



SPP TPL-007-4 Standard Guidance Document

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SPP Planning

Revision History

Date or Version Number	Author	Change Description	Comments
12/15/2016	TPL Task Force	Proposed draft	Proposed draft
03/02/2017	TPL Task Force	Revised draft	Draft incorporates changes reflecting comments received.
06/14/2019	TPL Task Force	Revised draft	Updated to reflect FERC approval of TPL-007-2 and TPL-007-3.
09/29/2019	TPL Task Force	Revised draft	Updated to reflect FERC approval of TPL-007-4.

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Executive Summary

This document consists of two parts. Section 1¹ annotates the requirements of the North American Electric Reliability Corporation (NERC) Transmission System Planning TPL-007-4 standard and identifies respective responsibilities between SPP, as the Planning Coordinator, and its members, as Transmission Planners, Transmission Owners, and Generator Owners. Section 2² is intended to provide guidance for these entities towards meeting their responsibilities in accordance with TPL-007-4.

¹ Section 1 requires approval by the Transmission Working Group (TWG).

² Section 2 is intended for continuous improvement and is subject to amendment as further experience is gained through the performance of the initial and subsequent GMD Vulnerability Assessments. Section 2 will be viewed as living document as SPP and its Member companies execute analysis in support of the initial GMD Vulnerability Assessment. Changes to Section 2 will require review by TPLTF and approval by the TPLTF.

Terminology

The purpose of this section is to clarify terms used in this guidance document.

Geomagnetic Disturbance (GMD): Perturbations in space weather that lead to terrestrial magnetic field interactions. When of sufficient magnitude, GMD may affect the Bulk Electric System (BES) through GIC.

Geomagnetically-Induced Current (GIC): Quasi-DC currents driven by terrestrial magnetic field changes due to GMD. GICs are quasi-DC in nature due to their low frequency (0.0001Hz to 1.0 Hz), relative to power system frequency. GICs move through transmission lines and transformer windings, along the lowest-impedance path to ground. GIC flow in transformer windings may cause half-cycle saturation of transformer cores leading to increased transformer hotspot heating, generation of harmonics, and reactive power absorption.

GIC System model: a DC-equivalent representation of the BES³ that includes all power transformers with a high side, wye-grounded winding with a terminal voltage greater than 200 kV. The GIC System model is used to calculate GIC flow on the transmission system and is based upon the traditional AC System model.

GMD Model Set: a System model-based set of steady-state models that incorporate GIC-related effects. The GMD Model Set is developed in two stages. First, the GIC System model containing GIC-related system information (such as substation grounding values, latitude/longitude, etc.) is used to determine the magnitude of GIC currents. Second, GIC currents are integrated into System models, translating GIC effects to the AC power system representations. The resultant set of System models, containing the GIC-related impacts is referred to as the GMD Model Set.

Steady-state GIC analysis: the process of determining the steady-state system impacts of GIC upon the AC power system, such as reactive power (MVAR) absorption of power transformers due to GIC. The GMD Model Set is used for steady-state GIC analysis.

System model: an AC-equivalent representation of the BES, as well as certain non-BES Elements, used to conduct steady-state load flow analysis. SPP System models are developed as part of the SPP Model Development Working Group (MDWG) model building process, in accordance with the applicable NERC Modeling, Data, and Analysis (MOD) Standards. Development of the System model is outside the scope of this guidance document.

Terminal voltage: describes line-to-line voltage.

Transmission Planning Task Force (TPLTF): the group consisting of representatives from SPP member companies and SPP staff responsible for drafting the original version of this document.

Written request, or written notification: either a certified letter or electronic letter, signed by appropriate authority at the sending entity.

³ TPL-007-4 limits the equipment necessary for modeling GIC effects. However, this document is not intended to preclude GIC-related data for non-BES equipment within the GIC System model, if submitted by an applicable entity.

Implementation Note

On 22 September 2016, the Federal Energy Regulatory Commission (FERC) issued Order 830 which approved the TPL-007-1 Standard. Before the implementation of TPL-007-1 was complete, FERC Order 851 was issued on 15 November 2018 and two revisions were made leading to TPL-007-3 and a revised implementation plan. Subsequently, FERC directed revisions to TPL-007-3 which were drafted and approved by FERC on 19 March 2020. The TPL-007-4 implementation plan builds off of the data collection, Benchmark GMD Vulnerability Assessment, and transformer Thermal Assessment originally required for TPL-007-1, as well as was updated in each approved revision. The TPL-007-4 implementation plan allows necessary time for entities to develop the required models, proper sequencing of assessments, and necessary time for development of viable Corrective Action Plans. The requirements of TPL-007-4 become effective according to the following implementation plan; requirements already enforceable are highlighted in **YELLOW** and the new requirement of TPL-007-4 is highlighted in **GREEN**:

TPL-007-4 Requirement	Enforcement Date (Compliance Date)
R1	01 July 2017 [†]
R2	01 July 2018 [†]
R3	01 January 2023
R4	01 January 2023
R5	01 January 2020 [‡]
R6	01 January 2022
R7	01 January 2024
R8	01 January 2023
R9	01 January 2020
R10	01 January 2022
R11	01 January 2024
R12*	01 July 2021
R13*	01 July 2021

[†] - The Effective Date of TPL-007-4 is 01 October 2020. Requirements from previous versions of the TPL-007 Reliability Standard that became enforceable prior to the TPL-007-4 Effective Date remain enforceable and have their Compliance Dates updated to 01 October 2020 (original Compliance Dates maintained for reference in table above).

[‡] - TPL-007-1 Requirement R5 became effective 01 January 2019. While the requirement did not change from TPL-007-1 to TPL-007-3 to TPL-007-4, the enforcement date was shifted later upon each subsequent FERC approval. The updated Compliance Date for Requirement R5 is the same as the Effective Date of TPL-007-4 (01 October 2020).

* - Due to the insertion of a new TPL-007-4 Requirement R11, the former TPL-007-3 Requirement R11 becomes TPL-007-4 Requirement R12 and the former TPL-007-3 Requirement R12 becomes TPL-007-4 Requirement R13. The Compliance Dates of TPL-007-4 Requirements R12 and R13 are unchanged from the applicable TPL-007-3 implementation plan.

This guidance document has been composed for the purpose of addressing the individual and joint responsibilities for SPP members given implementation of the TPL-007-4 standard.

Scope of Applicability

The TPL-007-4 standard is applicable to Planning Coordinators, Transmission Planners, Transmission Owners, and Generator Owners with Facilities that include power transformers with a high side, wye-grounded winding with terminal voltage greater than 200 kV. However, data necessary to construct and maintain appropriate geomagnetic-induced current (GIC) models may extend beyond Facilities specific to the applicability of TPL-007-4 part 4.2. Therefore, this guidance document defines a broader scope of entities that may be required to supply data for the purpose of facilitating the applicable entities compliance with the requirements of TPL-007-4.

Section 1: Individual and Joint Responsibilities

This section establishes the individual and joint responsibilities for maintaining models and performing the studies needed to complete benchmark and supplemental GMD Vulnerability Assessments.

R1

Requirement R1: Each Planning Coordinator, in conjunction with its Transmission Planner(s), shall identify the individual and joint responsibilities of the Planning Coordinator and Transmission Planner(s) in the Planning Coordinator's planning area for maintaining models and performing the study or studies needed to complete benchmark and supplemental GMD Vulnerability Assessment(s), and implementing process(es) to obtain GMD measurement data as specified in this standard.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Meet the requirements of R1 by adopting the responsibilities assigned to SPP, specified in parts R2 through R13 below.

Transmission Planners, within the SPP Planning Coordinator area, shall:

- Meet the requirements of R1 by adopting the responsibilities assigned to Transmission Planners, specified in parts R2 through R13 below.

Transmission Owners, within the SPP Planning Coordinator area, shall:

- Meet the requirements of R1 by adopting the responsibilities assigned to Transmission Owners, specified in parts R2 through R13 below.

Generator Owners, within the SPP Planning Coordinator area, shall:

- Meet the requirements of R1 by adopting the responsibilities assigned to Generator Owners, specified in parts R2 through R13 below.

Joint Responsibilities

None.

R2

Requirement R2: Each responsible entity, as determined in Requirement R1, shall maintain System models and GIC System models of the responsible entity's planning area for performing the study or studies needed to complete benchmark and supplemental GMD Vulnerability Assessments.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Maintain the SPP GMD Model Set.
- Request updates to data and information supporting the SPP GMD Model Set from each Transmission Owner, and Generator Owner within the SPP Planning Coordinator area annually.
- Make the SPP GMD Model Set available to all Transmission Planners, Transmission Owners, and Generator Owners within the SPP Planning Coordinator area.

Transmission Owners, within the SPP Planning Coordinator area, shall:

- Provide data and information in support of the SPP GMD Model Set, to SPP as the Planning Coordinator and to the applicable Transmission Planner.
- Provide either updated data or an explanation with a technical basis within 90 days from receipt of written notification from SPP, as Planning Coordinator, or a Transmission Planner regarding technical concerns with the data submitted by the Transmission Owner under Requirement R2.

Generator Owners, within the SPP Planning Coordinator area, shall:

- Provide data and information in support of the SPP GMD Model Set, to SPP as the Planning Coordinator and to the applicable Transmission Planner.
- Provide either updated data or an explanation with a technical basis within 90 days from receipt of written notification from SPP, as Planning Coordinator, or a Transmission Planner regarding technical concerns with the data submitted by the Generator Owner under Requirement R2.

Joint Responsibilities

SPP, as Planning Coordinator, in conjunction with Transmission Planners within its Planning Coordinator area shall:

- Review the data and information submitted by Transmission Owner(s) and Generator Owner(s) within their respective planning areas, in support of the SPP GMD Model Set.
- Submit written notification to Transmission Owner(s) and Generator Owner(s) regarding technical concerns, when applicable, with data submitted in support of the SPP GMD Model Set, including the technical basis or reasons for the technical concerns.

R3

Requirement R3: Each responsible entity, as determined in Requirement R1, shall have criteria for acceptable System steady state voltage performance for its System during the GMD events described in Attachment 1.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Have criteria for acceptable System steady-state voltage performance for its Planning Coordinator area during the benchmark and supplemental GMD events.

Transmission Planners, within the SPP Planning Coordinator area, shall:

- Adopt, as minimum criteria⁴, the SPP acceptable System steady-state voltage performance criteria during the benchmark and supplemental GMD events for the Facilities which it acts as Transmission Planner.

Joint Responsibilities

SPP, as Planning Coordinator, in conjunction with Transmission Planners within its Planning Coordinator area shall:

- Develop criteria for acceptable System steady-state voltage performance for its Planning Coordinator area during the benchmark and supplemental GMD events.

⁴ Transmission Planners may have more restrictive criteria than SPP, as Planning Coordinator.

R4

Requirement R4: Each responsible entity, as determined in Requirement R1, shall complete a benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon at least once every 60 calendar months. This benchmark GMD Vulnerability Assessment shall use a study or studies based on models identified in Requirement R2, document assumptions, and document summarized results of the steady state analysis.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Complete studies necessary for the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon.
- Ensure that studies completed for the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon include conditions representing System On-Peak Load for at least one year within the Near-Term Transmission Planning Horizon (R4.1.1) and System Off-Peak Load for at least one year within the Near-Term Transmission Planning Horizon (R4.1.2).
- Ensure that studies completed for the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon determine whether the Planning Coordinator area meets the performance requirements in TPL-007-4 Table 1 under benchmark GMD event conditions (R4.2).
- Provide study results and information necessary for the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon to the Transmission Planners within its Planning Coordinator area.
- Develop the “GMD Vulnerability Assessment Report” document, including narrative and results of the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon.
- Provide the “GMD Vulnerability Assessment Report” to the Transmission Planners within its Planning Coordinator area, as well as SPP, as Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, and to any functional entity that submits a written request and has a reliability-related need, within 90 calendar days of completion⁵ (R4.3).
- Make a documented response to recipients of the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of SPP, as Planning Coordinator, receiving the comments (R4.3.1).

⁵ SPP, as Planning Coordinator, may receive written requests for the “GMD Vulnerability Assessment Report” after 90 calendar days from the completion of the report. For all such written requests, SPP, as Planning Coordinator, will provide the most-recently completed GMD Vulnerability Assessment Report, typically congruent with the 60 calendar months specified in TPL-007-4/R4.

Transmission Planners, within the SPP Planning Coordinator area, shall:

- Review the “GMD Vulnerability Assessment Report” provided by SPP, the Planning Coordinator.
- Provide the “GMD Vulnerability Assessment Report” to the Reliability Coordinator(s), adjacent Planning Coordinator(s), or adjacent Transmission Planner(s) for the Facilities which it acts as Transmission Planner (R4.3).
- Provide the “GMD Vulnerability Assessment Report” to any functional entity⁶ that submits a written request and has a reliability-related need for information related to the Facilities for which it acts as Transmission Planner, within 90 calendar days of completion (R4.3).
- Shall make a documented response to recipients of the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of the Transmission Planner receiving the comments (R4.3.1).

Joint Responsibilities

SPP, as Planning Coordinator, and Transmission Planners, within the SPP Planning Coordinator area, shall:

- Collaboratively complete a benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon once every 60 calendar months.

⁶ TPL-007-4/R4.3 specifically refers to requests from functional entities. This is interpreted to refer to entities that are NERC-registered according to roles defined by the NERC Functional Model.

R5

Requirement R5: Each responsible entity, as determined in Requirement R1, shall provide GIC flow information to be used for the benchmark transformer thermal impact assessment specified in Requirement R6 to each Transmission Owner and Generator Owner that owns an applicable Bulk Electric System (BES) power transformer in the planning area.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Provide GIC flow information, as the maximum effective GIC value for the worst case geoelectric field orientation given the benchmark GMD event, to be used for the transformer thermal impact assessment to each Transmission Owner and Generator Owner that owns an applicable BES power transformer within the SPP Planning Coordinator area (R5.1), upon completion of the studies necessary for the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon, within the 60-month periodicity.
- Provide GIC flow information, as the effective GIC time series [GIC(t)] given the benchmark GMD event, within 90 calendar days of a written request by a Transmission Owner or Generator Owner that owns an applicable BES power transformer within the SPP Planning Coordinator area (R5.2), upon completion of the studies necessary for the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon, within the 60-month periodicity.
- Provide GIC flow information, given to Transmission Owners and Generator Owners within the SPP Planning Coordinator area for BES transformers, to the applicable Transmission Planner.

Joint Responsibilities⁷

None.

⁷ During development of scope documentation for the benchmark GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon, SPP, as Planning Coordinator, and Transmission Planners within the SPP Planning Coordinator area, may collaboratively determine that the NERC-provided GIC time series data is insufficient for performance of transformer thermal impact assessments, based upon actual measured data available from GIC-related sensors within the Planning Coordinator area. It is expected that SPP, as Planning Coordinator, and Transmission Planners within the SPP Planning Coordinator area, may collaboratively develop GIC time series data from measured GIC data obtained within the SPP Planning Coordinator area to replace the NERC-provided GIC time series data, when determined insufficient and justified in the benchmark GMD Vulnerability Assessment study scope.

R6

Requirement R6: Each Transmission Owner and Generator Owner shall conduct a benchmark thermal impact assessment for its solely and jointly owned applicable BES power transformers where the maximum effective GIC value provided in Requirement R5, Part 5.1, is 75 A per phase or greater.

Individual Responsibilities

Each Transmission Owner within the SPP Planning Coordinator area, shall:

- Conduct a benchmark thermal impact assessment for its solely and jointly owned applicable BES power transformers where the maximum effective GIC value is 75 A per phase or greater.
- Document the benchmark thermal impact assessments for its solely and jointly owned applicable BES power transformers in a “Transformer Thermal Impact Assessment Report”.
- Ensure that the analysis conducted in support of benchmark thermal impact assessments for its solely and jointly owned applicable BES power transformers is based upon the effective GIC value provided by SPP, as Planning Coordinator (R6.1).
- Ensure that the assumptions used in the analysis conducted in support of the benchmark thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R6.2).
- Ensure that suggested actions and the analysis supporting the mitigation of GIC impacts identified in the benchmark thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R6.3).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area to SPP, as Planning Coordinator, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R6.4).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area, to the accountable Transmission Planner, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R6.4).

Each Generator Owner within the SPP Planning Coordinator area, shall:

- Conduct a benchmark thermal impact assessment for its solely and jointly owned applicable BES power transformers where the maximum effective GIC value is 75 A per phase or greater.
- Document the benchmark thermal impact assessments for its solely and jointly owned applicable BES power transformers in a “Transformer Thermal Impact Assessment Report”.

- Ensure that the analysis conducted in support of benchmark thermal impact assessments for its solely and jointly owned applicable BES power transformers is based upon the effective GIC value provided by SPP, as Planning Coordinator (R6.1).
- Ensure that the assumptions used in the analysis conducted in support of the benchmark thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R6.2).
- Ensure that suggested actions and the analysis supporting the mitigation of GIC impacts identified in the benchmark thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R6.3).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area to SPP, as Planning Coordinator, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R6.4).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area, to the accountable Transmission Planner, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R6.4).

Joint Responsibilities

None.

R7

Requirement R7: Each responsible entity, as determined in Requirement R1, that concludes, through the benchmark GMD Vulnerability Assessment conducted in Requirement R4, that their System does not meet the performance requirements for the steady state planning benchmark GMD event contained in Table 1, shall develop a Corrective Action Plan (CAP) addressing how the performance requirements will be met.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- List System deficiencies identified as part of the benchmark GMD Vulnerability Assessment in the “GMD Vulnerability Assessment Report” (7.1).
- Ensure that collaboratively developed CAP(s) identified as part of the benchmark GMD Vulnerability Assessment are documented in the “GMD Vulnerability Assessment Report”.
- Include a timetable for implementing the selected actions of the CAP(s) (7.3).
- Specify that non-hardware mitigations, if any, shall be implemented within two years of development of the CAP(s) (7.3.1).
- Specify that hardware mitigations, if any, shall be implemented within four years of development of the CAP(s) (7.3.2).
- Provide the CAP(s) annotated in the “GMD Vulnerability Assessment Report” to SPP Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, functional entities referenced in the CAP(s), and to any functional entity that submits a written request and has a reliability-related need, within 90 calendar days of completion (R7.5). These entities will have 90 calendar days to review and submit their feedback on the “GMD Vulnerability Assessment Report” to SPP Planning Coordinator.
- Notify the Reliability Coordinator, adjacent Planning Coordinator(s), adjacent Transmission Planner(s), and functional entities referenced in the CAP within 90 calendar days of the development of new, or revisions to, CAP(s).
- At the end of the 90-day review period, make a documented response to recipients of CAP(s) annotated in the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of SPP, as Planning Coordinator (R7.5.1).

Transmission Planners, within the SPP Planning Coordinator area, shall:

- Provide the CAP(s) annotated in the “GMD Vulnerability Assessment Report” to the Reliability Coordinator(s), adjacent Planning Coordinator(s), or adjacent Transmission Planner(s) for the Facilities which it acts as Transmission Planner (R7.5).

- Provide the CAP(s) annotated in the “GMD Vulnerability Assessment Report” to any functional entity that submits a written request and has a reliability-related need for information related to Facilities which it acts as Transmission Planner, within 90 calendar days of completion (R7.5.1).
- Make a documented response to recipients of the CAP(s) annotated in the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of the Transmission Planner receiving the comments (R7.5.1).

Each Transmission Owner and Generator Owner within the SPP Planning Coordinator area, shall:

- Notify SPP, as Planning Coordinator, and the Transmission Planner of pertinent⁸ Facilities for which it acts as Transmission Planner upon completion of the CAP(s) implementation.
- Notify SPP, as Planning Coordinator, and the Transmission Planner of pertinent Facilities for which it acts as Transmission Planner of any delays that may compromise completion of the CAP(s) within its documented timetable.
- When unable to implement the CAP within its documented timetable, develop a revised CAP with a request for a time extension suitable for submission to the Compliance Enforcement Authority (7.4). The extension request shall include revisions to CAPs that document: the circumstances causing the delay in implementing the selected actions (7.4.1), how those circumstances are beyond the control of the responsible entity (7.4.1), necessary revisions to the selected actions, if any, including utilization of Operating Procedures (7.4.2), and an updated timetable for implementing the selected actions (7.4.3).
- If a request for a time extension is necessary for a CAP unable to be implemented within its documented timetable, provide the revised CAP with the request for a time extension suitable for submission to the Compliance Enforcement Authority to SPP, as Planning Coordinator, and to the Transmission Planner of pertinent Facilities for which it acts as Transmission Planner.

Joint Responsibilities

SPP, as Planning Coordinator, and Transmission Planners, within the SPP Planning Coordinator area, in conjunction with affected Transmission Owners and Generator Owners, shall:

- Collaboratively develop a CAP(s) to address deficiencies indicated in the benchmark GMD Vulnerability Assessment by the inability to meet performance requirements.
- Collaboratively determine and document in the “GMD Vulnerability Assessment Report” which entity is responsible for implementing the CAP(s). In most cases, the entity responsible for implementing the CAP(s) is that entity which owns the equipment identified as deficient

⁸ All usage of “Transmission Planner of pertinent Facilities for which it acts as Transmission Planner” in this document is intended to specify that only the Transmission Planner of Facilities for which it acts as Transmission Planner are pertinent Facilities.

or unable to meet performance requirements, indicated by the benchmark GMD Vulnerability Assessment.

- Ensure that the collaboratively developed CAP(s) list actions required to achieve performance requirements (R7.1).
- Ensure that CAP(s) identified as necessary to address the inability to meet performance requirements in prior “GMD Vulnerability Assessment Report” documents are reviewed as part of the benchmark GMD Vulnerability Assessment.
- Develop a timetable for implementing CAPs (7.3).
- When notified by a Transmission Owner or Generator Owner that a CAP(s) is unable to be implemented within its documented timetable, SPP, as Planning Coordinator, and the Transmission Planner of pertinent Facilities for which it acts as Transmission Planner, shall collaboratively develop, in conjunction with the Transmission Owner or Generator Owner with the CAP, the revised CAP. The revised CAP document shall include revisions to CAPs that document: the circumstances causing the delay in implementing the selected actions (7.4.1), how those circumstances are beyond the control of the responsible entity (7.4.1), necessary revisions to the selected actions, if any, including utilization of Operating Procedures (7.4.2), and an updated timetable for implementing the selected actions (7.4.3).
- Collaboratively develop a response to comments received from SPP Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, functional entities referenced in the CAP(s), and to any functional entity that submits a written request and has a reliability-related need about the “GMD Vulnerability Assessment Report”.

R8

Requirement R8: Each responsible entity, as determined in Requirement R1, shall complete a supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon at least once every 60 calendar months. This supplemental GMD Vulnerability Assessment shall use a study or studies based on models identified in Requirement R2, document assumptions, and document summarized results of the steady state analysis.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Complete studies necessary for the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon.
- Ensure that studies completed for the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon include conditions representing System On-Peak Load for at least one year within the Near-Term Transmission Planning Horizon (R8.1.1) and System Off-Peak Load for at least one year within the Near-Term Transmission Planning Horizon (R8.1.2).
- Ensure that studies completed for the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon determine whether the Planning Coordinator area meets the performance requirements in TPL-007-4 Table 1 under supplemental GMD event conditions (R8.2).
- Provide study results and information necessary for the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon to the Transmission Planners within its Planning Coordinator area.
- Develop the “GMD Vulnerability Assessment Report” document, including narrative and results of the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon.
- Provide the “GMD Vulnerability Assessment Report” to the Transmission Planners within its Planning Coordinator area, as well as SPP, as Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, and to any functional entity that submits a written request and has a reliability-related need, within 90 calendar days of completion⁹ (R8.3).
- Make a documented response to recipients of the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of SPP, as Planning Coordinator, receiving the comments (R8.3.1).

⁹ SPP, as Planning Coordinator, may receive written requests for the “GMD Vulnerability Assessment Report” after 90 calendar days from the completion of the report. For all such written requests, SPP, as Planning Coordinator, will provide the most-recently completed “GMD Vulnerability Assessment Report”, typically congruent with the 60 calendar months specified in TPL-007-4/R4.

Transmission Planners, within the SPP Planning Coordinator area, shall:

- Review the “GMD Vulnerability Assessment Report” provided by SPP, the Planning Coordinator.
- Provide the “GMD Vulnerability Assessment Report” to the Reliability Coordinator(s), adjacent Planning Coordinator(s), or adjacent Transmission Planner(s) for the Facilities which it acts as Transmission Planner (R8.3).
- Provide the “GMD Vulnerability Assessment Report” to any functional entity¹⁰ that submits a written request and has a reliability-related need for information related to the Facilities for which it acts as Transmission Planner, within 90 calendar days of completion (R8.3).
- Shall make a documented response to recipients of the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of the Transmission Planner receiving the comments (R8.3.1).

Joint Responsibilities

SPP, as Planning Coordinator, and Transmission Planners, within the SPP Planning Coordinator area, shall:

- Collaboratively complete a supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon once every 60 calendar months.

¹⁰ TPL-007-4/R8.3 specifically refers to requests from functional entities. This is interpreted to refer to entities that are NERC-registered according to roles defined by the NERC Functional Model.

R9

Requirement R9: Each responsible entity, as determined in Requirement R1, shall provide GIC flow information to be used for the supplemental transformer thermal impact assessment of transformers specified in Requirement R10 to each Transmission Owner and Generator Owner that owns an applicable Bulk Electric System (BES) power transformer in the planning area.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Provide GIC flow information, as the maximum effective GIC value for the worst case geoelectric field orientation given the supplemental GMD event, to be used for the transformer thermal impact assessment to each Transmission Owner and Generator Owner that owns an applicable BES power transformer within the SPP Planning Coordinator area (R9.1), upon completion of the studies necessary for the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon, within the 60-month periodicity.
- Provide GIC flow information, as the effective GIC time series [GIC(t)] given the supplemental GMD event, within 90 calendar days of a written request by a Transmission Owner or Generator Owner that owns an applicable BES power transformer within the SPP Planning Coordinator area (R9.2), upon completion of the studies necessary for the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon, within the 60-month periodicity.
- Provide GIC flow information, given to Transmission Owners and Generator Owners within the SPP Planning Coordinator area for BES transformers, to the applicable Transmission Planner.

Joint Responsibilities¹¹

None.

¹¹ During development of scope documentation for the supplemental GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon, SPP, as Planning Coordinator, and Transmission Planners within the SPP Planning Coordinator area, may collaboratively determine that the NERC-provided GIC time series data is insufficient for performance of transformer thermal impact assessments, based upon actual measured data available from GIC-related sensors within the Planning Coordinator area. It is expected that SPP, as Planning Coordinator, and Transmission Planners within the SPP Planning Coordinator area, may collaboratively develop GIC time series data from measured GIC data obtained within the SPP Planning Coordinator area to replace the NERC-provided GIC time series data, when determined insufficient and justified in the supplemental GMD Vulnerability Assessment study scope.

R10

Requirement R10: Each Transmission Owner and Generator Owner shall conduct a supplemental thermal impact assessment for its solely and jointly owned applicable BES power transformers where the maximum effective GIC value provided in Requirement R9, Part 9.1, is 85 A per phase or greater.

Individual Responsibilities

Each Transmission Owner within the SPP Planning Coordinator area, shall:

- Conduct a supplemental thermal impact assessment for its solely and jointly owned applicable BES power transformers where the maximum effective GIC value is 85 A per phase or greater.
- Document the supplemental thermal impact assessments for its solely and jointly owned applicable BES power transformers in a “Transformer Thermal Impact Assessment Report”.
- Ensure that the analysis conducted in support of supplemental thermal impact assessments for its solely and jointly owned applicable BES power transformers is based upon the effective GIC value provided by SPP, as Planning Coordinator (R10.1).
- Ensure that the assumptions used in the analysis conducted in support of the supplemental thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R10.2).
- Ensure that suggested actions and the analysis supporting the mitigation of GIC impacts identified in the supplemental thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R10.3).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area to SPP, as Planning Coordinator, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R10.4).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area, to the accountable Transmission Planner, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R10.4).

Each Generator Owner within the SPP Planning Coordinator area, shall:

- Conduct a supplemental thermal impact assessment for its solely and jointly owned applicable BES power transformers where the maximum effective GIC value is 85 A per phase or greater.
- Document the supplemental thermal impact assessments for its solely and jointly owned applicable BES power transformers in a “Transformer Thermal Impact Assessment Report”.

- Ensure that the analysis conducted in support of supplemental thermal impact assessments for its solely and jointly owned applicable BES power transformers is based upon the effective GIC value provided by SPP, as Planning Coordinator (R10.1).
- Ensure that the assumptions used in the analysis conducted in support of the supplemental thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R10.2).
- Ensure that suggested actions and the analysis supporting the mitigation of GIC impacts identified in the supplemental thermal impact assessment for its solely and jointly owned applicable BES power transformers are documented in the “Transformer Thermal Impact Assessment Report” (R10.3).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area to SPP, as Planning Coordinator, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R10.4).
- Provide its “Transformer Thermal Impact Assessment Report” for all applicable solely and jointly-owned BES power transformers within the SPP Planning Coordinator area, to the accountable Transmission Planner, within 24 calendar months of receiving GIC flow information from SPP, as Planning Coordinator (R10.4).

Joint Responsibilities

None.

R11

Requirement R11: Each responsible entity, as determined in Requirement R1, that concludes through the supplemental GMD Vulnerability Assessment conducted in Requirement R8 that their System does not meet the performance requirements for the steady state planning supplemental GMD event contained in Table 1, shall develop a Corrective Action Plan (CAP) addressing how the performance requirements will be met.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- List System deficiencies identified as part of the supplemental GMD Vulnerability Assessment in the “GMD Vulnerability Assessment Report” (11.1).
- Ensure that collaboratively developed CAP(s) identified as part of the supplemental GMD Vulnerability Assessment are documented in the “GMD Vulnerability Assessment Report”.
- Include a timetable for implementing the selected actions of the CAP(s) (11.3).
- Specify that non-hardware mitigations, if any, shall be implemented within two years of development of the CAP(s) (11.3.1).
- Specify that hardware mitigations, if any, shall be implemented within four years of development of the CAP(s) (11.3.2).
- Provide the CAP(s) annotated in the “GMD Vulnerability Assessment Report” to SPP Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, functional entities referenced in the CAP(s), and to any functional entity that submits a written request and has a reliability-related need, within 90 calendar days of completion (R11.5). These entities will have 90 calendar days to review and submit their feedback on the “GMD Vulnerability Assessment Report” to SPP Planning Coordinator.
- Notify the Reliability Coordinator, adjacent Planning Coordinator(s), adjacent Transmission Planner(s), and functional entities referenced in the CAP within 90 calendar days of the development of new, or revisions to, CAP(s).
- At the end of the 90-day review period, make a documented response to recipients of CAP(s) annotated in the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of SPP, as Planning Coordinator (R11.5.1).

Transmission Planners, within the SPP Planning Coordinator area, shall:

- Provide the CAP(s) annotated in the “GMD Vulnerability Assessment Report” to the Reliability Coordinator(s), adjacent Planning Coordinator(s), or adjacent Transmission Planner(s) for the Facilities which it acts as Transmission Planner (R11.5).

- Provide the CAP(s) annotated in the “GMD Vulnerability Assessment Report” to any functional entity that submits a written request and has a reliability-related need for information related to Facilities which it acts as Transmission Planner, within 90 calendar days of completion (R11.5.1).
- Make a documented response to recipients of the CAP(s) annotated in the “GMD Vulnerability Assessment Report” who provide documented comments on the results, within 90 calendar days of the Transmission Planner receiving the comments (R11.5.1).

Each Transmission Owner and Generator Owner within the SPP Planning Coordinator area, shall:

- Notify SPP, as Planning Coordinator, and the Transmission Planner of pertinent Facilities for which it acts as Transmission Planner upon completion of the CAP(s) implementation.
- Notify SPP, as Planning Coordinator, and the Transmission Planner of pertinent Facilities for which it acts as Transmission Planner of any delays that may compromise completion of the CAP(s) within its documented timetable.
- When unable to implement the CAP within its documented timetable, develop a revised CAP with a request for a time extension suitable for submission to the Compliance Enforcement Authority (11.4). The extension request shall include revisions to CAPs that document: the circumstances causing the delay in implementing the selected actions (11.4.1), how those circumstances are beyond the control of the responsible entity (11.4.1), necessary revisions to the selected actions, if any, including utilization of Operating Procedures (11.4.2), and an updated timetable for implementing the selected actions (11.4.3).
- If a request for a time extension is necessary for a CAP unable to be implemented within its documented timetable, provide the revised CAP with the request for a time extension suitable for submission to the Compliance Enforcement Authority to SPP, as Planning Coordinator, and to the Transmission Planner of pertinent Facilities for which it acts as Transmission Planner.

Joint Responsibilities

SPP, as Planning Coordinator, and Transmission Planners, within the SPP Planning Coordinator area, in conjunction with affected Transmission Owners and Generator Owners, shall:

- Collaboratively develop a CAP(s) to address deficiencies indicated in the supplemental GMD Vulnerability Assessment by the inability to meet performance requirements.
- Collaboratively determine and document in the “GMD Vulnerability Assessment Report” which entity is responsible for implementing the CAP(s). In most cases, the entity responsible for implementing the CAP(s) is that entity which owns the equipment identified as deficient or unable to meet performance requirements, indicated by the supplemental GMD Vulnerability Assessment.
- Ensure that the collaboratively developed CAP(s) list actions required to achieve performance requirements (R11.1).

- Ensure that CAP(s) identified as necessary to address the inability to meet performance requirements in prior “GMD Vulnerability Assessment Report” documents are reviewed as part of the supplemental GMD Vulnerability Assessment.
- Develop a timetable for implementing CAPs (11.3).
- When notified by a Transmission Owner or Generator Owner that a CAP(s) is unable to be implemented within its documented timetable, SPP, as Planning Coordinator, and the Transmission Planner of pertinent Facilities for which it acts as Transmission Planner, shall collaboratively develop, in conjunction with the Transmission Owner or Generator Owner with the CAP, the revised CAP. The revised CAP document shall include revisions to CAPs that document: the circumstances causing the delay in implementing the selected actions (11.4.1), how those circumstances are beyond the control of the responsible entity (11.4.1), necessary revisions to the selected actions, if any, including utilization of Operating Procedures (11.4.2), and an updated timetable for implementing the selected actions (11.4.3).
- Collaboratively develop a response to comments received from SPP Reliability Coordinator, adjacent Planning Coordinators, adjacent Transmission Planners, functional entities referenced in the CAP(s), and to any functional entity that submits a written request and has a reliability-related need about the “GMD Vulnerability Assessment Report”.

R12

Requirement R12: Each responsible entity, as determined in Requirement R1, shall implement a process to obtain GIC monitor data from at least one GIC monitor located in the Planning Coordinator's planning area or other part of the system included in the Planning Coordinator's GIC System model.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Implement a process to obtain GIC monitor data from locations within the SPP Planning Coordinator planning area.
- At least once annually, make a GIC monitor data set available to Transmission Planners, Transmission Owners, and Generator Operators within the SPP Planning Coordinator planning area.

Joint Responsibilities

None.

R13

Requirement R13: Each responsible entity, as determined in Requirement R1, shall implement a process to obtain geomagnetic field data for its Planning Coordinator's planning area.

Individual Responsibilities

SPP, as Planning Coordinator, shall:

- Implement a process to obtain geomagnetic field data for its Planning Coordinator planning area. At a minimum, the process shall obtain geomagnetic field data from the United States Geological Survey's Boulder Magnetic Observatory¹².
- At least once annually, make an updated geomagnetic field data set available to applicable TPL-007-4 Transmission Planners, Transmission Owners, and Generator Operators within the SPP Planning Coordinator area.

Joint Responsibilities

None.

¹² The geographic latitude and longitude of the United States Geological Survey's Boulder Magnetic Observatory is 40.1375°N, 105.2372°W. The approximate geographic latitude and longitude extents of the SPP Planning Coordinator planning area are: 31.5°N to 49.0°N and 89.0°W to 108.5°W, respectively. Between 01 Jan 2015 and 01 Jan 2019, the average magnetic field total intensity at the Boulder Observatory was 52299.4 nT (standard deviation of 135.5 nT). When compared to the estimated average magnetic field total intensity over the entire spatial extents of the SPP Planning Coordinator planning area during the same four-year period (52432.2 nT with SD of 2666.1 nT), it indicates that the Boulder Observatory is a satisfactory source of geomagnetic field data for the SPP Planning Coordinator's planning area, as well as supports the well-known observation that geomagnetic field at the earth's surface does not vary greatly over relatively short terrestrial-scale distances. Source data and calculations were obtained from the United States National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) using the World Magnetic Model (WMM), jointly-developed by the United States National Geospatial-Intelligence Agency (NGA) and the United Kingdom Defense Geographic Centre (DGC).

Section 2: Standard Application Guidance

THIS SECTION IS INTENDED FOR CONTINUOUS IMPROVEMENT AND IS SUBJECT TO AMENDMENT AS FURTHER EXPERIENCE IS GAINED THROUGH THE PERFORMANCE OF THE INITIAL AND SUBSEQUENT GMD VULNERABILITY ASSESSMENTS.

This section is intended to give guidance on the individual and joint responsibilities annotated in the previous section. The guidance provided in this section complements the responsibilities in accordance with TPL-007-4 and lays out how each functional entity works together towards the successful completion and reporting of benchmark and supplemental GMD Vulnerability Assessments. It is noted that, although the requirements of TPL-007-4 are fixed, the guidance provided in this section is intended to adapt over time. As the knowledge and experience gained by the applicable entities increases, it is intended that this guidance section will likewise be updated and improved. The TPLTF, or group delegated by TWG, is responsible for updating and approving changes to Section 2. The TPLTF, or group delegated by TWG, will review Section 2 periodically, but no less frequently than every 60 months, consistent with the periodicity of benchmark and supplemental GMD Vulnerability Assessments.

R1

The purpose of the “Section 1: Individual and Joint Responsibilities” section of this document is to establish the individual and joint responsibilities for maintaining models and performing the studies needed to complete benchmark and supplemental GMD Vulnerability Assessments. SPP, as Planning Coordinator, in conjunction with SPP member Transmission Planners, meet the requirements of R1 through mutual adoption of this guidance document. Responsibilities for Transmission Owners and Generator Owners integral to the GIC/GMD data collection and study process, likewise, are specified in this guidance document.

R2

SPP, as Planning Coordinator, will maintain the SPP GMD Model Set containing all appropriate TPL-007-4 Requirement R2 GIC System model and System model data used as part of both the benchmark and supplemental GMD Vulnerability Assessment¹³. The SPP GMD Model Set will contain the GIC System model, a DC-equivalent representation of the BES that includes all power transformers with a high side, wye-grounded winding with a terminal voltage greater than 200 kV¹⁴, integrated into System models in Siemens/PTI PSS/E 34.5 (or later version) format for the SPP Planning Coordinator area. SPP as Planning Coordinator will request GIC System model updates from each Transmission Planner, Transmission Owner, and Generator Owner within the SPP Planning Coordinator area. System model

¹³ TPL-007-4 Requirement R2 specifies two model representations, the System model and the GIC System model. For clarity, a distinction is made between the GIC System model and System model in this guidance document. However, it is typical industry practice to maintain the two model schemas together, as part of the same software-based representation.

¹⁴ Discrete modeling of GIC effects on the power system may rely upon equipment information below the 200kV voltage threshold. SPP, as Planning Coordinator, and Transmission Planners may request data below 200kV, on a case-by-case basis.

updates are performed under the existing SPP MDWG model building process¹⁵ in accordance with the applicable NERC Modeling, Data, and Analysis (MOD) Standards, and are outside the scope of this guidance document. SPP, as Planning Coordinator, meets the requirements of R2 by maintaining a set of two SPP GMD Model Set cases, representing system topology for Year One and Year Five summer peak¹⁶ load from the annual SPP Model Development Working Group (MDWG) approved model series. The rationale for the use of summer peak cases is to ensure that more restrictive ambient temperature Facility Ratings, for entities that use seasonal Facility Ratings, are incorporated into models used for GMD Vulnerability Assessments. Clearly, the objective is to select cases that will produce the most severe thermal and voltage conditions under benchmark and supplemental GMD event conditions. It will be an on-going effort to ensure that the most appropriate cases are part of the GMD Model Set.

SPP, as Planning Coordinator, will make the SPP GMD Model Set available to all TPL-007-4 applicable Transmission Planners, Transmission Owners, and Generator Owners within the SPP Planning Coordinator area.

Each Transmission Planner within the SPP Planning Coordinator area meets the requirements of R2 by maintaining its respective planning area in the SPP GMD Model Set. Participation in periodic SPP requests for GIC Model data does not preclude the Transmission Planner from maintaining its own planning area System models and GIC System models, nor does this require the Transmission Planner to use the SPP GMD Model Set to perform studies needed to complete its benchmark and supplemental GMD Vulnerability Assessment. However, by submitting the appropriate GIC data to SPP, as the Planning Coordinator, and participating in the maintenance of the SPP GMD Model Set, the Transmission Planner meets the requirements of R2 for its planning area.

Transmission Owners and Generator Owners do not typically have planning areas unless they are registered as a planning entity (e.g., Transmission Planner). However, the participation of each Transmission Owner and Generator Owner within the SPP Planning Coordinator area is critical for ensuring that the GIC Model data for their respective equipment is properly maintained in the SPP GMD Model Set. Each Transmission Owner and Generator Owner within the SPP Planning Coordinator area will submit the appropriate GIC data to SPP as the Planning Coordinator and to their respective Transmission Planner, if applicable, in support of the periodic SPP GMD Model Set data request. Data submitted by Transmission Owners and Generator Owners will adhere to the GMD/GIC data request specified by the SPP Planning Coordinator and MDWG, as well be compatible with PSS/E software.

R3

SPP, as Planning Coordinator, will meet the requirements of R3 by establishing criteria for acceptable System steady-state voltage performance within its Planning Coordinator area during the benchmark and supplemental GMD event described in Attachment 1. These criteria will be developed in

¹⁵ Coordination with the MDWG is necessary to incorporate data collection requirements into existing model development processes, as well the SPP MDWG Procedure Manual.

¹⁶ Additional cases, such as a shoulder load case, may be of value for benchmark or supplemental GMD event simulation and analysis, given that the topology is typically identical to peak cases with differing load profiles. The determination of what cases, in addition to the required peak cases, may have value for assessing system effects given a benchmark or supplemental GMD event will be an on-going process.

conjunction with Transmission Planners within the SPP Planning Coordinator area. SPP, as Planning Coordinator, will ensure that all Facilities within its Planning Coordinator area have System steady-state voltage performance criteria.

Each Transmission Planner within the SPP Planning Coordinator area will meet the requirements of R3 by adopting the criteria for acceptable System steady-state voltage performance established by the Planning Coordinator. Further, each Transmission Planner will participate in the development of the System steady-state voltage performance criteria, in conjunction with SPP, as Planning Coordinator.

It is well-accepted by industry that transmission equipment loaded above continuous ampacity ratings for extended periods will cause life reduction, regardless if the increased loading is caused by a GMD event or otherwise. Similarly, system equipment will suffer increased stress, possible misoperation, and potential life reduction when transmission voltages deviate outside of continuous equipment voltage ratings. The individual responsibility of Transmission Planners, in accordance with R3, to “adopt” SPP steady-state voltage performance criteria at a minimum is intended to emphasize that existing criteria should not be relaxed simply for benchmark or supplemental GMD event analysis. If, through the process of study and analysis, a technical basis for modifying steady-state voltage performance criteria for GMD events is identified, changes should be proposed through the standardized SPP criteria change process. Given that the SPP footprint extends from latitudes 32° to 49° North, the effects of GMD events will vary significantly across the SPP Planning Coordinator area. While each applicable entity may have unique needs based upon the GIC effects induced by local geography, geology, and system topologies, the importance of maintaining sufficient steady-state voltage performance criteria is paramount.

SPP, as Planning Coordinator, and Transmission Planners within the Planning Coordinator area will review the established GMD steady-state voltage criteria annually as part of the SPP GMD Model Set data request.

R4 and R8

SPP, as Planning Coordinator, and the Transmission Planners meet the requirements of R4 and R8 by collaboratively completing periodic benchmark and supplemental GMD Vulnerability Assessments. The SPP, as Planning Coordinator, will coordinate and perform the studies necessary for both the benchmark and supplemental GMD Vulnerability Assessment. The Transmission Planners within the SPP Planning Coordinator area will participate in and review the studies necessary for the benchmark and supplemental GMD Vulnerability Assessment. The narrative and the results of the benchmark and supplemental GMD Vulnerability Assessment will be compiled into a “GMD Vulnerability Assessment Report” by SPP, as Planning Coordinator, in collaboration with the Transmission Planners.

The GMD analysis module for Siemens/PTI PSS/E software (versions 34.5 or later) will be used by SPP, as Planning Coordinator, to perform necessary simulations in support the benchmark and supplemental GMD Vulnerability Assessment. Data submitted by all applicable entities will adhere to the GMD/GIC data requests specified by the SPP Planning Coordinator and MDWG, as well and be compatible with PSS/E software.

R5 and R9

The GIC flow information to be used for the transformer thermal impact assessment specified in Requirements R5 and R9 will be derived from the SPP GMD Model Set. SPP, as Planning Coordinator, and the Transmission Planners meet the requirements of R5 and R9 by providing GIC flow information, based upon load flow results obtained from analysis performed using the SPP GMD Model Set, to each Transmission Owner and Generator Owner that owns an applicable BES power transformer in the SPP Planning Coordinator area.

SPP, as Planning Coordinator, and the Transmission Planners meet the requirements of R5.1 by simulating the worst-case geoelectric field orientation for both the benchmark and supplemental GMD event described in Attachment 1 of TPL-007-4 during study utilizing the SPP GMD Model Set. SPP, as Planning Coordinator, provides the derived maximum effective GIC value flow information, based upon load flow results from the SPP GMD Model Set, to the Transmission Owner or Generator Owner that owns each applicable BES power transformer in the planning area. As the data derived from the SPP GMD Model Set is shared between SPP, as Planning Coordinator, and the Transmission Planners, all GIC flow information that must be provided to Transmission Owners and Generator Owners in accordance with R5.1 and R9.1 will be transmitted by SPP, as Planning Coordinator, copying the applicable Transmission Planner. This assures that GIC flow information is communicated efficiently and consistently, while allowing SPP, as Planning Coordinator, and the Transmission Planners to meet the obligations of R5.1 and R9.1.

As the Planning Coordinator, SPP must be responsive to requests for GIC flow data to be used for the purpose of transformer thermal impact assessment. In accordance with R5.2 and R9.2, when SPP, as Planning Coordinator, receives a written request for effective GIC flow information or time series data for an applicable BES power transformer in the SPP Planning Coordinator area, SPP will respond to the request within 90 calendar days of the inquiry. The GIC time series is calculated from the SPP GMD Model Set, reflecting simulated benchmark or supplemental GMD event conditions, described in Attachment 1 of TPL-007-4. As the data derived from the SPP GMD Model Set is shared between SPP, as Planning Coordinator, and the Transmission Planners, all GIC flow information that must be provided to Transmission Owners and Generator Owners in accordance with R5.2 and R9.2 will be transmitted by SPP, as Planning Coordinator, copying the applicable Transmission Planner. This assures that effective GIC time series information is communicated efficiently and consistently, while allowing SPP, as Planning Coordinator, and the Transmission Planners to meet the obligations of R5.2 and R9.2.

GIC time series information is presently available from NERC. The NERC dataset provides scaled geoelectric field data based upon calculations made from data measured at the Ottawa Magnetic Observatory on March 13-14, 1989. This legacy data may be insufficient for analysis within the SPP Planning Coordinator area. It is likely that as monitoring of GMD magnitudes, GIC currents, and other GIC-related telemetry increases, that better GIC time series information may be developed, better suited to the SPP Planning Coordinator area. As better data becomes available SPP, as Planning Coordinator, and the Transmission Planners within the Planning Coordinator area may determine GIC time series data sets that are more appropriate to support transformer thermal impact assessments.

R6 and R10

Each Transmission Owner and Generator Owner that owns an applicable BES power transformer in the SPP Planning Coordinator area meets the requirements of R6 by conducting a thermal impact assessment for its solely and jointly owned transformers where the maximum effective GIC value for the benchmark GMD event is 75 A per phase or greater.

Each Transmission Owner and Generator Owner that owns an applicable BES power transformer in the SPP Planning Coordinator area meets the requirements of R10 by conducting a thermal impact assessment for its solely and jointly owned transformers where the maximum effective GIC value for the supplemental GMD event is 85 A per phase or greater.

During simulations of the SPP Planning Coordinator planning area supporting Requirements R5 and R9, each applicable transformer has a unique maximum effective GIC value calculated based upon a geoelectric field magnitude determined from:

- a reference peak geoelectric field amplitude of either 8 V/km (benchmark) or 12 V/km (supplemental);
- scaled to account for the local geomagnetic latitude of the particular transformer;
- scaled to account for local earth conductivity (based on the earth model) for the particular transformer; and,
- at the worst case geoelectric field orientation for the particular transformer.

The maximum effective GIC values are important quantities used for selecting transformers that meet the thermal impact assessment thresholds of Requirement R6 and R10. However, it is critical to observe that the approximate geographic latitude and longitude extents of the SPP Planning Coordinator planning area (31.5°N to 49.0°N and 89.0°W to 108.5°W) yield geomagnetic latitude extents of approximately 38.5°N to 58.5°N. Given that the benchmark and supplemental GMD events are defined for the reference Quebec (SHIELD) earth model at 60°N reference geomagnetic latitude, this implies that every transformer within the SPP footprint has a geomagnetic scaling factor less than 1.0 (TPL-007-4 Attachment 1, Table 2). Furthermore, every transformer in the SPP footprint resides at a location with an earth model yielding a geoelectric field scaling factor less than 1.0 (TPL-007-4 Attachment 1, Figure 1 and Table 3). Therefore, while each transformer maximum effective GIC value is based upon a benchmark or supplemental reference peak geoelectric field amplitude, the specific geoelectric fields that couple with each SPP transmission line across the expanse of the SPP footprint must be appropriately scaled based upon specific locations, geographic routing, and earth conditions. This unique combination of factors gives rise to the maximum effective GIC value for each individual transformer in the SPP footprint.

An additional important observation is that the maximum effective GIC values, calculated at the worst case geoelectric field orientation for each particular transformer, are not based upon the actual benchmark or supplemental geoelectric field time series waveforms in TPL-007-4 Attachment 1, Figure 4 and 5 for the benchmark event; Figure 7 for the supplemental event. This is self-evident considering that the eastward and northward orientations of the benchmark and supplemental GMD event geoelectric field waveforms yield a geoelectric field vector with a corresponding orientation for each time increment. In other words, the geoelectric field magnitude and orientation at each instant of the benchmark and supplemental GMD event waveforms is almost guaranteed to NOT yield the same GIC value as if the electric field magnitude were at its maximum at the same instant the field

was oriented in the worst-case direction for any particular transformer in the SPP footprint. The practical implication of this observation is to recognize that the maximum effective GIC value calculated for any particular transformer is nearly assured to be greater than or equal to the maximum value of the GIC time series for either the benchmark or supplemental GMD events. It is noted that the maximum geoelectric field magnitudes illustrated by TPL-007-4 Attachment 1 geoelectric field time series are larger in the eastward-westward orientation for both the benchmark and supplemental GMD events. This physical phenomenon has been observed in GIC time series results, where transformers in the SPP footprint that are more strongly affected by transmission lines that couple geoelectric field in the east-west direction tend to yield higher GIC time series magnitudes than those affected by transmission lines with stronger north-south coupling.

There exists some ambiguity in how TPL-007-4 Requirement R6, Part 6.1 refers to “effective GIC flow information provided in Requirement R5.” This ambiguity is identical in Requirement R10, Part 10.1 that refers to “effective GIC flow information provided in Requirement R9.” In fact, both Requirement R5 and Requirement R9 specify “GIC flow information” as being comprised of two parts:

- maximum effective GIC value for the worst case geoelectric field orientation for the benchmark (R5) or supplemental (R9) GMD event; and,
- effective GIC time series, $GIC(t)$, calculated using the benchmark (R5) or supplemental (R9) GMD event.

To be clear, the Requirement R6, Part 6.1 and Requirement R10, Part 10.1 requirements for the respective benchmark and supplemental transformer thermal assessments to be “based on the effective GIC flow information” imply that:

1. All transformers that demonstrate a Requirement R5, Part 5.1 (benchmark) or Requirement R9, Part 9.1 (supplemental) maximum effective GIC value at or above the screening threshold (75A per phase for the benchmark event; 85A per phase for the supplemental event) shall have a transformer thermal assessment performed.
2. The transformer thermal assessment shall use the effective GIC time series calculated using the benchmark and/or supplemental GMD event geoelectric field waveforms in TPL-007-4 Attachment 1.
3. At each time increment of the benchmark or supplemental GMD event time series, the effective GIC magnitude is calculated based upon:
 - a. the geoelectric field amplitude of the benchmark or supplemental GMD geoelectric field waveforms (TPL-007-4 Attachment 1, Figure 4 and 5 for the benchmark event; Figure 7 for the supplemental event);
 - b. scaled to account for the local geomagnetic latitude of the particular transformer;
 - c. scaled to account for local earth conductivity (based on the earth model) for the particular transformer; and,
 - d. at the geoelectric field orientation of the benchmark or supplemental GMD geoelectric field waveforms (TPL-007-4 Attachment 1, Figure 4 and 5 for the benchmark event; Figure 7 for the supplemental event) for the particular transformer.
4. Given that the effective GIC time series already includes geomagnetic latitude and local earth conductivity scaling factors, further scaling or alterations to the benchmark or supplemental GMD geoelectric field waveform magnitudes and orientations are inappropriate.

Each Transmission Owner and Generator Owner will provide results of its benchmark or supplemental transformer thermal impact assessment to SPP, as Planning Coordinator, and each applicable Transmission Planner within 90 days of completion. The data provided will be utilized by SPP, as Planning Coordinator, and the Transmission Planners during development of the benchmark and supplemental GMD Vulnerability Assessments.

R7 and R11

SPP, as Planning Coordinator, and the Transmission Planners meet the requirements of R7 and R11 by developing CAP(s) when portions of their respective planning areas do not meet the performance requirements of TPL-007-4 Table 1. All CAP(s), subject to confidentiality restrictions¹⁷, will be included in the GMD Vulnerability Assessment Report.

SPP, as Planning Coordinator, and the Transmission Planners meet the requirements of R7.1 and R11.1 by ensuring all CAP(s), developed by SPP, as Planning Coordinator, in collaboration with the Transmission Planners list System deficiencies and the associated actions needed to achieve System performance specified in TPL-007-4 Table 1. It is well understood that, in most cases, the entity responsible for implementing the CAP(s) is that entity which owns the equipment identified as deficient or unable to meet performance requirements, indicated by the benchmark or supplemental GMD Vulnerability Assessment. This demands collaboration between SPP, as Planning Coordinator, the Transmission Planners of pertinent Facilities for which they act as Transmission Planner, as well as the Transmission Owner or Generator Owner of equipment necessitating a CAP(s) during the CAP(s) development. Likewise, the Transmission Owner or Generator Owner of equipment necessitating a CAP(s) assist SPP, as Planning Coordinator, and relevant Transmission Planners to remain aware of the status of CAP(s) implementation and any potential delays in achieving the timetable.

Upon compiling all CAP(s), the mitigating actions contained within them should be re-simulated to ensure that the GIC effects under GMD benchmark or supplemental event conditions do not cause the failure to achieve System performance specified in TPL-007-4 Table 1. It is possible that some mitigating actions, such as GIC blocking devices or operating guidance, may correct local adverse GIC effects, but simultaneously exacerbate GIC effect elsewhere in the system. The benchmark and supplemental GMD Vulnerability Assessment study scope should specify the procedure for collaboration to develop CAP(s), as well as the process by which the mitigating actions are re-simulated to complete the analysis necessary for the benchmark and supplemental GMD Vulnerability Assessments.

SPP, as Planning Coordinator, meets the requirements of R7.2 and R11.2 by ensuring all necessary CAP(s) are developed within one year of completion of the benchmark and supplemental GMD Vulnerability Assessment.

SPP, as Planning Coordinator, and the Transmission Planners meet the requirements of R7.3 and R11.3 by collaboratively developing an implementation timetable for each CAP, in conjunction with

¹⁷ Publishing Corrective Action Plans is a sensitive topic and policies vary across the industry. By emphasizing confidentiality restrictions here, the intention is to highlight the importance of making Corrective Action Plans available to entities with valid reliability-related needs, while respecting the proprietary nature of proposed solutions.

the Transmission Owners and Generator Owners of equipment identified by the CAP. The timetables are subject to revision by the applicable responsible entity(ies) and must specify 1) any non-hardware mitigations to be in-service within two years of development of the CAP; or 2) any hardware mitigation within four years of development of the CAP.

If situations arise that are beyond the control the Transmission Owner or Generator Owner of equipment necessitating a CAP(s), as well as beyond the control of SPP, as Planning Coordinator, or the Transmission Planner of Facilities for which they act as Transmission Planner, preventing the implementation of a CAP as specified in the implementation timetable, SPP and the applicable Transmission Planners meet the requirements of R7.4 and R11.4 by collaboratively reviewing revisions to the applicable CAP(s) developed by the Transmission Owner or Generator Owner of equipment necessitating a CAP(s) to document the following:

1. The circumstances causing the delay for fully or partially implementing the selected actions;
2. How the circumstances causing the delay are beyond the control of the responsible entity;
3. Revisions to the selected actions, if any, including utilization of Operating Procedures if applicable; and;
4. An updated timetable for implementing the selected actions.

Once the CAP(s) is revised, the Transmission Owner or Generator Owner of equipment necessitating a CAP(s), as well as SPP, as Planning Coordinator, and the Transmission Planner of Facilities for which they act as Transmission Planner meet the requirements of R7.4 and R11.4 by collaboratively submitting the request for an extension of time to the Compliance Enforcement Authority. All entities, including the entity responsible for the CAP, affected by the revised CAP meet the requirements of R7.4 and R11.4 by virtue of collaboratively submitting the request for an extension of time. It is noted that a single submission to the Compliance Enforcement Authority is sufficient and prevents confusion.

SPP, as Planning Coordinator, and the Transmission Planners meet the requirements of R7.5 and R11.5 by providing the respective Reliability Coordinator, adjacent Planning Coordinator(s), adjacent Transmission Planner(s), and functional entities referenced in the CAP, the applicable CAP(s) subject to confidentiality restrictions, within 90 calendar days of completion of the benchmark and supplemental parts of the “GMD Vulnerability Assessment Report.” Similarly, for all written requests not originating from the Reliability Coordinator, adjacent Planning Coordinator(s), adjacent Transmission Planner(s), or functional entities referenced in the CAP, SPP, as Planning Coordinator, and the applicable Transmission Planner(s) will ensure that a reliability-related need is justified prior to releasing CAP information. When a written request is received after the 90 calendar day period following completion of the benchmark and supplemental parts of the “GMD Vulnerability Assessment Report,” SPP as Planning Coordinator, and the applicable Transmission Planner will respond within 30 calendar days.

R12

SPP, as Planning Coordinator, meets the requirements of R12 by implementing the process annotated in Appendix 1 to obtain GIC monitor data within the SPP planning area. At a minimum, SPP shall obtain GIC monitor data according to the process annotated in Appendix 1 annually.

SPP, as Planning Coordinator, meets the requirements of R12 by establishing at least one point within the SPP planning area from which GIC monitor data may be collected. As of 01 August 2020, SPP exceeded this requirement given that SPP member Western Area Power Administration – Upper Great Plains Region (WAPA-UGPR) maintains two GIC monitors installed at the Watertown and White substations in South Dakota within the SPP Planning Coordinator planning area.

SPP, as Planning Coordinator, will make GIC monitor data available to all applicable Transmission Planners, Transmission Owners, and Generator Owners within the SPP planning area in support of GMD Model Set development and transformer thermal assessments, when applicable. SPP, as Planning Coordinator, will at least once annually provide an updated GIC monitor data set.

R13

SPP, as Planning Coordinator, meets the requirements of R13 by implementing the process annotated in Appendix 1 to obtain geomagnetic field data for the SPP planning area. At a minimum, SPP shall obtain geomagnetic field data according to the process annotated in Appendix 1 annually.

SPP, as Planning Coordinator, meets the requirements of R13 by obtaining geomagnetic field data from the United States Geological Survey’s Boulder Magnetic Observatory located near Boulder, Colorado. Although rare, any magnetometers owned by SPP member Transmission Owners or Generator Owners may supplement the geomagnetic field data that SPP, as Planning Coordinator, collects annually.

SPP, as Planning Coordinator, will make available geomagnetic field data to all applicable Transmission Planners, Transmission Owners, and Generator Owners within the SPP planning area. SPP, as Planning Coordinator, will at least once annually provide an updated geomagnetic field data set.

Appendix 1 – SPP Process to Obtain GMD Measurement Data

The following annotates the process by which SPP, as Planning Coordinator, obtains GMD-related measurement data consisting of:

1. GIC monitor data from at least one GIC monitor located in the Planning Coordinator’s planning area or other part of the system included in the Planning Coordinator’s GIC System model; and,
2. Geomagnetic field data for its Planning Coordinator’s planning area.

Changes to the SPP Process to Obtain GMD Measurement Data

SPP, as Planning Coordinator, may independently make changes to the processes annotated herein when required without necessitating review or approval of the SPP TPL-007-4 Standard Guidance Document.

Periodicity

SPP, as Planning Coordinator, shall collect GMD-related measurement data at least annually. Additional GMD field data collections may be collected ad hoc by SPP to support special assessments of specific GMD events, to perform model validations, or when directed by the Electric Reliability Organization (ERO).

GIC Monitor Data Collection

The following questionnaire will be transmitted to all Transmission Owners and Generator Owners in the SPP Planning Coordinator planning area annually seeking, at a minimum:

1. Do you have a GIC monitor(s) installed? *Yes/No*.

If Yes, please answer the following questions:

2. Where is the GIC monitor(s) located?
 - Latitude/longitude; and,
 - What type of equipment is the GIC monitor(s) installed on (e.g., neutral of 345/230/13.8kV autotransformer).
3. What are the GIC monitor(s) specifications?
 - Connection type (e.g., common neutral of a 3-phase transformer, common neutral of three single-phase transformers, neutral of single-phase transformer, phase conductor, etc.);
 - Ampacity range (e.g., 0.5-80 A);
 - Ambient temperature rating (e.g., -30°F to 120°F);
 - Monitor manufacturer; and,

- Date of installation.
4. What is the GIC monitor(s) sampling rate? Please specify in “samples per 10-seconds.”
 5. What is the GIC monitor(s) data retention period, e.g. how long is the GIC monitor(s) data retained?
 6. What were the following GIC monitored data from the prior calendar year (01 January to 31 December)?
 - Average GIC magnitude; and,
 - Peak GIC magnitude (with timestamp) observed.
 7. If requested, can you provide GIC monitor(s) data for specific time periods from the prior calendar year in the following data format? *Yes/No*.

Field 1: MM/DD/YYYY.

Field 2: HH:MM:SS in Coordinated Universal Time (UTC).

Field 3: Polarity (positive sourcing current from ground; negative sinking current to ground).

Field 4: GIC magnitude (one-digit decimal precision, e.g. 14.3 amps).

SPP will use the annual GIC monitor questionnaire information to support special requests that may be made for GIC monitor data from those entities within the SPP Planning Coordinator planning area with known GIC monitors installed. Special collections of GIC monitor data may be requested based upon specific targeted time periods. For example, a request may be made for specific time periods from a previous year when the NOAA/NWS Space Weather Prediction Center (SWPC) issued a Kp-7 or above alert. SPP may use the open-source SWPC prior year alert data (available at <ftp://ftp.swpc.noaa.gov/pub/warehouse>) to obtain prior year Daily Geomagnetic Data records to parse for Kp-7 or above events of interest. This information may assist SPP, as Planning Coordinator, to define specific collection periods for subsequent requests including any special collections necessary to validate the GIC results calculated as part of the TPL-007-4 R5 and R9 assessments.

Geomagnetic Data Collection

The following questionnaire will be transmitted to all Transmission Owners and Generator Owners in the SPP Planning Coordinator planning area annually seeking, at a minimum:

1. Do you have a magnetometer(s) installed? *Yes/No*.

If Yes, please answer the following questions:

2. Where is the magnetometer(s) located, e.g. latitude/longitude?
3. What is the magnetometer(s) specifications?
 - Data orientation (geographic or geomagnetic);
 - B-field precision (magnetic data significant digits);
 - Monitor manufacturer; and,
 - Date of installation.

4. What is the magnetometer(s) sampling rate? Please specify in “samples per second.”
5. What is the magnetometer(s) data retention period, e.g. how long is the magnetometer data retained?
6. What were the following magnetometer(s) data from the prior calendar year (01 January to 31 December)?
 - Average B-field (north vector) magnitude;
 - Average B-field (east vector) magnitude;
 - Average B-field (inclination vector) magnitude; and,
 - Peak Euclidean B-field magnitude and orientation (with timestamp) observed.
7. If requested, can you provide magnetometer(s) data for specific time periods from the prior calendar year in the following data format? **Yes/No.**

Field 1: MM/DD/YYYY.

Field 2: HH:MM:SS in Coordinated Universal Time (UTC).

Field 3: B-field (north vector; nano-Tesla [nT]).

Field 4: B-field (east vector; nano-Tesla [nT]).

Field 5: B-field (inclination vector; nano-Tesla [nT]).

SPP will use the annual magnetometer questionnaire information to support special requests that may be made for magnetometer data from those entities within the SPP Planning Coordinator planning area with known magnetometers installed. Special collections of magnetometer data may be requested based upon specific targeted time periods. This information may assist SPP, as Planning Coordinator, to define specific collection periods for subsequent requests including any special collections necessary to review GMD-related assumptions.

SPP, as Planning Coordinator, will collect USGS data obtained at the Boulder Magnetometer Observatory at least once annually. The data may be collected in IAGA2002 format with fixed-field length, using automated html queries such as:

- Day snapshot (1-second resolution; useful when the Space Weather Prediction Center is monitoring a storm):

http://geomag.usgs.gov/ws/edge/?id=BOU&sampling_period=1&type=adjusted

- Historical time period (1-minute resolution; useful for TPL-007-4 Requirement R13 per annum):

http://geomag.usgs.gov/ws/edge/?id=BOU&type=adjusted&elements=X,Y,Z,F&sampling_period=60&starttime=2020-06-01T00:00:00Z&endtime=2020-06-30T23:59:59Z

The USGS query returns the following data fields:

- Timestamp
- BOUX = Boulder observed northward magnetic field (Bx)

- BOUY = Boulder observed eastward magnetic field (B_y)
- BOUZ = Boulder observed vertical downward towards earth center magnetic field (B_z)
- BOUF = intensity component is the scalar magnetic field (analogous to a scalar voltage)

When utilizing USGS magnetometer data, the following shall be considered:

- The Euclidean vector magnitude of B_x , B_y , B_z is very similar to scalar magnetic intensity.
- Queries of json format in lieu of IAGA2002 allow report of BOUF intensity only in vector format. IAGA queries return a minimum of four fields.
- USGS magnetometer data is tagged with one of four geomagnetic data types. Experience has shown that queries of “definitive” or “quasi-definitive” for near-final or final data adopted values by the observatory are rarely successful. Instead, reported (raw) and adjusted (data spikes removed, time shifts fixed, etc.) have demonstrated the best query success from the Boulder Magnetometer Observatory.
- Queries of 3600-second periodicity have not been historically successful. Instead, 1-second and 60-second data queries are better suited.