Power Quality Interconnection Requirements (PQIR)

For Interconnection to Manitoba Hydro's Electrical System

Manitoba Hydro

Version 3.0 February 2020

Available in accessible formats upon request.

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1.0 General Information

1.1 Legislative Authority

Section 15.0.3(1) of *The Manitoba Hydro Act* (C.C.S.M. c. H190) authorizes Manitoba Hydro to: (a) make rules, set terms and conditions, or issue directions respecting (i) the interconnection of the works of others with the corporation's works, and (ii) the operation of the works of others that are interconnected with the corporation's works; and (b) carry out studies to evaluate the effects of a proposed interconnection. Works is defined as including all roads, railroads, plant, machinery, buildings, structures, erections, constructions, installations, materials, devices, fittings, apparatus, appliances, equipment, and other property for the development, generation, transmission, distribution, or supply of power. In addition, pursuant to Section 10 of Regulation 186/90 – Electric Power Terms and Conditions and Supply, 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 interconnection requirements for the facilities of third parties interconnected to Manitoba Hydro's electrical system.

1.2 Authors

This document revision was developed in collaboration with staff from Distribution Asset Management, System Planning, System Performance and Customer Energy Services.

1.3 Revisions

Version	Date	Changes
3.0	January 2020	• Major Updates; • Updated Voltage Unbalance; • Updated Load Start Restrictions • Updated Voltage Distortion Limits
2.0	April 2011	• Changed PCC to POI • Updated Standard References • Separated Design & Measurement Criteria
1.0	January 2005	• added Flicker criteria • revised harmonic burst criteria • revised the section related to mitigation responsibilities • created a General Information section
0.0	November 2000	Document created, addressed harmonics only

Note: Manitoba Hydro periodically updates this document and makes revisions necessary to reflect changing system conditions and industry practices. It is the customer's responsibility to ensure they are following the latest version of this document.

1.4 Applicability

This document specifies the technical performance requirements for interconnecting to the Manitoba Hydro electrical system in keeping with:

- The Manitoba Hydro Transmission System Interconnection Requirements;
- The Manitoba Hydro Distribution System Customer Load Interconnection Requirements;
- The Manitoba Hydro Distribution Distributed Resource Interconnection Requirements;
- Manitoba Hydro Electric Service Agreements.

This document does not address other Provincial or Municipal requirements associated with interconnection to the Manitoba Hydro electrical system.

This document is based on the standards provided in the reference section and include adaptations by Manitoba Hydro.

1.5 Mitigation of Power Quality Problems

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

In certain 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, power quality 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.

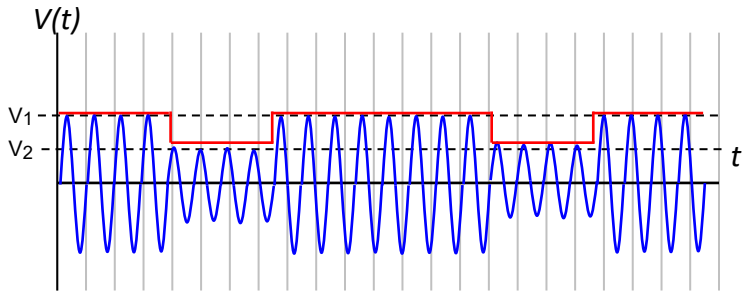
Manitoba Hydro may perform a post installation power quality analysis for comparison with the original Power Quality Benchmark. If power quality limits are exceeded, Manitoba Hydro will assist the customer in determining the cause of the problem only.

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

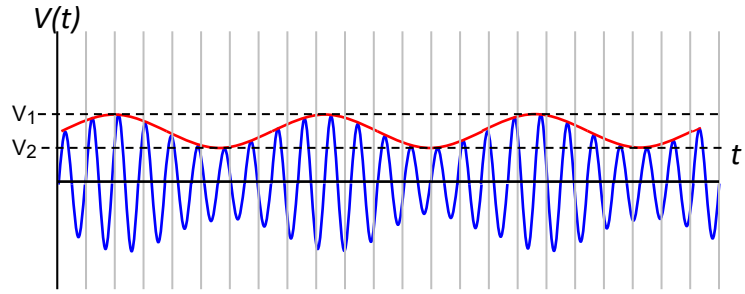
1.6 Definitions

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:

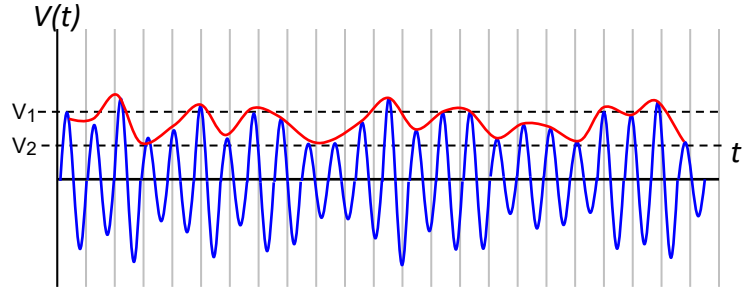
Cyclic (periodic) Fluctuations are part of the normal, continuous operation of the customer facility. The voltage magnitude varies between two values resulting in amplitude modulation of the AC sine wave envelope, as shown in the examples below.



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

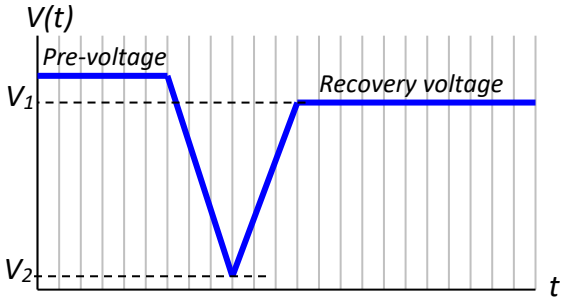


Periodic voltage fluctuation that results in sinusoidal modulation of the 60 Hz waveform. e.g.: induction furnace.



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

Dynamic Voltage Fluctuation: Can be a single or cyclic voltage changes 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 V_1 is the voltage prior to the event and V_2 is the minimum or maximum rms voltage associated with the event.



$$\text{dynamic voltage fluctuation (\%DVF)} = \frac{|V_1 - V_2|}{V_1} \times 100\%$$

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 CAN/CSA 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 CAN/CSA 61000-4-15.

h : Integer multiple of the fundamental frequency (60 Hz).

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 CAN/CSA-IEC 61000-4-7.

I_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 I_h is comprised of the magnitudes at the 175, 180 and 185 Hz frequencies

I_L: typically, the maximum demand recorded at the POI within the last 24 months.

I_{SC}: the single or three phase short-circuit current calculated at the POI during normal system operation.

I_{SC}/I_L: a ratio used to identify maximum customer facility harmonic current emissions.

Measurement Period: The monitoring duration required to complete a benchmark report and verify compliance with this document. The preferred duration is 7 days, while shorter durations may be used to resolve other concerns.

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 location of the electrical connection between the customer and Manitoba Hydro's electrical system. Normally, this is the point where ownership changes from Manitoba Hydro to the customer.

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 by Manitoba Hydro which evaluates power quality measurements taken at the POI based on Manitoba Hydro's Power Quality Interconnection Requirements document.

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 voltage content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the fundamental, as defined by CAN/CSA-IEC 61000-4-7.

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

Total Demand Distortion (TDD): the ratio of the root mean square of the harmonic current 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.

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

$\mathbf{V}_h$: magnitude of the square root of the sum of the squares of the harmonic voltage 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).

$\mathbf{V}_1$: the magnitude of the nominal fundamental frequency voltage.

2.0 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 adding motors;
- customers adding power factor or voltage correction capacitors;
- customers adding 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

Refer to Manitoba Hydro's *Transmission System Interconnection Requirements* or *Distribution System Customer Interconnection Requirements* documents 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 or near the POI to assist customers with determining requirements for interconnection.

system data:

i) short circuit level

ii) supply transformer nameplate information

iii) impedance spectrum

measured data:

iv) Power Quality Benchmark

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,

$$\%unbalance^{1} = \sqrt{\frac{6 \cdot (|V_{ab}|^2 + |V_{bc}|^2 + |V_{ca}|^2)}{(|V_{ab}| + |V_{bc}| + |V_{ca}|)^2} - 2}$$

[1] CAN/CSA 61000-2-2

Table 1: Voltage Unbalance Limits

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

2.3.2 Current and Voltage Harmonic Distortion Design Limits

The Customer is to design their facility such that total harmonic emissions, calculated at the POI, are expected to be at or below the design harmonic distortion limit multipliers for the percent duration of the measurement period identified in Table 2.

Table 2: Harmonic Multipliers for Measurement Period Duration

Tables 3 & 4 Design Limit Multipliers	Percent Duration of Monitoring Period	Time Duration of Monitoring Period (Minutes)
1.0 x (design limit)	95.0%	Continuous
1.5 x (design limit)	4.9%	494
2.0 x (design limit)	0.1%	10

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 3.

Table 3: Maximum Current Harmonic Distortion Limits Current Harmonic and Interharmonic Distortion In Percent of I_L Individual Harmonic Order (Odd Harmonics)

$V_{bus} \leq 69kV$						
I_{sc}/I_L	<11	11≤h<17	17≤h<23	23≤h<35	35≤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≤h<17	17≤h<23	23≤h<35	35≤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≤h<17	17≤h<23	23≤h<35	35≤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 are not allowed (e.g., half-wave converters).

* Refer to Section 2.3.2.2 for generation.

2.3.2.2 Generation Current Distortion

Harmonic current emissions for transmission connected generation as defined in Manitoba Hydro's "Transmission System Interconnection Requirements" shall be limited to the I_{SC}/I_L values identified with an "*" in Table 3.

Harmonic current emissions for Type 4 distributed generation as defined in Manitoba Hydro's Interconnection Guideline for Connecting Distributed Resources to the Manitoba Hydro Distribution System shall be limited to the I_{SC}/I_L values identified with an "*" in Table 3.

Harmonic current emissions for Types 1 thru 3 distributed generation as defined in Manitoba Hydro's Interconnection Guideline for Connecting Distributed Resources to the Manitoba Hydro Distribution System shall be assessed as a typical customer load in keeping with the Power Quality Interconnection Requirements.

2.3.2.3 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 4 below.

Table 4: Maximum Customer Voltage Harmonic and Interharmonic Distortion Design Limits

Bus Voltage at POI (V_{bus})	Voltage Individual Harmonic or Interharmonic Distortion (%)	Voltage Total Harmonic Distortion THD (%)
$25kV \geq V_{bus}$	3.0	5.0
$66kV \geq V_{bus} > 25kV$	2.0	3.5
$138kV \geq V_{bus} > 69kV$	1.0	1.5
$V_{bus} > 138kV$	1.0	1.0

2.3.3 System Frequency

Calculations and design shall consider a fundamental frequency range of:

Table 5: Frequency

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

2.3.4 System Voltage

Steady State Voltages at the POI are maintained in accordance with Manitoba Hydro's planning criteria identified in the following documents;

- Transmission System Interconnection Requirements;
- Distribution System Customer Load Interconnection Requirements;
- Electric Service Agreements.

2.4 Measurement Limits

The criteria in this section shall be applied to evaluate measured facility performance to required design 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 measurement harmonic distortion limit multipliers for the percent duration of the measurement period identified in Table 6.

Table 6: Harmonic Multipliers for Measurement Period Duration

Tables 3 & 7 Measurement Limit Multipliers	Percent Duration of Monitoring Period	Time Duration of Monitoring Period (Minutes)
1.0 x (measurement limit)	95.0%	Continuous
1.5 x (measurement limit)	4.9%	494
2.0 x (measurement limit)	0.1%	10

2.4.2 Voltage Harmonic Distortion Measurement Limits

These limits represent normal system distortion levels based on the cumulative contribution of all connected customers. Customer equipment must have an electromagnetic compatibility to operate in this environment.

Table 7: Maximum System Voltage Harmonic and Interharmonic Distortion at the POI

Voltage at POI (V_{bus})	Voltage Individual Harmonic Distortion (%)	Voltage Total Harmonic Distortion THD (%)
$25kV \geq V_{bus}$	5.0	8.0
$69kV \geq V_{bus} > 25kV$	3.0	5.0
$138kV \geq V_{bus} > 69kV$	1.5	2.5
$V_{bus} > 138kV$	1.0	1.5

2.4.3 Voltage Measurement Limits

Steady State Voltages at the POI are maintained in accordance with Manitoba Hydro's operating criteria identified in the following documents:

- Transmission System Interconnection Requirements;
- Distribution System Customer Load Interconnection Requirements;
- Electric Service Agreements.

2.5 Measurement

The criteria in this section shall be applied to evaluate measured facility performance to required design limits.

2.5.1 Measurement Period

When performing a Power Quality Benchmark, Manitoba Hydro shall normally assess measurements at the customer POI for a measurement period of one week (7 days) 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 Voltage Measurement Period

For voltages at the POI ≥ 100 kV, steady-state long-duration voltage variation performance targets are defined in the Transmission System Interconnection Requirement document.

For voltages at the POI < 100 kV, steady state voltage is assessed during the measurement period in accordance with Section 9 of CSA C235:19 Preferred Voltage Levels for AC Systems up to 50 000 V.

2.5.3 Equipment

The measurement instrument used to assess compliance shall comply with the specifications in CAN/CSA-CAN/CSA 61000-4-30 and CAN/CSA 61000-4-15.

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:

$$I*T = IRMS \times TIF$$

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:

Table 8: Maximum I*T Limits @POI (Amps)

Balanced I*T	Residual I*T
6000	100

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 dBrnc, (decibel C-message weighted). Measurements of noise to ground (Ng) ≤ 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.

3.0 Flicker

3.1 Introduction

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

- voltage magnitude outside accepted planning tolerances;
- flickering light sources.

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 5 hp 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 are met.

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 9. The calculations shall assume there is no background flicker. The P_{ST} design limits are also represented as flicker curves in Appendix 1.

Table 9: Customer Emission Limits[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

[1] at or below these limits in keeping with Section 3.4.1

3.3.1.1 Automatic Acceptance

Generally speaking, if the rate of dynamic or cyclic 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:

$$\frac{\Delta V}{V} * 100 = \frac{Smax}{Scs} * 100$$

- 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

Table 10: Limits for Relative Power Variations[2]

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

[2] CAN/CSA-C61000-3-7

Loads having ΔV/V % values at or below the levels specified in Table 10 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 fluctuation (%DVF) at the POI does not exceed the limits in Table 11.

Table 11: %DVF Restrictions

Operation Restriction	%DVF @ POI	
	≤ 25 kV	> 25 kV
Not Allowed	%DVF > 6	%DVF > 5
4 per day	5 ≤ %DVF ≤ 6	4 ≤ %DVF ≤ 5
1 per hour	4 ≤ %DVF < 5	3 ≤ %DVF < 4
2 per hour	3 ≤ %DVF < 4	2 ≤ %DVF < 3
No Restriction	%DVF < 3	%DVF < 2

Notes:

1. In some applications, equipment operation (e.g. jogging or jamming) may exceed restrictions beyond the intended use of Table 11, for these situations, Section 3.3.1 applies.
2. For induction motors, Manitoba Hydro assumes a 6X locked rotor current inrush to calculate %DVF unless provided with more accurate data.

3.3.3 Flicker due to Multiple Sources

This section provides a guideline during the design phase for estimating total facility flicker due to multiple pieces of equipment causing dynamic voltage fluctuations or flicker. For multiple arc furnaces or other accepted calculation methods, refer to CAN/CSA-C61000-3-7.

Total P_{ST} emission levels of multiple pieces of equipment can be estimated using a three step process.

Step 1: determine the equipment operating characteristics

Determine the percent dynamic voltage fluctuation (ΔV/V%) and voltage charges per minute for each piece of operating equipment of concern, voltage charges per minute must be constant.

Step 2: determine the P_{ST} level

Using the ΔV/V% and voltage charges per minute, estimate the PST using 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.

Step 3: Total P_{ST}

Use the general summation law found in section 3.5 to combine the multiple P_{ST} levels identified in step 2.

3.4 Measurement Limits

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

3.4.1 Flicker Measurement Limits

Flicker measurements at the POI are expected to be at or below the limits identified in Table 9 for 99% of the time during a 24 hour period during the measurement period.

3.4.2 Dynamic Voltage Fluctuation Measurement Limits

%DVF measurements at the POI are expected to be at or below the limits and operation restrictions identified in Table 11 during the measurement period.

%DVF exceeding limits may be accepted by Manitoba Hydro on a 'case by case' review, provided the Manitoba Hydro electrical system or customers are not adversely impacted, e.g. equipment outages, infrequent transformer energization may be allowed, but significant motor starts may not be allowed.

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.

Customer generated flicker will be calculated by assessing background flicker levels when the customer is not operating and subtracting this value from measured flicker during customer operation as measured at the POI using the general summation law refer to CAN/CSA-C61000-3-7, specifically;

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

Where a = 2 for arc furnaces or a = 3 for most other cases. Refer to CAN/CSA-C61000-3-7 for other coefficients.

P_{ST} = Measured P_{ST} in keeping with Sections 3.4.1 and 3.5

Dynamic voltage fluctuation will be calculated during customer current inrush or voltage events as measured at the POI during the measurement period.

3.5.1 Measurement Period

When performing a Power Quality Benchmark, Manitoba Hydro shall normally assess measurements at the customer POI for one week (7 day 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.

3.5.2 Equipment

The measurement instrument used to assess compliance shall comply with the specifications in CAN/CSA-IEC 61000-4-30 Class A and CAN/CSA-IEC 61000-4-15.

References

CAN/CSA-C61000-2-2: "Electromagnetic compatibility (EMC) - Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems"

CAN/CSA-C61000-2-12: "Electromagnetic Compatibility (EMC) - Part 2-12: Environment - Compatibility Levels for Low-Frequency Conducted Disturbances and Signalling in Public Medium-Voltage Power Supply Systems"

CAN/CSA-IEC/TS 61000-3-5: "Electromagnetic compatibility (EMC) — Part 3-5: Limits — Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 75 A"

CAN/CSA-C61000-3-6: "Electromagnetic compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power system"

CAN/CSA-C61000-3-7: "Electromagnetic Compatibility (EMC) - Part 3: Limits - Section 7: Assessment of Emission Limits for Fluctuating Loads in MV and HV Power Systems - Basic EMC Publication"

CAN/CSA-IEC 61000-4-7: "Electromagnetic compatibility (EMC) — Part 4-7: Testing and measurement techniques — General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto"

CAN/CSA-IEC 61000-4-15: Electromagnetic compatibility (EMC) — Part 4-15: Testing and measurement techniques - Flickermeter - Functional and design specifications"

CAN/CSA-IEC 61000-4-30: "Electromagnetic Compatibility (EMC) — Part 4-30: Testing and Measurement Techniques - Power Quality Measurement Methods"

CSA C235:19 "Preferred Voltage Levels for AC Systems up to 50,000 V"

IEEE Std. 519: "IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems."

IEEE P519.1/D9A: "Guide For Applying Harmonic Limits on Power Systems", January, 2004. (This guide is still in draft)

IEEE Std. 776: "IEEE Recommended Practice for Inductive Coordination of Electric Supply

and Communication Lines"

IEEE Std. 1453: "IEEE Recommended Practice for Measurement and Limits of Voltage Flicker on AC Power Systems"

Manitoba Hydro: Distribution System Customer Load Interconnection Requirements (750-100,000 V)

Manitoba Hydro: Interconnection Guideline for Connecting Distributed Resources to the Manitoba Hydro Distribution System,"

Manitoba Hydro: Transmission System Interconnection Requirements

Note:

CAN/CSA = Canadian Standards Association

IEEE = Institute of Electrical and Electronics Engineers

IEC = International Electrotechnical Commission

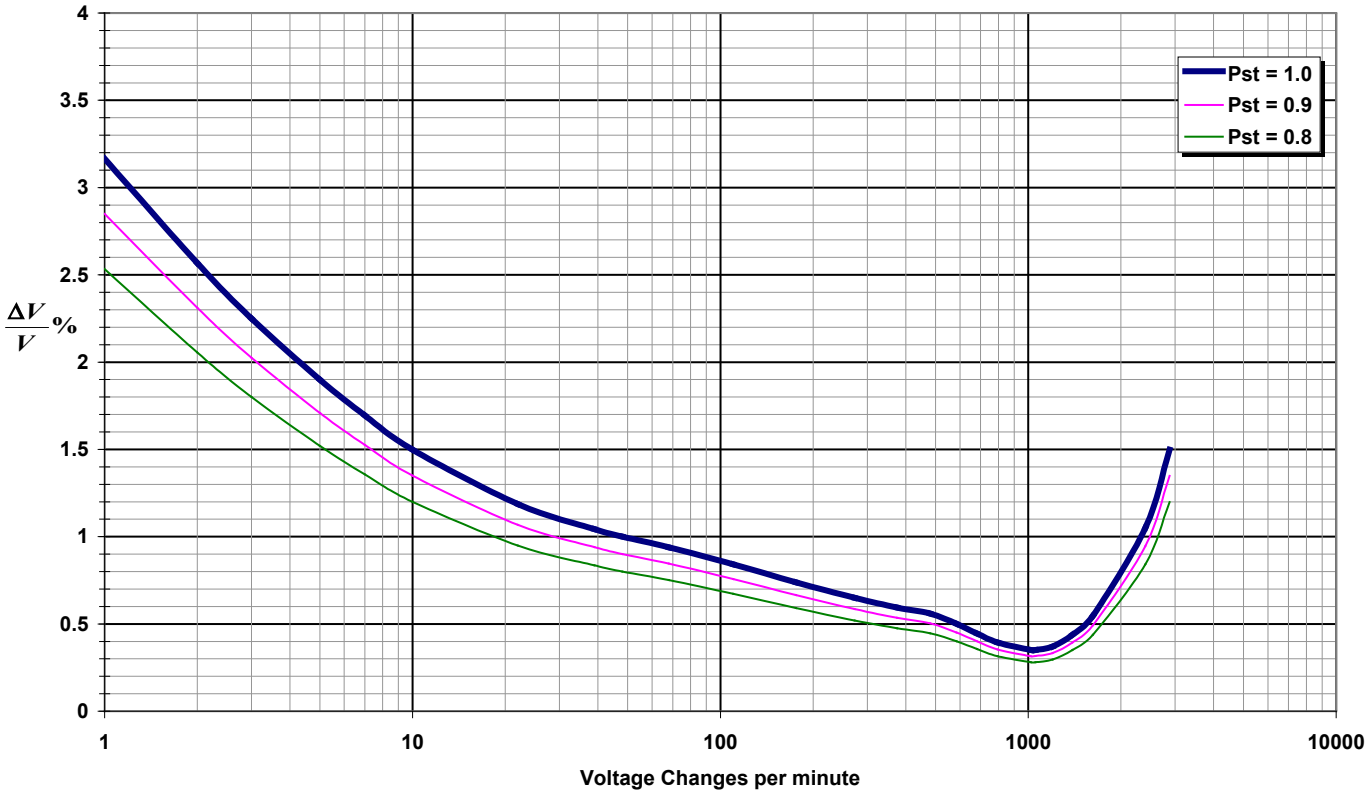
Appendix 1 – Flicker Curve for Periodic Voltage Fluctuations

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: CAN/CSA-C61000-3-7 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 ΔV/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) ΔV/V % should be checked against a representative range of fluctuation rates.