NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

May 7, 2021

VIA ELECTRONIC FILING

Ms. Christine E. Long
Registrar & Board Secretary
Ontario Energy Board
27th Floor 2300 Yonge Street
Toronto, ON M4P 1E4

Re: *North American Electric Reliability Corporation*

Dear Ms. Long:

The North American Electric Reliability Corporation ("NERC") hereby submits Informational Filing of the North American Electric Reliability Corporation Regarding Geomagnetic Disturbance Research Work Plan Final Report. NERC requests, to the extent necessary, a waiver of any applicable filing requirements with respect to this filing.

Please contact the undersigned if you have any questions concerning this filing.

Sincerely,

/s/ Lauren Perotti

Lauren Perotti
Senior Counsel for the North American Electric Reliability Corporation

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INFORMATIONAL FILING OF THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION REGARDING GEOMAGNETIC DISTURBANCE RESEARCH WORK PLAN FINAL REPORT

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INFORMATIONAL FILING OF THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION REGARDING GEOMAGNETIC DISTURBANCE RESEARCH WORK PLAN FINAL REPORT

The North American Electric Reliability Corporation ("NERC") hereby submits an informational filing regarding the results of research performed under the NERC Geomagnetic Disturbance Research Work Plan ("GMD Research Work Plan"). The purpose of the GMD Research Work Plan was to conduct research on topics related to geomagnetic disturbances ("GMDs") and their impacts on the reliability of the Bulk Power System ("BPS"). NERC submitted the plan in its final form on April 24, 2018.[1]

The completion of the GMD Research Work Plan marks an important milestone in NERC and industry's comprehensive approach to reducing the risks that severe GMD events can pose to the reliability and resilience of the North American grid. NERC has prepared a final report, titled *Order No. 830 GMD Research Work Plan: Results and Recommendations for the ERO* (Feb. 2021) ("Final Report"), to summarize the results of the research and identify recommendations for further action. This report is included as **Attachment 1** to this filing.

As summarized below, and discussed in more detail in **Attachment 1**, the results from this research provide further technical justification and support for the currently effective GMD planning standard, TPL-007-4 (Transmission System Planned Performance for Geomagnetic

[1] *See Revised Geomagnetic Disturbance Research Work Plan of the North American Electric Reliability Corporation,* (April 24, 2018) at attach. 1.

Disturbance Events). The outcomes from this research project affirm the efficacy of the TPL-007 Reliability Standard and provide tools and insights for the ERO, industry, and research partners to use in accurately performing GMD Vulnerability Assessments. While the report has identified several opportunities for further monitoring and outreach, NERC has not identified any potential reliability gaps in the standard that must be addressed through the standard revision process. As part of the required periodic review of the TPL-007 Reliability Standard, NERC will consider these research findings, as well as any new developments in space weather research and other insights that are gained during the implementation of the standard, to determine whether further improvements and refinements to the standard are necessary.[2]

I. BACKGROUND

On March 5, 2015, NERC submitted the first version of the GMD planning Reliability Standard, Reliability Standard TPL-007-1 – Transmission System Planned Performance for Geomagnetic Disturbance Events.[3] In its order approving the standard, the Federal Energy Regulatory Commission ("FERC") directed NERC to submit a work plan describing how NERC would conduct research on the GMD-related topics specified by FERC and any additional topics selected in NERC's discretion and subsequently, one or more informational filings addressing the results of this research.[4] FERC stated, "We expect that work completed through the GMD research

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[2] NERC conducts periodic reviews of Reliability Standards in accordance with Section 317 of its Rules of Procedure and Section 13.0 of its Standard Processes Manual, Appendix 3A to the NERC Rules of Procedure. The NERC Rules of Procedure are available at https://www.nerc.com/AboutNERC/Pages/Rules-of-Procedure.aspx.

[3] *Notice of Filing of the North American Electric Reliability Corporation of Proposed Reliability Standard TPL-007-1 Transmission System Planned Performance for Geomagnetic Disturbance Events,* (Mar. 3, 2015). NERC submitted revised versions of the standard on February 27, 2018 (TPL-007-2), February 20, 2019 (TPL-007-3), and February 25, 2020 (TPL-007-4).

[4] Order No. 830, *Reliability Standard for Transmission System Planned Performance for Geomagnetic Disturbance Events*, 156 FERC ¶ 61,215 at P 77 (2016), *reh'g denied*, Order No. 830-A, 158 FERC ¶ 61,041 (2017) [hereinafter Order No. 830].

work plan, as well as other analyses facilitated by the increased collection and availability of [geomagnetically induced current] GIC monitoring and magnetometer data…will lead to further modifications to Reliability Standard TPL-007-1 as our collective understanding of the threats posed by GMD events improves."[5]

NERC submitted a preliminary GMD Research Work Plan on June 5, 2017.[6] On April 24, 2018, NERC submitted a final plan, as noted above.

The GMD Research Work Plan contemplated the engagement of the Electric Power Research Institute ("EPRI"), electricity sector participants, U.S. national laboratories, equipment manufacturers, and other North American research collaborators in examining areas of GMD study. EPRI initiated a $3.6 million, multi-year project for GMD research, the costs of which were shared among NERC and electricity sector participants. The GMD Research Work Plan consisted of the nine research and work components, referred to as "tasks," intended to improve the capabilities and accuracy of GMD Vulnerability Assessments[7] performed by NERC entities and help ensure the effectiveness of GMD Reliability Standards in reducing risks to the BPS from severe GMD events.

On August 1 2019, NERC provided an informational filing summarizing the results of work completed up to that time.[8] Work continued under the GMD Research Work Plan throughout the remainder of 2019 and into 2020. For the research-related tasks, EPRI released technical

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5 *Id.* at P 26.

6 *Geomagnetic Disturbance Research Work Plan of the North American Electric Reliability Corporation,* (June 5, 2017).

7 GMD Vulnerability Assessment is defined in the *Glossary of Terms Used in NERC Reliability Standards* as "Documented evaluation of potential susceptibility to voltage collapse, Cascading, or localized damage of equipment due to geomagnetic disturbances." The Glossary is available at https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf.

8 *First Informational Filing of NERC Regarding Work Performed under the Geomagnetic Disturbance Research Work Plan*, (Aug. 1, 2019) (summarizing work completed up until that time).

reports summarizing the results and made those reports publicly available, free of charge.[9] NERC provided opportunities for technical and scientific review of EPRI's research results through the NERC GMD Task Force.[10]

II. Final Report: *Order No. 830 GMD Research Work Plan: Results and Recommendations for the ERO*

NERC is pleased to provide the GMD Research Work Plan Final Report. The Final Report reflects the culmination of several years of collaborative research between NERC, its industry partners, and other research collaborators. This work has confirmed the technical underpinnings of the TPL-007 Reliability Standard and has provided industry with additional insights and tools to help protect the grid from the risks posed by severe GMD events. This section provides a summary of the key findings and recommendations from the GMD Research Work Plan final report, organized by research task. For additional details and analysis, please refer to final report included as **Attachment 1.**

Consistent with the recommendations in the final report, NERC will continue to monitor developments in scientific research and facilitate the sharing of new information and best practices to enhance the effectiveness of GMD Vulnerability Assessments through the NERC Reliability and Security Technical Committee.

A. Task 1: Further Analyze Spatial Averaging Used in the Benchmark GMD Event

9 The cost to execute the research components of the plan was shared among NERC and electricity sector participants through a research program executed by EPRI.

10 The NERC GMD Task Force was open to the public and included participants from U.S. and Canadian government space weather researchers, representatives from the manufacturer and vendor community, and subject matter experts from both within and outside the electric power industry. The issuance of the attached final report marked the conclusion of the GMD Task Force's work, and NERC disbanded the GMD Task Force in early 2021. As noted below, further GMD work will occur through the NERC Reliability and Security Technical Committee.

Additional information on the GMD Task Force is available on NERC's website at https://www.nerc.com/comm/PC/Pages/Geomagnetic-Disturbance-Task-Force-(GMDTF)-2013.aspx.

The key findings from the work performed under Task 1: Further Analyze Spatial Averaging used in the Benchmark GMD Event are summarized as follows. Analysis of an extensive space weather data set supports the industry's use of the Benchmark GMD Event to represent a severe 100-year GMD event in GMD Vulnerability Assessments. In response to a separate FERC directive in Order No. 830,[11] NERC revised the TPL-007 standard to require entities to assess vulnerabilities to geoelectric field enhancements through the defined Supplemental GMD Event. Research into the characteristics and spatial scales of extreme GMD events (i.e., geographic size, locations affected, durations, intensity and direction) provided additional insight about geoelectric field enhancements that can occur during severe GMD events. These details can assist industry planners with how they apply the Supplemental GMD Event to assess the impact that geoelectric field enhancements can have on the system. Notably, studies have shown that the presence of a localized enhancement does increase GIC flow and reactive power losses and reduces system voltages in the vicinity of the field enhancements; the effects are not limited to within the localized enhancement itself.

Based on the research findings, there is no recommendation for any new, specific scales for localized enhancements for 1-in-100 year GMD event planning scenarios beyond that reflected in the current version of the standard, Reliability Standard TPL-007-4. The final report recommends that NERC: (1) monitor further research performed by the space weather community to further understand the characteristics of extreme GMD events, including localized geoelectric field enhancements; and (2) promote awareness of research findings and use of best practices among TPL-007 applicable entities, through the NERC Reliability and Security Technical Committee and industry forums.

[11] *See* Order No. 830 at P 44 (directing 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").

B. <u>Task 2: Further Analyze Latitude Scaling</u>

The key findings from the work performed under Task 2: Further Analyze Latitude Scaling are as follows. Scaling the peak geoelectric field of the Benchmark GMD Event according to the geomagnetic latitude of the system area is consistent with analysis of space weather data and advanced simulation modeling. Researchers confirmed that the geoelectric field intensity during a severe 100-year GMD event is expected to decrease by an order of magnitude across the 60-degree to 40-degree geomagnetic latitude band.

The final report recommends that NERC monitor further research performed by the space weather community to characterize the latitude thresholds of extreme GMD events.

C. <u>Task 3: Improve Earth Conductivity Models for GIC Studies</u>

The results of the work performed under Task 3: Improve Earth Conductivity Models for GIC Studies are summarized as follows. Newly-available earth conductivity data for the U.S. was used to better define regional boundaries in conductivity maps used by industry to calculate geoelectric fields. Through the GMD Research Work Plan, conductivity maps, earth models, and earth conductivity scaling factors are available for industry and software designers to use in performing GMD Vulnerability Assessments. These models cover the North American BPS, with uncertainty only in regions where magnetotelluric (MT) measurements or other modeling information is unavailable to perform comparisons. In addition, EPRI published technical guidance for validating models with GIC and magnetometer data collected during actual GMD events.

The final report contains four recommendations for additional work in this area. First, the final report recommends that NERC Staff and EPRI continue to work with software vendors to adopt new region boundaries and modeling information in available GIC software. Second, the final report recommends that NERC and EPRI engage technical experts, researchers, and software vendors to develop advanced modeling techniques that address unique challenges of areas with significant non-uniformity that impact GIC estimates. Third, the final report recommends that NERC, working collaboratively with Regional Entities Northeast Power Coordinating Council and Western Electricity Coordinating Council, support application of this and future research into the described coastal effect through regional technical committees and working groups. Fourth, the final report recommends that NERC, working through the Reliability and Security Technical Committee, Real-time Operations Subcommittee, and technical partners: (i) promote model validation best practices; (ii) encourage planning entities to validate GMD models with data collected during GMD events of interest; and (iii) support technical groups in continuing to advance GMD modeling disciplines.

D. Task 4: Study Transformer Thermal Impact Assessment Approach and Task 5: Further Analyze the 75 A per Phase Criterion Used for Transformer Thermal Impact Assessments

The results and key findings from the work performed under Task 4: Study Transformer Thermal Impact Assessment Approach and Task 5: Further Analyze the 75 A per Phase Criterion Used for Transformer Thermal Impact Assessments are summarized as follows.

The GMD Research Work Plan improved industry capabilities for assessing transformer thermal impacts from GMD events and provided further technical justification for the 75 A/phase screening criterion used in TPL-007 to mitigate risk to the BPS. Transformer thermal impact screening and assessment, along with an evaluation of system susceptibility to voltage collapse and Cascading, is part of the GMD Vulnerability Assessment process required by Reliability Standard TPL-007. The research produced thermal models for over 80 different transformer types and designs which can be used in an industry-available thermal modeling tool. Simulations using the expanded set of models indicate that the TPL-007 thermal impact screening criterion is generally effective, however specific designs were identified that could possibly exceed transformer thermal criteria. The findings enable industry to expand screenings for these designs and perform additional risk analysis.

The final report recommends that NERC monitor further technical development supporting transformer thermal modeling and GMD risk assessment. As additional transformer models are developed through industry and research partner efforts, techniques such as those demonstrated as part of this work should be used to evaluate the continued efficacy of the benchmark GMD event for GMD Vulnerability Assessments. The final report also recommends that NERC continue to prioritize efforts to enable industry to assess and mitigate GMD risk to transformers by: (1) expanding the availability of transformer thermal models to represent more manufacturers, and using field measurement data collected by EPRI and industry to validate theoretical models; (2) updating the ERO-endorsed Implementation Guidance *TPL-007 Transformer Thermal Impact Assessment* with results of EPRI's research in this task;[12] and (3) engaging TPL-007 applicable entities through the Reliability and Security Technical Committee and industry forums to promote awareness of transformer thermal model availability and assessment best practices.

E. <u>Task 6: Section 1600 Data Request</u>

The activities in Task 6: Section 1600 Data Request consisted of developing the necessary guidance, technical guidelines, and solutions to support a request for data or information under Section 1600 of the NERC Rules of Procedure for the collection of existing and new GIC data and

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[12] Specifically, Table 1 provides upper-bound hot spot heating. This table should be revised to reflect the results of EPRI's analysis, including transformer models T24 and T25. The Implementation Guidance is available on NERC's web site at https://www.nerc.com/pa/comp/guidance/Pages/default.aspx.

magnetometer data. The purpose of this data collection is to respond to FERC's Order No. 830 directive to collect GMD monitoring data and to make that data available.[13]

The GMD Data Collection portal became operational in October 2020. The first annual reporting deadline is June 2021 and will include recorded information going back to May 2013.[14] NERC will monitor implementation and conduct outreach to identify whether and to what extent additional guidance or support is necessary. The objective is to maintain a high-quality collection of GIC and magnetometer data for industry and research use. Although the NERC GMD Data Collection Program is not a real-time application, industry GIC monitors and magnetometers can provide data to system operators in real-time for enhancing their GMD operating procedures.

F. Task 7: Geoelectric Field Tool Evaluation and Calculation of Beta Factors

Work under Task 7: Geoelectric Field Tool Evaluation and Calculation of Beta Factors built upon the other components of NERC's GMD Research Work Plan to improve scientific understanding and advance the models and tools available for modeling GIC. This task involved evaluating available tools for calculating geoelectric field from magnetic field data for a given earth conductivity structure and developing guidance as necessary to meet the needs of the industry. The final report provides updated beta scaling factors for calculating geoelectric fields used in GMD Vulnerability Assessments based on newly available MT information.

As it is presently written, the TPL-007 standard provides flexibility to accommodate the updated beta scaling factors in GMD planning studies. The final report recommends updating Attachment 1 during the next periodic review of the standard. The final report also recommends

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13 *See* Order No. 830 at P 93. The directive applies to only U.S. responsible entities (See n. 118). However, responsible entities in other NERC jurisdictions including Canada are encouraged to participate in order to obtain relevant GMD data for the North American Bulk-Power System.

14 GMD data reporting information is available on the NERC website: https://www.nerc.com/pa/RAPA/GMD/Pages/GMDHome.aspx.

that NERC collaborate with EPRI and GIC modeling software vendors to incorporate beta scaling factors or modeling techniques into the software that is available for industry planners.

G. Task 8: Improve Harmonics Analysis Capability

Under Task 8: Improve Harmonics Analysis Capability, EPRI developed an open-source tool that industry can use to perform GMD-related harmonic studies of the power system and made it available at no cost. GMD-related harmonics are caused by the part-cycle saturation of transformers. These harmonic currents and voltages resulting from transformer saturation can impact system operations during severe GMD events. The tool, GICHarm, provides planners with capability to perform wide-area harmonic analysis that existing commercial tools did not address.

The final report recommends that NERC engage TPL-007 applicable entities through the NERC Reliability and Security Technical Committee and industry forums to promote awareness of available tools, support development, and promote use of best practices for GMD-related harmonic analysis.

H. Task 9: Harmonic Impact Studies

The results and key findings from the work performed under Task 9: Harmonic Impact Studies are summarized as follows. Research on transformer mechanical vibrations caused by GIC concluded that severe GMD events are not likely to adversely impact transformer mechanical integrity. EPRI, participating utilities, and transformer manufacturers collaborated to examine factory and field test data on power transformers of various construction types and sizes. Among other findings, the factory data revealed that vibrations reach their maximum at low levels of GIC and do not increase significantly as GIC levels rise.

Task 9 also included research into vibration and other effects that severe GMD events can have on turbine generators. Harmonic currents from severe GMD events have the potential to cause rotor heating and stimulate mechanical vibrations at frequencies turbine generator designers did not anticipate. A Harmonic Assessment Guide was released that includes generator harmonic screening criteria, a generator case study, and generator protection guidance. Generator impact analysis was also included in the GIC harmonic tool.

The final report recommended that industry continue to support ongoing research and tool development to assess generator risk from severe GMD events. The final report also recommended that NERC request EPRI provide updates to the Reliability and Security Technical Committee periodically on the status of its efforts.

III. CONCLUSION

The completion of the GMD Research Work Plan marks an important milestone in NERC and industry's comprehensive approach to reducing the risks that severe GMD events can pose to the reliability and resilience of the North American grid. Importantly, the findings of this GMD research support the use of the TPL-007 Reliability Standard and provide tools and insights for the ERO, industry, and research partners to use in accurately performing the GMD Vulnerability Assessments required by the standard. As part of the required periodic review of the TPL-007 Reliability Standard, NERC will consider these research findings, as well as any new developments in space weather research and other insights that are gained during the implementation of the standard, to determine whether further improvements and refinements to the standard are necessary.

Respectfully submitted,

<u>/s/ Lauren A. Perotti</u>

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May 7, 2021

<u>Attachment 1</u>

GMD Research Work Plan
Results and Recommendations for the ERO