NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

DRAFT Implementation Guidance
Submitted for ERO Enterprise Endorsement

Transmission System Planned Performance for Geomagnetic Disturbance Events

Implementation Guidance for Reliability Standard TPL-007-4

April 2020

RELIABILITY | RESILIENCE | SECURITY


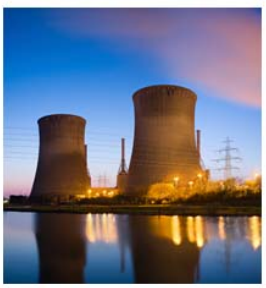

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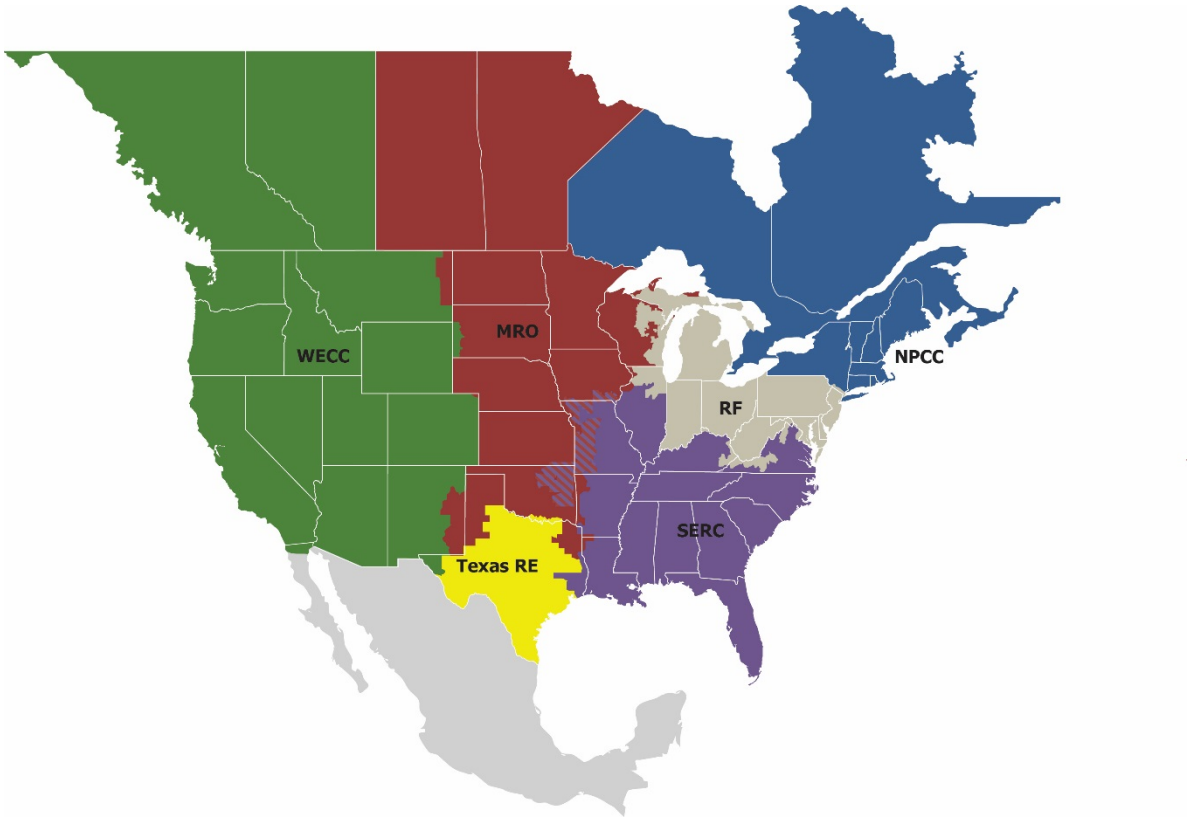
Table of Contents

Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the six Regional Entities (REs), is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is divided into six RE boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Region while associated Transmission Owners/Operators participate in another.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Introduction

Background

The Standards Project 2019-01 Modifications to TPL-007-3 standard drafting team prepared this Implementation Guidance to provide example approaches for compliance with the modifications to TPL-007 – Transmission System Planned Performance for Geomagnetic Disturbance Events. Implementation Guidance does not prescribe the only approach, but highlights one or more approaches that would be effective in achieving compliance with the standard. Because Implementation Guidance only provides examples, entities may choose alternative approaches based on engineering judgement, individual equipment, and system conditions.

The first version of the standard, TPL-007-1 which was approved in FERC's Order No. 779 [1], requires entities to assess the impact to their systems from a defined event referred to as the "Benchmark GMD Event." The second version of the standard, TPL-007-2, adds new Requirements R8, R9, and R10 to require responsible entities to assess the potential implications of a "Supplemental GMD Event" on their equipment and systems in accordance with FERC's directives in Order No. 830 [2]. Some GMD events have shown localized enhancements of the geomagnetic field. The supplemental GMD event was developed to represent conditions associated with such localized enhancement during a severe GMD event for use in a GMD Vulnerability Assessment. The third version of the standard, TPL-007-3, adds a Canadian variance for Canadian Registered Entities to leverage operating experience, observed GMD effects, and on-going research efforts for defining alternative Benchmark GMD Events and/or Supplemental GMD Events that appropriately reflect their specific geographical and geological characteristics. No continent-wide requirements were changed between the second and the third versions of the standard. The fourth version, TPL-007-4, addresses the directives issued by FERC in Order No. 851 [3] to modify Reliability Standard TPL-007-3. FERC directed NERC to submit modifications to: (1) require the development and implementation of corrective action plans to mitigate assessed supplemental GMD event vulnerabilities (P 29); and (2) to replace the corrective action plan time-extension provision in TPL-007-3 Requirement R7.4 with a process through which extensions of time are considered on a case-by-case basis (P 54).

Requirement R1

In some areas, planning entities may determine that the most effective approach to conduct a GMD Vulnerability Assessment is through a regional planning organization. No requirement in the standard is intended to prohibit a collaborative approach where roles and responsibilities are determined by a planning organization made up of one or more Planning Coordinator(s).

Requirement R2

The projected System condition for GMD planning may include adjustments to the System that are executable in response to space weather information. These system adjustments could for example include recalling or postponing maintenance outages.

Underground pipe-type cables present a special modeling situation in that the steel pipe that encloses the power conductors significantly reduces the geoelectric field induced into the conductors themselves, while they remain a path for GIC. Solid dielectric cables that are not enclosed by a steel pipe will not experience a reduction in the induced geoelectric field. If applicable, include the above special modeling situations in the GIC System model.

Requirement R3

Requirement R3 allows a responsible entity the flexibility to determine the System steady state voltage criteria for System steady state performance in Table 1: Steady State Planning GMD Event found in TPL-007-4. Steady state voltage limits are an example of System steady state performance criteria.

Requirement R4

Distribution of benchmark GMD Vulnerability Assessment results provides a means for sharing relevant information with other entities responsible for planning reliability. Consider impact on neighboring systems when evaluating GIC study results.

Requirement R5

The maximum effective GIC value provided in Part 5.1 is used for the benchmark thermal impact assessment. Only those transformers that experience an effective GIC value of 75 A or greater per phase require evaluation in Requirement R6.

A Transmission Owner or Generator Owner that desires GIC(t) may request it from the responsible entity. The responsible entity shall provide GIC(t) upon request once GIC has been calculated, but no later than 90 calendar days after receipt of a request from the owner and after completion of Requirement R5, Part 5.1 (see Requirement R5).

Requirement R6

ERO Enterprise-Endorsed Implementation Guidance for conducting the thermal impact assessment of a power transformer is presented in the *Transformer Thermal Impact Assessment White Paper*, October 2016 [4].

Transformers are exempt from the benchmark thermal impact assessment requirement if the effective GIC value for the transformer is less than 75 A per phase, as determined by a GIC analysis of the System. A documented design specification exceeding this value is also a justifiable threshold criterion that exempts a transformer from Requirement R6.

The benchmark thermal impact assessment of a power transformer may be based on manufacturer-provided GIC capability curves, thermal response simulation, thermal impact screening, or other technically justified means. The benchmark thermal impact assessment shall be based on the effective GIC flow information (see Requirement R6). For additional information, refer to the above referenced white paper and the *Screening Criterion for Transformer Thermal Impact Assessment White Paper*, October 2017 [5].

Approaches for conducting the thermal impact assessment of transformers for the benchmark event are presented in the *Transformer Thermal Impact Assessment White Paper*, October 2017 [6].

Thermal impact assessments for the benchmark event are provided to the responsible entity, as determined in Requirement R1, so that identified issues can be included in the GMD Vulnerability Assessment (Requirement R4) and the Corrective Action Plan (CAP) (Requirement R7) as necessary.

Requirement R7

This requirement addresses directives in FERC Order No. 830 for establishing CAP deadlines associated with GMD Vulnerability Assessments. In FERC Order No. 830, FERC directed revisions to TPL-007 such that CAPs are developed within one year from the completion of GMD Vulnerability Assessments (P 101). Furthermore, FERC directed NERC to establish implementation deadlines after the completion of the CAP as follows (P 102):

- Two years for non-hardware mitigation; and
- Four years for hardware mitigation.

Part 7.4 requires entities to submit to the CEA a request for extension when implementation of planned mitigation is not achievable within the deadlines established in Part 7.3. Examples of situations beyond the control of the responsible entity include, but are not limited to:

- Delays resulting from regulatory/legal processes, such as permitting;
- Delays resulting from stakeholder processes required by tariff;
- Delays resulting from equipment lead times; or
- Delays resulting from the inability to acquire necessary Right-of-Way.

Supplemental GMD Vulnerability Assessment

The exact spatial extent, local time of occurrence, latitude boundary, number of occurrences during a GMD event, and geoelectric field characteristics (amplitude and orientation) inside/outside the local enhancement cannot yet be scientifically determined.

TPL-007-4 provides flexibility in applying the supplemental GMD event to the planning area. This guide provides examples of approaches and boundaries to apply the supplemental event based on what is presently understood on localized enhancements. As provided in the standard (Attachment 1) "Other methods to adjust the benchmark GMD event analysis to account for the localized geoelectric field enhancement of the supplemental GMD event" may be used.

1. Spatial extent considerations:
    a. Apply a local geoelectric field enhancement consistent with available recordings of past events, e.g., greater than or equal to 100 km (West-East) by 100 km (North-South). Additional analysis may be performed by varying the spatial extent. Note that the 100 km North-South spatial extent is better understood than the West-East length, which could be 500 km or more; or
    b. Apply the peak geoelectric field for the supplemental GMD event (12 V/km scaled to the planning area) over the entire planning area. Note that this implies studying a GMD event rarer than 1-in-100 years.
2. Geoelectric field inside the local enhancement considerations:
    a. Amplitude: 12 V/km (scaled to the planning area); and
    b. Orientation: West-East (geomagnetic reference). Additional analysis may be performed varying the orientation of the geoelectric field.
3. Geoelectric field outside[1] the local enhancement consideration:
    a. Amplitude: Greater than or equal to 1.2 V/km (scaled to the planning area); i.e., an order of magnitude smaller than the field inside the local enhancement; and
    b. Orientation: West-East (geomagnetic reference). Additional analysis may be performed varying the orientation of the geoelectric field.
4. Position of the local enhancement considerations:
    a. Use engineering judgement to position the local enhancement on critical areas of the system. For example, the benchmark vulnerability assessment may identify areas with depressed voltages, lack of dynamic reactive reserves, large GIC flows through transformers, etc. Impacts to critical infrastructure or other externalities may also be considered; or
    b. Systematically move the position of the local enhancement throughout the entire planning area.

The schematic in Figure 1 illustrates an example of applying the supplemental GMD event. The local enhancement is 100 km by 100 km, the geoelectric field inside the local enhancement is 12 V/km (scaled to the planning area) with West-East orientation, and the geoelectric field outside the local enhancement is 1.2 V/km (scaled to the planning area) with a West-East orientation.

[1] The characteristics of the geoelectric field outside the local enhancement, for example amplitude, orientation, and spatial extent, are still being reviewed by the scientific community.

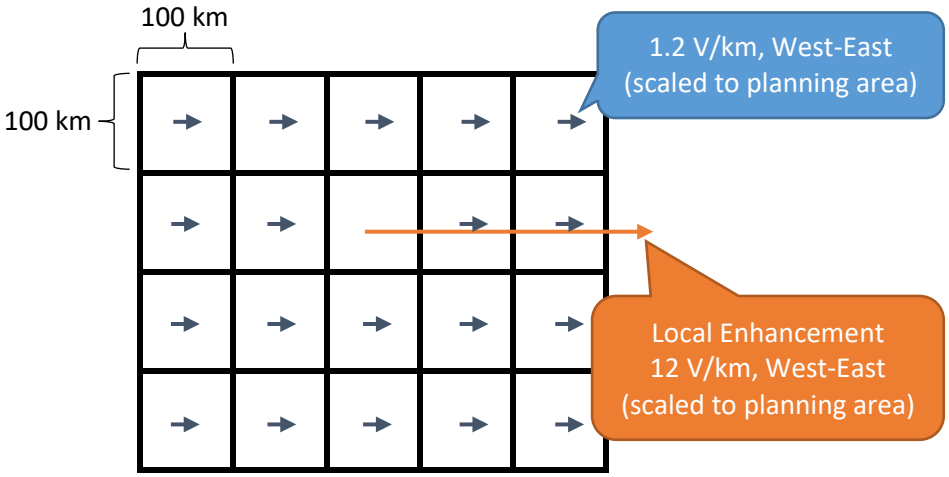


Figure 1. An Example of Applying the Supplemental Event.

Requirement R8

Distribution of supplemental GMD Vulnerability Assessment results provides a means for sharing relevant information with other entities responsible for planning reliability. Consider impact on neighboring systems when evaluating GIC study results.

Requirement R9

The maximum effective GIC value provided in Part 9.1 is used for the supplemental thermal impact assessment. Only those transformers that experience an effective GIC value of 85 A or greater per phase require evaluation in Requirement R10.

A Transmission Owner or Generator Owner that desires GIC(t) may request it from the responsible entity. The responsible entity shall provide GIC(t) upon request once GIC has been calculated, but no later than 90 calendar days after receipt of a request from the owner and after completion of Requirement R9, Part 9.1 (see Requirement R9).

Requirement R10

ERO Enterprise-Endorsed Implementation Guidance for conducting the thermal impact assessment of a power transformer is presented in the *Transformer Thermal Impact Assessment White Paper*, October 2016 [4].

Transformers are exempt from the supplemental thermal impact assessment requirement if the effective GIC value for the transformer is less than 85 A per phase, as determined by a GIC analysis of the System. A documented design specification exceeding this value is also a justifiable threshold criterion that exempts a transformer from Requirement R10.

The supplemental thermal impact assessment of a power transformer may be based on manufacturer-provided GIC capability curves, thermal response simulation, thermal impact screening, or other technically justified means. The supplemental thermal impact assessment shall be based on the effective GIC flow information (see Requirement R10). For additional information, refer to the above referenced white paper and the *Screening Criterion for Transformer Thermal Impact Assessment White Paper*, October 2017 [5].

Approaches for conducting the thermal impact assessment of transformers for the supplemental event are presented in the *Transformer Thermal Impact Assessment White Paper*, October 2017 [6].

Thermal impact assessments for the supplemental event are provided to the responsible entity, as determined in Requirement R1, so that identified issues can be included in the GMD Vulnerability Assessment (R8) and the Corrective Action Plan (R11) as necessary.

Requirement R11

This requirement addresses directives in FERC Order No. 851 to develop and submit modifications to Reliability Standard TPL-007-2 (and TPL-007-3) to require corrective action plans for assessed supplemental GMD event vulnerabilities. This requirement is analogous to Requirement R7, such that CAPs are developed within one year from the completion of supplemental GMD Vulnerability Assessments and establishes implementation deadlines after the completion of the CAP as follows:

- Two years for non-hardware mitigation; and
- Four years for hardware mitigation.

Part 11.4 requires entities to submit to the CEA a request for extension when implementation of planned mitigation is not achievable within the deadlines established in Part 11.3. Examples of situations beyond the control of the responsible entity include, but are not limited to:

- Delays resulting from regulatory/legal processes, such as permitting;
- Delays resulting from stakeholder processes required by tariff;
- Delays resulting from equipment lead times; or
- Delays resulting from the inability to acquire necessary Right-of-Way.

Requirement R12

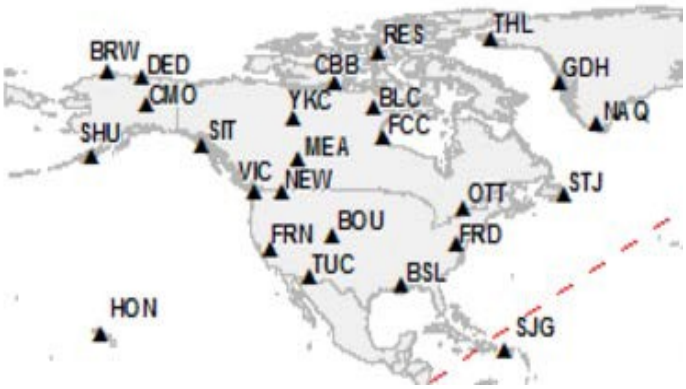
Responsible entities can consider the guidance found in NERC Rules of Procedure Section 1600 Data Request for the collection of GMD Data.[2]

[2] As of November 2019, a draft copy can be found at: https://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GMD_Data_Reporting_Instruction_draft.docx

Requirement R13

Responsible entities can consider the guidance found in NERC Rules of Procedure Section 1600 Data Request for the collection of GMD Data.[3]

The following map shows locations of magnetometers operated by U.S. Geological Survey (USGS) and Natural Resources Canada (NRCan). For a full listing refer to *International Real-Time Magnetic Observatory Network* [7].



Additional data could be found at research institutions and academic universities or other entities with installed magnetometers.

The *INTERMAGNET Technical Reference Manual*, Version 4.6, 2012 [8] provides equipment specifications and data format protocols.

[3] As of November 2019, a draft copy can be found at: https://www.nerc.com/comm/PC/Geomagnetic%20Disturbance%20Task%20Force%20GMDTF%202013/GMD_Data_Reporting_Instruction_draft.docx

References

1. FERC Order No. 779, https://www.nerc.com/FilingsOrders/us/FERCOrdersRules/Order779_GMD_RM12-22_20130516.pdf
2. FERC Order No. 830, https://www.nerc.com/filingsorders/us/FERCOrdersRules/E-4.pdf
3. FERC Order No. 851, https://www.nerc.com/FilingsOrders/us/FERCOrdersRules/E-3_Order%20No%20851.pdf
4. Transformer Thermal Impact Assessment White Paper, ERO Enterprise-Endorsed Implementation Guidance, NERC, Atlanta, GA, October 28, 2016, https://www.nerc.com/pa/comp/guidance/EROEndorsedImplementationGuidance/TPL-007-1_Transformer_Thermal_Impact_Assessment_White_Paper.pdf
5. Screening Criterion for Transformer Thermal Impact Assessment White Paper, NERC, Atlanta, GA, October 2017, https://www.nerc.com/pa/Stand/Project201303GeomagneticDisturbanceMitigation/Screening_Criterion_Clean_2017_October_Clean.pdf
6. Transformer Thermal Impact Assessment White Paper, NERC, Atlanta, GA, October 2017, https://www.nerc.com/pa/Stand/Project201303GeomagneticDisturbanceMitigation/Thermal_Impact_Assessment_2017_October_Clean.pdf
7. International Real-Time Magnetic Observatory Network, http://www.intermagnet.org/index-eng.php
8. INTERMAGNET Technical Reference Manual, Version 4.6, 2012, http://www.intermagnet.org/publications/intermag_4-6.pdf