NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Industry Advisory

Preparing for Geo-Magnetic Disturbances

Initial Distribution: May 10, 2011

NERC and Regional Entities are monitoring the threat to bulk power system reliability caused by damaged equipment from Geo-Magnetic Disturbances. This Advisory provides industry with a set of operational and planning actions to prepare for the effects of severe Geo-Magnetic Disturbances on the bulk power system.

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Status:	Industry Advisory – No Action Necessary
	**PUBLIC:** No Restrictions **More on handling >>**
Instructions:	NERC Advisories are designed to improve reliability by disseminating critical reliability information and are made available pursuant to Rule 810 of NERC's Rules of Procedure, for such use as your organization deems appropriate. **No response is necessary.** This NERC Advisory is not the same as a reliability standard, and your organization will not be subject to penalties for a failure to implement this Advisory. Additionally, issuance of this Advisory does not lower or otherwise alter the requirements of any approved NERC Reliability Standard, or excuse the prior failure to follow the practices discussed in the Advisory if such failure constitutes a violation of a NERC Reliability Standard.
Distribution:	**Primary Distribution based on NERC Functional Model:** Reliability Coordinator, Balancing Authority, Transmission Owner, Transmission Operator, Generation Owner, Generation Operator, Planning Authority (Coordinator), Interchange Authority, Transmission Planner, Transmission Service Provider **Who else will get this alert? >>** **What are my responsibilities? >>**
Rating:	The ES-ISAC estimates that the risk to bulk power system reliability from this vulnerability is ***Medium***. This rating is due to potential damage on significant numbers of transmission assets including outages of bulk power system facilities and electric supply due to geomagnetically induced currents (GIC) caused by solar activity.
Geo-Magnetic Disturbance Primer	*For additional GMD information see the attached background document.*

Time Horizon	Solar Cycle 24 started in January 2009 with a peak expected in May 2013.[1]
Limitations	The impacts of severe Geo-Magnetic Disturbances (GMDs) and subsequent effects on the bulk power system differ depending on solar storm orientation, intensity, and duration. In the U.S., warning levels from the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC) do not fully represent the impact of the storm intensity because of limited ability to initially detect key parameters.[2] Therefore, as SWPC issues higher levels of warnings, monitoring of system and equipment conditions is important. The Reliability Coordinators can coordinate actions between Transmission and Generator Operators as well as Balancing Authorities so that appropriate actions are taken to protect equipment and support restoration efforts. NERC's Draft GMD Guideline provides additional background on warning levels and information exchange.[3] While the impacts of Geo-Magnetic Disturbances in the Northern Hemisphere have been primarily observed in the northern latitudes, a severe GMD can reach the central and southern portions of the United States. ***The following categorized lists provide prospective examples based on industry experience that could be used by entities to reduce or mitigate the impacts of high levels of GIC resulting from severe GMD.***
Obtaining Alerts for Geo-Magnetic Disturbance	NERC's Reliability Standard, IRO-005-2, Requirement R6,[4] states: *"Each Reliability Coordinator shall ensure its Transmission Operators and Balancing Authorities are aware of Geo-Magnetic Disturbance (GMD) forecast information and assist as needed in the development of any required response plans."* The information from the NOAA SWPC is sent to the Midwest ISO's St. Paul, Minnesota office and Western Electric Coordinating Council's (WECC's) Reliability Coordinators in Vancouver, WA and Loveland, CO, which have been designated to receive and disseminate notifications of potentially severe GMDs to Reliability Coordinators (RC), Balancing Authorities (BA), and Transmission Operators (TOP). The Midwest ISO RC disseminates this information to the Eastern and ERCOT Interconnections and the WECC RC to the Western Interconnection. SWPC monitors the preliminary values of the K-index, minute-by-minute, and notifies NYISO, WECC RC and the

[1] http://www.swpc.noaa.gov/SolarCycle/index.html
[2] See http://www.swpc.noaa.gov/info/Kindex.html. K9 is the highest level, however, it represents all storms at 500 nanotesla/minute or higher.
[3] See PDF page 127 of NERC's Operating Manual at http://www.nerc.com/files/opman_12-13Mar08.pdf and NERC's GMD Draft Guideline: http://www.nerc.com/files/GMD_Guideline_v2_clean.pdf
[4] See http://www.nerc.com/files/IRO-005-2.pdf

	Midwest ISO when the critical thresholds of K-index is greater than 5. NERC informs designated Regional Entity contacts of K-index storms greater than 6 through phone and email correspondence. The Québec Interconnection receives notifications of possible GMDs from the Solar Terrestrial Dispatch Center (STDC) in Canada. The SWPC and the Geological Survey of Canada of the Department of Natural Resources Canada (NRCAN), serve as backup to STDC.
GMD Warning Notification System	To receive NOAA K-Index Alerts and Warnings, resister here: https://pss.swpc.noaa.gov/LoginWebForm.aspx?ReturnUrl=%2fproductsubscriptionservice Space Weather Canada forecasts can be found here: http://www.spaceweather.gc.ca/index-eng.php
Advisory Actions	*Each entity should determine which of these actions are best suited for their system, considering their own system topology, location, ground resistivity, equipment susceptibility to GIC, and experience with past GMD events. All operating actions are coordinated between the Transmission and Generator Operators, Balancing Authorities and their respective Reliability Coordinators.*
Operations Planning Actions	**Operational Planning actions to be considered by the Reliability Coordinator after a severe GMD event (K>6)[5] is predicted by NOAA or STDC, or that GIC activity being measured by monitoring equipment, reaches a pre-determined level. All activities are meant to be considered prior to impacts on real-time operations:** 1. Increase import capability: • Discontinue non-critical maintenance work and restore out-of-service transmission lines, wherever possible. • Evaluate postponing/rescheduling planned outage and maintenance activities. Avoid taking transmission lines out of service unless to interrupt a major path of GIC current, and the bulk power system reliability affects of the line outage has been evaluated. 2. The Reliability Coordinator may instruct Generator Operators to increase real and reactive reserves to preserve system integrity during a strong GMD event by performing such actions as: • Reducing generator loading.

[5] The K-Index is further described in the GMD Background Document at the following link (update prior to posting)

- Evaluate generator re-dispatch mix to implement.
- Bringing equipment on-line that is capable of providing reactive power, such as generators, synchronous condensers, static VAr compensators, etc.

3. Transmission Operators and Generator Operators should increase attention to situation awareness and enhance surveillance procedures. Reliability Coordinators should be informed of all actions such as:
   - Unusual voltage and/or MVAr variations and unusual temperature rise are detected on transformers and GSU's.
   - Abnormal noise and increased dissolved gas on transformers, where monitoring capability exists.
   - Trips by protection or unusual faults that are detected in shunt capacitor banks and static VAR compensators.

Real-Time Operations Actions	**Operator Actions to be coordinated with the Reliability Coordinator after receiving a severe GMD warning (K>6), prior to the detection of increased base-line GIC levels (30 to 60 minutes prior to storm impact).** 1. Increase reactive reserves and decrease loading on susceptible equipment and coordinate the following actions with their Reliability Coordinator such as: • Bringing equipment online to provide additional reactive power reserves. • Increasing dynamic reactive reserves by adjustment of voltage schedules or other methods.[6] • Reducing power transfers to increase available transfer capability and system reactive power reserves. • Decreasing loading on susceptible transformers through reconfiguration of transmission and re-dispatching of generation. 2. Increase attention to situation awareness and coordinate information and actions with Reliability Coordinator such as: • Reducing power output at susceptible generator stations if erratic reactive power output from generators or excess reactive power consumption by generator step-up transformers is detected. • Removing transmission equipment from service if excessive GIC is measured or unusual equipment behavior is experienced and the system affects of the equipment outage has been evaluated.

[6] **Note:** Raising voltage levels may place transformers closer to saturation

Long Term Stakeholder Actions

Actions to be considered by Transmission Planners, Generation Planners, and Planning Authorities to prepare for future occurrences of severe Geo-Magnetic Disturbances:

1. Modeling and Simulation
    - Based on historical geomagnetic induced current (GIC) data and transmission facility geographical location, simulate the effects of GIC on the power system from a variety of geomagnetic storm orientation and intensities to identify transformers and/or steel core inductors that can be damaged from heat caused by half-cycle core saturation, increased system reactive requirements, and the introduction of harmonics. Knowledge of how transformers (type and construction) will react, and how grid hardening options, such as in-line blocking devices will perform in transformer-saturated environments induced by GIC is vital to completing this task.
    - Review operating practices, especially for areas susceptible to GMD events to ensure that voltages do not approach operating range limits.
    - Consider using transformer manufacturer simulation models to identify heating effects due to GIC, and determine performance capabilities of cooling systems.
2. Review Relaying:
    - Evaluate negative-sequence-current relay settings on transformers, generators and transmission lines to determine if adjustments are needed which could be elevated due to high harmonic current levels.
    - Verify that protective relaying on capacitor banks, static VAr compensators (SVCs), synchronous convertors, and other reactive supplies are resilient to reactive power swings, over/under voltage, and employ adequate harmonic suppression to avoid misoperation during GMD events.
    - Verify and consider adjusting current transformer (CT) ratio and transformer differential relays including harmonic restraint. High levels of direct current can cause CT saturation and therefore unreliable outputs; CT's in neutral circuit locations could also experience over current due to high harmonics.
3. Inventory assessment:
    - Due to their long-lead manufacture time, identify those installed

high voltage transformers (such as transformers with a high-side greater than 200kV),[7] that could be damaged from high levels of GIC.

- Inventory spare transformer assets and ensure type and location of assets are identified.
- Alternative asset lists and emergency contacts may be necessary in the event of computer malfunction.

4. Design Information
   - Install monitoring devices on equipment most susceptible to GIC to measure transformer neutral (quasi-dc) currents to provide better data on GIC activity and ground impedances. Data collection (e.g. SCADA) of GIC values should be used to provide operators with real time monitoring data and information tools; increasing their situational awareness and decision making.
   - Evaluate reactive demand due to transformers' core saturation based on historical GIC data and transmission facility geographical locations. Determine levels of "dynamic" reactive capability (generator head-room, SVCs, automated switched cap banks) on the power system to preserve voltage and prevent collapse.
   - Consider design change options to address the effects from these high levels of GIC.

NERC Ongoing Activities

NERC is actively addressing a range of high impact, low frequency (HILF) event risks to bulk power system reliability through the efforts of: NERC's Geo-Magnetic Disturbance, Spare Equipment Database, Cyber and Physical Attack, and Severe Impact Resilience Task Forces, under direction of the Planning, Operating, and Critical Infrastructure Protection Committees.

The objective of these efforts is to develop models to better understand the nature and affects of Coronal Mass Ejections (CME), the vulnerabilities of equipment, bulk power system design considerations, ability to reduce the operational and real time impacts of GMD on the bulk power system, inventory long-lead time equipment, and restoration methods.

Additional information will be issued as findings from this assessment are completed.

[7] FERC-ORNL Metatech 319 identified transformers at Risk: http://www.ornl.gov/sci/ees/etsd/pes/pubs/ferc_Meta-R-319.pdf

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