HydroOttawa			TITLE: **Technical Guideline**	
RECOMMENDED:	Y. Béchamp	P. Eng	NO: **ECG0008**	REV: **5**
APPROVED:	E. Donkersteeg	P. Eng		
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Distribution System Voltage

and

Power Quality

REVISION SHEET

Revision	Description of Change	Date	Initial
0	Original Document	2006-02-24	fk/csm
1	Expanded Section 9 on tingle voltage	2008-02-01	mdf/csm
2	Revised Section 9 on stray voltage	2009-09-09	mdf/csm
3	General Formatting Update. General Update based on new revision of IEEE Stds. Updated THD limits for Public Road Authority	2015-05-14	smc/csm
4	Update Harmonic Distortive Limits	2016-02-03	smc/csm
5	Revised Section 5.0 on Limitations to Steady State Voltages Revised Energy Resource to Distributed Energy Resource	2024-09-24	yb/ed

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1.0 Introduction

The Ontario Energy Board (OEB) requires Hydro Ottawa (HOL) to provide electrical power in a fair and consistent manner to all its customers. The OEB also requires HOL to define its terms and conditions for connection and disconnection of its customers while ensuring power quality is part of HOL's requirement to its customers.

HOL's Conditions of Service, ECS0012, defines some of the more regularly encountered power quality type issues such as:

- Connection and disconnection of service;
- Planned and unplanned interruptions;
- Balancing load between phases;
- Protection of equipment with the loss of one, or many, phases;
- Long secondary supply cables and voltage control;
- Electromagnetic fields (EMF);
- The restrictions of using the HOL electrical system for telecommunications via a power line carrier;

If the customer has on-going concerns of voltage and power quality levels and limits with their equipment on their side of the point of supply, with qualified help the customer may undertake a controlled assessment period to locate and correct the area of concern. HOL may be able to provide assistance to customers with power quality concerns – see HOL document ECS0012 for more information.

Customers should also take appropriate precautions or protective measures to prevent or at least limit damage to equipment, in the event that compatibility levels and limits are exceeded.

2.0 References

ANSI/IEEE C62.41-1991	IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
ANSI/IEEE C84.1-1982	American National Standard Preferred Voltage Ratings for Electric Power Systems and Equipment
ANSI/IEEE 141-1986	IEEE Recommended Practice for Electric Power Distribution for Industrial Plants
CEA 161 D456B	Canadian Electricity Association - Probabilistic Coordination of Fuses
CEA 131 D489	Impact of Cold Load Pickup on Voltage Profiles and Overcurrent Protection in the Distribution System
CAN/CSA-C61000	Electromagnetic Compatibility
CAN/CSA-C61000-3-7:04	Emission Limits for Fluctuating Loads
CSA CAN3-C235-83	Preferred Voltage Levels for AC Systems, 0 to 50,000 V
Hydro Ottawa ECG0006	Distributed Energy Resource Technical Requirements
Hydro Ottawa ECS0012	Conditions of Service
Hydro Ottawa ECS0037	Initial Customer Energy Account Rate Classification

Hydro Ottawa ECS0028	Farm Stray Voltage Customer Response Procedure
Hydro Ottawa GDC0001	Sequence Impedances of Overhead and Underground Conductors
IEEE 519–1992	Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems
IEEE 519–2014	Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems
IEEE 929	Recommended Practice for Utility Interface of Photovoltaic (PV) Systems
IEEE 1159-1995	Recommended Practices for Monitoring Electric Power Quality
ITI	ITI (CBEMA) Curve – Revised 2000 - http://www.itic.org.
NEMA MG1-10.37.2	Motors and Generators
Ontario Energy Board	Distribution System Code (DSC)
Ontario Energy Board	2006 Electricity Distribution Rate Handbook (ERH)
Ontario	The Ontario Electrical Safety Code (OESC)

3.0 Scope

The scope of this document is to provide guidelines for consistent and standard applications for voltage and power quality requirements on or connected to HOL's distribution system. Normally voltage limits, voltage distortion, and current distortion are measured at the customer's Point of Supply as per HOL document ECS0012.

This document does not cover the following power quality issues:

- Voltage control when the Independent Electrical System Operator (IESO) has declared a voltage reduction or an electrical system emergency;
- Non-standard conditions such as a force majeure (e.g. war, sabotage, labour disruption, malicious damage, accidental influence by a third party, severe weather, contamination, and animal interference), and;
- Defining the requirements and inspecting the installation for the customer's electrical protection and control of equipment under normal and fault conditions, and its electrical safety requirements. The Electrical Safety Authority (ESA) administers the Ontario Electrical Safety Code (OESC).

4.0 Definitions

'AC' means "Alternating Current".

'ACSR' means "Aluminum Cable Steel Reinforced".

'ANSI' means the "American National Standards Institute".

'Apparent Power' means the total power measured in kiloVolt Amperes (kVA).

'CBEMA' means the "Computer and Business Equipment Manufacturers Association".

‘CEA’ means the “Canadian Electricity Association”.

‘CSA’ means the “Canadian Standards Association”.

‘DC’ means “Direct Current”.

‘DSC’ means the Ontario Energy Board “Distribution System Code”.

‘ERH’ means the Ontario Energy Board “Electricity Distribution Rate Handbook”.

‘ESA’ means the “Electrical Safety Authority”.

‘Extreme Operating Conditions’ means where voltages lie outside the indicated limits for normal operating conditions, but within the indicated limits for extreme operating conditions, improvement or corrective action should be taken.

‘HOL’ means “Hydro Ottawa Limited”.

‘HP’ means “HorsePower”.

‘Hz’ denotes frequency, in Hertz.

‘IEEE’ means the “Institute of Electrical and Electronics Engineers”.

‘IESO’ means the “Independent Electrical System Operator”.

‘ITI’ means the “Information Technology Industry” council.

‘ITE’ means “Information Technology Equipment”.

‘kcmil’ – see “MCM”.

‘kHz’ means “kiloHertz”; see also “Hz”.

‘kV’ means “kiloVolt”.

‘kVA’ means “kiloVolt Ampere”; see also “Apparent Power”.

‘kW’ means “kiloWatt”; see also “Real Power”.

‘LRA’ means “Locked Rotor Amps”.

‘MCM’ means “thousand Circular Mils”, or more commonly “kcmil”; a unit of measure that denotes the cross-sectional area of a cable.

‘NEMA’ means the “National Electrical Manufacturers Association”.

‘NEV’ means “Neutral Earth Voltage”.

‘Normal Operating Conditions’ means where voltages lie within the indicated limits, no improvement or corrective action is required.

‘NPCC’ means the “Northwest Power Coordinating Committee”.

‘OEB’ means the “Ontario Energy Board”.

‘OESC’ means the “Ontario Electrical Safety Code”.

‘PCC’ means “Point of Common Coupling”; in this document, the PCC is taken to be at the Supply Point for the customer’s service.

‘PILC’ means “Paper Insulated Lead Covered”.

‘Power Factor’ means the cosine of the angle taken between Real Power (kW) and Apparent Power (kVA).

‘Real Power’ means the power component that can be used to perform real work, measured in kiloWatts (kW).

‘RMS’ means “Root Mean Squared”.

‘Supply Point’ – see definition of “Supply Point” in HOL document ECS0012.

‘THD’ means “Total Harmonic Distortion”.

5.0 Limitations to Steady State Operating Voltage Levels

To ensure consistency with all Canadian Standards Association approved equipment and regulatory requirements from the Independent Electrical System Operator, the Northeast Power Coordinating Council, and the OEB Distribution System Code, HOL will maintain voltage in the distribution system according to CSA document CAN3-C235-83 for steady-state conditions. Hydro Ottawa may indefinitely operate voltages within the “Allowable Deviation from Nominal” found in Table 1. Under normal operations, voltages may exceed the “Allowable Deviation from Nominal” for periods under one minute.

Customers may occasionally experience voltage variations outside these limits when operating under extreme conditions (see Table 2 and Table 3 of this document).

Distributed energy resources shall operate within the CSA document CAN3-C235-83 normal limits in steady-state. For Short-duration secondary voltage variations, the Information Technology Council (ITI / CBEMA) voltage tolerance envelope limits (see Appendix A: ITI (CBEMA) Curve Application Notes) shall apply.

Accordingly, HOL will strive to maintain the following distribution system voltages under normal conditions at the point of connection:

Nominal Voltage (RMS V)	Allowable Deviation from Nominal (%)**	Normal Minimum Voltage (RMS V)	Normal Maximum Voltage (RMS V)	Reference
120V / 240V	+4.17% ; -8.33%	110V / 220V	125V / 250V	At Service Entrance per CSA CAN3-C235-83 Table 3.0
120V / 208Y	+4.17% ; -6.67%	112V / 194Y	125V / 216Y	At Service Entrance per CSA CAN3-C235-83 Table 3.0
347V / 600Y	+3.75% ; -8.33%	318V / 550Y	360V / 625Y	At Service Entrance per CSA CAN3-C235-83 Table 3.0
2400V / 4160Y	+6.00% ; -6.00%	2256V / 3910Y	2544V / 4410Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
4800V / 8320Y*	+6.00% ; -6.00%	4512V / 7821Y	5088V / 8819Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
7200V / 12470Y	+6.00% ; -6.00%	6768V / 11722Y	7632V / 13218Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
7600V / 13200Y*	+6.00% ; -6.00%	7144V / 12408Y	8056V / 13992Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
15930V / 27600Y*	+6.00% ; -6.00%	14974V / 25944Y	16886V / 29256Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
44000V*	+6.00% ; -6.00%	41360V	46640V	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
46000V	+6.00% ; -6.00%	43240V	48760V	At Point of Sale per CSA CAN3-C235-83 Clause 6.1

Table 1: Steady State Operating Voltage Ranges Under Normal Conditions, adapted from CSA document CAN3-C235-83.
* **Note:** Voltage not recognized in CSA CAN3-C235-83.
** **Note:** Voltage Deviations outside the nominal range for up to 1 minute may occur. Voltages may operate within the allowable deviation range continuously.

In some instances HOL may need to operate the distribution system under extreme operating conditions. Accordingly, HOL will strive to maintain the following distribution system voltages under extreme operating conditions:

Nominal Voltage (RMS V)	Allowable Deviation from Nominal (%)**	Extreme Min. Voltage (RMS V)	Extreme Max. Voltage (RMS V)	Reference
120V / 240V	+5.83% ; -11.67%	106V / 212V	127V / 254V	At Service Entrance per CSA CAN3-C235-83 Table 3.0
120V / 208Y	+5.83% ; -8.65%	110V / 190Y	127V / 220Y	At Service Entrance per CSA CAN3-C235-83 Table 3.0
347V / 600Y	+5.76% ; -11.82%	306V / 530Y	367V / 635Y	At Service Entrance per CSA CAN3-C235-83 Table 3.0
2400V / 4160Y	+6.00% ; -6.00%	2256V / 3910Y	2544V / 4410Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
4800V / 8320Y*	+6.00% ; -6.00%	4512V / 7821Y	5088V / 8819Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
7200V / 12470Y	+6.00% ; -6.00%	6768V / 11722Y	7632V / 13218Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
7600V / 13200Y*	+6.00% ; -6.00%	7144V / 12408Y	8056V / 13992Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
15930V / 27600Y*	+6.00% ; -6.00%	14974V / 25944Y	16886V / 29256Y	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
44000V*	+6.00% ; -6.00%	41360V	46640V	At Point of Sale per CSA CAN3-C235-83 Clause 6.1
46000V	+6.00% ; -6.00%	43240V	48760V	At Point of Sale per CSA CAN3-C235-83 Clause 6.1

Table 2: Steady State Operating Voltage Ranges Under Extreme Conditions, adapted from CSA document CAN3-C235-83.
* Note: Voltage not recognized in CSA CAN3-C235-83.
** **Note:** Voltage Deviations outside the nominal range for up to 1 minute may occur. Voltages may operate within the allowable deviation range continuously.

6.0 Limitations to Voltage Flicker

HOL will limit the operation of all equipment that results in substantial voltage variations to a maximum number of operations. As a reference baseline, HOL will reference IEEE document, IEEE 519-1992, Figure 10.3 (reproduced in this document as Figure 1), for the determination of allowable voltage variances on the distribution system. All customer loads shall not be operated at any point above the “Border Line of Irritation” curve.

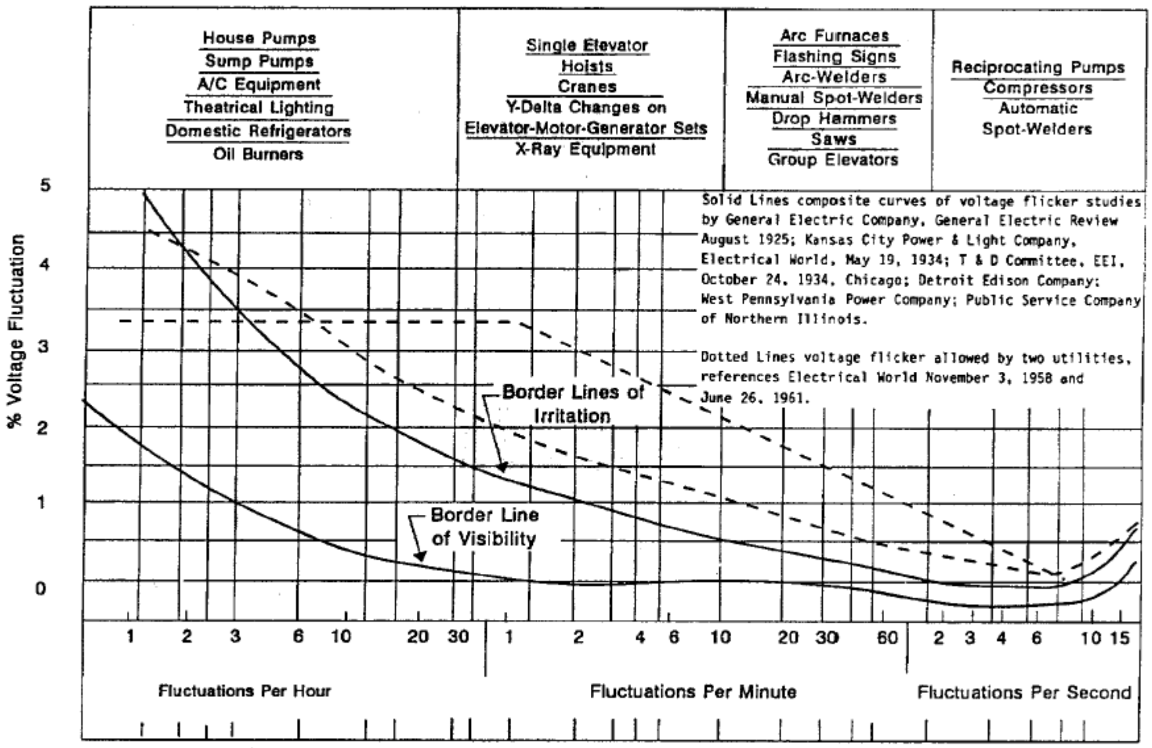

Figure 1: Allowable Voltage Flicker as per IEEE document 519-1992, Figure 10.3

7.0 Maximum Allowable Motor Starting Current

The maximum allowable motor starting current will be based on the impact on feeder voltage and secondary transformer voltage.

The impact of repetitive current surges on the fusible elements will not be considered as a limiting factor for the maximum allowable motor starting. However, reduced voltage starting may be needed if satisfactory transformer fusing cannot be obtained, due to excessive starting current or a relatively long starting cycle.

7.1 General Guidelines for Motor Starting Driven by Secondary Voltages

The starting current for 120V, 1-Phase motors and unitary equipment including air conditioners and heat pumps shall not exceed 50A. The starting current for 240V, 1-Phase motors and unitary equipment such as air conditions and heat pumps shall not exceed 75A[1].

The nameplate data on the self-contained 120V/240V, 1-Phase air conditioning unit shall consist of voltage rating, full load current, starting current, running power factor, and nominal horsepower rating[1].

For 600V, 3-Phase services, the starting current for 3-Phase motors shall not exceed 240A[1].

7.2 NEMA Code Letters for Locked-Rotor kVA

The letter designations for locked-rotor kVA per horsepower as measured at full voltage and rated frequency are as follows.

Letter Designation	kVA per Horsepower (HP)		Letter Designation	kVA per Horsepower (HP)	
	Minimum	Maximum		Minimum	Maximum
A	0	3.15	K*	8.0	9.0
B	3.15	3.55	L*	9.0	10.0
C	3.55	4.0	M	10.0	11.2
D	4.0	4.5	N	11.2	12.0
E	4.5	5.0	P	12.0	14.0
F*	5.0	5.6	R	14.0	16.0
G*	5.6	6.3	S	16.0	18.0
H*	6.3	7.1	T	18.0	22.0
J*	7.1	8.0	U	22.0	22.4
			V	22.4	& up

Table 3: Taken from NEMA National Equipment Manufacturers Association Standard MG1-10.37.2
* Code letters usually applied to ratings of motors normally started on full voltage.

[1] – Adapted from Ottawa Hydro Service Regulations CP1989-1.

7.3 Calculation of Locked Rotor Amps (LRA)

To calculate the locked rotor amps, for a 3-phase motor, for the NEMA class designations the following formula will be used:

$$LRA = \frac{1000\ x\ (Starting\ kVA\ per\ HP)\ x\ HP}{\sqrt{3}\ x\ Voltage(Line-Line)}$$

By using the results of the locked rotor amps, the motor's starting impedance can be calculated using the following;

$$Z_{ms} = \frac{Voltage(Phase-Phase)}{LRA}$$

$$Z_{ms} = \frac{Voltage(Phase-Phase)\ x\left(\sqrt{3}\ x\ Voltage(Line-Line)\right)}{1000\ x\ (Starting\ kVA\ per\ HP)\ x\ HP}$$

All upstream system impedances should be calculated. The line impedance should be calculated by using the positive sequence impedances defined in HOL document GDC0001. The system source impedance should be calculated according to the following;

$$Z_s = \frac{(Voltage\ (in\ kV, Phase-Phase))^2}{Short\ Circuit\ Level\ (\ kVA)}$$

Upstream impedance and the motor starting impedance should be converted to a Thevenin equivalent circuit to calculate the actual motor starting current. This current can then be used to calculate voltage drop associated with the current.

Table 4 – Summary of Motor Starting Voltage Fluctuations for 4.16 kV

NEMA Motor Class	Motor Size (HP)	Voltage Fluctuation (on entire feeder)	Voltage Fluctuation (on secondary bus)	# Starts permitted per hour based on IEEE 519
TYPE A	500	1.44% - 1.49%	8.63% - 8.69%	N/A**
	400	1.17% - 1.22%	7.03% - 7.07%	N/A**
	300	0.89% - 0.93%	5.37% - 5.40%	N/A**
	200	0.61% - 0.63%	3.64% - 3.76%	N/A**
	100	0.31% - 0.32%	1.85% - 1.87%	N/A**
TYPE F	500	2.40% - 2.49%	14.38% - 14.46%	8***
	400	1.97% - 2.05%	11.85% - 11.92%	15
	300	1.53% - 1.59%	9.16% - 9.21%	N/A**
	200	1.05% - 1.09%	6.30% - 6.34%	N/A**
	100	0.54% - 0.56%	3.25% - 3. 27%	N/A**
TYPE G	500	2.68% - 2.78%	15.05% - 15.14%	5***
	400	2.21% - 2.29%	12.41% - 12.49%	10
	300	1.71% - 1.77%	9.61% - 9.67%	20
	200	1.18% - 1.22%	6.62% - 6.66%	N/A**
	100	0.61% - 0.63%	3.42% - 3.44%	N/A**
TYPE H	500	2.93% - 3.04%	17.56% - 17.65%	5***
	400	2.43% - 2.52%	14.56% - 14.64%	8
	300	1.89% - 1.96%	11.33% - 11.40%	15
	200	1.31% - 1.36%	7.85% - 7.90%	N/A**
	100	0.68% - 0.71%	4.09% - 4.11%	N/A**
TYPE J	500	3.23% - 3.35%	19.35% - 19.46%	4***

NEMA Motor Class	Motor Size (HP)	Voltage Fluctuation (on entire feeder)	Voltage Fluctuation (on secondary bus)	# Starts permitted per hour based on IEEE 519
	400	2.68% - 2.79%	16.11% - 16.20%	6
	300	2.10% - 2.18%	12.59% - 12.66%	12
	200	1.46% - 1.52%	8.76% - 8.81%	N/A**
	100	0.76% - 0.79%	4.58% - 4.61%	N/A**
TYPE K	500	3.54% - 3.68%	21.26% - 21.37%	3***
	400	2.96% - 3.07%	17.76% - 17.86%	5
	300	2.32% - 2.41%	13.94% - 14.02%	10
	200	1.62% - 1.69%	9.75% - 9.80%	N/A**
	100	0.85% - 0.89%	5.12% - 5.16%	N/A**
TYPE L	500	3.85% - 3.99%	23.08% - 23.19%	2***
	400	3.23% - 3.35%	19.35% - 19.46%	4
	300	2.54% - 2.64%	15.25% - 15.34%	8
	200	1.79% - 1.85%	10.71% - 10.78%	N/A**
	100	0.94% - 0.98%	5.66% - 5.70%	N/A**

* - Note: Based on customer with 1000 kVA transformer @ 5.0 %IZ

** - Denotes “Not Applicable”

*** - Note: Individual loads above 300kVA are not permitted on 4kV circuits

Table 5 – Summary of Motor Starting Voltage Fluctuations for 8.32 kV

NEMA Motor Class	Motor Size (HP)	Voltage Fluctuation (on entire feeder)	Voltage Fluctuation (on secondary bus)	# Starts permitted per hour based on IEEE 519
TYPE A	500	1.50% - 1.56%	4.51% - 4.57%	N/A**
	400	1.21% - 1.26%	3.64% - 3.69%	N/A**
	300	0.92% - 0.95%	2.76% - 2.79%	N/A**
	200	0.62% - 0.64%	1.85% - 1.88%	N/A**
	100	0.31% - 0.32%	0.94% - 0.95%	N/A**
TYPE F	500	2.58% - 2.68%	7.75% - 7.84%	1
	400	2.10% - 2.18%	6.30% - 6.37%	15
	300	1.60% - 1.66%	4.80% - 4.86%	15
	200	1.08% - 1.13%	3.25% - 3.29%	N/A**
	100	0.55% - 0.57%	1.65% - 1.67%	N/A**
TYPE G	500	2.65% - 2.75%	15.90% - 15.98%	5
	400	2.19% - 2.27%	13.13% - 13.21%	12
	300	1.70% - 1.76%	10.19% - 10.24%	15
	200	1.17% - 1.22%	7.03% - 7.07%	N/A**
	100	0.61% - 0.63%	3.64% - 3.67%	N/A**
TYPE H	500	3.21% - 3.33%	9.62% - 9.74%	1
	400	2.62% - 2.72%	7.85% - 7.95%	5
	300	2.0% - 2.08%	6.01% - 6.08%	10
	200	1.36% - 1.41%	4.09% - 4.14%	N/A**
	100	0.70% - 0.72%	2.09% - 2.11%	N/A**

TYPE J	500	3.57% - 3.71%	10.71% - 10.84%	3
	400	2.92% - 3.03%	8.76% - 8.86%	5
	300	2.24% - 2.32%	6.72% - 6.80%	12
	200	1.53% - 1.59%	4.58% - 4.64%	N/A**
	100	0.78% - 0.81%	2.34% - 2.37%	N/A**
TYPE K	500	3.96% - 4.11%	11.89% - 12.03%	2
	400	3.25% - 3.37%	9.75% - 9.86%	4
	300	2.50% - 2.59%	7.49% - 7.58%	7
	200	1.71% - 1.77%	5.12% - 5.19%	20
	100	0.88% - 0.91%	2.63% - 2.66%	N/A**
TYPE L	500	4.35% - 4.51%	13.04% - 13.19%	2
	400	3.57% - 3.71%	10.71% - 10.84%	3
	300	2.75% - 2.86%	8.26% - 8.36%	5
	200	1.89% - 1.96%	5.66% - 5.73%	15
	100	0.97% - 1.01%	2.91% - 2.95%	N/A**

** - Denotes "Not Applicable"

Table 6 – Summary of Motor Starting Voltage Fluctuations for 13.2 kV

NEMA Motor Class	Motor Size (HP)	Voltage Fluctuation (on entire feeder)	Voltage Fluctuation (on secondary bus)	# Starts permitted per hour based on IEEE 519
TYPE A	500	0.44% - 0.5%	2.84% - 2.89%	N/A**
	400	0.35% - 0.4%	2.28% - 2.33%	N/A**
	300	0.27% - 0.3%	1.72% - 1.76%	N/A**
	200	0.18% - 0.2%	1.15% - 1.18%	N/A**
	100	0.09% - 0.1%	0.58% - 0.59%	N/A**
TYPE F	500	0.76% - 0.86%	4.93% - 5.03%	N/A**
	400	0.61% - 0.70%	3.99% - 4.07%	N/A**
	300	0.47% - 0.53%	3.02% - 3.08%	N/A**
	200	0.31% - 0.36%	2.03% - 2.08%	N/A**
	100	0.16% - 0.18%	1.03% - 1.05%	N/A**
TYPE G	500	0.85% - 0.97%	5.51% - 5.63%	N/A**
	400	0.69% - 0.78%	4.46% - 4.55%	N/A**
	300	0.52% - 0.59%	3.38% - 3.45%	N/A**
	200	0.35% - 0.40%	2.28% - 2.33%	N/A**
	100	0.18% - 0.20%	1.15% - 1.18%	N/A**
TYPE H	500	0.95% - 1.08%	6.17% - 6.29%	N/A**
	400	0.77% - 0.88%	5.00% - 5.10%	N/A**
	300	0.59% - 0.67%	3.80% - 3.87%	N/A**
	200	0.4% - 0.45%	2.56% - 2.62%	N/A**
	100	0.20% - 0.23%	1.30% - 1.33%	N/A**
TYPE J	500	1.06% - 1.21%	6.90% - 7.04%	N/A**

	400	0.86% - 0.98%	5.60% - 5.71%	N/A**
	300	0.66% - 0.75%	4.26% - 4.34%	N/A**
	200	0.44% - 0.50%	2.88% - 2.94%	N/A**
	100	0.23% - 0.26%	1.46% - 1.49%	N/A**
TYPE K	500	1.19% - 1.35%	7.70% - 7.85%	N/A**
	400	0.96% - 1.10%	6.25% - 6.38%	N/A**
	300	0.73% - 0.83%	4.76% - 4.83%	N/A**
	200	0.50% - 0.57%	3.23% - 3.29%	N/A**
	100	0.25% - 0.29%	1.64% - 1.67%	N/A**
TYPE L	500	1.31% - 1.48%	8.48% - 8.64%	N/A**
	400	1.06% - 1.21%	6.90% - 7.04%	N/A**
	300	0.81% - 0.92%	5.27% - 5.37%	N/A**
	200	0.55% - 0.63%	3.57% - 3.65%	N/A**
	100	0.28% - 0.32%	1.82% - 1.86%	N/A**

** - Denotes "Not Applicable"

Table 7 – Summary of Motor Starting Voltage Fluctuations for 27.6 kV

NEMA Motor Class	Motor Size (HP)	Voltage Fluctuation (on entire feeder)	Voltage Fluctuation (on secondary bus)	# Starts permitted per hour based on IEEE 519
TYPE A	500	0.51% - 0.57%	3.05% - 3.11%	N/A**
	400	0.41% - 0.46%	2.46% - 2.51%	N/A**
	300	0.31% - 0.35%	1.85% - 1.89%	N/A**
	200	0.21% - 0.23%	1.24% - 1.27%	N/A**
	100	0.10% - 0.12%	0.63% - 0.64%	N/A**
TYPE F	500	0.88% - 0.99%	5.30% - 5.40%	N/A**
	400	0.71% - 0.80%	4.29% - 4.37%	N/A**
	300	0.54% - 0.61%	3.25% - 3.31%	N/A**
	200	0.37% - 0.41%	2.19% - 2.23%	N/A**
	100	0.18% - 0.21%	1.11% - 1.13%	N/A**
TYPE G	500	2.88% - 2.99%	8.63% - 8.74%	4
	400	2.34% - 2.43%	7.03% - 7.11%	5
	300	1.79% - 1.86%	5.37% - 5.43%	20
	200	1.21% - 1.26%	3.64% - 3.69%	N/A**
	100	0.62% - 0.64%	1.85% - 1.88%	N/A**
TYPE H	500	1.10% - 1.23%	6.63% - 6.75%	N/A**
	400	0.90% - 1.00%	5.37% - 5.47%	N/A**
	300	0.68% - 0.76%	4.09% - 4.16%	N/A**
	200	0.46% - 0.51%	2.76% - 2.81%	N/A**
	100	0.23% - 0.26%	1.40% - 1.43%	N/A**
TYPE J	500	1.23% - 1.38%	7.41% - 7.54%	N/A**

	400	1.00% - 1.12%	6.02% - 6.13%	N/A**
	300	0.76% - 0.85%	4.58% - 4.67%	N/A**
	200	0.52% - 0.58%	3.10% - 3.16%	N/A**
	100	0.26% - 0.29%	1.57% - 1.61%	N/A**
TYPE K	500	1.36% - 1.52%	9.50% - 9.65%	N/A**
	400	1.11% - 1.24%	7.75% - 7.87%	N/A**
	300	0.85% - 0.95%	5.93% - 6.02%	N/A**
	200	0.58% - 0.64%	4.03% - 4.10%	N/A**
	100	0.29% - 0.33%	2.06% - 2.09%	N/A**
TYPE L	750	2.17% - 2.42%	13.04% - 13.27%	6
	500	1.52% - 1.69%	9.09% - 9.25%	20
	400	1.23% - 1.38%	7.41% - 7.54%	N/A**
	300	0.94% - 1.05%	5.66% - 5.77%	N/A**
	200	0.64% - 0.72%	3.85% - 3.92%	N/A**
	100	0.33% - 0.37%	1.96% - 2.00%	N/A**

** - Denotes "Not Applicable"

8.0 Maximum Allowable Distributed Energy Resource Connection

The maximum allowable distributed energy resource connections will be based on one of two criteria. The first criteria deals with the allowable voltage drop on the substation bus and will determine the maximum single or aggregate distributed energy resources that can be connected to each substation bus under normal operating configurations. The second criteria deal with the maximum load limit of the circuit based on typical conductor capacity.

8.1 Criteria #1 – Maximum Distributed Energy Resource per Substation Bus

The first criteria will take into consideration sudden losses in distributed energy resource and the effect to the substation bus. Sudden losses of load due to distributed energy resource rejection are seen by the station as a sudden increase in load supplied from the station. This additional load results in an under voltage situation or sag at the substation bus which affects all customer connected to the bus. In order to minimize these impacts to customers with voltage sensitive equipment a maximum allowable voltage deviation of 3.5% will be allowed on the substation bus. This will result in limiting the allowable distributed energy resource rejection to three (3) per hour (it is understood that it will take approximately 20 minutes per incident to reset relays, flags etc, and contact HOL's System Control Authority prior to re-synchronizing).

8.2 Criteria #2 – Maximum Distributed Energy Resource per Substation Feeder

The second criteria will take into consideration the normal ampacity of the conductors that are in use in the distribution system.

Voltage (kV)	Allowable Outages per Hour	Maximum Allowable Voltage Deviation	Max. Distributed Energy Resource per Bus (MVA)	Typical Feeder Ampacity* (A)	Max. Distributed Energy Resource per Feeder (MVA)
4.16	3	3.5 %	3.5	250	1.8
8.32	3	3.5 %	3.5	430*	3.5
12.47	3	3.5 %	3.5	430*	3.5
13.2 (per bus pair)	3	3.5 %	12	350**	8.0
27.6	3	3.5 %	12	430***	12
44	3	3.5 %	30	600****	30

Table 8: Maximum Distributed Energy Resource per Substation Feeder

Note: * – Based on 500 MCM aluminum direct buried
** – Based on 500 MCM copper PILC in duct
*** – Based on 500 MCM aluminum in three ducts
**** – Based on 477 ACSR overhead

9.0 General Statements and Guidelines on Power Quality for Customers

Some customer owned equipment may be sensitive to harmonics, interruptions, or other disturbances on the electrical system. HOL strives to maintain voltage, power quality, and frequency within the CSA standard, but on occasion, system disturbances may cause variations or interruptions to the customer's supply[1].

Customers are advised to protect their sensitive equipment or processes against disturbances either from the HOL system or from within their own premises (e.g. welders, arc furnaces, motor starting, switching power supplies, etc.) [1].

Customers installing a welder, motor, or any other equipment causing highly fluctuating loads or harmonics may create system disturbances that cause undue interference with other customers. HOL may either require a separate intermediate transformer be installed at the customer's expense or require customers to correct the problem within their own premises[1].

Three phase customers shall ensure their load and/or distributed energy resource facility equipment are balanced between all three phases to within 15%.

10.0 Harmonics

To minimize any impacts on the power quality of the utility distribution system, the customer shall ensure that harmonic distortion generated by its facilities is within the limits prescribed by IEEE 519–2014 and associated IEEE standards referenced within it. If these limits are exceeded, corrective action on the part of the customer shall be required unless otherwise determined by HOL. All costs required to mitigate problems due to harmonic generation will be the responsibility of the customer.

10.0.1. The value for I_{SC} (available short-current current) shall be determined at , or computed for, the Supply Point for the customer's service.

10.0.2. The value for I_L (maximum demand load current) shall be based on one of the following:

10.0.2.1. Computed based on a minimum of one year of historical billing demand data.

10.0.2.2. In the absence of sufficient historical metering data (i.e. for a new service or non-demand customers), the value for I_L shall be based on one of the following, whichever is larger:

10.0.2.2.1. Computed based on the customer supplied load summary for their service.

10.0.2.2.2. Using one of the following methods, depending on the voltage supplied to the customer:

10.0.2.2.2.1. If the customer's service entrance voltage is supplied at a primary voltage (i.e. greater than 750V), I_L shall be taken as the nominal ampacity rating of the customer's service entrance.

10.0.2.2.2.2. If the customer's service entrance voltage is a secondary voltage (i.e. less than, or equal to, 750V), I_L shall be taken as 80% of the value found the "Amperage" column of Schedule 1, of HOL document ECS0037, from the row corresponding to the voltage of the customer's service entrance and customer classification.

10.1 THD Limits for Loads Owned and Operated by a Public Road Authority

For loads owned and operated by a public road authority, the following limits shall apply:

10.1.1. Total harmonic voltage & current distortion (THD), for odd numbered harmonics, shall be kept strictly less than 12% under steady-state full load conditions (i.e. periods of time longer than 10 minutes).

10.1.2. Total harmonic current and voltage distortion (THD), for even numbered harmonics, for be kept within the limits prescribed in this document.

11.0 Stray Voltage and Stray Currents

Both stray voltage and stray currents may appear beyond the Point of Supply. Consequences of these stray issues may result in electrical protective and control equipment mis-operation, material corrosion, telecommunication interference, tingle voltage, and public & worker safety.

Both HOL and its customers shall ensure that the source(s) of these stray electrical issues are mitigated to acceptable levels. Current distortion that results in a DC offset (e.g. from half-wave converters) are not permitted. If a customer has specific equipment contributing significantly to these consequences, the customer shall apply specific remedies to their stray electrical issues to bring them to within acceptable levels.

11.1 Customer Stray Voltage Concerns

The issue of stray voltage is a phenomenon that is not unique to the province of Ontario. HOL designs its electrical distribution system in compliance with national and provincial legislation, regulations and codes, and good utility practice. The electrical distribution system is designed to have the neutral earth voltage (NEV) requirement not to exceed 10V RMS under steady state conditions (i.e. periods of time longer than 3 seconds), as per rule 75-814 of the OESC[2].

Should a customer inform HOL of a tingle voltage concern, HOL will conduct an investigation to validate the existence of a tingle voltage and to determine the source of the voltage. If the source of this tingle voltage is determined as a direct result of HOL equipment, then HOL will remediate the situation to meet the OESC requirements. If the cause of tingle voltage is determined to be customer equipment or their electrical system, the customer will be advised to retain a qualified electrical contractor who can remedy the problem.

11.2 Farm Stray Voltage Concerns

Stray voltage on farm properties is also known as “tingle voltage” or “farm stray voltage”. The DSC contains requirements for stray voltage on a customer property primarily used for livestock farming.

HOL’s response to inquiries and complaints of farm stray voltage is outlined in HOL document ECS0028, and is publically available at http://www.hydroottawa.com.

12.0 Fundamental Frequency

HOL has no control over the grid’s fundamental frequency. The fundamental electrical frequency of the Ontario electrical grid is defined and controlled by the Independent Electrical System Operator (IESO).

Distributed energy resource facilities shall operate at 60Hz with a maximum frequency drift of ±0.05%.

13.0 Power Factor

All customer loads shall operate with a Power Factor within ±10% of unity Power Factor as per HOL document ECS0012.

Distributed energy resource facilities shall operate with a Power Factor that is within ±10% of unity Power Factor.

[2] - Rule reference is to the 28th edition of the OESC.

Appendix A: ITI (CBEMA) Curve Application Notes

The ITI (CBEMA) Curve, included within this Application Note as Figure 3, is published by Technical Committee 3 (TC3) of the Information Technology Industry Council (ITI, formerly known as the Computer & Business Equipment Manufacturers Association, CBEMA). It is available at http://www.itic.org.

A.1 Scope:

The ITI (CBEMA) Curve and this Application Note describe an AC input voltage envelope which typically can be tolerated (no interruption in function) by most Information Technology Equipment (ITE). The Curve and this Application Note comprise a single document and are not to be considered separately from each other. They are not intended to serve as a design specification for products or AC distribution systems. The Curve and this Application Note describe both steady-state and transitory conditions.

A.2 Applicability

The Curve and this Application Note are applicable to 120V nominal voltages obtained from 120V, 120V/208Y, and 120V/240V 60Hz systems. Other nominal voltages and frequencies are not specifically considered and it is the responsibility of the user to determine the applicability of these documents for such conditions.

A.3 Discussion

This section provides a brief description of the individual conditions which are considered in the Curve. For all conditions, the term "nominal voltage" implies an ideal condition of 120V RMS, 60Hz. Seven types of events are described in this composite envelope. Each event is briefly described in the following sections, with two similar line voltage sags being described under a single heading. Two regions outside the envelope are also noted. All conditions are assumed to be mutually exclusive at any point in time, and with the exception of steady-state tolerances, are assumed to commence from the nominal voltage. The timing between transients is assumed to be such that the ITE returns to equilibrium (electrical, mechanical, and thermal) prior to commencement of the next transient.

a. Steady-State Tolerances

The steady-state range describes an RMS voltage which is either very slowly varying or is constant. The subject range is ±10% from the nominal voltage. Any voltages in this range may be present for an indefinite period, and are a function of normal loadings and losses in the distribution system.

b. Line Voltage Swell

This region describes a voltage swell having an RMS amplitude of up to 120% of the RMS nominal voltage, with a duration of up to 0.5 seconds. This transient may occur when large loads are removed from the system or when voltage is supplied from sources other than the electric utility.

c. Low-Frequency Decaying Ringwave

This region describes a decaying ringwave transient which typically results from the connection of power-factor-correction capacitors to an AC distribution system. The frequency of this transient may range from 200Hz to 5kHz, depending upon the resonant frequency of the AC distribution system. The magnitude of the transient is expressed as a percentage of the peak 60Hz nominal voltage (not the RMS value). The transient is assumed to be completely decayed by the end of the half-cycle in which it occurs. The transient is assumed to occur near the peak of the nominal voltage waveform. The amplitude of the transient varies from 140% for 200Hz ringwaves to 200% for 5kHz ringwaves, with a linear increase in amplitude with increasing frequency. Refer to Figure 2 below for an example of a typical waveform.

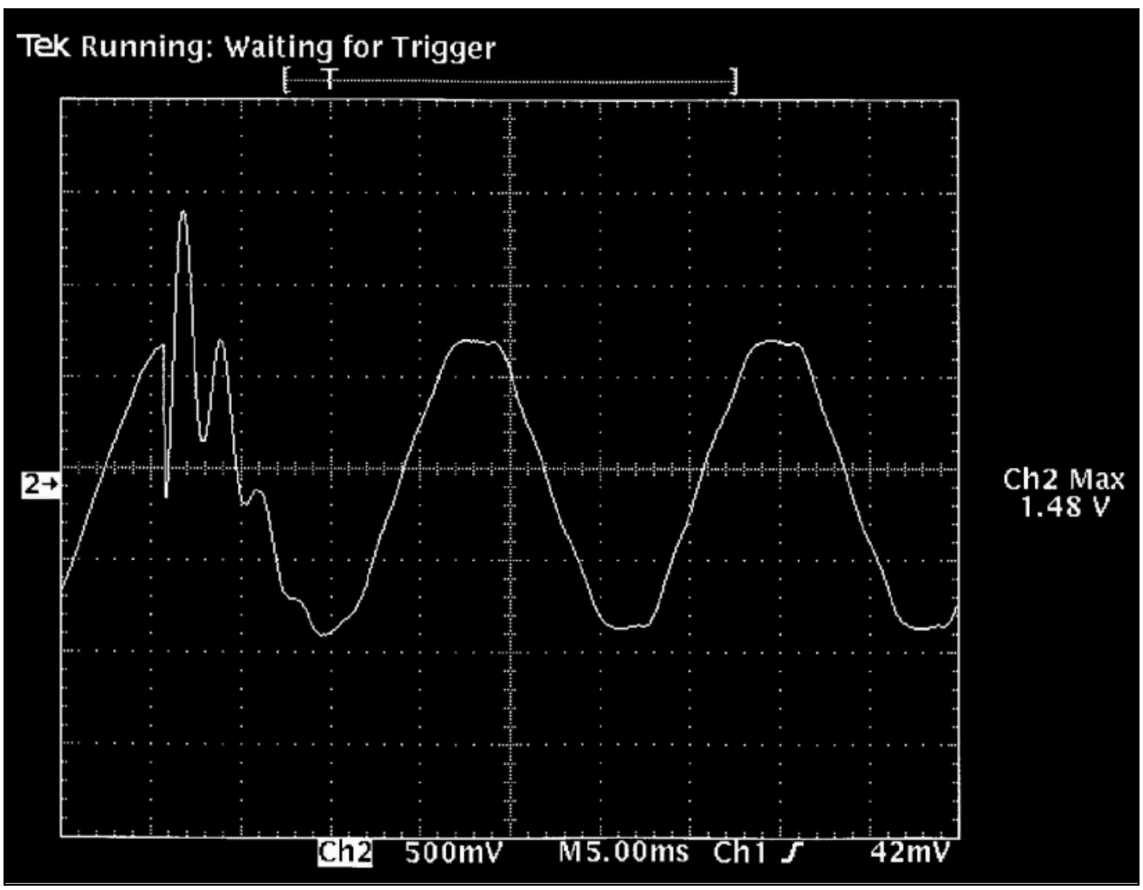

Figure 2: Typical Low Frequency Decaying Ringwave

d. High-Frequency Impulse and Ringwave

This region describes the transients, which typically occur as a result of lightning strikes. Wave shapes applicable to this transient and general test conditions are described in ANSI/IEEE C62.41-1991. This region of the curve deals with both amplitude and duration (energy), rather than amplitude. The intent is to provide an 80 Joule minimum transient immunity.

e. Voltage Sags

Two different voltage sags are described. Generally, these transients result from application of heavy loads, as well as fault conditions, at various points in the distribution system. Sags to 80% of nominal (maximum deviation of 20%) are assumed to have a typical duration of up to 10 seconds, and sags to 70% of nominal (maximum deviation of 30%) are assumed to have a duration of up to 0.5 seconds.

f. Dropout

A voltage dropout includes both severe voltage sags and complete interruptions of the applied voltage, followed by immediate re-application of the nominal voltage. The interruption may last up to 20 milliseconds. This transient typically results from the occurrence and subsequent clearing of faults in the distribution system.

g. No Damage Region

Events in this region include sags and dropouts, which are more severe than those, specified in the preceding paragraphs, and continuously applied voltages, which are less than the lower limit of the steady-state tolerance range. The normal functional state is not typically expected during these conditions, but no damage should result.

h. Prohibited Region

This region includes any surge or swells which exceeds the upper limit of the envelope. If is subjected to such conditions, damage to the may result.

ITI (CBEMA) Curve (Revised 2000)

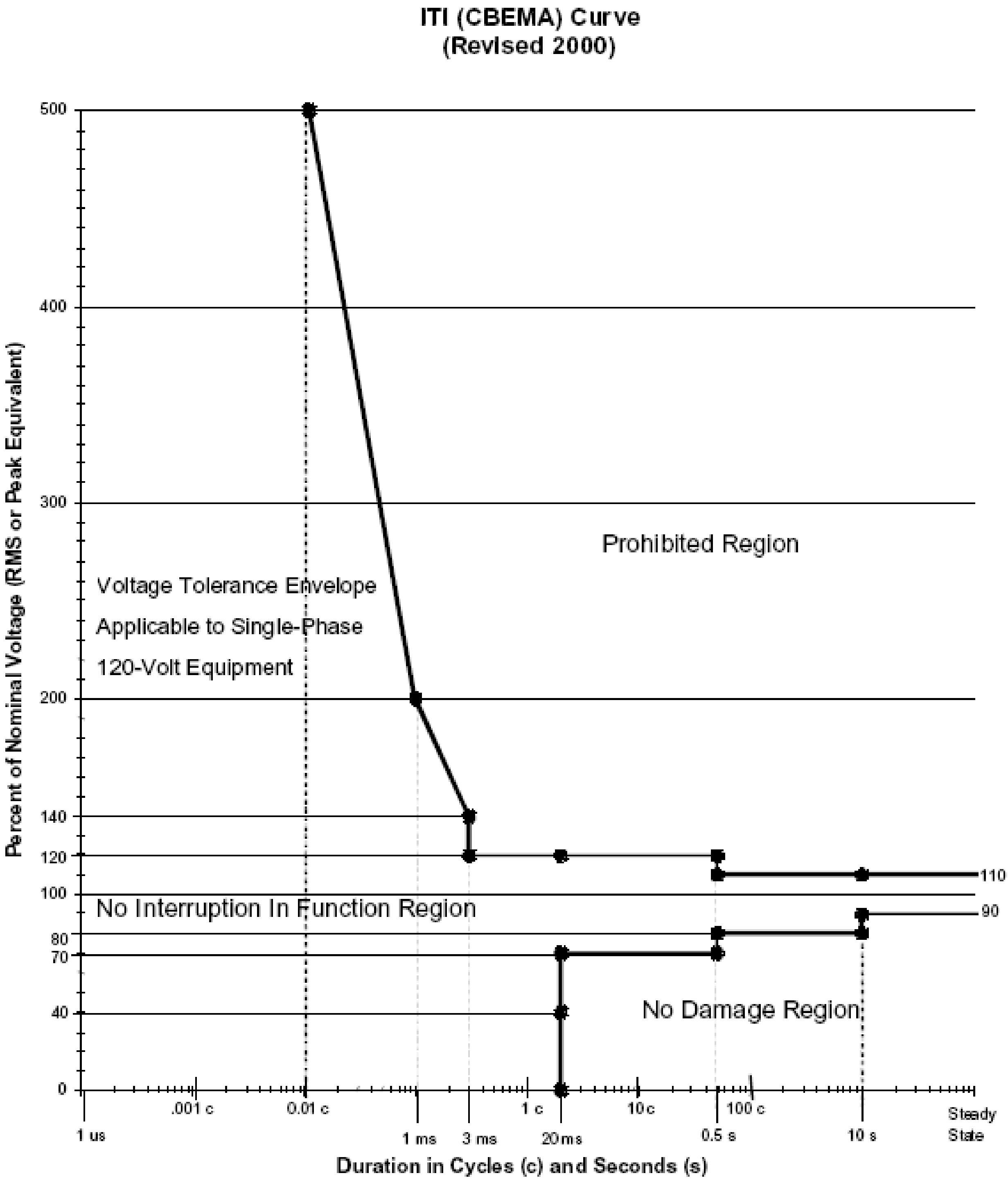

Figure 3: ITI CBEMA Curve

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