

156 FERC ¶ 61,215
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part 40

[Docket No. RM15-11-000; Order No. 830]

Reliability Standard for Transmission System Planned Performance for
Geomagnetic Disturbance Events

(Issued September 22, 2016)

AGENCY: Federal Energy Regulatory Commission.

ACTION: Final rule.

SUMMARY: The Federal Energy Regulatory Commission (Commission) approves Reliability Standard TPL-007-1 (Transmission System Planned Performance for Geomagnetic Disturbance Events). The North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization, submitted Reliability Standard TPL-007-1 for Commission approval in response to a Commission directive in Order No. 779. Reliability Standard TPL-007-1 establishes requirements for certain registered entities to assess the vulnerability of their transmission systems to geomagnetic disturbance events (GMDs), which occur when the sun ejects charged particles that interact with and cause changes in the earth's magnetic fields. Applicable entities that do not meet certain performance requirements, based on the results of their vulnerability assessments, must develop a plan to achieve the performance requirements. In addition, the Commission directs NERC to develop modifications to Reliability Standard TPL-007-1: (1) to modify the benchmark GMD event definition set forth in

Attachment 1 of Reliability Standard TPL-007-1, as it pertains to the required GMD Vulnerability Assessments and transformer thermal impact assessments, so that the definition is not based solely on spatially-averaged data; (2) to require the collection of necessary geomagnetically induced current monitoring and magnetometer data and to make such data publicly available; and (3) to include a one-year deadline for the development of corrective action plans and two and four-year deadlines to complete mitigation actions involving non-hardware and hardware mitigation, respectively. The Commission also directs NERC to submit a work plan and, subsequently, one or more informational filings that address specific GMD-related research areas.

EFFECTIVE DATE: This rule will become effective [**INSERT DATE 60 days after publication in the FEDERAL REGISTER**].

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SUPPLEMENTARY INFORMATION:

156 FERC ¶ 61,215
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Before Commissioners: Norman C. Bay, Chairman;
Cheryl A. LaFleur, Tony Clark,
and Colette D. Honorable.

Reliability Standard for Transmission System Planned Performance for Geomagnetic Disturbance Events Docket No. RM15-11-000

ORDER NO. 830

FINAL RULE

(Issued September 22, 2016)

1. Pursuant to section 215 of the Federal Power Act (FPA), the Commission approves Reliability Standard TPL-007-1 (Transmission System Planned Performance for Geomagnetic Disturbance Events).¹ The North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization (ERO), submitted Reliability Standard TPL-007-1 for Commission approval in response to a Commission directive in Order No. 779.² Reliability Standard TPL-007-1 establishes requirements for certain registered entities to assess the vulnerability of their transmission systems to geomagnetic disturbance events (GMDs), which occur when the sun ejects

¹ 16 U.S.C. 824o.

² *Reliability Standards for Geomagnetic Disturbances*, Order No. 779, 78 FR 30,747 (May 23, 2013), 143 FERC ¶ 61,147, *reh'g denied*, 144 FERC ¶ 61,113 (2013).

charged particles that interact with and cause changes in the earth's magnetic fields. Reliability Standard TPL-007-1 requires applicable entities that do not meet certain performance requirements, based on the results of their vulnerability assessments, to develop a plan to achieve the requirements. Reliability Standard TPL-007-1 addresses the directives in Order No. 779 by requiring applicable Bulk-Power System owners and operators to conduct initial and on-going vulnerability assessments regarding the potential impact of a benchmark GMD event on the Bulk-Power System as a whole and on Bulk-Power System components.³ In addition, Reliability Standard TPL-007-1 requires applicable entities to develop and implement corrective action plans to mitigate identified vulnerabilities.⁴ Potential mitigation strategies identified in the proposed Reliability Standard include, but are not limited to, the installation, modification or removal of transmission and generation facilities and associated equipment.⁵ Accordingly, Reliability Standard TPL-007-1 constitutes an important step in addressing the risks posed by GMD events to the Bulk-Power System.

2. In addition, pursuant to section 215(d)(5) of the FPA, the Commission directs NERC to develop modifications to Reliability Standard TPL-007-1: (1) to revise the

³ See Reliability Standard TPL-007-1, Requirement R4; *see also* Order No. 779, 143 FERC ¶ 61,147 at PP 67, 71.

⁴ See Reliability Standard TPL-007-1, Requirement R7; *see also* Order No. 779, 143 FERC ¶ 61,147 at P 79.

⁵ See Reliability Standard TPL-007-1, Requirement R7.

benchmark GMD event definition set forth in Attachment 1 of Reliability Standard TPL-007-1, as it pertains to the required GMD Vulnerability Assessments and transformer thermal impact assessments, so that the definition is not based solely on spatially-averaged data; (2) to require the collection of necessary geomagnetically induced current (GIC) monitoring and magnetometer data and to make such data publicly available; and (3) to include a one-year deadline for the completion of corrective action plans and two- and four-year deadlines to complete mitigation actions involving non-hardware and hardware mitigation, respectively.⁶ The Commission directs NERC to submit these revisions within 18 months of the effective date of this Final Rule. The Commission also directs NERC to submit a work plan (GMD research work plan) within six months of the effective date of this Final Rule and, subsequently, one or more informational filings that address specific GMD-related research areas.

I. Background

A. Section 215 and Mandatory Reliability Standards

3. Section 215 of the FPA requires the Commission to certify an ERO to develop mandatory and enforceable Reliability Standards, subject to Commission review and approval. Once approved, the Reliability Standards may be enforced in the United States by the ERO, subject to Commission oversight, or by the Commission independently.⁷

⁶ 16 U.S.C. 824o(d)(5).

⁷ *Id.* 824o(e).

B. GMD Primer

4. GMD events occur when the sun ejects charged particles that interact with and cause changes in the earth's magnetic fields.⁸ Once a solar particle is ejected, it can take between 17 to 96 hours (depending on its energy level) to reach earth.⁹ A geoelectric field is the electric potential (measured in volts per kilometer (V/km)) on the earth's surface and is directly related to the rate of change of the magnetic fields.¹⁰ A geoelectric field has an amplitude and direction and acts as a voltage source that can cause GICs to flow on long conductors, such as transmission lines.¹¹ The magnitude of the geoelectric field amplitude is impacted by local factors such as geomagnetic latitude and local earth conductivity.¹² Geomagnetic latitude is the proximity to earth's magnetic north and south poles, as opposed to earth's geographic poles. Local earth conductivity is the ability of the earth's crust to conduct electricity at a certain location to depths of hundreds of kilometers down to the earth's mantle. Local earth conductivity impacts the magnitude

⁸ North American Electric Reliability Corp., 2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System at i-ii (February 2012), <http://www.nerc.com/files/2012GMD.pdf> (GMD Interim Report).

⁹ *Id.* ii.

¹⁰ *Id.*

¹¹ *Id.*

¹² NERC Petition, Ex. D (White Paper on GMD Benchmark Event Description) at 4.

(i.e., severity) of the geoelectric fields that are formed during a GMD event by, all else being equal, a lower earth conductivity resulting in higher geoelectric fields.¹³

C. Order No. 779

5. In Order No. 779, the Commission directed NERC, pursuant to section 215(d)(5) of the FPA, to develop and submit for approval proposed Reliability Standards that address the impact of geomagnetic disturbances on the reliable operation of the Bulk-Power System. The Commission based its directive on the potentially severe, wide-spread impact on the reliable operation of the Bulk-Power System that can be caused by GMD events and the absence of existing Reliability Standards to address GMD events.¹⁴

6. Order No. 779 directed NERC to implement the directive in two stages. In the first stage, the Commission directed NERC to submit, within six months of the effective date of Order No. 779, one or more Reliability Standards (First Stage GMD Reliability Standards) that require owners and operators of the Bulk-Power System to develop and implement operational procedures to mitigate the effects of GMDs consistent with the reliable operation of the Bulk-Power System.¹⁵

7. In the second stage, the Commission directed NERC to submit, within 18 months of the effective date of Order No. 779, one or more Reliability Standards (Second Stage

¹³ *Id.*

¹⁴ Order No. 779, 143 FERC ¶ 61,147 at P 3.

¹⁵ *Id.* P 2.

GMD Reliability Standards) that require owners and operators of the Bulk-Power System to conduct initial and on-going assessments of the potential impact of benchmark GMD events on Bulk-Power System equipment and the Bulk-Power System as a whole. The Commission directed that the Second Stage GMD Reliability Standards must identify benchmark GMD events that specify what severity of GMD events a responsible entity must assess for potential impacts on the Bulk-Power System.¹⁶ Order No. 779 explained that if the assessments identified potential impacts from benchmark GMD events, the Reliability Standards should require owners and operators to develop and implement a plan to protect against instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, as a result of a benchmark GMD event. The Commission directed that the development of this plan could not be limited to considering operational procedures or enhanced training alone but should, subject to the potential impacts of the benchmark GMD events identified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, system configuration or location of specific equipment.¹⁷ Order No. 779 observed that these strategies could, for example, include automatically blocking GICs from entering the Bulk-Power System, instituting specification requirements for

¹⁶ *Id.*

¹⁷ *Id.*

new equipment, inventory management, isolating certain equipment that is not cost effective to retrofit or a combination thereof.

D. Order No. 797

8. In Order No. 797, the Commission approved Reliability Standard EOP-010-1 (Geomagnetic Disturbance Operations).¹⁸ NERC submitted Reliability Standard EOP-010-1 for Commission approval in compliance with the Commission's directive in Order No. 779 corresponding to the First Stage GMD Reliability Standards. In Order No. 797-A, the Commission denied the Foundation for Resilient Societies' (Resilient Societies) request for rehearing of Order No. 797. The Commission stated that the rehearing request "addressed a later stage of efforts on geomagnetic disturbances (i.e., NERC's future filing of Second Stage GMD Reliability Standards) and [that Resilient Societies] may seek to present those arguments at an appropriate time in response to that filing."¹⁹ In particular, the Commission stated that GIC monitoring requirements should be addressed in the Second Stage GMD Reliability Standards.²⁰

¹⁸ *Reliability Standard for Geomagnetic Disturbance Operations*, Order No. 797, 79 FR 35,911 (June 25, 2014), 147 FERC ¶ 61,209, *reh'g denied*, Order No. 797-A, 149 FERC ¶ 61,027 (2014).

¹⁹ Order No. 797-A, 149 FERC ¶ 61,027 at P 2.

²⁰ *Id.* P 27 (stating that the Commission continues "to encourage NERC to address the collection, dissemination, and use of geomagnetic induced current data, by NERC, industry or others, in the Second Stage GMD Reliability Standards because such efforts could be useful in the development of GMD mitigation methods or to validate GMD models").

E. NERC Petition and Reliability Standard TPL-007-1

9. On January 21, 2015, NERC petitioned the Commission to approve Reliability Standard TPL-007-1 and its associated violation risk factors and violation severity levels, implementation plan, and effective dates.²¹ NERC also submitted a proposed definition for the term “Geomagnetic Disturbance Vulnerability Assessment or GMD Vulnerability Assessment” for inclusion in the NERC Glossary of Terms (NERC Glossary). NERC maintains that Reliability Standard TPL-007-1 is just, reasonable, not unduly discriminatory or preferential and in the public interest. NERC further contends that Reliability Standard TPL-007-1 satisfies the directive in Order No. 779 corresponding to the Second Stage GMD Reliability Standards.

10. NERC states that Reliability Standard TPL-007-1 applies to planning coordinators, transmission planners, transmission owners and generation owners who own or whose planning coordinator area or transmission planning area includes a power transformer with a high side, wye-grounded winding connected at 200 kV or higher.²² NERC explains that the applicability criteria for qualifying transformers in Reliability Standard

²¹ Reliability Standard TPL-007-1 is not attached to this final rule. Reliability Standard TPL-007-1 is available on the Commission’s eLibrary document retrieval system in Docket No. RM15-11-000 and on the NERC website, www.nerc.com. NERC submitted an errata on February 2, 2015 containing a corrected version of Exhibit A (Proposed Reliability Standard TPL-007-1).

²² A power transformer with a “high side wye-grounded winding” refers to a power transformer with windings on the high voltage side that are connected in a wye configuration and have a grounded neutral connection. NERC Petition at 13 n.32.

TPL-007-1 are the same as that for the First Stage GMD Reliability Standard in Reliability Standard EOP-010-1, which the Commission approved in Order No. 797.

11. Reliability Standard TPL-007-1 contains seven requirements. Requirement R1 requires planning coordinators and transmission planners to determine the individual and joint responsibilities in the planning coordinator's planning area for maintaining models and performing studies needed to complete the GMD Vulnerability Assessment required in Requirement R4.

12. Requirement R2 requires planning coordinators and transmission planners to maintain system models and GIC system models needed to complete the GMD Vulnerability Assessment required in Requirement R4.

13. Requirement R3 requires planning coordinators and transmission planners to have criteria for acceptable system steady state voltage limits for their systems during the benchmark GMD event described in Attachment 1 (Calculating Geoelectric Fields for the Benchmark GMD Event).

14. Requirement R4 requires planning coordinators and transmission planners to conduct a GMD Vulnerability Assessment every 60 months using the benchmark GMD event described in Attachment 1 to Reliability Standard TPL-007-1. The benchmark GMD event is based on a 1-in-100 year frequency of occurrence and is composed of four elements: (1) a reference peak geoelectric field amplitude of 8 V/km derived from statistical analysis of historical magnetometer data; (2) a scaling factor to account for local geomagnetic latitude; (3) a scaling factor to account for local earth conductivity; and (4) a reference geomagnetic field time series or wave shape to facilitate time-domain

analysis of GMD impact on equipment.²³ The product of the first three elements is referred to as the regional geoelectric field peak amplitude.²⁴

15. Requirement R5 requires planning coordinators and transmission planners to provide GIC flow information, to be used in the transformer thermal impact assessment required in Requirement R6, to each transmission owner and generator owner that owns an applicable transformer within the applicable planning area.

16. Requirement R6 requires transmission owners and generator owners to conduct thermal impact assessments on solely and jointly owned applicable transformers where the maximum effective GIC value provided in Requirement R5 is 75 amperes per phase (A/phase) or greater.

17. Requirement R7 requires planning coordinators and transmission planners to develop corrective action plans if the GMD Vulnerability Assessment concludes that the system does not meet the performance requirements in Table 1 (Steady State Planning Events).

²³ See Reliability Standard TPL-007-1, Att. 1; see also NERC Petition, Ex. D (White Paper on GMD Benchmark Event Description) at 5.

²⁴ NERC Petition, Ex. D (White Paper on GMD Benchmark Event Description) at 5.

F. Notice of Proposed Rulemaking

18. On May 14, 2015, the Commission issued a notice of proposed rulemaking (NOPR) proposing to approve Reliability Standard TPL-007-1.²⁵ In addition, the Commission proposed to direct that NERC develop three modifications to Reliability Standard TPL-007-1. First, the Commission proposed to direct NERC to revise the benchmark GMD event definition in Reliability Standard TPL-007-1 so that the definition is not based solely on spatially-averaged data. Second, the Commission proposed to direct NERC to revise Reliability Standard TPL-007-1 to require the installation of GIC monitors and magnetometers where necessary. Third, the Commission proposed to direct NERC to revise Reliability Standard TPL-007-1 to require corrective action plans (Requirement R7) to be developed within one year and, with respect to the mitigation actions called for in the corrective action plans, non-hardware mitigation actions to be completed within two years of finishing development of the corrective action plan and hardware mitigation to be completed within four years. The NOPR also proposed to direct NERC to submit a work plan and, subsequently, one or more informational filings that address specific GMD-related research areas and sought comment on certain issues relating to the transformer thermal impact assessments

²⁵ *Reliability Standard for Transmission System Planned Performance for Geomagnetic Disturbance Events*, Notice of Proposed Rulemaking, 80 FR 29,990 (May 26, 2015), 151 FERC ¶ 61,134 (2015) (NOPR).

(Requirement R6) and the meaning of language in Table 1 of Reliability Standard TPL-007-1.

19. On August 20, 2015 and October 2, 2015, the Commission issued notices setting supplemental comment periods regarding specific documents. On March 1, 2016, Commission staff led a technical conference on Reliability Standard TPL-007-1 and issues raised in the NOPR.²⁶

20. On April 28, 2016, NERC made a filing notifying the Commission that “NERC identified new information that may necessitate a minor revision to a figure in one of the supporting technical white papers. This revision would not require a change to any of the Requirements of the proposed Reliability Standard.”²⁷ On June 28, 2016, NERC submitted the revised technical white papers referenced in the April 28, 2016 filing. On June 29, 2016, the Commission issued a notice setting a supplemental comment period regarding the revised technical white papers submitted by NERC on June 28, 2016.

21. In response to the NOPR and subsequent notices, 28 entities filed initial and supplemental comments. We address below the issues raised in the NOPR and comments. The Appendix to this Final Rule lists the entities that filed comments in response to the NOPR and in response to the supplemental comment period notices.

²⁶ Written presentations at the March 1, 2016 Technical Conference and the Technical Conference transcript referenced in this Final Rule are accessible through the Commission’s eLibrary document retrieval system in Docket No. RM15-11-000.

²⁷ NERC April 28, 2016 Filing at 1.

II. Discussion

22. Pursuant to section 215(d) of the FPA, the Commission approves Reliability Standard TPL-007-1 as just, reasonable, not unduly discriminatory or preferential and in the public interest. While we recognize that scientific and operational research regarding GMD is ongoing, we believe that the potential threat to the bulk electric system warrants Commission action at this time, including efforts to conduct critical GMD research and update Reliability Standard TPL-007-1 as appropriate.

23. First, we find that Reliability Standard TPL-007-1 addresses the directives in Order No. 779 corresponding to the development of the Second Stage GMD Reliability Standards. Reliability Standard TPL-007-1 does this by requiring applicable Bulk-Power System owners and operators to conduct, on a recurring five-year cycle,²⁸ initial and on-going vulnerability assessments regarding the potential impact of a benchmark GMD event on the Bulk-Power System as a whole and on Bulk-Power System components.²⁹ In addition, Reliability Standard TPL-007-1 requires applicable entities to develop and implement corrective action plans to mitigate vulnerabilities identified through those recurring vulnerability assessments.³⁰ Potential mitigation strategies identified in the

²⁸ A detailed explanation of the five-year GMD Vulnerability Assessment and mitigation cycle is provided in paragraph 103, *infra*.

²⁹ See Reliability Standard TPL-007-1, Requirement R4; see also Order No. 779, 143 FERC ¶ 61,147 at PP 67, 71.

³⁰ See Reliability Standard TPL-007-1, Requirement R7; see also Order No. 779, 143 FERC ¶ 61,147 at P 79.

proposed Reliability Standard include, but are not limited to, the installation, modification or removal of transmission and generation facilities and associated equipment.³¹ Accordingly, Reliability Standard TPL-007-1 constitutes an important step in addressing the risks posed by GMD events to the Bulk-Power System.

24. The Commission also approves the inclusion of the term “Geomagnetic Disturbance Vulnerability Assessment or GMD Vulnerability Assessment” in the NERC Glossary; Reliability Standard TPL-007-1’s associated violation risk factors and violation severity levels; and NERC’s proposed implementation plan and effective dates. The Commission also affirms, as raised for comment in the NOPR, that cost recovery for prudent costs associated with or incurred to comply with Reliability Standard TPL-007-1 and future revisions to the Reliability Standard will be available to registered entities.³²

25. While we conclude that Reliability Standard TPL-007-1 satisfies the directives in Order No. 779, based on the record developed in this proceeding, the Commission determines that Reliability Standard TPL-007-1 should be modified to reflect the new information and analyses discussed below, as proposed in the NOPR. Accordingly, pursuant to section 215(d)(5) of the FPA, the Commission directs NERC to develop and submit modifications to Reliability Standard TPL-007-1 concerning: (1) the calculation of the reference peak geoelectric field amplitude component of the benchmark GMD

³¹ See Reliability Standard TPL-007-1, Requirement R7.

³² NOPR, 151 FERC ¶ 61,134 at P 49 n.60.

event definition; (2) the collection and public availability of necessary GIC monitoring and magnetometer data; and (3) deadlines for completing corrective action plans and the mitigation measures called for in corrective action plans. The Commission directs NERC to develop and submit these revisions for Commission approval within 18 months of the effective date of this Final Rule.

26. Furthermore, to improve the understanding of GMD events generally, the Commission directs NERC to submit within six months from the effective date of this Final Rule a GMD research work plan.³³ Specifically, we direct NERC to: (1) further analyze the area over which spatial averaging should be calculated for stability studies, including performing sensitivity analyses on squares less than 500 km per side (e.g., 100 km, 200 km); (2) further analyze earth conductivity models by, for example, using metered GIC and magnetometer readings to calculate earth conductivity and using 3-D readings; (3) determine whether new analyses and observations support modifying the use of single station readings around the earth to adjust the spatially averaged benchmark for latitude; (4) research, as discussed below, aspects of the required thermal impact assessments; and (5) in NERC's discretion, conduct any GMD-related research areas generally that may impact the development of new or modified GMD Reliability Standards. We expect that work completed through the GMD research work plan, as

³³ Following submission of the GMD research work plan, the Commission will notice the filing for public comment and issue an order addressing its proposed content and schedule.

well as other analyses facilitated by the increased collection and availability of GIC monitoring and magnetometer data directed herein, will lead to further modifications to Reliability Standard TPL-007-1 as our collective understanding of the threats posed by GMD events improves.

27. Below we discuss the following issues raised in the NOPR and NOPR comments:

(1) the benchmark GMD event definition described in Reliability Standard TPL-007-1, Attachment 1 (Calculating Geoelectric Fields for the Benchmark GMD Event); (2) transformer thermal impact assessments in Requirement R6; (3) GMD research work plan; (4) collection and public availability of GIC monitoring and magnetometer data; (5) completion of corrective action plans in Requirement R7; (6) meaning of “minimized” in Table 1 (Steady State Planning Events) of Reliability Standard TPL-007-1; (7) NERC’s proposed implementation plan and effective dates; and (8) other issues.

A. Benchmark GMD Event Definition

NERC Petition

28. NERC states that the purpose of the benchmark GMD event is to “provide a defined event for assessing system performance during a low probability, high magnitude GMD event.”³⁴ NERC explains that the benchmark GMD event represents “the most severe GMD event expected in a 100-year period as determined by a statistical analysis

³⁴ NERC Petition at 15.

of recorded geomagnetic data.”³⁵ The benchmark GMD event definition is used in the GMD Vulnerability Assessments and thermal impact assessment requirements of Reliability Standard TPL-007-1 (Requirements R4 and R6).

29. As noted above, NERC states that the benchmark GMD event definition has four elements: (1) a reference peak geoelectric field amplitude of 8 V/km derived from statistical analysis of historical magnetometer data; (2) a scaling factor to account for local geomagnetic latitude; (3) a scaling factor to account for local earth conductivity; and (4) a reference geomagnetic field time series or wave shape to facilitate time-domain analysis of GMD impact on equipment.³⁶

30. The standard drafting team determined that a 1-in-100 year GMD event would cause an 8 V/km reference peak geoelectric field amplitude at 60 degree geomagnetic latitude using Québec’s earth conductivity.³⁷ The standard drafting team stated that:

the reference geoelectric field amplitude was determined through statistical analysis using ... field measurements from geomagnetic observatories in northern Europe and the reference (Quebec) earth model The Quebec earth model is generally resistive and the geological structure is relatively well understood. The statistical analysis resulted in a conservative peak geoelectric field amplitude of approximately 8 V/km The frequency of occurrence of this benchmark GMD event is estimated to be approximately 1 in 100 years.³⁸

³⁵ *Id.*

³⁶ NERC Petition, Ex. D (White Paper on GMD Benchmark Event Description) at 5.

³⁷ *Id.*

³⁸ *Id.* (footnotes omitted).

31. The standard drafting team explained that it used field measurements taken from the IMAGE magnetometer chain, which covers Northern Europe, for the period 1993-2013 to calculate the reference peak geoelectric field amplitude used in the benchmark GMD event definition.³⁹ As described in NERC's petition, the standard drafting team "spatially averaged" four different station groups of IMAGE data, each spanning a square area of approximately 500 km (roughly 310 miles) in width.⁴⁰ The standard drafting team justified the use of spatial averaging by stating that Reliability Standard TPL-007-1 is designed to "address wide-area effects caused by a severe GMD event, such as increased var absorption and voltage depressions. Without characterizing GMD on regional scales, statistical estimates could be weighted by local effects and suggest unduly pessimistic conditions when considering cascading failure and voltage collapse."⁴¹

32. NERC states that the benchmark GMD event includes scaling factors to enable applicable entities to tailor the reference peak geoelectric field to their specific location

³⁹ *Id.* at 8. The International Monitor for Auroral Geomagnetic Effects (IMAGE) consists of 31 magnetometer stations in northern Europe maintained by 10 institutes from Estonia, Finland, Germany, Norway, Poland, Russia, and Sweden. *See* IMAGE website, <http://space.fmi.fi/image/beta/?page=home#>.

⁴⁰ As applied by the standard drafting team, spatial averaging refers to the averaging of geoelectric field amplitude readings within a given area. NERC Petition, Ex. D (White Paper on GMD Benchmark Event Description) at 9.

⁴¹ NERC Petition, Ex. D (White Paper on GMD Benchmark Event Description) at 9.

for conducting GMD Vulnerability Assessments. NERC explains that the scaling factors in the benchmark GMD event definition are applied to the reference peak geoelectric field amplitude to adjust the 8 V/km value for different geomagnetic latitudes and earth conductivities.⁴²

33. The standard drafting team also identified a reference geomagnetic field time series from an Ottawa magnetic observatory during a 1989 GMD event that affected Québec.⁴³ The standard drafting team used this time series to estimate a geoelectric field, represented as a time series (i.e., 10-second values over a period of days), that is expected to occur at 60 degree geomagnetic latitude during a 1-in-100 year GMD event. NERC explains that this time series is used to facilitate time-domain analysis of GMD impacts on equipment.⁴⁴

34. In the sub-sections below, we discuss two issues concerning the benchmark GMD event definition addressed in the NOPR: (1) reference peak geoelectric field amplitude; and (2) geomagnetic latitude scaling factor.

⁴² NERC Petition at 18-19.

⁴³ NERC Petition, Ex. D (White Paper on GMD Benchmark Event Description) at 5-6, 15-16 (“the reference geomagnetic field waveshape was selected after analyzing a number of recorded GMD events... the March 13-14, 1989 GMD event, measured at NRCan’s Ottawa geomagnetic observatory, was selected as the reference geomagnetic field waveform because it provides generally conservative results when performing thermal analysis of power transformers”).

⁴⁴ *Id.* at 5-6.

1. Reference Peak Geoelectric Field Amplitude

NOPR

35. The NOPR proposed to approve the benchmark GMD event definition. The NOPR stated that the “benchmark GMD event definition proposed by NERC complies with the directive in Order No. 779 ... [c]onsistent with the guidance provided in Order No. 779, the benchmark GMD event definition proposed by NERC addresses the potential widespread impact of a severe GMD event, while taking into consideration the variables of geomagnetic latitude and local earth conductivity.”⁴⁵

36. In addition, the NOPR proposed to direct NERC to develop modifications to Reliability Standard TPL-007-1. Specifically, the NOPR proposed to direct NERC to modify the reference peak geoelectric field amplitude component of the benchmark GMD event definition so that it is not calculated based solely on spatially-averaged data. The NOPR explained that this could be achieved, for example, by requiring applicable entities to conduct GMD Vulnerability Assessments (and, as discussed below, thermal impact assessments) using two different benchmark GMD events: the first benchmark GMD event using the spatially-averaged reference peak geoelectric field value (8 V/km) and the second using the non-spatially averaged peak geoelectric field value cited in the GMD Interim Report (20 V/km). The NOPR stated that the revised Reliability Standard could then require applicable entities to take corrective actions, using engineering judgment,

⁴⁵ NOPR, 151 FERC ¶ 61,134 at P 32.

based on the results of both assessments. The NOPR explained that applicable entities would not always be required to mitigate to the level of risk identified by the non-spatially averaged analysis; instead, the selection of mitigation would reflect the range of risks bounded by the two analyses, and be based on engineering judgment within this range, considering all relevant information. The NOPR stated that, alternatively, NERC could propose an equally efficient and effective modification that does not rely exclusively on the spatially-averaged reference peak geoelectric field value.

Comments

37. NERC does not support revising the benchmark GMD event definition. NERC maintains that the spatially-averaged reference peak geoelectric field amplitude value in Reliability Standard TPL-007-1 is “technically-justified, scientifically sound, and has been published in a peer-reviewed research journal covering geomagnetism and other topics.”⁴⁶ NERC contends that the standard drafting team determined that using the non-spatially averaged 20 V/km figure in the GMD Interim Report would “consistently overestimate the geoelectric field of a 1-in-100 year GMD event.”⁴⁷ NERC states that, by contrast, spatial averaging “properly associates the relevant spatial scales for the analyzed and applied geoelectric fields and would not distort the complexity of the potential

⁴⁶ NERC Comments at 6.

⁴⁷ *Id.* at 7.

impacts of a GMD event.”⁴⁸ NERC claims that the 500 km-wide square areas used to determine the areas of spatial averaging are “based on consideration of transmission systems and geomagnetic observation patterns ... [and are] an appropriate scale for a system-wide impact in a transmission system.”⁴⁹ To support this position, NERC cites a June 2015 peer-reviewed publication authored in part by some members of the standard drafting team.⁵⁰

38. Industry commenters, largely represented by the Trade Associations’ comments, do not support revising the benchmark GMD event definition.⁵¹ The Trade Associations’ reasons largely mirror NERC’s. While recognizing that the spatially-averaged reference peak geoelectric field amplitude is lower than the non-spatially averaged figure, the Trade Associations contend that the non-spatially averaged value is inappropriate because: (1) the peak geoelectric field only affects relatively small areas and quickly

⁴⁸ *Id.* at 8.

⁴⁹ *Id.*

⁵⁰ See Pulkkinen, A., Bernabeu, E., Eichner, J., Viljanen, A., Ngwira, C., “Regional-Scale High-Latitude Extreme Geoelectric Fields Pertaining to Geomagnetically Induced Currents,” *Earth, Planets and Space* (June 19, 2015) (2015 Pulkkinen Paper).

⁵¹ Trade Associations Comments at 13-18. AEP, APS, ATC, BPA, CEA, Hydro One, ITC, Joint ISOs/RTOs and Exelon indicated that they do not support the NOPR proposal in separate comments and/or by joining the Trade Associations’ comments. See AEP Comments at 3; APS Comments at 2; ATC Comments at 3; BPA Comments at 3-4; CEA Comments at 8-13; Hydro One Comments 1-2; ITC Comments at 3-5; Joint ISOs/RTOs Comments at 4-5; Exelon Comments at 2.

declines with distance from the peak; (2) Reliability Standard TPL-007-1 is intended to address the wide-scale effects of a GMD event; and (3) the benchmark GMD event definition is designed to provide a realistic estimate of wide-area effects caused by a severe GMD event. The Trade Associations contend that a non-spatially averaged reference peak geoelectric field amplitude “would be weighted by local effects and suggest unrealistic conditions for system analysis ... [which] could lead to unnecessary costs for customers, while yielding very little tangible benefit to reliability.”⁵² Like NERC, the Trade Associations cite to the 2015 Pulkkinen Paper to support the use of 500 km-wide squares in performing the spatial averaging analysis. The Trade Associations note, however, that the selection of 500 km is “only the beginning ... [of the] exploration of spatial geoelectric field structures pertaining to extreme GIC.”⁵³

39. The Trade Associations, while not supportive of the NOPR proposal, recommend that if the Commission remains concerned about relying on NERC’s proposed spatially-averaged reference peak geoelectric field amplitude, the Commission should:

allow NERC to further determine the appropriate localized studies to be performed by moving the “local hot spot” around a planning area. This approach may better ensure that the peak values only impact a local area instead of unrealistically projecting uniform peak values over a broad area. This approach also should better align with the Commission’s concerns because this type of study would more accurately reflect the real-world impact of a GMD event on the [Bulk-Power System]. The Trade

⁵² Trade Associations Comments at 15.

⁵³ *Id.* at 17 (quoting 2015 Pulkkinen Paper at 6).

Associations understand that existing planning tools may not yet have such capabilities, but the tools can be modified to allow such study.⁵⁴

40. Industry commenters raise other concerns with the NOPR proposal. CEA states that it would be inappropriate to rely on the non-spatially averaged 20 V/km reference peak geoelectric field figure because that figure is found in a single publication. CEA also contends that it is impractical to use “engineering judgment” to weigh the GMD Vulnerability Assessments using the spatially-averaged and non-spatially averaged reference peak geoelectric field amplitudes, as described in the NOPR.⁵⁵ ITC states that NERC’s proposal is reasonable and that the reference peak geoelectric field amplitude value can be revised periodically based on new information. Joint ISOs/RTOs state that the Commission should afford due weight to NERC’s technical expertise.

41. A September 2015 paper prepared by the Los Alamos National Laboratory states that it analyzed the IMAGE data using a different methodology to calculate reference peak geoelectric field amplitude values based on each of eight different magnetometer installations in Northern Europe. However, unlike the standard drafting team, the Los Alamos Paper did not spatially average the IMAGE data. The authors calculated peak geoelectric field amplitudes ranging from 8.4 V/km to 16.6 V/km, with a mean of

⁵⁴ *Id.* at 16.

⁵⁵ *See also* Hydro One Comments at 1-2; Resilient Societies Comments at 24-25.

the eight values equal to 13.2 V/km.⁵⁶ The authors used a statistical formula and probability distribution to determine their 1-in-100 year GMD event parameters, as opposed to the 20 V/km non-spatially averaged event from the 2012 paper cited in the GMD Interim Report that visually extrapolated the data.

42. Roodman contends that “NERC’s 100-year benchmark GMD event is appropriately conservative in magnitude (except perhaps in the southern-most US) if unrealistic in some other respects.”⁵⁷ Roodman states that “overall NERC’s analytical frame does not strongly clash with the data.”⁵⁸ However, Roodman contends that actual data support local hot-spots in a larger region of lower magnitude geoelectric fields that are not typically uniform in magnitude or direction.⁵⁹ Roodman addresses comments by Kappenman against the benchmark GMD event by stating that the Oak Ridge Report’s Meta-R-319 study, authored by Kappenman, modeled a 1-in-100 year GMD event based largely on misunderstandings of historic GMDs, both in magnitude and geographic

⁵⁶ Rivera, M., Backhaus, S., “Review of the GMD Benchmark Event in TPL-007-1,” Los Alamos National Laboratory (September 2015) (Los Alamos Paper).

⁵⁷ Roodman Comments at 4. Roodman criticizes the proposed benchmark GMD event definition because it assumes that the induced electrical field resulting from a GMD event is spatially uniform. Roodman also contends that a GMD event that is less than a 1-in-100 year storm could potentially damage transformers. *Id.* at 12-14.

⁵⁸ Roodman Comments at 9.

⁵⁹ *Id.* at 10, 12-13.

footprint.⁶⁰ Roodman recommends that the Commission “require a much larger array of events for simulation” in light of the “deep uncertainty and complexity of the GMD.”⁶¹

43. Commenters opposed to the benchmark GMD event definition proposed by NERC maintain that the standard drafting team significantly underestimated the reference peak geoelectric field amplitude value for a 1-in-100 year GMD event by relying on data from the IMAGE system and by applying spatial averaging to that data set.⁶² For example, Resilient Societies states that the standard drafting team should have analyzed “real-world data from within the United States and Canada, including magnetometer readings from the [USGS] and Natural Resources Canada observatories ... [h]ad NERC and the Standard Drafting Team collected and analyzed available real-world data, they would have likely found that the severity of GMD in 1-in-100 Year reference storm had been set far below a technically justified level and without a ‘strong technical basis.’”⁶³ Likewise, Kappenman contends that there are multiple examples where the benchmark GMD event and the standard drafting team’s model for calculating geoelectric fields under-predict

⁶⁰ *Id.* at 5-6 (citing Oak Ridge National Laboratory, *Geomagnetic Storms and Their Impacts on the U.S. Power Grid: Meta-R-319* at pages I-1 to I-3 (January 2010), http://www.ornl.gov/sci/ees/etsd/pes/pubs/ferc_Meta-R-319.pdf (Meta-R-319 Study).

⁶¹ *Id.* at 15.

⁶² *See, e.g.*, JINSA Comments at 2; Emprimus Comments at 1. *See also* Gaunt Comments at 9 (indicating that the proposed benchmark GMD event definition may underestimate the effects of a 1-in-100 GMD event).

⁶³ Resilient Societies Comments at 20-21.

actual, historical GIC readings.⁶⁴ Commenters opposed to NERC's proposal variously argue that the reference peak geoelectric field amplitude should be set at a level commensurate with the 1921 Railroad Storm or 1859 Carrington Event or at the 20 V/km level cited in the GMD Interim Report.⁶⁵

Commission Determination

44. The Commission approves the reference peak geoelectric field amplitude figure proposed by NERC. In addition, the Commission, as proposed in the NOPR, directs NERC to develop revisions to the benchmark GMD event definition so that the reference peak geoelectric field amplitude component is not based solely on spatially-averaged data. The Commission directs NERC to submit this revision within 18 months of the effective date of this Final Rule.

45. NERC and industry comments do not contain new information to support relying solely on spatially-averaged data to calculate the reference peak geoelectric field amplitude in the benchmark GMD event definition. The 2015 Pulkkinen Paper contains the same justifications for spatial averaging as those presented in NERC's petition. In addition, the 2015 Pulkkinen Paper validates the NOPR's concerns with relying solely on

⁶⁴ Kappenman Comments at 15- 29.

⁶⁵ See, e.g., EIS Comments at 2 (advocating use of 20 V/km); Gaunt Comments at 6-9 (contending that NERC's proposed figure results in a "possible underestimation of the effects of GICs" without suggesting an alternative figure); JINSA Comments at 2 (advocating use of 20 V/km); Emprimus Comments at 1 (advocating use of 20 V/km); Briggs Comments at 1 (advocating that the benchmark GMD event should be a "Carrington Class solar superstorm").

spatial averaging generally and with the method used by the standard drafting team to spatially average the IMAGE data specifically. The 2015 Pulkkinen Paper, for example, states that “regional scale geoelectric fields have not been considered earlier from the statistical and extreme analyses standpoint” and “selection of an area of 500 km [for spatial averaging] ...[is] subjective.”⁶⁶ Further, the 2015 Pulkkinen Paper notes that “we emphasize that the work described in this paper is only the beginning in our exploration of spatial geoelectric field structures pertaining to extreme GIC ... [and] [w]e will ... expand the statistical analyses to include characterization of multiple different spatial scales.”⁶⁷ On the latter point, NERC “agrees that such research would provide additional modeling insights and supports further collaborative efforts between space weather researchers and electric utilities through the NERC GMD Task Force.”⁶⁸ These statements support the NOPR’s observation that the use of spatial averaging in this context is new, and thus there is a dearth of information or research regarding its application or appropriate scale.

46. While we believe our directive addresses concerns with relying solely on spatially-averaged data, we reiterate the position expressed in the NOPR that a GMD event will have a peak value in one or more location(s) and the amplitude will decline over distance

⁶⁶ 2015 Pulkkinen Paper at 2.

⁶⁷ *Id.* at 6.

⁶⁸ NERC Comments at 8.

from the peak; and, as a result, imputing the highest peak geoelectric field value in a planning area to the entire planning area may incorrectly overestimate GMD impacts.⁶⁹

Accordingly, our directive should not be construed to prohibit the use of spatial averaging in some capacity, particularly if more research results in a better understanding of how spatial averaging can be used to reflect actual GMD events.

47. The NOPR proposed to direct NERC to revise Reliability Standard TPL-007-1 so that the reference peak geoelectric field value is not based solely on spatially-averaged data. NERC and industry comments largely focused on the NOPR's discussion of one possible example to address the directive (i.e., by running GMD Vulnerability Assessments using spatially-averaged and non-spatially averaged reference peak geoelectric field amplitudes). However, while the method discussed in the NOPR is one possible option, the NOPR did not propose to direct NERC to develop revisions based on that option or any specific option. The Trade Associations' comments, discussed above, demonstrate that there is another way to address the NOPR directive (i.e., by performing planning models that also assess planning areas for localized "hot spots"). This approach may have merit if, for example, the geographic size of the hot spot is supported by actual data and the hot spot is centered over one or more locations that include an entity's facilities that become critical during a GMD event. Without pre-judging how NERC proposes to address the Commission's directive, NERC's response to this directive

⁶⁹ NOPR, 151 FERC ¶ 61,134 at P 35.

should satisfy the NOPR's concern that reliance on spatially-averaged data alone does not address localized peaks that could potentially affect the reliable operation of the Bulk-Power System.

48. We believe our directive should also largely address the comments submitted by entities opposed to NERC's proposed reference peak geoelectric field amplitude. Those commenters endorsed using a higher reference peak geoelectric field amplitude value, such as the 20 V/km cited in the GMD Interim Report. At the outset, we observe that the comments critical of the standard drafting team's use of the IMAGE data only speculate that had the standard drafting team used other sources, the calculated reference peak geoelectric field amplitude value would have been higher.⁷⁰ Moreover, among the commenters critical of NERC's proposal, there is disagreement over the magnitude of historical storms which some of these commenters would use as a model.⁷¹ While NERC has discretion on how to propose to address our directive, NERC could revise Reliability Standard TPL-007-1 to apply a higher reference peak geoelectric field amplitude value to assess the impact of localized hot spots on the Bulk-Power System, as suggested by the

⁷⁰ See, e.g., Resilient Societies Comments at 21 (“Had NERC and the Standard Drafting Team collected and analyzed available real-world data, they *would have likely found* that the severity of GMD in 1-in-100 Year reference storm had been set far below a technically justified level ...” (emphasis added)).

⁷¹ See, e.g., Gaunt Comments at 13 (stating that the 1859 Carrington Event is “probably outside the re-occurrence frequency of 1:100 years adopted by NERC for the benchmark event”); Briggs Comments at 1 (advocating using a “‘Carrington Class’ super storm” as the benchmark GMD event).

Trade Associations. The effects of such hot spots could include increases in GIC levels, volt-ampere reactive power consumption, harmonics on the Bulk-Power System (and associated misoperations) and transformer heating. Moreover, the directive to revise Reliability Standard TPL-007-1 and, as discussed below, the directives to research geomagnetic latitude scaling factors and earth conductivity models as part of the GMD research work plan and to revise Reliability Standard TPL-007-1 to require the collection of necessary GIC monitoring and magnetometer data to validate GMD models should largely address or at least help to focus-in on factors that may be causing any inaccuracies in the standard drafting team's model.

49. Consistent with Order No. 779, the Commission does not specify a particular reference peak geoelectric field amplitude value that should be applied to hot spots given present uncertainties. While 20 V/km would seem to be a possible value, the Los Alamos Paper suggests that the 20 V/km figure may be too high. The Los Alamos Paper analyzed the non-spatially averaged IMAGE data to calculate a reference peak geoelectric field amplitude range (i.e., 8.4 V/km to 16.6 V/km) that is between NERC's proposed spatially-averaged value of 8 V/km and the non-spatially averaged 20 V/km figure cited in the GMD Interim Report.

50. Although the NOPR did not propose to direct NERC to submit revisions to Reliability Standard TPL-007-1 by a certain date with respect to the benchmark GMD event definition, the Commission determines that it is appropriate to impose an 18-month deadline from the effective date of this Final Rule. As discussed below, the Commission approves the five-year implementation period for Reliability Standard TPL-007-1

proposed by NERC. Having NERC submit revisions to the benchmark GMD event definition within 18 months of the effective date of this Final Rule, with the Commission acting promptly on the revised Reliability Standard, should afford enough time to apply the revised benchmark GMD event definition in the first GMD Vulnerability Assessment under the timeline set forth in Reliability Standard TPL-007-1's implementation plan. If circumstances, such as the complexity of the revised benchmark GMD event, require it, NERC may propose and justify a revised implementation plan.

2. Geomagnetic Latitude Scaling Factor

NOPR

51. The NOPR proposed to approve the geomagnetic latitude scaling factor in NERC's proposed benchmark GMD event definition. However, the NOPR sought comment on whether, in light of studies indicating that GMD events could have pronounced effects on lower geomagnetic latitudes, a modification is warranted to reduce the impact of the scaling factors.⁷²

⁷² NOPR, 151 FERC ¶ 61,134 at P 37 (citing Ngwira, C. M., Pulkkinen, A., Kuznetsova, M. M., Glocer, A., "Modeling extreme 'Carrington-type' space weather events using three-dimensional global MHD simulations," 119 *Journal of Geophysical Research: Space Physics* 4472 (2014) (finding that in Carrington-type events "the region of large induced ground electric fields is displaced further equatorward ... [and] thereby may affect power grids ... such as [those in] southern states of [the] continental U.S."); Gaunt, C. T., Coetzee, G., "Transformer Failures in Regions Incorrectly Considered to have Low GIC-Risk," 2007 *IEEE Lausanne* 807 (July 2007) (stating that twelve transformers were damaged and taken out of service in South Africa (at -40 degrees latitude) during the October 2003 Halloween Storm GMD event)). *See also* Liu, C., Li, Y., Pirjola, R., "Observations and modeling of GIC in the Chinese large-scale high-voltage power networks," *Journal Space Weather Space Climate* 4 at A03-p6 (2014) (Liu

(continued...)

Comments

52. NERC contends that the geomagnetic latitude scaling factor in Reliability Standard TPL-007-1 “accurately models the reduction of induced geoelectric fields that occurs over the mid-latitude region during a 100-year GMD event scenario ... [and] describes the observed drop in geoelectric field that has been exhibited in analysis of major recorded geomagnetic storms.”⁷³ NERC maintains that modifying the scaling factor is not technically justified based on the publications cited in the NOPR. NERC states that the first paper cited in the NOPR is based on models that are not mature and reflect a 1-in-150 year storm. NERC contends that the second paper does not clearly show that the purported transformer damage in South Africa was the result of abnormally high GICs during the October 2003 Halloween Storm. NERC further states that the standard drafting team analyzed the October 2003 Halloween Storm when developing the proposed geomagnetic latitude scaling factor.

53. The Trade Associations support the geomagnetic latitude scaling factor proposed by NERC. Like NERC, the Trade Associations contend that the papers cited in the NOPR do not support modifications because the models in the first paper “remain highly

Paper), <http://www.swsc-journal.org/articles/swsc/pdf/2014/01/swsc130009.pdf> (finding that GICs of about 25A/phase had been measured in a transformer at a nuclear power plant at 22.6 degrees north latitude (significantly further away from the magnetic pole than Florida)).

⁷³ NERC Comments at 9 (citing Ngwira, C., Pulkkinen, A., Wilder, F., Crowley, G., “Extended Study of Extreme Geoelectric Field Event Scenarios for Geomagnetically Induced Current Applications,” 11 Space Weather 121 (2013) (Ngwira 2013 Paper)).

theoretical and not sufficiently validated” and because the second paper likely involved other causal factors leading to the transformer failure.⁷⁴ Joint ISOs/RTOs also support the geomagnetic latitude scaling factor proposed by NERC. ITC states that NERC’s proposal is a “reasonable approach given the current state of the science pertaining to GMD ... [but] that as the science pertaining to GMD matures and more data becomes available, the scaling factors should be revisited and revised.”⁷⁵ ITC suggests revisiting the geomagnetic latitude scaling factor every five years to incorporate any new developments in GMD science.

54. Several commenters question or disagree with the geomagnetic latitude scaling factors in Reliability Standard TPL-007-1 based on simulations and reports of damage to transformers in areas expected to be at low risk due to their geomagnetic latitude.⁷⁶ EIS contends that the proposed geomagnetic latitude scaling factor’s assumption of a storm centered at 60 degrees geomagnetic latitude is inconsistent with a study relied upon by NERC.⁷⁷ The Los Alamos Paper’s analysis suggests that NERC’s proposed geomagnetic latitude scaling factors, while they fit well with weaker historical GMD events from

⁷⁴ Trade Associations Comments at 18-19.

⁷⁵ Joint ISOs/RTOs Comments at 5.

⁷⁶ *See, e.g.*, Gaunt Comments at 6; JINSA Comments at 2; Emprimus Comments at 2-3; Roodman Comments at 9; Resilient Societies Comments at 31-31; Kappenman Comments at 41-42.

⁷⁷ EIS Comments at 5 (citing Ngwira 2013 Paper).

which they were derived, may not accurately represent the effects of a 1-in-100 year GMD event at lower geomagnetic latitudes. The Los Alamos Paper states that a model of the electrojet is needed to “effectively extrapolate the small to moderate disturbance data currently in the historical record to disturbances as large as the TPL-007-1 Benchmark Event.”⁷⁸ The Los Alamos Paper uses a larger number of geomagnetic disturbances (122 instead of 12) and a wider range of observatories by using the world-wide SuperMAG magnetometer array data, which includes the INTERMAGNET data used to support NERC’s geomagnetic latitude scaling factors. The Los Alamos Paper shows that for more severe storms ($Dst < -300$, for which there are nine storms in the data set) the NERC scaling factors tend to be low, off by a factor of up to two or three at some latitudes. The Los Alamos Paper also recommends “an additional degree of conservatism in the mid-geomagnetic latitudes” until such time as a model is developed.⁷⁹ The Los Alamos Paper authors recommend a factor of 2 as a conservative correction.

Commission Determination

55. The Commission approves the geomagnetic latitude scaling factor in the benchmark GMD event definition. In addition, the Commission directs NERC to conduct further research on geomagnetic latitude scaling factors as part of the GMD research work plan discussed below.

⁷⁸ Los Alamos Paper at 12.

⁷⁹ *Id.*

56. Based on the record, the Commission finds sufficient evidence to conclude that lower geomagnetic latitudes are, to some degree, less susceptible to the effects of GMD events. The issue identified in the NOPR and by some commenters focused on the specific scaling factors in Reliability Standard TPL-007-1 in light of some analyses and anecdotal evidence suggesting that lower geomagnetic latitudes may be impacted by GMDs to a larger degree than reflected in Reliability Standard TPL-007-1.

57. The geomagnetic latitude scaling factor in Reliability Standard TPL-007-1 is supported by some of the available research.⁸⁰ In addition, with the exception of the Los Alamos Paper, commenters did not provide new information on the proposed scaling factor nor did commenters suggest alternative scaling factors. However, the Commission finds that there are enough questions regarding the effects of GMDs at lower geomagnetic latitudes to warrant directing NERC to study this issue further as part of the GMD research work plan. The Los Alamos Paper and the sources cited in the NOPR are suggestive that a 1-in-100 year GMD event could have a greater impact on lower

⁸⁰ See NERC Comments at 9 (citing Ngwira 2013 Paper). We disagree with the contention made by EIS that NERC's proposed geomagnetic latitude scaling factors are inconsistent with the Ngwira 2013 Paper. EIS maintains that the Ngwira 2013 Paper supports the conclusion that the benchmark GMD event should be centered at 50 degrees geomagnetic latitude instead of the 60 degree geomagnetic latitude figure in Reliability Standard TPL-007-1. The Ngwira 2013 Paper contains no such conclusion. Instead, the Ngwira 2013 Paper found that the latitude threshold boundary is a transition region having a definite lower bound of 50 degrees geomagnetic latitude but with an upper range as high as 55 degrees geomagnetic latitude. Ngwira 2013 Paper at 127, 130. The Ngwira 2013 Paper also stated that its findings were "in agreement with earlier observations by [Thomson et al., 2011] and more recently by [Pulkkinen et al., 2012], which estimated the location to be within 50 [degrees]–62 [degrees]." *Id.* at 124.

geomagnetic latitudes than NERC's proposed scaling factor assumes. But, as the Los Alamos Paper recognizes, the current absence of historical data on large GMD events precludes a definitive conclusion based on an empirical analysis of historical observations. Moreover, in prepared comments for the March 1, 2016 Technical Conference, Dr. Backhaus, one of the authors of the Los Alamos Paper, recommended that "the current NERC analysis should be adopted and further analysis performed with additional observational data and severe disturbance modeling efforts with the intent of refining the geomagnetic latitude scaling law in future revisions."⁸¹ The Commission directs NERC to reexamine the geomagnetic latitude scaling factors in Reliability Standard TPL-007-1 as part of the GMD research work plan, including using existing models and developing new models to extrapolate from historical data on small to moderate GMD events the impacts of a large, 1-in-100 year GMD event on lower geomagnetic latitudes.

B. Thermal Impact Assessments

NERC Petition

58. Reliability Standard TPL-007-1, Requirement R6 requires owners of transformers that are subject to the Reliability Standard to conduct thermal analyses to determine if the transformers would be able to withstand the thermal effects associated with a benchmark GMD event. NERC states that transformers are exempt from the thermal impact

⁸¹ Statement of Scott Backhaus, March 1, 2016 Technical Conference at 2.

assessment requirement if the maximum effective GIC in the transformer is less than 75 A/phase during the benchmark GMD event as determined by an analysis of the system. NERC explains that “based on available power transformer measurement data, transformers with an effective GIC of less than 75 A/phase during the Benchmark GMD Event are unlikely to exceed known temperature limits established by technical organizations.”⁸²

59. As provided in Requirements R5 and R6, “the maximum GIC value for the worst case geoelectric field orientation for the benchmark GMD event described in Attachment 1” determines whether a transformer satisfies the 75 A/phase threshold. If the 75 A/phase threshold is satisfied, Requirement R6 states, in relevant part, that a thermal impact assessment should be conducted on the qualifying transformer based on the effective GIC flow information provided in Requirement R5.

60. In its June 28, 2016 filing, NERC states that it identified an error in Figure 1 (Upper Bound of Peak Metallic Hot Spot Temperatures Calculated Using the Benchmark GMD Event) of the White Paper on Screening Criterion for Transformer Thermal Impact Assessment that resulted in incorrect plotting of simulated power transformer peak hot-spot heating from the benchmark GMD event. NERC revised Figure 1 in the White Paper on Screening Criterion for Transformer Thermal Impact Assessment and made corresponding revisions to related text, figures and tables throughout the technical white

⁸² NERC Petition at 30.

papers supporting the proposed standard. NERC maintains that even with the revision to Figure 1, “the standard drafting team determined that the 75 A per phase threshold for transformer thermal impact assessment remains a valid criterion ... [and] it is not necessary to revise any Requirements of the proposed Reliability Standard.”⁸³

NOPR

61. The NOPR proposed to approve the transformer thermal impact assessments in Requirement R6. In addition, as with the benchmark GMD event definition, the NOPR proposed to direct NERC to revise Requirement R6 to require registered entities to apply spatially averaged and non-spatially averaged peak geoelectric field values, or some equally efficient and effective alternative, when conducting thermal impact assessments. The NOPR also noted that Requirement R6 does not use the maximum GIC-producing orientation to conduct the thermal assessment for qualifying transformers; instead, the requirement uses the effective GIC time series described in Requirement R5.2 to conduct the thermal assessment on qualifying transformers. The NOPR sought comment from NERC as to why qualifying transformers are not assessed for thermal impacts using the maximum GIC-producing orientation and directed NERC to address whether, by not using the maximum GIC-producing orientation, the required thermal impact assessments could underestimate the impact of a benchmark GMD event on a qualifying transformer.

⁸³ NERC June 28, 2016 Filing at 1.

Comments

62. NERC opposes modifying the thermal impact assessments in Requirement R6 so that the assessments do not rely only on spatially-averaged data. NERC claims that the benchmark GMD event definition will “result in GIC calculations that are appropriately scaled for system-wide assessments.”⁸⁴ NERC also contends that the “analysis performed by the standard drafting team of the impact of localized enhanced geoelectric fields on the GIC levels in transformers indicates that relatively few transformers in the system are affected.”⁸⁵ In response to the question in the NOPR of why qualifying transformers are not assessed for thermal impacts using the maximum GIC producing orientation, NERC states that “the orientation of the geomagnetic field varies widely and continuously during a GMD event ... [and] would be aligned with the maximum GIC-producing orientation for only a few minutes.”⁸⁶ NERC concludes that “[i]n the context of transformer hot spot heating with time constants in the order of tens of minutes, alignment with any particular orientation for a few minutes at a particular point in time is not a driving concern.”⁸⁷ NERC further states that the wave shape used in Reliability

⁸⁴ NERC Comments at 17.

⁸⁵ *Id.*

⁸⁶ *Id.* at 19.

⁸⁷ *Id.*

Standard TPL-007-1 provides “generally conservative results when performing thermal analysis of power transformers.”⁸⁸

63. The Trade Associations and CEA do not support the proposed NOPR directive because, they state, it focuses too heavily on individual transformers. The Trade Associations maintain that Reliability Standard TPL-007-1 “was never intended to address specific localized areas that might experience peak conditions and affect what we understand to be a very small number of assets that are unlikely to initiate a cascading outage.”⁸⁹

64. Certain non-industry commenters contend that the 75 A/phase qualifying threshold for thermal impact assessments is not technically justified. Emprimus contends that “many transformers have GIC ratings less than 75 amps per phase,” but Emprimus claims that an Idaho National Lab study showed that “GIC introduced at 10 amps per phase on high voltage transformers exceed harmonic levels allowed under IEEE 519.”⁹⁰

Emprimus also maintains that a 2013 IEEE paper “suggest[s] that there can be generator rotor damage at GIC levels which exceed 50 amps per phase.”⁹¹ Gaunt contends, based on his analysis of historical events, that “degradation is initiated in transformers by

⁸⁸ *Id.*

⁸⁹ Trade Associations Comments at 21.

⁹⁰ Emprimus Comments at 4.

⁹¹ *Id.*

currents that are significantly below the 75 amps per phase.”⁹² Gaunt states that “[u]ntil better records are kept of transformer [dissolved gas in oil analysis] and transformer failure, the proposed level of 75 [A/phase] of GIC needed to initiate assessment of transformer response must be considered excessively high.”⁹³ Gaunt recommends a qualifying threshold of 15 amps per phase. Resilient Societies states that the 75 A/phase threshold is based on a mathematical model for one type of transformer and that several tests referenced in the standard drafting team’s White Paper on Transformer Thermal Impact Assessment were carried out under no load or minimal load conditions. In addition, Resilient Societies contends that applying the 75 A/phase threshold and NERC’s proposed benchmark GMD event (i.e., using the spatially-averaged reference peak geoelectric field amplitude) results in only “two out of approximately 560 extra high voltage transformers” requiring thermal impact assessments in the PJM region; only one 345 kV transformer requiring thermal impact assessment in Maine; and zero transformers requiring thermal impact assessments in ATC’s network.⁹⁴ Kappenman contends that the

⁹² Gaunt Comments at 13.

⁹³ *Id.* at 14.

⁹⁴ Resilient Societies Comments at 5-14. Resilient Societies states that modeling performed by Central Maine Power Co. and Emprimus for the Maine Public Utilities Commission indicates that eight 345 kV transformers (53 percent according to Resilient Societies) would require thermal impact assessments in Maine if the reference peak geoelectric field amplitude were set at 20 V/km. *Id.* at 10. Resilient Societies also contends that this result is consistent with the Oak Ridge Meta-R-319 Study’s finding that eight transformers would be “at risk” in Maine under a “30 Amp At-Risk Threshold scenario.” *Id.* Central Maine Power Co. calculated that the scaled NERC benchmark

(continued...)

75 A/phase threshold does not consider transformers with tertiary windings or autotransformers which may be impacted at lower GIC levels than 75 A/phase.⁹⁵

Commission Determination

65. Consistent with our determination above regarding the reference peak geoelectric field amplitude value, the Commission directs NERC to revise Requirement R6 to require registered entities to apply spatially averaged and non-spatially averaged peak geoelectric field values, or some equally efficient and effective alternative, when conducting thermal impact assessments.

66. In the NOPR, the Commission requested comment from NERC regarding why Requirement R6 does not use the maximum GIC-producing orientation to conduct the thermal assessment for qualifying transformers. After considering NERC's response, we continue to have concerns with not using the maximum GIC-producing orientation for the thermal assessment of transformers. However, at this time we do not direct NERC to modify Reliability Standard TPL-007-1. Instead, as part of the GMD research work plan discussed below, NERC is directed to study this issue to determine how the geoelectric field time series can be applied to a particular transformer so that the orientation of the

GMD event for the northernmost point in Maine would be 4.53 V/km. Resilient Societies' calculations regarding ATC estimate that the scaled benchmark GMD event for Wisconsin would be 2 V/km. *Id.* at 14.

⁹⁵ The Commission received two comments following NERC's June 28, 2016 Filing. However, the supplemental comments did not specifically address the revisions submitted in NERC's June 28, 2016 filing.

time series, over time, will maximize GIC flow in the transformer, and to include the results in a filing with the Commission.

67. We are not persuaded by the comments opposed to Requirement R6's application of a 75 A/phase qualifying threshold. The standard drafting team's White Paper on Thermal Screening Criterion, as revised by NERC in the June 28, 2016 Filing, provides an adequate technical basis to approve NERC's proposal. As noted in the revised White Paper on Thermal Screening Criterion, the calculated metallic hot spot temperature corresponding to an effective GIC of 75 A/phase is 172 degrees Celsius; that figure is higher than the original figure of 150 degrees Celsius calculated by the standard drafting team but is still below the 200 degree Celsius limit specified in IEEE Std C57.91-2011.⁹⁶ The comments, particularly those of Gaunt, attempt to correlate historical transformer failures to past GMD events (e.g., 2003 Halloween Storm), while arguing that the transformers damaged in those events did not experience GICs of 75 A/phase. The evidence adduced by Gaunt and others is inconclusive.⁹⁷ We therefore direct NERC to include further analysis of the thermal impact assessment qualifying threshold in the GMD research work plan.

⁹⁶ NERC June 28, 2016 Filing, Revised White Paper on Screening Criterion for Transformer Thermal Impact Assessment at 3.

⁹⁷ *See, e.g.*, Gaunt Comments at 13 (“Although it has not been possible to assemble an exact model of the power system during the period 29-31 October 2003, and data on the ground conductivity in Southern Africa is not known with great certainty, we are confident that the several calculations of GIC that been carried out are not grossly inaccurate.”).

68. In NOPR comments and in comments to the standard drafting team, Kappenman stated that delta winding heating due to harmonics has not been adequately considered by the standard drafting team and that, thermally, this is a bigger concern than metallic hot spot heating.⁹⁸ The standard drafting team responded that the vulnerability described for tertiary winding harmonic heating is based on the assumption that delta winding currents can be calculated using the turns ratio between primary and tertiary winding, which is incorrect when a transformer is under saturation.⁹⁹ The standard drafting team concluded that Kappenman's concerns regarding delta windings being a problem from a thermal standpoint are unwarranted and that the criteria developed by the standard drafting team use state-of-the-art analysis methods and measurement-supported transformer models. The Commission believes that the heating effects of harmonics on transformers, as discussed at the March 1, 2016 Technical Conference, are of concern and require further research.¹⁰⁰ Accordingly, we direct NERC to address the effects of harmonics, including

⁹⁸ Kappenman Comments at 45.

⁹⁹ Consideration of Comments Project 2013-03 Geomagnetic Disturbance Mitigation at 39 (December 5, 2014), http://www.nerc.com/pa/Stand/Project201303GeomagneticDisturbanceMitigation/Comment%20Report%20_2013-03_GMD_12052014.pdf.

¹⁰⁰ At the March 1, 2016 Technical Conference, Dr. Horton, a member of the standard drafting team, discussed the potential negative impacts of harmonics generated by GMDs on protection systems, reactive power resources and generators. Slide Presentation of Randy Horton, March 1, 2016 Technical Conference at 2-6.

tertiary winding harmonic heating and any other effects on transformers, as part of the GMD research work plan.¹⁰¹

C. GMD Research Work Plan

NOPR

69. The NOPR proposed to address the need for more data and certainty regarding GMD events and their potential effect on the Bulk-Power System by directing NERC to submit informational filings that address GMD-related research areas. The NOPR proposed to direct NERC to submit in the first filing a GMD research work plan indicating how NERC plans to: (1) further analyze the area over which spatial averaging should be calculated for stability studies, including performing sensitivity analyses on squares less than 500 km per side (e.g., 100 km, 200 km); (2) further analyze earth conductivity models by, for example, using metered GIC and magnetometer readings to calculate earth conductivity and using 3-D readings; (3) determine whether new analyses and observations support modifying the use of single station readings around the earth to adjust the spatially averaged benchmark for latitude; and (4) assess how to make GMD data (e.g., GIC monitoring and magnetometer data) available to researchers for study.

70. With respect to GIC monitoring and magnetometer readings, the NOPR sought comment on the barriers, if any, to public dissemination of such readings, including if

¹⁰¹ NERC indicated in its comments that it is already studying the issue of harmonics. NERC Comments at 14 (“NERC is collaborating with researchers to examine more complex GMD vulnerability issues, such as harmonics and mitigation assessment techniques, to enhance the modeling capabilities of the industry”).

their dissemination poses a security risk and if any such data should be treated as Critical Energy Infrastructure Information or otherwise restricted to authorized users. The NOPR proposed that NERC submit the GMD research work plan within six months of the effective date of a final rule in this proceeding. The NOPR also proposed that the GMD research work plan submitted by NERC should include a schedule for submitting one or more informational filings that apprise the Commission of the results of the four additional study areas, as well as any other relevant developments in GMD research, and should assess whether Reliability Standard TPL-007-1 remains valid in light of new information or whether revisions are appropriate.

Comments

71. NERC states that continued GMD research is necessary and that the potential impacts of GMDs on reliability are evolving. NERC, however, prefers that the NERC GMD Task Force continue its research without the GMD research work plan proposed in the NOPR. NERC contends that allowing the NERC GMD Task Force to continue its work would “accomplish NERC’s and the Commission’s shared goals in advancing GMD understanding and knowledge, while providing the flexibility necessary for NERC to work effectively with its international research partners to address risks to the reliability of the North American Bulk-Power System.”¹⁰² NERC also claims that, in addition to being unnecessary given the work of the NERC GMD Task Force, the NOPR

¹⁰² NERC Comments at 13.

proposal “poses practical challenges ... [because it would] bind[] NERC to a specific and inflexible research plan and report schedule to be determined six months (or even a year) following the effective date of a final rule in this proceeding.”¹⁰³

72. The Trade Associations and CEA do not support the GMD research work plan. Instead, they contend that NERC should be allowed to pursue GMD research independently.

73. Several commenters, while not addressing the NOPR proposal specifically, state that additional research is necessary to validate or improve elements of the benchmark GMD event definition.¹⁰⁴

74. The Trade Associations state that monitoring data should be available for academic research purposes. Resilient Societies contends that monitoring data should be publicly disseminated on a regular basis and that there is no security risk in releasing such data because they relate to naturally occurring phenomena. Emprimus states that it supports making GIC and magnetometer monitoring data available to the public. Bardin supports making GIC and GMD-related information to the public or at least to “legitimate researchers.”

¹⁰³ *Id.* at 16.

¹⁰⁴ *See, e.g.*, USGS Comments at 1 (addressing earth conductivity models), Bardin Comments at 2 (addressing earth conductivity models); Roodman Comments at 3 (addressing reference peak geoelectric field amplitude); Gaunt Comments at 7 (addressing spatial averaging).

75. Hydro One and CEA do not support mandatory data sharing without the use of non-disclosure agreements.

Commission Determination

76. The Commission recognizes, as do commenters both supporting and opposing proposed Reliability Standard TPL-007-1, that our collective understanding of the threats posed by GMD is evolving as additional research and analysis are conducted. These ongoing efforts are critical to the nation's long-term efforts to protect the grid against a major GMD event. While we approve NERC's proposed Reliability Standard TPL-007-1 and direct certain modifications, as described above, the Commission also concludes that facilitating additional research and analysis is necessary to adequately address these threats. As discussed in the next two sections of this final rule, the Commission directs a three-prong approach to further those efforts by directing NERC to: (1) develop, submit, and implement a GMD research work plan; (2) develop revisions to Reliability Standard TPL-007-1 to require responsible entities to collect GIC monitoring and magnetometer data; and (3) collect GIC monitoring and magnetometer data from registered entities for the period beginning May 2013, including both data existing as of the date of this order and new data going forward, and to make that information available.

77. First, the Commission adopts the NOPR proposal and directs NERC to submit a GMD research work plan and, subsequently, informational filings that address the GMD-related research areas identified in the NOPR, additional research tasks identified in this Final Rule (i.e., the research tasks identified in the thermal impact assessment discussion above) and, in NERC's discretion, any GMD-related research areas generally that may

impact the development of new or modified GMD Reliability Standards.¹⁰⁵ The GMD research work plan should be submitted within six months of the effective date of this final rule. The research required by this directive should be informed by ongoing GMD-related research efforts of entities such as USGS, National Atmospheric and Oceanic Administration (NOAA), National Aeronautics and Space Administration, Department of Energy, academia and other publicly available contributors, including work performed for the National Space Weather Action Plan.¹⁰⁶

78. As part of the second research area identified in the NOPR (i.e., further analyze earth conductivity models by, for example, using metered GIC and magnetometer readings to calculate earth conductivity and using 3-D readings), the GMD research work plan should specifically investigate “coastal effects” on ground conductivity models.

79. In addition, the large variances described by USGS in actual 3-D ground conductivity data raise the question of whether one time series geomagnetic field is sufficient for vulnerability assessments. The characteristics, including frequencies, of the time series interact with the ground conductivity to produce the geoelectric field that

¹⁰⁵ The GMD research work plan need not address the fourth research area identified in the NOPR (i.e., assess how to make GIC monitoring and magnetometer data available to researchers for study) given the Commission’s directive and discussion below regarding the collection and dissemination of necessary GIC monitoring and magnetometer data.

¹⁰⁶ National Science and Technology Council, National Space Weather Action Plan (October 2015), https://www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatheractionplan_20151028.pdf.

drives the GIC. Therefore, the research should address whether additional realistic time series should be selected to perform assessments in order to capture the time series that produces the most vulnerability for an area.

80. The comments largely agree that additional GMD research should be pursued, particularly with respect to the elements of the benchmark GMD event definition (i.e., the reference peak geoelectric field amplitude value, geomagnetic latitude scaling factor, and earth conductivity scaling factor). There is ample evidence in the record to support the need for additional GMD-related research.¹⁰⁷ For example, USGS submitted comments indicating that USGS's one dimensional ground electrical conductivity models used by the standard drafting team have a "significant limitation" in that they assume that a "[one dimensional] conductivity-with-depth profile can adequately represent a large geographic region," which USGS describes as a "gross simplification."¹⁰⁸ USGS observes that while the "proposed standard attempted to incorporate the best scientific research available ... it must be noted that the supporting science is quickly evolving."¹⁰⁹ USGS recommends that "the proposed standard should establish a process for updates and improvements that

¹⁰⁷ See, e.g., NERC October 22, 2015 Supplemental Comments at 7-8 (expressing support for additional research regarding geomagnetic latitude scaling factors and earth conductivity models).

¹⁰⁸ USGS Comments at 1.

¹⁰⁹ *Id.*

acknowledges and addresses the quickly evolving nature of relevant science and associated data.”¹¹⁰

81. Opposition to the proposal centers on the contention that the proposed directive is unnecessary and potentially counterproductive given the continuing work of the NERC GMD Task Force. We do not find these comments persuasive. Our directive requires NERC to submit a work plan for the study of GMD-related issues that are already being examined or that NERC agrees should be studied.¹¹¹ Nothing in our directive precludes NERC from continuing to use the NERC GMD Task Force as a vehicle for conducting the directed research or other research. Indeed, we encourage NERC to continue to use

¹¹⁰ *Id.* We note that Reliability Standard TPL-007-1, Att. 1 (Calculating Geoelectric Fields for the Benchmark GMD Event) already provides that a “planner can also use specific earth model(s) with documented justification...” Accordingly, Reliability Standard TPL-007-1 includes a mechanism for incorporating improvements in earth conductivity models when calculating the benchmark GMD event.

¹¹¹ *See, e.g.*, NERC Comments at 8 (“NERC agrees that [spatial averaging] research would provide additional modeling insights and supports further collaborative efforts between space weather researchers and electric utilities through the NERC GMD Task Force”), at 10 (“NERC agrees that additional [geomagnetic latitude scaling] research is necessary, and supports the significant research that is occurring throughout the space weather community to develop and validate models and simulation techniques”), at 13 (“Working with EPRI, researchers at USGS, and industry, NERC will work to improve the earth conductivity models that are a vital component to understanding the risks of GMD events in each geographic region”), and at 23 (“efforts are already underway to expand GMD monitoring capabilities ... [and] [t]hrough these efforts, NERC and industry should effectively address the concerns noted by the Commission in the NOPR, including ensuring a more complete set of data for operational and planning needs and supporting analytical validation and situational awareness”).

the GMD Task Force as a forum for engagement with interested stakeholders. In addition, we do not set specific deadlines for completion of the research; we only require NERC to submit the GMD research work plan within six months of the effective date of a final rule. The GMD research work plan, in turn, should include target dates for the completion of research topics and the reporting of findings to the Commission. The Commission intends to notice and invite comment on the GMD research work plan. An extension of time to submit the GMD research work plan may be available if six months proves to be insufficient. In addition, given the uncertainties commonly associated with complex research projects, the Commission will be flexible regarding changes to the tasks and target dates established in the GMD research work plan.

D. Monitoring Data

NERC Petition

82. Reliability Standard TPL-007-1, Requirement R2 requires responsible entities to “maintain System models and GIC System models of the responsible entity’s planning area for performing the study or studies needed to complete GMD Vulnerability Assessment(s).” NERC states that Reliability Standard TPL-007-1 contains “requirements to develop the models, studies, and assessments necessary to build a picture of overall GMD vulnerability and identify where mitigation measures may be necessary.”¹¹² NERC explains that mitigating strategies “may include installation of

¹¹² NERC Petition at 13.

hardware (e.g., GIC blocking or monitoring devices), equipment upgrades, training, or enhanced Operating Procedures.”¹¹³

NOPR

83. The NOPR proposed to direct NERC to revise Reliability Standard TPL-007-1 to require the installation of monitoring equipment (i.e., GIC monitors and magnetometers) to the extent there are any gaps in existing GIC monitoring and magnetometer networks. Alternatively, the NOPR sought comment on whether NERC should be responsible for installation of any additional, necessary magnetometers while affected entities would be responsible for installation of additional, necessary GIC monitors. The NOPR also proposed that, as part of NERC’s work plan, NERC identify the number and location of current GIC monitors and magnetometers in the United States to assess whether there are any gaps. The NOPR sought comment on whether the Commission should adopt a policy specifically allowing recovery of costs associated with or incurred to comply with Reliability Standard TPL-007-1, including for the purchase and installation of monitoring devices.

Comments

84. NERC does not support the NOPR proposal regarding the installation of GIC monitoring devices and magnetometers. NERC contends that the proposed requirement is not necessary because Reliability Standard TPL-007-1 “supports effective GMD

¹¹³ *Id.* at 32.

monitoring programs, and additional efforts are planned or underway to ensure adequate data for reliability purposes.”¹¹⁴ NERC also maintains that the proposed directive “poses implementation challenges ... [because] GMD monitoring capabilities and technical information have not yet reached a level of maturity to support application in a Reliability Standard, and not all applicable entities have developed the comprehensive understanding of system vulnerabilities that would be needed to deploy GMD monitoring devices for the greatest reliability benefit.”¹¹⁵ NERC also notes that a requirement mandating the installation of monitoring devices for situational awareness purposes would be outside the scope of a planning Reliability Standard.

85. The Trade Associations, CEA, ITC, Hydro One and Tri-State, while agreeing that more data are useful to analytical validation and situational awareness, do not support the NOPR proposal. CEA does not support the proposal because Reliability Standard TPL-007-1 is a planning standard; a one-size-fits-all monitoring approach will not work; the responsibility for monitoring, which in Canada is done by the Canadian government, should not fall to industry or NERC; and the proposal is too costly. Likewise, ITC contends that it would not be prudent or cost effective for entities to have to install

¹¹⁴ NERC Comments at 21. NERC cites as examples the 40 GIC monitoring nodes operated by EPRI’s SUNBURST network; the use of GIC monitoring devices by some registered entities (e.g., PJM); and the magnetometer networks operated by USGS and EPRI. *Id.* at 23-25.

¹¹⁵ *Id.*

monitoring equipment. Hydro One does not support a Reliability Standard that prescribes the number and location of monitoring devices that must be installed. The Trade Associations and ITC, instead, support directing NERC to develop a plan to address this issue. The Trade Associations state that such a plan should involve a partnership between government and industry. Tri-State maintains that NERC, working with USGS and NOAA, should be responsible for determining the need for and installation of any needed magnetometers. If the Commission requires applicable entities to install monitoring devices, the Trade Associations, Tri-State and Exelon agree that there should be cost recovery.

86. BPA supports the NOPR proposal for increased monitoring because BPA believes it will improve situational awareness. As a model, BPA states that the “Canadian government in collaboration with Canadian transmission owners” have developed a “technique that shows real promise of increasing visibility of GIC flows and localized impacts for a regional transmission grid.”¹¹⁶ AEP encourages the Commission to expand the “number and scope of the permanent geomagnetic observatories and install permanent geoelectric observatories in the United States.”¹¹⁷

87. Resilient Societies supports requiring the installation of GIC monitoring devices and magnetometers, noting that GIC monitors are commercially available and cost as

¹¹⁶ BPA Comments at 4.

¹¹⁷ AEP March 29, 2016 Supplemental Comments at 1.

little as \$10,000 to \$15,000 each. Emprimus supports developing criteria that inform the need for and location of monitoring devices.

Commission Determination

88. We conclude that additional collection and disclosure of GIC monitoring and magnetometer data is necessary to improve our collective understanding of the threats posed by GMD events. The Commission therefore adopts the NOPR proposal in relevant part and directs NERC to develop revisions to Reliability Standard TPL-007-1 to require responsible entities to collect GIC monitoring and magnetometer data as necessary to enable model validation and situational awareness, including from any devices that must be added to meet this need. The NERC standard drafting team should address the criteria for collecting GIC monitoring and magnetometer data discussed below and provide registered entities with sufficient guidance in terms of defining the data that must be collected, and NERC should propose in the GMD research work plan how it will determine and report on the degree to which industry is following that guidance.

89. In addition, the Commission directs NERC, pursuant to Section 1600 of the NERC Rules of Procedure, to collect GIC monitoring and magnetometer data from registered entities for the period beginning May 2013, including both data existing as of the date of this order and new data going forward, and to make that information available.¹¹⁸ We also provide guidance that, as a general matter, the Commission does not believe that

¹¹⁸ The Commission's directives to collect and make available GIC monitoring and magnetometer data do not apply to non-U.S. responsible entities or Alaska and Hawaii.

GIC monitoring and magnetometer data should be treated as Confidential Information pursuant to the NERC Rules of Procedure.

Collection of GIC and Magnetometer Data

90. In developing a requirement regarding the collection of magnetometer data, NERC should consider the following criteria discussed at the March 1, 2016 Technical Conference: (1) the data is sampled at a cadence of at least 10-seconds or faster; (2) the data comes from magnetometers that are physically close to GIC monitors; (3) the data comes from magnetometers that are not near sources of magnetic interference (e.g., roads and local distribution networks); and (4) data is collected from magnetometers spread across wide latitudes and longitudes and from diverse physiographic regions.¹¹⁹

91. Each responsible entity that is a transmission owner should be required to collect necessary GIC monitoring data. However, a transmission owner should be able to apply for an exemption from the GIC monitoring data collection requirement if it demonstrates that no or little value would be added to planning and operations. In developing a requirement regarding the collection of GIC monitoring data, NERC should consider the following criteria discussed at the March 1, 2016 Technical Conference: (1) the GIC data is from areas found to have high GIC based on system studies; (2) the GIC data comes from sensitive installations and key parts of the transmission grid; and (3) the data comes from GIC monitors that are not situated near transportation systems using direct current

¹¹⁹ Slide Presentation of Luis Marti (Third Panel), March 1, 2016 Technical Conference at 3, 9.

(e.g., subways or light rail).¹²⁰ GIC monitoring and magnetometer locations should also be revisited after GIC system models are run with improved ground conductivity models. NERC may also propose to incorporate the GIC monitoring and magnetometer data collection requirements in a different Reliability Standard (e.g., real-time reliability monitoring and analysis capabilities as part of the TOP Reliability Standards).

92. Our determination differs from the NOPR proposal in that the NOPR proposed to require the installation of GIC monitors and magnetometers. The comments raised legitimate concerns about incorporating such a requirement in Reliability Standard TPL-007-1 because of the complexities of siting and operating monitoring devices to achieve the maximum benefits for model validation and situational awareness. In particular, responsible entities may not have the technical capacity to properly install and operate magnetometers, given complicating issues such as man-made interference, calibration, and data interpretation. Accordingly, the Commission determines that requiring responsible entities to collect necessary GIC monitoring and magnetometer data, rather than install GIC monitors and magnetometers, affords greater flexibility while obtaining significant benefits. For example, responsible entities could collaborate with universities and government entities that operate magnetometers to collect necessary magnetometer data, or responsible entities could choose to install GIC monitors or magnetometers to comply with the data collection requirement. While the Commission's primary concern

¹²⁰ *Id.* at 8.

is the quality of the data collected, we do not establish a requirement for either approach or promote a particular device for collecting the required data. We also find that cost recovery for prudent costs associated with or incurred to comply with Reliability Standard TPL-007-1 and future revisions to the Reliability Standard, including for the purchase and installation of monitoring devices, will be available to registered entities.¹²¹

Data Availability

93. We also direct NERC, pursuant to Sections 1500 and 1600 of the NERC Rules of Procedure, to collect and make GIC monitoring and magnetometer data available.¹²² We determine that the dissemination of GIC monitoring and magnetometer data will facilitate a greater understanding of GMD events that, over time, will improve Reliability Standard TPL-007-1. The record in this proceeding supports the conclusion that access to GIC monitoring and magnetometer data will help facilitate GMD research, for example, by helping to validate GMD models.¹²³ To facilitate the prompt dissemination of GIC monitoring and magnetometer data, we address whether GIC monitoring or

¹²¹ NOPR, 151 FERC ¶ 61,134 at P 49 n.60.

¹²² If GIC monitoring and magnetometer data is already publicly available (e.g., from a government entity or university), NERC need not duplicate those efforts.

¹²³ *See, e.g.*, March 1, 2016 Technical Conference Tr. 58:22-59:13 (Love); 128:5-129:2 (Overbye); ATC Comments at 6-7 (“as more measuring devices (including magnetometers and GIC monitors) continue to propagate, the body of field data on magnetic fields and the resultant GICs will continue to increase the understanding of this phenomena and result in better models that more closely match real world conditions ... [a]bsent this field data, it is difficult to build accurate models that can be used to plan and operate the transmission system”).

magnetometer data should qualify as Confidential Information under the NERC Rules of Procedure.¹²⁴

94. Based on the record in this proceeding, we believe that GIC and magnetometer data typically should not be designated as Confidential Information under the NERC Rules of Procedure. We are not persuaded that the dissemination of GIC monitoring or magnetometer data poses a security risk or that the data otherwise qualify as Confidential Information. CEA and Hydro One have objected, without elaboration, to making data available without the use of non-disclosure agreements.¹²⁵ At the March 1, 2016 Technical Conference, panelists were questioned on the topic yet could not identify a security-based or other credible reason for not making such information available to requesters. In comments submitted after the March 1, 2016 Technical Conference, the Trade Associations explained that “GIC measurements, while not as sensitive as transmission planning studies, should also be protected ... [because a] potentially malicious actor could conceivably combine GIC information with information from other sources to deduce the configuration and operating conditions of the grid or some portion

¹²⁴ Providers of GIC and magnetometer data may request that NERC treat their GIC monitoring and magnetometer data as “Confidential Information,” as that term is defined in Section 1500 of the NERC Rules of Procedure. Under the NERC Rules of Procedure, disclosure of Confidential Information by NERC to a requester requires a formal request, notice and opportunity for comment, and an executed non-disclosure agreement for requesters not seeking public disclosure of the information. NERC Rules of Procedure, Section 1503 (Requests for Information) (effective Nov. 4, 2015).

¹²⁵ CEA Comments at 15; Hydro One Comments at 2.

of it.”¹²⁶ The Trade Associations’ comments, however, do not substantiate the assertion that the release of GIC monitoring (or magnetometer data) alone poses any risk to the Bulk-Power System. The Trade Associations’ comment is also vague by not identifying what “information from other sources” could be combined with GIC monitoring “to deduce the configuration and operating conditions of the grid or some portion of it.”

95. In conclusion, given both the lack of substantiated concerns regarding the disclosure of GIC and magnetometer data, and the compelling demonstration that access to these data will support ongoing research and analysis of GMD threats, the Commission expects NERC to make GIC and magnetometer data available. Notwithstanding our findings here, to the extent any entity seeks confidential treatment of the data it provides to NERC, the burden rests on that entity to justify the confidential treatment.¹²⁷

Exceptions are possible if the providing entity obtains from NERC, at the time it submits data to NERC, a determination that GIC or magnetometer data qualify as Confidential Information.¹²⁸ Entities denied access to GIC and magnetometer data by NERC or

¹²⁶ Trade Associations March 7, 2016 Supplemental Comments at 5.

¹²⁷ See NERC Rules of Procedure, Section 1502.1. To address any substantiated concerns regarding the need for confidentiality of an entity’s GIC or magnetometer data, NERC could develop a policy for disseminating such data only after an appropriate time interval (e.g., six months).

¹²⁸ We understand that NERC typically does not determine whether information submitted to it under a claim of confidentiality is Confidential Information when receiving such information. See *North American Electric Reliability Corp.*, 119 FERC ¶ 61,060, at PP 195-196 (2007). We expect that, when a submitter seeks a determination

(continued...)

providers denied Confidential Information treatment of GIC and magnetometer data may appeal NERC's decision to the Commission.

E. Corrective Action Plan Deadlines

NERC Petition

96. Reliability Standard TPL-007-1, Requirement R7 provides that:

Each responsible entity, as determined in Requirement R1, that concludes, through the GMD Vulnerability Assessment conducted in Requirement R4, that their System does not meet the performance requirements of Table 1 shall develop a Corrective Action Plan addressing how the performance requirements will be met

NERC explains that the NERC Glossary defines corrective action plan to mean, "A list of actions and an associated timetable for implementation to remedy a specific problem."¹²⁹

Requirement R7.3 states that the corrective action plan shall be provided within "90 calendar days of completion to the responsible entity's Reliability Coordinator, adjacent Planning Coordinator(s), adjacent Transmission Planner(s), functional entities referenced in the Corrective Action Plan, and any functional entity that submits a written request and has a reliability-related need."

NOPR

97. The NOPR proposed to direct NERC to modify Reliability Standard TPL-007-1 to require corrective action plans to be developed within one year of the completion of the

by NERC of a claim that GIC or magnetometer data qualify as Confidential Information, NERC will decide promptly.

¹²⁹ NERC Petition at 31.

GMD Vulnerability Assessment. The NOPR also proposed to direct NERC to modify Reliability Standard TPL-007-1 to require a deadline for non-equipment mitigation measures that is two years following development of the corrective action plan and a deadline for mitigation measures involving equipment installation that is four years following development of the corrective action plan. Recognizing that there is little experience with installing equipment for GMD mitigation, the NOPR stated that the Commission is open to proposals that may differ from its proposal, particularly from any entities with experience in this area. The NOPR also sought comment on appropriate alternative deadlines and whether there should be a mechanism that would allow NERC to consider, on a case-by-case basis, requests for extensions of required deadlines.

Comments

98. NERC states that it does not oppose a one-year deadline for completing the development of corrective action plans.¹³⁰ However, NERC contends that imposing deadlines on the completion of mitigation actions would be problematic because of the uncertainties regarding the amount of time needed to install necessary equipment. NERC maintains that deadlines that are too short may cause entities to take mitigation steps that,

¹³⁰ NERC contends that a deadline is unnecessary because “NERC expects that applicable entities would determine necessary corrective actions as part of their GMD Vulnerability Assessments for the initial assessment [due 60 months after a final rule in this proceeding goes into effect] as well as subsequent assessments [due every 60 months thereafter].” NERC Comments at 28.

while quicker, would not be as effective as mitigations that take more time to complete. NERC supports allowing extensions if the Commission adopts the NOPR proposal.

99. AEP states that, even if possible, a one-year deadline for developing corrective action plans is too aggressive and would encourage narrow thinking (i.e., registered entities would address GMD mitigation rather than pursue system improvements generally that would also address GMD mitigation). AEP, instead, proposes a two-year deadline. AEP does not support a Commission-imposed deadline for completing mitigation actions, although it supports requiring a time-table in the corrective action plan. AEP notes that the Commission did not impose a specific deadline for completion of corrective actions in Reliability Standard TPL-001-4 (Transmission System Planning Performance). CEA does not support a deadline for the development of corrective action plans because it is already part of the GMD Vulnerability Assessment process. Like AEP, CEA does not support specific deadlines for the completion of mitigation actions and instead supports including time-tables in the corrective action plan. CEA also contends that an extension process would be impracticable.

100. Trade Associations, BPA and Tri-State support the imposition of corrective action plan deadlines as long as entities can request extensions. Gaunt supports the corrective action plan deadlines proposed in the NOPR. Emprimus supports the imposition of deadlines but contends that non-equipment mitigation actions should be completed in 6 months and that there should be a rolling four-year period for equipment mitigation (i.e., after each year, 25 percent of the total mitigation actions should be completed).

Commission Determination

101. The Commission directs NERC to modify Reliability Standard TPL-007-1 to include a deadline of one year from the completion of the GMD Vulnerability Assessments to complete the development of corrective action plans. NERC's statement that it "expects" corrective action plans to be completed at the same time as GMD Vulnerability Assessments concedes the point made in the NOPR that Reliability Standard TPL-007-1 currently lacks a clear deadline for the development of corrective action plans.

102. The Commission also directs NERC to modify Reliability Standard TPL-007-1 to include a two-year deadline after the development of the corrective action plan to complete the implementation of non-hardware mitigation and four-year deadline to complete hardware mitigation. The comments provide contrasting views on the practicality of imposing mitigation deadlines, with NERC and some industry commenters arguing that such deadlines are not warranted while the Trade Associations and other industry commenters support their imposition. Most of these comments, however, support an extension process if the Commission determines that deadlines are necessary. The Commission agrees that NERC should consider extensions of time on a case-by-case basis. The Commission directs NERC to submit these revisions within 18 months of the effective date of this Final Rule.

103. Following adoption of the mitigation deadlines required in this final rule, Reliability Standard TPL-007-1 will establish a recurring five-year schedule for the identification and mitigation of potential GMD risks on the grid, as follows: (1) the

development of corrective action plans must be completed within one year of a GMD Vulnerability Assessment; (2) non-hardware mitigation must be completed within two years following development of corrective action plans; and (3) hardware mitigation must be completed within four years following development of corrective action plans.

104. As discussed elsewhere in this final rule, the Commission recognizes and expects that our collective understanding of the science regarding GMD threats will improve over time as additional research and analysis is conducted. We believe that the recurring five-year cycle will provide, on a going-forward basis, the opportunity to update Reliability Standard TPL-007-1 to reflect new or improved scientific understanding of GMD events.

F. Minimization of Load Loss and Curtailment

NERC Petition

105. Reliability Standard TPL-007-1, Requirement R4 states that each responsible entity “shall complete a GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon once every 60 calendar months.” Requirement R4.2 further states that the “study or studies shall be conducted based on the benchmark GMD event described in Attachment 1 to determine whether the System meets the performance requirements in Table 1.”

106. NERC maintains that Table 1 sets forth requirements for system steady state performance. NERC explains that Requirement R4 and Table 1 “address assessments of the effects of GICs on other Bulk-Power System equipment, system operations, and

system stability, including the loss of devices due to GIC impacts.”¹³¹ Table 1 provides, in relevant part, that load loss and/or curtailment are permissible elements of the steady state:

Load loss as a result of manual or automatic Load shedding (e.g. UVLS) and/or curtailment of Firm Transmission Service may be used to meet BES performance requirements during studied GMD conditions. The likelihood and magnitude of Load loss or curtailment of Firm Transmission Service should be minimized.

NOPR

107. The NOPR sought comment on the provision in Table 1 that “Load loss or curtailment of Firm Transmission Service should be minimized.” The NOPR stated that because the term “minimized” does not represent an objective value, the provision is potentially subject to interpretation and assertions that the term is vague and may not be enforceable. The NOPR also explained that the modifier “should” might indicate that minimization of load loss or curtailment is only an expectation or a guideline rather than a requirement. The NOPR sought comment on how the provision in Table 1 regarding load loss and curtailment will be enforced, including: (1) whether, by using the term “should,” Table 1 requires minimization of load loss or curtailment; or both and (2) what constitutes “minimization” and how it will be assessed.

¹³¹ NERC Petition at 39.

Comments

108. NERC states the language in Table 1 is modeled on Reliability Standard TPL-001-4, which provides in part that “an objective of the planning process should be to minimize the likelihood and magnitude of interruption of Firm transmission Service following Contingency events.” NERC explains that Reliability Standard TPL-007-1 “does not include additional load loss performance criteria used in normal contingency planning because such criteria may not be applicable to GMD Vulnerability Assessment of the impact from a 1-in-100 year GMD event.”¹³² However, NERC points out that the enforcement of Requirement R4 “would include an evaluation of whether the system meets the Steady State performance requirements of Table 1 which are aimed at protecting against instability, controlled separation, and Cascading.”¹³³ NERC further states that “minimized” in the context of Reliability Standard TPL-007-1 means that “planned Load loss or curtailments are not to exceed amounts necessary to prevent voltage collapse.”¹³⁴

109. The Trade Associations agree with the NOPR that the lack of objective criteria could create compliance and enforcement challenges and could limit an operator’s actions in real-time. The Trade Associations state that the Commission “should consider

¹³² NERC Comments at 29.

¹³³ *Id.*

¹³⁴ *Id.*

whether such language in mandatory requirements invites the unintended consequences of raising reliability risks, especially during real-time emergency conditions ... [but] [i]n the interim, the Trade Associations envision that NERC will consider further discussions with stakeholders on the issue prior to TPL-007 implementation.”¹³⁵

Commission Determination

110. The Commission accepts the explanation in NERC’s comments of what is meant by the term “minimized” in Table 1.

G. Violation Risk Factors and Violation Severity Levels

111. Each requirement of Reliability Standard TPL-007-1 includes one violation risk factor and has an associated set of at least one violation severity level. NERC states that the ranges of penalties for violations will be based on the sanctions table and supporting penalty determination process described in the Commission approved NERC Sanction Guidelines. The NOPR proposed to approve the violation risk factors and violation severity levels submitted by NERC, for the requirements in Reliability Standard TPL-007-1, consistent with the Commission’s established guidelines.¹³⁶ The Commission did not receive any comments regarding this aspect of the NOPR. Accordingly, the Commission approves the violation risk factors and violation severity levels for the requirements in Reliability Standard TPL-007-1.

¹³⁵ Trade Associations Comments at 28.

¹³⁶ *North American Electric Reliability Corp.*, 135 FERC ¶ 61,166 (2011).

H. Implementation Plan and Effective Dates

NERC Petition

112. NERC proposes a phased, five-year implementation period.¹³⁷ NERC maintains that the proposed implementation period is necessary: (1) to allow time for entities to develop the required models; (2) for proper sequencing of assessments because thermal impact assessments are dependent on GIC flow calculations that are determined by the responsible planning entity; and (3) to give time for development of viable corrective action plans, which may require applicable entities to “develop, perform, and/or validate new or modified studies, assessments, procedures ... [and because] [s]ome mitigation measures may have significant budget, siting, or construction planning requirements.”¹³⁸

113. The proposed implementation plan states that Requirement R1 shall become effective on the first day of the first calendar quarter that is six months after Commission approval. For Requirement R2, NERC proposes that the requirement shall become effective on the first day of the first calendar quarter that is 18 months after Commission approval. NERC proposes that Requirement R5 shall become effective on the first day of the first calendar quarter that is 24 months after Commission approval. NERC proposes that Requirement R6 shall become effective on the first day of the first calendar quarter that is 48 months after Commission approval. And for Requirement R3, Requirement

¹³⁷ NERC Petition, Ex. B (Implementation Plan for TPL-007-1).

¹³⁸ *Id.* at 2.

R4, and Requirement R7, NERC proposes that the requirements shall become effective on the first day of the first calendar quarter that is 60 months after Commission approval.

NOPR

114. The NOPR proposed to approve the implementation plan and effective dates submitted by NERC. However, given the serial nature of the requirements in Reliability Standard TPL-007-1, the Commission expressed concern about the duration of the timeline associated with any mitigation stemming from a corrective action plan and sought comment from NERC and other interested entities as to whether the length of the implementation plan, particularly with respect to Requirements R4, R5, R6, and R7, could be reasonably shortened.

Comments

115. NERC does not support shortening the implementation period. NERC maintains that the proposed implementation period is “appropriate and commensurate with the requirements of the proposed standard” and is based on “industry ... projections on the time required for obtaining validated tools, models and data necessary for conducting GMD Vulnerability Assessments through the standard development process.”¹³⁹ NERC notes that the standard drafting team initially proposed a four-year implementation plan, but received substantial comments expressing concern with only having four years.

¹³⁹ NERC Comments at 30.

116. The Trade Associations, BPA, CEA, Joint ISOs/RTOs and Tri-State support the proposed implementation plan for largely the same reasons as NERC.

117. Gaunt proposes a shorter implementation period wherein the initial GMD Vulnerability Assessment would be performed 48 months following the effective date of a final rule in this proceeding, as opposed to the proposed implementation plan's 60 months. Subsequent GMD Vulnerability Assessments would be performed every 48 months thereafter. Briggs states that a "3 or 4 year timeline would likely provide industry with enough time to implement corrective measures and should be considered."¹⁴⁰

Commission Determination

118. The Commission approves the implementation plan submitted by NERC. When registered entities begin complying with Reliability Standard TPL-007-1, it will likely be the first time that many registered entities will have planned for a GMD event, beyond developing the GMD operational procedures required by Reliability Standard EOP-010-1. Registered entities will gain the capacity to conduct GMD Vulnerability Assessments over the course of the five-year implementation plan by complying with, at phased intervals, the foundational requirements in Reliability Standard TPL-007-1 (i.e., establishing responsibilities for planning and developing models and performance criteria). In addition, as discussed above, NERC's implementation plan affords sufficient

¹⁴⁰ Briggs Comments at 7.

time for NERC to submit and for the Commission to consider the directed revisions to Reliability Standard TPL-007-1 before the completion of the first GMD Vulnerability Assessment. As such, the five-year implementation plan will allow for the incorporation of the revised Reliability Standard in the first round of GMD Vulnerability Assessments.

I. Other Issues

119. Several commenters indicated that the Commission should address the threats posed by EMPs or otherwise raised the issue of EMPs.¹⁴¹ For example, Briggs states that the Commission should “initiate a process to improve the resilience of the U.S. electric grid to the threat of high altitude electromagnetic pulse (HEMP) attacks, which can be more severe than solar superstorms.”¹⁴² However, as the Commission stated in Order No. 779 in directing the development of GMD Reliability Standards and in Order No. 797 in approving the First Stage GMD Reliability Standards, EMPs are not within the scope of the GMD rulemaking proceedings.¹⁴³

120. Holdeman contends that the Commission “should modify the current preemption of States preventing them from having more stringent reliability standards for Commission regulated entities than Commission standards.”¹⁴⁴ As the Commission

¹⁴¹ See Briggs Comments at 7; EIS Comments at 3; JINSA Comments at 2.

¹⁴² Briggs Comments at 7.

¹⁴³ Order No. 797, 147 FERC ¶ 61,209 at P 42 (citing Order No. 779, 143 FERC ¶ 61,147 at P 14 n.20).

¹⁴⁴ Holdeman Comments at 2.

indicated in response to similar comments in Order No. 797, section 215(i)(3) of the FPA provides in relevant part that section 215 does not “preempt any authority of any State to take action to ensure the safety, adequacy, and reliability of electric service within that State, as long as such action is not inconsistent with any reliability standard.”¹⁴⁵

Moreover, Reliability Standard TPL-007-1 does not preclude users, owners, and operators of the Bulk-Power System from taking additional steps that are designed to mitigate the effects of GMD events, provided those additional steps are not inconsistent with the Commission-approved Reliability Standards.

121. Certain commenters opposed to Reliability Standard TPL-007-1 contend that its approval could absolve industry of any legal liability should a GMD event cause a disruption to the Bulk-Power System. For example, Resilient Societies “ask[s] the Commission to clarify its expectation that the FERC jurisdictional entities will be held to account, and be subject to liability in the event of gross negligence or willful misconduct in planning for and mitigating solar geomagnetic storms.”¹⁴⁶ Resilient Societies also contends that the Commission does not have the legal authority “to grant immunity from liability by setting reliability standards.”¹⁴⁷

¹⁴⁵ Order No. 797, 147 FERC ¶ 61,209 at P 44 (citing 16 U.S.C. 824o(i)(3)).

¹⁴⁶ Resilient Societies Comments at 62; *see also* CSP Comments at 1 (“It would be far better for FERC to remand Standard TPL-007-1 in its entirety than to approve a reliability standard that would grant liability protection to utilities while blocking the electric grid protection for the public that a 21st century society requires.”).

¹⁴⁷ Resilient Societies Comments at 62.

122. The Commission has never stated in the GMD Reliability Standard rulemakings that compliance with Commission-approved Reliability Standards absolves registered entities from legal liability generally, to the extent legal liability exists, should a disruption occur on the Bulk-Power System due to a GMD event. Resilient Societies' comment appears to misconstrue language in Order No. 779 in which the Commission stated, when directing the development of the Second Stage GMD Reliability Standards, that the "Second Stage GMD Reliability Standard should not impose 'strict liability' on responsible entities for failure to ensure the reliability operation of the Bulk-Power System in the face of a GMD event of unforeseen severity."¹⁴⁸ The Commission's statement merely recognized that the Second Stage GMD Reliability Standard should require registered entities to plan against a defined benchmark GMD event, for the purpose of complying with the proposed Reliability Standard, rather than any GMD event generally (i.e., a GMD event that exceeded the severity of the benchmark GMD event). The Commission did not suggest, nor could it suggest, that compliance with a Reliability Standard would absolve registered entities from general legal liability, if any, arising from a disruption to the Bulk-Power System. The only liability the Commission was referring to in Order No. 779 was the potential for penalties or remediation under section 215 of the FPA for failure to comply with a Commission-approved Reliability Standard.

¹⁴⁸ Order No. 779, 143 FERC ¶ 61,147 at P 84.

123. Kappenman, Resilient Societies and Bardin filed comments that addressed the NERC “Level 2” Appeal Panel decision.¹⁴⁹ As a threshold issue, we agree with the Appeal Panel that the issues raised by the appellants in that proceeding are not procedural; instead they address the substantive provisions of Reliability Standard TPL-007-1. Section 8 (Process for Appealing an Action or Inaction) of the NERC Standards Process Manual states:

Any entity that has directly and materially affected interests and that has been or will be adversely affected by any procedural action or inaction related to the development, approval, revision, reaffirmation, retirement or withdrawal of a Reliability Standard, definition, Variance, associated implementation plan, or Interpretation shall have the right to appeal. This appeals process applies only to the NERC Reliability Standards processes as defined in this manual, not to the technical content of the Reliability Standards action.

The appellants, who have the burden of proof under the NERC Rules of Procedure, have not shown that NERC or the standard drafting team failed to comply with any procedural requirements set forth in the NERC Rules of Procedure.¹⁵⁰ Instead, it would appear that the appeal constitutes a collateral attack on the substantive provisions of Reliability Standard TPL-007-1. As the appellants’ substantive concerns with Reliability Standard TPL-007-1 have been addressed in this Final Rule, issues surrounding the NERC “Level 2” Appeal Panel decision are, in any case, moot.

¹⁴⁹ NERC August 17, 2015 Filing at Appendix 1 (Decision of Level 2 Appeal Panel SPM Section 8 Appeal the Foundation For Resilient Societies, Inc. TPL-007-1).

¹⁵⁰ NERC Rules of Procedure, Appendix 3A (Standard Processes Manual), Section 8 (Process for Appealing an Action or Inaction) (effective June 26, 2013).

III. Information Collection Statement

124. The collection of information contained in this final rule is subject to review by the Office of Management and Budget (OMB) regulations under section 3507(d) of the Paperwork Reduction Act of 1995 (PRA).¹⁵¹ OMB's regulations require approval of certain informational collection requirements imposed by agency rules.¹⁵²

125. Upon approval of a collection(s) of information, OMB will assign an OMB control number and an expiration date. Respondents subject to the filing requirements of a rule will not be penalized for failing to respond to these collections of information unless the collections of information display a valid OMB control number.

126. The Commission solicited comments on the need for this information, whether the information will have practical utility, the accuracy of the burden estimates, ways to enhance the quality, utility, and clarity of the information to be collected or retained, and any suggested methods for minimizing respondents' burden, including the use of automated information techniques. The Commission asked that any revised burden or cost estimates submitted by commenters be supported by sufficient detail to understand how the estimates are generated. The Commission received comments on specific requirements in Reliability Standard TPL-007-1, which we address in this Final Rule. However, the Commission did not receive any comments on our reporting burden

¹⁵¹ 44 U.S.C. 3507(d).

¹⁵² 5 CFR 1320.11.

estimates or on the need for and the purpose of the information collection requirements.¹⁵³

Public Reporting Burden: The Commission approves Reliability Standard TPL-007-1 and the associated implementation plan, violation severity levels, and violation risk factors, as discussed above. Reliability Standard TPL-007-1 will impose new requirements for transmission planners, planning coordinators, transmission owners, and generator owners. Reliability Standard TPL-007-1, Requirement R1 requires planning coordinators, in conjunction with the applicable transmission planner, to identify the responsibilities of the planning coordinator and transmission planner in the planning coordinator's planning area for maintaining models and performing the study or studies needed to complete GMD Vulnerability Assessments. Requirements R2, R3, R4, R5, and R7 refer to the "responsible entity, as determined by Requirement R1," when identifying which applicable planning coordinators or transmission planners are responsible for maintaining models and performing the necessary study or studies. Requirement R2 requires that the responsible entities maintain models for performing the studies needed to complete GMD Vulnerability Assessments, as required in Requirement R4. Requirement R3 requires responsible entities to have criteria for acceptable system steady

¹⁵³ While noting the uncertainties surrounding the potential costs associated with implementation of Reliability Standard TPL-007-1 and the potential costs that could arise from a revised Reliability Standard, the Trade Associations stated that they "have no specific comments regarding the OMB cost estimate in the NOPR." Trade Associations Comments at 9.

state voltage performance during a benchmark GMD event. Requirement R4 requires responsible entities to complete a GMD Vulnerability Assessment of the near-term transmission planning horizon once every 60 calendar months. Requirement R5 requires responsible entities to provide GIC flow information to transmission owners and generator owners that own an applicable bulk electric system power transformer in the planning area. This information is necessary for applicable transmission owners and generator owners to conduct the thermal impact assessments required by proposed Requirement R6. Requirement R6 requires applicable transmission owners and generator owners to conduct thermal impact assessments where the maximum effective GIC value provided in proposed Requirement R5, Part 5.1 is 75 A/phase or greater. Requirement R7 requires responsible entities to develop a corrective action plan when its GMD Vulnerability Assessment indicates that its system does not meet the performance requirements of Table 1 – Steady State Planning Events. The corrective action plan must address how the performance requirements will be met, must list the specific deficiencies and associated actions that are necessary to achieve performance, and must set forth a timetable for completion. The Commission estimates the annual reporting burden and cost as follows:

FERC-725N, as modified by the Final Rule in Docket No. RM15-11-000 (TPL-007-1 Reliability Standard for Transmission System Planned Performance for Geomagnetic Disturbance Events)¹⁵⁴						
	Number of Respondents (1)	Annual Number of Responses per Respondent (2)	Total Number of Responses (1)*(2)=(3)	Average Burden Hours & Cost Per Response¹⁵⁵ (4)	Total Annual Burden Hours & Total Annual Cost (3)*(4)=(5)	Cost per Respondent (\$) (5)÷(1)
(One-time) Requirement 1	121 (PC & TP)	1	121	Eng. 5 hrs. (\$331.75); RK 4 hrs. (\$149.80)	1,089 hrs. (605 Eng., 484 RK); \$58,267.55 (\$40,141.7 5 Eng., \$18,125.80 RK)	\$481.55
(On-going) Requirement 1	121 (PC & TP)	1	121	Eng. 3 hrs. (\$199.05); RK 2 hrs. (\$74.90)	605 hrs. (363 Eng., 242 RK); \$33,147.95 (\$24,085.0 5 Eng., \$9,062.90 RK)	\$273.95

¹⁵⁴ Eng.=engineer; RK =recordkeeping (record clerk); PC=planning coordinator; TP=transmission planner; TO=transmission owner; and GO=generator owner.

¹⁵⁵ The estimates for cost per response are derived using the following formula: Burden Hours per Response * \$/hour = Cost per Response. The \$66.35/hour figure for an engineer and the \$37.45/hour figure for a record clerk are based on data on the average salary plus benefits from the Bureau of Labor Statistics obtainable at http://www.bls.gov/oes/current/naics3_221000.htm and <http://www.bls.gov/news.release/ecec.nr0.htm>.

(One-time) Requirement 2	121 (PC & TP)	1	121	Eng. 22 hrs. (\$1,459.7 0); RK 18 hrs. (\$674.10)	4840 hrs. (2,662 Eng., 2,178 RK); \$258,189.8 0 (\$176,623. 70 Eng., \$81,566.10 RK)	\$2,133. 80
(On-going) Requirement 2	121 (PC & TP)	1	121	Eng. 5 hrs. (\$331.75); RK 3 hrs. (\$112.35)	968 hrs. (605 Eng., 363 RK); \$53,736.10 (\$40,141.7 5 Eng., \$13,594.35 RK)	\$444.10
(One-time) Requirement 3	121 (PC & TP)	1	121	Eng. 5 hrs. (\$331.75); RK 3 hrs. (\$112.35)	968 hrs. (605 Eng., 363 RK); \$53,736.10 (\$40,141.7 5 Eng., \$13,594.35 RK)	\$444.10
(On-going) Requirement 3	121 (PC & TP)	1	121	Eng. 1 hrs. (\$66.35); RK 1 hrs. (\$37.45)	242 hrs. (121 Eng., 121 RK); \$12,559.80 (\$8,028.35 Eng., \$4,531.45 RK)	\$103.80

(On-going) Requirement 4	121 (PC & TP)	1	121	Eng. 27 hrs. (\$1,791.4 5); RK 21 hrs. (\$786.45)	5,808 hrs. (3,267 Eng., 2,541 RK); \$311,919.8 5 (\$216,765. 45 Eng., \$95,154.40 RK)	\$2,277. 85
(On-going) Requirement 5	121 (PC & TP)	1	121	Eng. 9 hrs. (\$597.15); RK 7 hrs. (\$262.15)	1936 hrs. (1,089 Eng., 847 RK); \$103,975.3 0 (\$72,255.1 5 Eng., \$31,720.15 RK)	\$859.30
(One-time) Requirement 6	881 (TO & GO)	1	881	Eng. 22 hrs. (\$1,459.7 0); RK 18 hrs. (\$674.19)	35,240 hrs. (19,382 Eng., 15,858 RK); \$1,879,957. 09 (\$1,285,99 5.70 Eng., \$593,961.3 9 RK)	\$2,133. 89
(On-going) Requirement 6	881 (TO & GO)	1	881	Eng. 2 hrs. (\$132.70); RK 2 hrs. (\$74.90)	3,524 hrs. (1,762 Eng., 1762 RK); \$182,895.6 0 (\$116,908. 70 Eng., \$65,986.90 RK)	\$207.60

(On-going) Requirement 7	121 (PC & TP)	1	121	Eng. 11 hrs. (\$729.85); RK 9 hrs. (\$337.05)	2,420 hrs. (1,331 Eng., 1,089 RK); \$129,094.9 0 (\$88,311.8 5 Eng., \$40,783.05 RK)	\$1,066. 90
TOTAL			2851		57,640¹⁵⁶ hrs. (31,792 Eng., 25,848 RK); \$3,077,480. 04 (\$2,109,39 9.20 Eng., \$968,080.8 4 RK)	

Title: FERC-725N, Mandatory Reliability Standards: TPL Reliability Standards.

Action: Approved Additional Requirements.

OMB Control No: 1902-0264.

Respondents: Business or other for-profit and not-for-profit institutions.

Frequency of Responses: One time and on-going.

Necessity of the Information: The Commission has reviewed the requirements of

Reliability Standard TPL-007-1 and has made a determination that the requirements of

¹⁵⁶ Of the 57,640 total burden hours, 42,137 hours are one-time burden hours, and 15,503 hours are on-going annual burden hours.

this Reliability Standard are necessary to implement section 215 of the FPA.

Specifically, these requirements address the threat posed by GMD events to the Bulk-Power System and conform to the Commission's directives regarding development of the Second Stage GMD Reliability Standards, as set forth in Order No. 779.

Internal review: The Commission has assured itself, by means of its internal review, that there is specific, objective support for the burden estimates associated with the information requirements.

127. Interested persons may obtain information on the reporting requirements by contacting the Federal Energy Regulatory Commission, Office of the Executive Director, 888 First Street, NE, Washington, DC 20426 [Attention: Ellen Brown, e-mail: DataClearance@ferc.gov, phone: (202) 502-8663, fax: (202) 273-0873].

128. Comments concerning the information collections proposed in this notice of proposed rulemaking and the associated burden estimates, should be sent to the Commission in this docket and may also be sent to the Office of Management and Budget, Office of Information and Regulatory Affairs [Attention: Desk Officer for the Federal Energy Regulatory Commission]. For security reasons, comments should be sent by e-mail to OMB at the following e-mail address: oir_submission@omb.eop.gov. Please reference FERC-725N and OMB Control No. 1902-0264 in your submission.

IV. Environmental Analysis

129. The Commission is required to prepare an Environmental Assessment or an Environmental Impact Statement for any action that may have a significant adverse effect on the human environment.¹⁵⁷ The Commission has categorically excluded certain actions from this requirement as not having a significant effect on the human environment. Included in the exclusion are rules that are clarifying, corrective, or procedural or that do not substantially change the effect of the regulations being amended.¹⁵⁸ The actions here fall within this categorical exclusion in the Commission's regulations.

V. Regulatory Flexibility Act

130. The Regulatory Flexibility Act of 1980 (RFA)¹⁵⁹ generally requires a description and analysis of final rules that will have significant economic impact on a substantial number of small entities. The Small Business Administration's (SBA) Office of Size Standards develops the numerical definition of a small business.¹⁶⁰ The SBA revised its size standard for electric utilities (effective January 22, 2014) to a standard based on the

¹⁵⁷ *Regulations Implementing the National Environmental Policy Act of 1969*, Order No. 486, 52 FR 47897 (Dec. 17, 1987), FERC Stats. & Regs. Preambles 1986-1990 ¶ 30,783 (1987).

¹⁵⁸ 18 CFR 380.4(a)(2)(ii).

¹⁵⁹ 5 U.S.C. 601-12.

¹⁶⁰ 13 CFR 121.101.

number of employees, including affiliates (from a standard based on megawatt hours).¹⁶¹

Under SBA's new size standards, planning coordinators, transmission planners, transmission owners, and generator owners are likely included in one of the following categories (with the associated size thresholds noted for each):¹⁶²

- Hydroelectric power generation, at 500 employees
- Fossil fuel electric power generation, at 750 employees
- Nuclear electric power generation, at 750 employees
- Other electric power generation (e.g., solar, wind, geothermal, biomass, and other), at 250 employees
- Electric bulk power transmission and control,¹⁶³ at 500 employees

131. Based on these categories, the Commission will use a conservative threshold of 750 employees for all entities.¹⁶⁴ Applying this threshold, the Commission estimates that there are 440 small entities that function as planning coordinators, transmission planners, transmission owners, and/or generator owners. However, the Commission estimates that only a subset of such small entities will be subject to the approved Reliability Standard

¹⁶¹ SBA Final Rule on "Small Business Size Standards: Utilities," 78 FR 77,343 (Dec. 23, 2013).

¹⁶² 13 CFR 121.201, Sector 22, Utilities.

¹⁶³ This category covers transmission planners and planning coordinators.

¹⁶⁴ By using the highest number threshold for all types of entities, our estimate conservatively treats more entities as "small entities."

given the additional applicability criterion in the approved Reliability Standard (i.e., to be subject to the requirements of the approved Reliability Standard, the applicable entity must own or must have a planning area that contains a large power transformer with a high side, wye-grounded winding with terminal voltage greater than 200 kV).

132. Reliability Standard TPL-007- 1 enhances reliability by establishing requirements that require applicable entities to perform GMD Vulnerability Assessments and to mitigate identified vulnerabilities. The Commission estimates that each of the small entities to whom the approved Reliability Standard applies will incur one-time compliance costs of \$5,193.34 and annual ongoing costs of \$5,233.50.

133. The Commission does not consider the estimated cost per small entity to impose a significant economic impact on a substantial number of small entities. Accordingly, the Commission certifies that the approved Reliability Standard will not have a significant economic impact on a substantial number of small entities.

VI. Document Availability

134. In addition to publishing the full text of this document in the Federal Register, the Commission provides all interested persons an opportunity to view and/or print the contents of this document via the Internet through FERC's Home Page (<http://www.ferc.gov>) and in FERC's Public Reference Room during normal business hours (8:30 a.m. to 5:00 p.m. Eastern time) at 888 First Street, N.E., Room 2A, Washington, DC 20426.

135. From FERC's Home Page on the Internet, this information is available on eLibrary. The full text of this document is available on eLibrary in PDF and Microsoft

Word format for viewing, printing, and/or downloading. To access this document in eLibrary, type the docket number excluding the last three digits of this document in the docket number field.

136. User assistance is available for eLibrary and the FERC's website during normal business hours from FERC Online Support at 202-502-6652 (toll free at 1-866-208-3676) or email at ferconlinesupport@ferc.gov, or the Public Reference Room at (202) 502-8371, TTY (202)502-8659. E-mail the Public Reference Room at public.referenceroom@ferc.gov.

VII. Effective Date and Congressional Notification

137. These regulations are effective [**INSERT DATE 60 days after publication in the FEDERAL REGISTER**]. The Commission has determined, with the concurrence of the Administrator of the Office of Information and Regulatory Affairs of OMB, that this rule is not a "major rule" as defined in section 351 of the Small Business Regulatory Enforcement Fairness Act of 1996.

By the Commission.

(S E A L)

Nathaniel J. Davis, Sr.,
Deputy Secretary.

APPENDIX**Commenters****Initial Comments**

Abbreviation	Commenter
AEP	American Electric Power Service Corporation
APS	Arizona Public Service Company
ATC	American Transmission Company
Baker	Greta Baker
Bardin	David J. Bardin
BPA	Bonneville Power Administration
Briggs	Kevin Briggs
CEA	Canadian Electricity Association
CSP	Center for Security Policy
EIS	Electric Infrastructure Security Council
Emprimus	Emprimus LLC
Exelon	Exelon Corporation
Gaunt	Charles T. Gaunt
Holdeman	Eric Holdeman
Hydro One	Hydro One Networks Inc.
ITC	International Transmission Company
Lloyd's	Lloyd's America, Inc.
JINSA	Jewish Institute for National Security Affairs
Joint ISOs/RTOs	ISO New England Inc., Midcontinent Independent Transmission System Operator, Inc., Independent Electricity System Operator, New York Independent System Operator, Inc., and PJM Interconnection, L.L.C.
Kappenman	John G. Kappenman and Curtis Birnbach
Morris	Eric S. Morris
NERC	North American Electric Reliability Corporation
Resilient Societies	Foundation for Resilient Societies
Roodman	David Roodman
Trade Associations	American Public Power Association, Edison Electric Institute, Electricity Consumers Resource Council, Electric Power Supply Association, Large Public Power Council, National Rural Electric Cooperative Association
Tri-State	Tri-State Generation and Transmission Association, Inc.
USGS	United States Geological Survey

Supplemental Comments

AEP	American Electric Power Service Corporation
Bardin	David J. Bardin
CSP	Center for Security Policy
Gaunt	Charles T. Gaunt
IEEE	IEEE Power and Energy Society Transformers Committee
Kappenman	John G. Kappenman and Curtis Birnbach
NERC	North American Electric Reliability Corporation
Resilient Societies	Foundation for Resilient Societies
Roodman	David Roodman
Trade Associations	American Public Power Association, Edison Electric Institute, Electricity Consumers Resource Council, Electric Power Supply Association, Large Public Power Council, National Rural Electric Cooperative Association
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