

Power Quality Specification

**For Interconnection To Manitoba
Hydro's Electrical System**

PQS2000

revision 02

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1 General Information

1.1 Legislative Authority

Section 15(5) of *The Manitoba Hydro Act* authorizes Manitoba Hydro to set, coordinate and enforce standards for the security, reliability and quality control of the transmission and distribution lines, of any person whose lines are interconnected with the transmission and distribution lines of Manitoba Hydro. Pursuant to section 10 of *The Manitoba Hydro Act* Regulation 186/90 – Electric Power Terms and Conditions of Supply Regulation, Manitoba Hydro is authorized to determine the voltage, frequency, phasing and other characteristics of power, the determination of which is final and binding on the user. Pursuant to this legislative authority, Manitoba Hydro has established the following Power Quality Specification.

1.2 Authors

This document was written in collaboration with staff from Distribution Planning & Design, System Planning, & Customer Engineering Services.

1.3 Revisions

Revision Date	Major Changes
02 – April 2011	<ul style="list-style-type: none"> ▪ Changed PCC to POI ▪ Updated Standard References ▪ Separated Design & Measurement Criteria
01 – January 2005	<ul style="list-style-type: none"> ▪ added Flicker criteria ▪ revised harmonic burst criteria ▪ revised the section related to mitigation responsibilities ▪ created a General Information section
00 – November 2000	Document created, addressed harmonics only

Note:

Manitoba Hydro will review this document periodically and make revisions necessary to reflect changing system conditions and industry practices. When revisions are made, Manitoba Hydro will distribute the revised document to recipients of prior versions of this document as soon as practically possible and make copies available upon request. However, it is the customer's responsibility to ensure it has the latest version of this document.

1.4 Scope

This is a technical document and does not address other policy or contractual requirements associated with interconnection to the Manitoba Hydro system.

1.5 Mitigation Of Power Quality Problems

When Limits Are Exceeded:

It is Manitoba Hydro's intent to plan and design its system so power quality levels are within the limits specified in this document.

In emergency situations, it may be necessary for Manitoba Hydro to make temporary changes to its system which may adversely affect power quality levels. Under these circumstances, harmonic distortion and/or flicker levels at the POI may be temporarily exceeded.

Manitoba Hydro service contracts with individual customers deal with concerns when limits are exceeded and covers responsibilities for mitigation of power quality interference issues.

Manitoba Hydro may perform a post installation power quality analysis for comparison with the original Power Quality Benchmark. If power quality limits are exceeded, Manitoba Hydro will assist the customer in determining the cause of the problem only.

Manitoba Hydro at its discretion may impose operating restrictions on the customer until recommendations made in the Power Quality Mitigation Report have been completed.

1.6 Definitions

The following definitions used herein are specific to Manitoba Hydro and may differ from definitions given to these terms by IEEE and other industry standards:

flicker: the impact a voltage fluctuation has on the luminous intensity of lamps and fluorescent tubes such that they are perceived to 'flicker' when viewed by the human eye. The level at which it becomes irritating is a function of both the magnitude of the voltage change and how often it occurs.

Flicker is quantified using the following:

P_{ST}: the short-term flicker index, a unit of flicker level as defined in IEC Standard 61000-4-15 based on a 10 minute period. P_{ST} is obtained by direct measurement using the IEC "flicker meter", calculated analytically, or obtained through computer simulation. In North America, a P_{ST} of 1.0 (one) corresponds to the 'threshold of flicker irritation' for rectangular (step) voltage changes applied to a 120V incandescent lamp.

P_{LT}: the long-term flicker index. P_{LT} is calculated using 12 consecutive (120 minutes) P_{ST} samples and is given by:

$$P_{LT} = \sqrt[3]{\frac{1}{12} \cdot \sum_{j=1}^{12} P_{ST_j}^3}$$

emission level: the maximum allowable P_{ST} contribution available to a customer connecting a load assuming there is zero background flicker.

planning level: this is the maximum P_{ST} and P_{LT} level used by the utility for planning purposes and is used to control the cumulative impact of all fluctuating loads connected to the system.

flicker curve: a graph that plots voltage fluctuations vs. frequency of occurrence. The points on the curve are based on laboratory experiments that applied a periodic voltage fluctuation to a light bulb and determined the levels at which the flicker becomes irritating to the human eye. Most published flicker curves are based on rectangular modulation of the 60 Hz AC voltage waveform.

flicker meter: an instrument used to measure the severity of flicker and determine the level in terms of P_{ST} and P_{LT} . The specifications for a flicker meter are outlined in IEC Standard 61000-4-15.

harmonic: are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is operating. Harmonic distortion exists due to the nonlinear characteristics of devices and loads on the power system.

interharmonic: are sinusoidal voltages or currents having frequencies that are not an integer multiple of the frequency at which the supply system is operating. The interharmonic is the sum of the squared intermediate frequencies between two integer harmonics excluding the spectral lines directly adjacent to the two integer harmonics as defined by IEC Standard 61000-4-7.

non-linear load: are AC loads where the current and voltage are not proportional to each other and contain harmonic components. Typical non-linear loads are variable speed drives, arc furnaces, etc.

point of interconnection (POI): the point where the customer's conductors electrically and physically interconnect with Manitoba Hydro's conductors (point of ownership change) and where the electrical energy exchange is measured.

Power Quality Assessment Report: a technical report supplied to Manitoba Hydro by the customer which includes but is not limited to the following:

- detailed description of equipment being installed outlined in Sections 2.2.2 and/or 3.2.2.
- projected impact the facility and new equipment will have on the limits identified in this document
- description of measures that will be taken to mitigate the levels exceeding the limits specified in this document
- calculations and/or computer simulation that consider the worst case plant operating modes, equipment tolerances, system unbalance and resonances when determining compliance of the design with the limits identified in this document

Power Quality Benchmark: a report which evaluates power quality measurements taken at the POI based on Manitoba Hydro's Power Quality Specification. Measurements include voltage and current harmonics, and flicker. A Power Quality Benchmark is usually performed when a customer is planning a facility modification, or the installation of a non-linear load or power factor correction system.

Power Quality Mitigation Report: a technical report supplied to Manitoba Hydro by the customer which includes but is not limited to the following:

- summary of the impact the facility and new equipment have on the limits identified in this document as documented in the Power Quality Benchmark,
- description of measures that will be taken to mitigate the levels exceeding the limits specified in this document,
- calculations and/or computer simulations that consider the worst case plant operating modes, equipment tolerances, system unbalance and resonances when determining compliance of the design with the limits identified in this document,
- detailed description of additional or modified equipment being installed in the facility, as outlined in Sections 2.2.2 and/or 3.2.2, needed to mitigate the levels exceeding the limits specified in this document.

Total Harmonic Distortion (THD): the ratio of the root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the fundamental, as defined by IEC Standard 61000-4-7.

$$THD = \frac{\sqrt{\sum_{h=2}^{50} V_h^2}}{V_1} \times 100\%$$

where:

- V_h = magnitude of the square root of the sum of the squares of the rms value of a harmonic and the two spectral components immediately adjacent to it, (e.g. the 3rd harmonic V_h is comprised of the magnitudes at the 175, 180 and 185 Hz frequencies).
- h = Integer multiple of the fundamental frequency (60Hz)-
- V_1 = the magnitude of the nominal fundamental frequency voltage

Total Demand Distortion (TDD): the ratio of the root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the maximum annual demand or load current.

$$TDD = \frac{\sqrt{\sum_{h=2}^{50} I_h^2}}{I_L} \times 100\%$$

where:

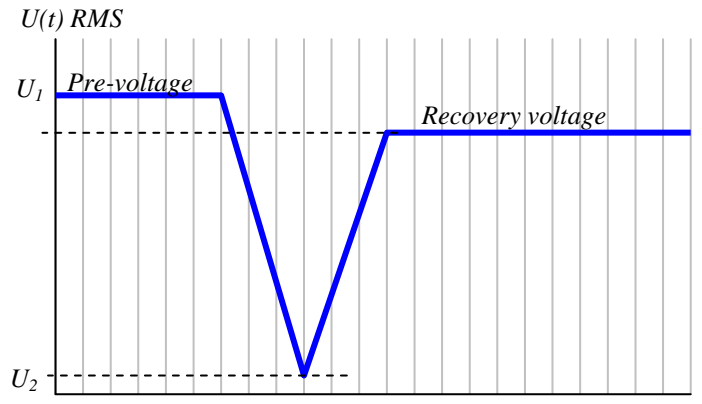
- I_h = magnitude of the square root of the sum of the squares of the r.m.s. value of a harmonic and the two spectral components immediately adjacent to it, (e.g. the 3rd harmonic I_h is comprised of the magnitudes at the 175, 180 and 185 Hz frequencies)
- h = Integer multiple of the fundamental frequency (60Hz).
- I_L = maximum annual demand or contract load current

voltage fluctuation: a series of voltage changes or a continuous variation on the RMS voltage magnitude. Fluctuations are typically small voltage variations, (but not necessarily), ranging anywhere between 0.9 and 1.1 per unit (p.u.) in magnitude.

Voltage fluctuations can be one of two types:

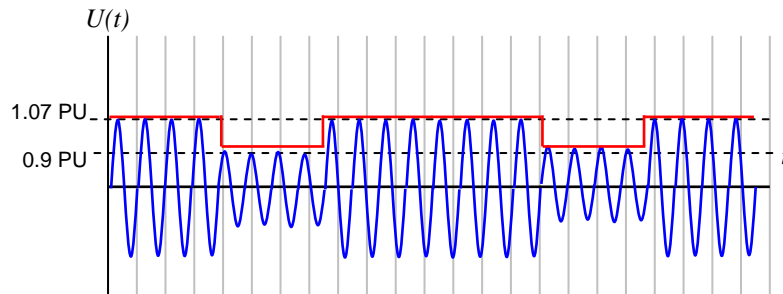
dynamic (aperiodic) fluctuation: is a change in voltage caused by equipment operation such as motor starting, capacitor switching or energizing a transformer. The magnitude of a dynamic voltage fluctuation is calculated using the following equation where U_1 is the rms voltage prior to the event and U_2 is the minimum or maximum rms voltage associated with the event.

$$\text{Magnitude of Dynamic Voltage Fluctuation} = \frac{|U_1 - U_2|}{U_1} \times 100\%$$



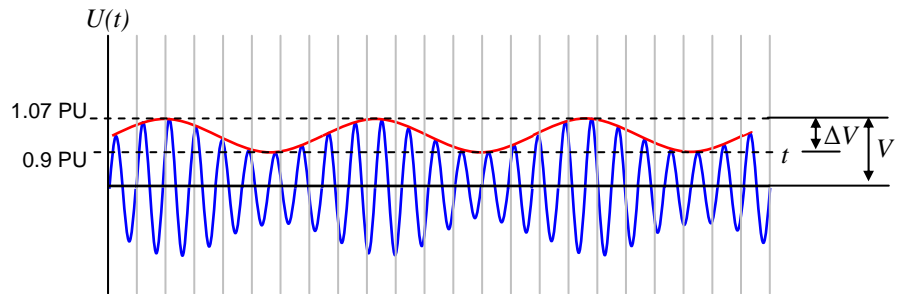
cyclic (periodic) fluctuations are part of the normal, continuous operation of the customer facility. The RMS voltage magnitude varies between two values resulting in amplitude modulation of the AC sine wave envelope.

Periodic voltage fluctuation that results in rectangular modulation of the 60 Hz waveform. e.g.: wood running through a sawmill

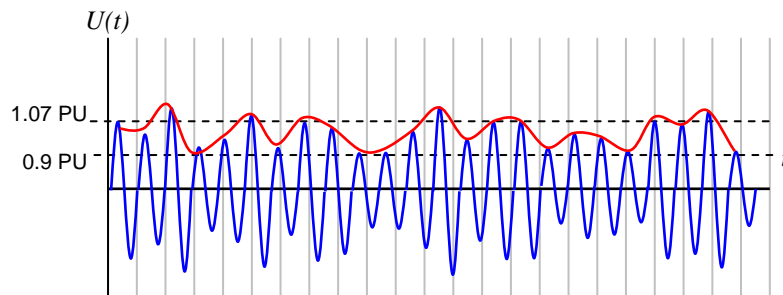


Periodic voltage fluctuation that results in sinusoidal modulation of the 60 Hz waveform. e.g.: Induction Furnace. The %voltage fluctuation is calculated using:

$$\frac{\Delta V}{V} \cdot 100$$



Periodic voltage fluctuation that results in random modulation of the 60 Hz waveform. e.g.: arc furnace during its melting cycle



2 Harmonic and Interharmonic Distortion

2.1 Purpose

The purpose of this section is to establish responsibilities and to specify limits for harmonic and interharmonic distortion created by customer facilities connecting to the Manitoba Hydro electrical system.

2.2 General Requirements

It is Manitoba Hydro's responsibility to provide and maintain a voltage supply within harmonic limits as specified in this document. Based on engineering information provided by Manitoba Hydro, it is the customer's responsibility to ensure its load does not increase harmonic levels on the Manitoba Hydro system beyond limits specified herein and does not impact other customers' electrical services. This section describes the obligations regarding the flow of information between Manitoba Hydro and the customer.

2.2.1 Customers Affected By This Section

All new or existing customers whose load or generation may exceed acceptable harmonic levels or who may be affecting nearby customers are impacted by this document. This is typical of:

- customers adding non-linear loads
- customers who have or who are considering installing power factor correction capacitors
- customers who are installing generation
- interconnections with neighboring utilities

2.2.2 Information Supplied By The Customer

Whenever customers propose connecting equipment (as defined in 2.2.1) to the Manitoba Hydro system, or whenever existing customers may be exceeding harmonic limits, Manitoba Hydro at its discretion requires all relevant information pertaining to the connected loads, including but not limited to:

- i) single-line diagram of the installation
- ii) all non-harmonic producing loads
- iii) all harmonic producing loads and their harmonic spectrums
- iv) transformer ratings and impedance
- v) cable impedance that should be included for harmonic analysis
- vi) power factor correction capacitor and filter information

note: For 100 kV and greater interconnections, refer to Manitoba Hydro's "Transmission System Interconnection Requirements" document for more details regarding other information that may be required.

2.2.3 Information Supplied to the Customer

Manitoba Hydro may provide the following information (when applicable) at the POI to assist customers with determining requirements for interconnection.

system data:

- i) normal short circuit MVA level
- ii) supply transformer nameplate information
- iii) impedance spectrum

measured data:

- iv) voltage and current levels
- v) total harmonic distortion, (voltage and current)
- vi) flicker

2.2.4 Power Quality Assessment Report

The customer must provide Manitoba Hydro with a Power Quality Assessment Report. This report must include information outlined in Section 2.2.2 and demonstrate that the limits specified in Section 2.3 and Section 2.6 are met.

Service connection or load increase will not be granted until the report is received and reviewed by Manitoba Hydro.

Manitoba Hydro reviews the Power Quality Assessment Report. However, accepting and reviewing the report shall not be deemed to be a guarantee by Manitoba Hydro of the accuracy of the Power Quality Assessment Report.

2.2.5 Power Quality Benchmark Report

Upon reviewing the information supplied in 2.2.2, Manitoba Hydro, at its discretion, will perform a Power Quality Benchmark to verify compliance with the limits specified in Sections 2.3 (voltage unbalance) and Section 2.4.

2.2.6 Power Quality Mitigation Report

Upon receiving the Power Quality Benchmark or communication interference complaint, the customer must provide Manitoba Hydro with a Power Quality Mitigation Report if the facility is not in compliance with this document. This report must include information outlined in Section 2.2.2 and demonstrate that the limits specified in this document are met.

Service connection or load increase will not be granted until the report is received and reviewed by Manitoba Hydro.

Manitoba Hydro reviews the Power Quality Mitigation Report. However, accepting and reviewing the report shall not be deemed to constitute a guarantee by Manitoba Hydro of the accuracy of the Power Quality Mitigation Report.

2.3 Design Limits

The criteria in this section shall be applied to design studies and equipment specifications.

2.3.1 Voltage Unbalance

The customer's design shall account for unbalance in the voltage supply using Table 1, where unbalance is defined as the ratio of negative sequence voltage to positive sequence voltage, or alternatively,

$$\%unbalance = \frac{\text{Highest deviation from the average voltage of the 3 phases}}{\text{Average voltage of the 3 phases}}$$

Voltage Level	Rural	Urban
25kV and less	5.0%	4.0%
greater than 25kV	2.0%	

Table 1 Voltage Unbalance Limits

2.3.2 Current and Voltage Harmonic Distortion Design Limits

All customer facilities are expected to be at or below the maximum allowable design harmonic distortion limits, Tables 2 and 3, 95% of the time during all normal operating cycles. For shorter periods, during start ups or other transient conditions, the limits may be exceeded by up to 50% (1.5x the design limit). The harmonic distortion must be less than 1.5x the design limit 99% of the time during all normal operating cycles, with no occurrences exceeding 2.0x the design limit.

2.3.2.1 Customer Current Harmonic Distortion

As part of the Power Quality Assessment Report and Power Quality Mitigation Report, the customer shall demonstrate that current harmonic distortion limits at the POI will not exceed the limits as specified in this document. The values are summarized in Table 2.

$V_{bus} \leq 69kV$						
I_{sc}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20 - 49	7.0	3.5	2.5	1.0	0.5	8.0
50 - 99	10.0	4.5	4.0	1.5	0.7	12.0
100 - 1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
$69kV < V_{bus} \leq 138kV$						
I_{sc}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
<20*	2.0	1.0	0.75	0.3	0.15	2.5
20 - 49	3.5	1.75	1.25	0.5	0.25	4.0
50 - 99	5.0	2.25	2.0	0.75	0.35	6.0
100 - 1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0
$V_{bus} > 138kV$						
I_{sc}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
<50*	2.0	1.0	0.75	0.3	0.15	2.5
≥ 50	3.0	1.5	1.15	0.45	0.22	3.75

- Harmonics and interharmonics up to $h = 50$ shall be included in all design calculations
- Even harmonics are limited to 25% of the odd harmonics listed above
- Current harmonic distortion that result in a DC offset, e.g., half-wave converters, are not allowed
- Duration of harmonic levels is outlined in Section 2.3.2

*All power generation equipment is limited to these values of current harmonic distortion, regardless of actual I_{sc}/I_L or voltage level

where:

I_{sc} = short-circuit current for normal system conditions that result in minimum short circuit capacity at the POI, considering all supply alternatives

I_L = maximum annual demand load current (fundamental frequency component) recorded at the POI

Table 2 Current Harmonic Distortion Limits Maximum Current Harmonic and Interharmonic Distortion In Percent of I_L Individual Harmonic Order (Odd Harmonics)

2.3.2.2 Customer Voltage Harmonic Distortion

The customer shall design its installation and specify equipment such that the voltage harmonic distortion (V_{THD}) contribution due to the installation complies with Table 3 below.

Bus Voltage at POI (V_{bus})	Voltage Individual Harmonic or Interharmonic Distortion (%)	Voltage Total Harmonic Distortion THD (%)
69kV and less	2.0	3.5
$138kV \geq V_{bus} > 69kV$	1.0	1.5
$V_{bus} > 138kV$	1.0	1.0

Table 3 Maximum Customer Voltage Harmonic and Interharmonic Distortion Design Limits

2.3.3 System Frequency

Calculations and design shall consider a fundamental frequency range of:

Duration	Frequency
Continuous	60 ± 0.2 Hz
≤ 30 seconds	58 Hz to 63.5 Hz

Table 4 Frequency

2.4 Measurement Limits

2.4.1 Current and Voltage Harmonic Distortion Measurement Limits

Current and voltage harmonic distortion measurements at the POI are expected to be at or below the maximum allowable measured distortion limits, Tables 2 & 5, 95% of the time during all normal operating cycles. For shorter periods, during start ups or other transient conditions, the limits may be exceeded by up to 50% (1.5x the design limit). The distortion must be less than 1.5x the design limit 99% of the time during all normal operating cycles, with no occurrences exceeding 2.0x the design limit.

2.4.2 POI Voltage Harmonic Distortion Measurement Limits

Manitoba Hydro strives to keep the voltage harmonic distortion levels at the POI at or below the following maximum values:

<i>Bus Voltage at POI</i> (V_{bus})	Voltage Individual Harmonic or Interharmonic Distortion (%)	Voltage Total Harmonic Distortion THD (%)
69kV and less	3.0	5.0
$138kV \geq V_{bus} > 69kV$	1.5	2.5
$V_{bus} > 138kV$	1.0	1.5

Table 5 Maximum System Voltage Harmonic and Interharmonic Distortion at the POI

These values represent distortion levels based on the cumulative effect of all customers connected to the same point on the supply.

2.5 Harmonic Measurement

2.5.1 Measurement Period

When performing a Power Quality Benchmark, Manitoba Hydro shall normally perform measurements at the customer POI for one week (168 hour period) during typical production load levels. The effect of a shorter production cycle and seasonal variation of loads will be considered in determining when a benchmark is performed. Manitoba Hydro reserves the right to choose the date/time and duration of the benchmark measurements.

2.5.2 Equipment

Power harmonic analyzers must be capable of performing power quality measurements and harmonic calculations from n=1 to 50. They shall have a minimum sampling rate of 128 samples/cycle (8kHz) with a measurement technique compliant with IEC 61000-4-7. They are to have a recording resolution of at least once every demand interval as defined by Measurement Canada.

2.6 Limits of Interference With Communication Circuits

2.6.1 Power Line Interference on Telephone Lines

Communication circuits most susceptible to power line interference are low frequency, analog telephone circuits. The interference is a function of separation between the power circuit and the telephone line, the parallel distance, and the plant susceptibility and interference potential of the power line.

The interference potential of the power line can be estimated using the I·T product described by;

$$I \cdot T = I_{RMS} \times TIF$$

however, the complexity of the problem makes it extremely difficult to accurately calculate the interference level with all 3 factors included. As a result, this specification relies on measurements to check compliance.

2.6.2 Design Limits

The maximum balanced and residual Inductive Influence (I·T) levels shall be as follows:

Balanced I·T	Residual I·T
6000	100

Table 6 Maximum I·T Limits @POI (Amps)

If there is more than one line feeding the POI then a higher IT level at the POI may be acceptable as discussed in Section 2.6.3.

Power line influenced noise can be measured at the telephone plant. Using special instruments, “noise to ground” can be measured in dBnc, (decibel C-message weighted).

Measurements of noise to ground (N_g) \leq 80 dBnrc will generally not cause telephone interference.

2.6.3 Communication Interference

Manitoba Hydro strives to keep the balanced I-T product harmonic interference level below 6000 on any one line that may cause induction into communication circuits. For any particular application, Manitoba Hydro is prepared, if necessary, to discuss the allowable I-T as specified in Section 2.6.2 with the understanding that any required interference mitigation directly resulting is the responsibility of the customer.

After the customer has demonstrated that its facility meets Section 2.6.2 the communication company, with Manitoba Hydro's cooperation, is responsible for demonstrating the violation of telephone interference limits and identifying (when applicable) the customer suspected of causing interference problems.

3 Flicker

3.1 Introduction

Two issues of concern with voltage fluctuation caused by equipment operation are:

- the risk of the voltage magnitude being outside accepted tolerances
- ‘flicker’ effect from light sources as a result of the fluctuation

Section 3 explains the flicker requirements of facilities connecting to the Manitoba Hydro system.

3.1.1 Manitoba Hydro’s Flicker Philosophy

For economic reasons, Manitoba Hydro does not plan or design its network to carry the starting current requirements of individual loads. As a result, voltage fluctuations introduced by these loads may cause visible flicker depending on the size of the load, the impedance of the system at that point, and the frequency of the fluctuations.

Manitoba Hydro’s responsibility is to ensure that overall flicker levels are kept within acceptable levels by placing limits on voltage fluctuations introduced at the customer’s point of interconnection. Based on engineering information provided by Manitoba Hydro, it is the customer’s responsibility to ensure its load does not introduce voltage fluctuations beyond limits specified in this document.

3.1.2 Purpose

Section 3 establishes a uniform practice pertaining to voltage fluctuations and their impact on the Manitoba Hydro electrical system and other customers. This creates equity among customers in different parts of the Province, clarifies responsibilities of both the customer and Manitoba Hydro, and protects the overall integrity of the Manitoba Hydro system.

3.1.3 Scope

Section 3 establishes responsibilities for and specifies limits of voltage fluctuations introduced at the point of interconnection between the Manitoba Hydro electrical system and its customers. It covers the following voltage ranges:

HV System	> 25 kV
MV System	1000 V - 25 kV
LV System	<1000 V

3.2 General Requirements

3.2.1 Customers Affected By This Section

All new or existing customers whose load introduces voltage fluctuations, or who may be affecting nearby customers are impacted by this document. This is typical of:

- customers adding large non-linear loads to the Manitoba Hydro system
- customers who have or who are considering installing large motors (typically 15hp or greater for 3 phase, and 5hp or greater for 1 phase)

3.2.2 Information Supplied By The Customer

Whenever customers propose connecting equipment (as defined in Section 3.2.1) to the Manitoba Hydro system, or whenever existing customers are introducing voltage fluctuations that impact Manitoba Hydro's system or its customers, Manitoba Hydro may require all relevant information pertaining to the connected load(s).

General information is documented in the Application for Electric/Gas Service Form (1901A). Additional information specific to flicker producing loads includes but is not limited to;

- the load starting request form
- maximum voltage fluctuation and expected rate of fluctuation during operation

3.2.3 Information Supplied To The Customer

For motors and other large loads, Manitoba Hydro will provide load starting calculations and starting restriction(s).

In the case of loads that produce periodic fluctuations during normal operation, Manitoba Hydro may provide;

- a background flicker measurement
- the short circuit MVA at the POI

3.2.4 Power Quality Assessment Report

The customer must provide Manitoba Hydro with a Power Quality Assessment Report. This report must include information outlined in Section 3.2.2 and demonstrate that the limits specified in Section 3.3.

Service connection or load increase will not be granted until the report is received and reviewed by Manitoba Hydro.

Manitoba Hydro reviews the Power Quality Assessment Report. However, accepting and reviewing the report shall not be deemed to constitute a guarantee by Manitoba Hydro of the accuracy of the Power Quality Assessment Report.

3.2.5 Power Quality Benchmark Report

Upon reviewing the information supplied in 3.2.2, Manitoba Hydro, at its discretion, will perform a Power Quality Benchmark to verify compliance with the limits specified in

Section 3.4

3.2.6 Power Quality Mitigation Report

Upon receiving the Power Quality Benchmark, the customer must provide Manitoba Hydro with a Power Quality Mitigation Report if the facility is not in compliance with this document. This report must include information outlined in Section 3.2.2 and demonstrate that the limits specified in this document are met.

Service connection or load increase will not be granted until the report is received and reviewed by Manitoba Hydro.

Manitoba Hydro reviews the Power Quality Mitigation Report. However, accepting and reviewing the report shall not be deemed to constitute a guarantee by Manitoba Hydro of the accuracy of the Power Quality Mitigation Report.

3.3 Design Limits

3.3.1 Design Limits For Flicker Levels

The customer shall design its equipment such that its flicker emission levels do not exceed the limits in Table 7. The calculations shall assume there is no background flicker. The P_{ST} design limits are also represented as flicker curves in Appendix 1.

POI Voltage	P_{ST}	P_{LT}
HV (>25 kV)	0.8	0.6
MV (1000 V – 25 kV)	0.9	0.7
LV (<1000 V)	1.0	0.8

Table 7 Customer Emission Limits¹

¹ at or below these limits, 99% of the time, based on a representative load cycle 1 day or greater

3.3.1.1 Automatic Acceptance

Generally speaking, if the rate of voltage fluctuation is known, the first step in evaluating the disturbance level of a new load is to relate the maximum apparent power (S_{max}) of the load to the short-circuit power (S_{sc}) available at the POI:

$$\frac{\Delta V\%}{V} = \frac{S_{max}}{S_{sc}} \cdot 100$$

- S_{max} should include the maximum power seen during starting
- for induction motors, S_{max} is typically 6X to 8X rated power
- for induction furnaces, S_{max} is typically 2X to 4X rated power

Changes per minute	$\frac{\Delta V}{V} (\%)$
< 10	0.4%
10 to 200	0.2%
> 200	0.1%

Table 8 Limits for Relative Power Variations¹

¹ Taken from IEC 61000-3-7 Table 3

Loads having $\Delta V/V$ % values at or below the levels specified in Table 8 are considered acceptable and **further flicker analysis is not required**. For values above the limits, Sections 3.4.2 and 3.3.1 apply.

3.3.2 Design Limits For Dynamic Voltage Fluctuations

The customer shall design its equipment such that the dynamic voltage fluctuations at the POI do not exceed the limits in Table 9.

$\Delta V/V$ % @POI	Restriction
<2.0%	no restriction
2.0 – 2.4%	twice per hour
2.5 – 2.9%	once per hour
3.0 – 3.4%	once every 2 hours
3.5 – 3.9%	once every 4 hours
4.0 – 4.9%	once per day
>5.0%	not allowed ⁵

Table 9 Load Starting Restrictions

Notes:

1. In some applications, a motor may cause voltage fluctuations during its normal operation (jogging, jamming) and starting restrictions alone may not be sufficient. For these situations, Section 3.3.1 applies.
2. For induction motors, Manitoba Hydro assumes a 6X locked rotor current unless provided with more accurate data.
3. Computer simulation is used to determine the maximum voltage fluctuation.
4. The table assumes **one start produces 2 voltage changes** per minute
5. Will be reviewed on a 'case by case' basis, and may be allowed in certain situations, (e.g. a once-per-year transformer energization)

3.4 Measurement Limits

3.4.1 Flicker Level Measurement Limits

Manitoba Hydro strives to maintain a cumulative background flicker planning level of $P_{ST} < 1.0$ and $P_{LT} < 0.8$, 99% of the time, throughout its system. To achieve this, flicker emission limits have been established for individual loads connecting at various POI voltages.

3.4.2 Dynamic Voltage Fluctuation Measurement Limits

Manitoba Hydro limits the magnitude of dynamic voltage fluctuation caused by the operation of electrical loads to the values shown in Table 9.

3.5 Flicker Measurement

Background flicker levels and voltage fluctuations shall be measured by:

- measuring the overall flicker level (P_{ST} and P_{LT}) over a representative load cycle 1 day or greater.
- capturing the inrush current and voltage sag event at the customer's POI using a power quality device capable of capturing high speed events.

3.5.1 Measurement Period

When performing a Power Quality Benchmark, Manitoba Hydro shall normally perform measurements at the customer POI over a representative load cycle one day or greater. The effect of a shorter production cycle and seasonal variation of loads will be considered in determining when a benchmark is performed. Manitoba Hydro reserves the right to choose the date/time and duration of the benchmark measurements.

3.5.2 Equipment

The flicker level shall be measured using a power quality device that meets the requirements of the IEC Flickermeter Standard 61000-4-15. The data from a flicker measurement shall be evaluated using a cumulative frequency method. This is explained in Appendix 2.

The dynamic voltage fluctuation magnitude shall be calculated using one half cycle rms measurements obtained from a power quality device with a minimum sampling rate of 128 samples/cycle (8kHz).

3.6 Application

3.6.1 Customers With Multiple Flicker Producing Loads

In some cases, customers may have more than one flicker producing load. The cumulative impact at the POI is determined as follows:

For dynamic fluctuations:

- Starting restrictions in Table 9 have been conservatively selected to account for multiple voltage fluctuations
- For customers connecting multiple motors at POI voltages 25kV and less, the %voltage fluctuation is calculated based on the largest motor. Motors cannot be started simultaneously.
- For multiple motors connected at POI voltages greater than 25kV, cumulative flicker is calculated using the methods described in IEC Standard 61000-3-7.

For periodic fluctuations:

- The cumulative effect of operating two or more arc furnaces, for example, will be evaluated using the methods described in IEC Standard 61000-3-7 regardless of the system voltage.

3.6.2 Estimating P_{ST} Levels

For loads that produce periodic flicker, the P_{ST} emission level of an individual load can be estimated using a two step process.

Step 1: determine the %change in voltage fluctuation and fluctuation frequency

This requires the short circuit level and in-depth knowledge of the load and its operating characteristics. In some cases, applying the appropriate shape factor (see IEC 61000-3-7) may also be necessary. For arc furnaces, the fluctuation frequency is not constant and multiple frequencies will have to be examined.

Step 2: determine the P_{ST} level

Due to the linear relationship between the P_{ST} level and the flicker curve, the P_{ST} can be determined directly from the flicker curve in Appendix 1. For example, if the ΔV/V % = 1.2% with a frequency of 10 changes/minute, the expected P_{ST} level is 0.8.

Note: Manitoba Hydro will supply the short circuit level at the POI. The customer is expected to provide the projected voltage fluctuation and fluctuation frequency (rate)

Several flicker levels can be added together using the following formula:

$$Total P_{ST} = \sqrt[3]{\sum_i P_{ST_i}^3}$$

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Note:

CSA = Canadian Standards Association

CEA = Canadian Electrical Association

IEEE = Institute of Electrical and Electronics Engineers

IEC = International Electrotechnical Commission

Appendix 1 – Flicker Curve For Periodic Voltage Fluctuations

When voltage fluctuations are produced by the normal operation of a load (or loads), they are called 'periodic fluctuations'. Periodic fluctuations usually (but not necessarily) occur at frequencies greater than 1.0 changes/minute. Loads displaying this characteristic are typical of, but not limited to:

- arc furnaces
- welders
- motor jogging
- saw mills

Manitoba Hydro requires that individual loads do not introduce periodic fluctuations, at their POI, above the curves shown in the figure below.

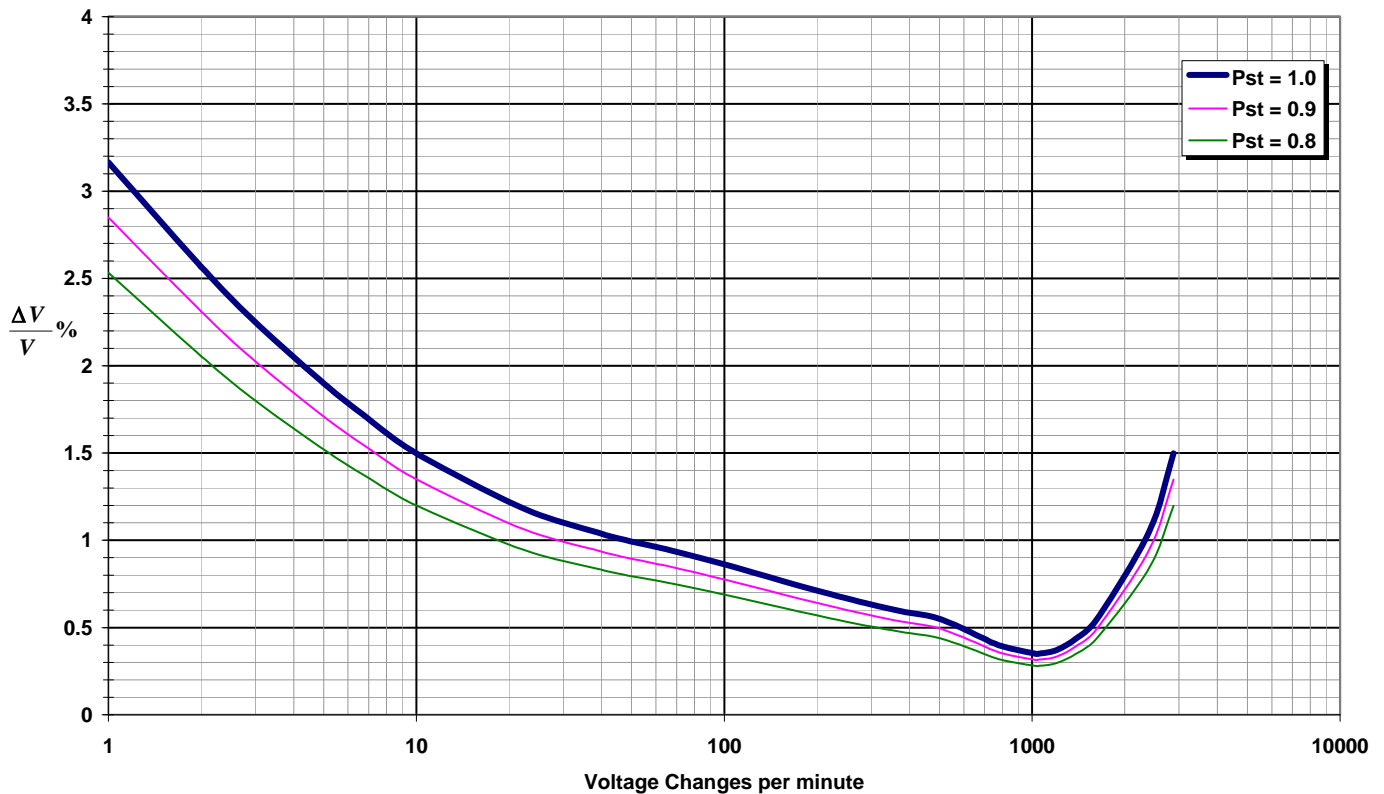


Figure 1 – IEC 61000-3-7 Flicker Curve For Periodic Voltage Fluctuations.

Notes:

1. The values were obtained experimentally through rectangular modulation of the 60 Hz AC waveform.
2. The human eye is most sensitive to fluctuations occurring at 8Hz, or 16 voltage changes per second. To convert the horizontal scale to fluctuations/sec. (Hz), divide by 120.
3. To meet the limits Table 3.3.1, the $\Delta V/V$ % must fall on or below the corresponding P_{ST} curve, at the projected fluctuation rate. For loads with varying fluctuation rates (e.g. arc furnace) $\Delta V/V$ % should be checked against a representative range of fluctuation rates.

Appendix 2 – Cumulative Frequency Analysis

The flicker data collected during a representative benchmark measurement is sometimes difficult to analyze (see top graph below). As a result, it is best analyzed by plotting the P_{ST} values in a cumulative frequency graph. From this graph, the number of P_{ST} values above or below a particular threshold can be determined. (see bottom graph below)

