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Scope
This manual is one of a series containing standards for construction of the BC Hydro electrical distribution plant within the service area of BC Hydro. A new distribution plant shall be designed, constructed, owned, operated, maintained and repaired to these standards.

Purpose of Standards
BC Hydro objectives require standardization to:
   a) Ensure uniform safety requirements comply with BC statutes and regulations.
   b) Provide uniform system reliability.
   c) Provide uniform operating practices.
   d) Permit economic bulk purchasing of materials.
   e) Achieve optimum life cycle cost of plant construction.
   f) Effect efficient quality assurance.

Responsibility
The Distribution Standards Department prepares these standards and verifies that specified plant and procedures will perform adequately under all normally expected conditions encountered throughout the province of British Columbia. These standards are approved by Professional Engineers. It is the responsibility of BC Hydro Managers to ensure that the standards are followed unless abnormal conditions are encountered that require variations. These variations should be kept to a minimum and their performance shall be the responsibility of the Professional of Record in charge of the project, who will record and seal the variation based on satisfactory qualifications and experience to do so. As per the latest revision of the BC Hydro Distribution Owner’s Engineer Guide, these variations must be accepted by BC Hydro’s Owner’s Engineer.

Use of Stock Materials
The electrical distribution plant covered by these standards is built using stock materials approved by a Professional Engineer as required by law. The use of non-stock materials for special and unusual situations must be approved by Distribution Standards or the BC Hydro Engineer responsible for the project.

Revisions to Manual
These standards are revised from time to time to improve the safety, performance, workability, cost effectiveness or appearance of the plant. The existing plant built to previous standards need not be updated unless so specifically advised by BC Hydro. When maintenance or other work, such as voltage conversion or conductor change is being done, updating plant to current standards is encouraged.

Mailing Addresses
The manual has been issued to a corporation or firm rather than to an individual. The corporation or firm is responsible for the safekeeping of the manual, and for keeping it current. Changes of address or in number of copies required must be reported promptly.

Suggestions for changes in the manual, or required changes of address may be made on the pre-addressed comment sheet included in the Manual and with each issue of revision.
ES55 Design Standards
Q4-05 – Voltage Flicker

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Revision History

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MEDIUM-VOLTAGE CUSTOMER EMISSION LIMITS

VOLTAGE FLICKER

ENGINEERING STANDARD

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## Reviewed:

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<thead>
<tr>
<th>Name</th>
<th>Department</th>
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<tbody>
<tr>
<td>Sergey Kryuchkov</td>
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Scope

This standard defines the method for determining flicker emission limits for customers connecting to, or requesting connection to BC Hydro’s public medium-voltage (MV) distribution network. It also describes the assessment process for verifying compliance with prescribed flicker emission limits.

Definitions

These terms are used in this section:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flicker</td>
<td>Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.</td>
</tr>
<tr>
<td>Rapid Voltage Changes</td>
<td>Changes in fundamental frequency r.m.s. voltages over several cycles; rapid voltage changes could also be in the form of cyclic changes.</td>
</tr>
<tr>
<td>Public Network</td>
<td>Low or medium voltage networks are considered ‘public’ when they serve, or are intended to serve, more than one customer from the same transformer.</td>
</tr>
<tr>
<td>Private Network</td>
<td>Low or medium voltage networks are considered ‘private’ when they serve, and are only intended to serve, one customer from a dedicated transformer.</td>
</tr>
<tr>
<td>( P_{ST} )</td>
<td>Short term flicker severity index calculated by IEC flicker meters over 10 minute intervals.</td>
</tr>
<tr>
<td>( P_{LT} )</td>
<td>Long term flicker severity index calculated from 12 consecutive ( P_{ST} ) values.</td>
</tr>
<tr>
<td>Emission Level</td>
<td>The level of a given electromagnetic disturbance emitted from a particular device, equipment or system.</td>
</tr>
<tr>
<td>Low Voltage (LV)</td>
<td>Describes networks with a rated voltage of ( 0 , V &lt; U_n \leq 1,000 , V ).</td>
</tr>
<tr>
<td>Medium Voltage (MV)</td>
<td>Describes networks with a rated voltage of ( 1,000 , V &lt; U_n \leq 35,000 , V ).</td>
</tr>
<tr>
<td>Cumulative Probability (CP[x])</td>
<td>The probability that the measured variable falls within a specified range [x]. For example, the CP95 value for a set of voltage measurements refers to the voltage quantity that was exceeded during 5% of the recorded period. Refer to Q1-02 for discussion about CP[x] statistical notation.</td>
</tr>
</tbody>
</table>
Application

Q4 is intended for application by distribution planning engineers, regional engineers, designers and power quality engineers for:

1) Calculation of customer emission limits for approved operation on a BC Hydro-owned public MV network, and
2) Assessment of customer emission performance for confirmation of operational compliance with prescribed limits.

Q4 emission limit determination is valid for all customers connected to, or requesting connection to, a BC Hydro-owned public MV network.

Q4-05 specifically defines BC Hydro’s emission limit requirements for flicker.

What is Voltage Flicker?

When voltage changes occur in rapid succession, with magnitudes large enough to cause lighting level variations which are noticeable or annoying to human beings, the effect is called flicker.

The severity of flicker is a function of both the frequency and magnitude of voltage fluctuations, and is most commonly associated with periodic voltage changes at frequencies between 1 and 20 Hz. Because flicker is a human sensory experience, it is highly subjective and is perceived differently by each person.

Flicker can lead to customer irritation and complaints. Occasional step changes of 3% or more will produce visible changes in light level, but often the problem is due to rapid and repetitive voltage changes of smaller magnitudes. The human eye-brain response is most sensitive to periodic r.m.s. voltage changes that occur at around 8-10 cycles per second. Fluctuation of r.m.s. voltages can lead to customer complaints with magnitudes as low as 0.2%.

Typical Causes

In large industrial facilities, operation of motors and arcing equipment are the causes of flicker on the public MV network. Examples of such equipment include:

- large gas compressors;
- liquid or gas pumps;
- wood cutting equipment, i.e. saws, chippers;
- hard material crushing equipment, i.e. steel, rock;
• arc-furnaces and welders, and
• heavy-duty power tools.

Effects

The primary effect of light flicker is visual discomfort imposed on people. Periodic or repetitive changes in voltage cause corresponding changes in light output, especially with use of incandescent lamps. Repetitive lighting level fluctuations cause visual disturbance for people; this can lead to physiological symptoms such as eye-strain, headache and malaise, and seizure for those who experience photosensitive epilepsy.

Occasional step changes of 3% or more will produce more drastic changes in light output, but often the problem is due to small magnitude repetitive voltage changes. The human eye is most sensitive to r.m.s. voltage changes which occur with frequency between 8 and 20 Hz. Periodic changes within that frequency range can lead to customer irritation, even at magnitudes as low as 0.2% of nominal voltage.

MV Customer Emission Limits

Flicker emission limits on BC Hydro’s public MV network are allocated such that overall network performance complies with planning limits defined in ES55 Q2-05.

All customers connected to, or applying for connection to, BC Hydro’s public MV network are subject to flicker emission limits.

This section describes the method for allocating emission limits to customers; sample MV-customer calculations are conducted in ES55 Q5-02 for further clarification as required.

Step 1: Simplified Evaluation for Immediate Approval

The simplified evaluation method involves comparison of maximum known or expected apparent power fluctuations (ΔS) with the short circuit power (S_sc) available at the customer’s proposed or existing PCC.

1) If \( \frac{\Delta S}{S_{sc}} \) is small and the number of fluctuations per minute (r) is within the limits shown below in Table 1, then the customer installation is acceptable for immediate approval.
2) If immediate approval is granted through application of the simplified evaluation method, the customer’s flicker emission limits shall correspond with BC Hydro’s MV planning limits (ES55 Q2-05).

3) If immediate approval is not granted through application of the simplified evaluation method, then proceed to Step 2 for detailed limit calculations.

Notes:

1) Available short circuit power ($S_{sc}$) can vary widely depending on BC Hydro’s network configuration. The most typical network operating fault levels should be used.

2) The $\Delta S$ value is not the rated equipment power, $S_N$. For example, the starting power of a motor may be 6-8 times the rated power $S_N$; $\Delta S$ is evaluated as the change from $S=0$ to $S_{MAX}$ (maximum starting power).

3) When determining the fluctuation rate ($r$), each voltage drop followed by recovery constitutes two voltage changes (one motor start corresponds to a value of $r=2$).

Step 2 – MV Flicker Emission Limit Calculation

When customer installations do not qualify for immediate approval, their flicker emission limits must be calculated independently. Each customer is assigned an emission limit in accordance with their share of the total capacity of the MV network to which they are connected.

MV customer flicker emission limits are calculated for both short and long-term flicker, $P_{ST}$ and $P_{LT}$ respectively. Limits for $P_{ST}$ and $P_{LT}$ are calculated using MV system planning levels, MV feeder capacity, sum of LV connected loads, and the customer’s load characteristics, as shown below in (EQ 1) and (EQ 2):
\[ E_{PSTi} = G_{PSTMV} \cdot \frac{S_i}{\sqrt{(S_T - S_{LV})}} \]  
\[ (EQ \ 1) \]

\[ E_{PLTi} = G_{PLTMV} \cdot \frac{S_i}{\sqrt{(S_T - S_{LV})}} \]  
\[ (EQ \ 2) \]

\[ E_{PSTi}, E_{PLTi} \] short and long term emission limits for the customer installation supplied at MV.

\[ G_{PSTMV}, G_{PLTMV} \] short and long term MV planning levels.

\[ S_i \] MV customer’s agreed power (MVA) – See ES55 Q1-04.

\[ S_T \] total supply capacity of BC Hydro’s MV feeder, including provisions for future load growth (MVA).

\[ S_{LV} \] sum of all existing and future LV loads to be served by the BC Hydro feeder (MVA).

\[ \alpha \] summation law exponent (most often \( \alpha = 3 \)). See below for further discussion.

**Summation Law Exponent (\( \alpha \))**

The value chosen for \( \alpha \) depends on the characteristics of the fluctuating loads. The value selected for \( \alpha \) represents the likelihood of coincident operation of flicker-causing equipment.

- \( \alpha = 1 \) should be used when there is very high risk of coincident flicker occurrence, e.g. where multiple motors are started at once.
- \( \alpha = 2 \) should be used where coincident flicker occurrences are likely to occur, e.g. simultaneous operation of more than one arc furnace.
- \( \alpha = 3 \) should be used for most types of loads where risk of coincident flicker occurrence is low.
Notes:

1) For most applications a value of $\alpha=3$ is used to calculate customer flicker emission limits.

2) When highly fluctuating loads operate on the same MV network a value of $\alpha=2$ is used. Highly fluctuating loads include:
   a. arc furnaces or welders,
   b. wood-chippers,
   c. steel-crushers, and
   d. rock-crushers.

3) If you suspect a customer to have a highly fluctuating load that is not listed above, consult a Power Quality Engineer for guidance.

Minimum Flicker Emission Limits

For customers with small connected MVA, the approach for calculating flicker emission limits may yield values that are unrealistically low. To account for such instances, the minimum short and long term flicker emission limits that shall be imposed on customers are shown below in Table 2.

Table 2 - Low-power customer emission limits

<table>
<thead>
<tr>
<th>$P_{ST}$</th>
<th>0.35</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{LT}$</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Step 3: Acceptance of Higher Emission Levels

Under some circumstances, the BC Hydro MV network can tolerate emission levels higher than might be calculated in Step 2. The following factors may provide some margin for allocating higher emission limits than that which was calculated in Step 2:

- The summation law exponent may be too conservative for the application.
- Some customer installations do not produce significant amounts of flicker; thus some of that customer’s flicker emission allocation could be re-assigned to others.
- Conditionally higher emission limits can be allowed when a customer is forced to operate under degraded network configurations through no fault of their own.
If any of the above scenarios might apply to the emission limit assessment, consult a Power Quality Engineer for guidance.

Performance Criteria

Customer Emissions Assessment

Customer emission performance with respect to flicker is assessed as follows:

- a minimum of 1000 consecutive 10 minute $P_{ST}$ values (1 week) shall be recorded using an IEC flickermeter, and
- a minimum of 84 consecutive 2hr $P_{LT}$ values (1 week) shall be recorded using an IEC flickermeter, and
- CP99 weekly probability values for $P_{ST}$ and CP95 weekly probability values for $P_{LT}$ must be less than prescribed emission limits, and
- no three consecutive $P_{ST}$ or two consecutive $P_{LT}$ values shall exceed prescribed emission limits, and
- no $P_{ST}$ value associated with customer load operation shall exceed 1.3 x the prescribed $P_{ST}$ emission limit.

Flicker emissions shall be correlated with customer load operation to exclude impact from neighbouring customer loads.

Evaluation shall exclude all network fault events, as they produce erroneously high flicker values and are uncontrollable by the customer.

Meter Specifications

To determine compliance with prescribed flicker emission limits, $P_{ST}$ and $P_{LT}$ values must be obtained using a power quality meter with Class A performance as defined by CAN/CSA 61000-4-30 and CAN/CSA 61000-4-15.

CAN/CSA 61000-4-30 defines only the measurement certainty for a Class A flickermeter. The technical details of the IEC flickermeter specification are found in CAN/CSA 61000-4-15.

Customer Response

When a customer's operation violates prescribed emission limits on the BC Hydro system, mitigation must occur within 60 days of notification.

Where mitigation requires a complex engineered solution, an extension of time may be granted, at BC Hydro’s discretion, of up to 90 days to allow
for design, procurement, and commissioning of new equipment and/or process.

BC Hydro Power Quality Engineers are available to assist with standards interpretation, data collection and analysis, and compliance evaluation:

- They may, where applicable, offer general advice relating to potential mitigation options.
- They will not make recommendations of a specific nature for any customer facility.

Customers should act solely on advice from qualified professional electrical engineers, who are hired by the customer, when mitigation is required at their facility.

BC Hydro Response

When a customer’s operation violates prescribed emission limits, BC Hydro will notify the customer of their violation. Written notification may be communicated via electronic or regular mail, and the notice will be clear that the customer’s use of electricity is causing a disturbance to the BC Hydro electrical system. Where previous communication has been established electronically between BC Hydro and the customer, email notification shall be considered suitable written notification.

The written notice to the customer should outline that, if a customer fails to meet emission limit requirements within the approved timeframe, then BC Hydro may disconnect the customer from the public network to prevent further disturbing operation. Where upgrades can be installed on the BC Hydro network to mitigate the disturbance, BC Hydro can offer to install such upgrades at the customer’s cost. The customer’s written confirmation for assuming responsibility of these costs should be obtained before installing upgrades for the benefit of the customer.

References

- ES55 Q1-04 Customer Apparent Power Assessment
- ES55 Q2-05 Network Planning Limits - Flicker

Sources


- CAN/CSA-C61000-2-2-04 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-C61000-3-7-09 Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems.


- CAN/CSA-C61000-4-30-10 Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement techniques - Power quality measurement methods