NERC TPL-007-4 Benchmark and Supplemental Geomagnetic Disturbance 2026 Needs Assessment Scope of Work Revision 1

Revision to the April 28 Presentation

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Purpose

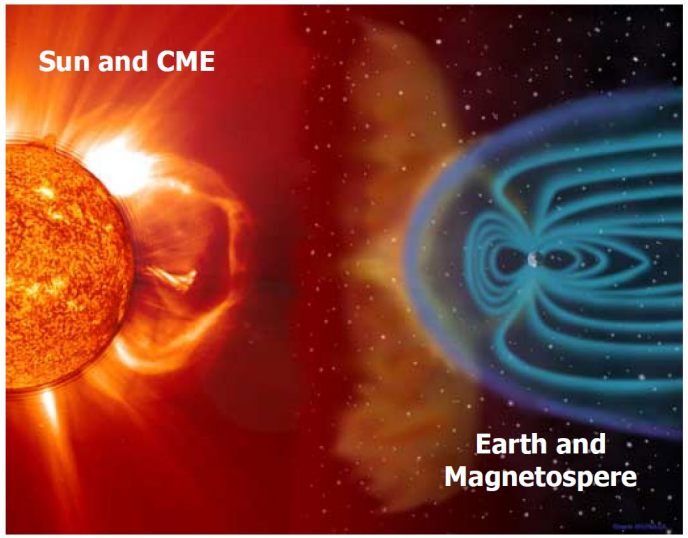
- Present the NERC TPL-007-4 Benchmark and Supplemental Geomagnetic Disturbance (GMD) 2026 Needs Assessment Scope of Work

Overview

- Introduction
- Objectives
- Modeling assumptions
- Study methodology
- Schedule/Next steps
- Appendix

Introduction of GMD Event and NERC Standard TPL-007-4

- Coronal mass ejections (CMEs, a.k.a. solar flares) from the sun produce expulsions of plasma (with accompanying magnetic fields) that can travel towards earth and react with the earth's magnetic field
  - This can cause disturbances of the earth's magnetic field
  - These events are known as Geomagnetic Disturbances (GMDs)



Introduction of GMD Event and NERC Standard TPL-007-4, cont.

- One recorded CME event is shown in the link
- Impacts of GMD events to the power system
  - GMD events introduce Geomagnetically-induced currents (GIC) to the power system
  - GIC may drive transformer cores into saturation, which may result in
    - Overheating
    - Increasing reactive power losses
    - Depressing system voltage
    - Creating harmonic currents that affects relay operations
- GMD events have caused power system issues in the past
  - March 1989 blackout in Quebec
    - 9 hour blackout of Hydro-Quebec's network
    - The GMD event affected power grids all over North America and northern Europe

Introduction of GMD Event and NERC Standard TPL-007-4, cont.

= Completed task

- NERC TPL-007-1, Transmission System Planned Performance for Geomagnetic Disturbance Events, came into effect on Jan 1, 2017
- The activities and analyses required to meet this standard include
  - Gather, review and collate Geomagnetically-Induced Current (GIC) modeling data
    - Required for facilities that include power system data with power transformers with a high side, wye-grounded winding with terminal voltage greater than 200 kV
    - Worked with neighboring Planning Coordinators to include neighboring GIC modeling data
  - Provide Benchmark and Supplemental GIC Flow Information to owners of applicable Bulk Electric System (BES) transformers
    - GIC flow information is necessary for applicable transformer owners to conduct GIC thermal impact assessment, if the GIC flow is over certain threshold
    - There were no issues identified and no further action needed based on the transformer owner's GIC thermal impact assessment
  - Implement process to obtain GIC monitoring data and Geomagnetic field data
  - ***Perform GMD Benchmark and Supplemental vulnerability assessment, based on the Needs Assessment process outlined in Attachment K***
  - If necessary, identify corrective action plans to address GMD vulnerability issues, based on the Solutions Study or competitive solutions process described in Attachment K
- The work needed to meet the standard is new and different from planning studies typically carried out in the industry
  - A new Planning Procedure 11* (PP11) has been created to support GMD related work

* This is the link to PP11, Planning Procedure to Support Geomagnetic Disturbance Analysis.

Introduction of GMD Event and NERC Standard TPL-007-4, cont.

= Completed task

NERC Timeline – TPL-007-4

2019

- **Jul 1, 2019** Standard becomes effective
  R1 – Define Roles and Responsibilities
  R2 – Maintain System GIC Models

2020

- **Jan 1, 2020**
  R5, R9 – Provide Benchmark and Supplemental GIC Flow Information

2021

- **Jul 1, 2021**
  R12 – Implement Process to Obtain GIC Monitor Data
- **R13** – Implement Process to Obtain Geomagnetic Field Data

2022

- **Jan 1, 2022**
  R6, R10 – Complete Benchmark and Supplemental Transformer Thermal Assessment

2023

- **Jan 1, 2023**
  R3 – Specify Voltage Criteria
  R4, R8– Complete Benchmark and Supplemental GMD Vulnerability Assessment

2024

- **Jan 1, 2024**
  R7,R11 – Develop Corrective Action Plans

NE Implementation Plan

2019

- **Jan 1, 2019**
  R2 – Maintain System GIC Models (ISO, App. TOs, Lead MPs for App. GOs)
- **May 3, 2019**
  R1 – Define roles and responsibilities (ISO, TPs)

2020

- **Dec 1, 2019**
  R5, R9 - Provide Benchmark and Supplemental GIC Flow Information (ISO)

2021

- **Mar 31, 2021**
  R12 – Implement Process to Obtain GIC Monitor Data (ISO, TPs)
- **Mar 31, 2021**
  R13 – Implement Process to Obtain Geomagnetic Field Data (ISO)

2022

- **Jan 1, 2022**
  R6, R10 – Complete Benchmark and Supplemental Transformer Thermal Assessment (App. TOs and App. GOs)

2023

- **Complete ASAP, but no later than Jan 1, 2023**
  R3 – Specify criteria for steady state voltage performance
- **Jan 1, 2023**
  R4, R8 – Complete Benchmark and Supplemental GMD Vulnerability Assessment (ISO)

2024

- **If needed, complete no later than Jan 1, 2024**
  R7, R11 – Develop corrective action plans (ISO and App. TPs)

Introduction of GMD Event and NERC Standard TPL-007-4, cont.

- What are Benchmark and Supplemental GMD Events?
  - TPL-007 specifies a "Benchmark GMD Event" for performing the GMD Needs Assessment, which is composed of
    - A reference peak geoelectric field of 8 V/km applied over the study area and neighboring areas
    - Scaling factors to account for local geomagnetic latitude
    - Scaling factors to account for local earth conductivity
    - A reference geomagnetic field time series or waveform to facilitate time-domain analysis of GMD impact on equipment
  - TPL-007 specifies a "Supplemental GMD Event" for performing the GMD Needs Assessment, which is composed of similar elements as the Benchmark GMD event, except
    - A reference peak geoelectric field of 12 V/km applied over the study area, and a reference peak geoelectric field of 1.2 V/km assumed for neighboring areas
    - The geomagnetic field time series or waveform includes a local enhancement

Introduction of GMD Event and NERC Standard TPL-007-4, cont.

Benchmark GMD Event

(less intense, spread over a larger area)

vs.

Supplemental GMD Event

(more intense, concentrated within a smaller area)

Objectives

- The objective of the NERC TPL-007-4 Benchmark and Supplemental GMD 2026 Needs Assessment is to determine whether the New England System meets the performance requirements for the steady state GMD event specified in Table 1 of the TPL-007-4 standard*

* This is the link to NERC Standard TPL-007-4, Transmission System Planned Performance for Geomagnetic Disturbance Events

Modeling Assumptions

- Study Area
  - The GMD Needs Assessment study area is the entire New England (NE) system, and the focus is on facilities connected to the transmission system at 200 kV and above
- Study Horizon and Load Levels
  - The study year is 2026 and focused on two load levels:
    - A 90/10 peak load level (summer evening) utilizing the 2021 Capacity, Energy, Loads and Transmission (CELT) Report*
    - An off-peak load level (nighttime minimum, low renewables) with the New England load fixed at approximately 7,477 MW
- DC model study assumptions
  - The DC model was developed to include facilities connected to 200 kV and above in the NE system
  - Some 115 kV transmission lines were included
  - DC models of the New Brunswick (NB) Power and New York (NY) ISO system were included

* 2021 CELT report link: https://www.iso-ne.com/static-assets/documents/2021/04/2021_celt_report.xlsx

Modeling Assumptions, cont.

- AC model study assumptions
  - All existing and future generators with an FCA 15 obligation are modeled at their Summer Qualified Capacity (QC) rating
  - All other existing generators that do not have a QC value are modeled using their summer seasonal claimed capability (SCC) value
  - All submitted retirement de-list bids through FCA 16 will be excluded from the cases
  - The Needs Assessment will include resources with financially binding contracts and state sponsored Request for Proposals (RFP)* according to Attachment K of the Open Access Transmission Tariff (OATT)**
    - New England Clean Energy Connect (NECEC) HVDC project
    - Vineyard Wind project
    - Revolution Wind project
    - Park City Wind project
    - Mayflower Wind project

* Several RFPs in Maine that are connected to 115 kV and below are not included as these projects do not meet the minimum voltage threshold required for the GMD study.

** https://www.iso-ne.com/static-assets/documents/2021/07/sect_ii_att_k.pdf

Modeling Assumptions, cont.

- Renewable resources are modeled based on the renewable generation dispatch assumptions listed here:

Renewable Generator Type	Dispatch in Peak Load Case	Dispatch in Off-Peak Load Case
Hydro	Min(Historical Output, Summer Qualified Capacity), if no historical data, Min(10% of summer NRC, Summer QC)	Min(Historical Output, Summer Qualified Capacity), if no historical data, Min(10% of summer NRC, Summer QC)
On-shore Wind	Min(5% of summer NRC, Summer QC)	Min(5% of summer NRC, Summer QC)
Off-shore Wind	Min(5% of summer NRC, Summer QC)	Min(15% of summer NRC, Summer QC)
Photovoltaic	Min(26% of summer NRC, Summer QC)	0
Pumped Hydro	50% of QC	0
Battery Storage	Discharging at the lower of Nameplate MW, or (Nameplate MWh, divided by 6)	0

- External interfaces levels for the peak and off-peak load levels are shown below:

Inter-area Interface	Peak Load Case (MW)	Off-Peak Load Case (MW)
NB-NE	700	0
NY-NE	1,400	0
Phase II Imports	1,400	950
CSC Imports	0	0
Highgate Imports	225	225

Modeling Assumptions, cont.

- New England load levels (excludes transmission losses)

Category	System Peak 2026 90/10 Load (MW)	System Off-peak 2026 Load (MW)
CELT 2021 Forecast	30,442	N/A
Fixed New England load	N/A	7,477
Non-CELT Manufacturing load in New England	319	0
Available CELT 2021 EE Forecast for study year (modeled as negative load)	-3,618	0
Available FCA 15 ADCR (modeled as negative load)	-548	0
Available CELT 2021 PV Forecast for study year (modeled as negative load)	-2,182	0
Net load modeled in New England (Excludes Station Service)	24,413	7,477

Modeling Assumptions, cont.

- Transmission upgrades with an In-Service date before June 2026 and a focus on facilities connected to the transmission system at 200 kV and above:
  - RSP Project Tracking Sheet - All reliability upgrades in the March 2022 RSP Project List (Table 1a and 1b) that were Proposed, Planned and Under Construction were included in the base cases
  - Asset Condition Tracking Sheet - In general, all Asset Condition projects that are listed in the March 2022 Asset Condition listing that were Planned, Proposed, or Under Construction are included in the base cases
  - Local System Plan (LSP) Projects Tracking Sheet – Using the information from the October 2021 LSP, projects with a PPA approval for which the ISO had modeling data available have been included in the base cases
  - Tracking sheets can be found at:
    - https://smd.iso-ne.com/operations-services/ceii/pac/2022/01/ceii_final_steady_state_2021_tp_base_case_library_rev1.zip

Modeling Assumptions, cont.

- Reactive power losses due to transformer saturation during GMD events
  - Reactive power losses for each applicable transformer are calculated in PSSE using GIC data received from the TOs and Lead Market Participants for the generator owners
  - All of the applicable transformer reactive power losses are summed up for the New England, New York and New Brunswick areas for the Benchmark and Supplemental GMD events and are shown below:

Category	Maximum Benchmark GMD Event Reactive Power Losses (MVAR)	Maximum Supplemental GMD Event Reactive Power Losses (MVAR)
Reactive power losses in NE	590	830
Reactive power losses in NY	1,160	200
Reactive power losses in NB	440	80

  - Additional cases with various reactive power losses based on geoelectric field orientations at 0°, 30°, 60°, 90°, 120°, and 150° for the Benchmark and Supplemental GMD events are also considered
    - In these cases, the total reactive power losses for the entire study area are less than the MVAR losses in the maximum reactive power losses case but the MVAR loss on individual transformers could be greater than the MVAR loss in the maximum reactive power losses case

Modeling Assumptions, cont.

- Additional AC Model Assumptions for GMD study
  - Summary of the GMD Needs Assessment AC Cases

Case Number	Case Description*
#1	Peak case with no reactive power losses
#2	Off-peak case with no reactive power losses
#3	Benchmark GMD event peak case w/ maximum reactive power losses
#4-#9	Benchmark GMD event peak case w/ corresponding reactive losses for geoelectric field orientations at 0°, 30°, 60°, 90°, 120°, 150°
#10	Benchmark GMD event off-peak case w/ maximum reactive power losses
#11-#16	Benchmark GMD event off-peak case w/ corresponding reactive losses for geoelectric field orientations at 0°, 30°, 60°, 90°, 120°, 150°
#17	Supplemental GMD event peak case w/ maximum reactive power losses
#18-#23	Supplemental GMD event peak case w/ corresponding reactive losses for geoelectric field orientations at 0°, 30°, 60°, 90°, 120°, 150°
#24	Supplemental GMD event off-peak case w/ maximum reactive power losses
#25-#30	Supplemental GMD event off-peak w/ corresponding reactive losses for geoelectric field orientations at 0°, 30°, 60°, 90°, 120°, 150°

* Reactive power losses noted in each of the case descriptions refer to the transformer saturation during GMD events.

Study Methodology

- Steady-State Voltage Criteria
  - TPL-007-4 standard applies to facilities that include power transformers with a high side, wye-grounded winding with terminal voltage greater than 200 kV
  - TPL-007-4 standard requires that 'voltage collapse, cascading, and uncontrolled islanding shall not occur'

Facility	Voltage Level (kV)	Bus Voltage Limits		
		Normal Conditions (N-0) (p.u)	GMD Event (Post-Contingency)	
			Pre-Switching (p.u)	Post-Switching (p.u)
Transmission/Generation	200 and above and less than 345	$0.95\overline{0} - 1.05\overline{0}$	$0.8\overline{0} - 1.05\overline{0}$	$0.8\overline{0} - 1.05\overline{0}$
	345	$0.95\overline{0} - 1.0492\overline{0}$	$0.8\overline{0} - 1.0492\overline{0}$	$0.8\overline{0} - 1.0492\overline{0}$
Millstone/Seabrook	345	$1.\overline{0} - 1.0492\overline{0}$	$1.\overline{0} - 1.0492\overline{0}$	$1.\overline{0} - 1.0492\overline{0}$

Study Methodology, cont.

- Contingency Development
  - Facilities removed as a result of Protection System operation or mis-operation due to harmonics during the GMD event are considered as contingencies in this GMD Needs Assessment

Table 1: Steady State Planning GMD Event

Steady State:

a. Voltage collapse, Cascading and uncontrolled islanding shall not occur.
b. Generation loss is acceptable as a consequence of the steady state planning GMD events.
c. Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.

Category	Initial Condition	Event	Interruption of Firm Transmission Service Allowed	Load Loss Allowed
Benchmark GMD Event – GMD Event with Outages	1. System as may be postured in response to space weather information[1], and then 2. GMD event[2]	Reactive Power compensation devices and other Transmission Facilities removed as a result of Protection System operation or Misoperation due to harmonics during the GMD event	Yes[3]	Yes[3]
Supplemental GMD Event – GMD Event with Outages	1. System as may be postured in response to space weather information[1], and then 2. GMD event[2]	Reactive Power compensation devices and other Transmission Facilities removed as a result of Protection System operation or Misoperation due to harmonics during the GMD event	Yes	Yes

Table 1: Steady State Performance Footnotes

1. The System condition for GMD planning may include adjustments to posture the System that are executable in response to space weather information.
2. The GMD conditions for the benchmark and supplemental planning events are described in Attachment 1.
3. 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.

Study Methodology, cont.

- Contingency Development
  - The ISO relied on the TOs to identify facilities that should be included in the contingency list to be used in the study. The facilities were broken up into five groups. For the purpose of the first GMD Needs Assessment, the ISO focused the contingency selection on transmission elements that are protected by electromechanical and solid state electronic relays, since these relays are considered more susceptible to the effects of GICs*
    - Group #1: 200 kV or higher transmission lines protected by at least one electromechanical and/or solid-state relaying package with a line length greater than 10 miles between terminals
    - Group #2: Grounded-wye shunt capacitors protected by electromechanical and/or solid-state relaying;
    - Group #3: Static VAR compensators (SVCs) and static synchronous compensators (STATCOMs);
    - Group #4: HVDC Installations;
    - Group #5: Power transformers with a high side, wye-grounded winding with terminal voltage greater than 200 kV
  - In addition, the TOs were relied on to identify those facilities on the contingency list that were considered at risk for protection system operation and mis-operation due to harmonics during GMD events
  - Generator contingencies are not included in the contingency list because GICs are isolated from the transmission system due to the delta-wye connection of the generator step-up transformer

* For Groups #2 through #4, the focus was to identify facilities connected to the transmission system at 200 kV or higher. However, the TOs were asked to include facilities below 200 kV, if including the data is appropriate and could potentially impact the results observed at facilities connected at 200 kV and above.

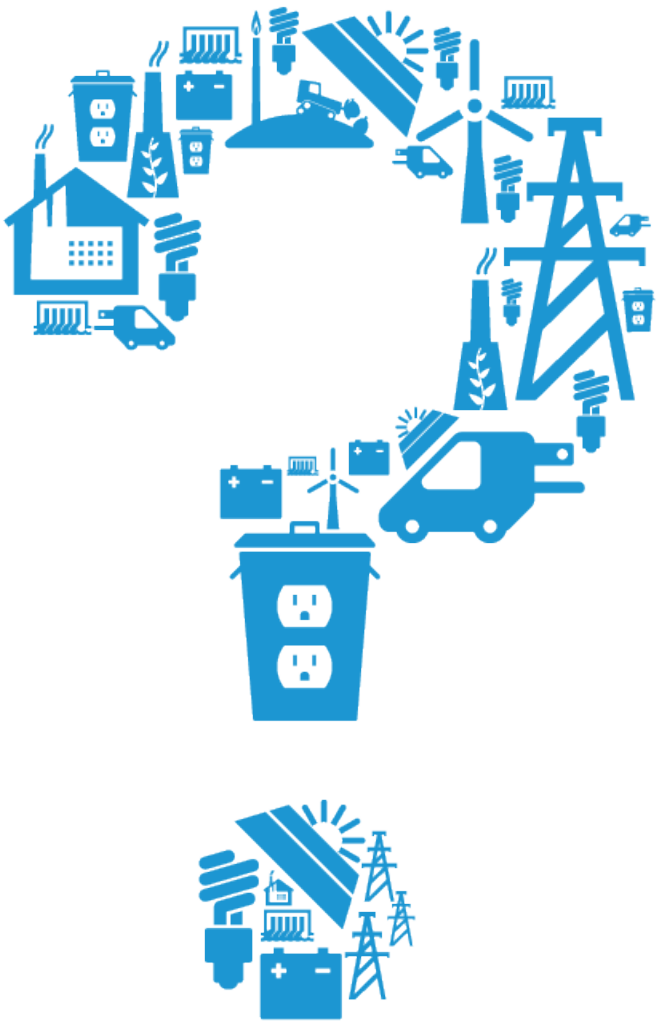
Study Methodology, cont.

- Steady state thermal and voltage analysis will be performed, for N-0 (all-facilities-in), N-1 (all-facilities-in, first contingency), for the described set of benchmark and supplemental GMD events
  - The list of first contingencies were provided by the TOs and will be tested individually

Schedule/Next Steps

- Once the draft GMD 2026 Needs Assessment Scope of Work and intermediate study files are posted, the ISO will collect comments on the report:
  - Until May 13, 2022, if the report is posted prior to the April 28th PAC meeting
  - Until 15 days after the posting of the report, if the report is posted on April 28th or later
- Please submit comments to pacmatters@iso-ne.com

Questions



APPENDIX: BACKGROUND INFORMATION

NERC and NE Implementation Plan Timelines

TPL-007 Requirement	Responsible Entities	TPL-007-4 NERC Compliance Deadlines	NE Implementation Plan Due Date
[R1] – Define Roles and Responsibilities	ISO/TPs	7/1/2019	Compliance requirement met
[R2] – Maintain System GIC Models	ISO, App. TOs/App. Lead MPs for GOs	7/1/2019	Ongoing effort, compliance requirement met
[R3] – Specify Steady State Voltage Performance Criteria for GMD Vulnerability Assessment	ISO/TPs	1/1/2023	Complete ASAP, but no later than 1/1/2023
[R4] – Complete Benchmark GMD Vulnerability Assessment	ISO	1/1/2023	1/1/2023
[R5] – Provide Benchmark GIC Flow Information to Applicable TOs and Lead MPs for Applicable GOs	ISO	1/1/2020	12/1/2019
[R6] – Complete Benchmark GIC Thermal Impact Assessment on > 200 kV BES Transformers	App. TOs/App. GOs	1/1/2022	1/1/2022
[R7] – Develop Corrective Action Plans based on R4 results, as Needed	ISO/App. TPs	1/1/2024	If needed, complete no later than 1/1/2024

NERC and NE Implementation Plan Timelines, cont.

TPL-007 Requirement	Responsible Entities	TPL-007-4 NERC Compliance Deadlines	NE Implementation Plan Due Date
[R8] – Complete Supplemental GMD Vulnerability Assessment	ISO	1/1/2023	1/1/2023
[R9] – Provide Supplemental GIC Flow Information to Applicable TOs and Lead MPs for Applicable GOs	ISO	1/1/2020	12/1/2019
[R10] – Complete Supplemental GIC Thermal Impact Assessment on > 200 kV BES Transformers	App. TOs/App. GOs	1/1/2022	1/1/2022
[R11] – Develop Corrective Action Plans based on R8 results, as Needed	ISO/App. TPs	1/1/2024	If needed, complete no later than 1/1/2024
[R12] – Implement Process to Obtain GIC Monitoring Data	ISO/TPs	7/1/2021	Compliance requirement met
[R13] – Implement Process to Obtain Geomagnetic Field Data	ISO	7/1/2021	Compliance requirement met