UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Reliability Standards for Geomagnetic Disturbances	**))**	**Docket No. RM12-22-000**

COMMENTS OF THE FOUNDATION FOR RESILIENT SOCIETIES

Submitted to FERC on April 1, 2013

Pursuant to the Federal Energy Regulatory Commission's ("FERC" or "Commission") Notice of Proposed Rulemaking (NOPR) issued on October 18, 2012,[1] the Foundation for Resilient Societies respectfully submits Supplemental Comments on the Commission's proposal to direct the North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization (ERO), to submit for approval Reliability Standards that address the impact of geomagnetic disturbances (GMD) on the reliable operation of the Bulk-Power System (BPS).

The Foundation for Resilient Societies (or "Foundation") is incorporated in the State of New Hampshire as a non-profit organization engaged in scientific research and education with the goal of protecting technologically-advanced societies from infrequently occurring natural and man-made disasters. All technologically-advanced societies rely on critical infrastructures—electric power generation and transmission, telecommunications, transportation, financial services, petrochemical refining, food production, water, and sanitation, to name just a few. Sustained interruption of any one of these critical infrastructures can result in economic, political, and social chaos. The profit incentive, which normally serves society well, provides inadequate protection from disasters that occur infrequently but have impact beyond the responsibilities of commercial enterprises. The Foundation seeks to identify cost-effective opportunities to protect societies and then develop policy initiatives. Its Board of Directors

[1] Reliability Standards for Geomagnetic Disturbances, Notice of Proposed Rulemaking, 141 FERC ¶ 61,045 (2012) ("GMD NOPR").

consists of persons residing in New Hampshire, Arizona, California, Massachusetts, and Virginia. Information about the Foundation may be found at www.resilientsocieties.org.

NECESSITY AND TIMING OF SUPPLEMENTAL COMMENTS

We file these Supplemental Comments, together with Appendices, in FERC Docket RM12-22-000. We request that all these documents, together with the twenty seven (27) click-through document references in our research report, "Solar Storm Risks for Maine and the New England Electric Grid, and Potential Protective Measures," (Appendix 1), and the click-through reference to the Geomagnetic Disturbance Operating Procedures of ISO-New England be a part of the Docket record, so as to assist the Commission and Commission Staff in rulemaking and any related FERC Order on GMD.

The filing deadline for FERC Docket RM12-22-000 was December 24, 2013. No FERC Order has yet been made on Docket RM12-22-000. The docket is still open and comments are still being posted in the FERC Online eLibrary. For example, FERC accepted a reply comment by NERC dated January 10, 2013 which is now posted.

The Foundation for Resilient Societies respectfully requests that the Commissioners give full consideration to our Supplemental Comments and reference documents for the following reasons:

1. Public testimony before the Energy, Utilities and Technology Committee of the Maine State Legislature by ISO-New England and Central Maine Power regarding their GMD operating procedures did not take place until March 21, 2013.

2. ISO-New England released updated GMD operating procedures on February 1, 2013 and then released substantially new GMD operating procedures with a first publication date of February 20, 2013.

3. Limited, single observation GIC data for Seabrook nuclear power plant was made available to the GMD Task Force via the NERC website on March 17, 2013.

4. On March 21, 2013, Central Maine Power voluntarily released 20 years of GIC data for its Chester, Maine substation in response to a request by the Energy, Utilities and Technology Committee of the Maine State Legislature.[2]

5. The NERC GMD Operating Procedure Templates were not approved by the NERC Planning Committee and released to the GMD Task Force until March 6, 2013.

6. With rare exception, electric utilities have not released data from their GIC readings, instead keeping this data confidential.[3]

7. With rare exception, the Electric Power Research Institute (EPRI) has not released data from its SUNBURST database of GIC readings, instead keeping this data confidential.[4]

8. NERC has not released data from its Generating Availability Data System (GADS) and Transmission Availability Data System (TADS) databases that could have been used to investigate impacts of GIC upon power transformers.

In summary, new and significant information has become available since the December 24, 2012 docket deadline. This new and significant information is directly related to the pending FERC NOPR for GMD protection and should be given full weight by the Commissioners.

Moreover, NERC and the electric utility industry have in their possession data on GIC and its potential impacts to the bulk power system, but for the most part this data has not been available for FERC consideration of the pending NOPR. As a result, when GIC and system impact data does become available, it should be given full weight by the Commissioners.

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[2] By its voluntary and good-faith release of GIC data and system impacts, Central Maine Power has set a new standard among privately owned utilities for appropriate disclosure.

[3] In response to a Freedom of Information Act request by the Foundation for Resilient Societies, Bonneville Power Administration released 20 years of GIC data for 12 monitoring stations in October 2012.

[4] In response to a Freedom of Information Act request by the Foundation for Resilient Societies, Tennessee Valley Authority has agreed to release GIC data and the Electric Power Research Institute has expressed willingness to provide technical support for this request.

BACKGROUND

FERC Notice of Proposed Rule Making on GMD

In the FERC NOPR, the Commissioners proposed two stages of rule-making, with development of a NERC standard on "operational procedures" (also commonly referred to as "operating procedures") being the first stage. (Emphasis added.):

> Pursuant to section 215(d)(5) of the Federal Power Act (FPA), the Federal Energy Regulatory Commission (Commission) proposes to direct the North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization (ERO), to file for approval with the Commission Reliability Standards (GMD Reliability Standards) that address the risks posed by geomagnetic disturbances (GMD) to the reliable operation of the Bulk-Power System. The Commission proposes to direct NERC to develop the GMD Reliability Standards in two stages. *In the first stage, within 90 days of the effective date of a final rule in this proceeding, NERC would file one or more proposed 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.* In the second stage, within six months of the effective date of a final rule in this proceeding, NERC would file one or more proposed Reliability Standards that require owners and operators of the Bulk-Power System to conduct initial and on-going assessments of the potential impact of GMDs on Bulk-Power System equipment and the Bulk-Power System as a whole. Based on those assessments, the Reliability Standards would require owners and operators to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. *This plan cannot be limited to operational procedures or enhanced training alone*, but should, subject to the needs identified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, or location of specific equipment. These strategies could include automatically blocking geomagnetically induced currents (GICs) from entering the Bulk-Power System, instituting specification requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to retrofit. This second stage would be implemented in phases, focusing first on the most critical Bulk-Power System assets.

LD 131 under Consideration in Maine State Legislature

On January 29, 2013, Legislative Document (LD) 131, "An Act To Secure the Safety of Electrical Power Transmission Lines" was introduced in the Maine State Legislature. The Energy, Utilities and Technology Committee has conducted several public hearings on LD 131, including a hearing on March 21, 2013 that examined GMD operating procedures of ISO-New England. As part of its scientific and educational mission, and in preparation for the March 21, 2013 hearing, the Foundation authored a research report, "Solar Storm Risks for Maine and the New England Electric Grid, and Potential Protective Measures." This report is contained in Appendix 1.

COMMENTS

Geomagnetic Disturbance Operating Procedures and Templates

Regional Transmission Operators/Independent System Operators (RTO/ISO have used GMD operating procedures to mitigate solar storm effects in their control areas for over a decade. For example, ISO-New England, with a control area subject to frequent GMD conditions, has had GMD operating procedures in place since February 13, 2003.The current Geomagnetic Disturbance Control Room Operating Procedure of ISO-New England can be found at:

http://www.iso-ne.com/rules_proceds/operating/sysop/cr_ops/crop_24003.pdf

As part of its charter to study GMD and develop recommendations, the Geomagnetic Disturbance Task Force ("GMD Task Force") of NERC produced a Geomagnetic Disturbance Operating Procedure Template ("GMD Operating Procedure Template") for Transmission Operators and another largely similar template for Generation Operators. Both NERC GMD Operating Procedure Templates were approved by the NERC Planning Committee on March 6, 2013. These templates are reproduced in Appendix 2 and Appendix 3.

It is the position of the Foundation for Resilient Societies that most, if not all, of the GMD operating procedures currently in use by electric utilities are paper exercises that will not reliably prevent grid blackouts or equipment damage during severe solar storms. Instead, the primary benefit of GMD operating procedures has been to reassure the FERC Commissioners and a trusting public that the electric utility industry has prudently acted on its own and therefore that no formal reliability standard on GMD is required, either for operating procedures or for hardware to protect critical equipment within the bulk power system. By approving GMD Operating Procedure Templates, NERC and its Planning Committee now apparently seek to provide an extra layer of legitimacy to a GMD mitigation system that is, at its very core, technically deficient. Given limited solar storm warning times, perhaps ten or twenty minutes from ACE satellite detection, and significantly less prompt generating reserves than projected outages from both generation and transmission systems, industry “operating procedures” appear to be unrealistic and imprudent.

The GMD operating procedures currently in use and the templates recently approved by the NERC Planning Committee are technically deficient for many reasons, but for the purposes of this Supplemental Comment, we examine three of the most major and obvious reasons:

1. GMD operating procedures in current use and the new NERC GMD Operating Procedure Templates do not require advance mathematical modeling.[5]

2. GMD operating procedures currently in use and the new NERC GMD Operating Procedure Templates do not require system-wide GIC instrumentation or real-time GIC reporting to control rooms and to regional grid balancing authorities.

3. The load shedding, system reconfiguration, and removal from service of transformers and transmission lines suggested by GMD operating procedures currently in use and the new GMD operating procedures templates cannot be reliably performed within the short warning time provided by a satellite in the Lagrange 1 position ("L1 position"). This

[5] The NERC GMD Operating Procedure Templates state in the "Overview" section, "Some actions listed below should only be undertaken if supported by an adequate GIC impact study and/or if adequate monitoring systems are available. Otherwise they can make matters worse." Unfortunately, "adequate GIC impact study" could be interpreted as a qualitative, non-mathematic study. In addition, the template contains no further definition for "adequate monitoring systems." These template deficiencies are especially problematic when utility GMD studies are not open to public examination.

warning time using solar wind data could be as short as 10 minutes for the fastest moving and most severe solar storms.

Case Study of ISO-New England GMD Operating Procedures

ISO-New England released a new version of GMD Control Room Operating Procedures on February 20, 2013. The procedures specify actions that may be taken in response to a GMD event or alert:

Condition(s) to perform this step:

Notification of an Actual GMD event of intensity 7 or greater with GIC activity of 10 Amps or greater.

Or notified of a GMD Alert of intensity 7 or greater with a probability of 40% or greater with GIC activity of 10 Amps or greater.

Step 1.9 Determine if any actions will be taken.

Instructions

While determining what actions to take the Operations Shift Supervisor may consult LCCs; neighboring RC/BA; GMD monitoring sites; Manager, Control Room Operations; or the Director, Operations to help with evaluating the situation.

The following are possible actions that could be taken:

a. Discontinue maintenance work and restore out of service high voltage transmission lines. Avoid taking long lines out of service
b. Maintain system voltages within acceptable operating range to protect against voltage swings
c. Review the availability of the Chester SVC and capacitor banks to respond to voltage deterioration if necessary
d. Adjust the loading on Phase II, the Cross Sound Cable and Highgate HVdc ties to be within the 40% to 90% range of nominal rating of each pole
e. Reduce the loading on Inter-RCA/BAA ties and on other internal critical transmission lines and interfaces to 90%, or less, of their security limits
f. Do not lower TMSR below 50%, spinning units online will provide more reactive reserves. If geomagnetic activity is severe enough consider increasing TMSR forcing more units with reactive reserves online.
g. Consider posturing Generators operating at their Eco Max to provide room for reserves and reactive capacity in accordance with CROP.25001 Posturing.

h. Dispatch generation to manage system voltage, tie line loading and to distribute operating reserve
i. Bring equipment capable of synchronous condenser operation on line to provide reactive power reserve
j. In conjunction with personnel at those locations where GMD measurements are to be taken, ensure the monitoring equipment is in service
k. Closely monitor RTCA Voltage contingencies and consider the impact of tripping large shunt and series capacitor banks and static VAR compensators.
l. If conditions are severe enough, consult with LCCs and consider reclosing tripped capacitor banks and SVCs ASAP that are likely tripped by erroneous relay action and not damage.

March 21, 2013 public testimony before the Maine Legislature on the ISO-New England Geomagnetic Disturbance Control Room Operating Procedures—upon which the NERC GMD Operating Procedure Templates are partially based—recently confirmed three major and obvious technical deficiencies:

1. ISO-New England has conducted no advance mathematical modeling of its GMD operating procedures.

2. With approximately 100 high voltage transformers within New England, ISO-New England relies on only two GIC monitoring stations—at Chester, Maine and at the Seabrook nuclear power plant in New Hampshire. According to the GMD operating procedures currently in use by ISO-New England, "GIC monitor at Seabrook station is not an active monitor it requires a technician to manually take the reading;" GIC readings would therefore be delayed. There is no automated and real time display of GIC data in the ISO-New England control room.

3. In a busy control room, a ten-minute warning time would be inadequate to implement the GMD operating procedures currently in use by ISO-New England.

The Foundation for Resilient Societies conducted an independent examination of the ISO-New England GMD operating procedures. See our research report, "Solar Storm Risks for Maine and the New England Electric Grid, and Potential Protective Measures," at Appendix 1. We concluded that:

1. Operating procedures do not reduce the Geomagnetically-Induced Current flows that cause transformer heating and harmonic production, two of the most serious geomagnetic disturbance effects. Unmitigated GIC flows could cause unplanned equipment trips and power reductions.

2. Rudimentary mathematic calculations show that generation and transmission resources at risk for unplanned outage during solar storms greatly exceed the ISO-New England capacity planning allowances, and therefore their concurrent loss would result in load shedding and blackout.

3. ISO-New England monitoring of GIC during solar storms is limited to Chester, Maine and Seabrook, New Hampshire and is likely inadequate to give operators enough up-to-date information for prudent decisions.

4. The general operating procedures of ISO-New England, as well as specific GMD operating procedures, require time-consuming coordination and therefore could not be implemented during rapid-onset solar storms.

5. Recently available GIC data for one of the largest generation sites in ISO-New England, Seabrook nuclear power plant, can be used to back-estimate to likely GIC flows during historically severe solar storms—such as the 1921 New York Central Storm or 1859 Carrington Event. We use simple ratios to estimate 1,600 amps of neutral GIC at Seabrook from a severe solar storm with dB/dt of 4,800 nanoTesla/minute, an intensity equivalent to the 1921 New York Central Storm. Therefore, according to the 190 amp "down power" criteria for Seabrook transformers in the ISO-New England operating procedures, even a moderate solar storm could require a complete shutdown of Seabrook nuclear plant, eliminating 1,247 MW of generation capacity.

Decision-Making Processes of the GMD Task Force

As part of its duties as ERO, NERC initiated Phase II of its Geomagnetic Disturbance Task Force ("GMD Task Force") to study GMD and provide recommendations in a special assessment report. Industry trade associations have been supportive of the GMD Task Force, as evidenced by this comment jointly filed by the American Public Power Association, the Edison Electric Institute, the Large Public Power Council and the National Rural Electric Cooperative Association ("Trade Associations") under FERC Docket RM12-22:

> **II. The Trade Associations support the efforts and findings of the NERC GMD Task Force and believe its work presents a foundation for effective mitigation of GMD risks.**
>
> In 2010, NERC established the GMDTF to address the implication of severe GMD events. This included assessment of GMD studies developed after the 1989 GMD storm, performing analysis of GMD scenarios as set forth in the NERC/DOE HILF report, and reporting on the impacts that a GMD event would have on the BPS. GMDTF was also charged with focusing on enhancing and improving existing prevention, mitigation and system restoration approaches.
>
> The Trade Associations cannot emphasize enough that the GMDTF represents an open and inclusive process, leveraging a large body of technical expertise with decades of experience. For example, the GMDTF is a joint task force reporting to the NERC Planning Committee and Operating Committee, with participation by the Critical Infrastructure Protection Committee. The GMDTF includes NERC member entities, equipment suppliers and manufacturers, GMD experts, government agencies (Federal, Provincial, and State), and NERC staff. Moreover, it is also significant that the GMDTF work is peer reviewed and collaboratively developed including input from non-NERC members. Specifically, the results of the GMDTF efforts are reviewed periodically by the leadership of the technical committees, in coordination with the Electricity Sub-Sector Coordinating Council. The Trade Associations underscore the importance of an organized effort that includes a broad range of experienced technical experts who are dedicated to identifying technical challenges, conducting thorough analyses, and seeking to address those challenges with reasonable and integrated solutions.

As a matter of official NERC policy, and in marked contrast to the supportive comments of the Trade Associations, the real decision-making processes of the GMD Task Force are dominated by and effectively controlled by owners and operators of the bulk power system. As evidence, we present the "GMD Task Force Phase 2 Scope and Project Plan" approved by the NERC Planning Committee on June 19, 2012 and endorsed by the NERC Operating Committee on June 20, 2012. This plan states that "The task force is comprised of "members" and "observers,"" that "Task Force members represent the owners and operators who are ultimately accountable for the reliable planning and operation of the bulk powers system, and they are responsible for approving the deliverables of the GMDTF," and that GMD Task Force decision-making will determined by "a vote by GMDTF members":

> **Members**
>
> The task force chair and vice chair are appointed from the task force membership by the chairs of the NERC Planning Committee (PC) and Operating Committee (OC). The vice chair should be available to act on the chair's behalf should the chair be unavailable. Members are users, owners, and operators of bulk power system assets and represent stakeholders with an associated NCR number, or subject matter experts from Regional Entity staff. Task Force members represent the owners and operators who are ultimately accountable for the reliable planning and operation of the bulk powers system, and they are responsible for approving the deliverables of the GMDTF.
>
> **Observers**
>
> Observers provide essential subject matter expertise to the GMDTF, particularly in areas not directly related to bulk power system planning and operation. Observers may represent Federal, State and Provincial Government agencies, vendors, academics, the scientific community, or other interested parties. Guest participation of subject matter experts may be requested by the GMDTF Chair.
>
> **Order of Business**
>
> The GMDTF will develop its conclusions using sound engineering judgment on the basis of sound peer-reviewed data and analysis. In general, the desired, normal tone of GMDTF business is to strive for consensus. If consensus cannot be achieved, the GMDTF will defer to a vote by GMDTF members, or if necessary by the Planning Committee, to make decisions.

For over a year, multiple public stakeholders have objected to the membership criteria and unbalanced decision-making processes of the GMD Task Force. On February 6, 2013 these stakeholders again wrote the NERC General Counsel with their concerns, pointing out that the membership criteria and decision-making processes of the GMD Task Force appear to be in direct conflict with Title 16 United States Code§ 215, which requires that NERC, as the designated ERO, assure "balanced decisionmaking in any ERO committee or subordinate organizational structure" and provide "balance of interests in developing reliability standards and otherwise exercising its duties." The text of the public stakeholder letter to NERC is contained in Appendix 4. In his reply letter dated February 22, 2013, the NERC General Counsel stated, "I find that your assertions on this issue are without merit."[6]

The Foundation for Resilient Societies participated in the public stakeholder process for the NERC GMD Operating Procedure Templates and made commonsense suggestions. For example, the Foundation for Resilient Societies commented:[7]

> The Template does not recommend advance modeling of the effects of proposed "Real Time Actions" on system stability. Nonetheless, the Template recommends actions which would affect power generated/transmitted and could also affect network stability. Actions include:
>
> - "Selective load shedding"
> - "System reconfiguration"
> - "Remove transformer(s) from service if imminent damage due to overheating"
> - "Remove transmission line(s) from service (especially lines most influenced by GMD)"

In the template drafting process, the GMD Task Force leaders for the Operating Procedures Subgroup dismissed our comment in their written "Consideration of Comments," saying that:

> "System operators routinely evaluate the effects of real time actions in advance using State Estimators and other real-time tools. The same would be true for any action as part of a GMD operating procedure."

Notably, the ultimately approved version of the NERC GMD Operating Procedure Templates does not suggest that procedures be mathematically modeled, but only "studied."

[6] Because the NERC reply letter was marked "PRIVILEGED AND CONFIDENTIAL," it is not included in this comment.
[7] The complete text of the Foundation for Resilient Societies comments on the draft NERC GMD Operating Procedure Templates is contained in Appendix 5.

Real-time actions (based on results of day-of-event monitoring):

1. Safe system posturing (only if supported by study)

    a. Selective load shedding

    b. Manually start fans/pumps on selected transformers to increase thermal margin (check that oil temperature is above 50° C as forced oil flow at lower temperatures may cause static electrification)

2. System reconfiguration (only if supported by study)

    a. Remove transformer(s) from service if imminent damage due to overheating (possibly automatic by relaying)

    b. Remove transmission line(s) from service (especially lines most influenced by GMD)

Even the most moderate investigation by the GMD Task Force would have turned up the real-world example of ISO-New England and shown the error of assuming that owners and operators will perform not only qualitative "studies," but also mathematically model their GMD operating procedures.[8]

CONCLUDING OBSERVATIONS

The real-world example of GMD operating procedures for ISO-New England shows how electric utilities can have significant and ongoing deficiencies in planning for severe solar storms and associated GMD. Even the most rudimentary mathematic calculations of generation and transmission resources at risk during a severe solar storm, as compared to reserve resources, are likely to show that "successfully" implemented GMD operating procedures would result in load shedding and grid outages. Moreover, without sufficient warning time, and without real-time GIC instrumentation, it is unrealistic and imprudent to propose that complex and unmodeled GMD operating procedures could be implemented during rapid-onset solar storms.

[8] An engineer from ISO-New England currently serves on the Operating Procedures subgroup of the GMD Task Force and the GMD operating procedures of ISO-New England were made available to the GMD Task Force.

The NERC GMD Operating Procedure Templates resulted from unbalanced decision-making processes at NERC that promoted the narrow interests of electric utility owners and operators at the expense of the public good. With representatives of public interest organizations deprived of membership and voting rights within the GMD Task Force, the result has been an imprudent emphasis upon unworkable "operating procedures" and a refusal to assess the financial benefits of installing hardware protective equipment. Persistent NERC non-compliance with Section 215 of the Federal Power Act is not just a procedural deficiency; NERC's failure to develop a balance between owners/operators and public stakeholders produces faulty decision-making and perpetuates needless risks to public welfare and safety.

Pending a severe solar geomagnetic storm, and without widespread installation of hardware protections for critical equipment, the President of the United States has the authority to require de-energizing of some generation and transmission equipment within the bulk power system. At significant cost in human life, this alternative "operating procedure" could preserve critical equipment and reduce the duration of regional or nationwide blackouts. But even a Presidential order would be difficult to implement in 10 minutes. Unfortunately, this is the primary "operating procedure" that the electric utility industry leaves the President, absent hardware-based protections that FERC might direct in a rulemaking.

Respectfully submitted by:

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Appendix 1

Solar Storm Risks for Maine and the New England Electric Grid, and Potential Protective Measures

Interim Report
March 19, 2013

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EXECUTIVE SUMMARY

- A severe solar storm—a historical example being the Carrington Event of 1859—could cause a power system collapse for the State of Maine, the New England regional grid, and much of the eastern United States.
- Severe solar storms—of the intensity of the 1921 New York Central Storm—could damage high voltage transformers in Maine and other New England states, resulting in a widespread and prolonged blackout.
- Replacement time for transformers damaged in a solar storm could be several years, because nearly all high voltage transformers are custom-made in foreign countries, with long order backlogs.
- The Maine Power Reliability Program (MPRP) design presently does not include hardware protection from solar storms.
- According to Oak Ridge National Laboratory, 45% of the high voltage (345 kilovolt) electric power grid in Maine would be at risk during a severe solar storm.
- The Phase II High Voltage Direct Current (HVDC) Tie and the Chester, Maine Static Var Compensator (SVC), two critical resources for the Maine electric grid, have previously tripped off during moderate level solar storms.
- The Seabrook, New Hampshire nuclear power plant appears to be particularly exposed to currents induced by solar storms, and had an unplanned outage commencing one day after a solar storm.
- Transformer explosions and fires at nuclear power plants, including some caused by solar storms, are a serious nuclear safety issue.
- The general operating procedures of ISO-New England require time-consuming coordination and therefore would be inadequate during rapid-onset solar storms.
- The specific solar storm operating procedures of ISO-New England have not been tested during a severe solar storm.
- ISO-New England monitoring of Geomagnetically Induced Currents (GIC) during solar storms is confined to Chester, Maine and Seabrook, New Hampshire and is likely inadequate to give operators enough up-to-date information for prudent decisions.
- Generation and transmission resources at risk for unplanned outage during solar storms greatly exceed the ISO-New England capacity planning allowances, and therefore their concurrent loss would result in load shedding and blackout.
- The estimated equipment cost to protect the Maine grid high voltage transformers from solar storms would be $4.2 million, or only one-third of one percent of the MRPR cost.
- Commercially available protective equipment, if installed throughout ISO-New England, would not only reduce the risk of Maine electric blackout, but would also reduce the risks of long-term loss of power and resulting radiation release from the Seabrook, New Hampshire plant and nuclear plants elsewhere in New England.

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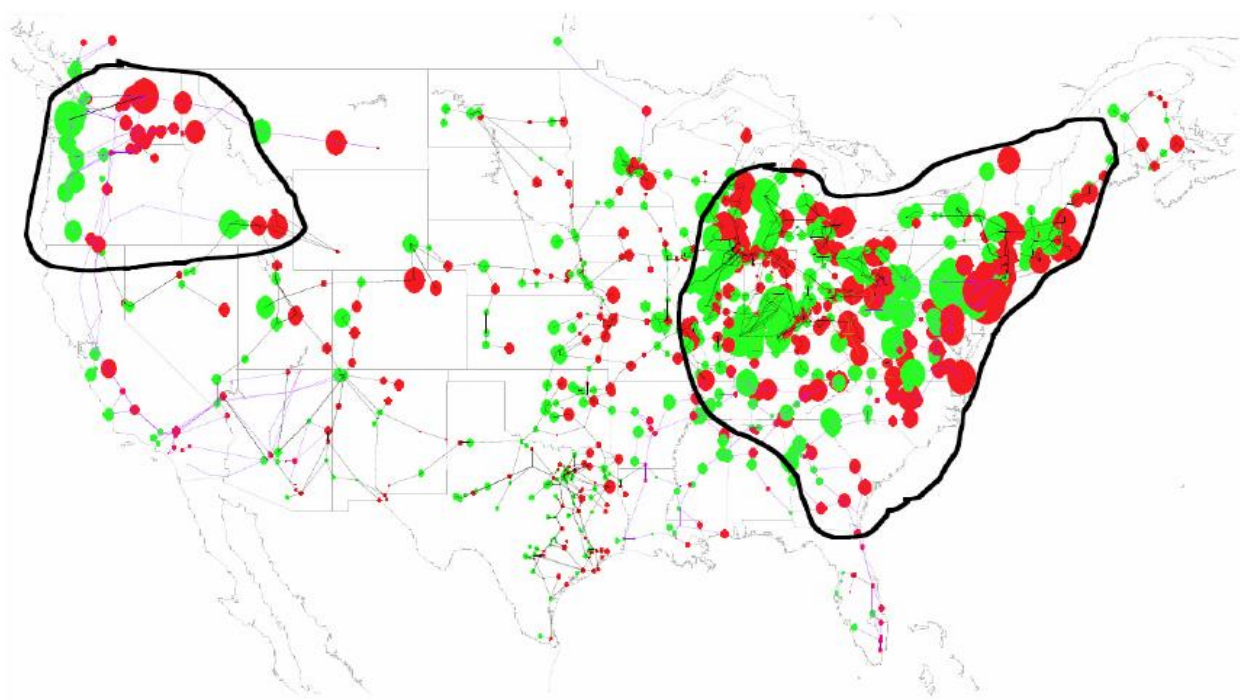
1. Introduction

When sunspots erupt during solar storms, they send masses of charged particles toward the earth. These particles disturb the Earth's magnetic field, inducing harmful currents in high voltage transmission lines. The disturbance of the Earth's magnetic field is termed a "geomagnetic disturbance." The harmful currents induced are called "Geomagnetically-Induced Currents (GIC)."

In March 1989, a relatively small solar storm plunged the Province of Quebec into a widespread grid blackout. *The report "*Geomagnetic Storms and Their Impacts on the U.S. Power Grid*," produced by Oak Ridge National Laboratory for the Federal Energy Regulatory Commission in joint sponsorship with the U.S. Department of Energy and the Department of Homeland Security, concluded that* a four to ten-times larger solar storm—historical examples being the Carrington Event of 1859 or the 1921 New York Central Storm—could cause a power system collapse across the State of Maine and much of the eastern United States.

The below map of the United States shows high voltage transformer locations, with the size of the dots related to estimated magnitude of GIC during a severe solar storm. Areas of large estimated GIC are most at risk for power grid collapse, including the southern portion of Maine.



Areas of Probable Power System Collapse During Severe Solar Storm

Source:"Geomagnetic Storms and Their Impacts on the U.S. Power Grid," Oak Ridge National Laboratory

The Oak Ridge National Laboratory report also concluded that transformer failures and long-term blackout could result from a severe solar storm. Replacement time for damaged transformers likely would be several years. A U.S. Department of Energy report, "Large Power Transformers and the U.S. Electric Grid" (2012) examines transformer spare inventory and replacement lead time issues in detail, confirming the findings of the Oak Ridge National Laboratory report.

Infrastructure failures caused by solar storms are within a larger class of *common mode failures,* such as those caused earthquakes and tsunamis, which, though infrequent, deserve mitigation investments to prevent widespread and nearly simultaneous loss of critical infrastructure. The Japan earthquake and resulting tsunami in 2011 are illustrative of how natural hazards can cause common mode failures in electric grids and nuclear power plants. The Nuclear Regulatory Commission conducted a study of common mode failures at nuclear power plants as part of its report, "Recommendations for Enhancing Reactor Safety in the 21'' Century: The Near Term Task Force Review of Insights from the Fukushima Dai-ichi Accident."

2. Maine High Voltage Transmission System

The Maine high voltage transmission system is principally operated by Central Maine Power and Bangor Hydro Electric. Currents induced by solar storms mainly affect high voltage transmissions systems, because the resistance of high voltage lines is lower. The 345 kilovolt transmission backbone in Maine has nine existing high voltage substations.

According to the U.S. Energy Information Administration, approximately one third of Maine electric power is imported from outside the state, on average, excluding power that is both locally generated and consumed by large industrial companies. Power import paths include two 345 kilovolt transmission lines from New Brunswick and another four 345 kilovolt transmission lines from New Hampshire.

The transmission system in Maine was designed around the now-decommissioned Maine Yankee nuclear power plant and therefore contains lines that do not optimally connect generation to load. To support new wind power generation facilities in northern Maine, as well as additional import of power from New Brunswick, Central Maine Power and Bangor Hydro Electric proposed the Maine Power Reliability Program (MPRP). This project was approved in 2010. At a projected cost of $1.4 Billion, MPRP is the largest construction project in Maine history. Most of the new transmission lines for MRPR start and end near existing 345 kilovolt substations. Another five substations are planned as part of the MPRP.

Maine Power Reliability Program (MPRP)

Status as of 2/25/13

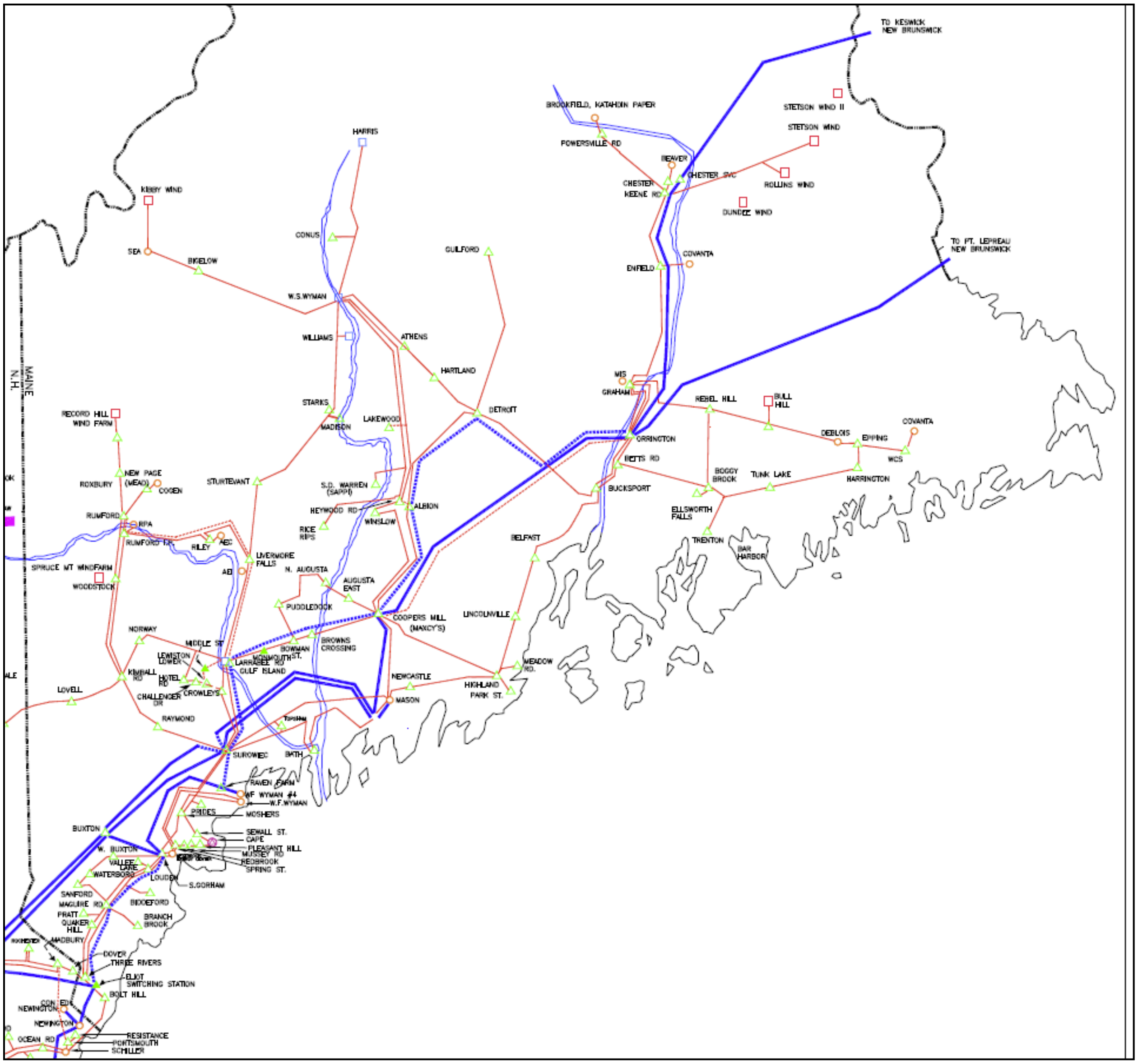
Project Benefit: Addresses long-term system needs of Bangor Hydro Electric and Central Maine Power, thermal and voltage issues in western Maine and supports load growth in southern Maine

New 345 kV Lines	Expected In-Service	Present Stage
Construct New Section 3023 Orrington to Albion Road	April-13	3
Construct New Section 3024 Albion Road to Coopers Mills	Mar-14	2
Construct New Section 3025 Coopers Mills to Larrabee Road	Jul-14	3
Construct New Section 3026 Larrabee Road to Surowiec	Dec-12	4
Construct New Section 3020 Surowiec to Raven Farm	May-13	3
Construct New Section 3021 South Gorham to Maguire Road	Nov-13	2
Construct New Section 3022 Maguire Road to Eliot	Dec-13	2

Source: "NEPOOL Participants Committee Report," ISO-New England

According to the February 19, 2013 testimony of Central Maine Power before the Committee on Energy, Utilities and Technology of the Maine State Legislature, the MRPR should not be redesigned to include hardware protection from solar storms:

> The $1.4 billion Maine Power Reliability Program has been under construction for over two years, and won't be completed until 2015. It involves over 400 miles of transmission lines and 5 new large substations with autotransformers. Its design was approved in 2010. Redesigning the project at this point to some new standards would cost millions of dollars and cause potential delays costing tens of millions.



NEW ENGLAND
GEOGRAPHIC
TRANSMISSION MAP
THROUGH 2022

ISO NEW ENGLAND, Inc.

12-6-12 (Revision 0)
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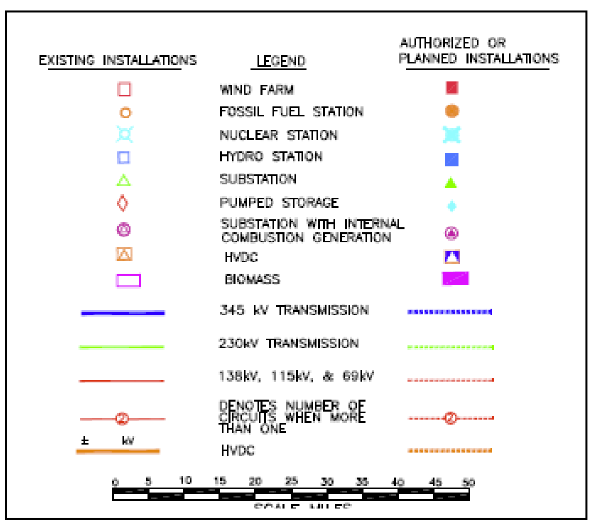


3. Vulnerability of Maine Grid to Solar Storms

3.1 Modeling of Solar Storm Scenarios

An Oak Ridge National Laboratory report sponsored by the U.S. Department of Homeland Security and other federal agencies found that Maine is severely at-risk during solar storms. As part of the report analysis, the U.S. electric grids were mathematically modeled during various solar storm scenarios. The modeling showed that 45% of high voltage power in Maine would be at risk during a severe solar storm that induced 90 amps or more of current into 345 kV transmission lines:

Table 4-1. Comparison of 345kV at-risk transformers for 90 amp/phase and 30 amp/phase GIC levels

90 Amp GIC At-Risk Threshold

345kV At-Risk Transformers (90 Amp/phase GIC Level)

State	345kV MVA	# of At-Risk 345kV	% of MVA Capacity
AR	600	1	30.1%
CO	2,430	6	29.6%
CT	1,376	5	15.8%
IA	1,060	2	8.6%
ID	2,750	4	38.2%
IL	5,540	20	9.4%
IN	10,896	21	26.5%
KS	4,401	8	27.5%
KY	1,467	4	10.6%
MA	5,764	12	33.3%
ME	2,332	4	45.3%
MI	63,495	27	35.4%
MN	5,342	9	27.0%
MO	4,241	7	17.1%
ND	400	1	7.4%
NE	1,408	4	10.6%
NH	930	4	100.0%
NJ	1,385	2	38.1%
NM	235	1	1.7%
NV	680	2	11.3%
NY	12,274	20	29.0%
OH	8,555	15	15.0%
OK	1,049	3	6.3%
PA	2,234	4	14.7%
SD	400	1	11.5%
UT	3,638	6	23.4%
VT	448	1	29.6%
WA	3,944	6	86.8%
WI	6,459	13	35.6%
WY	690	1	24.6%
345kV Total	**156,423**	**214**	**20.0%**

30 Amp GIC At-Risk Threshold

345kV At-Risk Transformers (30 Amp/phase GIC Level)

State	345kV MVA	# of At-Risk 345kV	% of MVA Capacity
AR	1,400	3	70.2%
AZ	625	1	5.9%
CA	600	2	100.0%
CO	6,800	15	82.7%
CT	2,991	10	34.3%
IA	3,908	9	31.9%
ID	3,698	7	51.4%
IL	27,702	87	46.8%
IN	25,590	62	62.2%
KS	9,851	19	61.5%
KY	5,848	12	42.2%
MA	13,256	27	76.5%
ME	4,232	8	82.2%
MI	125,374	56	70.0%
MN	12,552	23	63.4%
MO	15,160	28	61.2%
ND	3,598	10	66.9%
NE	6,491	15	49.0%
NH	930	6	100.0%
NJ	1,385	2	38.1%
NM	3,547	9	25.3%
NV	3,300	12	54.8%
NY	25,530	55	60.4%
OH	32,500	69	56.9%
OK	10,800	21	64.7%
OR	554	1	100.0%
PA	9,049	18	59.5%
RI	479	1	24.6%
SD	1,000	3	28.7%
TX	7,620	13	6.4%
UT	10,721	25	69.1%
VA	732	1	32.9%
VT	1,512	3	100.0%
WA	4,544	7	100.0%
WI	10,620	27	58.5%
WV	3,277	6	39.9%
WY	2,700	4	96.4%
345kV Total	**400,476**	**677**	**51.2%**
Increase %	**156.0%**	**216.4%**	

Source:"Geomagnetic Storms and Their Impacts on the U.S. Power Grid," Oak Ridge National Laboratory

3.2 Previous Transformer Failures Shortly After Solar Storms

On April 28, 1991 a solar storm hit New England. Within 24 hours, a GSU transformer at the now-decommissioned Maine Yankee exploded. The proximate cause of the Maine Yankee transformer failure was the solar storm. The resulting transformer oil and generator hydrogen fire burned for 4 hours and was classified as a safety event by the Nuclear Regulatory Commission. The Associated Press article, "Maine Governor Left In Dark About Fire For More Than 12 Hours," gives additional background.

On November 8-9, 1998, a solar storm hit New England. On November 10, 1998, a high temperature condition was discovered in a Seabrook Generator Step Up (GSU) transformer and the plant had an unplanned outage. Subsequent examination of the transformer revealed internal melting of metal components, requiring rebuilding of the Phase "A" transformer equipment. The proximate cause of the Seabrook GSU transformer was Geomagnetically-Induced Current and resulting transformer vibrations during the solar storm.

A transformer at Salem nuclear power plant in New Jersey failed shortly after the March 1989 solar storm. Below is a picture of the failed transformer and internal windings:

Figure 2-33. Damaged transformer at the Salem Nuclear Plant.

Source:"Geomagnetic Storms and Their Impacts on the U.S. Power Grid," Oak Ridge National Laboratory

3.3 Equipment Trips and Power Reductions during Solar Storms

3.3.1 Phase II HVDC Tie

The Phase II HVDC tie from Quebec to Sandy Pond, Massachusetts is a critical import line for the New England grid.

Sandy Pond, Massachusetts Converter Station for Phase II HVDC Tie from Quebec

Source: "ABB HVDC Reference Projects in North America," ABB

According to the equipment vendor, ABB, this HDVC tie was the first large scale multi-terminal HVDC transmission in the world:

> When ABB was awarded the contract for the Québec- New England Phase II HVDC project in 1986 by Hydro Québec and National Grid USA (formerly New England Electric Systems), it was the first large multi-terminal HVDC system ever contracted. The power is generated at the La Grande II hydro power station in the James Bay area, converted into DC at the Radisson Converter Station, and transmitted over the multi-terminal system to load centers in Montreal and Boston.

Observed power import from Quebec is approximately 1,600 MW, according to real-time information published on the ISO-New England website. Below is a snapshot of import data in Megawatts for Monday, March 18, 2013:

Interchange - Phase I/II Real Time Market Daily Actual Scheduled Interchange(as of 2013-03-18 15:00:00 EDT)

Trading Interval	Purchase (MWh)	Sales (MWh)	Interchange (MWh)
01	-1550	0	-1550
02	-1550	0	-1550
03	-1428	0	-1428
04	-1550	0	-1550
05	-1550	0	-1550
06	-1550	0	-1550
07	-1550	0	-1550
08	-1583	0	-1583
09	-1583	0	-1583
10	-1582	0	-1582
11	-1583	0	-1583
12	-1600	0	-1600
13	-1600	0	-1600
14	-1600	0	-1600
15	-1599	0	-1599
16	-1600	0	-1600

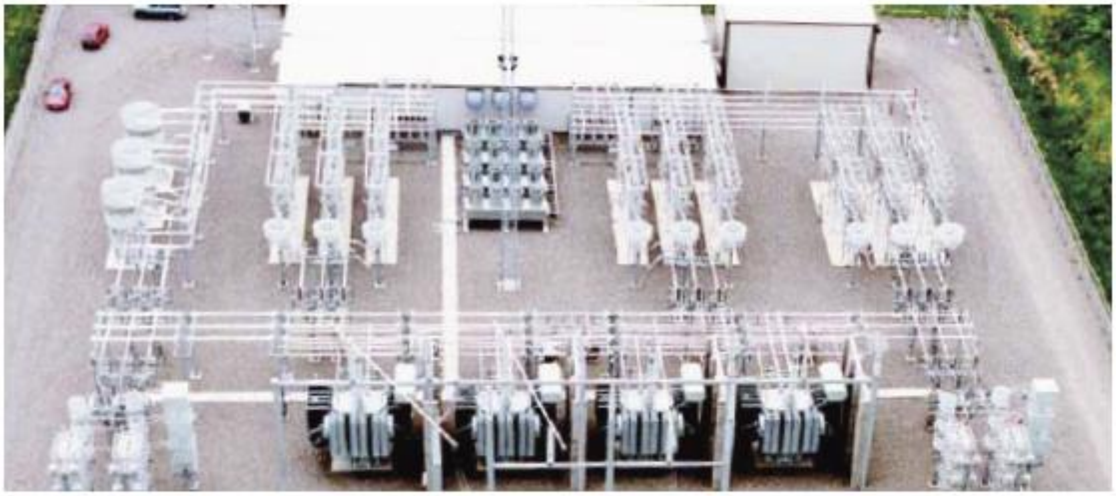
Source: “Real-Time Daily Net Interchange Requests,” ISO-New England

The Phase II HVDC tie imports more power than a large nuclear power plant such as Seabrook produces. If the entire Phase II tie were to trip off unexpectedly, this would cause a major system contingency for ISO-New England. To minimize the chance of a large contingency and to provide redundancy, the Phase II tie consists of two “poles” that independently transmit power.

Both poles of the Phase II HVDC tie tripped out during at a solar storm on October 28, 1991. More recently, the Phase II HVDC tie caused a cascading event on November 16, 2007; while this event was caused by a shield wire failure, it shows that the Phase II tie still has the potential to cause a cascading outage.

3.3.2 Static Var Compensator at Chester, Maine

The Chester, Maine substation Static Var Compensator (SVC) is a critical piece of equipment for the New England power grid.



Static Var Compensator at Chester, Maine Substation

Source: "SVC to stabilize an AC system connected to a large HVDC interconnection," ABB

The Chester SVC, according to an online description by vendor ABB allows import of 2,700 MW of power and is necessary for system stability during "disturbances" on the Phase II HVDC interconnection (emphasis added):

> The purpose of the SVC is to reinforce the line between Keswick in New Brunswick, Canada, and Orrington in the New England network, to allow an import of 700 MW to New England along this line, with simultaneous import of 2,000 MW on the Québec-New England Phase II HVDC system (also supplied by ABB). *The SVC is necessary in order to meet stability requirements for the New England system for cases involving disturbances on the Phase II HVDC interconnection.*

Notably, the ABB promotional literature makes special mention of the importance of the Chester SVC during "large system disturbances" (emphasis added):

> Because of its importance for voltage control during *large system disturbances* in the New England area and in the provinces of New Brunswick and Nova Scotia, the SVC has been designed to satisfy stringent performance requirements. The control system is fully redundant, to secure maximum availability of the SVC.

The Chester SVC tripped out during a solar storm on March 24, 1991.

Numerous alarms were recorded at the Chester substation during the October 29, 2003 solar storm, as listed below:

Wednesday October 29, 2003

- 01:31 hrs - Maine, Chester SVC reports Level 2 ground-induced-current alarms
- 02:09 hrs - SEC reports – Warning: Geomagnetic K index 6 expected (3rd party forecaster predicted K8)
- 02:15 hrs - Maine, Chester SVC reports Level 3 ground-induced-current alarms
- 02:15 hrs - ISO New England
  —*Implemented M/S # 2 Abnormal Conditions Operating Procedure for all New England effective for next 24 hours due to SMD activity. (Implementation of this Operating Procedure authorizes the New England system operator to assume an emergency condition defensive posture to protect the reliability of power system)*
  —*Cancelled scheduled 345-kV circuit breaker maintenance at nuclear plants in Vermont and Connecticut.*
- 02:17 hrs - Quebec limiting exports to New England due to SMD activity in the Nicolet area of Montreal. (System operator had already begun to add generators to network.)
- *Both New England HVDC converter station imports limited to >40% to <90% of normal rating*
- *New Brunswick imports are limited to 600 MW maximum.*
- *ISO re-dispatching New England area generation to cover load demand*
- 02:23 hrs - SEC reports – Alert: Geomagnetic K index 7 or greater expected
- 02:49 hrs - SEC reports – Alert: Geomagnetic K index 7
- 03:45 hrs - SEC reports – Alert: Geomagnetic K index 8
- 03:55 hrs - Maine, SVC reports Level 4 ground-induced-current alarms
- 04:41 hrs - SEC reports Alert: Geomagnetic K index of 9
- 07:28 hrs - SEC reports Alert: Geomagnetic K index of 7
- 09:26 hrs - Maine, SVC reports Level 3 ground-induced-current alarms locked with chattering, Level 4-induced current alarm spikes
- 09:54 hrs - Vermont HVDC imports from Quebec being reduced to below 185 MW due to increased SMD activity
- 09:58 hrs - Maine, SVC reports Level 4 ground-induced-current alarms
- 10:07 hrs - Ontario – reports voltage and MW swings observed at the Bruce Nuclear Units on Lake Huron and Pembrooke region
- 10:07 hrs - Ontario – reports Mountain Chute Unit #2 tripped (Pembrooke region)
- 10:07 hrs - Ontario – reports Bruce Nuclear Units reducing VAR output to stabilize
- 10:14 hrs - Maine, SVC reports Level 2 ground-induced-current alarms

Source: "Societal and Economic Impacts of Severe Space Weather, Workshop," National Academy Press, National Research Council

3.3.3 Seabrook Nuclear Power Plant

The Seabrook nuclear power plant, rated to generate 1,247 MW of power, is located on the New Hampshire coastline adjacent to a salt marsh. The salt marsh provides good conductivity for geomagnetically-induced currents. Seabrook has three single phase Generator Step Up (GSU) transformers of 410 MW capacity each, a design characteristic that makes the transformers more susceptible to Geomagnetically-Induced Currents from solar storms.

A modest solar storm of November 8-9, 1998 vibrated loose a stainless steel bolt in the Phase A transformer at Seabrook. The loose bolt caused the transformer windings to melt, requiring the transformer to be sent offsite for remanufacture. The Seabrook plant was shut down for twelve days.

Seabrook, New Hampshire Nuclear Power Plant Located Adjacent to Salt Marsh

Source: Nuclear Regulatory Commission

A significant solar storm occurred on October 29, 2003. On the same day, two nuclear power plants in the Northeast reduced power due to geomagnetic disturbances. For Seabrook nuclear power plant in New Hampshire—located within 16 miles of Maine—the power was reduced to only 30% of capacity. The comments line for Seabrook did not note geomagnetic disturbance; the comments line instead read, “HOLDING POWER FOR REACTOR PHYSICS.”

Power Reactor	Power (%)	Comments
Hope Creek 1	80	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
Point Beach 1	100	DECREASING POWER DUE TO GRID GEO-MAGNETIC DISTURBANCES
Seabrook 1	30	HOLDING POWER FOR REACTOR PHYSICS

Selected NRC Power Reactor Status Reports, October 29, 2003

Source: Power Reactor Status Reports, NRC

The NRC Power Reactor Status Report for Seabrook nuclear plant in New Hampshire on July 16, 2012 reads:

> REDUCED POWER DUE TO SOLAR MAGNETIC ACTIVITY CAUSING HIGH CIRCULATING CURRENT IN UNIT 1 TRANSFORMER - POWER LIMITED TO 85% BASED ON GENERATOR STATOR COOLING DELTA T LIMIT - SWITCHYARD MAINTENANCE ON-GOING UNTIL APPROX. 7/17/12

Power for the Seabrook nuclear plant was reduced to 68% of capacity on July 16, according to the NRC status report. Moreover, Seabrook station experienced the nation’s highest Geomagnetically-Induced Current of any recorded in the EPRI SUNBURST system, 25 amps. Hence, there is reason to be concerned that the Seabrook nuclear plant, operating without neutral ground blocking equipment, is vulnerable to power reductions, unplanned outage, and transformer damage in future solar storms.

4. Solar Storm Safety Issues at Nuclear Power Plants

According to a document of the Nuclear Regulatory Commission, nine GSU transformers at U.S. nuclear plants failed in the aftermath of the March 1989 storm that hit Hydro-Quebec. Additionally, according to an official report of the North American Electric Reliability Corporation, a GSU transformer at the Salem nuclear plant in New Jersey failed during the March 1989 solar storm. Finally, the proximate cause of failure for GSU transformers at Seabrook and Maine Yankee nuclear plant was solar storms.

*Nuclear plants commonly experience reactor trips after unexpected transformer failures, some of which occur due to normal aging and stress. The problem has become so acute that the Nuclear Regulatory Commission released a special bulletin, "*NRC INFORMATION NOTICE 2009-10: TRANSFORMER FAILURES—RECENT OPERATING EXPERIENCE*." Reactor trips are a nuclear safety issue.*

Coastal locations are more susceptible to Geomagnetically-Induced Current from solar storms. The Seabrook, Pilgrim, and Millstone nuclear plants are on the Atlantic Coast.

As events at the Fukushima Daiichi nuclear plants amply showed, backup diesel generators do not always work; reactors and spent fuel pools without power can explode or catch fire. Spent fuel assemblies without water and power for cooling can emit radiation. New Hampshire, Vermont, Massachusetts, and Connecticut all have active nuclear power plants and associated spent fuel pools.

In March 2011, The Foundation for Resilient Societies submitted a petition for rulemaking, PRM-50-96, to the Nuclear Regulatory Commission (NRC) that would require operators of nuclear power plants to install long-term backup power for cooling of spent fuel pools. In an action dated December 18, 2012, the NRC concluded:

> Recent experience and associated analyses regarding space weather events suggest a potentially adverse outcome for today's infrastructure if a historically large geomagnetic storm should recur. The industry and the FERC are considering whether EHV transformers that are critical for stable grid operation should be hardened to protect them from potential GIC damage and whether existing procedures for coping with a GIC event require significant improvements....Thus, the NRC concludes that the issues and concerns raised by the petitioner need to be further evaluated. To that end, the NRC will consider the issues raised in the petition in the NRC rulemaking process.

5. ISO-New England Operating Procedures

*General operating procedures for ISO-New England are designed around slow moving capacity shortfalls, such as those caused by heat waves or cold snaps. According to "*Appendix A - Estimates of Additional Generation and Load Relief From System Wide Implementation of Actions in ISO New England Operating Procedure No. 4 - Action During a Capacity Deficiency Based on a 26,462 MW System Load," these *procedures require phone calls and coordination with large industrial customers, generation facilities, the New York ISO, and individual retail consumers. The procedures even have provisions for television appeals for conservation by State Governors. The "Grand Total" of additional generation and load relief under these procedures is 2535 – 5035 MW. The times required for coordination in these ISO-New England operating procedures are inconsistent with rapid-onset solar storms and it is doubtful that they would* *work in all conditions—during the moderate March 1989 solar storm, the Hydro-Quebec system collapsed in only 93 seconds.*

*"SOP- RTMKTS.0120.0050 Implement Solar Magnetic Disturbance Remedial Action" of ISO-New England was first implemented on February 13, 2003 and most recently revised on February 1, 2013. Only three weeks later, in a document dated February 20, 2013, a new set of solar storm operating procedures "*Geo-Magnetic Disturbance*," was made available by ISO-New England.*

Because there have been no solar storms in New England of intensity equivalent to the March 1989 storm since February 13, 2003, the ISO-New England operating procedures have not demonstrated their effectiveness during a severe solar storm.

5.1 Geomagnetically-Induced Current Monitoring

ISO-New England has access to one GIC monitoring device located at the Chester, Maine Substation and can receive manual readings from another GIC monitor at the Seabrook nuclear power plant, but only by a request to Seabrook. United Illuminating Company in Southern Connecticut also has four GIC monitoring stations, but this data is not provided in real time to ISO-New England.

Because the Seabrook nuclear plant may be particularly affected by GIC, timely Seabrook data would be essential for prudent monitoring of geomagnetic disturbances by ISO-New England.

GIC monitoring equipment is commonly bundled with newly replaced or installed transformers that would be installed in New England, including equipment that could be installed as part of the Maine Power Reliability Program.

5.2 Downrating of Transmission Lines

The ISO-New England operating procedures specify the following actions during solar storms, as appropriate:

- "Adjust the loading on Phase II, the Cross Sound Cable and Highgate HVdc ties to be within the 40% to 90% range of nominal rating of each pole"
- "Reduce the loading on Inter-RCA/BAA ties and on other internal critical transmission lines and interfaces to 90%, or less, of their security limits"

The observed loading of the Phase II tie is 1,600 MW, with a maximum rated capacity of 2,000 MW. If loading were to be reduced to 40% of 2,000 MW capacity, this would result in 800 MW less power imported into ISO-New England. For comparison, the now decommissioned Maine Yankee nuclear plant supplied 587 MW of power, on average, over its operational lifetime.

The rated capacity of the Highgate tie is 218 MW. If loading were to be reduced to 40% of 218 MW, this would result in 131 MW less power imported into ISO-New England.

The capacity of the Keswick–Keene Rd and Point Lepreau-Orrington 345 kV transmission lines from New Brunswick into Maine is 1,000 MW. If their loading were to be reduced by 10%, this would result in 100 MW less power imported into Maine. If loading were to be reduced by 50%, this would result in 500 MW less power imported into Maine.

5.3 Down Power of Seabrook Nuclear Power Plant

The new ISO-New England solar storm operating procedures disclose:

- "If the DC neutral ground current reading is > 190 Amps sustained for 60 minutes or greater, Seabrook is required to initiate either a normal down power or a rapid down power."

According to the International Atomic Energy Agency Power (IAEA) Reactor Information System, the rated power of Seabrook is 1,247 MW. All of this substantial generation would be lost in a Seabrook "down power."

According to multiple industry sources, newly designed Generator Step Up transformers at nuclear plants are generally specified for 25-50 amps of Geomagnetically-Induced Current for a short duration such as 15 minutes. A "DC neutral ground current reading" of 190 Amps would equate to 63 amps per transformer for a three transformer bank, such as the one at Seabrook. Therefore, unless the transformers at Seabrook have superior specifications, and have been tested to those specifications, prudence might require "down power" at amperage less than the 190 amps neutral current specified in the ISO-New England operating procedures.

5.4 Reactive Power Posturing

The most recent publicly available version of the ISO-New England operating procedures specifies the following action during solar storms, as appropriate:

- "Consider posturing Generators operating at their Eco Max to provide room for reserves and reactive capacity in accordance with CROP.25001 Posturing."

Production of "reactive power" (used for long distance transmission and electric motors) reduces real power generation due to heating limits in generators, contributing to diminished reserves.

6. Solar Storm Scenarios

Approximately one-third of Maine power is imported and therefore Maine is highly dependent on the ISO-New England control area. ISO-New England plans for up to two system contingencies, so-called "N-2" planning. The ISO-New England planning document, "ISO-NE 2013 Operable Capacity Analysis," dated February 15, 2013, shows 600 MW of operable capacity margin from Real-Time Demand Response and another 400 MW of operable capacity from Real-Time Emergency Generation, for a total of 1,000 MW emergency capacity.

OPCAP MARGINS				
OPCAP MARGIN MW	OPCAP FROM OP4 ACTIVE REAL-TIME DR MW	OPCAP MARGIN w/ OP4 actions through OP4 Step 2 MW	OPCAP FROM OP4 REAL-TIME EMER. GEN MW	OPCAP MARGIN w/ OP4 actions through OP4 Step 6 MW
[11]	[12]	[13]	[14]	[15]
(2,706)	600	(2,106)	400	(1,706)

Source: ISO-NE 2013 Operable Capacity Analysis," ISO-New England, dated February 15, 2013

6.1 Reduced Power Imports from Canada and New York ISO

Solar storms are widespread phenomena. Moderate or severe solar storms would simultaneously affect neighboring control areas, making it less likely that ISO-New England power imports could be maintained, and also making it less likely that reserves could be augmented by Emergency Energy Transactions from outside New England. If a widespread natural disaster such as a solar storm were to affect the New England control area and also affect the ability of Hydro-Quebec to supply power through the Phase II HVDC tie, or affect the ability of New York ISO to supply power by Emergency Energy Transactions, or affect the ability of New Brunswick System Operator to supply power through the Keswick–Keene Rd and Point Lepreau–Orrington ties, ISO-New England would be hard pressed to make up the lost import capacity of up to 4,818 MW.

Resource	*Import Capacity*
Phase II HDVC Tie	*2,000 MW*
Highgate HDVC Tie	*218 MW*
New Brunswick (Keene Road and Orrington)	*1,000 MW*
New York Northport-Norwalk	*200 MW*
New York Northern AC	*1,400 MW*

Source: "External Transactions—Introduction to Wholesale Electricity Markets (WEM 101)," ISO-New England

6.2 Reduced Generation and Transmission Capacity within New England

During a severe solar storm, both generation capacity and transmission capacity could be reduced. We present the below table of potentially affected resources within New England during solar storms:

Resource	*Capacity*
Chester Substation Static Var Compensator (SVC)	*2,700 MW*
*Phase II HDVC Tie**	*2,000 MW*
Seabrook Nuclear Power Plant	*1,247 MW*
Pilgrim Nuclear Power Plant	*685 MW*
Highgate HDVC Tie	*200 MW*
Millstone 2 Nuclear Power Plant	*869 MW*
Millstone 3 Nuclear Power Plant	*1,233 MW*
Vermont Yankee Nuclear Power Plant	*620 MW*

* *2,000 MW Phase II HVDC capacity also contained in Chester Substation SVC capacity.*

Sources: ABB and International Atomic Energy Agency Power (IAEA) Reactor Information System

6.2.1 Seabrook Plant Unplanned Outage or Power Reduction

Seabrook nuclear plant has already experienced an unexpected outage after a solar storm, as well as several solar-storm related power reductions. An unexpected outage of the Seabrook nuclear power plant, occurred on November 10, 1998, when a transformer failed after the November 8-9 solar storm. Power for Seabrook was reduced to 30% of capacity on October 29, 2003 during a moderate solar storm, according to the NRC Power Reactor Status Report. Power for Seabrook was reduced to 68% of capacity on July 16, 2012 during a minor solar storm, according to the NRC Power Reactor Status Report.

During the July 14-16, 2012 solar storm, a maximum GIC reading of 25 amps was observed at Seabrook. During the same storm, a maximum dB/dt reading of 75 nanoTesla/minute was observed at the nearby Ottawa, Canada magnetic observatory. Using simple linear extrapolation of the dB/dt magnetic flux readings at Ottawa, we estimate 267 amps of GIC at Seabrook during the March 13, 1989 storm. We estimate 1,600 amps of GIC at Seabrook from a severe solar storm of 4,800 nanoTesla/minute. (An intensity equivalent to the 1921 New York Central Storm). Therefore, according to the 190 amp "down power" criteria for Seabrook in the ISO-New England operating procedures, even a moderate solar storm could require a complete shutdown of Seabrook nuclear plant, eliminating 1,247 MW of generation capacity.

6.2.2 Phase II HVDC Trip

The Phase II HVDC tie consists of two poles rated at approximately 2,000 MW together. If an unexpected contingency tripped both poles at the same time, it would be difficult for ISO-New England to manage this contingency because the typical loading of the Phase II tie exceeds real-time reserves. It is fortunate that a cascading blackout did not occur when both poles of the Phase II HVDC tie tripped out on October 28, 1991, during a moderate solar storm of only 500 nanoTesla/minute at the Ottawa, Canada observatory. In comparison, the March 13, 1989 storm that caused a blackout in Quebec had intensity of 800 nanoTesla/minute at the Ottawa observatory; the Phase II tie was not yet in service on this date.

6.2.3 Chester Substation SVC Trip

The Chester SVC supports 700 MW of imported power from Kenswick, New Brunswick to Orrington, Maine and another 2,000 MW of imported power on the Phase II HVDC tie, as explained by promotional literature *of the vendor, ABB.* An unexpected tripping of the Chester Substation Static Var Compensator (SVC), providing reactive power support for 2,700 MW of transmission, occurred during a solar storm on March 24, 1991 of only 400 nanoTesla/minute at the Ottawa observatory.

6.2.4 Nuclear Power Plant Shutdown by Order of Nuclear Regulatory Commission

Were a severe solar storm to be forecast, the Nuclear Regulatory Commission (NRC) might order the New England nuclear plants to be shut down, according to NRC staff testimony at the Federal Energy Regulatory Commission (FERC) Staff Technical Conference on Geomagnetic Disturbances to the Bulk Power System held on April, 30, 2012. The following is an exchange between Mr. Robert Snow of FERC and Mr. Singh Matharu of the NRC regarding shutdown of nuclear plants when the National Oceanic and Atmospheric Administration (NOAA) predicts a severe solar storm:

> MR. SNOW: Singh, I understand that in nuclear, you speak for yourself, not your agency, and I understand that position, so this is a question for you as an engineer. I know if there's a hurricane predicted, that the plants that are in the path of the hurricane typically shut down and are in cold shutdown mode prior to the event occurring. Hurricanes can go in all different directions, you know, may not. But certainly the grid wasn't designed to handle a full hurricane force. So you, in your general design criteria 17, you'd be in compliance with that. Since you've now heard or the [North American Electric Reliability Corporation] interim report talks about we expect the system to collapse in a large [solar] storm, what would you expect the plants to be doing?
>
> MR. MATHARU: If you are postulating the loss of offsite power event in the vicinity of a nuclear power plant.
>
> MR. SNOW: Loss of the grid, including offsite power.

MR. MATHARU: I understand, I understand. Let's start from just at the plant itself, and again the expectation would be for the plant to bring to a total shutdown, and be in a safe condition, so it can be on the diesel generators if needed. If you are postulating then if you stretch yourself to the collapse of the grid, then the obvious answer is yes, you would expect all the plants to be shut down.

MR. SNOW: But Michael has kind of told you or Bill told you that it's going to take 20 minutes. No plant's going to shut down, or at least be in a cold shutdown mode in that time frame. So what would you expect them to do ahead of time, use the 18 hours?

MR. MATHARU: Given the warning from NOAA that a storm was due in 18 hours, and the prediction was that the whole grid is going to collapse, I think they expect –

MR. SNOW: Whichever. I'm basically trying to understand, what would you be expecting from them?

MR. MATHARU: Again, the safe position for the nuclear plant is the shutdown condition. So you would trip the plants, if that dire situation was predicted. Now you started off by discussing what happens in the hurricane situation. If the procedures that we have right now, and we are postulating a station blackout, to avoid that, what we expect the plant to do is if the hurricane is four hours away from hitting the site, the plant should be a cold shutdown at that point. So to extend that to what you're asking, we would actually expect the plant to be in some kind of shutdown.

Nuclear power plants in New England account for 4,654 MW of generation resources that would be lost if the NRC were to order plant shutdowns in advance of a predicted solar storm.

Resource	*Capacity*
Seabrook Nuclear Power Plant	*1,247 MW*
Pilgrim Nuclear Power Plant	*685 MW*
Millstone 2 Nuclear Power Plant	*869 MW*
Millstone 3 Nuclear Power Plant	*1,233 MW*
Vermont Yankee Nuclear Power Plant	*620 MW*

Sources: International Atomic Energy Agency Power (IAEA) Reactor Information System; and NRC staff testimony, FERC Technical Conference, April 30, 2012.

6.2.5 Combined New England Scenarios

*According to the ISO-New England document "*ISO-NE 2013 Operable Capacity Analysis," the maximum allowance for unplanned outages is 3,600 MW and the minimum allowance is 2,100 MW, depending on the time of year. This same document specifies *1,000 MW of real time emergency reserves.*

Assuming only the Chester Substation, Phase II HVDC tie, and Seabrook nuclear power plant would be affected in a solar storm, 3,947 MW of ISO-New England resources would be at risk, compared with only 1,000 MW of real time emergency reserves. These resources have all previously had unplanned outages during or shortly after solar storms, with the storms being the proximate cause of the outages.

Assuming the Chester Substation, Phase II HVDC tie, and all New England nuclear power plants would be affected in a solar storm, 7,354 MW of ISO-New England resources would be at risk, compared with only 1,000 MW of real time emergency reserves.

In summary, the resources at risk for unplanned outage during solar storms greatly exceed the capacity planning allowances, and could result in load shedding and widespread blackout.

7. Hardware Protective Devices

Operating procedures, such as those used by ISO-New England and Maine utilities, are designed mostly to bolster reactive power reserves. As we have shown, operating procedures are likely to be overwhelmed by severe solar storms. Moreover, operating procedures do not reduce the Geomagnetically-Induced Current flows that cause transformer heating and harmonic production, two of the most serious geomagnetic disturbance effects.

Hardware protective devices for solar storms include series capacitors and neutral current blocking devices. These devices eliminate the root cause of solar storm issues—transformer half-cycle saturation—and eliminate transformer heating, reactive power consumption, and harmonic production. Hardware protective devices are currently available from commercial vendors. According to Emprimus, a vendor of neutral blocking devices, a set of devices for a transformer neutral would cost approximately $250,000 to $300,000.

With nine existing high voltage substations in Maine, and another five substations planned as part of the MPRP, *the estimated equipment cost to protect the Maine grid from solar storms would be $4.2 million, or only one-third of one percent of the MRPR cost*. When averaged over Maine's households, the cost to protect the Maine grid from solar storms would be an estimated $1.52 per household per year, assuming annual costs equal to 20% of equipment cost. With a longer period of equipment depreciation, the per household costs of solar storm protection would be just pennies per year.

8. Conclusions

Policymakers should inquire as to the types and cost-effectiveness of hardware protective equipment that Maine electric utilities have considered or are now considering to protect critical electric grid infrastructure against solar storms. Hardware protective equipment specified *during the planning stage for new transmission lines, such as the Maine Power Reliability Program for Central Maine Power, would be more cost-effective than retrofits.*

Retrofitting neutral ground blocking devices at extra high voltage (EHV) transformers, can be done at relatively modest costs – about $300,000 per transformer neutral. Some equipment can serve multiple transformers, thereby reducing the costs of both transformer protection and reducing the levels of Geomagnetically Induced Currents that enter the regional electric grid.

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Appendix 2

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Geomagnetic Disturbance Operating Procedure Template

Transmission Operator

Overview

Operating procedures are the quickest way to put in place actions that can mitigate the adverse effects of geomagnetically induced currents (GIC) on system reliability. They also have the merit of being relatively easy to change as new information and understanding concerning this threat becomes available. Operating procedures need to be easily understood by, and provide clear direction to, operating personnel. This is especially true since most operators are unlikely to frequently respond to significant GMD events.

Some actions listed below should only be undertaken if supported by an adequate GIC impact study and/or if adequate monitoring systems are available. Otherwise they can make matters worse. Those actions are indicated by the phrase "if supported by studies".

Determining that a geomagnetic disturbance (GMD) is significant enough to warrant the initiation of special operating procedure(s) depends on the geographical location of the power system/equipment in question coincident with the location of the GMD measurement and forecast. Amount of advance notice obviously factor heavily in what specific actions can and should be taken. Note these are recommended actions; specific actions may vary by system configuration, system design and geographic location of the entity.

Information and Indications

The following are triggers that could be used to initiate operator action:

- External:
  - NOAA Space Weather Prediction Center or other organization issues:
    - Geomagnetic storm Watch (1-3 day lead time)
    - Geomagnetic storm Warning (as early as 15-60 minutes before a storm, and updated as solar storm characteristics change)
    - Geomagnetic storm Alert (current geomagnetic conditions updated as k-index thresholds are crossed)
- Internal:
  - System-wide:
    - Reactive power reserves
    - System voltage/MVAR swings/current harmonics
  - Equipment-level:

- GIC measuring devices
- Abnormal temperature rise (hot-spot) and/or sudden significant gassing (where on-line DGA available) in transformers
- System or equipment relay action (e.g., capacitor bank tripping)

Actions Available to the Operator

The following are possible actions for Transmission Operators based on available lead-time:

Long lead-time (1-3 days in advance, storm possible)

1. Increase situational awareness
    a. Assess readiness of black start generators and cranking paths
    b. Notify field personnel as necessary of the potential need to report to individual substations for on-site monitoring (if not available via SCADA/EMS)
2. Safe system posturing (only if supported by study; allows equipment such as transformers and SVCs to tolerate increase reactive/harmonic loading; reduces transformer operating temperature, allowing additional temperature rise from core saturation; prepares for contingency of possible loss of transmission capacity)
    a. Return outaged equipment to service (especially series capacitors where installed)
    b. Delay planned outages
    c. Remove shunt reactors
    d. Modify protective relay settings based on predetermined harmonic data corresponding to different levels of GIC (provided by transformer manufacturer).

Day-of-event (hours in advance, storm imminent):

1. Increase situational awareness
    a. Monitor reactive reserve
    b. Monitor for unusual voltage, MVAR swings, and/or current harmonics
    c. Monitor for abnormal temperature rise/noise/dissolved gas in transformers[1]
    d. Monitor geomagnetically induced current (GIC[2]) on banks so-equipped[3]
    e. Monitor MVAR loss of all EHV transformers as possible

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[1] Requires proper instrumentation (e.g., fiber to hot-spot). Note there may be unusual heating in a location other than the normal hot-spot location. Dissolved gas analysis may be available in real-time if the transformer is so-equipped; otherwise, post-event DGA may be performed.

[2] 10 amperes per phase GIC is a good starting point for potential impacts on heavily loaded transformers when actual limits are unknown. Newer transformers may have significantly higher GIC withstand capability if specified at the time of construction. For vulnerable transformers, the OEM can perform analytical withstand studies to better define a particular design's GIC vs. Time withstand capability

[3] Regarding the effects of GIC on transformers, real-time mitigation (after a storm is already in progress) should not be taken based solely on a single indicator (e.g., increased GIC). At least one additional indicator should be monitored to determine if the transformer is actually being adversely affected (e.g., increased MVAR loss, abnormal temperature rise, etc)

   f. Prepare for unplanned capacitor bank/SVC/HVDC tripping[4]
   g. Prepare for possible false SCADA/EMS indications if telecommunications systems are disrupted (e.g., over microwave paths)
2. Safe system posturing (only if supported by study)
   a. Start off-line generation, synchronous condensers
   b. Enter conservative operations with possible reduced transfer limits
   c. Ensure series capacitors are in-service (where installed)

Real-time actions (based on results of day-of-event monitoring):

1. Safe system posturing (only if supported by study)
   a. Selective load shedding[5]
   b. Manually start fans/pumps on selected transformers to increase thermal margin (check that oil temperature is above 50° C as forced oil flow at lower temperatures may cause static electrification)
2. System reconfiguration (only if supported by study)
   a. Remove transformer(s) from service if imminent damage due to overheating (possibly automatic by relaying)
   b. Remove transmission line(s) from service (especially lines most influenced by GMD)

Return to normal operation

This should occur two to four hours after the last observed geomagnetic activity.

Related Documents and Links

2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbance on the Bulk Power System, dated February 2012
http://www.nerc.com/files/2012GMD.pdf

Industry Advisory: Preparing for Geomagnetic Disturbances, dated May 10, 2011
http://www.nerc.com/fileUploads/File/Events%20Analysis/A-2011-05-10-01_GMD_FINAL.pdf

[4] Consideration should be given to replacing protective relaying (as part of planned GIC mitigation projects) to prevent false tripping of reactive assets due to GIC should be considered. Note that capacitor units have harmonic overload limits that should be observed (see IEEE Std 18).
[5] Giving preference of course to the most critical/sensitive loads (e.g., national security, nuclear fuel storage site, nuclear plant offsite sources, chemical plants, emergency response centers, hospitals, etc)

Appendix 3

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Geomagnetic Disturbance Operating Procedure Template

Generator Operator

Overview

Operating procedures are the quickest way to put in place actions that can mitigate the adverse effects of geomagnetically induced currents (GIC) on system reliability. They also have the merit of being relatively easy to change as new information and understanding concerning this threat becomes available. Operating procedures need to be easily understood by, and provide clear direction to, operating personnel. This is especially true since most operators are unlikely to frequently respond to significant GMD events.

Some actions listed below should only be undertaken if supported by an adequate GIC impact study and/or if adequate monitoring systems are available. Otherwise they can make matters worse. Those actions are indicated by the phrase "if supported by studies".

Determining that a geomagnetic disturbance (GMD) is significant enough to warrant the initiation of special operating procedure(s) depends on the geographical location of the power system/equipment in question coincident with the location of the GMD measurement and forecast. Amount of advance notice obviously factor heavily in what specific actions can and should be taken. Note these are recommended actions; specific actions may vary by system configuration, system design and geographic location of the entity.

Information and Indications

The following are triggers that could be used to initiate operator action:

- External:
    - NOAA Space Weather Prediction Center or other organization issues:
        - Geomagnetic storm Watch (1-3 day lead time)
        - Geomagnetic storm Warning (as early as 15-60 minutes before a storm, and updated as solar storm characteristics change)
        - Geomagnetic storm Alert (current geomagnetic conditions updated as k-index thresholds are crossed)
- Internal:
    - Generator:
        - Reactive power reserves
        - System voltage/MVAR swings/current harmonics
    - Generator Step-Up (GSU) Transformer:
        - GIC measuring devices

- Abnormal temperature rise (hot-spot) and/or sudden significant gassing (where on-line DGA available)
- MVAR losses

Actions Available to the Operator

The following are possible actions for Generator Operators based on available lead-time:

Day-of-event (hours in advance, storm imminent):

1. Increase situational awareness
   a. Monitor for unusual voltage, MVAR swings, and/or current harmonics[1]
   b. Monitor for Abnormal temperature rise/noise/dissolved gas in transformers
   c. Monitor geomagnetically induced current (GIC[2]) on banks so-equipped[3]
   d. Monitor MVAR loss of all EHV GSU transformers as possible
2. Safe system posturing (only if supported by study)
   a. Redispatch generation (possible implement autorunback[4] if available)

Real-time actions (based on results of day-of-event monitoring):

1. Safe system posturing
   a. Manually start fans/pumps on selected transformers to increase thermal margin (check that oil temperature is above 50° C as forced oil flow at lower temperatures may cause static electrification)

2. Unloading reactive load of on-line generation (provides operating margin in case of loss of system reactive capability from SVC/shunt capacitors which may trip due to harmonics)

3. System reconfiguration (only if supported by study)
   a. Remove transformer(s) from service if imminent damage due to overheating (possibly automatic by relaying)

Return to normal operation

This should occur two to four hours after the last observed geomagnetic activity.

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[1] Harmonic currents can cause rotor heating similar to, but more severe than, negative sequence current heating. Manufacturer should be consulted to determine allowable threshold.
[2] 10 amperes per phase GIC is a good starting point for potential impacts on transformers when GIC capability data and/or triggering levels of GIC are unknown. Newer transformers may have significantly higher GIC capability if specified at the time of construction. For vulnerable transformers, the OEM can perform analytical capability studies to better define a particular design's GIC vs. Time capability for different transformer loadings.
[3] Regarding the effects of GIC on transformers, real-time mitigation (after a storm is already in progress) should not be taken based solely on a single indicator (e.g., increased GIC). At least one additional indicator should be monitored to determine if the transformer is actually being adversely affected (e.g., triggering levels of MVAR loss, current harmonics, temperature rise, etc)
[4] "Autorunback" is a planned automatic rapid load reduction at a relatively higher-than-normal rate (e.g., 15%/min rather than the typical 3-5%/min).

Related Documents and Links

2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbance on the Bulk Power System, dated February 2012
http://www.nerc.com/files/2012GMD.pdf

Industry Advisory: Preparing for Geomagnetic Disturbances, dated May 10, 2011
http://www.nerc.com/fileUploads/File/Events%20Analysis/A-2011-05-10-01_GMD_FINAL.pdf

Appendix 4

February 6, 2013

Charles A. Berardesco, Esq.
General Counsel
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Dear Mr. Berardesco:

We are writing to express our concerns with respect to apparent NERC noncompliance with Section 215 of the Federal Power Act and NERC Bylaws in the ongoing conduct of Phase 2 of the Geomagnetic Disturbance (GMD) Task Force of the North American Electric Reliability Corporation (NERC).

On February 1, 2013, we received an email communication titled "Request for Comment, GMD Task Force Operating Procedure Template" with the contact point of Monica Benson, Standards Development Administrator at NERC. In addition to requesting comments, the communication stated:

> The task force is comprised of members and observers. Members are users, owners, and operators of bulk power system assets and represent stakeholders or subject matter experts from Regional Entity staff. Task Force members represent the owners and operators who are ultimately accountable for the reliable planning and operation of the bulk powers system, and they are responsible for approving the deliverables of the GMDTF. Observers provide essential subject matter expertise to the GMDTF, particularly in areas not directly related to bulk power system planning and operation. Observers may represent Federal, State and Provincial Government agencies, vendors, academics, the scientific community, or other interested parties.

This most recent communication expresses discriminatory membership criteria that are nearly identical to the GMD Task Force policy conveyed in previous communications, both written and verbal, to task force participants in Phase 1 of the GMD Task Force.

NERC's discriminatory membership criteria for the GMD Task Force have been in effect since public stakeholders—including non-profit organizations and independent experts—expressed grave concern in the winter of 2012 during Phase 1 of the GMD Task Force that the task force was:

- Failing to request, obtain, and analyze empirical data and case studies of transformer failures during and following solar geomagnetic storms;

- Assuming that the engineering judgment of representatives for transformer vendors was a more reliable source for risk assessment than empirical data on transformer failures; and
- Holding secret and exclusionary meetings of selected participants in the GMD Task Force while excluding other public stakeholders, some of whom had greater subject-matter expertise than the specially invited participants.

Should there be any doubt of the discriminatory "membership" policy of the GMD Task Force, the last published rosters from February 2012 of GMD Task Force "Members" and "Observers"—once available on the GMD Task Force page of the NERC website but now removed—show that only owners and operators of the bulk power system are presently accepted as GMD Task Force "Members," along with a few representatives of Regional Entities. (These once published but now removed NERC rosters are attached to this letter.)

This arbitrary reclassification in Phase 1 of the GMD Task Force between preferential "Members" and mere "Observers" when combined with restricted access to Phase 1 GMD Task Force draft reports, and denial of opportunity for timely comment by "Observers" before report transmittal to the NERC Board of Trustees, effectively defeats the purposes of the Section 215 of the Federal Power Act. The Act was designed to assure a balance of decisionmaking and openness to safeguard the public need for a reliable bulk power system. Unfortunately, some of these same practices continue in Phase 2 of the GMD Task Force and the public good is now likely to suffer the same harm.

An examination of the most recent NERC Roster, dated January 2013, shows that the section for the GMD Task Force, while included in the January 2012 NERC Roster, has been deleted from the most recent roster. The current NERC Roster can be found at http://www.nerc.com/files/roster.pdf. Moreover, the January 2013 NERC Roster shows that with the exception of the Board of Trustees and Operating Committee, none of the other NERC committees or subordinate organizational structures has been divided into "Members" and "Observers." In fact, membership and even leadership of other NERC committees and subordinate organizational structures are populated by representatives of government agencies, vendors, academics, and the scientific community—the very categories of stakeholders that have been reclassified as "Observers" for the GMD Task Force.

Notably, even some "Small End-Use Electricity Customers" (according to the current "NERC Membership List" on the NERC website) evidently do not qualify for membership in the GMD Task Force, examples being Emprimus and Schweitzer Engineering Laboratories. Other similarly situated "Small End-Use Electricity Customers" (not "*users…of bulk power system assets*", per the discriminatory terminology in February 1, 2013 NERC email) evidently do not qualify for GMD Task Force's arbitrary selection of membership either, despite being clearly eligible for NERC Membership, per the NERC Bylaws.

In contrast, not being a "NERC Member" is not a disqualification for serving on most NERC committees—a prominent example being EPRI representatives serving on the Smart Grid Task Force despite EPRI not being a "member" of NERC. In fact, an EPRI representative serves as Vice-Chair Planning and Operations for the Smart Grid Task Force. In summary, the qualifications for serving as a “member” or even a designated leader of a NERC subordinate organizational structure—and the GMD Task Force in particular—do not appear to conform to any standard other than the caprice of NERC management.

Section 215 specifically requires that NERC “assure its independence of the users and owners and operators of the bulk-power system, while assuring fair stakeholder representation in the selection of its directors and balanced decisionmaking in any ERO committee or subordinate organizational structure.” Clearly, the GMD Task Force and each of its subgroups are *subordinate organizational structure[s]* within NERC.

NERC as an organization is accountable under Section 215 of the Federal Power Act for the reliable planning and operation of the bulk power system, and also is responsible for approving the deliverables of the GMD Task Force, but we know of no legal authority that imbues the category of “owners and operators” with exclusionary rights or responsibilities in the conduct of NERC business or approval of task force deliverables. Do the General Counsel of NERC and the NERC Board of Trustees propose that the legislative history and purpose of the Energy Policy Act of 2005 (as codified in Section 215 of the Federal Power Act)—in the aftermath of the Northeast Blackout of 2003—were intended to provide exclusionary powers and a *de facto* monopoly in standards-setting and other exercise of NERC duties for "owners and operators" of the bulk power system?

We ask the legal basis for the exclusion of multiple categories of public stakeholders, including “Small End-Use Electricity Customers,” in the “membership” of the GMD Task Force. We ask the legal basis for the peculiar organization of the GMD Task Force—arbitrarily divided into “Members” and “Observers.” Finally, we ask the legal basis for the policy statement that “Task Force members represent the owners and operators who are ultimately accountable for the reliable planning and operation of the bulk powers (sic) system, and they are responsible for approving the deliverables of the GMDTF.”

Section 215 also requires that NERC “provide for reasonable notice and opportunity for public comment, due process, openness, and balance of interests in developing reliability standards and otherwise exercising its duties.” In the conduct of Phase 2 of the GMD Task Force, there have been significant shortfalls in “openness” and “reasonable notice,” as required by Section 215. We give the following examples:

1. The GMD Task Force has been divided into four “subgroups,” also alternatively identified as “Teams 1, 2, 3, and 4.” Public stakeholders have been told by the NERC manager assigned to GMD Task Force that they could be assigned to only one “Team.” In this way, public “observers” have been effectively prevented from observing the work of the whole of the GMD Task Force.
2. In all of calendar year 2012, there was only one public face-to-face meeting of the GMD Task Force. Instead, the majority of task force business has been conducted by teleconferences of selected “leadership” designees without advance notice to the public or public stakeholder participation. Sparse minutes of eight “Leadership Teleconferences” conducted from September 21, 2012 to January 7, 2013 were delayed in public release until January 9, 2013. Public stakeholders have not been provided

advance notice of any of these teleconferences by task force email or posting on the NERC website.

3. For the first "Leadership Teleconference" conducted on September 21, 2012, the minutes read "A proposal to establish group sites for teams to maintain mailing lists and file-sharing location was deemed unnecessary; the team felt it was sufficient to continue exchanging files via email." GMD Task Force leadership is in possession of technical materials, including information from transformer manufacturers and operating procedure templates from transmission network operators, that have not been made available on common file-sharing locations, because common file-sharing locations do not exist by explicit leadership decision. This practice is in notable contrast to Phase 1 of the GMD Task Force, where a password-protected common file-sharing location did exist.
4. A number of actions have been taken by GMD Task Force leadership that have the effect of preventing open communication, including technical interchanges, between participants in the task force. No current email roster for the GMD Task Force has been published, a departure from the published email roster for Phase 1 of the GMD Task Force. While a NERC-maintained email listserver still exists for the GMD Task Force, the Chair specifically requested during the August 28-30, 2012 face-to-face meeting in Atlanta that use of the GMD Task Force listserver be minimized and further stated that he would delete any listserver communications that he deemed superfluous. Prior to the August 28-30 meeting, task force participants conducted a technical interchange via the task force email listserver regarding downrating of the Seabrook nuclear power plant because of "high circulating currents" in the Generator Step Transformers during the July 15, 2012 solar storm. The remarks of the Chair have had a chilling effect on task force communications via the email listserver; there have been no further technical interchanges on the listserver since the August 28-30, 2012 meeting.
5. Electric utility insiders or proponents who are not technically "Members" of the GMD Task Force, but instead have been arbitrarily classified as "Observers" have nonetheless been selectively invited to teleconferences of GMD Task Force leadership. Examples include the attendance of an EPRI representative at the October 5, 2012 and November 30, 2012 "Leadership Teleconferences."
6. While "Leadership Teleconferences" have been frequent, meetings of the GMD Task Force "Teams" have been much less frequent. For example, there have been two teleconferences of Team 1 and there has been only one teleconference for Team 2. The number of teleconferences for Team 3 is unknown to the signers of this letter, because public stakeholders have been effectively prevented from learning the activities of all teams. We commend Team 4 for holding three well-coordinated teleconferences.
7. There has not been reasonable notice of some Team teleconferences because the emailed notices were sent shortly before weekends and holidays, for teleconferences to be held shortly after the weekend or holiday. For example, for the Team 1 teleconference held on Tuesday, January 29, 2013 at 11am Eastern Time, the notice was emailed on Thursday, January 24 at 4:21 pm Eastern Time, less than three business days of notice. For example, for the Team 2 teleconference held at 8am Pacific Time on the Monday after Thanksgiving, the notice was emailed at 4:20am Pacific Time on Thanksgiving Day; because standard corporate practice in the United States is to give Thanksgiving and the following Friday as holidays, there was no effective notice for this meeting for U.S. participants.

The requirements of Section 215 of the Federal Power Act are not mere formalities. Congress specifically established these safeguards to balance the otherwise dominant interests of electric utility owners and operators. NERC's exclusion from information access for virtually all public stakeholders, including those that that depend upon electric supplies below the 100kV level, has the effect of disenfranchising public consumers. In the current conduct of the GMD Task Force, it appears that NERC is ignoring not only the intent of Congress, but also NERC's own Bylaws and specific requirements of federal law.

The hazards for which the GMD Task Force has been convened–including long-term blackout of over 130 million Americans, as described in the U.S Government-sponsored report of the Oak Ridge National Laboratory, "Electromagnetic Pulse: Effects on the U.S. Power Grid"–could conceivably cause more harm to the public good than any other reliability issue regulated by NERC. Consequently, the need for public stakeholder access and balanced decisionmaking should be greater than for other NERC committees and subordinate organizations. Yet it is for precisely the GMD Task Force that NERC has established exclusionary "Membership" criteria and has restricted public stakeholder access.

Finally, we must note that both NERC management and the GMD Task Force have suffered from significant management turnover. The first NERC manager of the GMD Task Force was replaced after the publication of the Phase 1 GMD Task Force interim report, the second NERC manager of the GMD Task Force left NERC employment on January 10, 2013, and the third NERC manager of the GMD Task Force has told us of his intent to leave NERC and may have departed as of the date of this letter. The previous Chair of the GMD Task Force was replaced after Phase 1 of the GMD Task Force. The previous CEO of NERC retired on January 1, 2010 after giving a speech in November 2009 to the NERC Board of Trustees and electric utility representatives about extreme threats to the electric grid and North American societies. And, as you are aware, the previous General Counsel of NERC announced his retirement in the fall of 2011 during Phase 1 of the GMD Task Force.

We ask for your prompt reply to our concerns. More importantly, we seek prompt reform of the procedures and balancing of interests in the conduct of NERC's GMD Task Force and all subordinate entities.

Sincerely,

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cc:
1. John Anderson, Chairman, NERC
2. Gerald Cauley, CEO, NERC
3. Christine Schwab, Chair, NERC Reliability Issues Steering Committee
4. Jeffrey L. Mitchell, Chairman, NERC Planning Committee
5. Kenneth Donohoo, Chairman, GMD Task Force
6. Monica Benson, Standards Development Administrator, NERC

Attachments:

1. NERC Email with Contact Point of Monica Benson, Standards Development Administrator, "Request for Comment, GMD Task Force Operating Procedure Template," dated February 1, 2013.

2. Section 215 of Federal Power Act (Title 16 United States Code § 215)

3. GMD Task Force "Members" Roster, February 2012

4. GMD Task Force "Observers" Roster, February 2012

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Request for Comment

GMD Task Force
Operating Procedure Template

Informal Comment from Task Force Members: February 1-15, 2013

Now Available

Team 4 (System Operating Practices, Tools, and Training) of the GMD Task Force has developed a draft Operating Procedure template for Transmission Operators and Generator Operators under Task 2.2 of the Phase 2 Project Plan. Task Force members are requested to review the draft Operating Procedure template and provide comments for the team to consider.

Instructions

An informal comment period is open through 8 p.m. Eastern on **Friday, February 15, 2013**. Please use this electronic form to submit comments. If you experience any difficulties in using the electronic form, please contact Monica Benson at monica.benson@nerc.net.

Next Steps

A webinar on the draft Operating Procedure template will be conducted on February 4, 2013 from 1-2 p.m. Eastern. A registration link is available on the calendar at the NERC website.

Team 4 will review the comments, consider revisions, and present a summary at the GMD Task Force meeting February 25 - 27. Under Task 2.2 of the GMD Task Force phase 2 project plan, the GMD Task Force is considering industry input to update the Industry Advisory on GMD.

Background

As described in the approved GMD Task Force Phase 2 Project plan, the GMDTF will review, and verify where applicable, the work products of NERC and other industry and scientific organizations in support of two key areas:

- Assessing the vulnerability of the North American transformer fleet, incorporating power system modeling with space weather simulation and transformer thermal characteristics
- Surveying the industry for best practices in operations to respond to GMD and updating the NERC Industry Alert

Specifically, the GMDTF will address the 4 recommendations identified in the 2012 GMD Interim Report:

- Recommendation 1: Improvement of tools for industry planners to develop GMD mitigation strategies
- Recommendation 2: Improvement of tools for system operators to manage GMD impacts
- Recommendation 3: Education and information exchanges between researchers and industry
- Recommendation 4: Review the need to enhance NERC Reliability Standards

The task force is comprised of members and observers. Members are users, owners, and operators of bulk power system assets and represent stakeholders or subject matter experts from Regional Entity staff. Task Force members represent the owners and operators who are ultimately accountable for the reliable planning and operation of the bulk powers system, and they are responsible for approving the deliverables of the GMDTF. Observers provide essential subject matter expertise to the GMDTF, particularly in areas not directly related to bulk power system planning and operation. Observers may represent Federal, State and Provincial Government agencies, vendors, academics, the scientific community, or other interested parties.

For more information or assistance, please contact Monica Benson, Standards Process Administrator, at monica.benson@nerc.net or at 404-446-2560.

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RELIABILITY | ACCOUNTABILITY

Title 16 United States Code§ 215

___SEC. 215. ELECTRIC RELIABILITY…

___(b) JURISDICTION AND APPLICABILITY.—(1) The Commission shall have jurisdiction, within the United States, over the ERO certified by the Commission under subsection (c), any regional entities, and all users, owners and operators of the bulk-power system, including but not limited to the entities described in section 201(f), for purposes of approving reliability standards established under this section and enforcing compliance with this section. All users, owners and operators of the bulk-power system shall comply with reliability standards that take effect under this section.

___(2) The Commission shall issue a final rule to implement the requirements of this section not later than 180 days after the date of enactment of this section.

___(c) CERTIFICATION.—Following the issuance of a Commission rule under subsection (b)(2), any person may submit an application to the Commission for certification as the Electric Reliability Organization. The Commission may certify one such ERO if the Commission determines that such ERO—

___(1) has the ability to develop and enforce, subject to subsection (e)(2), reliability standards that provide for an adequate level of reliability of the bulk-power system; and

___(2) has established rules that—

___(A) assure its independence of the users and owners and operators of the bulk-power system, while assuring fair stakeholder representation in the selection of its directors and balanced decisionmaking in any ERO committee or subordinate organizational structure;

___(B) allocate equitably reasonable dues, fees, and other charges among end users for all activities under this section;

___(C) provide fair and impartial procedures for enforcement of reliability standards through the imposition of penalties in accordance with subsection (e) (including limitations on activities, functions, or operations, or other appropriate sanctions);

___(D) provide for reasonable notice and opportunity for public comment, due process, openness, and balance of interests in developing reliability standards and otherwise exercising its duties; and

___(E) provide for taking, after certification, appropriate steps to gain recognition in Canada and Mexico.

Appendix 5

Comments on Operating Procedures Template
Foundation for Resilient Societies, Thomas Popik

All of these comments pertain to the "Operating Procedures Template" provided in the request for comment:

1. The Template does not state which of these potentially conflicting goals of "operating procedures" would be of highest priority:

Preventing load shedding

—OR—

Preventing system instability, uncontrolled separation, or cascading failures

—OR—

Preventing permanent damage to transformers or other critical equipment

2. The Template states, "Determining that a geomagnetic disturbance (GMD) is significant enough to warrant the initiation of special operating procedure(s) depends on the geographical location of the power system/equipment in question coincident with the location of the GMD measurement and forecast." This is a general and qualitative statement that does not specify which geographic locations would be most affected by GMD; rigorous GIC modeling, validated by empirical data, would be required to determine these locations.

3. The Template does not recommend any advance studies of system vulnerability to GIC, including mathematical modeling of transmission lines predicted to have GIC flows under a range of solar geomagnetic storm intensities. In contrast, Chapter 11 of the GMD Task Force Interim report, "Operating Procedures to Mitigate GIC," specifies under "11.3 Information Needed for Decisionmaking" "Studies to identify system vulnerabilities and actions is most likely to help" and ""GIC system models both as part of off-line studies and as part of a real-time analysis tool."

4. The Template does not recommend any advance assessment or inventory of equipment vulnerable to GIC. In contrast, Chapter 11 of the GMD Task Force Interim report, "Operating Procedures to Mitigate GIC," specifies "Studies to identify system vulnerabilities" and "Listing Transformers that are particularly vulnerable to the effects of GIC." Advance assessments might include:

- Transformers that may overheat or vibrate when subjected to GIC over a threshold criteria
- Transformers that may consume reactive power when subjected to GIC over a threshold criteria.
- Relays or other equipment protective devices that may trip when subjected to harmonics over a threshold criteria

5. The Template does not recommend advance modeling of the effects of proposed “Real Time Actions” on system stability. Nonetheless, the Template recommends actions which would affect power generated/transmitted and could also affect network stability. Actions include:

- “Selective load shedding”
- “System reconfiguration”
- “Remove transformer(s) from service if imminent damage due to overheating”
- “Remove transmission line(s) from service (especially lines most influenced by GMD)”

6. Nearly all major networks have “State Estimators” with simulation capability, but the Template does not recommend use of State Estimators to evaluate “Real Time Actions”, either in real-time or in advance of solar storms.

7. The Template does not recommend instrumentation of transformers and transmission lines for GIC flows, especially at instrumentation points that modeling would predict would experience higher than average GIC flows. Instead, the Template seems to take that approach that whatever instrumentation that is already in place would be sufficient to enable operator action. In contrast, Chapter 11 of the GMD Task Force Interim report, “Operating Procedures to Mitigate GIC,” specifies under “11.3 Information Needed for Decisionmaking” and “Improved monitoring with additional sensors and links to outside information sources.”

8. The Template does not recommend establishment of threshold criteria for operator action based on forecasted or observed solar storm indicators. In contrast, Chapter 11 of the GMD Task Force Interim report, “Operating Procedures to Mitigate GIC,” specifies under “11.3 Information Needed for Decisionmaking” and “Thresholds for actions based on this enhanced knowledge.” Threshold criteria for specific operator actions could include:

- Common space weather measures such as the K Index or NOAA “G”Scale.
- Observed dB/dt at publicly available instrumentation points
- Observed GIC, either in-network, or at publicly available instrumentation points

9. The template does not recommend establishment of threshold criteria for operator action based on network measurements. In contrast, Chapter 11 of the GMD Task Force Interim report, “Operating Procedures to Mitigate GIC,” specifies under “11.3 Information Needed for Decisionmaking,” “Thresholds for actions based on this enhanced knowledge.” Threshold indicators could include:

- Percent reactive power reserve
- Percent system voltage swing

- Percent MVAR swings
- Amps of GIC (Except for the threshold criterion of “10 Amps” of GIC for transformers where “actual limits are unknown”)
- Percent temperature rise or absolute temperature rise at instrumentation points in transformers

10. The Template states, “Regarding the effects of GIC on transformers, real-time mitigation (after a storm is already in progress) should not be taken based solely on a single indicator (e.g., increased GIC). At least one additional indicator should be monitored to determine if the transformer is actually being adversely affected (e.g., increased MVAR loss, abnormal temperature rise, etc).” There is no analytic or modeled basis for this statement; further we would not know if other system monitoring data (for example, increased VAR consumption, harmonics, etc.) might be available that would reveal other impacts. It is conceivable that in some cases where redundant indicators are not available, that prudence and mathematical modeling may indicate that a single extreme indicator would be sufficient for action.

11. The Template states, “10 amperes per phase GIC is a good starting point for potential impacts on heavily loaded transformers when actual limits are unknown.” This appears to be a rule of thumb based on past experience. There is no modeled basis for 10 amperes being a prudent limit. Moreover, no duration is specified for the limit of “10 amperes per phase GIC” when duration of GIC could significantly affect impacts on transformers.

12. The Template states, “DC bias is only a concern if GIC flow exceeds AC current flow.” There are no modeling, analysis, and/or test results to support this statement.

13. The Template states, “Newer transformers may have significantly higher GIC withstand capability if specified at the time of construction.” Specifications for GIC withstand that are untested and therefore uncertified do not provide sufficient assurance for electric reliability. Data on transformer GIC withstand should be collected by the GMDTF, so that assessments can include this important aspect of network vulnerability.

14. The Template states, “For vulnerable transformers, the OEM can perform analytical withstand studies to better define a particular design's GIC vs. Time withstand capability.” Analytical withstand studies that are not validated with testing or that deviate dramatically from existing transformer design standards do not provide sufficient assurance for electric reliability.

15. Transformer GIC withstand templates provided by manufacturers are being utilized by various asset owner/operators. Yet these templates have not been made available to the whole of the GMDTF, or for independent expert review, or any public review, except in the case of one template published by IEEE. The template survey effort should include requests for this relevant information to be provided and made public, so that reliability of these templates can be further assessed.

16. The Template contains no provision for training, drills, practice, or testing of operating procedures in advance of solar storm conditions. In contrast, Chapter 11 of the GMD Task Force Interim report, “Operating Procedures to Mitigate GIC,” includes “11.5 Geomagnetic Disturbance Operator Training.”