PART 1 GENERAL

1.1 SCOPE

.1 This specification shall apply to the materials, design, fabrication, inspection, and testing of 600 V Variable Frequency Drives (VFD) used to control the speed and torque of NEMA design B induction motors.
.2 Detailed specifications on the VFD shall be indicated in this specification, drawings and attachments. In case of a conflict between the various specifications, the vendor shall contact the Contract Administrator for clarification. The VFD shall be manufactured by ABB or approved equal in accordance with B6.
.3 Ensure VFD can handle the motor loads of the equipment actually purchased by the Contractor.

1.2 RELATED SECTIONS

.1 Section 23 73 11 - Air Handling Units - Packaged.
.2 The City of Winnipeg Standard Construction Specifications Section CW1110 – General Instructions.

1.3 REFERENCES

.1 The VFD shall be designed, manufactured and tested in accordance with the latest applicable standards of CSA, NEMA, ANSI and UL, including but not limited to:
.1 CSA C22.2 No. 14-M91—Industrial Control Equipment
.2 IEEE 519-1992 – Guide for Harmonic Content and Control
.3 NEMA ICS7—Industrial Control and Systems Adjustable Frequency Drives
.4 NEMA MG1—Motors and Generators
.5 NEMA ICS 7.1—Safety Standards for Construction and Guide for Selection Installation and Operation of Adjustable Frequency Drives
.2 In all cases where more than one regulation, code, standard or specification applies to the same conditions, the most stringent one shall apply. Conflicts among any of the provisions of these listed codes, standards or specifications shall be referred to the Contract Administrator for resolution.

1.4 SHOP DRAWINGS AND PRODUCT DATA

.1 Submit shop drawings and product data in accordance with The City of Winnipeg Standard Construction Specifications Section CW1110 – General Instructions.
.2 Drawings shall be in SI units. If imperial units are used as well, they shall be shown in parenthesis after the SI units. In case of conflict between the two, SI units shall be considered to be correct.
.3 Equipment tag number, purchase order number and project name shall be shown on all Supplier supplied drawings. Data shall be located close to the title block.
.4 All drawings and data shall be submitted in a form that is easily reproduced. All data and drawings shall be submitted in both paper and electronic form. Final drawings are all required to be as-built.
.5 Review or approval of Supplier’s drawings, design calculations and other documentation does not relieve Supplier of any

responsibility for correctness of such drawings, calculations or other documentation.

.6 The following information shall be submitted to the Contract Administrator for approval:
.1 Master drawing index
.2 Dimensioned front view elevation
.3 Dimensioned floor plan
.4 Dimensioned top view
.5 Unit control schematics and wiring diagrams
.6 Nameplate schedule
.7 Cable entry/exit locations
.8 Assembly ratings, including short circuit, voltage, and continuous current ratings
.9 Major component ratings
.10 Minimum clearances to other equipment.
.11 Frequency spectrum for harmonic currents at line side of filter (where provided) at 50% and 100% of rated load.
.12 Compliance to IEEE 519 – harmonic analysis for particular jobsite including total harmonic voltage distortion and toral harmonic current distortion (TDD). The VFD manufacturer shall provide calculations specific to the installation, showing total harmonic voltage distortion is less than 5%. Input filters shall be sized and provided as required by the VFD manufacturer to ensure compliance with IEEE electrical system standard 519. All VFDs shall include a minimum of 3% equivalent impedance reactors. VFDs shall include some form of active mitigation.
.13 Manufacturers technical data sheets

1.5 CLOSEOUT SUBMITTALS

.1 Provide operation and maintenance data for motor starters for incorporation into manual specified in Section 21 05 01 - Common Work Results for Mechanical.

.2 Operation and maintenance manuals shall include as a minimum for each type and style of starter: Instruction books and/or leaflets, recommended renewal parts list and a complete set of as-built drawings.

.3 The following information shall be submitted to Contract Administrator for record purposes:
.1 Final as-built drawings and information
.2 Certified production test reports
.3 Installation information
.4 Seismic certification and equipment anchorage details (where applicable)

PART 2 PRODUCTS

2.1 GENERAL

.1 All VFDs shall be a solid state AC to AC inverter controlled device utilizing the latest isolated gate bipolar transistor (IGBT) technology. The VFD shall utilize Direct Torque Control (DTC) as the primary motor control, employing an inner loop torque control strategy that mathematically determines the optimal motor torque and flux every 25 microseconds. The VFD must also provide an optional motor control operational mode for scalar of V/Hz operation.

.2 The VFDs will be fed from a MCC and be protected by Breakers. Vendor shall indicate recommended breaker size.

.3 The benefits that the motor control DTC shall make available for

the operation of a NEMA design B induction motor shall be:
.1 Steady state speed accuracy within 1/10th the slip without an encoder, for process repeatability.
.2 100% motor torque from zero speed available for acceleration with the VFD continuous current rating equal to or greater then the motor full load amp rating.
.3 At and below 90% speed, 100% torque is achievable even with 10% low line voltage.
.4 Ability to limit torque to protect the mechanical system with a common single torque setting above and below field weakening.
.5 Ability to provide torque in % of motor shaft torque (with in +/- 4% linearity) on the VFD control panel, analog output or via field bus of actual.
.6 Quiet motor operation for audibly friendly working environment in comparison to other low voltage PWM solutions utilizing a carrier frequency.
.7 Have available the ability to operate in open loop torque control, with an ability to switch between speed and torque control on the fly with the change of state to a digital input.
.8 Have an ability to share load or speed between two or more induction AC motors connected to the same system, when those motors are controlled by separate VFDs.

2.2 RATINGS

.1 The VFD shall be designed for heavy-duty applications and in accordance with applicable datasheets.
.2 The VFD shall be rated to operate from 3-phase power at 525 to 690 VAC (600 Vac, UL and CSA) +10/-10%. The overvoltage trip level shall be a minimum of 30% over nominal, and the undervoltage trip level shall be a minimum 35% under the nominal voltage.
.3 The VFD shall be rated to operate at the following environmental operating conditions: ambient temperature 0 to 40°C continuous. VFDs that can operate at 40° C intermittently (during a 24 hour period) are not acceptable and must be oversized. Altitude 0 to 3300 feet above sea level without derating, less than 95% humidity, non-condensing.
.4 The VFD shall be rated to operate from input power from 48Hz to 63Hz.
.5 Output voltage and current ratings shall match the adjustable frequency operating requirements of standard NEMA design A or NEMA design B motors.
.6 The Heavy Duty overload current capacity shall be 150% of rated current for one (1) minute out of five (5) minutes.
.7 The VFD efficiency shall be 98% or better of the full rated capability of the VFD at full speed and load.
.8 The VFD shall be capable of starting when fed from temporary diesel generator (nominal size of 500 kVA).
.9 Drive rated for a minimum fault current of 65 kA Sym. I.C.

2.3 CONSTRUCTION

.1 All models shall provide a complete, ready-to-install solution.
.2 The latest, most efficient IGBT power technology shall be used. This technology shall be used for all power and voltage ranges offered by the manufacturer.
.3 The VFD shall offer microprocessor based control logic that is isolated from power circuitry.
.4 The VFD shall use the same main control board for all ratings.
.5 Control connections shall remain consistent for all power ratings.
.6 Wall mountable VFDs shall be available from 1.0 to 200HP and have

the following features;
.1 Wall mounted NEMA Type 12 enclosures for electrical / mechanical rooms
.2 Wall mounted NEMA Type 4X enclosures for plant floor locations
.3 Include a control panel mounted on the front of the VFD
.4 Include coated circuit boards as standard
.5 Include integrated internal AC line reactor or DC choke
.6 Offer option internally mounted braking chopper for use in dynamic braking with 100% continuous duty operation.

.7 Desired optional features shall be furnished and mounted by the VFD manufacturer and shall also be available as field installable kits as an alternative. All optional features shall carry all of the necessary certifications as described above. Field installed kits shall not affect the VFD's certification.

.8 Provide equipment identification in accordance with Section 26 05 01 - Common Work Results - Electrical. Nameplates shall be permanently attached with screws.

.9 The enclosure shall have appropriate warning labels indicating "CAUTION MULTIPLE CONTROL POWER SOURCES"

.10 A panel mounted non-resetable elapsed-time meter to measure operating hours with a minimum 6 digits display.

2.4 OPERATOR INTERFACE

.1 The VFD shall be equipped with a front mounted operator control panel consisting of a four- (4) line by 20-character back-lit alphanumeric LCD display and a keypad with keys for Run/Stop, Local/Remote, Increase/Decrease, Reset, Menu navigation and Parameter select/edit.

.2 The control panel shall be removable, capable of remote mounting and allow for uploading and downloading of parameter settings as an aid for start-up of multiple VFDs.

.3 The display of the control panel shall have the following features:
.1 The LCD display shall have contrast adjustment provisions to optimize viewing at angle.
.2 All parameter names, fault messages, warnings and other information shall be displayed in complete English words or standard English abbreviations to allow the user to understand what is being displayed without the use of a manual or cross-reference table.
.3 During normal operation, one (1) line of the control panel shall display the speed reference, and run/stop forward/reverse and local/remote status. The remaining three (3) lines of the display shall be programmable to display the values of any three (3) operating parameters. The selection shall include at least the following values:
.1 Speed/torque in percent (%), RPM or user-scaled units
.2 Output frequency, voltage, current and torque
.3 Power and kilowatt hours
.4 Heatsink temperature and DC bus voltage
.5 Status of discrete inputs and outputs
.6 Values of analog input and output signals
.7 Values of PID controller reference, feedback and error signals

.4 The control panel shall be used for local control, for setting all parameters, and for stepping through the displays and menus.

.5 A copy function to upload and store parameter settings from a VFD and download stored parameter settings to the same VFD or to another VFD shall exist.

.6 An intelligent start-up assistant shall be provided as standard.

The Start-up routine will guide the user through all necessary adjustments to optimize operation.
.1 The Start-Up routine shall include "plug and produce" operation, which automatically recognizes the addition of options and fieldbus adapters and provides the necessary adjustment assistance.
.2 The Start-Up routine shall prompt the user for Motor Nameplate Data including power, speed, voltage, frequency and current.
.3 An auto-tune function shall identify the optimal motor tuning parameters for typical applications.
.4 An auto-tune function shall also be available to tune the PID speed regulator loop. Manual adjustments shall also be allowed.
.5 A selection of at least six (6) pre-programmed application macro parameter sets shall be provided to minimize the number of parameter adjustments required during start-up. Macros offered shall include Factory Default, Hand/Auto, PID Control, and Torque Control. A selection of two (2) user defined macros shall are also be available.
.6 Selection shall be offered for both 2-wire and 3-wire Start/Stop control.

2.5 PROTECTIVE FEATURES

.1 For each programmed warning and fault protection function, the VFD shall display a message in complete English words or Standard English abbreviations. The five (5) most recent fault messages and times shall be stored in the VFD's fault history.
.2 The VFD shall include internal MOV's for phase to phase and phase to ground line voltage transient protection.
.3 Output short circuit and ground fault protection rated for 100,000 amps without relying on line fuses shall be provided per UL508C.
.4 Motor phase loss protection shall be provided.
.5 The VFD shall provide electronic motor overload protection qualified per UL508C.
.6 Protection shall be provided for AC line or DC bus overvoltage at 130% of maximum rated voltage or undervoltage at 65% of min. rated voltage.
.7 The VFD shall protect itself against input phase loss.
.8 A power loss ride through feature shall allow the VFD to remain fully operational after losing power as long as kinetic energy can be recovered from the rotating mass of the motor and load.
.9 Stall protection shall be programmable to provide a warning or stop the VFD after the motor has operated above a programmed torque level for a programmed time limit.
.10 Underload protection shall be programmable to provide a warning or stop the VFD after the motor has operated below a selected underload curve for a programmed time limit.
.11 Over-temperature protection shall provide a warning if the power module temperature is less than 5°C below the over-temperature trip level.
.12 Input terminals shall be provided for connecting a motor thermistor (PTC type) to the VFD's protective monitoring circuitry. An input shall also be programmable to monitor an external relay or switch contact.

2.6 CONTROL INPUTS AND OUTPUTS

.1 Discrete Inputs
.1 Minimum of six (6) discrete inputs shall be provided.
.2 A minimum of six (6) of the inputs shall be independently

programmable with function selections (run/stop using 2 wire or 3 wire control, hand-off-auto, etc.).
.3 Inputs shall be designed for use with either the VFD's internal 24 VDC supply or a customer supplied external 24 VDC supply.

.2 Discrete outputs
.1 Minimum of three (3) form C relay contact outputs shall be provided
.2 All outputs shall be independently programmable to activate with at least 30 function selections including;
.1 Operating conditions such as drive ready, drive running, reversed and at set speed
.2 General warning and fault conditions
.3 Adjustable supervision limit indications based on programmed values of operating speed, speed reference, current, torque and PID feedback.
.4 Relay contacts shall be rated to switch 2 Amps at 24 VDC or 115/230 VAC.

.3 Analog Inputs
.1 Minimum of two (2) analog inputs shall be provided:
.1 At least one (1) must support bi-polar voltage input
.2 Resolution of analog inputs must be at least 11bit total resolution
.2 Inputs shall be independently programmable to provide signals including speed / frequency reference, torque reference or set point, PID set point and PID feedback / actual.
.3 A differential input isolation amplifier shall be provided for each input.
.4 Analog input signal processing functions shall include scaling adjustments, adjustable filtering and signal inversion.
.5 If the input reference is lost, the VFD shall give the user the option of the following. The VFD shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus.
.1 Stopping and displaying a fault
.2 Running at a programmable preset speed
.3 Hold the VFD speed based on the last good reference received
.4 Cause a warning to be issued, as selected by the user.
.6 When inputs are used as speed references, reference signal processing shall include increase/decrease floating point control and control of speed and direction using a "joystick" reference signal. Two (2) analog inputs shall be programmable to form a reference by addition, subtraction, multiplication, minimum selection or maximum selection.

.4 Analog Outputs
.1 Minimum of two (2) 0 / 4-20 mA analog outputs shall be provided.
.2 Outputs shall be independently programmable to provide signals proportional to output function selections including output speed, frequency, voltage, current and power.

2.7 CONTROL FUNCTIONS AND ADJUSTMENTS

.1 Output frequency shall be adjustable between 0Hz and 300Hz. Operation above motor nameplate shall require programming changes to prevent inadvertent high-speed operation.
.2 Stop mode selections shall include coast to stop and ramp to stop.
.3 The VFD shall be capable of controlling deceleration of a load without generating an overvoltage fault caused by excessive regenerated energy. Overvoltage control on deceleration shall extend the ramp time beyond the programmed value to keep the

amount of regenerated energy below the point that causes overvoltage trip.

.4 The VFD shall be capable of starting into a rotating motor with or without existing magnetic flux on the motor regardless of the motor direction. From the time the start signal is given to the VFD to the time the VFD has control of the motor shall not exceed two (2) seconds. Once the VFD has control of the motor it will than accelerate or decelerate the motor to the active reference speed without tripping or faulting or causing component damage to the VFD. The VFD shall also be capable of flux braking at start to stop a reverse spinning motor prior to ramp.

.5 The VFD shall have the ability to automatically restart after an overcurrent, overvoltage, undervoltage, or loss of input signal protective trip. The number of restart attempts, trial time, and time between reset attempts shall be programmable.

.6 Control functions shall include two (2) sets of acceleration and deceleration ramp time adjustments with linear and an s-curve ramp time selection.

.7 Speed control functions shall include:

.1 Adjustable min/max speed limits.

.2 Selection of up to 15 preset speed settings for external speed control.

.3 Three sets of critical speed lockout adjustments.

.4 A built-in PID controller to control a process variable such as pressure, flow or fluid level.

.8 Functions shall include flux optimization for optimizing energy efficiency and limit the audible noise produced by the motor by providing the optimum magnetic flux for any given speed / load operating point.

.9 The VFD shall be capable of sensing a loss of load (broken belt / broken coupling) and signal the loss of load condition. The VFD shall be programmable to signal this condition via a keypad warning, relay output and/or over the serial communications bus. Relay output shall include programmable time delays that will allow for VFD acceleration from zero speed without signaling a false underload condition.

.10 Three (3) programmable critical frequency lockout ranges shall be provided to prevent the VFD from operating the load continuously at an unstable speed.

.11 The VFD shall offer software to select the VFDs action in the event of a loss of the primary speed reference.

.12 The VFD shall have fifteen (15) internal adaptive programming blocks capable of twenty (20) different functions. These blocks shall be connectable to VFD’s actual signals and functions allowing the user to tailor the VFD to the specific application requirements without additional hardware. These blocks shall be programmable through the standard operator panel and through the use of programming software.

2.8 COMMUNICATIONS

.1 The VFD shall be capable of communicating with other VFDs or controllers via a serial communications link. A variety of communications interface modules for the typical overriding control systems shall be available.

.2 The VFD shall have a Modbus/TCP interface module for remote interrogation by a DCS or PLC controller. Vendor shall indicate all drive parameters that are accessible from this interface.

.3 Interface modules shall mount directly to the VFD control board or be connected via fiber optic cables to minimize interference and provide maximum throughput.

.4 I/O shall be accessible through the serial communications adapter.

Serial communication capabilities shall include, but not be limited to:
.1 Run-Stop control
.2 Hand-Off-Auto Control
.3 Speed Adjustment
.4 PID (proportional/integral/derivative) control adjustments
.5 Current Limit
.6 Accel/Decel time adjustments

.5 The VFD shall have the capability of allowing the overriding controller to monitor feedback such as process variable feedback, output speed/frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), relay outputs, and diagnostic warning and fault information.

.6 A connection shall also be provided for personal computer interface. Software shall be available for VFD setup, diagnostic analysis, monitoring and control. The software shall provide real time graphical displays of VFD performance.

2.9 FACTORY TESTING

.1 The manufacturer's standard factory tests shall be performed on the equipment provided under this section. All tests shall be in accordance with the latest version of CSA and NEMA standards. Results from the test shall be provided with closeout submittals.

2.10 ACCEPTABLE PRODUCT

.1 ABB ACS800-U1 Series VFD c/w TCI HG7 Harmonic Filter or approved equal in accordance with B6.

PART 3 EXECUTION

3.1 INSTALLATION

.1 Install in accordance with Manufacturer's installation instructions and recommendations.
.2 Hire factory trained representative for setup and commissioning of VFD. Provide written report to Contract Administrator.
.3 Hire factory trained representative to provide one day of training for City of Winnipeg personnel.
.4 Confirm power lugs and VFD can accommodate the pump motor cables leads.
.5 Setup VFD so that equipment is controlled as per controls narrative.

END OF SECTION