MCB and SGR-C702.MCB involve racking operations on the circuit breakers and are therefore MANUAL ONLY operations, as CB-C701-T is normally "racked-out", NO automatic switching of Tie breaker CB-C701-T is possible.
   4. Generator paralleling controls shall be integrated into the Unit Controllers for each engine generator. The generator paralleling and load sharing controls shall perform automatic synchronization, but shall allow for manual operation and synchronization of each individual genset, and shall provide load management, monitoring, and alarm annunciation functions of the paralleled engine generator system.
   5. The control logic shall be distributed between the generator paralleling controls and each engine generator such that each engine generator is capable of starting and closing onto the 12.47 kV genset bus, in the event of failure of the generator paralleling controls and receipt of a start signal from the generator system master controller.
   6. Automatic operation of the generator units shall only be possible when the Generator Master Control Mode Selector and the respective generator Unit Control Selector Switches are in the "AUTOMATIC' position.

C. Generator System Load Management Control
   1. The generator system load management controls shall generate an alarm if the measured generator load exceeds a preset percentage of the on-line generation capacity for an established period of time. The alarm shall be displayed on the generation system HMI and shall also be issued as a fail-safe contact output. The load level alarm set point shall be user adjustable and shall be password protected.
   2. If the connected load exceeds the capacity of generation system, resulting in a decrease in generator system frequency to a specified, adjustable setpoint or less, the generation system load management controls shall signal the plant PLC / operator to initiate load shedding to reduce the plant load to within the generation system capacity. The generator set point shall be in accordance with codes and standards, nominally the maximum frequency reduction shall not exceed 10 percent for greater than 3 seconds.

D. HMI – HUMAN/MACHINE INTERFACE
   1. HMI system interface shall be via a touch screen with the following characteristics:
      a. Color, 19 inch (diagonal) TFT LCD industrial display capable of displaying both text and graphics.
      b. The touch screen shall be clear glass, with light transmission of 95 percent or better, furnished with a Surface Acoustic Wave touch interface.
      c. The display shall support a minimum resolution of 1280 x 1024 pixels, 16 million displayable colors, 24~60kHZ horizontal scan rate, 56-75kHZ refresh rate.
      d. The HMI touch screen processor shall contain no moving parts.
   2. The HMI automation shall provide the following screens. The screens shall provide (at minimum) the information, metering, control, annunciations, settings and indications listed below:
      a. Main menu screen with a complete listing of major screens,
      b. System overview screen with an animated graphic display of the electrical one line,
      c. System control screen,
      d. System metering screen,
      e. System settings screen,
      f. System alarm screen,
      g. Generator set control screen for each generator set,
      h. Generator set metering screen for each generator set,
      i. Generator set settings screen,
      j. Generator set demand priority control and status screen,
      k. Generator set load shed control and status screen,
      l. Engine monitoring screens for each generator set that shall contain a graphical representation of engine gauges and data,
      m. Annunciator screens as follows:
         1) System annunciation screen that shall contain status, lamp test and alarm points.
         2) Generator set annunciator screen for each generator set that shall contain status, lamp test, pre-alarms and shutdown faults.
         3) Password entry screen that shall contain a numeric keypad for password entry.
         4) Alarm summary screen that shall contain a time/date stamped system alarm summary.
         5) Report menu screen as follows:
            a) System settings report
            b) Generator set settings report

c) Plant test report – including all current operational parameters
d) Alarm summary report
6) System real time trend screen.
7) Generator set real time trending screens.
8) Historical trending package.

3. A unit display shall be furnished for each motor generator set shall be mounted on the door of the switchgear section containing the associated generator set controls. The unit display shall have as a minimum a 5.7" graphic LCD transflective display, and shall be capable of monitoring and controlling its associated generator set.

2.6 SWITCHGEAR

A. Switchgear SGR-C701, SGR-C702, and SGR-C790 shall be supplied by the generator system Manufacturer/Vendor.

B. Switchgear SGR-C701, SGR-C702, and SGR-C790 shall be of the same type, class, and manufacture and shall utilize the same make and type of vacuum circuit breaker.

C. The generator set Manufacturer/Vendor shall be the integrator for the Generator System, Switchgear SGR-C701, SGR-C702, SGR-C790 and Load Bank LDB-Y793 equipment into a functional and fully operational system in accordance with the Specifications and Drawings and shall include the costs for the integration in his scope of supply.

D. Shop Drawings shall be provided and submitted in accordance with the requirements of Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results – Electrical. Submit all 12.47 kV switchgear and generator system drawings (including genset control drawings) as a single seamless package. Submittal of this equipment in different package submittals will automatically be rejected.

2.7 EXHAUST SYSTEM

A. Refer to Section 23 51 01, Generator Exhaust System and Stacks.

2.8 STARTING SYSTEM

A. Provide a 24VDC electric starting system with positive engagement.

B. Unit mounted thermal circulation type water heater(s) (jacket water heater) shall be installed on the engine. The heater power rating shall be sized by the Manufacturer to maintain jacket water temperature at 40 degrees C with a minimum ambient temperature of -40 degrees C. Heater supply voltage shall be 600 VAC, 3Ø, 60 Hz. Control voltage can be derived from a common 208 VAC, 1Ø supply.

C. Manufacturer shall state the engine jacket water heater wattage, and voltage at the time of Bid.

D. The engine heater(s) shall be automatically disconnected when the engine is running and shall have an independent means of being disconnected or switched off for maintenance.

2.9 ENCLOSURE.

A. Generator set shall be suitable for indoor application and no external weather enclosure is required. The genset shall be designed to start and run at an ambient temperature of -40 degrees C to allow for the possibility of heating system malfunctions. Generator combustion and cooling air is at ambient temperatures and will not be tempered.

2.10 APPROVED GENERATOR SET MANUFACTURERS

A. Toromont/Caterpillar or approved equal in accordance with B8.

2.11 LOAD BANK

A. Refer to Section 26 32 20, Generator Load Bank (15 kV) for a detailed description and requirements for the load bank.

2.12 FACTORY TESTING

A. All testing indicated in this section is supplemental to the requirements of Section 26 08 05, Acceptance Testing.

B. QA Requirements
   1. Submit an Inspection and Test Plan in accordance with this specification, applicable Standards and NETA Acceptance Testing Standards.

C. Shop Inspection and Testing
   1. Equipment will be subject to inspection at the following stages of manufacture:
      a. Prior to shop testing,
      b. Prior to packaging for shipment.
   2. Test equipment to ensure satisfactory operation prior to shipping. Provide Certification of Satisfactory performance.
   3. Test and inspect all equipment, materials, works in accordance with scope of work, specifications, all applicable codes, standards, regulations, laws and provide Certification and Records.
   4. Provide the Contract Administrator, or designate, with proper access to work, equipment, tools and facilities for carrying out such inspection, test, witness inspection or test points, surveillance or audit, whether it is in preparation or progress.
   5. Provide upon request, the following information:
      a. Non-destructive test records/results,
      b. Welding procedures and welder qualifications,

D. Routine Factory Tests
   1. Test the equipment per applicable standards and provide test data.
   2. The Contract Administrator, or designate, reserves the right to witness any or all tests.
   3. Prior to proceeding with the tests, provide in writing, a list of the tests to be performed at least four weeks before the tests are scheduled to begin, and an approximate schedule, with dates anticipated for the tests.
   4. The equipment shall be tested at the manufacturing plant prior to shipment and in accordance with the latest applicable standards.

E. Design Tests (Type Tests)
   1. For the design tests, include the following:
      a. Dielectric tests,
      b. Power frequency voltage withstand on auxiliary equipment and control circuits,
      c. Partial discharge,
      d. Radio interference,
      e. Temperature rise,
   2. The tests classified by the standards as optional may be carried out or waived at Contract Administrator's discretion, e.g., tests for radio interference, tests with simulated internal arcing fault, operational tests in extreme atmospheric conditions, etc.
   3. Perform the design tests in the Manufacturer's plant or elsewhere by an internationally recognized laboratory.
   4. Where design type test results have been previously obtained and have been certified by an internationally recognized testing laboratory, they may be acceptable in lieu of the above specified type tests at the discretion of the Contract Administrator.

F. Factory Acceptance Tests (FAT)
   1. Witness Factory Acceptance Tests (FAT) are required for the Individual Engine Generator Sets and Incorporated Controls as well as for the Integrated Generator System/Controls and Generator Switchgear.
   2. The FAT for the Individual Engine Generator Sets and Incorporated Controls shall be carried out at the generator set Manufacturer's factory prior to packing and shipment to Site.
   3. The Individual Engine Generator Set and Incorporated Controls FATs shall include, but not be limited to, the following for each engine generator set:
      a. Starting test,
      b. Starting battery capacity test,
      c. Verification of the correct functioning of all engine protection shutdowns and alarms,
      d. Engine speed governor functionality verification,
      e. Alternator excitation functionality verification,
      f. Alternator Voltage regulator functionality (no-load, ¼ load, ½ load, ¾ load, full load) ,
      g. A block load application test of the engine generator set at "block load" nameplate rating, the block load shall be applied in a single step,
      h. A full load run test at the generator set nameplate KVA/KW rating. Test duration shall be a minimum of 6 hours at full capacity after both engine and alternator temperatures have stabilized. For the purposes of this test temperature stability shall be defined as $\Delta t \leq 0.5$ degrees C/hr for both engine and generator. In accordance with the requirements of CSA C282 this test may be run at 1.0 Pf if the alternator has been previously tested at the factory to full capacity at 0.8 Pf. If the alternator has not been factory load tested at 0.8 Pf, the FAT test shall be conducted at 0.8 Pf.
   4. Prior to proceeding with the Individual Engine Generator Sets and Incorporated Controls FAT tests the Manufacturer shall provide, in writing, a written Inspection and Test Plan in accordance with the requirements of Specification Section 26 08 05, Acceptance Testing. The Inspection and Test Plan shall include a detailed list of the tests to be performed, test procedures, sample data forms, and a testing schedule with anticipated

test dates. Provide notice a minimum of two weeks before the tests are scheduled commence.

5. The Integrated Generator System/Controls and Generator Switchgear FAT should preferably be carried out at the generator set Manufacturer's factory, but may alternatively be carried out at the Vendor's premises, subject to the availability of proper facilities and test equipment. The location for this testing shall be subject to the agreement of the Contract Administrator, or designate.
6. The Integrated Generator System/Controls and Generator Switchgear FAT shall be conducted at 1.0 Pf and may be conducted at a reduced load capacity of 2MW total system loading.
7. The Integrated Generator System/Controls and Generator Switchgear FAT shall include, but not be limited to, the following:
   a. Verification of automatic generator set automatic starting, synchronization, and connection of the engine generator sets to the generator switchgear bus,
   b. Verification of Isynchronous governor functionality (no-load, 1/4 load, 1/2 load),
   c. Verification of demand and load sharing between the two engine generator sets at the above loadings,
   d. Verification of correct operation of generator switchgear protection relay systems,
   e. Verification of automatic shutdown and disconnection of the engine generator sets from the generator switchgear bus.
8. Prior to proceeding with the Integrated Generator System/Controls and Generator Switchgear FAT tests the Manufacturer shall provide, in writing, a written Inspection and Test Plan in accordance with the requirements of Specification Section 26 08 05, Acceptance Testing. The Inspection and Test Plan shall include a detailed list of the tests to be performed, test procedures, sample data forms, and a testing schedule with anticipated test dates. Provide notice a minimum of two weeks before the tests are scheduled commence.

PART 3 EXECUTION

3.1 MANUFACTURER'S INSTRUCTION

A. Compliance: comply with Manufacturer's written recommendations or Specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSTALLATION

A. The following equipment shall be installed for each engine-generator set:
   1. A heavy duty, flooded lead acid 24VDC battery shall be shipped loose by the generator set Manufacturer.
   2. An automatic means shall be provided for maintaining the storage battery in a charged condition. The battery charger shall be as follows:
      a. Fully automatic, dual-rate type with float and equalize modes,
      b. Float voltage shall be 2.17 volts per cell,
      c. Equalize voltage shall be 2.33 volts per cell,

d. Shall include overload protection, silicon diode full wave rectifiers, voltage surge suppressor, DC ammeter, DC voltmeter, and fused AC input,
e. Input voltage shall be 120 VAC, 1Ø, from a 15A circuit,
f. Charger shall have LED annunciation for low DC volts, rectifier failure, loss of AC power, high DC volts,
g. Shall be wall-mounting type,
h. Shall be capable of recharging a battery discharged by two full cranking cycles to 80 percent of capacity within 4 hours and to full capacity within 12 hours,
i. Output rating shall not be less than 10 Amperes.

3. The battery charger shall be shipped loose by the generator set Manufacturer and shall be installed and connected by the Contractor.

B. Contractor shall install the complete electrical generating system including all fuel connections in accordance with the Manufacturer's recommendations as reviewed by the Contract Administrator.

C. Contractor shall supply and install anchors for the engine/generator base in the pad and connect to isolating devices on base.

D. Batteries shall be filled with electrolyte, charged and connected.

E. Contractor shall supply and install interconnecting wiring between engine/generator, switchgear, load bank, remote annunciator, dampers and other equipment.

F. Contractor shall provide power connections to all accessories. Use a separate suitably sized branch circuit for each separate component.

3.3 FIELD TESTING

A. Provide factory trained technicians to verify the completed installation and to perform an initial startup and testing as per Section 26 08 05, Acceptance Testing.

B. All testing indicated in this section is supplemental to the requirements of Section 26 08 05, Acceptance Testing.

C. Initial site installation performance tests shall be performed in accordance with the requirements of CSA C282, Section 10.

1. The “Operational Test” shall be performed in accordance with the requirements of CSA C282 Clause 10.2.1, the operational test shall be continued for a period of 1 hour, after which normal power shall be restored to the plant and satisfactory re-transfer to normal power and cool-down and shutdown of the emergency generator sets shall be verified.
2. Following the “Operational Test” the “Maximum Site Design Load Test” shall be conducted by connecting the generator sets to the load bank individually and operating each generator set at its rated nameplate unity power factor capacity until stable engine and alternator temperatures have been achieved followed by an additional 6 hours at rated capacity. The generator set load for this test shall be applied immediately upon the engine reaching its rated speed, and the rated nameplate “block load” shall be applied in a single step.

3. All data shall be recorded in accordance with the requirements of CSA C282, and a detailed report shall be submitted in accordance with Section 26 08 05, Acceptance Testing.
4. The initial site installation performance tests shall be performed under the control and supervision of the Manufacturer's factory trained technicians.

D. Provide Contract Administrator with detailed photos of the generator set, and generator set controls during and after construction.

3.4 DEMONSTRATION AND TRAINING

A. Provide demonstration by factory trained representative in use and maintenance of Generator set Systems.
   1. Allocate a minimum of two separate 8-hour for training sessions. The date for each training session will be set by the Contract Administrator. Note that the training sessions will NOT be on 2 successive days.
   2. Training shall include, but not be limited to the following items:
      a. Overall system description and theory of operation,
      b. Automatic operation, shall be coordinated with 12.47kV switchgear system instruction sessions,
      c. Manual operation,
      d. Safeties and protective relaying,
      e. Recommended system check lists and log sheets in accordance with the requirements of CSA C282,
      f. Recommended preventive maintenance,
      g. Instruction on the operation of the assembly and major components within the assembly,

3.5 FINAL ACCEPTANCE

A. If required by final field testing/commissioning results make adjustments/or changes such that an efficient and fully operational installation is achieved. Such adjustments or requirements shall be to the suppliers account. Final acceptance by the Contract Administrator will be conditional upon fulfillment of all requirements.

B. For equipment subject to inspection by a government ministry, department, or agency, submit original copies of the test data reports and all other documentation required for the final field inspection of the equipment by the government ministry, department or agency.

C. Following completion of the work, issue a history docket comprised of the quality certificates, inspection and test records, and all other relevant documents related to manufacture and testing for the Contract Administrator's record files.

3.6 WARRANTY

A. The Contractor shall provide a complete warrantee (covering all aspects of the installation) for all equipment, labor, materials supplied for the 66 kV Substation, 15 kV switchgear, Gensets, and Genset Load Bank, valid for a period of 4 years from the date of the completed and fully signed (by all parties) Form 104.

END OF SECTION

SECTION 26 32 20

GENERATOR LOAD BANK (15 KV)

PART 1 GENERAL

1.1 RELATED SPECIFICATION SECTIONS

A. Section 26 13 18, Primary Switchgear Assembly to 15kV

B. Section 26 32 10, Diesel Electric Generating Units (Liquid Cooled)

1.2 CODES AND STANDARDS

A. The most recent adopted version of the following standards:
1. CSA C22.1-15 – Canadian Electrical Code, Part I, Safety Standard For Electrical Installations (CEC)
2. CSA C22.2 NO. 14 – Industrial control equipment
3. CSA C22.2 NO. 47-13 – Air-cooled transformers (dry type)
4. CAN/CSA-C802.2-12 – Minimum efficiency values for dry-type transformers
5. CSA C282 – Emergency Electrical Power Supply for Buildings
6. CAN3/CSA Z299.3 - Quality Assurance Program – Category 3
7. CAN/CSA-E61131-2-06 (R2011) – Programmable Controllers - Part 2: Equipment Requirements and Tests (Adopted IEC 61131-2:2003, second edition, 2003-02, including Corrigendum 1:2004, with Canadian deviations)
8. UL 508 – Standard for Industrial Control Panels (Note that as of Jan. 27, 2017, UL 508 will be replaced by the UL 60947 series and UL-508 series approvals will be withdrawn),
9. UL 60947 (series) –Low-Voltage Switchgear and Controlgear, (Note that as of Jan. 27, 2017, the UL 508 series of Standards will be replaced by the UL 60947 series of Standards including:
   a. UL 60947-1– Low-Voltage Switchgear and Controlgear - Part 1: General rules,
   b. UL 60947-4-1A – Low-Voltage Switchgear and Controlgear - Part 4-1: Contactors and Motor-Starters - Electromechanical Contactors and Motor-Starters,
   c. UL 61131-2 – Programmable Controllers – Part 2: Equipment requirements and tests.

1.3 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Result – Electrical.

B. Submit shop drawings:
1. Complete set of equipment drawings.
2. Interconnecting wiring diagrams.
3. Weight of all equipment.
4. Dimensions of all equipment.
5. Material List.
6. Control panel schematics.
7. Control interconnection diagrams / interface with the switchgear

8. Manufacturer's and Vendor's written warranty.
9. Emissions data (sound and environmental).
10. List of replaceable components, including fuses, make, model, size.
11. Single line drawing, showing all the connections, sizes and components of the system.

C. Product Data:
1. Submit manufacturer’s printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations. Specific model shall be indicated.

D. Owner’s Manual:
1. Paper and digital copies of owner’s manual specific to the product supplied must be provided. General operating instructions, preventative maintenance, wiring diagrams, schematics and parts exploded views specific to the supplied model must be included.

1.4 MAINTENANCE

A. Provide maintenance materials for incorporation into the Operation and Maintenance (O&M) manuals in accordance with Section 26 05 01, Common Work Results – Electrical.

1.5 QUALITY ISSURANCE

A. Prior to shipment, the manufacturer shall factory test the medium voltage load bank at full load, and full voltage level to assure compliance with the equipment specifications defined here-in.

B. A certified test and compliance report shall be provided to the Contract Administrator of successful completion of performance tests.

PART 2 PRODUCTS

2.1 GENERATOR LOAD BANK

A. General:
1. A medium voltage, transformer type, air-cooled, automatic resistive load bank is required for permanent installation as a component of the standby power engine generator system. The load bank will be used for the periodic, scheduled, supervised maintenance exercising and testing of the standby generator systems. The load bank shall be operable remotely in both manual and/or automatic controlled sequenced modes.

B. Installation:
1. The load bank shall be installed outdoors on a grade level concrete pad.

C. Load Bank Rating:
1. Load Power Capacity: 2000KW, 1.0Pf., resistive,
2. Power Input Voltage: 12,470 V AC, 3Ø, 3W,
3. Power Input Frequency: 60 Hz,
4. Auxiliary Power Voltage (Fans, Heaters, & Controls): 600 V AC, 3Ø, 3W,

5. Auxiliary Power Frequency: 60Hz,
6. Load step resolution: 50KW
7. Ambient Operating Temperature: -40 degrees C to +40 degrees C
8. Duty Cycle: Continuous
9. Suitable for use with a 12.47kV, 3Ø, 4W resistance grounded, diesel powered generator rated 2000 KW, 60 Hz, 0.8 P_f Lagging, (2500 KVA).

D. Load Bank Design
1. General:
   a. The load bank shall be a completely self-contained, freestanding skidded unit which shall include all transformations, resistive load elements, load control devices, load element branch circuit fuse protection, main load bus and terminals, cooling system, system controller, local control panel, remote control panel, and malfunction detection system in a NEMA type 3R enclosure or enclosures.
   b. The medium voltage load bank shall be completely assembled as a single, unitized, structural steel skid supported unit. The Medium voltage load bank shall include the following principle elements which are supplied, installed, and connected by the manufacturer to form a complete working assembly:
   c. Load bank transformer section, including, but not limited to:
      1) 12.47kV:600V dry type transformer,
      2) Incoming primary 12.47kV cable connections, including space provisions for high voltage terminators (stress cones). The incoming 12.47kV cable terminators will be supplied and installed by the Electrical Contractor,
      3) Transformer 600VAC, 3Ø, 4W secondary protection and load connections,
      4) Transformer heating, heating control thermostats and contactors.
   d. 600VAC, 3Ø, 4W resistive load section, including, but not limited to:
      1) Tray mounted resistive load elements,
      2) Cooling fan(s) and fan motor(s)
      3) Airflow sensors, and
      4) Temperature sensors, safety interlocks, etc.
   e. Load bank control section, including, but not limited to:
      1) Load element 600V sub-distribution,
      2) Load element branch circuit fuse protection,
      3) Load element control contactors (120VAC control),
      4) 600V:120V control transformer(s),
      5) Cooling fan breaker, motor starter, and motor overload protection,
      6) Load bank protective relaying and malfunction detection,
      7) Control logic panel,
      8) Local control panel,
      9) Control circuit disconnect,
      10) 600V incoming “auxiliary” cable terminations.
   f. The load bank shall require only the following connections to be completely operational:
      1) One (1) medium voltage power feeder at 12.47 kV 3Ø,
      2) One (1) external 600 VAC, 3Ø, 3W “auxiliary” supply, from one 70A, 600 VAC, 3 pole circuit breaker,
      3) One RS485 communication cable connection between the load bank and the remote control panel,

4) One 24 VDC or 120 V AC or DC power supply cable between the load bank and the remote control panel.
5) One 6C #16 AWG, 300V type Teck90 cable to the generator system master controls for interlocking/control of the "Load Dump" signal incorporated into the load bank (if required).

g. The load bank shall be supplied complete with a separate remote control panel in addition to the integral local control panel. The remote control panel shall be enclosed in a NEMA type 12 gasketed enclosure suitable for wall or floor mounting and shall be separately crated and shipped loose with the medium voltage load bank.

h. All cable access shall be bottom entry. Manufacturer to provide dimensioned layout drawing of cable access openings to equipment and associated requirements for the concrete support pad.

2. Structural Sub-base (Support Skid):
   a. The load bank shall be supported and assembled on a structural steel sub-base (support skid) suitable for installation outdoors on a concrete pad type foundation. The load bank shall incorporate anchor points for fixing the support skid to the concrete pad. All other load bank components or sub-assemblies shall be anchored to the support skid and shall not require direct anchoring to the concrete pad.
   b. The support skid shall be designed to support the weight of the complete unit, plus snow loading.
3. Enclosures:
   a. General
      1) The medium voltage load bank shall be designed for outdoor installation and the entire assembly shall be rated NEMA 3R (minimum).
   b. Load Bank Transformer Enclosure
      1) The load bank transformer enclosure shall be a minimum of NEMA type 3R designed for outdoor installation.
      2) The load bank transformer enclosure shall be either naturally ventilated by convection or alternately may be forced air ventilated via the load bank main cooling fan(s).
      3) The load bank transformer enclosure shall be installed on the structural sub-base adjacent to the low voltage load bank module(s).
      4) The load bank transformer enclosure shall be equipped with bolted hinged lockable doors and a key interlock system to control access to the high voltage portions of the enclosure in accordance with the requirements of CEC Section 36. Non-Hinged removable access panels are <u>NOT acceptable</u>.
      5) The load bank transformer enclosure shall be equipped with ventilation louvers to provide the required cooling airflow as required.
      6) Ventilation louvers shall be equipped with screens to prevent the ingress of birds, rodents and vermin, shall be removable only from within the enclosure, and so arranged to prevent the ingress of rain or wind driven snow.
      7) Door hardware, hinges and closure bolts shall be stainless steel. Closure bolts shall be captive to prevent loss.
   c. Load Bank Low Voltage Load Module Enclosure
      1) The load bank low voltage load module enclosure shall be NEMA type 3R, designed for outdoor installation.

2) The load bank low voltage load module enclosure shall be segregated into separate compartments for:
   a) 600V resistive load elements,
   b) 600V load element distribution, load element branch circuit fuse protection and load element control contactors,
   c) Control and protection.
3) The 600V resistive load bank low voltage load module enclosure(s) shall be of double wall construction to provide a cool exterior and thermal isolation of the load elements.
4) Cooling airflow through the load bank low voltage load module enclosure shall be vertical with cold air intake at the bottom and hot air exhaust out the top.
5) The load bank low voltage load module shall be equipped with a removable discharge plenum/elbow designed to provide horizontal discharge of the exhaust cooling airflow and to prevent the ingress of wind driven rain or snow into the resistive elements. The discharge plenum and elbow shall be designed to be reversible along the long dimension of the load bank to permit the cooling airflow discharge to be directed in the general downwind direction of the prevailing wind. Discharge plenums discharging the exhaust air in a vertical direction are NOT acceptable.
6) All interior spaces of the load bank enclosure shall be accessible by hinged, bolted lockable doors. Bolt-on panels are NOT acceptable.
7) The low voltage load bank module enclosure shall be equipped with ventilation louvers to provide the required cooling airflow as required.
8) The ventilation intake louvers and the exhaust plenum/elbow shall be equipped with screens to prevent the ingress of birds, rodents, vermin, shall be removable only from within the enclosure, and so arranged to prevent the ingress of rain or wind driven snow.
9) Door hardware, hinges and closure bolts shall be stainless steel. Closure bolts shall be captive to prevent loss.
10) The enclosure shall be painted with an industrial enamel using a UL listed material and process.

4. Load Bank Power Transformer:
   a. The medium-voltage load bank shall be equipped with a power transformer to step-down the applied generator voltage of 12.47kV, 3Ø, 3W to the load bank low voltage load module voltage of 600V, 3Ø, 4W.
   b. Transformer shall be dry type, copper wound, VPI-epoxy impregnated with the following characteristics:
   c. Minimum continuous operating capacity: 2200KVA, 2000KW.
   d. Primary: 12.47kV, 3Ø, 3W, delta connected, impulse rating 60kV BIL,
   e. Primary winding: Copper, layer type winding,
   f. Secondary: 600V, 3Ø, 4W, wye connected with solidly grounded neutral, impulse withstand rating 10kV BIL.
   g. Secondary winding: Copper, layer type winding. Sheet or foil type windings NOT accepted,
   h. Taps: Primary side, 2 @ 2.5 percent FCAN, 2 @ 2.5 percent FCBN,
   i. Design impedance: 6 percent @ 170 degrees C on base KVA,
   j. Cooling: Natural Convection or Forced (see below),
   k. Insulation: Class H (220 degrees C),

l. Average winding temperature rise: 150 degrees C, at 40 degrees C ambient,
m. Maximum hot spot temperature rise: 180 degrees C, at 40 degrees C ambient,
n. Maximum winding temperature: 220 degrees C, 30 degrees C average ambient over 24 hours, maximum 40 degrees C ambient at any time,
o. Suitable for use with a 12.47kV, 3Ø, 4W resistance grounded, diesel powered generator rated 2000 KW, 60 Hz, 0.8 Pf Lagging, (2500 KVA).
    1) Transformer secondary shall connect to a full rated, 600V, load break, fusible disconnect switch equipped with class-L time delay fuses. The load break switch shall be externally operable and shall have a lockable handle mechanism.
    2) Transformer shall be enclosed within an environmentally controlled enclosure as indicated above.
p. Load Bank Equipment Heating and Heating Controls:
    1) The load bank enclosure (transformers and auxiliaries as required) shall be equipped with interior space heaters under thermostatic control which will heat the interior components to a temperature which will allow the load bank to be energized from the generator under test and have load immediately applied (up to and including full load) over the entire specified environmental temperature range (-40 degrees C to +40 degrees C).
    2) An energized “warm-up” period on generator supply prior to load application shall NOT be required.
    3) The load bank control system shall incorporate all necessary controls, contactors, and interlocks to allow manual control of heating during periods of low ambient temperatures and prevent the application of load to the transformer or load bank until the required interior temperatures for safe loading of the equipment (including the transformer) have been attained.
    4) Provide for operator control (start/stop) of the heating system on both the load bank internal control panel and the “remote” control panel. As testing of the generator is a “scheduled” event the load bank enclosure heating shall normally be “off” and shall be enabled by Operator action prior to scheduled testing. Instruction manual shall indicate the duration of the required warm-up period.
    5) Provide interlocks c/w indication of a low temperature “load lockout condition” on both the load bank internal control panel and the “remote” control panel.
    6) The enclosure heaters shall be powered from the common 600V 3Ø “auxiliary” supply or from the internally derived 120V control/power supplies and shall NOT require a separate source of external power.

5. Load elements:
    a. Load resistive elements shall be of open, helically wound chromium alloy electrical resistance wire. The resistance wire shall be sized to operate at 50 percent to 60 percent of the maximum continuous temperature rating of the wire. The element resistance wire shall be mechanically supported over its entire length in such a way that should a wire break, the broken wire segments will not short to adjacent conductors or to ground.
    b. Load elements shall be individually serviceable and replaceable in the field without major disassembly of the load bank. Load elements shall be installed in multiple resistor cases or trays which shall be removable in such a way that any element is easily accessible without disturbing any other elements.

c. All materials used in the mounting and installation of the load elements shall be suitable for the temperatures encountered, both in normal operation and under fault conditions.
d. Materials in direct contact with the element resistance wire shall be ceramic. Elements shall be fully supported across the entire length exposed to the cooling air stream by segmented ceramic insulators. The ceramic support insulator shall be installed upon, reinforced and supported by stainless steel structures designed to accommodate the required thermal expansion of the insulator. Other materials which structurally support the load elements or form the cooling air duct within which the elements are mounted shall be steel or stainless steel.
e. Plastics, glass reinforced plastic materials, and flammable materials are NOT acceptable for the installation, support and mounting of load elements or in the construction of the load bank cooling air duct.
f. The change in resistance due to temperature shall be minimized by maintaining conservative element power densities. The overall tolerance of the load bank shall be –0 percent to +5 percent KW at rated voltage. The load bank shall deliver rated KW at rated voltage.

6. Resistive load element circuit protection and control:
   a. The resistive load element units shall be 3Ø delta connected, 600V rated and in fused branch circuits of not more than 50 KW each.
   b. Load element units shall be individually connected and individually fused. Load element unit circuit fuses shall be 200 KAIC, current limiting type, extremely fast acting, and 600V rated.
   c. Load control contactors shall be electrically operated, electrically held, rated 70A (minimum), contacts shall be silver surfaced, and contactor control voltage shall be 120V. One load control contactor shall be supplied for each 50 KW load element unit.
   d. Load element unit power wiring shall be stranded: 150 degrees C insulated, -40 degrees C rated.
   e. Main terminals shall be copper, with a maximum current density of 1000A per square inch of cross section.
7. Cooling system:
   a. Forced air cooled by motor driven propeller fan.
   b. Cooling fan motor(s) shall be TEFC or TEAO (where the fan propeller is direct mounted on the motor), shall be 1800 RPM (maximum), 600V rated, 575V utilization voltage. Fan motor shall be controlled by a circuit breaker combination motor starter c/w non-self-resetting overloads sized for the motor running current in accordance with the motor manufacturer's recommendations and the CEC.
   c. The fan propeller shall be of aluminum or stainless steel with an airfoil profile. Flat bladed or non-airfoil profile fans are NOT acceptable.
   d. Direct drive cooling fans where the propeller is directly mounted on the motor shaft are preferred, belted drive fans may be acceptable.
   e. Where belted drive fans are proposed, the drive shall utilize a minimum of 2 belts, belts shall be standard B/C type, drive service factor shall be 1.5 x motor Hp (minimum), maximum reduction shall be 2.5:1. Pillow blocks shall be extra heavy duty, with an L_{10} bearing life of 60,000 hours (minimum).
   f. The cooling fan(s) shall operate at 600V AC line voltage. Load control circuits and fan motor controls shall operate at 120V 1Ø, via control power isolation

transformers. Control circuit fuses shall be 100 KAIC current limiting types, 600V rated.

8. Malfunction detection system
   a. Provide a malfunction detection system consisting of sensors within the load bank, load bank enable/disable permissive circuit, and alarms. Malfunction detection sensors shall include, but not be limited to:
   b. Cooling air intake temperature element(s) (mechanical switches, Resistance Temperature Detectors (RTDs), or thermocouples), with operating setpoint set to 48 degrees C,
   c. Exhaust air temperature sensors, with operating point set at not more than 41 degrees C above the maximum rated temperature rise, and
   d. Air pressure sensors (differential pressure type) to sense for loss of cooling airflow.
9. Control Panels
   a. The load bank controls shall be configured for 8 step load operation (minimum), so the system can increase the load from 0 KW to 2000 kW in 50 KW increments, as follows:
   b. 2 steps of 50 KW,
   c. 2 steps of 100 KW,
   d. 1 step of 200 KW,
   e. 3 steps of 500 kW.
   f. The load controls shall be designed such that “Block Load” type operation (no load to full load in a single step) is possible
   g. Provide both local and remote control panels.
   h. The local panel shall consist of the following:
      1) Power supply for load bank control circuits.
   i. Malfunction detection/auto disconnect system.
   j. Cooling fan automatic start-stop control.
   k. Anti-condensation thermostatically controlled heater.
   l. Remote load dump circuit to allow use of remote dry contacts (close to run) to trip load bank off line. Unit shall be shipped with a clearly marked removable jumper to permit the “Load Dump” feature to be field activated.
   m. Input/output devices and control circuits for operation of load bank from remote control panel and automatic controller.
   n. Auxiliary dry contacts to indicate "normal operation"/"system failure"
   o. Local Manual Control Panel to include, but not be limited to, the following:
      1) Off/Manual/Auto/Remote mode control selector switch
      2) Transformer enclosure heating “Start/Stop” pushbuttons
      3) Manual Run/Stop pushbuttons
      4) Bypass switch to override remote load dump
      5) Master load switch
      6) Load step switches
   p. Status annunciator with the following indications:
      1) Auxilairy 600 Vac power “On”.
      2) 12.47kV Power connected
      3) Transformer low temperature load bank operation inhibit indication
      4) Local-manual run
      5) Local-auto run
      6) Remote mode

7) Load dump
8) Load dump bypass
9) Normal operation / System malfunction
10) Cooling failure
11) Master load on
12) Load step on (one for each load step)
13) Press-to-test pushbutton for indicators

10. The remote panel (tagged as CP-C795 located within the electrical room shown on drawing 1-0102-EGAD-C001) shall consist of the following / have the following features:
    a. Enclosure Type 1, with hinge-open front door with the following front mounted controls:
        1) Transformer enclosure heating “Start/Stop” pushbuttons
        2) Off/Manual/Auto/Remote mode switch
        3) Manual Run-Stop pushbuttons
        4) Bypass switch to override remote load dump
        5) Master load switch
        6) Load step switches
        7) Automatic Test Start/Stop Pushbuttons
        8) Automatic Test Program selector switch
    b. Status annunciator with the following indicators:
        1) Auxiliary 600 VAC power “On”.
        2) 12.47kV Power connected
        3) Transformer low temperature load bank operation inhibit indication
        4) Remote -manual run
        5) Remote -auto run
        6) Remote mode
        7) Load dump
        8) Load dump bypass
        9) Normal operation / System malfunction
        10) Cooling failure
        11) Master load on
        12) Load step on (one for each load step)
        13) Press-to-Test pushbutton for indicators
    c. Access to data recording. If an external laptop / software are required, access to the data logger shall be possible through a front door mounted USB interface connector. Data recording shall be stored in memory at the load bank and shall be accessible by the remote control panel.
11. The load bank shall be equipped with a programmable automatic controller, which will be enabled when the load bank mode selector switch is placed in the “automatic” position.
    a. The automatic controller is **NOT** intended to operate when the generators are on-line supplying the plant loads or for the purposes of maintaining generator or plant loading.
    b. In load bank “automatic mode” the programmable automatic controller shall provide a minimum of three user selectable / user configurable programs to allow for the fully sequenced automatic testing of one connected 2 MVA diesel engine powered

generator at a time with the load bank. All testing will be performed with the generator switchgear isolated from the remainder of the plant electrical system.

c. Starting of the generator to be tested and connection of the generator to the generator switchgear (SGR-C790) will be under the control of the generator control system with the generator master controls in the “manual start or test mode”. Connection of the MV load bank to the SGR-C790 “generator switchgear” will be by manual closing of load bank 12.47 kV circuit breaker CB-Y793 in SGR-C790.

d. Test sequences provided and data recorded by the programmable automatic controller shall comply with the testing and data recording requirements of CSA C282 part 11 “Operation and maintenance program”. Note however that clauses and requirements in CSA C282 relating to “health care facilities”, “life safety” or “essential electrical systems in conformance with CSA Z32” do not apply to this facility.

e. Routine generator testing will be manually initiated by the user at frequencies determined by the user. Automatic clock or calendar based initiation of routine testing is not contemplated or required for this system or facility.

f. The automatic test programs provided by the programmable automatic controller shall be generally as follows:

1) Stepped Load Application – Generator Testing (Program # 1):

a) Once the load bank has been set to “automatic mode”, the automatic testing sequence shall be initiated by operator action (mechanical or “software” pushbutton”),

b) Upon operator initiation the program shall increase the load applied, to the generator under test, in a smooth controlled manner by applying a series of load steps to a selected “test load level” in a time delayed sequence. Selection of a “test load level” greater than the nameplate capacity of the generator shall not be possible.

c) Once the “test load level” has been reached, the program shall maintain the generator load at this level for a selected duration.

d) At the end of the above test duration the program shall decrease the generator loading to “no-load” in a smooth controlled manner by removing the load, either in the reverse sequence of [b) above] with the same step-to-step time delays, or by dropping the load to “no-load” in a single step.

e) After reducing generator loading to “no-load” the program shall terminate.

f) The program shall automatically abort for the following events (including but not limited to):

(1) Load bank electrical fault,
(2) Loss of load bank cooling air,
(3) Excessive inlet or exhaust air temperatures,
(4) Loss or obstruction of power step down transformer cooling airflow,
(5) Excessive power step down transformer temperature,
(6) Other conditions which the load bank supplier deems necessary,
(7) Loss of generator supplied voltage (generator trip),
(8) Breaker CB-Y793 trip, or
(9) Operation of an emergency shutdown device by the operator.

g) User Programmable / selectable settings

(1) Test load level,
(2) Load step application order,

(3) Time delay between the application, or reduction, of successive load steps (settable on a step-by-step basis),
(4) Test operational time duration at “test load level” (selectable two (2), three (3), four(4) hours, or user set, and
(5) Load reduction methodology [e) above] shall be user selectable.

2) Stepped Load Application – Generator Testing (Program # 2):
   a) The same as Stepped Load Application Program # 1, but with differing load steps, load step application order, test load level, or operating duration under operation at the test load level.
3) Block Load Application – Generator Testing (Program # 3):
   a) Once the load bank has been set to “automatic mode”, the automatic testing sequence shall be initiated by operator action (mechanical or “software” pushbutton”),
   b) Upon operator initiation the program shall apply a selected load (block load) to the generator under test as a single load step. (Can be interlocked with the generator controls by utilizing the “Load Dump” input on the load bank to apply the load). Selection of the applied block load to a value greater than the nameplate block load capacity of the generator shall not be possible.
   c) Once the “block load” has been applied, the program shall maintain the generator load at this level for a selected duration.
   d) At the end of the above test duration the program shall decrease the generator loading to “no-load” in a single step.
   e) After reducing generator loading to “no-load” the program shall terminate.
   f) The program shall automatically abort for the following events (including but not limited to):
      (1) Load bank electrical fault,
      (2) Loss of load bank cooling air,
      (3) Excessive inlet or exhaust air temperatures,
      (4) Loss or obstruction of power step down transformer cooling airflow,
      (5) Excessive power step down transformer temperature,
      (6) Other conditions which the load bank supplier deems necessary,
      (7) Loss of generator supplied voltage (generator trip),
      (8) Breaker CB-Y793 trip, or
      (9) Operation of an emergency shutdown device by the operator.
   g) User Programmable / selectable settings
      (1) Block load level,
      (2) Test operational time duration at “block load level” user set.
4) Data Recording Requirements:
   a) The system shall generate an electronic time-stamped record of the testing (including but not limited to):
      (1) Load step,
      (2) Duration of test segments,
      (3) Currents,
      (4) Voltages,
      (5) Power,
      (6) Resistor unit parameters and status signals as indicated above,
      (7) Successful completion of test or test failure,

(8) Reason for test failure, etc.

b) The Recorded Data shall structured and formatted to be compatible with the requirements of CSA document “C282 Logbook-15, Emergency electrical power supply for buildings maintenance logbook”.

c) The test record shall be retained in non-volatile memory (SSD, “flash” memory, etc.) as an ASCII formatted columnar text file (“.txt” format) and structured as indicated above. The test records shall be downloadable and shall be capable of being outputted to a USB drive via a USB interface supplied with the system. The file name shall include the date and time of the test (initiation).

g. Programmable Controller:

1) Note that the City of Winnipeg has standardized on PLC controllers and for this project the Schneider Electric/Modicon M580 ePAC is the preferred controller.

12. Warranty, the load bank shall be supplied with a four-year manufacturer's warranty, which covers all materials and includes the provision of on-site service labor. The manufacturer shall demonstrate the availability of factory service technicians in support of the load bank.

13. Commissioning and start-up service:

a. The load bank manufacturer shall provide a factory trained service technician to supervise the testing, commissioning, and initial start-up of the load bank on-site (after the load bank has been installed and connected). Allow for a minimum of five days on-site to perform all of the on-site requirements defined here in. Note that the on-site requirements detailed in Section 3.4 “Demonstration and Training” are in addition to the on-site requirements of this section.

14. Qualifications of load bank manufacturer

a. The load bank shall be the product of a firm regularly engaged in the design and manufacture of stationary generator load banks.

b. The load bank manufacturer shall demonstrate at least five years experience with at least ten successful installations of load banks similar or equal to the load bank specified herein.

c. Approved manufacturer: Simplex, Avtron, or Approved Equal in accordance with section B8 – Substitutes, of the Bid Opportunity Documents.

PART 3 EXECUTION

3.1 MANUFACTURER’S INSTRUCTIONS

A. Compliance: comply with manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets.

3.2 INSTALLATION

A. The following equipment shall be installed:

1. Load bank system,
2. Load bank auxiliary systems,
3. Remote Control panel,

4. All other systems detailed on the vendor shop drawings, for a complete and working system.

B. The Contractor shall supply and install anchors as required to fasten the load bank structural sub-base or vibration isolating devices (where provided) to the concrete pad.

C. The Contractor shall supply and install interconnecting wiring between remote control panel and the local control panel.

D. The Contractor shall provide 600V, normal power connection to the load bank for powering all accessories.

E. The Contractor shall supply and install ground electrodes, and grounding of the transformer and load bank in accordance with the requirements of the CEC.

3.3 TESTING

A. Load Bank
1. Inspect and test the load bank in accordance with the Manufacturer's instructions and the requirements of the commissioning procedures.
2. It is anticipated that in order to test the load bank to its full electrical load capacity it will be necessary to employ one of the installed 2MW diesel powered generator units being installed at site together with the 12.47kV generator switchgear SGR-C790.

B. System Commissioning
1. System commissioning testing shall demonstrate the performance of the combined generator set, generator controls, generator switchgear, and load bank as an integrated system. The load bank supplier shall coordinate its testing, commissioning, and start-up activities with those of the diesel generator and switchgear supplier(s) to demonstrate and prove a completely coordinated and functional system.
2. Initial site installation performance tests to prove generator system performance in conjunction with the load bank shall be performed in accordance with the requirements of CSA C282, Section 10.
   a. The "Operational Test" shall be performed in accordance with the requirements of CSA C282 Clause 10.2.1, the operational test shall be continued for a period of 1 hour, after which normal power shall be restored to the plant and satisfactory retransfer of the load and shutdown of the emergency generator sets shall be demonstrated.
   b. Following the Operational test the "Maximum Site Design Load Test" shall be conducted by connecting the generator sets to the load bank individually and operating each generator set at its rated nameplate unity power factor capacity until stable engine and alternator temperatures have been achieved followed by an additional 6 hours at rated capacity. Load shall be applied immediately upon the engine reaching its rated speed, and the rated nameplate load shall be applied in a single step.
   c. All data shall be recorded in accordance with the requirements of CSA C282, and a detailed report shall be submitted in accordance with Section 26 08 05, Acceptance Testing.

d. The initial site installation performance tests shall be performed under the control and supervision of the manufacturer's factory trained technicians.

C. Provide factory trained technicians to verify the completed installation and to perform an initial startup and testing as per Section 26 08 05, Acceptance Testing and in accordance with Section 26 32 10, Diesel Electric Generating Units.

3.4 DEMONSTRATION AND TRAINING

A. Provide demonstration by factory trained representative in use and maintenance of the load bank in coordination with the generator sets.
   1. Allocate a minimum of two separate 8-hour for training sessions. The date for each training session will be set by the Contract Administrator, and will not be on 2 successive days.
   2. Training shall include, but not be limited to the following items:
      a. Overall system description and theory of operation.
      b. Automatic operation.
      c. Manual operation.
      d. Safeties and protective relaying.
      e. Recommended system check lists and log sheets.
      f. Recommended preventive maintenance.
      g. Instruction on the operation of the assembly, circuit breakers, and major components within the assembly.

3.5 FINAL ACCEPTANCE

A. If required by final field testing/commissioning results make adjustments/or changes such that an efficient and fully operational installation is achieved. Such adjustments or requirements shall be to the suppliers account. Final acceptance by the Contract Administrator will be conditional upon fulfillment of all requirements.

B. For equipment subject to inspection by a government ministry, department, or agency, submit original copies of the test data reports and all other documentation required for the final field inspection of the equipment by the government ministry, department or agency.

C. Following completion of the work, issue a history docket comprised of the quality certificates, inspection and test records, and any other relevant documents related to manufacture and testing for the Contract Administrator's record files.

3.6 WARRANTY

A. The Contractor shall provide a complete warrantee (covering all aspects of the installation) for all equipment, labor, materials supplied for the 66 kV Substation, 15 kV switchgear, Gensets, and Genset Load Bank, valid for a period of 4 years from the date of the completed and fully signed (by all parties) Form 104.

END OF SECTION

SECTIION 26 33 43

BATTERY CHARGERS AND BATTERY BANK – 125 VDC

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. Canadian Standards Association- CSA C22.2 No. 107.2- Battery Chargers.

B. NEMA PE 5 – Utility Type Battery Chargers.

C. UL 1012 - Standard for Power Units Other Than Class 2.

D. IEEE 946 - IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations.

E. ANSI / IEEE 37.90.1 – Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit Shop Drawings to include:
   1. System configuration with single-line diagrams.
   2. Functional relationship of equipment including weights, dimensions, and heat dissipation.
   3. Battery bank data:
      a. Individual battery cells, type, size, Ah capacity at 8hr discharge rate, electrolyte, materials for container, cover, separators, retainers, posts and inter-cell connectors.
      b. Cell charge and discharge curves of voltage, current, time and capacity.
      c. Maximum short circuit current.
      d. Maximum charging current recommended for fully discharged condition.
      e. Fully charged voltage per cell.
      f. Fully discharged voltage per cell.
      g. Proof of 20 year design life.
   4. Battery Charger Data:
      a. Temperature rise.
      b. Ventilation requirements.
      c. Control & wiring schematic.
      d. Maximum short circuit current.
   5. Descriptions of equipment to be furnished.
   6. Wiring connection schematics, including details of breaker shunt trip.

7. Dimensions, size and weight of equipment to be handled by the installing contractor.
8. Detailed installation drawings including all terminal locations.
9. Nameplates.
10. Bill of materials.
11. Recommended spare parts.
12. Submit completed Electrical Data Sheet for 125 VDC Station Battery Charger & Battery Bank spreadsheet, confirming compliance with all requirements laid out therein.

1.3 CLOSEOUT SUBMITTALS

A. Provide data for incorporation into operation and maintenance manual specified in Section 01 77 00, Closeout Procedures

B. Operations and Maintenance manual to include:
1. Operation and maintenance instructions concerning design elements, construction features, component functions and maintenance requirements to permit effective operations maintenance and repair.
2. Testing and Commissioning report, both factory test & site testing reports.
3. Technical Data:
a. Approved, signed and dated Shop Drawings.
b. Project data.
c. Technical description of components.
d. Parts list with name and addresses of suppliers.
e. Functional description of the equipment with block diagrams.
f. Safety precautions.
g. Instructions and step-by-step operating procedures.
h. Routine maintenance guidelines, including illustrations.

1.4 SYSTEM START-UP

A. Provide factory authorized service personnel to supervise start-up of system, checking, adjusting and testing on site.

1.5 FACTORY TESTING

A. Test the equipment per applicable standards and provide test data.

B. Submit copy of test results to Contract Administrator for review, before shipping the equipment.

PART 2 PRODUCTS

2.1 BATTERY CHARGER

A. Conformance with CSA C22.2, No. 107.2, UL 1012 and built and tested to NEMA PE 5.

B. The battery chargers shall be sized for and shall be compatible with Valve Regulated Lead Acid (VRLA) batteries for electrical switchgear use.

C. CSA/cUL approved.

D. Mean time between failure (MBTF) of 300 000 hours.

E. The battery chargers shall automatically maintain the battery bank in a fully charged state while the charger AC mains power is available.

F. The chargers are to be suitable for all types of standby applications and to be capable of supplying the load while recharging the batteries within eight hours to a 90 percent state of charge condition.

G. To reduce harmonics on the input line and to reduce the impact of AC ripple a 12 pulse charger must be used.

H. The battery charger is to be solid state of the SCR technology controlled by a Digital Signal Processor with an MTBF of 300,000 hours. It must be designed to float or equalize batteries using a constant voltage, current limiting logic.

I. Static regulation is to be (plus or minus) 0.25 percent RMS voltage from 0 to 100 percent full load having a +10 percent / -12 percent input voltage variation and plus or minus 5 percent frequency.

J. The DC voltage regulation of the constant voltage battery charger shall be maintained during line, load and temperature variations. Include for temperature monitoring probes to allow for automatic compensation of the DC voltage output of the battery charger.

K. The AC power input to the battery charger shall be 208 VAC. It shall be equipped with an AC input circuit breaker of suitable rating. The circuit breaker shall be equipped with a lock & tag facility. Refer to datasheet for additional detail.

L. Automatic output voltage equalization activation modes must be based on: Time, low voltage, charger start, AC fail, current or AH count with an adjustable delay of up to 40 hours, current limit, with an adjustable delay of up to 40 hours.

M. Ripple is to be limited to 100mVrms or less for 125VDC systems when connected to a resistive load with no battery connected. Also, in order to minimize the effects of ripple on battery life, the ripple total power shall be limited to a maximum of 1 Watt at frequencies of 3 kHz or less. The battery charger shall be able to operate without being connected to a battery

N. Provide a shunt trip coil equipped AC input circuit breaker with the shunt trip operated by the rectifier (SCR/diode shorting) fail alarm. Also provide a maintained contact type emergency stop mushroom pushbutton (C/W clear plastic guard to prevent inadvertent operation) for the manual trip operation of the breaker from panel front. Provide a fused power supply / control transformer integral to the unit as required for powering shunt trip.

O. The battery chargers output voltage to be temperature compensated. Minimum output voltage is 105 VDC and the maximum shall be 147 VDC. Refer to datasheet for additional detail.

P. The Battery High Temperature alarm will have 2 temperature probes: A room probe and a battery probe. Battery High temperature alarm can be based on battery temperature alone or on the delta value with the room temperature.

Q. Charging system shall have two identical chargers. Both chargers shall be of identical design and rating. Forced current sharing must be provided with no common circuit or control wiring between chargers to prevent one common point failure. Both chargers shall be equipped with an output voltage blocking diode.

R. Battery charger warrantee period shall be a minimum of 60 months.

2.2 BATTERY CHARGER ACCESSORIES

A. Provide mains AC voltmeter with voltage selector switch, accuracy plus or minus 2 percent of full scale, to measure AC input voltage.

B. Provide a rectifier output DC voltmeter with control fuses, accuracy plus or minus 2 percent of full scale, to measure rectifier output DC voltage, and installed before the rectifier DC circuit breaker.

C. Provide a battery DC voltmeter with control fuses, and accuracy plus or minus 2 percent of full scale, to measure DC voltage on battery terminals.

D. Provide a load DC ammeter, accuracy plus or minus 2 percent of full scale, to measure DC load current.

E. Provide two DC output load circuit breakers (2 pole, 300 VDC) for 125V DC load circuits, as indicated on the datasheet.

F. Provide auxiliary contact relay output and alarm for AC power failure with time delay to prevent alarm during short power outages.

G. Provide local indication and annunciation of alarms. Each alarm must be displayed on the charger's touchscreen display. Memory chips must keep the last 250 events with a date and time stamp. The event logs shall be available locally on the display as well as remotely via communication modbus TCP/IP communication protocol.

H. Three local LED indicator lights shall be as follows:
   1. Green LED: AC ON
   2. Amber LED: Minor alarm
   3. Red LED: Major alarm

I. Alarms shall be:
   1. Major Alarms
      a. Rectifier failure
      b. AC Fail.
      c. High DC volts.
      d. Low DC volts (2 independent levels shall be supplied)
      e. Positive ground fault.
      f. Negative ground fault.

g. Rectifier Low output current.
h. High volt shutdown (Must be cyclic and allow for the charger to start again when the battery voltage has reached a predetermined value).
i. No DC Output (No Charge).
j. Battery imbalance alarm.

2. Minor Alarms
   a. High Ripple
   b. Low & High Frequency alarm and shutdown and automatic restart.
   c. High & Low charger temperature alarm and programmable cyclic. shutdown,
   d. High & Low battery temperature alarm and programmable cyclic shutdown.
   e. Rectifier High output current.
   f. Rectifier High Volt.
   g. Rectifier Low Volt.
   h. Equalization on.

J. Automatic Testing Capability:
   1. Periodical Automatic Battery continuity tester and open battery alarm. Each test must be compared to the baseline test, should battery performance fail to meet baseline results an alarm shall be initiated.
   2. Periodical Automatic battery service test. Partial battery capacity test must be done online without affecting the intended backup time. Each test must be compared to the baseline test, should battery performance fail to meet baseline results an alarm shall be initiated.
   3. Battery Service Tester and Periodical battery capacity tester must operate with an imbedded 25Amp or 50Amp resistive load. (The choice of resistive load will be made based on battery size or required substation breaker tripping current).

K. Acceptable Manufacturer:
   1. BAE type OPzV or approved equal in accordance with B8 - Substitutes.

2.3 STORAGE BATTERIES

A. Shall be sealed, Valve Regulated Acid Battery (VRLA) of Absorbed Glass Mat (AGM) technology or better.

B. Submit battery gassing data with proposal, to determine the ventilation requirements for the electrical room.

C. Cell containers and cover shall be one piece moulded polypropylene or equivalent, to ANSI/UL 94.

D. Terminal posts shall be bolted type, connectors and lead posts shall have copper or brass inserts at the posts.

E. Design life: Each valve regulated cell or block should be designed and manufactured to standards guaranteeing a 20 year design life in standby use at an average temperature of 25 degrees C with occasional excursions to not more than 40C for short periods of time permitted.

F. The Manufacturer shall provide calculated battery capacity data referred to standard conditions (20 degrees C).

G. Batteries shall be capable of being recharged to 95 percent full charge within 12 hours, with no harmful effects on battery, including leaking or foaming of electrolyte.

H. The battery shall be placed in the electrical switchgear room and hence must be equipped with monitors to prevent overcharging by the battery charger.

I. Batteries shall be capable of 1000 cycles to 80 percent depth of discharge.

J. Battery shall be rated to deliver specified output over an extreme ambient temperature range of: minus 10 degrees C to plus 30 degrees C (indoor).

K. Provide a 2 pole DC circuit breaker or isolation disconnect switch for the battery system connection including lock and tag facility, as specified in the datasheet. This can be mounted on battery enclosure itself.

L. The warranty will be 5 years full and 15 years pro-rata. After one year in service supplier will replace any cell that shows a greater than plus or minus 2 percent voltage swing after proper equalization.

M. The Manufacturer shall provide a factory load test down to 80 percent depth of discharge. The test result document shall be communicated to the Contract Administrator for approval before shipment.

N. The Manufacturer shall ensure that all cells of the same battery are to come from the same batch and have the same manufacturing date.

2.4 ENCLOSURE

A. Battery compartment/enclosure shall be NEMA-1 vented.

B. Battery shall be fully enclosed such that inadvertent contact with live parts is prevented. Open or non-enclosed batteries & battery racks will not be accepted.

C. NEMA-1 enclosure for battery charger.

D. Enclosure shall have a front access hinged door.

E. Air natural vented.

F. Provide lifting eyes and base channels for handling either by a crane or a forklift.

G. Apply finish in accordance with standard industrial practices.

H. Maximum temperature rise of any part shall not exceed 55 degrees C over an ambient temperature of 30 degrees C.

I. Cable entry shall be from the top or bottom.

2.5 PROTECTION

A. AC and DC surge suppression as per ANSI/IEEE 37.90.1.

B. AC Lightning arrester as per ANSI/IEEE C62.11.

C. AC input circuit breaker c/w with a high DC volts shunt trip and Open circuit form C alarm contact.

D. Two-pole DC output circuit breaker.

E. Two-pole battery maintenance disconnect switch.

F. Refer to Drawings for protection sizes.

2.6 GROUND TERMINALS

A. Provide suitable ground conductor termination point inside the equipment enclosures for the battery charger and the batteries.

2.7 AUXILIARY RELAYS

A. All auxiliary relays for alarm and trip outputs for customer use shall be CSA approved, with heavy duty form C contacts, rated for operation on 125 volts DC, with visual indication of coil energization.

B. Provide individual form C alarm output contacts (125/250V, AC/DC, 10A) for: AC fail, DC voltage high, DC voltage low, DC ground fault, AC contactor/ Circuit breaker trip etc.

2.8 CONNECTION AND WIRING

A. Wiring shall be CSA approved, flame retardant switchboard insulation system (SIS) type, XLPE insulated VW-1, 14 AWG minimum, stranded copper conductors rated 600 volt, 90 degrees C minimum.

B. All wiring not terminated on devices shall be terminated on terminal blocks. Not more than two (2) wires shall be connected to any device terminal or at any one terminal side. Interconnecting jumpers between terminal block positions shall be included in the 2 wire per side limitation. General and control wiring shall utilize self retaining compression type spade connectors where wiring is terminated on hardware (relays, meters, switches, etc).

C. Communication Wiring
   1. The equipment shall be equipped with one DNP3/ Modbus TCP/IP over Ethernet RJ45 communication port for communication of system status, alarm & trip status with PLC system.

2.9 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results – Electrical

B. Provide battery charger/battery hazard warning and caution labels as specified in CSA C22.2 No. 107.2-01.

C. Warning nameplates in the front of control compartments containing multiple sources of power.

D. All main equipment identification nameplates for the battery charger and the battery bank, indicating as a minimum;
   1. Battery charger input AC voltage, phases, DC output voltage and ampere rating; battery bank rated voltage & ampere hour capacity, type of battery model no. manufacturer, contact details etc.
   2. Maximum design temperature rise.
   3. Manufacturer's shop reference and drawing number, contact details, date of manufacturing, Purchase order reference.
   4. CSA approval, CSA design standard.
   5. Enclosure NEMA rating.
   6. Equipment weight

E. Equipment identification lamacoid for each Battery Charger to be size 8, example as followed:

BC-C751 INPUT: 208VAC, 3Ø, 75A OUTPUT: 125VDC, 125A

F. Equipment identification lamacoid for each Battery to be size 8, example as followed.

BAT-C750 125 VDC 840Ah

G. Provide separate DC panelboard identifier as per panelboard spec, section 26 33 43, example as followed:

PNL-C753 125VDC, 2Ø, 2W 400A

H. Vendor shall submit a detailed listing of proposed equipment nameplates to the Contract Administrator for review prior to fabrication and installation.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install and connect battery charger and battery bank. Installation shall comply with Manufacturer's instructions, drawings, and recommendations.

B. Wire devices to DC load panel.

C. Ensure all equipment is properly grounded.

D. Manufacturer shall provide a certified technical service representative to review the Contractor's installation and commission the unit.

E. Start-up battery charger and battery bank and make preliminary tests to ensure satisfactory performance.

F. If required by final field testing/Commissioning results, make adjustments/or changes such that an efficient and fully operational installation is achieved. Such adjustments or requirements shall be to the suppliers account. Final acceptance by the City will be conditional upon fulfillment of this requirement.

END OF SECTION

THE CITY OF WINNIPEG WATER AND WASTE DEPARTMENT	**ELECTRICAL DATA SHEET** **125VDC STATION BATTERY CHARGER & BATTERY BANK**	CH2MHILL SNC·LAVALIN

Data Sheet No: **A-0102-EDTS-C001**								Revision	
Project no. **WPG/474248**	REVISIONS							**No.**	**Date**
Bid Opp. No. **976-2016**	Rev	Date	Description	By	Chk	App		**00**	**2017/04/05**
Project Name: **SEWPCC Upgrading/Expansion**	00	17/04/05	Issued for Construction – 976-2016	VE	CWB	EMR			
Site: **South End Water Pollution Control Center**								Page	
Specification No. **26 33 43**								**1 of 7**	
Prepared by: VE	Checked by: CWB		Approved by: EMR		Client:				

INSTRUCTIONS:

1) Data and information requested by this data sheet shall be submitted to the City of Winnipeg Contract Administrator within 30 days of the award of contract.
2) A request for equal during the bid process shall utilize this fully completed data sheet as part of the submission process.
3) Perform work in accordance with the latest (at the time of contract signing) relevant codes and standards from the regulatory agencies and organizations indicated in the referenced Specification, Drawings, or as indicated below.
4) In the event of conflict between the reference codes and standards, drawings, specifications or Data Sheets, obtain clarification before proceeding with the work.
5) All listed technical requirements below are firm requirements of the Contract. These data sheets are a required submission as part of the formal shop drawing submittal process and satisfactory completion in conformance with specification requirements will be a mandatory part of that review. Any deviations shall be subject to acceptance or rejection by the Contract Administrator.
6) Vendors shall avoid the use of ambiguous words such as **"Noted", "Confirm", "Confirmed" "Ok", check marks or the use of an "X"** in responding to data sheets.
The use of the words **"YES"**, **"NO"**, a **numerical value**, a **clarifying comment** or **a reference** is acceptable.

Row	Description	Design Requirements	Vendor Confirmation	Rev.
1				
2	**GENERAL BIDDER DATA**			
3	EQUIPMENT NUMBERS	**BATTERY - B-C750 BATTERY CHARGERS - BC-C751 & BC-C752**		
4	VENDOR	VENDOR TO SPECIFY		
5	VENDOR QUOTATION NUMBER	VENDOR TO SPECIFY		
6	QUOTATION DATE	VENDOR TO SPECIFY		
7	EQUIPMENT MANUFACTURER	VENDOR TO SPECIFY		
8	EQUIPMENT MODEL DESIGNATION OR NUMBER	VENDOR TO SPECIFY		
9	REFERENCE DRAWINGS	**614099-ESLD-C010**		
10	MEASUREMENT SYSTEM	METRIC		
11				
12	**OPERATING ENVIRONMENT / PHILOSOPHY**			
13	ELEVATION ABOVE SEA LEVEL (FEET)	< 1000		
14	EQUIPMENT LOCATION (INDOORS / OUTDOORS)	INDOORS		
15	UNUSUAL CONDITIONS (GASSES & DUSTS)	NOT APPLICABLE		
16	HAZARDOUS AREA CLASSIFICATION	UNCLASSIFIED		
17	AMBIENT DESIGN TEMPERATURE RANGE (°C)	+10 to +30		
18	SEISMIC CLASSIFICATION	0		
19	OPERATING SCHEDULE	CONTINUOUS WITH SCHEDULED MAINTENANCE		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
20				
21	**APPLICABLE STANDARDS**			
22	CSA C22.2 NO. 107.1 [LATEST REVISION]	COMPLIANCE REQUIRED		
23	CSA C22.2 NO. 107.2 [LATEST REVISION]	COMPLIANCE REQUIRED		
24	IEEE 946 [LATEST REVISION]	COMPLIANCE REQUIRED		
25	ANSI / UL 94 [LATEST REVISION]	COMPLIANCE REQUIRED		
26				
27	**BATTERY CHARGER, GENERAL**			
28	CHARGER TYPE	TEMPERATURE COMPENSATED		
29	OPERATING MODE UNDER NORMAL OPERATION	TEMP. COMPENSATED CONSTANT VOLTAGE		
30	OPERATING MODE UNDER OVERLAOD / LIMIT CONDITIONS	CURRENT LIMIT		
31	MODEL	VENDOR TO SPECIFY		
32	CERTIFICATION	TO CSA C22.2 No. 107.1 C-UI		
33	NOISE (dBa)	REQUIRED ≤ 60 dB_a		
34	HEAT LOSS (W)	VENDOR TO SPECIFY		
35	MEAN TIME BETWEEN FAILURE	300,000 HOURS		
36				
37	**AC POWER INPUT**			
38	INPUT VOLTAGE (V)	120/208V, 3Ø, 4W, ±10%		
39	AC INPUT BREAKER	MINIMUM 25KA INTERRUPTING, LOCKABLE		
40	AC INPUT ISOLATION ON RECTIFIER SCR / DIODE SHORTING [AC CB TRIP OR CONTACTOR TRIP OPTION IS REQUIRED]	REQUIRED		
41	AC MAXIMUM INPUT CURRENT (A)	VENDOR TO SPECIFY		
42	AC INPUT CABLE SIZE (AWG, # CONDUCTORS / PHASE)	VENDOR TO SPECIFY		
43	FREQUENCY (Hz)	60 Hz, ±5%		
44	AC INPUT SURGE SUPPRESSION	NOT REQUIRED		
45	AC WIRING VOLTAGE RATING (V)	600V AC		
46	EFFICIENCY (%)	> 90%		
47				
48	**DC OUTPUT**			
49	NOMINAL OUTPUT VOLTAGE (V)	125V DC		
50	MINIMUM OUTPUT VOLTAGE (V)	90V DC		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
51	MAXIMUM OUTPUT VOLTAGE (V)	144V DC		
52	FLOAT VOLTAGE (V)	VENDOR TO SPECIFY		
53	BOOST CHARGE	REQUIRED		
54	EQUALIZE VOLTAGE (V)	VENDOR TO SPECIFY		
55	CHARGER RATED DC CURRENT OUTPUT (A)	VENDOR TO SPECIFY		
56	CHARGER MINIMUM OUTPUT CURRENT (A)	50A		
57	CHARGER MAXIMUM DC OUTPUT CURRENT @ 110% (A)	VENDOR TO SPECIFY		
58	DC OUTPUT FILTER RIPPLE	≤ 100 mV_{rms}		
59	RIPPLE TOTAL POWER	≤ 1 WATT @ 3kHZ		
60	DC VOLTAGE REGULATION (%)	±0.25% RMS (0-100% LOAD) TEMPERATURE COMPENSATED		
61	INPUT / OUTPUT ISOLATION (V)	1500V DC – INPUT / OUTPUT & GROUND		
62	DC SURGE SUPPRESSION	REQUIRED		
63	SOFT START	REQUIRED		
64	REVERSE BATTERY POLARITY PROTECTION	REQUIRED		
65	AUTOMATIC CURRENT LIMIT	REQUIRED		
66	DC WIRING VOLTAGE RATING	600V		
67	OUTPUT [FLOATING / GROUNDED]	FLOATING		
68	DC OUTPUT MINIMUM CABLE SIZE, CHARGER W/O BATTERY (AWG, # CONDUCTORS / PHASE)	VENDOR TO SPECIFY		
69				
70	**DC LOAD FEEDER BREAKER(S)**			
71	NUMBER OF OUTGOING LOAD FEEDER BREAKERS	1		
72	MANUFACTURER	VENDOR TO SPECIFY		
73	MODEL	VENDOR TO SPECIFY		
74	NO OF POLES	2 POLES EACH BREAKER		
75	VOLTS DC (V)	300V DC		
76	NOMINAL CURRENT RATING (A)	VENDOR TO SPECIFY		
77	INTERRUPTING CAPACITY (A)	VENDOR TO SPECIFY		
78				
79	**BATTERY**			
80	TYPE	OPzS TYPE BAE		
81	BATTERY DESIGN LIFE	20 YEARS		
82	MANUFACTURER	BAE OR APPROVED EQUAL		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
83	MODEL	VENDOR TO SPECIFY		
84	TOTAL REQUIRED CAPACITY (Ah)	840 Ah		
85	CONTINUOUS LOAD (A)	30 A ***(SEE NOTE 1)***		
86	MAXIMUM PEAK LOAD (A)	523A ***(SEE NOTE 1)***		
87	PEAK LOAD / TIME	***(SEE NOTE 1)***		
88	NO OF CELLS	60 CELLS		
89	BATTERY STANDBY / BACKUP TIME (HR)	8 HOURS MINIMUM		
90	BATTERY RECHARGE TIME	12 HOURS		
91	BATTERY ENCLOSURE	NEMA 1 VENTILATED		
92	BATTERY OUTGASSING DATA	VENDOR TO SPECIFY		
93	MID-BATTERY FUSE	REQUIRED		
94	BATTERY FUSE RATING (A)	VENDOR TO SPECIFY		
95				
96	**ENCLOSURE**			
97	CHARGER ENCLOSURE	REQUIRED		
98	OPERATION AND MAINTENANCE CLEARANCES [FRONT, BACK, SIDES, TOP] (INCHES)	VENDOR TO SPECIFY		
99	CABLE ENTRY /EXIT	TOP		
100	TYPE	INDOOR, NEMA/EEMAC TYPE 1		
101	SPECIAL PAINT COATINGS	RUST AND CORROSION RESISTANT		
102	EXTERIOR COLOUR	ANSI 61 GRAY		
103	INTERIOR COLOUR	WHITE		
104	ENCLOSURE SIZE [L x W x H] (INCHES)	VENDOR TO SPECIFY		
105	ENCLOSURE METAL GUAGE	VENDOR TO SPECIFY		
106	SHIPPING SPLITS	VENDOR TO SPECIFY		
107	CASE GROUNDING PAD	REQUIRED, FLAT PAD, NEMA STANDARD 2-HOLE		
108	GROUND BAR EXTERNAL CABLE CONNECTION	DRILLED - NEMA STANDARD 2-HOLE		
109				
110	**METERING AND MONITORING**			
111	AC VOLTMETER	REQUIRED		
112	TOUCHSCREEN DISPLAY	REQUIRED		
113	AC ON	REQUIRED		
114	AC CURRENT LIMIT	REQUIRED		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
115	DC REGULATION	REQUIRED		
116	DC CURRENT LIMIT	REQUIRED		
117	FLOAT	REQUIRED		
118	EQUALIZE	REQUIRED		
119	BOOST	REQUIRED		
120	DC VOLTMETER ON RECTIFIER DC OUTPUT	REQUIRED		
121	DC BATTERY VOLTMETER, CONNECTED TO BATTERY TERMINALS	REQUIRED		
122	CHARGER DC OUTPUT AMMETER	REQUIRED		
123	AC INPUT BREAKER AUXILIARY CONTACTS	2-NO, 2-NC		
124	DC OUTPUT BREAKER AUXILIARY CONTACTS	2-NO, 2-NC		
125				
126	**ALARMS**			
127	LOCAL ANNUNCIATION			
128	AC INPUT FAIL	FORM C, ISOLATED		
129	RECTIFIER FAILURE	FORM C, ISOLATED		
130	HIGH DC VOLTS	FORM C, ISOLATED		
131	LOW DC VOLTS	FORM C, ISOLATED		
132	POSITIVE GROUND FAULT	FORM C, ISOLATED		
133	NEGATIVE GROUND FAULT	FORM C, ISOLATED		
134	RECTIFIER LOW OUTPUT CURRENT	FORM C, ISOLATED		
135	HIGH RIPPLE	FORM C, ISOLATED		
136	LOW & HIGH FREQUENCY ALARM AND SHUTDOWN AND AUTOMATIC RESTART	FORM C, ISOLATED		
137	HIGH & LOW CHARGER TEMPERATURE ALARM AND PROGRAMMABLE CYCLIC SHUTDOWN	FORM C, ISOLATED		
138	RECTIFIER HIGH OUTPUT CURRENT	FORM C, ISOLATED		
139	RECTIFIER HIGH VOLT	FORM C, ISOLATED		
140	RECTIFIER LOW VOLT	FORM C, ISOLATED		
141	EQUALIZATION ON	FORM C, ISOLATED		
142	CONTACTS FOR REMOTE ANNUNCIATION			
143	RECTIFIER FAIL	FORM C, ISOLATED		

Row	Description	Design Requirements	Vendor Confirmation	Rev.
144	**COMMUNICATIONS**			
145	PROTOCOL	MODBUS TCP/IP		
146	DATA REQUIRED	STATUS, METERING VALUES, ALARMS		
147				
148	**BATTERY ISOLATING CIRCUIT BREAKER / DISCONNECT SWITCH**			
149	MANUFACTURER	VENDOR TO SPECIFY		
150	MODEL	VENDOR TO SPECIFY		
151	NO OF POLES	2 POLE		
152	VOLTAGE RATING	300V DC		
153	NOMINAL CAPACITY (A)	200A DC		
154	INTERRUPTING CAPACITY (KA)	10KA DC		
155	LOCKABLE / TAGABLE	REQUIRED		
156	DC BREAKER / DISCONNECT SWITCH AUXILIARY CONTACTS	2-NO, 2-NC		
157				
158	**NAMEPLATES**			
159	CHARGER NAMEPLATES	AS SPECIFIED IN SPEC		
160	BATTERY NAMEPLATES	AS SPECIFIED IN SPEC		
161	OTHER	CSA / ULC		
162				
163	**CONNECTIONS AND WIRING**			
164	WIRING	AS SPECIFIED IN SPEC		
165	COMMUNICATIONS	REQUIRED. ETHERNET		
166	COMMUNICATIONS PROTOCOL	ETHERNET IP		
167				
168	TESTING	AS PER NEMA PE 5		
169	PERFORMANCE	AS PER NEMA PE 5		
170	FUNCTIONAL	REQUIRED, AS SPECIFIED		
171				
172	**OTHER TECHNICAL REQUIREMENTS**	AS SPECIFIED		
173	PROVIDE COMPLIANCE STATEMENT TO SPECIFICATION REQUIREMENTS	VENDOR TO PROVIDE		

Row	Description	Design Requirements	Vendor Confirmation	Rev.

	ENGINEERING NOTES:			**Rev.**
174	1	**REQUIRED LOAD CYCLE**		
		A-1	522.68A FOR 1 MINUTE	
		A-2	29.18A FOR 478 MINUTES	
		A-3	177.68A FOR 1 MINUTE	
175	2			
176	3			

SIGNATURES: (Both signatures below are required)

Authorised Representative at Quoting Agency (Vendor)

Name [PRINT]	Signature	Position	Date

Authorised Representative at Manufacturer's Works (Manufacturer)

Name [PRINT]	Signature	Position	Date

— END of DOCUMENT —

SECTION 26 33 53

STATIC UNINTERRUPTIBLE POWER SUPPLY

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. Canadian Standards Association- CSA C22.2 No. 107.3- Uninterruptible Power Systems.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit Shop Drawings to include:
   1. System configuration with single-line diagrams.
   2. Functional relationship of equipment including weights, dimensions, and heat dissipation.
   3. Capacity data.
   4. Descriptions of equipment to be furnished.
   5. Size and weight of shipping units to be handled by installing contractor.
   6. Detailed installation drawings including all terminal locations.
   7. Bill of materials of components that can be replaced.
   8. Recommended spare parts.

1.3 CLOSEOUT SUBMITTALS

A. Provide data for incorporation into operation and maintenance manual specified in Section 01 77 00, Closeout Procedures

B. Operations and Maintenance manual to include:
   1. Operation and maintenance instructions concerning design elements, construction features, component functions and maintenance requirements to permit effective operations maintenance and repair.
   2. Testing & Commissioning report, both factory test & site testing reports.
   3. Technical Data:
      a. Approved Shop Drawings.
      b. Project data.
      c. Technical description of components.
      d. Parts lists with name and addresses of suppliers.
      e. Functional description of the equipment with block diagrams.
      f. Safety precautions.
      g. Instructions and step-by-step operating procedures.
      h. Routine maintenance guidelines, including illustrations.

1.4 SYSTEM START-UP

A. Provide factory authorized service personnel to supervise start-up of system, checking, adjusting and testing on site

PART 2 PRODUCTS

2.1 UNINTERRUPTIBLE POWER SUPPLY

A. Manufacturer and Model: APC MGE Galaxy 3500.

B. Conformance with CSA C22.2, No. 107.3.

C. CSA/cUL approved.

D. 200 percent neutral required as indicated on Drawings.

E. Technology
1. Online, double-conversion, solid state topology with static bypass switch.

F. Design Requirements – UPS Module
1. Voltage. Input/output voltage Specifications of the UPS shall be:
a. Rectifier Input: 208 volts, three-phase.
b. Output: 120/208 volts, three-phase, 4-wire plus ground.
2. Output Load Capacity. Specified output load capacity of the UPS shall be as indicated on Drawings at 0.8 lagging power factor.

G. Design Requirements – Battery
1. Battery Cells: Sealed, lead-acid, valve-regulated
2. Recharge Time: to 95 percent capacity within ten (10) times discharge time.
3. Provide means (circuit breaker or switch) to isolate the battery from the UPS
4. Runtime:
a. minimum 40 minutes at design full load

H. Modes of Operation
1. The UPS shall be designed to operate as an on-line system in the following modes:
a. Normal: The inverter and the rectifier shall operate in an on-line manner to continuously regulate the power to the critical load. The rectifier shall derive power from the AC input source and supply DC power to float charge the battery.
b. Emergency/Battery: Upon failure of utility AC power, the critical AC load shall continue being supplied by the inverter without any switching. The inverter shall obtain its power from the battery. There shall be no interruption in power to the critical load upon failure or restoration of the AC input source.
c. Recharge: Upon restoration of utility AC power, after a utility AC power outage, the UPS shall simultaneously recharge the battery and regulate the power to the critical loads.
d. Static Bypass: If the UPS must be taken out of service for maintenance or repair, or should the inverter overload capacity be exceeded, the static transfer switch shall

perform a reverse transfer of the load from the inverter to the bypass source with no interruption in power to the critical AC load. The static bypass switch shall be fully rated and shall be capable of manual operation. The UPS shall be able to recharge the batteries while supplying full power to the load via the static bypass switch.

e. Internal maintenance bypass switch: The UPS shall be provided with an internal manual bypass switch for supplying the load directly from the main supply, while the UPS is taken out for maintenance.

f. Maintenance Bypass Cabinet: The external maintenance bypass switch shall be located in a separate enclosure along with the main power supply transformer. This external switch shall be used to supply the load directly from the main supply, if the UPS system has to undergo maintenance or service. A UPS input, output, common output and bypass breaker shall be housed in the same assembly. The manual bypass breaker shall be monitored by the UPS via an auxiliary contact.

I. Performance Requirements

1. AC Input to UPS
   a. Voltage Configuration for Standard Units: three-phase, 3-wire plus ground.
   b. Voltage Range: +10 percent, -20 percent of nominal.
   c. Frequency: Nominal frequency plus or minus 5 percent.
   d. Power Factor: Up to 0.98 lagging at nominal input voltage and full rated UPS output load.
   e. Inrush Current: 500 percent of full load current maximum.
   f. Input Current Walk-In: Shall be linear from 0 to 100 percent of the load over a 15 second period.
   g. Current Distortion: <5 percent reflected THD maximum at full load.
   h. Surge Protection: Sustains input surges without damage per criteria listed in IEC 1000-4-5.
2. AC Output, UPS Inverter
   a. Voltage Configuration: three-phase, 4-wire plus ground
   b. Voltage Regulation:
      1) Plus or minus 1 percent three-phase RMS average for a balanced three-phase load for the combined variation effects of input voltage, connected load, battery voltage, ambient temperature, and load power factor
      2) Plus or minus 1 percent three-phase RMS average for a 100 percent unbalanced load for the combined variation effects of input voltage, connected load, battery voltage, ambient temperature, and load power factor
3. Frequency: Nominal frequency plus or minus 0.1 Hz in battery operation.
4. Phase Displacement:
   a. 20 degrees plus or minus 5 degree for balanced load.
   b. 20 degrees plus or minus 1 degree for 50 percent unbalanced load.
   c. 20 degrees plus or minus 3 degree for 100 percent unbalanced load.
5. Voltage Distortion
   a. <1.5 percent total harmonic distortion (THDi) for 100 percent linear loads
   b. <3.5 percent THD for 100 percent nonlinear loads without kVA/kW derating.
6. Load Power Factor Range: 0.5 lagging to 0.5 leading without derating.
7. Output Power Rating: Rated kVA at 0.8 lagging power factor
8. Overload Capability:
   a. 125 percent for ten minutes in normal and battery operation.

b. 150 percent for one minute in normal and battery operation.
c. 110 percent continuous bypass operation.
d. 800 percent for 500 milliseconds in bypass operation.

9. Inverter Output Voltage Adjustment: plus or minus 5 percent manual adjustment.
10. Voltage Transient Response:
    a. 100 percent load step plus or minus 5.0 percent.
11. Transient Recovery Time: 5- milliseconds to nominal.

J. Environmental Conditions
1. The UPS shall be able to withstand the following environmental conditions without damage or degradation of operating characteristics:
    a. Operating Ambient Temperature
        1) UPS Module: 0 degrees C to 40 degrees C.
        2) Battery: 15 degrees C to 25 degrees C.
    b. Storage/Transport Ambient Temperature
        1) UPS Module: -30 degrees C to 70 degrees C.
        2) Battery: -15 degrees C to 40 degrees C.
    c. Relative Humidity
        1) 0 to 95 percent, non-condensing.
    d. Altitude
        1) Operating: to 1000 meters above Mean Sea Level. Derated for higher altitude applications.

K. Audible Noise
1. Noise generated by the UPS under any condition of normal operation shall not exceed 51 dBA (10-20 kVA) or 55 dBA (30-40 kVA) measured 1 meter from surface of the UPS.

L. The UPS shall have provision for battery status monitoring, which shall include automatic battery tests on a scheduled basis, and be able to report on battery life remaining (estimate), total number of discharges, total time in discharge. The power to the load of the unit shall be completely protected from unanticipated battery failure during these tests

M. The UPS shall have controls mounted in panel front.

N. Factory Testing:
1. Before shipment, the Manufacturer shall fully and completely test the system to assure compliance with the Specification.

O. Relay Card
1. Provide status contacts for:
    a. UPS Fault
    b. Summary Alarm
    c. Low battery
    d. On Battery / ON UPS status
    e. On Bypass Status

P. Remote UPS Monitoring
1. Simple Network Management Protocol (SNMP)

2. Modbus TCP protocol and connection to a PLC for remote monitoring of the system.

2.2 MAINTENANCE BYPASS CABINET

A. Transformer in accordance with CAN/CSA-C22.2 No. 47.
   1. Internal 600:120/208 V transformer. Size as indicated on Drawing.

B. Include:
   1. Input and output breakers suitable for bypass switching.
   2. Make-before-break capability for all switching, including switch with UPS, Line, Service, and Off Positions.

2.3 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results – Electrical

B. Nameplate for each UPS to be size 9, example as followed:

UPS-K712 15 kVA 120/208V, 3Ø, 4W

C. Nameplate for each Maintenance Bypass Cabinet to be size 9, example as followed:

MTS-K712 WITH XFMR 30 kVA, 600-120/208V FED FROM MCC-K710

D. Nameplate for each Battery Cabinet (if required) to be size 9, example as followed.

BAT-K712 15 kVA

E. Add separate UPS panelboard identifier as per panelboard spec, example as followed:

PNL-K713U 120/208V, 3Ø, 4W FED FROM UPS-K712

PART 3 EXECUTION

3.1 INSTALLATION

A. Locate UPS and Maintenance Bypass Cabinets as indicated on the Drawings

B. Support and anchor the UPS as per Manufacturer's instructions

C. Connect and configure UPS and Maintenance Bypass Cabinets as per Manufacturer's Installation Manual.
   1. Wire input, output, and ground bus bars
   2. Connect control cables
   3. Connect AC main cables to main input terminal
   4. Connect UPS output to load panel
   5. Connection of internal batteries to be performed ONLY by factory authorized service personnel.

D. Start-up UPS and make preliminary tests to ensure satisfactory performance. Do not power UPS without factory authorized service personnel present.

3.2 DEMONSTRATION AND TRAINING

A. Provide demonstration by factory trained representative in use and maintenance of UPS system.
   1. Allocate a minimum of four hours for training for each UPS.

B. On-site Operational Training: During the factory-assisted start-up, operational training for site personnel shall include, but shall not be limited to:
   1. Keypad operation,
   2. LED indicators.
   3. Start-up and shutdown procedures.
   4. Maintenance Bypass.
   5. AC disconnect operations.
   6. Alarm information.

END OF SECTION

SECTION 26 35 33

ACTIVE HARMONIC FILTER POWER FACTOR CORRECTION

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. UL 1449 – Standard for Transient Voltage Surge Suppressers

B. CSA C22.2 No. 233.1- Surge withstand capacity

C. CSA C22.2, No. 14 – Industrial Control Equipment

D. CSA C22.2, No. 66 – Specialty Transformers, Industrial Products

E. ANSI IEEE 519 – Guide for Harmonic Control and Reactive Compensation of Static Power Converters

F. UL 508 - UL requirements for power conversion equipment

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Submit Shop Drawing and indicate:
   1. Outline dimensions, front, side and sectional views.
   2. Foundation and support details.
   3. Enclosure construction, lifting, supporting points, and weight.
   4. Conduit/cable entrance locations and requirements.
   5. Electrical single line diagram and equipment electrical ratings including voltage, frame size and trip rating, withstand ratings, and time current curves of equipment and components.
   6. Recommended supply breaker and cable sizes.
   7. Standard catalog sheets for current transformers.
   8. Compartment layout drawings showing device location.
   9. Wiring diagram indicating:
      a. Terminal blocks and terminal numbers
      b. C.T recommended wiring arrangement
      c. Control systems and signals
      d. Indicate field wiring as well as internal wiring. Differentiate between contractor field installed wiring.
   10. Recommended spare parts list.

11. Harmonic Filter/Power Factor correction size calculation.

D. Submit certified factory test results.

E. Closeout Submittals
1. Complete set of Shop Drawings and submittals
2. Operations and maintenance manuals.
3. Factory test reports
4. Literature detailing the programming and set points.

1.3 MAINTENANCE

A. Provide maintenance materials for incorporation into O & M manuals in accordance with Section 26 05 01, Common Work Results - Electrical.

1.4 QUALITY ISSURANCE

A. Prior to shipment, the Manufacturer shall fully the performance at full current and voltage while functioning as a harmonic correction device to assure compliance with equipment Specification defined here-in.

B. The Manufacturer to provide a factory certified report at successful completion of Performance Tests.

C. Provide testing and Commissioning documentation, signed by a factory certified representative.

PART 2 PRODUCTS

2.1 CHARACTERISTICS

A. CSA Approved.

B. 3 Phase.

C. Voltage: 600 VAC.

D. Run: 60 Hz.

E. Equipment to perform harmonic mitigation, power factor correction, load balancing and VAR support.

F. Rated Compensation Current: As indicated on Drawing.

G. Size equipment to correct the system power factor to between 0.96 and 0.99 lagging.

H. Interrupting Rating: As indicated on Drawing.

I. Operating Ambient Temperature rating: 0 degrees C to plus 40 degrees C.

J. Storage Temperature: minus 40 degrees C to plus 65 degrees C.

K. Active harmonic power factor filter shall be suitable for operation on an electrical system having a generator as its power source. The harmonics filter shall be designed and suitable to operate with either one of the main breakers open, and the tie breaker closed.

L. Ability to run multiple filters in parallel may be used to achieve total current requirements for combined power factor correction and harmonic cancellation.

M. Shall include internal current limiting devices for protection of IGBTs.

N. Harmonic distortion shall be less than or equal to 5 percent THD for the 2nd thru 50th order harmonics.

O. Total Demand Distortion (TDD) less than limits indicated in IEEE 519, Table 10.3.

P. Filter shall have automatic restart capability upon power loss return and fault resets.

Q. 120VAC, 5A form “C” rated dry contacts for alarm output, indicating any internal alarm condition. Provide LED indication visible from exterior.

R. Digital Human Machine Interface (HMI) accessible from exterior.

S. Controller shall be capable of but not limited to the following communication abilities:
   1. Ethernet TCP/IP
   2. RS485 Modbus RTU
   3. USB
   4. Automatic Email Reporting with frequency of reporting determined by customer.
   5. Android application for remote control, logging, monitoring and setting.

T. Modbus TCP/IP communication from the controller/HMI for feedback and status to external devices.

U. Separate grounding lug.

V. All equipment shall be CSA, or ULC rated. IEC rated equipment is not accepted.

2.2 CAPACITOR

A. CSA and UL approved.

B. Self-healing type utilizing a low-loss metalized polypropylene film dielectric system with a pressure sensitive interrupter. Metalized paper is not acceptable.

2.3 ENCLOSURE

A. NEMA Type 12 free standing enclosure with a door interlocked disconnect. When power is turned on the door cannot be opened.

B. Required fans and louvers to maintain specified temperature in enclosure.

C. Appropriate warning labels indicating dangerous voltages in enclosures.

D. Lifting lugs to allow for transport.

E. Size: to fit within the proposed location as shown on the Drawings.

2.4 CURRENT TRANSFORMERS

A. Three current transformers (one for each phase) located at the main breaker and at the tie breaker.

B. Rated Primary Current: Based on peak RMS Current, indicated on Drawing.

C. Nominal Voltage: 600 VAC.

D. Accuracy Class: 1.0 or better.

E. Output Power/ Burden: 2.5 VA per active filter used. (i.e. 5 VA for 2 active filters used in parallel)

F. Current transformer wiring as per Drawings and in accordance with the Manufacturer's recommendations.

G. Provide shorting terminal block, to allow for the system to be taken out of service for maintenance in a safe and reliable manner.

2.5 APPROVED MANUFACTUERS

A. Active Harmonic Power Factor Filter Manufacturer: Schneider Electric Accusine PCS+ or Electrotek Sinexcel AHF.

2.6 ACCESSORIES

A. Lifting lugs (minimum of 4).

B. Spare fuses (minimum 3 of each type or size)

2.7 FINISH

A. Finish exterior of unit in accordance with Section 26 05 01, Common Work Results -Electrical

2.8 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results - Electrical.

B. Nameplate for each active filter to be size 9, example as followed:

HF-R701 ACTIVE HARMONIC FILTER 200 A, 600V, 3Ø

2.9 WARNING SIGNS

A. Provide warning signs in accordance with Section 26 05 01, Common Work Results - Electrical and in accordance with the requirements of the CEC.

2.10 SOURCE QUALITY CONTROL

A. Submit to the Departmental Representative standard factory test certificates of each active harmonic power factor filter in accordance with CSA C2 and Specification Section 26 08 05, Acceptable Testing. Include test results in the O & M Manuals.

PART 3 EXECUTION

3.1 MANUFACTURER’S INSTRUCTION

A. Compliance: comply with Manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets

3.2 INSTALLATION

A. Install and connect active harmonic power factor filter. Installation shall comply with Manufacturer’s instructions, drawings, and recommendations. Provide correct breaker in accordance with the Manufacturer’s recommended size.

B. Ensure filter is grounded.

C. Wire and connect in accordance with the Manufacturer’s instructions.

D. Manufacturer shall provide a certified technical service representative to review the contractor’s installation and to oversee the testing and commission the unit. Programming shall be performed by the Manufacturer’s approved representative.

3.3 FIELD QUALITY CONTROL.

A. Perform tests in accordance with Section 26 05 01, Common Work Results - Electrical and Section 26 08 05, Acceptance Testing.

3.4 START-UP AND SITE TESTING

A. Provide a Manufacturer's certified field service representative to provide start-up and testing. Site testing shall be in accordance with Manufacturer's standards. The Manufacturer's approved service representative must perform Commissioning.

B. A three phase harmonic analyzer shall be used to measure TDD and THD (V) levels to verify performance meets Specification herein. Test reports shall be prepared for each point of test. Test reports shall be documented, signed, and dated. All tests shall be submitted.

C. Set-up and verify all parameters and settings. Verify correct operation with loads in operation.

D. Provide formatted, typed forms indicating all settings as programmed. Include in Operations and Maintenance manuals.

E. Provide all equipment to perform system programming. Turn over to the department representative.

F. The Contractor shall measure and verify using field data logging devices, the harmonics contribution of each branch breaker feeding process and mechanical equipment in order to assist the mechanical and process systems contractor in trouble shooting their equipment, and to make sure that the equipment is performing within the required Specification.

G. The Contractor will coordinate the startup of the harmonic filter power factor correction unit with the mechanical and process equipment contractor, to ensure proper operation of the system with all the process and mechanical loads online.

3.5 TRAINING

A. Furnish the services of a competent, factory trained-engineer or technician for a period of two 8 hour sessions to instruct City personnel in the operation and maintenance of the equipment, on a date requested by the Contact Administrator.

END OF SECTION

SECTION 26 41 13

LIGHTNING PROTECTION FOR STRUCTURES

PART 1 GENERAL

1.1 RELATED SECTIONS

A. Section 26 05 01, Common Work Results

B. Section 26 05 28, Grounding and Bonding

1.2 CODES AND STANDARDS

A. Institute of Electrical and Electronics Engineers, Inc. (IEEE) – IEEE 8372002, Standard for Qualifying Permanent Connection Used in Substation Grounding.

B. CAN/CSA-B72 M87 (R2008) – Installation Code for Lightning Protection Systems

C. UL 96A – Standard for Installation Requirements for Lightning Protection Systems

D. UL 96 – Lightning Protection Components

E. NFPA 780 – Standard for the Installation of Lightning Protection Systems

F. LPI 175 – Standard for the Design – Installation – Inspection of Lightning Protection Systems

1.3 QUALITY ASSURANCE

A. The lightning protection installation and Shop Drawing design submittal shall be performed by qualified contractor, with the following minimum standard:
   1. Minimum of 10 years specializing in lightning protection systems.
   2. Lightning Protection Institute (LPI) accredited installer and designer.

1.4 ACTION AND INFORMATIONAL SUBMITTALS

A. Shop Drawings:
   1. Submit Drawings stamped and signed by Professional Engineer registered or licensed in Manitoba, Canada.
   2. Indicate materials and methods of attachment of conductors to air terminals and electrodes.
   3. Submit datasheets of all components used, including make, model number, part number, physical details and measurements.

PART 2 PRODUCTS

2.1 ACCEPTED MATERIALS

A. All lightning protection system components shall be listed and approved for use as part of a lightning protection system, except hardware screws, bolts, washers, nuts.

B. Air terminals (Lightning Rods): Aluminum, minimum 305mm (12”) in height. Use of copper is restricted only to specific instances where galvanic interaction of dissimilar metals will cause corrosion and there is no other reasonable means to attach aluminum components.

C. Conductors on roof: Aluminum, stranded, minimum sizes required for the Class of structure. Use of copper is restricted only to specific instances where galvanic interaction of dissimilar metals will cause corrosion and there is no other reasonable means to attach aluminum components. Provide bimetal connection when splicing aluminum and copper conductors to prevent galvanic interaction of dissimilar metals.

D. Down conductors: Copper, stranded, minimum size 2 AWG. Provide bimetal connection when splicing copper conductors and aluminum conductors to prevent galvanic interaction of dissimilar metals.

E. Fastening and attachment straps: Aluminum. Use of copper is restricted only to specific instances where galvanic interaction of dissimilar metals will cause corrosion and there is no other reasonable means to attach aluminum components.

F. Ground electrodes: Copper clad steel, 19 mm diameter, minimum length of 3 m, joined end-to-end as required. Where multiple rods are connected to form a 6 m long rod, utilize a threadless compression coupling.

G. Use aluminum conductors, terminals, connectors and fastenings for aluminum sheathed buildings or equipment. Use copper conductors, terminals, connectors and fastenings for buildings or equipment sheathed in other than aluminum.

H. Connections: Where possible, all connections are to be formed by exothermic weld process. For copper connections, exothermic weld connections are required. For Aluminum connections, use compression connections, as exothermic welds are not readily available.

I. All connectors and splicers shall be of suitable configuration and type for the intended application and shall be of the same material as the conductor or of electrolytically compatible materials.

2.2 DESCRIPTION

A. System to consist of metallic air terminals, lightning conductors connecting air terminals to ground, and interconnected ground electrodes, and/or ground cables.

2.3 MANUFACTURERS

A. Acceptable Product / Component Manufacturers: Erico, Thompson Lightning Protection Inc, Advanced Lightning Technologies, or approved equal in accordance with B8.

PART 3 EXECUTION

3.1 EXAMINATION

A. Verification of Conditions: verify conditions of substrates and facilities previously installed under other Sections or Contracts are acceptable for lightning protection installation in accordance with Manufacturer's written instructions.
   1. Visually inspect substrate in presence of Contract Administrator.
   2. The Contractor is responsible for compaction of substrate to native soil conditions in order to install ground electrodes.
   3. Visually inspect facilities and buildings.

3.2 INSTALLATION

A. Supply and install lightning protection to CAN/CSA-B72, UL 96A and NFPA 780 standards.

B. Supply and install ground electrodes.

C. Air terminal layout and placement position with at least 2 directional paths to ground.

D. Protect any and all objects elevated above the normal roof height and with a surface thinner than 4.7mm (3/16”). This includes exhaust fan housings, air handling units, masts, exhaust vents and ducting, etc.

E. Metallic objects having a thickness greater then 4.7mm (3/16”) may serve as strike termination devices without the addition of air terminals. These bodies shall be made a part of the lightning protection system by connection and bonding fittings with 2000 mm^2 (3 in^2) of surface contact area.

F. Copper components shall not be mounted directly on aluminum or galvanized surfaces. Measures must be taken to avoid corrosion and reactions with dissimilar metals.

G. Attachment of cable secured to air terminals, and building shall be secured along the cable run and attachment shall not be more than 915mm apart.

H. Cable bend radius at corners or over building sidewalls with 90 degrees minimum 204mm (8”) radiuses.

I. Penetrations and connections to roof systems shall be done in accordance with the roofing contractor’s recommendations and requirements. Connection to the roofing system shall in no way compromise the integrity or warranty of the roof system.

J. Structural elements and design features shall be used whenever possible to minimize the visual impact of exposed conductors.

K. Cable down conductors to be protected and concealed using rigid PVC conduit.

L. Bond discharge conductors to service mast or other non-current-carrying electrical parts.

3.3 INSPECTION

A. Obtain inspection certificate certifying that the installation is compliant with applicable codes and standards from an LPI-IP Certified Field Inspector for the system. Submit to the Contract Administrator.

3.4 PROTECTION

A. Protect installed products and components from damage during construction.

B. Repair damage to adjacent materials caused by lightning protection installation.

END OF SECTION

SECTION 26 50 00

LIGHTING

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. Canadian Standards Association.

B. Underwriters Laboratories of Canada (ULC).

C. IES LM79 & LM80.

1.2 SUBMITTALS

A. Provide submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, specifications and datasheets and include product characteristics, performance criteria, and limitations.

C. Include equipment catalog numbers and fixture type on all submitted Shop Drawings.

1.3 QUALITY ASSURANCE

A. All equipment and materials are to be new and CSA approved.

PART 2 PRODUCTS

2.1 GENERAL

A. Luminaires shall carry the CSA label.

B. Provide supporting devices, plaster frames, junction boxes and outlet boxes where required.

C. Where soffits or ceilings have thermal insulation, provide fixtures which are CSA approved for such use.

D. Luminaire types shall be as indicated on the Drawings. In general, the Facility shall have a number of different luminaire type, which include fluorescent as well as LED. A requested for equal from a different luminaire Manufacturer / vendor shall be submitted and approved (if deemed to be equal by the Contract Administrator) in accordance with the Contract Documents prior to tender close.

E. Refer to the Drawings for the fixture types, manufacturer and model numbers.

2.2 FLUORESCENT LAMPS

A. Provide lamps for all fixtures as applicable.

B. Fluorescent lamps shall be T8 32W lamps (4’ fixtures) or to suit the luminaire.

C. Burn in fluorescent lamps for a minimum of 100 hours prior to switching in order to burn off all impurities.

2.3 FLUORESCENT BALLASTS AND ACCESSORIES

A. Provide ballasts and accessories to suit the fixture type. Ballasts shall be Manitoba Hydro power smart approved.

B. Provide ballasts with non-PCB type capacitors with pressure sensitive devices to prevent rupturing.

C. Provide discreet electronic rapid start fluorescent ballasts of 120V or 347V design, automatic reset thermal protected, 90 percent power factor, group A noise rating. Only Premium High Efficiency approved ballasts will be accepted.

2.4 LIGHT EMITTING DIODE (LED) LIGHTING

A. Refer to luminaire schedule on the Drawings for acceptable products.

B. Indoor Lighting
   1. Voltage Rating: As indicated on Drawing.
   2. Power rating: As indicated on Drawings.
   3. Input Frequency: 60 Hz.
   4. L70 at 60 000 hours or greater.
   5. Correlated Color Temperature (CCT): minimum 4000K.
   6. Color Rendering Index (CRI): >= 80.
   7. NEMA 4X or approved equal in accordance with B8.
   8. Aluminum or stainless steel housing.

C. Hazardous Locations, Class 1, Division 1.
   1. Voltage Rating: As indicated on Drawing.
   2. Power rating: As indicated on Drawings.
   3. Input Frequency: 60 Hz.
   4. L70 at 60 000 hours or greater.
   5. Correlated Color Temperature (CCT): minimum 4000K.
   6. Color Rendering Index (CRI): >= 70.
   7. Aluminum housing.
   8. Class 1, Division 1 rated.

D. Hazardous Locations, Class 1, Division 2.
   1. Voltage Rating: 347 VAC.
   2. Power rating: As indicated on Drawings
   3. Input Frequency: 60 Hz.

4. L70 at 60 000 hours.
5. Correlated Color Temperature (CCT): minimum 4000K.
6. Color Rendering Index (CRI): >= 70.
7. Aluminum housing.
8. Class 1, Division 2 rated.

E. Outdoor Lighting
1. Voltage Rating: 347 VAC.
2. Power rating: As indicated on Drawings.
3. Input Frequency: 60 Hz.
4. L70 at 54 000 hours.
5. Correlated Color Temperature (CCT): minimum 4000K.
6. Color Rendering Index (CRI): >= 70.
7. Ambient Operating Temperature: -40 degrees C -55 degrees C.

2.5 FINISH

A. Light fixture finish and construction to meet ULC listings and CSA certifications related to intended installation

PART 3 EXECUTION

3.1 MANUFACTURER’S INSTRUCTION

3.2 Compliance: comply with Manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets

3.3 INSTALLATION

A. General:
1. In general, the Contractor is responsible for upsizing conductors to account for voltage drop. Conductor sizes as described on the Drawings, panel schedules and elsewhere are minimum size, and are highly dependent on specific cable routing. The Contractor shall upsize wiring as required to meet the requirements herein, and in order to comply with CEC requirements.
2. For 120 VAC lighting wiring from a 1P, 15A breaker, upsize wiring in order to accommodate voltage drop (calculated based on 80 percent of the 15A breaker rating), in accordance with the following:
a. No. 12 AWG for runs up to a distance of 20M from the source panel.
b. No. 10 AWG for runs between a distance of 20M and 35M from the source panel.
c. No. 8 AWG for runs between a distance of 35M and 50M from the source panel.
d. No. 6 AWG for runs between a distance of 50M and 75M from the source panel.
e. Upsize further runs as required to meet the CEC.

3. For 347 VAC lighting wiring from a 1P, 15A breaker, upsize wiring in order to accommodate voltage drop (calculated based on 80 percent of the 15A breaker rating), in accordance with the following:
   a. No. 12 AWG for runs up to a distance of 80M from the source panel.
   b. No. 10 AWG for runs between a distance of 80M and 120M from the source panel.
   c. No. 8 AWG for runs between a distance of 120M and 200M from the source panel.
   d. No. 6 AWG for runs between a distance of 200M and 330M from the source panel.
   e. Upsize further runs as required to meet the CEC. For long runs voltage drop can be dealt with by reducing the circuit loading.

B. Locate and install luminaires as indicated on Drawings. Luminaires shall be installed using rigid supports. Acceptable means of support include:
   1. Rigid Aluminum Conduit / Pipe
   2. Threaded Rod
   3. Cantruss

C. Lighting fixtures shall be installed in accordance with fixture Manufacturer's recommendations, and the requirements herein. Each luminaire shall be solidly and rigidly installed in a manner so that the fixture does not move or swing.

D. Wire and connect fixtures using 12 AWG or larger, RW90 run in conduit. Conduit to be as specified in Section 26 05 34, Conduits, Conduit Fasteners, and Conduit Fittings.

E. Short flexible connections (less than 2 meters in length) to luminaires may be HL rated TECK 90 cable.

F. The Drawings do not show conduit routing or conduit sizes and wire counts. Supply and install a complete system of conduit and wire for the lighting system. Make all connections and install all conductors for the switching and branch circuiting indicated and required.

G. Conduits shall be sized in accordance with CEC requirements for wire counts installed. In no case shall conduit less than 21mm be used. Conductors shall be de-rated according to code requirements. Upsize conductors as required to meet CEC and voltage drop requirements.

H. Install a permanent label or lamacoid for all luminaires indicating the circuit(s) connected to:
   1. Example: R731-2 (Panel PNL-R731, circuit 2).

3.4 LUMINAIRE SUPPORTS

A. Provide adequate support to suit ceiling or wall mounted luminaires.

3.5 CONTROL.

A. Provide controls as indicated on Drawings.

3.6 FIELD QUALITY CONTROL

A. Operate each fixture after installation and connection. Each fixture shall be inspected for proper connection and operations.

B. Perform testing of all lighting systems.

C. Completely clean all luminaires, exterior, interior, lamps, lenses, etc after construction, and prior to turning over to the COW.

3.7 PROTECTION

A. Lighting fixtures, once installed, shall be protected from damage during the remainder of the construction period. Make good & replace any damages occurring during construction.

B. Damage to luminaires occurring during construction shall be replaced by the Contractor at the Contractor's expense. The decision as to what constitutes a damaged fixture which requires replacement is at the discretion of the Contract Administrator.

END OF SECTION

SECTION 26 52 02

CENTRAL EMERGENCY LIGHTING SYSTEM

PART 1 GENERAL

1.1 CODES AND STANDARDS

A. CSA C22.2 No. 141-10 - Emergency Lighting Equipment.

B. CSA C22.2 No. 107-3 - Uninterruptible Power Systems

C. UL 942 – Standard Emergency Lighting and Power Equipment.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

B. Product Data:
   1. Submit Manufacturer's printed product literature, Specifications and datasheets and include product characteristics, performance criteria, and limitations.

   C. Submit Shop Drawings to include:
   1. System configuration with single-line diagrams.
   2. Wiring diagrams, indicating terminal numbers.
   3. Over-current protection devices, indicating recommended breaker sizes.
   4. A complete set of equipment drawings.
   5. Equipment Specifications, including weights, dimensions, and heat dissipation.
   6. Capacity data.
   7. Descriptions of equipment to be furnished.
   8. Size and weight of shipping units to be handled by installing contractor.
   9. Bill of materials and recommended spare parts list.
   10. Detailed installation procedures.
   11. Instruction manuals. Manuals shall include a functional description of the equipment, installation instruction, safety precautions, step-by-step operating procedures and routine maintenance guidelines, including illustrations.
   12. Manufacturer recommended Field Commissioning and Test Procedures.

1.3 CLOSEOUT SUBMITTALS

A. Provide data for incorporation into operation and maintenance manual. Operations and Maintenance manual to include:
   1. Operation and maintenance instructions concerning design elements, construction features, component functions and maintenance requirements to permit effective operations maintenance and repair.
   2. Testing and Commissioning report, both factory test and site testing reports.

1.4 QUALITY ISSURANCE.

A. Before shipment, the Manufacturer shall fully and completely test the system to assure compliance with the Specification.

PART 2 PRODUCTS

2.1 CENTRAL BATTERY SYSTEM (CBS) CHARACTERSTICS:

A. CSA approved.

B. Load description:
   1. Lighting consisting of the following:
      a. LED Lighting.
      b. Incandescent Lighting.
      c. Fluorescent Lighting.

C. Voltage Rating:
   1. 347/600 VAC.
   2. 120/208 VAC.

D. Performance Requirements – AC Input to CBS
   1. Voltage Configuration for Standard Units: 3 phase, 4-wire plus ground.
   2. Voltage Range: (+10 percent, -15 percent)
   3. Frequency: 60 Hz.

E. Performance Requirements: AC Output, Inverter
   1. Voltage Configuration for Standard Units: 3 phase, 4-wire plus ground
   2. Output Harmonic Distortion: <5 percent.
   3. Frequency: 60 Hz.
   4. Load Power Factor Range: 0.7 lagging to 0.9 leading.
   5. Overload Capability:
      a. 120 percent Continuous rating.
      b. 150 percent for 1 minute.
      c. 200 percent for 10 seconds.
   6. Crest factor: <=3.
   7. Efficiency: >=97 percent.

F. Power Rating: As indicated on Drawing.

G. Transfer time: 500 ms maximum.

H. Modes of Operation
   1. The CBS shall be designed to operate in the following modes:
      a. Normal – The CBS shall be an off-line standby system and the utility AC power continuously supplies the essential loads while simultaneously providing floating charge to the battery.

b. Emergency/Battery - Upon failure of utility AC power, the essential AC load shall be transferred from the utility AC power to the battery system. There shall be no more than a 500 ms loss of power to the essential load upon failure or restoration of utility AC power.
c. Recharge - Upon restoration of utility AC power, the inverter shuts down. The CBS will automatically change position, providing the load with utility AC power again. The CBS starts recharging the batteries.

I. Battery Requirements
1. Provide sealed, valve regulated lead acid batteries for the CBS.
2. The battery reserve time shall be 30 minutes unless otherwise indicated.
3. The battery charger shall recharge the fully discharged batteries within a 24-hour period. The charger shall be constant voltage, current limited, with temperature compensation. The charge shall use modular construction.
4. Disconnect shall be included to isolate battery from CBS module.
5. Sealed Lead Calcium VRLA, 10 year life expectancy.

J. Environmental Conditions
1. The CBS shall be able to operate within the specified design and performance criteria, provided that the following environmental conditions are met:
a. Operating Ambient Temperature
1) 0 degrees C to 40 degrees C.
b. Storage/Transport Ambient Temperature
1) Electronics: 0 degrees C to 40 degrees C.
2) Battery: 20 degrees C to 30 degrees C.
c. Relative Humidity
1) 0 to 95 percent, non-condensing.
d. Altitude
1) Operating: to 3000 meters above Mean Sea Level. Derated for higher altitude applications.
e. Audible Noise
1) 45 dBA at 1 metre from the surface of the CBS.

2.2 DISPLAY AND CONTROLS

A. The system shall include an LCD display for local monitoring and control.

B. The system shall include but not limited to the following measurements:
1. AC Voltage Output per phase.
2. AC Output Current Normally Off per phase.
3. Battery Voltage.
4. Battery Charging Current.
5. Battery Discharging Current.
6. VA Output per phase.
7. Cabinet Internal Temperature.
8. Inverter Frequency.
9. Real-Time Clock.
10. Time Delay.

11. Monthly Tests Result.
12. Half Year Test Result.
13. Annual Test Result.
14. Event Log Reading.

C. Alarm Conditions -The system shall activate an alarm for at least the following conditions:
1. Battery High Voltage.
2. Battery Low Voltage.
3. Low Voltage Disconnect.
4. Charger Failure.
5. Supply from Battery.
6. Inverter Overvoltage.
7. Inverter Under voltage
8. Output overload or overcurrent.
9. High Internal temperature.
10. Inverter output frequency out of range.

2.3 COMMUNICATION INTERFACE

A. Form ‘C” Dry Contacts.
1. The system shall be equipped with at least two dry form “C” contacts that will change position during any system alarm condition.

B. Modbus RTU Communication.

2.4 MANUAL AND AUTOMATIC TESTING

A. The CBS shall provide manual testing and automatic test functions.

B. The CBS shall include the following types of tests:
1. Monthly diagnostic tests.
2. 1/3 discharge test every 6 months
3. Full discharge test every 12 months.

C. Date and time of test are programmable.

2.5 ENCLOSURE/CABINET

A. The CBS shall be located in a freestanding NEMA type 1 enclosure.

B. Front Access.

C. Forced air cooling during emergency and recharge modes.

2.6 EQUIPMENT IDENTIFICATION

A. Provide equipment identification in accordance with Section 26 05 01, Common Work Results – Electrical

B. Nameplate for each battery system to be size 9, example as followed:

ELB-K723E EMERGENCY BATTERY SYSTEM 13.5 kVA, 347/600V, 3Ø, 4W

2.7 APPROVED MANUFACTURERS.

A. Lumacell Arges Central Battery System Interruptible Power Supply.

PART 3 EXECUTION

3.1 MANUFACTURER’S INSTRUCTION

3.2 Compliance: comply with Manufacturer's written recommendations or specifications, including product technical bulletins, handling, storage and installation instructions, and datasheets

3.3 INSTALLATION

A. Locate CBS as indicated on the Drawings

B. Support and anchor the CBS as per Manufacturer’s instructions

C. Connect and configure CBS as per Manufacturer’s Installation Manual.
   1. All wiring shall be installed in conduit. Input and output wiring shall be in separate conduits entering the cabinet.

3.4 START-UP AND SITE TESTING

A. Provide a Manufacturer’s certified field service representative to provide start-up and testing. Site testing shall consist of a complete test of the CBS and accessories by the CBS Manufacturer in accordance with Manufacturer’s standards. The Manufacturer’s approved service representative must perform Commissioning.

B. Provide formatted, typed forms indicating all tests conducted and settings as programmed.

3.5 TRAINING

A. Furnish the services of a competent, factory trained-engineer or technician for a period of two 8 hour sessions to instruct City personnel in the operation and maintenance of the equipment, on a date requested by the Contact Administrator.

END OF SECTION

SECTION 26 53 00

EXIT LIGHTS

PART 1 GENERAL

1.1 SUBMITTALS

A. Canadian Electrical Code.

B. National Building Building Code of Canada.

C. National Fire Code of Canada.

D. Canadian Standards Association
1. CSA-C22.2 No.141, Emergency Lighting Equipment.
2. CAN/ULC-S572, Photoluminescent and Self-Luminous Signs and Path Marking Systems.

1.2 SUBMITTALS

A. Provide Submittals in accordance with Section 01 33 00, Submittal Procedures and Section 26 05 01, Common Work Results - Electrical.

PART 2 PRODUCTS

2.1 GENERAL

A. All exit signs shall be pictogram style.

B. All powered exit signs will be fed from an emergency central battery system unless indicated otherwise. Any exit sign not fed from battery system must be equipped with a battery unit and emergency LED lighting heads.

C. Non-powered, photoluminescent exit signs shall comply with the City of Winnipeg “Photoluminescent Exit Signs Checklist”.

D. Provide wall mount and ceiling mount kits as required to ensure exit sign visibility and optimal mounting arrangement.

2.2 STANDARD UNITS (POWERED)

A. Class 1, Division 1 Hazardous Locations:
1. Class 1, Division 1 rated.
2. White light-emitting diode (LED).
3. Voltage input: 120 VDC. Provide transfer panel for 347 VAC supply.
4. Less than 4 W.

5. Equipment frame: Industrial grade 14-gauge steel.
6. Faceplate: Three layers consisting of a white translucent panel, a legend film, and a clear poly-carbonate panel for rigidity enforcement.
7. Single or double face option. Shall include straight, right, and left faceplates.

B. Class 1, Division 2 Hazardous Locations:
1. Class 1, Division 2 rated.
2. White light-emitting diode (LED).
3. Voltage input: 347 VAC.
4. Less than 2.5 W.
5. Equipment frame: Industrial grade polyvinyl chloride.
6. Faceplate: Sealed heavy duty, vandal-resistant polycarbonate.
7. Single or double face option. Shall include straight, right, and left faceplates.

C. Non-Hazardous Industrial Locations.
1. NEMA-4X rated.
2. White light-emitting diode (LED).
3. Voltage input: 347 VAC.
4. Less than 2.5 W.
5. Equipment frame: Industrial grade polyvinyl chloride.
6. Faceplate: Sealed heavy duty, vandal-resistant polycarbonate.
7. Single or double face option. Shall include straight, right, and left faceplates.

D. Non-Industrial Locations (Office type areas)
1. White light-emitting diode (LED).
2. Voltage input: 120-347 VAC.
3. Less than 2.5 W.
4. Equipment frame: Extruded Aluminum.
5. Faceplate: Extruded aluminum with a protective clear polycarbonate panel.
6. Single or double face option. Shall include straight, right, and left faceplates.

2.3 NON-POWERED PHOTOLUMINESCENT UNITS.

A. Characteristics:
1. Illumination provided by borosilicate glass tubes, internally coated with zinc sulphide phosphor and filled with tritium gas.
2. Minimum life expectancy of 10 years.
3. Heavy duty ABS housing with aluminum frame.
4. CN/ULC-S572 complaint.
5. Single face. Shall include straight, right, and left faceplates.

2.4 APPROVED MANUFACTURER

A. Approved Manufacturer
1. Lumacell, Ready-Lite, Emergi-Lite or approved equal in accordance to B8 - Substitutes.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install exit lights to Manufacturer's recommendations, listing requirements, NFPA standard and local regulatory requirements.

B. Install exit signs at locations with direct arrows to suit the location, with single or double face as noted on Drawings. Provide all mounting devices, orientation, supports and installation.

C. Exit signs indicated on the Drawings are shown at their approximate location. The Contractor is to provide mounting supports, and is to adjust the exact location and mounting elevation in order to provide a clear field of view to the exit sign. Exit signs which are blocked by equipment or blocked due to location will not be accepted and shall be relocated at no additional cost in order to be clearly visible.

D. Connect fixtures to exit light circuits using 12 AWG or larger, RW90 wire. Wire and connect exit signs using conduit as specified in Section 26 05 34, Conduits, Conduit Fasteners, and Conduit Fittings.

E. The Contractor is to ensure that the exit signs are located in a manner such that they are visible throughout the required floor area. Coordinate location with other trades. Make location adjustments to suit at no additonal cost.

F. Provide tests in accordance with Section 26 08 05, Acceptance Testing.

END OF SECTION