NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

July 2019 - DRAFT Implementation Guidance
Pending Submittal for ERO Enterprise Endorsement

Transmission System Planned Performance for Geomagnetic Disturbance Events

Implementation Guidance for Reliability Standard TPL-007-4

July 2019

RELIABILITY | ACCOUNTABILITY



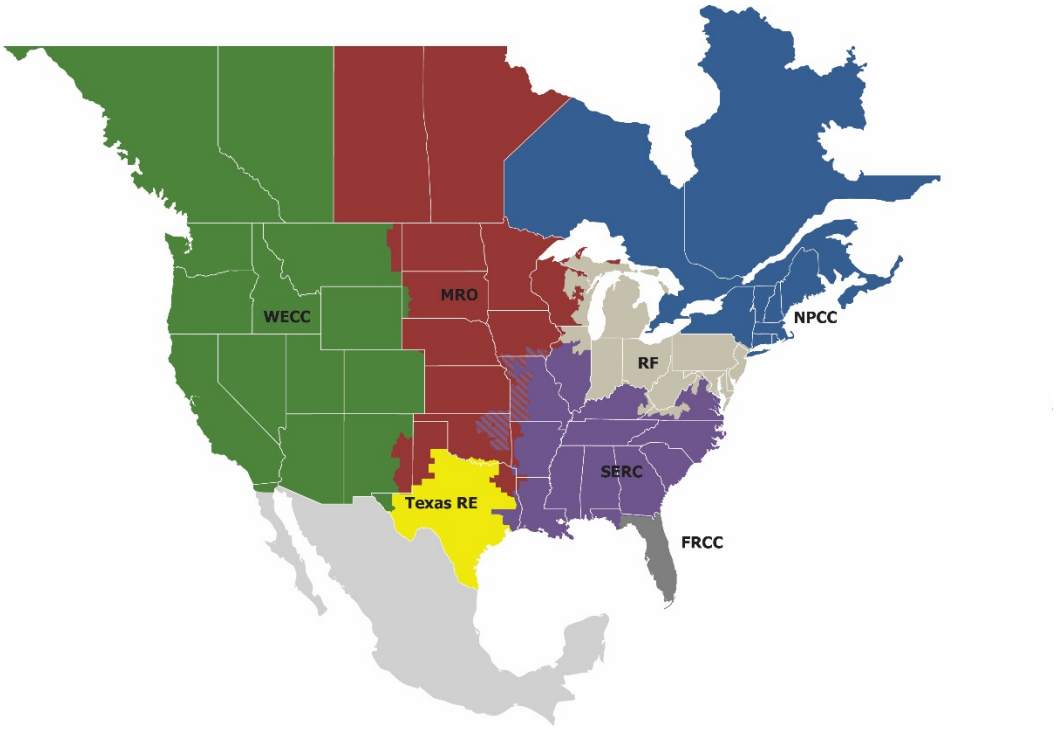

3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

Table of Contents

Preface

The vision for the Electric Reliability Organization (ERO) Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the seven 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.

The North American BPS is divided into seven 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.



FRCC	Florida Reliability Coordinating Council
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).

Chapter 1 – 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).

Chapter 2 – 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. A planning entity should account for special modeling situations, such as this, in the GIC system model, if applicable.

Chapter 3 – 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.

Chapter 4 – Requirement R4

Distribution of benchmark GMD Vulnerability Assessment results provides a means for sharing relevant information with other entities responsible for planning reliability. Results of GIC studies may affect neighboring systems and should be considered by transmission planners.

The provision of information in Requirement R4, Part 4.3, shall be subject to the legal and regulatory obligations for the disclosure of confidential and/or sensitive information.

Chapter 5 – 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 planning entity. The planning 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.

The provision of information in Requirement R5 shall be subject to the legal and regulatory obligations for the disclosure of confidential and/or sensitive information.

Chapter 6 – 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 threshold criteria and its associated transformer thermal impact must be evaluated on the basis of effective GIC. Refer to the above referenced white paper and *the Screening Criterion for Transformer Thermal Impact Assessment White Paper*, October 2017 [5], for additional information.

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 planning entity, as determined in Requirement R1, so that identified issues can be included in the GMD Vulnerability Assessment (R4) and the Corrective Action Plan (CAP; R7) as necessary.

The provision of information in Requirement R6, Part 6.4, shall be subject to the legal and regulatory obligations for the disclosure of confidential and/or sensitive information.

Chapter 7 – Requirement R7

The proposed 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 ERO with 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.

Chapter 8 – 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 for Transmission Planners to determine how to apply the supplemental GMD event to the planning area. This guide provides acceptable approaches and boundaries to apply the supplemental event.

1. Spatial extent:
    a. The local geoelectric field enhancement should not be smaller than 100 km (West-East) by 100 km (North-South).
    b. The transmission planner may perform a sensitivity analysis 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.
    c. The peak geoelectric field for the supplemental GMD event (12 V/km scaled to the planning area) can be applied 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:
    a. Amplitude: 12 V/km (scaled to the planning area).
    b. Orientation: at a minimum, a West-East[1] orientation should be considered when applying the supplemental event.
    c. The transmission planner may perform a sensitivity analysis varying the orientation of the geoelectric field.
3. Geoelectric field outside[2] the local enhancement:
    a. Amplitude: should not be smaller than 1.2 V/km (scaled to the planning area); i.e., an order of magnitude smaller than the field inside the local enhancement.
    b. Orientation: at a minimum, a West-East[3] orientation should be considered when applying the supplemental event.
    c. The transmission planner may perform a sensitivity analysis varying the orientation of the geoelectric field.
4. Position of the local enhancement:
    a. The transmission planner may use engineering judgement to position the local enhancement on critical areas of their system. For example, the benchmark vulnerability assessment may identify areas with depressed voltages, lack of dynamic reactive reserves, large GIC flows through transformers, etc. The transmission planner may also consider the impact to critical infrastructure or other externalities.
    b. The transmission planner may systematically move the position of the local enhancement throughout the entire planning area.

[1] West-East geomagnetic reference.

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

[3] West-East geomagnetic reference.

c. Despite the fact that local enhancements appear to be limited to auroral regions, geomagnetic latitude should not be used as a criterion to position the local enhancement.

The schematic in Figure 1 illustrates the boundaries to apply the supplemental GMD event. The local enhancement should not be smaller than 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 could be as low as 1.2 V/km (scaled to the planning area) with a West-East orientation.

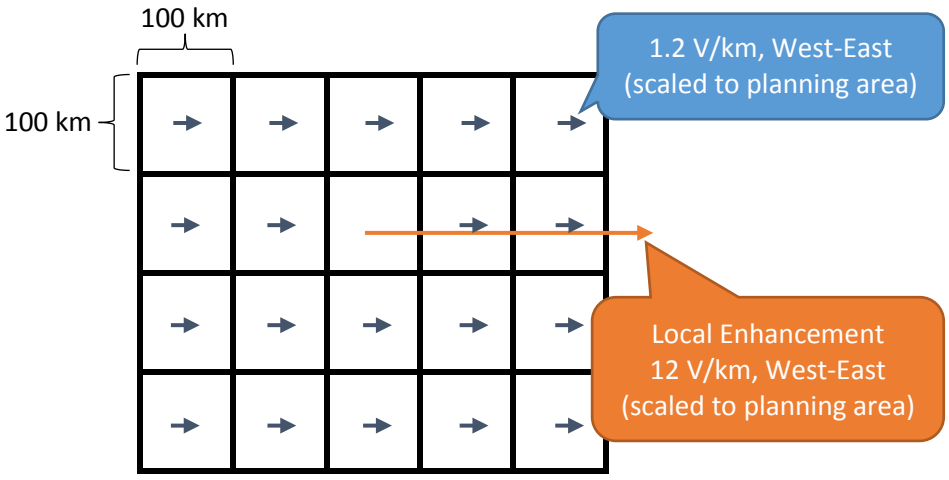


Figure 1. Schematic showing the boundaries to apply the supplemental event.

Chapter 9 – Requirement R8

Distribution of supplemental GMD Vulnerability Assessment results provides a means for sharing relevant information with other entities responsible for planning reliability. Results of GIC studies may affect neighboring systems and should be considered by transmission planners.

The provision of information in Requirement R8, Part 8.3, shall be subject to the legal and regulatory obligations for the disclosure of confidential and/or sensitive information.

Chapter 10 – 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 planning entity. The planning 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.

The provision of information in Requirement R9 shall be subject to the legal and regulatory obligations for the disclosure of confidential and/or sensitive information.

Chapter 11 – 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 threshold criteria and its associated transformer thermal impact must be evaluated on the basis of effective GIC. Refer to the above referenced white paper and the *Screening Criterion for Transformer Thermal Impact Assessment White Paper*, October 2017 [5] for additional information.

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 planning 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.

The provision of information in Requirement R10, Part 10.4, shall be subject to the legal and regulatory obligations for the disclosure of confidential and/or sensitive information.

Chapter 12 – Requirement R11

The 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 establishment of 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 ERO with 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.

Chapter 13 – Requirement R12

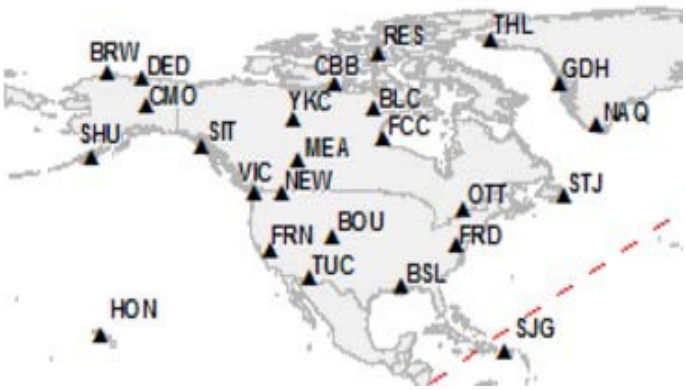
Responsible entities consider the following in developing a process for obtaining GIC monitor data:

- Monitor locations. An entity's operating process may be constrained by location of existing GIC monitors. However, when planning for additional GIC monitoring installations consider that data from monitors located in areas found to have high GIC based on system studies may provide more useful information for validation and situational awareness purposes. Conversely, data from GIC monitors that are located in the vicinity of transportation systems using direct current (for example subways or light rail) may be unreliable.
- Monitor specifications. Capabilities of Hall effect transducers, existing and planned, should be considered in the operating process. When planning new GIC monitor installations, consider monitor data range (for example -500 A through + 500 A) and ambient temperature ratings consistent with temperatures in the region in which the monitor will be installed.
- Sampling Interval. An entity's operating process may be constrained by capabilities of existing GIC monitors. However, when possible specify data sampling during periods of interest at a rate of 10 seconds or faster.
- Collection Periods. The process should specify when the entity expects GIC data to be collected. For example, collection could be required during periods where the Kp index is above a threshold, or when GIC values are above a threshold. Determining when to discontinue collecting GIC data should also be specified to maintain consistency in data collection.
- Data format. Specify time and value formats. For example, Greenwich Mean Time (GMT) (MM/DD/YYYY HH:MM:SS) and GIC Value (Ampere). Positive (+) and negative (-) signs indicate direction of GIC flow. Positive reference is flow from ground into transformer neutral. Time fields should indicate the sampled time rather than system or SCADA time if supported by the GIC monitor system.
- Data retention. The entity's process should specify data retention periods, for example one (1) year. Data retention periods should be adequately long to support availability for the entity's model validation process and external reporting requirements, if any.
- Additional information. The entity's process should specify collection of other information necessary for making the data useful, for example monitor location and type of neutral connection (for example three-phase or single-phase).

Chapter 14 – Requirement R13

Magnetometers measure changes in the earth's magnetic field. Entities should obtain data from the nearest accessible magnetometer. Sources of magnetometer data include:

- Observatories such as those operated by U.S. Geological Survey (USGS) and Natural Resources Canada (NRCan), see figure below for locations [7];



- Research institutions and academic universities; and
- Entities with installed magnetometers.

Entities that choose to install magnetometers should consider equipment specifications and data format protocols contained in the *INTERMAGNET Technical Reference Manual*, Version 4.6, 2012 [8].

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