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## Project QC-2026-03

### Follow-up to decision D-2022-110 – Impacts and Correction Action Plans Associated with Reliability Standard TPL-007-4

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#### 1. OVERVIEW OF THE STANDARDS

In its Decisions D-2021-015 and D-2022-110, the Régie de l'énergie (hereinafter, the "Régie") ordered the Reliability Coordinator (hereinafter, the "Coordinator") to file a new application presenting the impacts of Reliability Standard TPL-007-4, including, in particular, the results of geomagnetic disturbance (hereinafter, "GMD") vulnerability assessments conducted in accordance with Requirements E4 and E8, as well as the corrective action plans (hereinafter, "CAPs") developed pursuant to Requirement E11.

Through this present filing, the Coordinator responds to the follow-up requests made by the Régie de l'énergie, in accordance with paragraph 71 of Decision D-2021-015<sup>1</sup> and paragraph 54 of Decision D-2022-110<sup>2</sup>, including in particular:

- a summary description of the models and studies performed;
- the list of concerned entities and facilities;
- the current thresholds reached for the transformers subject to the reference and supplemental GMD vulnerability assessments;
- the results of the corrective action plans.

#### 1.1. Applicability

The Coordinator presents, for information purposes, the functions to which Reliability Standard TPL-007-4 applies in the table below.

Standard	Functions
TPL-007-4	<i>Planning Coordinator (PC)</i> <i>Transmission Planner (TP)</i> <i>Transmission Owner (TO)</i> <i>Generator Owner (GO)</i>

A list of concerned entities and facilities is presented in the document "Entities and facilities concerned by the TPL-007-4 standard".

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<sup>1</sup> Régie de l'énergie, decision D-2021-015, docket R-4123-2020, consulted on April 14, 2026 at: <https://www.regie-energie.qc.ca/storage/app/media/entites-visees-normes-de-fiabilite/normes-de-fiabilite/D-2021-015.pdf> (in French only)

<sup>2</sup> Régie de l'énergie, decision D-2022-110, docket R-4192-2022, consulted on April 14, 2026 at : <https://www.regie-energie.qc.ca/storage/app/media/entites-visees-normes-de-fiabilite/normes-de-fiabilite/D-2022-110.pdf> (in French only)

## 1.2. Regulatory context

The Reliability Standard TPL-007-4, as well as its appendix, adopted by the Régie in Decision D-2022-110<sup>3</sup>, came into force on April 1, 2023. Requirements R3, R4, R7, R8, and R11 of the standard come into effect on April 1, 2026. The previous version of Reliability Standard TPL-007, namely Reliability Standard TPL-007-3, was adopted by the Régie in its Decision D-2021-015<sup>4</sup> and came into force on April 1, 2021.

Since the required analyses have now been completed and the 60-month implementation period provided for in Requirement R11 has expired, the Coordinator is launching a public consultation to present the activities carried out by the Planning Coordinator (hereinafter, the “PC”), to outline the preliminary conclusions, and to collect comments from interested parties.

## 1.3. Specific provisions for Québec

Reliability Standard TPL-007-4, currently in force, applies to Facilities of the Main Transmission System (hereinafter, the “RTP”) comprising one or more power transformers whose high-voltage side has a grounded-wye winding and whose terminal voltage exceeds 200 kV. Although the present public consultation is intended to respond to the follow-up requirements imposed by the Régie de l’énergie in Decisions D-2021-015 and D-2022-110, the Coordinator also proposes to standardize the specific provisions carried forward from the Québec appendix to TPL-007-4, in accordance with paragraph 285 of Decision D-2024-060<sup>5</sup>, which specifies the wording and placement of specific provisions in any standard referring to the terms “Bulk Electric System” or “BES.”

Accordingly, the Coordinator proposes the following specific provision in the “Applicability” section:

“In the application of this standard, all reference to the terms “Bulk Electric System” or BES shall be replaced by the terms “Main Transmission System” or “RTP”, respectively.”

Lastly, a specific provision applicable to Québec was added to Section 4.2.2 of the Appendix in order to refer to the RTP rather than the BES. Accordingly, the Coordinator proposes the following specific provision in Section 4.2.2:

“Facilities that are part of the RTP that include power transformer(s) with a high side, wye-grounded winding with terminal voltage greater than 200 kV.”

## 2. OVERVIEW OF THE MODELS PERFORMED

The studies conducted in accordance with Reliability Standard TPL-007-4 are based on a set of modeling assumptions and data, from which geomagnetic disturbance (GMD) assessments are

<sup>3</sup> Régie de l’énergie, decision D-2022-110, docket R-4192-2022, consulted on April 14, 2026 at : <https://www.regie-energie.qc.ca/storage/app/media/entites-visees-normes-de-fiabilite/normes-de-fiabilite/D-2022-110.pdf> (in French only)

<sup>4</sup> Régie de l’énergie, decision D-2021-015, docket R-4123-2020, consulted on April 14, 2026 at: <https://www.regie-energie.qc.ca/storage/app/media/entites-visees-normes-de-fiabilite/normes-de-fiabilite/D-2021-015.pdf> (in French only)

<sup>5</sup> Régie de l’énergie, decision D-2024-060, docket R-4229-2024, consulted on April 14, 2026 at : [https://www.regie-energie.qc.ca/fr/participants/dossiers/R-4229-2023/doc/R-4229-2023-A-0020-Dec-Dec-2024\\_06\\_20.pdf](https://www.regie-energie.qc.ca/fr/participants/dossiers/R-4229-2023/doc/R-4229-2023-A-0020-Dec-Dec-2024_06_20.pdf) (in French only)

performed. The models provide the foundation for quantifying the effects of GMDs on transformers, system voltage, and protection equipment. These models are presented in Subsections 2.1 to 2.6.

### **2.1. 2021-2025 Power Flow Model – Voltage Stability Analysis**

The Planning Coordinator's (PC) GMD analyses are based on power flow models developed in accordance with Reliability Standards MOD-032-1 and TPL-001-4. These models represent the Québec transmission system for the 2025–2026 winter peak scenario as well as the 2026 summer off-peak scenario and are used for thermal and voltage analyses.

### **2.2. GIC Representation in PSS®E**

GMD events are applied using the Geomagnetically Induced Current (hereinafter, "GIC") analysis module of the Power System Simulator for Engineering (PSS®E) version 34.8.2 developed by Siemens. This module calculates the direct current induced in transformers as well as the reactive loads added to simulate transformer saturation, which is the primary cause of geomagnetic storm-related issues.

### **2.3. Geomagnetic Ground Conductivity Models**

These regional ground conductivity models, based on data and analyses from Natural Resources Canada (hereinafter, "NRCan"), define the local ground response to geomagnetic storms.

### **2.4. GMD Event Models (Reference and Supplemental)**

In accordance with Reliability Standard TPL-007-4 and the applicable regional differences for Canadian jurisdictions, two types of geomagnetic disturbance (GMD) events are considered: a reference event, with an approximate recurrence probability of once every 100 years, which is applied uniformly across the entire system, and a supplemental event, which corresponds to a more severe but localized event, allowing specific geographic areas to be targeted. These reference models define the intensity, geographic extent, and orientation of the storm used in the simulations.

The Planning Coordinator (PC) used Canadian geomagnetic field and ground conductivity models developed by Natural Resources Canada (NRCan), based on 40 years of magnetometer data. The applied geomagnetic fields are derived from NRCan's 1-in-100-year reference events, including ground conductivity models specific to Québec.

### **2.5. EMT Modeling for Harmonics**

Electromagnetic transient (hereinafter, "EMT") simulations are performed to assess the effects of induced currents on the system. These models are used to simulate the impact of GIC-related transformer saturation on relays and sensitive equipment, including the behavior of protection relays under such conditions.

### **2.6. Thermal Models for Power Transformers (Hitachi/ABB)**

These models, provided by the manufacturer Hitachi/ABB, were used to assess the thermal capability and temperature limits under the effects of GICs.

## **3. SUMMARY DESCRIPTION OF THE STUDIES PERFORMED**

As part of the GMD vulnerability assessment conducted in accordance with Reliability Standard TPL-007-4, the Coordinator presents below a summary of the main technical steps followed by the Planning Coordinator (PC) and the conclusions obtained.

In accordance with Appendix 1-CAN of Reliability Standard TPL-007-4, the PC used regional characteristics specific to Québec for both the reference event and the supplemental event. These characteristics are based on one-minute measurements from the Ottawa and Poste-de-la-Baleine/Sanikiluaq magnetometers. Data specific to the Canadian context—including geomagnetic field and ground conductivity—were therefore used for the vulnerability assessments. The values retained are based on a statistical extreme-value analysis conducted by Natural Resources Canada’s space weather group.

### **3.1. Transformer Thermal Assessment**

The transformer thermal assessment performed for a GMD event takes into account the fact that GICs may result in potentially damaging heating. GMDs were modeled under various loading conditions, and a direct-current (hereinafter, “DC”) network calculation was used to determine the GICs flowing through the transformers.

In accordance with Requirements E6 and E10 of Reliability Standard TPL-007-4, seven (7) transformers owned by HQ exceed the 75 A/phase threshold for the reference event, while five (5) additional transformers exceed 85 A/phase for the supplemental events. None of the transformers owned by the other affected Québec entities exceed these thresholds; therefore, no thermal heating analysis is required for either the reference or the supplemental events for those entities. This screening process allows the identification of transformers for which a more detailed assessment is required.

Such an assessment was conducted by Hitachi/ABB, which calculated winding and structural part temperatures using the GIC signature specified by NERC, assuming maximum loading conditions and an ambient temperature of 30 °C. The thermal limits recommended by IEEE C57.163-2023—namely 180 °C for windings and 200 °C for structural parts—were verified and met.

The results indicate that, for both the reference event and the supplemental events, no transformer exceeds its GIC thermal capability. The measured GIC values remain below the critical thresholds established by Hitachi/ABB. Accordingly, no technical issues are anticipated for the transformers assessed, and no corrective actions are required.

### **3.2. Steady-State Voltage Stability Evaluation**

The steady-state voltage stability assessment shows that GICs flowing through and saturating power transformers result in MVAR absorption on the system, which reduces voltage levels and may lead to voltage collapse. This assessment requires the addition of equivalent reactive loads to represent transformer saturation and to simulate the effects of a geomagnetic storm.

The steady-state voltage stability assessment consists of applying GMD electric fields in the PSS®E GIC module, solving for the direct currents induced in transformers, and subsequently deriving the reactive power absorption associated with transformer saturation. Harmonic effects and thermal constraints are verified in order to identify any potential equipment outages, which may require iteration of the calculations, as applicable. The alternating-current power flow is then solved to confirm compliance with the TPL-007 performance requirements and the post-contingency voltage limits specified in Requirement E3.

EMT simulations demonstrate that only certain capacitor bank protection schemes presented a risk of RMS pseudo-overload, which was corrected through a recall and settings update initiated in 2022,

thereby allowing these facilities to be considered available for the analysis. No other significant issues were identified for transmission lines, transformers, or static compensators, the latter having been significantly reinforced since the major power outage that occurred in Québec in 1989, which was caused by an extreme geomagnetic storm.

The results indicate that, for the reference event, voltage levels remain above acceptable limits at substations rated 200 kV and above, notably due to the presence of ~~23~~ static compensators, ~~6~~ synchronous condensers, and ~~53~~ series compensation platforms, which effectively mitigate the effects of GICs. Voltages at the 735 kV level recover within post-contingency limits following the required automatic switching operations.

For the supplemental events, using a localized displacement area of 100 km × 100 km applied around each 735 kV substation (and certain strategic 315 kV substations), the observed voltages—both within and outside the analyzed areas—also comply with the performance criteria of the standard, confirming that the system maintains adequate voltage stability even under severe localized GMD conditions.

### 3.3. Correction Action Plans (CAP)

As part of the work carried out in accordance with Reliability Standard TPL-007-4, Hydro-Québec has implemented the required corrective measures following the identification of a vulnerability affecting certain types of capacitor bank protection schemes.

More specifically, an update of the protection systems for seventeen (17) capacitor banks was initiated, including both firmware updates and the necessary settings adjustments to ensure their robustness in the presence of harmonics generated by transformer saturation under geomagnetic disturbances (GMDs). These corrective actions address the requirements of Requirements R7 and R11, which impose a maximum implementation period of two years for applicable corrective measures.

The required work is being carried out in compliance with these timelines. To date, the protection updates for twelve (12) of the seventeen (17) capacitor banks have been completed, and the remaining updates are expected to be finalized in 2026. No additional corrective actions were deemed necessary. The affected protection schemes now meet the expected performance criteria during GMD events, thereby ensuring the continued reliability of the system.

## 4. IMPACT ASSESSMENT

The affected capacitor bank protection schemes have been subject to the required adjustments to ensure adequate protection against harmonic overloads, including firmware updates and settings adjustments. Hydro-Québec is the sole owner of capacitor banks rated at 200 kV and above that are subject to the corrective action plan. The work, initiated in 2022, will be completed by the end of 2026, in accordance with Requirements R7 and R11 of Reliability Standard TPL-007-4. No additional corrective measures are required following the assessment of vulnerability to geomagnetic disturbances (GMDs) for the 2021–2025 period. For these reasons, the Coordinator is of the view that the impact of Reliability Standard TPL-007-4 and the associated corrective action plan is low.