NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

May 2024 Geomagnetic Disturbance Event Review Plan

June 2024

Summary and Objective

Multiple coronal mass ejections (CMEs) collided with earth's magnetosphere on May 10 - 12, 2024, resulting in the largest geomagnetic disturbance (GMD) in over two decades. Bulk power system (BPS) operators received early notification from the U.S. National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC) through existing protocols and Reliability Coordinators (RCs), Transmission Operators (TOPs) and other registered entities implemented GMD Operating Procedures. The BPS remained stable throughout the event as GMD conditions varied between Strong (G3) and Extreme (G5) over the three-day period. Operators observed isolated impacts to BPS transformers, voltage support equipment, transmission line breakers, and harmonic filters. Additionally, high levels of geomagnetically-induced currents (GIC) and harmonics were reported by operators and EPRI's SUNBURST monitoring network.

This major storm provides an important opportunity to deepen understanding of GMD events and their effects on the BPS and continue the industry and NERC's activities to reduce the risk that extreme GMD events pose to grid reliability. The operating reliability of the BPS was largely unaffected by the May 10-12 GMD Event (May GMD Event), but NERC's data sources, which include the GMD Data System and various equipment data systems, can provide information to complement industry observations and insights to provide expanded understanding. The results of this review will serve to inform industry operating procedures and practices and technical guidelines used for planning and operating the BPS. Results may also support better understanding of GMD events and their impacts to electricity infrastructure by the broader space weather community.

GMD Event Overview

On May 9, 2024, SWPC issued the following statement: "At least five Earth-directed coronal mass ejections (CMEs) were observed and expected to arrive as early as midday Friday, May 10, 2024, and persist through May 12, 2024. This is an unusual event." The statement continued "Several strong flares have been observed over the past few days and were associated with a large and magnetically complex sunspot cluster (NOAA region 3664), which is 16 times the diameter of Earth." A later update from NOAA stated that at least seven CMEs were in transit. The SWPC forecast for G5 (Extreme) conditions stated that this would be the first G5 event since the Halloween Storm of October 2003. SWPC initiated a GMD voice notification to RCs via hotline early on May 12 prior to CME arrival, in addition to SWPCs broadcast products for the end-users. System operators implemented GMD Operating Procedures and NERC began regular situational awareness updates to ERO leadership, FERC, and U.S. Department of Energy.

CMEs began producing a strong to extreme geomagnetic storm on Friday afternoon, May 10, and dynamic conditions existed through May 12. SWPC provided frequent voice notifications to RCs per established protocols.

Reported BPS Impacts

The BPS remained stable throughout the May GMD Event. Elevated levels of GIC and harmonic distortion were observed across the BPS, however most RCs indicated that the conditions produced by the May GMD Event did not impact the operation of the BPS in their areas. From the initial reports from system operators, impacts to the transmission system and equipment were limited to areas of the U.S. Northeast, U.S. Mid-Atlantic, and Western Canada.

GIC and harmonic currents during the May GMD Event affected operations in affected areas by triggering alarms and operating procedures to protect transformers and other equipment, as well as causing some transmission system components to trip off-line. GIC alarms that are set to protect power transformers were triggered in some affected areas. At one nuclear generating unit in the northeastern U.S., operators reduced power output in response to high GIC levels in the generator step-up (GSU) transformer in accordance with procedures. Elsewhere, there were several reports of transformer top-oil over-temperature alarms that resulted in operator monitoring or additional actions.

Harmonic distortion was observed in many parts of the transmission and distribution system. Harmonic filters on a 345 kV transmission line in Western Canada tripped during the GMD event. Harmonic distortion may have contributed to the reported tripping of a 110 kV transmission line, tripping of a 138 kV capacitor bank, and voltage oscillations at a solar photovoltaic (PV) generation unit and a battery bank in affected areas.

Review Plan

A rigorous review of the May GMD Event will support reducing risk to the BPS from severe GMD events by informing our existing mitigation activities and identifying needs for additional actions. In past GMD workshops hosted by NERC and EPRI, representatives from planning and operating entities have identified the need for continued improvements to tools and capabilities for addressing GMD risk. Data and observations from the May GMD Event have the potential to enable enhancements that will improve the accuracy and comprehensiveness of the GMD Vulnerability Assessments and the effectiveness of operating procedures that are required of entities by NERC reliability standards. The review plan will focus on the following objectives:

- **Impact of GIC-related harmonics on the BPS.** The review will obtain (i) information on impacts to equipment from GIC-related harmonics, and (ii) available measurement data to understand the levels of harmonic distortion on the system during the event. Where feasible, comparisons with modeled/expected levels of harmonics will be made. This objective is aimed at improving GMD Vulnerability Assessment tools, processes, and scope.
- **Transformer thermal impacts.** Transformers that were affected by high GIC will be identified and analysis will be performed to inform thermal impact modeling and vulnerability assessment. Also, NERC entities that have thermal instrumentation on transformers are encouraged to perform model

validation by comparing modeled and measured hot-spot temperatures, and provide insights. This objective supports effective and accurate modeling capabilities necessary for GMD Vulnerability Assessments.

- **GMD Benchmarks.** The review will use available transformer thermal models to examine the potential transformer hot-spot heating that can be produced by GIC signatures from solar storms that have characteristics similar to the May GMD Event. This effort can inform efficacy of the existing TPL-007 benchmark in representing a 100-year scenario.
- **GIC Model Validation.** The review will use collected GIC measurements and industry GIC estimates to validate GIC Models. Discrepancies will be analyzed to determine sources of modeling error and identify needs for improved data, processes, or tool capabilities. This objective supports accurate GMD Vulnerability Assessment processes and operating procedures.
- **GMD operations best practices.** The review will obtain information on the operating actions taken by RCs, TOPs, and Generator Operators (GOPs) and observations from system operators. Making this information available will support sharing of best-practices and could identify improvements in situational awareness capabilities.

Participants

NERC is requesting support from various experts and stakeholders to support this review plan. Participation is specifically requested from:

- **Industry planners**: representatives from Transmission Planners (TP) and Planning Coordinators (PC) that conduct GMD Vulnerability Assessments and can review observed impact information
- **Industry operators**: representatives from RCs, TOPs, GOPs and other system operators familiar with the GMD Operating Procedures that were implemented during the May GMD Event
- **Industry GMD Subject Matter Experts (SMEs)**: representatives from Transmission Owners (TO), Generator Owners (GO) and other registered entities with expertise in GMD effects on BPS equipment or operations that can review impact information
- **EPRI:** research collaborators and operators of the SUNBURST network
- **Space Weather Centers in U.S. and Canada:** NOAA SWPC, NR-Canada, and NASA collaborators that can provide information on the geomagnetic fields and geoelectric fields during the May GMD Event; Include U.S. Geological Survey and other earth conductivity modeling support as needed.
- **GMD SMEs from equipment vendors and manufacturers:** Representatives from transformer manufacturers and service providers that are familiar with GIC impact assessment; Representatives from providers of GIC simulation software

NERC is soliciting May GMD Event review participants directly by contacting attendees from past NERC/EPRI GMD Workshops and through the Real-time Operating Subcommittee (RTOS).

NERC, with support from the review participants, will provide public opportunities for stakeholders to be kept informed of the progress of the May GMD Event review and provide comments on deliverables.

Data and Information Sources

NERC and the project team will use ERO data sources and other information supplied by industry. ERO data sources include the following data collection programs:

- Geomagnetic Disturbance Data System
- Transmission Availability Data System
- Generating Availability Data System
- Misoperation Information Data Analysis System

In addition to these data programs, the event review will make use of other information (e.g., harmonic distortion measurements, transformer temperature monitoring, operator event information) that industry voluntarily provides to NERC for the purposes of understanding the impacts of the May 2024 GMD event on the BPS.

Some data and information that is collected and analyzed in the GMD Event Review may be considered confidential as defined in NERC Rules of Procedure Section 1500. NERC and participants will protect confidential information as specified in NERC Rules of Procedure. Reports, products, and deliverables for this review will not disclose confidential information, however every effort will be made to include sufficient details to ensure stakeholders can understand the impacts to the BPS from the May 2012 GMD Event.

Actions and Milestones			
Date	**Event**	**Description**	**Participants**
May 15	RTOS Web Meeting	During the regular meeting of the RTOS, RC participants described the operating actions and observations of the May 10-12 GMD Event. RCs agreed to follow-up meeting with SWPC to share insights.	RTOS
May 17	GMD Data System Event Notice	NERC notified GMD Data System reporting entities of data collection period and requested GIC and magnetometer data by June 30, 2024 (per approved Section 1600 Data Request, data must be submitted no later than June 30, 2025).	GMD Data System reporting entities
June 5	RC-SWPC-NERC Web Meeting	SWPC forecasters and RC representatives discuss feedback and lessons learned alerts, warnings, and operating procedures	SWPC-RTOS
June 12	Reliability and Security Technical Committee (RSTC) Hybrid Meeting	During the regular meeting of the RSTC, NERC will provide a summary of the BPS and operator response to the May GMD Event.	RSTC

Actions and Milestones			
Date	**Event**	**Description**	**Participants**
June 25	GMD Event Review Kick-off Web Meeting	NERC will discuss the GMD Event Review plan and obtain feedback from industry, research collaborators, and stakeholders.	NERC GMD technical group, EPRI, GMD Data Collection entities.
June 30	GMD Data System Reporting Period	NERC GMD Data System reporting entities are requested to provide GIC and Magnetometer data for the May GMD Event.	GMD Data System reporting entities
July - September	GMD Event Review Working Meetings (Webex)	Working meetings approx. every 2 weeks to collect, review, and analyze event information and data (detailed work plan will be developed separately)	GMD Event Review Participants
August TBD	GMD Event Review Project Update Webinar	NERC project update for stakeholders via open webinar	All Stakeholders
August 15	TADS Reporting Deadline	TADS Reporting Entities report transmission system data required by the TADS program.	TADS Reporting Entities
August 29	MIDAS Reporting Deadline	MIDAS Reporting Entities report protection system misoperations data required by the MIDAS program.	MIDAS Reporting Entities
September 11-12	RSTC Meeting	NERC update to the RSTC	RSTC Members and meeting observers
October 1-2	NERC-EPRI GMD Workshop (Hybrid)	2-day event will include discussion of initial findings, recommendations, and next steps. Attendees can participate at NERC HQ in Washington D.C. (subject to available meeting room capacity) and by Webex (open)	GMD Event Review Participants Stakeholders (Open)
November	GADS Reporting Deadline	GADS Reporting Entities report generating unit availability data required by the GADS program.	GADS Reporting Entities
November - December	GMD Event Review Reporting - Drafts	NERC will prepare materials (e.g., summary report, input to 2024 State of Reliability Report, presentations) to communicate findings and recommendations and solicit stakeholder feedback	NERC GMD Event Review Participants
December 11-12	RSTC Meeting	NERC update to the RSTC	RSTC Members and meeting observers

Actions and Milestones			
Date	**Event**	**Description**	**Participants**
January 2025	GMD Event Review Reporting - Final	NERC will finalize materials (e.g., summary report, input to 2024 State of Reliability Report, presentations) to communicate findings and recommendations	NERC GMD Event Review Participants
Beginning January 2025 -	Follow-on Outreach	After completing the May GMD Event review, NERC, EPRI, and participants will support outreach to communicate findings and recommendations	GMD Event Review Participants

Deliverables

NERC will document the results of the GMD Event Review at the conclusion. NERC will issue a report containing findings, recommendations, and supporting analysis. This could be accomplished in a stand-alone report, or through NERC's annual State of Reliability Report.

Communications

NERC Communications staff will support objectives for open, timely and effective engagement with stakeholders. If needed, a detailed communications plan will be developed to inform stakeholders of project status, opportunities for participation, and results of the May GMD Event review.