Limites d'émission de perturbations dans le réseau de transport d'Hydro-Québec

(version anglaise)

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Hydro Québec
TransÉnergie

Emission Limits for Disturbances on the Hydro-Québec Transmission System

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Terms or phrases in italics in this document are defined in footnotes.

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1 PURPOSE

This document sets out emission limits and emission level assessment methods for power quality disturbances on the Hydro-Québec transmission system.

1.1 APPLICATION

Emission limits and emission level assessment methods for disturbances apply to any *facility*[1] to be connected, to the Hydro-Québec transmission system, including the recommissioning of a *facility* that has been completely or partially shut down.

They also apply to any *facility* connected to the transmission system undergoing a modification that might alter its maximum disturbance emission levels (e.g., change of *facility* equipment or operating mode).

For an existing *facility* that has not undergone any modification which might alter its maximum disturbance emission levels since it was connected to the transmission system, the applicable emission limits are those that were specified initially during *facility* design and set out in the relevant emission study. However, if emission limits and assessment methods set out in this document are less stringent, they may apply to the *facility*.

1.2 GENERAL

Emission limits are defined for the most common power quality disturbances or electromagnetic disturbances: rapid voltage changes, flicker, load or current unbalance and harmonics.

Emission limits are aimed at ensuring and maintaining the quality of the voltage supplied by the Hydro-Québec transmission system.

Emission limits are set on a case-by-case basis for other power quality disturbances (e.g., interharmonics, subharmonics, harmonics above 3 kHz and repetitive bursts of harmonic currents).

[1] In this document, the term *facility* refers to any customer facility as defined in *Technical Requirements for the Connection of Customer Facilities to the Hydro-Québec Transmission System*, as approved from time to time by the Régie de l'énergie, and any *generating station* as defined in *Technical Requirements for the Connection of Generating Stations to the Hydro-Québec Transmission System*, as approved from time to time by the Régie de l'énergie, except *facilities* connected to the 735-kV system. Disturbance emission limits are set by the *Transmission Provider* on a case-by-case basis for any *facility* connected, or to be connected, to the 735-kV system. In the latter case, the disturbance emission limits, set on a case-by-case basis at voltage level 735 kV, will be subject to specific approval from the Régie de l'énergie, and this under Article 73.1 of the *Act respecting the Régie de l'énergie*.

The term *Transmission Provider* refers to Hydro-Québec when carrying on electric power transmission activities.

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2 EMISSION LIMITS

Emission limits are the maximum allowed levels, at the point of evaluation, of power quality disturbances generated by a *facility* and propagated on the transmission system.

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Emission limits and emission level assessment methods for rapid voltage changes, flicker, load or current unbalances and harmonics are presented in chapters 3, 4, 5 and 6, respectively.

2.1 EMISSION LEVEL

The emission level represents the contribution of a *facility* to the level of disturbances that may be transmitted over the transmission system by the *facility*.

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The emission level is assessed according to the methods specified in this document. The emission level must fall below the emission limits set at the point of evaluation.

Disturbance levels discussed in this document are measured according to the general approach set out in Appendix B, supplemented by an emission level assessment protocol subject to approval by Hydro-Québec.

2.2 COMPLIANCE WITH EMISSION LIMITS

For each disturbance, a simplified assessment or a detailed assessment where appropriate, demonstrating that the *facility* complies with applicable emission limits must be submitted to Hydro-Québec. The required technical information and the general procedure to be followed for assessing emission limit compliance are presented in Appendix A.

2.2.1 Simplified assessment

For each disturbance, if the *facility* meets the criteria for simplified assessment, Hydro-Québec must receive a written confirmation in this regard, including the requested data.

2.2.2 Detailed assessment

For each disturbance, if the facility does not meet the criteria for simplified assessment, Hydro-Québec must receive an emission study and when specified by Hydro-Québec, a report on measurements made in accordance with a protocol approved by Hydro-Québec.

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2.3 TRANSMISSION SYSTEM PARAMETERS

The transmission system main parameters indicated below are used as inputs for the assessments.

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2.3.1 Point of evaluation

The point of evaluation is a point located on the *high-voltage*[2] transmission system side where emission levels of the *facility* must be evaluated. This point will generally be the connection point.

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[2] As defined in *Conditions of Electricity Service,* as approved from time to time by the Régie de l'énergie, nominal phase-to-phase voltage of 44 kV or more.

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If a *facility* is connected to the transmission system at several connection points, the emission level must be evaluated at all of these connection points.

The *Transmission Provider* may specify another point of evaluation depending on the specific characteristics of the transmission system and on other nearby *facilities* connected to the transmission system.

2.3.2 System short-circuit power (S_{sc})

The MVA three-phase short-circuit power (S_{sc}) of the transmission system corresponds to the short-circuit current from the transmission system side for a three-phase fault at the point of evaluation for the *facility*.

Theoretical values of S_{sc} and the corresponding X/R ratio are supplied by the *Transmission Provider* for the point of evaluation, exclusively for the purpose of assessing compliance with emission limits under:

- General system operating conditions: $\mathbf{S_{sc,\,general}}$ and $\mathbf{X/R_{general}}$
- Occasional system operating conditions: $\mathbf{S_{sc,\,occasional}}$ and $\mathbf{X/R_{occasional}}$

The three-phase short-circuit current (I_{sc}) of the system is calculated using the three-phase short-circuit power (S_{sc}) and the *nominal voltage* (U_{nom}) of the system at the point of evaluation for the *facility* according to the following formula: $I_{sc} = S_{sc}/(\sqrt{3} \cdot U_{nom})$.

2.3.3 Reference power (S_r) and reference current (I_r)

The reference power (S_r) is the anticipated power of the *facility* in MVA. It is used to determine the emission limits applicable to the *facility* and to assess certain emission levels of the *facility*.

The reference current, also used for this purpose, is defined by the equation $\{I_r = S_r/(\sqrt{3} \cdot U_{nom})\}$, where U_{nom} is the *nominal voltage* of the system at the point of evaluation.

For non-three-phase *facilities*, the reference current corresponds to the current for a three-phase *facility* with the same power.

2.4 FACILITY OPERATING CONDITIONS

The *facility* operating conditions discussed below are also used as input for the detailed assessment of emission limit compliance.

Specific general or occasional operating conditions of the *facility* may be indicated by Hydro-Québec.

The *nominal voltage* of a system is the phase-to-phase RMS voltage used to designate the system in question. The *nominal voltages* (U_{nom}) of the *high-voltage* transmission system are generally as follows: 44 kV, 49 kV, 69 kV, 120 kV, 161 kV, 230 kV, 315 kV and 345 kV.

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2.4.1 General facility operating conditions

The general operating conditions of the *facility* include the most unfavorable and frequent or prolonged operating conditions of the *facility* — typically following a single-element contingency (n-1) — the overall statistical likelihood of which is greater than 5% over one year.

2.4.2 Occasional facility operating conditions

The occasional operating conditions of the *facility* include the operating conditions the overall statistical likelihood of which does not exceed 5% over one year. They correspond in particular to equipment outages under degraded conditions that may occur occasionally and result in higher emission levels.

2.5 EMISSION STUDY

An emission study is carried out, for each disturbance, to demonstrate that the maximum anticipated emission level of the *facility* does not exceed emission limits at the point of evaluation.

The emission study identifies and takes into account any corrective equipment and mitigation measures required to comply with emission limits.

The emission study must be performed by an engineer (whose title and practice are subject to the laws, codes and regulations applicable in Québec).

The emission study includes the required information and results for each disturbance.

The emission level is to be assessed using the methods including the transmission system parameters and the *facility* operating conditions.

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2.6 MEASUREMENT OF EMISSION LEVELS

Whenever Hydro-Québec requires a measurement report to be submitted, the measures in question must be made in accordance with a measurement protocol approved by Hydro-Québec.

The measurement protocol specifies in particular the methods for measurement and analysis of results, as well as any tests to be performed.

In light of measurements made by the *Transmission Provider*, Hydro-Québec may require a new assessment of compliance with emission limits, as well as the implementation of mitigation measures or operating restrictions for the *facility*, should the *facility* not comply with emission limits.

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2.7 REQUIRED INFORMATION

The detailed assessment must at least contain the information indicated below:

- Single-line diagram of the *facility* and key electrical characteristics of the main *facility* equipment
- Reference power (S_r) of the *facility*
- System short-circuit power (S_{sc}) under general and occasional conditions, as supplied by Hydro-Québec

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- General electrical characteristics and operating modes of disturbing equipment (e.g., power and types of converters, pulse numbers, impedances, short-circuit power, power and types of motors, inrush current and load cycles)
- Statement and justification of any assumption made in the course of assessing maximum disturbance emission levels
- General electrical characteristics of any corrective equipment (e.g., harmonic filters, motor starters, current-limiting series reactors and reactive power compensators)
- Description of general and occasional *facility* operating conditions taken into account

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3 RAPID VOLTAGE CHANGES (RVC)

Rapid voltage changes (RVC) are sudden random or cyclical variations in the RMS voltage between two successive voltage levels. Transient non-repetitive disturbances lasting less than two 60-Hz cycles (or 33.3 ms) are generally ignored in the assessment of RVC levels.

RVCs are in particular caused by switching operations (e.g., capacitor banks) which produce rapid changes in reactive power, at the startup and the stop of power equipment (e.g., motors ≥ 500 hp) and at the startup or rapid power changes of generators or wind turbines.

RVC emission limits apply to voltage changes that occur no more than 10 times per hour.

3.1 SIMPLIFIED ASSESSMENT

To be eligible for the simplified assessment:

- The *facility* must not include any equipment whose power demand or fluctuations may cause RVC.
- A diagram of the *facility* showing all used equipment (e.g., motors and furnaces) and a written confirmation that their operating mode will not cause any RVC must be submitted to Hydro-Québec.

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3.2 RVC EMISSION LIMITS

Table 1
RVC emission limits

Repetition rate f_{RVC} (changes/hour)	**$\Delta U_{3s}/U$ (%)** Under general conditions	**$\Delta U_{3s}/U$ (%)** Under occasional conditions
$f_{RVC} \leq 2$	3	6
$2 < f_{RVC} \leq 10$	2.5	5

Note: A drop in voltage followed by a rise, or vice versa, counts as two voltage changes.

These limits are defined according to the number of RVCs that may occur in one hour ($\mathbf{f}_{RVC}$); they are expressed as the percent ratio of the RMS voltage change (averaged over 3 seconds) to the transmission system voltage level ($\Delta U_{3s}/U$).

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These emission limits apply to each of the three phases; whichever emission level is the highest must comply with these limits.

Emission limits under general and occasional conditions apply to any *facility*, irrespectively of the $S_{sc,\ general}/S_r$ ratio.

3.3 RVC EMISSION LEVELS

Maximum RVC emission levels must be assessed for each of the three phases.

Emission levels are evaluated under general and occasional operating conditions.

Emission levels under general conditions are the emission levels generated when the transmission system operates under general conditions ($S_{sc,\ general}$).

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Emission levels under occasional conditions are the emission levels generated when the transmission system operates under occasional conditions ($S_{sc,\ occasional}$).

RVC emission levels may be approximated by the relative voltage change *d* ($\Delta U/U_{nom}$). Guidance on how to calculate the relative voltage change is provided by Canadian standard CAN/CSA-C61000-3-7[5] (paragraph E.1.2: *Simplified calculation of the relative voltage change d*).

Detailed parameters for calculating RVC levels are given in Appendix B.

3.4 RVC EMISSION STUDY

If Hydro-Québec requires a RVC emission study, it must be carried out under general and occasional conditions for all *facilities*, irrespectively of the $S_{sc,\ general}/S_r$ ratio.

The RVC emission study must present the following results:

- For each piece or set of equipment: its characteristics, active and reactive power fluctuations (ΔP and ΔQ, respectively) and their repetition rate (f_{RVC})
- Description of any mitigation measures, including planned restrictions on operating conditions, and their effect on emission levels
- Table of RVC emission levels ($\Delta U_{3s}/U$) and their repetition rates (f_{RVC}), including any mitigation measures

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4 FLICKER

Flicker is the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates over time. Flicker is the effect on lighting of repetitive voltage changes at frequencies to which the human eye is particularly sensitive, especially from 0.1 to 25 Hz.

These repetitive voltage changes can be attributed to equipment such as arc or induction furnaces, electric welding machines, generators or wind turbines producing rapid power changes, to variable-power process equipment (e.g., presses, winches, rolling mills), and to frequent motor startups.

Flicker refers to voltage changes that occur more than 10 times per hour.

4.1 SIMPLIFIED ASSESSMENT

To be eligible for the simplified assessment:

- Relative voltage changes ($\Delta U/U_{nom}$) must be less than or equal to the limits indicated in Table 2, under general operating conditions (i.e. taking into account $S_{sc,\ general}$ and the *facility* general operating conditions)

Table 2
Emission limits for relative voltage changes ($\Delta U/U_{nom}$) that may cause flicker

Repetition rate f_d (changes/minute)	$\Delta U/U_{nom}$ (%)
$0.17 < f_d \leq 0.5$	1.5
$0.5 < f_d \leq 1$	0.8
$1 < f_d \leq 10$	0.4
$10 < f_d \leq 200$	0.2
$200 < f_d$	0.1

Note: A drop in voltage followed by a rise, or vice versa, counts as two voltage changes.

These limits are defined according to the number of changes that may occur per minute (f_d) of the voltage changes that may cause flicker; they are expressed as the percent ratio of the RMS voltage change (over 1/60 s) to the nominal transmission system voltage ($\Delta U/U_{nom}$). Guidance on how to calculate the relative voltage change $\Delta U/U_{nom}$ is provided by Canadian standard CAN/CSA-C61000-3-7[6] (paragraph E.1.2: *Simplified calculation of the relative voltage change d*).

If several pieces or sets of equipment produce voltage changes (ΔU) simultaneously at repetition rates (f_d) indicated in Table 2, the relative voltage change ($\Delta U/U_{nom}$) limit

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for each piece or set of equipment must then be divided by $\sqrt[3]{x}$, where x is the total number of pieces or sets of equipment involved.

- Written confirmation must be submitted to Hydro-Québec, including the results indicated below:
  - For each piece or set of equipment: its characteristics, its active and reactive power fluctuations (ΔP and ΔQ, respectively) and their repetition rate (f_d)
  - Table of calculated relative voltage changes ($\Delta U/U_{nom}$) and their respective repetition rates (f_d)

4.2 EMISSION LIMITS FOR FLICKER

Table 3
Emission limits for flicker (P_{st})

Under	**Limits for severity index P_{st} (short-term flicker)**
General conditions	0.3
Occasional conditions	0.45

If any emission limit is exceeded, the *Transmission Provider* shall determine whether it may be raised based on the characteristics of the system under study and guidance provided by Canadian standard CAN/CSA-C61000-3-7[7].

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These emission limits apply to each of the three phases; whichever emission level is the highest must comply with these limits.

Emission limits under general and occasional conditions apply to any *facility*, irrespectively of the $S_{sc,\ general}/S_r$ ratio.

4.3 EMISSION LEVELS FOR FLICKER

Maximum flicker emission levels must be assessed for each of the three phases.

Emission levels are evaluated under general and occasional operating conditions.

Emission levels under general conditions are the emission levels generated when both the *facility* and the transmission system ($S_{sc,\ general}$) operate under general conditions.

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Emission levels under occasional conditions are the emission levels generated when the *facility* or the transmission system ($S_{sc,\ occasional}$) operate under occasional conditions.

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Guidance on how to assess emission levels for flicker (P_{st}), including summation methods used to calculate the combined effect of flicker causing equipment, is provided in Appendix E of Canadian standard CAN/CSA-C61000-3-7[8].

[7] Reference provided only for explanatory and informative purposes.

[8] See note 7.

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4.4 EMISSION STUDY FOR FLICKER

If Hydro-Québec requires the emission study for flicker, it must be carried out:

- under general conditions, if $S_{sc,\ general}/S_r \geq 30$
- under general and occasional conditions, if $S_{sc,\ general}/S_r < 30$

The emission study for flicker must present the results indicated below:

- Description of the electrical and operational characteristics of disturbing equipment, e.g.:
  - for arc furnaces: impedance and short-circuit power levels, type of process, type of raw material used in the furnace, operating cycles
  - for motors: power and type of motors, inrush currents, frequency of startups and load cycles
- For each piece or set of equipment: its characteristics, its active and reactive power fluctuations (ΔP and ΔQ, respectively) and their repetition rate (f_d)
- Table of calculated relative voltage changes ($\Delta U/U_{nom}$) and their respective repetition rates (f_d)
- Summation methods used to calculate the combined effect of flicker causing equipment, including a justification for their use based on equipment operating modes
- Resulting emission level for flicker (P_{st}) at the point of evaluation and applicable emission limit

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5 LOAD OR CURRENT UNBALANCE

Load or current unbalance results from the design or operation of a *facility* or piece of equipment (e.g., arc or induction furnaces, single- or two-phase loads or generators, and electric train alternating current power supply systems) whose current (or power consumption or generation) unbalance may cause a voltage unbalance on the system.

A current (or voltage) unbalance arises when the three currents (or voltages) of a three-phase system are not of equal magnitude or are not phase-shifted 120 degrees from one another.

The unbalance considered herein involves the negative-sequence component of 60-Hz currents or voltages calculated using the symmetrical component method (Fortescue's transformation).

5.1 SIMPLIFIED ASSESSMENT

To be eligible for the simplified assessment:

- I_2/I_{sc} (or $S_{single\text{-}phase}/S_{sc,\ general}$) $\leq$ 0.2%, where:

  I_2 = Negative-sequence component of the *facility* current

  I_{sc} = Three-phase short-circuit current of the transmission system, calculated using $S_{sc,\ general}$

  $S_{single\text{-}phase}$ = Single-phase load (or power) equivalent to the imbalance of the *facility*

- Written confirmation of the value of the single-phase power equivalent ($S_{single\text{-}phase}$) to the *facility*'s load or current unbalance must be submitted to Hydro-Québec.

5.2 EMISSION LIMITS FOR LOAD OR CURRENT UNBALANCE

Emission limits for current unbalance apply to all *facilities*, except those that include electric train power supply systems, to which emission limits for voltage load unbalance apply.

Emission limits under general and occasional conditions apply to any *facility*, irrespectively of the $S_{sc,\ general}/S_r$ ratio.

5.2.1 Emission limits for current unbalance — facilities

Table 4
Limits for negative-sequence component ratio (I_2 / I_r)

$S_{sc,\ general}/S_r$	I_2 / I_r (%) Under general conditions	I_2 / I_r (%) Under occasional conditions
5	4	6
20	7	10.5
50	13	19.5
100	20	30
200	30	45

These limits apply to the current unbalance ratio (I_2 /I_r) expressed as a percent, where:

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I_2 = Negative-sequence component of the current due to the power unbalance of the *facility* (A_{rms})

I_r = Reference current for the *facility* (A_{rms})

Emission limits applicable to any given *facility* depend on its $S_{sc,\ general}/S_r$ ratio; they are calculated as follows:

a) If **$5 \leq S_{sc,\ general}/S_r < 200$,** the emission limit is calculated according to Equation 1, i.e. using a linear interpolation between two consecutive limits specified in Table 4.

$$\text{Limit applicable to the } \textit{facility} = \left[\frac{(LIMIT)_B - (LIMIT)_A}{\left(\frac{S_{SC}}{S_r}\right)_B - \left(\frac{S_{SC}}{S_r}\right)_A}\right] \bullet \left[\left(\frac{S_{sc}}{S_r}\right)_f - \left(\frac{S_{sc}}{S_r}\right)_A\right] + (LIMIT)_A \quad \text{(Eq. 1)}$$

Where: ***f*** = Refers to the *facility* under study

A = Refers to the row in Table 4 containing the highest $S_{sc,\ general}/S_r$ ratio that is less than the value for the *facility*

B = Refers to the row in Table 4 containing the lowest $S_{sc,\ general}/S_r$ ratio that is greater than the value for the *facility*

LIMIT = Limit found in Table 4

$S_{SC} = S_{sc,\ general}$

b) If **$S_{sc,\ general}/S_r \geq 200$,** the percent emission limit under general conditions equals 30% and the limit under occasional conditions equals 45%.

c) If **$S_{sc,\ general}/S_r < 5$,** the *Transmission Provider* determines the specific emission limit and conditions applicable to the *facility* under study, based on the characteristics of the system under study and guidance provided by Canadian standard CAN/CSA-C61000-3-13[9].

5.2.2 Emission limits for voltage unbalance — electric trains

Table 5
Emission limits for voltage unbalance (U_2/U_1)
(electric trains)

Under	U_2/U_1 (%)
General conditions	0.2
Occasional conditions	0.3

This emission limit applies to the negative-sequence voltage unbalance, expressed at the percent ratio of the negative-sequence voltage to the positive-sequence voltage (U_2/U_1) for the *facility* under study.

[9] Reference provided only for explanatory and informative purposes.

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If any limit is exceeded, the *Transmission Provider* shall determine whether it may be raised based on the characteristics of the system under study and guidance provided by Canadian standard CAN/CSA-C61000-3-13[10].

5.3 EMISSION LEVELS FOR LOAD OR CURRENT UNBALANCE

Maximum emission levels must be assessed for load or current unbalance.

Emission levels are evaluated under general and occasional operating conditions.

Emission levels under general conditions are the emission levels generated when both the *facility* and the transmission system ($S_{sc,\ general}$) operate under general conditions.

Emission levels under occasional conditions are the emission levels generated when the *facility* or the transmission system ($S_{sc,\ occasional}$) operate under occasional conditions.

An unbalanced three-phase system is assessed using the symmetrical component method (Fortescue's transformation). In general, it consists in calculating the negative-sequence component of the line current (I_2) at the point of evaluation.

For complex cases, assessing unbalance emission levels requires the use of appropriate computer tools and models.

Anticipated emission levels of the *facility* do not include negative-sequence currents arising from transmission system voltage unbalance that are not due to unbalanced *facility* power conditions.

[10] Reference provided only for explanatory and informative purposes.

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5.4 EMISSION STUDY FOR LOAD OR CURRENT UNBALANCE

If Hydro-Québec requires the emission study for load or current unbalance, it must be carried out:

- Under general conditions, if $S_{sc,\ general}/S_r \geq 30$
- Under general and occasional conditions, if $S_{sc,\ general}/S_r < 30$

The emission study for load or current unbalance must present the results indicated below:

- List of power levels for equipment that produces load or current unbalance, their operating and connection modes
- Description of any mitigation measures
- Table of maximum emission levels for current unbalance (negative-sequence component) for the various operating modes

If required, Hydro-Québec may specify the phases onto which the unbalanced power must be redistributed so as to reduce the resulting level of voltage unbalance on the transmission system.

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6 HARMONICS

Harmonics are sinusoidal voltages or currents having frequencies that are integral multiples of the fundamental frequency of the system (60 Hz).

Emission limits for harmonics include emission limits for harmonic currents and emission limits for telephone influence.

Harmonics are mainly caused by harmonics-producing equipment (e.g., arc or induction furnaces, rectifiers used for electrolysis, motor drives, frequency converters, alternating current load controllers). Harmonics can also be amplified by other disturbing equipment (e.g., capacitor banks).

6.1 SIMPLIFIED ASSESSMENT

To be eligible for the simplified assessment:

- The total three-phase power of harmonics-producing equipment[11] used at the *facility* must be:
  - less than or equal to the power indicated in Table 6

Table 6
Maximum total three-phase power
of harmonics-producing equipment

Voltage level (kV)	Maximum total three-phase power of harmonics-producing equipment (MVA)
44, 49	1
69	1.5
120	2.7
161	3.6
230	5
315, 345	7

  - less than 0.25% of the short-circuit power under general transmission system operating conditions ($S_{sc,\ general}$)
- Written confirmation of the total three-phase power of harmonics-producing equipment must be submitted to Hydro-Québec.

[11] Harmonics-producing equipment do not include *synchronous* or *asynchronous generators* (as defined in the *Technical Requirements for the Connection of Generating Stations to the Hydro-Québec Transmission System*, as approved from time to time by the Régie de l'énergie) if, regarding harmonics and telephone interference, they comply with IEC (International Electrotechnical Commission) 60034–series standards or ANSI (American National Standards Institute) C50–series standards. These references are provided only for explanatory and informative purposes.

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6.2 EMISSION LIMITS FOR HARMONIC CURRENTS

Emission limits apply to each of the three phases. The highest emission level of individual harmonic currents ($I_{h,n}/I_r$) for each harmonic order n = 2 to 50, as well as the total harmonic distortion in current (THD_I), must respect those limits.

Emission limits under general and occasional conditions apply to any *facility*, irrespectively of the $S_{sc, general}/S_r$ ratio.

Tables 7 and 8 present limits applicable, respectively, to odd and even percent ratios of individual harmonic currents ($I_{h,n}/I_r$) under general conditions, where:

$I_{h,n}$ = Harmonic currents of order n = 2 to 50 (A_{rms})
I_r = Reference current for the *facility* (A_{rms})

Table 7
Limits for individual odd harmonic current ratios ($I_{h,n}/I_r$) (%), under general conditions

$S_{sc, general}/S_r$	n=3	n=5	n=7	n=9	n=11, 13	15≤n<23	23≤n<35	35≤n<50
5	1	1.2	0.8	0.5	0.5	0.4	0.3	0.2
20	1.5	2	1.5	0.75	1	0.65	0.45	0.3
50	2	3	2	1	1.5	1	0.7	0.5
200	4	6	4	2	3	2	1	0.7

Note: Under occasional conditions, emission limits for individual odd harmonic current ratios correspond to 1.5 times these emission limits.

Table 8
Limits for individual even harmonic current ratios ($I_{h,n}/I_r$) (%), under general conditions

$S_{sc, general}/S_r$	n=2	n=4	n=6	n=8	10≤n≤50
5	0.75	0.5	0.3	0.2	0.15
20	1.1	0.75	0.45	0.3	0.25
50	1.5	1	0.6	0.4	0.3
200	2.2	1.5	1	0.6	0.4

Note: Under occasional conditions, emission limits for individual even harmonic current ratios correspond to 1.5 times these emission limits.

Table 9 presents limits applicable to the total harmonic distortion in current (THD_I), as defined by Equation 2.

$$THD_I = \frac{1}{I_r}\sqrt{\sum_{n=2}^{50} I_{h,n}^2} \times 100\ \% \qquad \text{(Eq. 2)}$$

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Table 9
Limits for the total harmonic distortion in current (THD_I), under general conditions

$S_{sc,\ general}/S_r$	THD_I (%)
5	1.7
20	3
50	4.5
200	6

Note: Under occasional conditions, emission limits for the total harmonic distortion in current correspond to 1.5 times these emission limits.

Emission limits applicable to any given *facility* depend on its $S_{sc,\ general}/S_r$ ratio; they are calculated as follows:

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a) If **$5 \leq S_{sc,\ general}/S_r < 200$,** the emission limit is calculated according to Equation 3, i.e. using a linear interpolation between two consecutive limits specified in Tables 7, 8 and 9.

$$\text{Limit applicable to the } facility = \left[\frac{(LIMIT)_B - (LIMIT)_A}{\left(S_{SC}/S_r\right)_B - \left(S_{SC}/S_r\right)_A}\right] \bullet \left[\left(\frac{S_{sc}}{S_r}\right)_f - \left(\frac{S_{sc}}{S_r}\right)_A\right] + (LIMIT)_A \qquad \text{(Eq. 3)}$$

Where: f = Refers to the *facility* under study

A = Refers to the row in Table 7, 8 or 9 containing the highest $S_{sc,\ general}/S_r$ ratio that is less than the value for the *facility*

B = Refers to the row in Table 7, 8 or 9 containing the lowest $S_{sc,\ general}/S_r$ ratio that is greater than the value for the *facility*

LIMIT = Limit found in Table 7, 8 or 9

$S_{SC} = S_{sc,\ general}$

b) If **$S_{sc,\ general}/S_r \geq 200$,** the emission limit is calculated according to Equation 4, i.e. the limit is proportional to the $S_{sc,\ general}/S_r$ ratio of the *facility*

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$$\text{Limit applicable to the } facility = \left[\left(\frac{S_{sc}}{S_r}\right)_f \div 200\right] \bullet (LIMIT)_{200} \qquad \text{(Eq. 4)}$$

c) If **$S_{sc,\ general}/S_r < 5$,** the *Transmission Provider* determines the specific emission limit and conditions applicable to the *facility* under study based on the characteristics of the system under study and guidance provided by Canadian standard CAN/CSA-C61000-3-6[12].

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[12] Reference provided only for explanatory and informative purposes.

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6.3 EMISSION LIMITS FOR TELEPHONE INFLUENCE

The emission limit for telephone influence is applicable to the **I·T**$_{balanced}$ product, defined by Equation 5.

$$I \cdot T_{balanced} = \sqrt{\sum_{n=2}^{50} \left(I_{h,n} \cdot W_n\right)^2} \quad \text{(A)} \qquad \text{(Eq. 5)}$$

Where: $I_{h,n}$ = Harmonic currents of order n = 2 to 50 (A_{rms})

W_n = Weighting factor given in Table 10

Table 10
Weighting factors W_n for telephone influence

n	F(Hz)	W_n	n	F(Hz)	W_n
-	-	-	26	1 560	6 790
2	120	10	27	1 620	6 970
3	180	30	28	1 680	7 060
4	240	105	29	1 740	7 320
5	300	225	30	1 800	7 570
6	360	400	31	1 860	7 820
7	420	650	32	1 920	8 070
8	480	950	33	1 980	8 330
9	540	1 320	34	2 040	8 580
10	600	1 790	35	2 100	8 830
11	660	2 260	36	2 160	9 080
12	720	2 760	37	2 220	9 330
13	780	3 360	38	2 280	9 590
14	840	3 830	39	2 340	9 840
15	900	4 350	40	2 400	10 090
16	960	4 690	41	2 460	10 340
17	1 020	5 100	42	2 520	10 480
18	1 080	5 400	43	2 580	10 600
19	1 140	5 630	44	2 640	10 610
20	1 200	5 860	45	2 700	10 480
21	1 260	6 050	46	2 760	10 350
22	1 320	6 230	47	2 820	10 210
23	1 380	6 370	48	2 880	9 960
24	1 440	6 650	49	2 940	9 820
25	1 500	6 680	50	3 000	9 670

Table 11
Emission limits for telephone influence ($I \cdot T_{balanced}$ product)

Under	Limit for $I \cdot T_{balanced}$ product ($A_{weighted}$)
General conditions	20 000
Occasional conditions	30 000

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These emission limits apply to each of the three phases; whichever emission level is the highest must comply with these limits.

Emission limits under general and occasional conditions apply to any *facility*, irrespectively of the $S_{sc,\ general}/S_r$ ratio.

6.3.1 Specific limit

If the $\mathbf{I \cdot T_{balanced}}$ product exceeds the applicable limit indicated in Table 11, the *Transmission Provider* may allow the use of a higher specific limit depending on any one of the factors indicated below (the detailed calculation of which must be submitted to Hydro-Québec):

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- Distance separating the power lines affected and telephone lines
- Equivalent soil resistivity along the power lines affected
- Total equivalent length over which individual telephone lines run parallel to power lines affected

The *Transmission Provider* also determines which specific conditions apply and must receive drawings showing the relative geographic location of telephone lines near (<10 km) affected power lines.

If the $\mathbf{I \cdot T_{balanced}}$ product exceeds the applicable limit indicated in Table 11, the *Transmission Provider* shall indicate which transmission lines are affected upon request.

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6.3.2 Exemption

The *Transmission Provider* may grant an exemption if it receives a document certifying that there is no existing or planned voice-frequency analog telephone line within 10 km of the transmission lines affected.

If the $\mathbf{I \cdot T_{balanced}}$ product exceeds the applicable limit indicated in Table 11, the *Transmission Provider* shall indicate which transmission lines are affected upon request.

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6.4 EMISSION LEVELS FOR HARMONIC CURRENTS

Maximum emission levels for each individual odd and even harmonic current ($I_{h,n}/I_r$), as well as the total harmonic distortion in current (THD_I), must be evaluated for each of the three phases, taking into account all harmonics of orders n = 2 to 50. A harmonic current is a harmonic line current circulating at the point of evaluation.

Emission levels are evaluated under general and occasional operating conditions.

Emission levels under general conditions are the emission levels generated when the *facility* operates under general conditions.

Emission levels under occasional conditions are the emission levels generated when the *facility* operates under occasional conditions.

Emission levels are evaluated taking into account harmonic impedance loci, non-characteristic harmonic emissions and fluctuating harmonics, which are presented in sections 6.4.1, 6.4.2 and 6.4.3, respectively.

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Guidance on how to assess emission levels for harmonic currents is provided in section 6.3 of Canadian standard CAN/CSA-C61000-3-6[13].

In addition to these guidelines, the document *Caractéristiques de la tension fournie par le réseau de transport d'Hydro-Québec*[14] provides information on disturbance levels that may be found on the Hydro-Québec transmission system.

When assessing the *facility*'s emission levels for harmonic currents, harmonic filter performance must take into account the variation of ±0.2 Hz of the frequency on the transmission system. Asymmetries generated by the *facility*'s equipment must be added to that.

6.4.1 Harmonic impedance loci

The *Transmission Provider* shall provide information on harmonic impedance loci of the Hydro-Québec transmission system upon request.

This data corresponds to the parameters defining a range of possible impedances seen looking into the transmission system from the point of evaluation, for harmonic orders n = 2 to 50.

Harmonic impedance loci serve as input to assess harmonic emission levels for a given *facility*.

System harmonic impedance loci do not include the effect of the *facility* under study. That effect must be taken into account in assessing the emission levels. The interaction between the *facility* and the system, particularly the interaction between *facility* capacitors or filters and the system, can create resonances, which could amplify harmonic levels on the transmission system. Emission levels must take into account potential resonances and fall below emission limits.

After having assessed all sources of harmonics of orders n = 2 to 50 among equipment used in the *facility* under study (including any non-characteristic or fluctuating harmonics), maximum emission levels for individual harmonic currents ($I_{h,n}/I_r$) and total harmonic distortion in current (THD_I) must be evaluated by selecting the combinations of system impedance (within the impedance loci) and *facility* impedance (among the different operating conditions of the *facility*) that maximize emission levels. This may require successive iterations or an appropriate optimization algorithm.

6.4.2 Emission of non-characteristic harmonics

So-called "non-characteristic" harmonics are generated by a *facility* due to the existence of some degree of dissymmetry within the transmission system and the *facility* in question.

Guidance for assessing sources of non-characteristic harmonics within a given *facility* is provided in section 6.3.2 of Canadian standard CAN/CSA-C61000-3-6[15].

In addition to these guidelines, Table 12 specifies the voltage unbalance ratio, which reflects the degree of dissymmetry to be taken into account on the transmission system when

[13] Reference provided only for explanatory and informative purposes.

[14] See note 13.

[15] See note 13.

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assessing emission levels for non-characteristic harmonics. Asymmetries generated by the *facility*'s equipment must be added to that.

Table 12
Transmission system voltage unbalance ratios (U_2/U_1) specified according to *nominal voltage* at the point of evaluation, for the evaluation of emission levels of non-characteristic harmonics

***Nominal voltage* of the system**	**U_2/U_1**
230 kV, 315 kV and 345 kV	1%
69 kV, 120 kV and 161 kV	1.5%
44 kV and 49 kV	2%

6.4.3 Fluctuating harmonics

If harmonics are continuously and rapidly fluctuating, the evaluation of emission levels for harmonic currents relies on the harmonic group and subgroup method as explained in Canadian standard CAN/CSA-IEC 61000-4-7 [1][16]. Examples are given in Appendix C.3 *Fluctuating harmonics* of this standard.

6.5 EMISSION LEVELS FOR TELEPHONE INFLUENCE

Emission levels for telephone influence (**$I \cdot T_{balanced}$** product) are calculated using Equation 5 based on the above-defined emission levels for harmonic currents of orders n = 2 to 50.

Maximum emission levels must be evaluated for each of the three phases.

The **$I \cdot T_{balanced}$** product may be calculated taking into account the potential simultaneity of emission levels for all harmonics for different general or occasional *facility* operating conditions and different transmission system harmonic impedance values (within the impedance loci). The highest emission level obtained must respect the telephone influence limit.

6.6 EMISSION STUDY FOR HARMONICS

If Hydro-Québec requires the emission study for harmonics, it must be carried out:

- under general conditions, if $S_{sc,\ general}/S_r \geq 30$
- under general and occasional conditions, if $S_{sc,\ general}/S_r < 30$

The emission study for harmonics must present emission levels that take into account:

- harmonic impedance loci, as supplied by Hydro-Québec, if $S_{sc,\ general}/S_r < 100$
- non-characteristic harmonic emissions, if $S_{sc,\ general}/S_r < 30$
- any fluctuating harmonics

The emission study for harmonics must present the following results:

[16] In this document, a number in square brackets refers to the document numbered in the list of mandatory reference documents.

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- Relevant *facility* specifications, particularly regarding the characteristics of capacitor banks and filters, as well as assumptions regarding filter detuning and the angular displacement between converter units
- Potential resonances between the *facility*'s capacitors, filters or cables and the system
- Tables of results presenting, for harmonics of orders n = 2 to 50, under general conditions and, if required, occasional conditions:
  - Maximum harmonic currents generated by disturbing equipment within the *facility* under study, along with the respective angular displacements in the case of high pulse number converters represented by multiple equivalent harmonic current sources
  - *Facility* harmonic impedance values (amplitudes and angles), including capacitors and filters and the effect of detuning, possible switching operations, etc.
  - System harmonic impedance values that maximize each emission level for harmonic currents, based on system harmonic impedance loci, if applicable
  - Maximum emission levels for individual harmonic currents ($I_{h,n}/I_r$), for each harmonic order
  - Maximum emission level for the total harmonic distortion in current (THD_I) under the various operating conditions of the *facility*
- For emission levels for telephone influence under general conditions and, if required, occasional conditions:
  - Table of **$I \cdot T_{balanced}$** product calculations, for each harmonic order, under the various *facility* operating conditions
  - If the *Transmission Provider* has set any specific limit, drawings showing the relative geographic location of telephone lines and affected power lines, as well as detailed calculations of requested factors
  - If an exemption from emission limits for telephone influence is sought, a document certifying that there is no existing or planned voice-frequency analog telephone line within 10 km of the transmission lines affected

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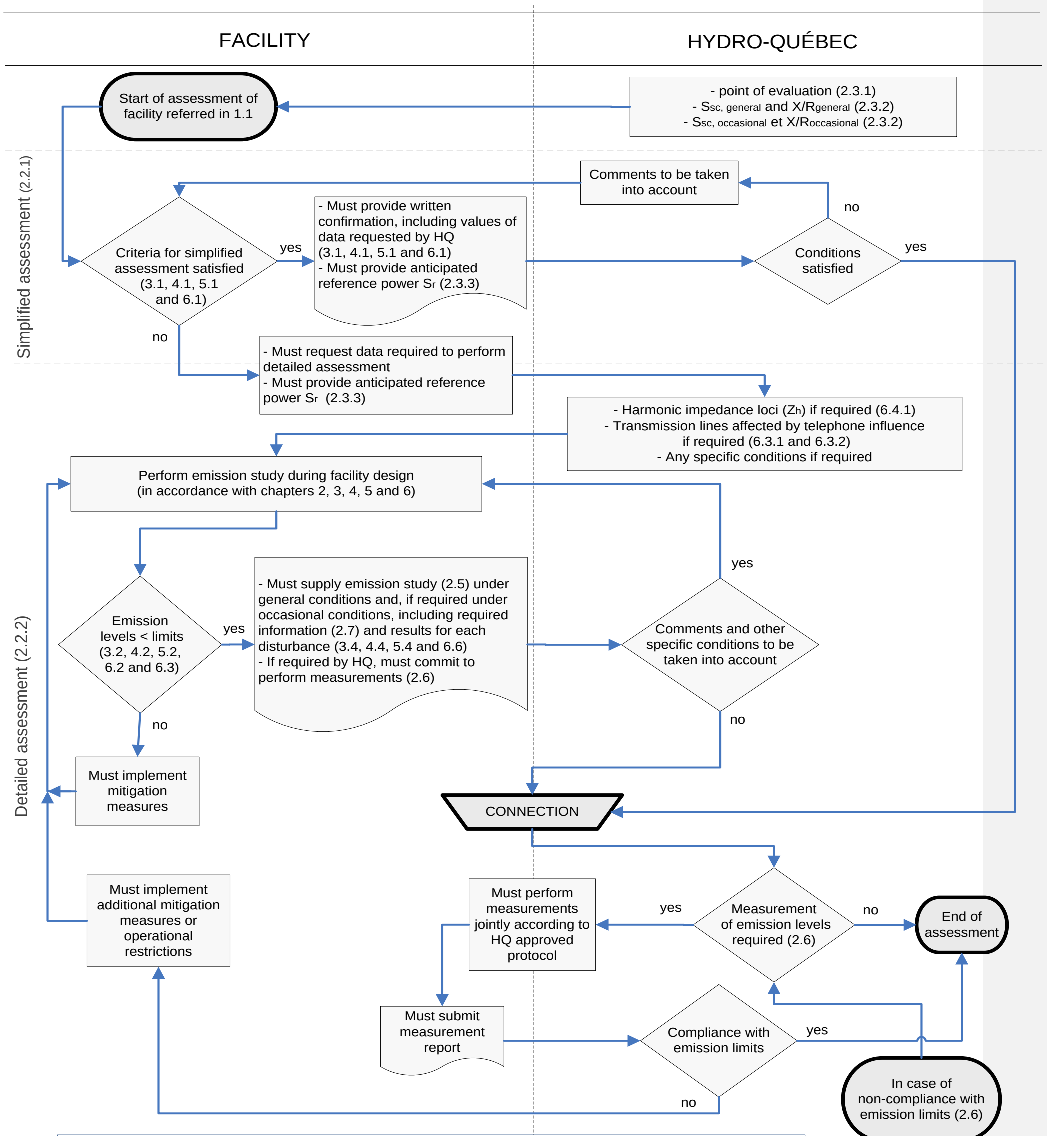
Appendix A: Required technical information and general procedure for assessing emission limit compliance



Note : Emission limits are set on a case-by-case basis for other power quality disturbances (1.2). HQ must receive a detailed assessment of compliance with any such limits.

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Appendix B: General guidelines for measuring power quality disturbances

General guidelines are provided for measuring power quality disturbances covered by the emission limits presented in this document. These guidelines are to be supplemented as needed by a measurement protocol in order to determine emission levels for a given *facility*.

B.1. Rapid voltage change (RVC)

The RVC is calculated based on consecutive values of the RMS voltage, calculated each second. Each value of the RMS voltage is the quadratic mean of the voltage over a 1 second aggregation interval.

The percent RVC is calculated for a given interval of 9 consecutive seconds according to the equation below:

$$RVC(\%) = \left[\frac{\max_{9s}(ISV_{3s\ avg}) - \min_{9s}(ISV_{3s\ avg})}{avg_{9s}(ISV_{3s\ avg})} \right] \times 100$$

Where:

- $ISV_{3s\ avg}$: Arithmetic mean of three consecutive values of the RMS voltage (each over a 1 second aggregation interval)
- $\max_{9s}(ISV_{3s\ avg})$: Maximum value of the 7 possible $ISV_{3s\ avg}$ averages calculated within the 9 second interval
- $\min_{9s}(ISV_{3s\ avg})$: Minimum value of the 7 possible $ISV_{3s\ avg}$ averages calculated within the 9 second interval
- $avg_{9s}(ISV_{3s\ avg})$: Arithmetic mean of the 7 possible $ISV_{3s\ avg}$ averages calculated within the 9 second interval preceding the end of the RVC detection interval

A RVC is an intermittent power quality disturbance. Assessment of compliance with emission limits is based on forecast maximum values rather than on statistical levels over time.

If the RMS voltage exceeds the voltage dip or the overvoltage threshold during a voltage change, the event is considered to be a voltage dip or an overvoltage rather than a RVC.

B.2. Flicker

The short-term flicker index (P_{st}) is measured over 10-minute aggregation intervals according to standard CAN/CSA-IEC 61000-4-15 [2] and Class A requirements of standard CAN/CSA-IEC 61000-4-30 [3] adjusted for 120-V lamps.

A measurement protocol is generally required to determine emission levels for flicker.

Measurements rely on statistical levels over time to assess compliance with emission limits. Compliance is achieved when the 95th percentile[17] value of daily recorded emission levels is less than the emission limit and when the 99th percentile[18] value is less than 1.25 times this limit.

[17] The 95th percentile value of daily recorded values is the maximum value obtained when ignoring the top 5% of values recorded during a given day.

[18] The 99th percentile value of daily recorded values is the maximum value obtained when ignoring the top 1% of values recorded during a given day.

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These statistical values are calculated by discarding flagged data according to standard CAN/CSA-IEC 61000-4-30 [3] (e.g., voltage dips, temporary overvoltages, momentary interruptions or other interruptions on the system).

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B.3. Load or current unbalance

The negative-sequence component of the current (or voltage) unbalance is assessed over 10-minute aggregation intervals, in accordance with Class A requirements of standard CAN/CSA-IEC 61000-4-30 [3].

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A measurement protocol is generally required to determine emission levels for current (or voltage) unbalance.

Measurements rely on statistical levels over time to assess compliance with emission limits. Compliance is achieved when the 95th percentile value of daily recorded emission levels is less than the emission limit and when the 99th percentile value is less than 1.5 times this limit.

These statistical values are calculated by discarding flagged data according to standard CAN/CSA-IEC 61000-4-30 [3] (e.g., voltage dips, temporary overvoltages, momentary interruptions or other interruptions on the system).

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B.4. Harmonics

Harmonic currents of orders n = 2 to 50 are measured over 10-minute aggregation intervals according to CAN/CSA-IEC 61000-4-7 [1] and Class A requirements of standard CAN/CSA-IEC 61000-4-30 [3].

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If harmonics are continuously and rapidly fluctuating, the evaluation of emission levels for harmonic currents relies on the group and subgroup method as described in standard CAN/CSA-IEC 61000-4-7 [1].

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A measurement protocol is generally required to determine emission levels for harmonic currents.

Measurements rely on statistical levels over time to assess compliance with emission limits. Compliance is achieved when the 95th percentile value of daily recorded emission levels is less than the emission limit and when the 99th percentile value is less than 1.5 times this limit.

These statistical values are calculated by discarding flagged data according to standard CAN/CSA-IEC 61000-4--30 [3] (e.g., voltage dips, temporary overvoltages, momentary interruptions or other interruptions on the system).

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MANDATORY REFERENCE DOCUMENTS

[1] 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. National Standard of Canada CAN/CSA-IEC 61000-4-7:13 (R2017).

[2] Electromagnetic compatibility (EMC) – Part 4-15: Testing and measurement techniques – Flickermeter – Functional and design specifications. National Standard of Canada CAN/CSA-IEC 61000-4-15:12 (R2016).

[3] Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods. National Standard of Canada CAN/CSA-IEC 61000-4-30:16.

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The *Transmission Provider* must display on its website a hyperlink pointing to the Canadian Standards Association (CSA) website, where it is possible to obtain any copyrighted standard.

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