MAINE PUBLIC UTILITIES COMMISSION

COMMISSION INITIATED INQUIRY:	**)**	
MEASURES TO MITIGATE THE EFFECTS OF	**)**	
GEOMAGNETIC DISTURBANCES AND	**)**	**CASE NO. 2013-00415**
ELECTROMAGNETIC PULSE ON THE	**)**	
TRANSMISSION SYSTEM IN MAINE	**)**	

COMMENTS OF
THE FOUNDATION FOR RESLIENT SOCIETIES
IN RESPONSE TO 14 QUESTIONS PROPOUNDED BY
THE PUBLIC UTILITIES COMMISSION OF
THE STATE OF MAINE
Together with Appendices
Submitted on
October 4, 2013

Foundation for Resilient Societies
52 Technology Way
Nashua, NH 03060
www.resilientsocieties.org

Maine investor-owned electric Transmission and Distribution (T&D) Utilities (Central Maine Power Company, Bangor Hydro-Electric Company and Maine Public Service Company) are directed to respond to the following:

1. Identify the most vulnerable components of the T&D utility's transmission system;

Based on experience during solar storms and vulnerability modeling, the most vulnerable components of the transmission system to Geomagnetic Disturbance (GMD) are:

1. Extra High Voltage (EHV) transformers used for transmission and Generator Step-Up (GSU) transformers; and.

2. Static VAR Compensators (SVC), designed to maintain voltage stability of alternating current EHV transmission lines;[1] and

3. High voltage direct current transmission (HVDC) lines, which provide large blocks of electric power imported from Canada, and which support "black start" needs following electric blackouts, and serve as sources of load balancing for ISO-New England during losses of other generation and transmission resources.

Vulnerable components to Electromagnetic Pulse (EMP)[2] include: communication links within utility firms, links connecting to ISO-New England and federal energy data centers and grid Supervisory Control and Data Acquisition (SCADA) system electronics

Highest priority for protection are:

Categories of vulnerable equipment with (i) high replacement cost and (ii) long lead times to replace and (iii) criticality to maintain electric grid operations. Equipment meeting these screens include: GSU transformers; EHV transformers, generators; Static VAR Compensators (SVC); and high voltage DC transmission substations.

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[1] Prototypes of Dynamic VAR Compensators (with significantly more rapid switching to enhance voltage stability) will be operational in year 2014, and might replace Static VAR Compensators that have a track record of multiple outages in past geomagnetic disturbances. For highlights, see Comments of Advanced Fusion Systems, LLC, "Hardware and Test Capabilities," section on "DVAR Systems" submitted on October 4, 2013 in Maine PUC Docket 2013-00415.

[2] Throughout these responses, "Electromagnetic Pulse" or "EMP" is used to refer to the high voltage, short rise time pulse caused by a nuclear detonation in the upper atmosphere and also more localized Intentional Electromagnetic Interference caused by radio frequency weapons.

Communication links capable of "operating through" electromagnetic pulse events and grid blackouts are essential for emergency load balancing, nuclear fuel protection, and "black start" operations.

2. Provide information about the T & D utility's present practices or mitigation measures to protect the transmission system from GMD or EMP;

This response pertains to GMD mitigation only. We are not aware of any current EMP mitigation for the Maine transmission system.

Current GMD mitigation practices for the ISO-New England control area are limited to "operating procedures," which are inadequate. No hardware blocking devices for GMD have been installed in the Maine grid.

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.

Operating procedures found in SOP- RTMKTS.0120.0050 implement the *Solar Magnetic Remedial Action Plan* of ISO-New England. These operating procedures were first implemented on February 13, 2003 and most recently revised on February 1, 2013. 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, neither the previous nor the revised ISO-New England operating procedures have demonstrated their effectiveness during a severe solar storm.

3. Discuss the extent to which present practices or mitigation measures can handle GMD or EMP events;

EMP Mitigation Measures

We are not aware of any current EMP mitigation measures for Maine or the New England grid. Present practices make it likely that large portions of the grid will experience catastrophic collapse under EMP exposure with the real possibility of permanent damage to transformers, generators, communication systems, and SCADA control devices.

GMD Mitigation Measures

Operating procedures, such as those used by ISO-New England and Maine utilities, are designed mostly to bolster reactive power reserves. Secondarily, operating procedures might bring on-line generating capacity undergoing routine maintenance. Operating procedures are likely to be overwhelmed by GMD during severe solar storms. Moreover, operating procedures do not reduce the Geomagnetically-Induced Current (GIC) that causes transformer heating and harmonic production, two of the most serious geomagnetic disturbance effects. Another less well understood hazard involves vibration within both transformers and generating equipment caused by GIC.

Operating procedures depend on advance warning that will not occur in the case of rapid onset GMD. Even when advance warning is available, operators are reluctant to implement mitigating load-shedding due to legal liabilities associated with intentionally-caused power outages.

Maine is highly dependent on the ISO-New England control area. ISO-New England plans for up to two system contingencies, so-called "N-1-1" 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

Below we examine a number of scenarios during solar storms that could overwhelm ISO-New England generation margins.

Scenario 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.

ISO-New England High Voltage Interties at Risk

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

Scenario 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:

Resources at Risk 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.

** Vermont Yankee is in a phased retirement plan.

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

Nearly all of the potentially affected resources are well in excess of the 1,000 MW emergency capacity for ISO-New England. In past decades, backup coal-fired electric plants might have come on-line in emergencies, but with recent EPA emissions limits for coal-fired electric generation, these resources are disappearing from ISO-New England emergency capabilities.

Scenario 3: Seabrook Plant Unplanned Outage or Power Reduction

Seabrook Station, though located along the New Hampshire coast, provides 345 kV electric transmission to Maine and serves as a major source of electric capacity for ISO-New England. Seabrook nuclear plant, located on a salt marsh that is vulnerable to geomagnetic storms, 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 the GSU transformer failed after the November 8-9 solar storm. Even with on-site repair of the transformer, electric output ceased for 12.2 days.

- Seabrook electric generation 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, 2012solar 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, when Seabrook Station was not measuring GIC intensities on-site. We project an estimated 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.

Scenario 4: 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 nanoTeslas/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.

Scenario 5: 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 (Maine) 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.[3]

Scenario 6: 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.*

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[3] See also comments of ISO New England on vulnerabilities of the existing Static VAR Compensator at Chester, Maine, found at pp. 38-39 of the 113 page submittal of October 4, 2013, in this same Docket 2013-00415.

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.

New England Nuclear Capacity at Risk of Concurrent Mandatory Shutdown

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, transcript in FERC Docket AD12-13-000.

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.

The present "operating procedures" applied throughout ISO-New England, and the proposed "Operating Procedures" that NERC Staff has issued (September 2013) as a draft Operating Procedures Standard[4] have the following weaknesses:

- The NERC proposed "operating procedures" do not apply to generation operators, who, if they fail to de-energize unprotected transformers and generators upon warning of a severe intense solar storm, risk irreversible damage to critical equipment (GSU transformers and generators) with extended replacement times, and risk a rapid "gap" between regional emergency generating capacity and regional electric demand, even with emergency conservation;

- The NERC proposed "operating procedures" for GMD mitigation were revised in September 2013 to exclude Balancing Authorities from their requirements. Balancing Authority participants in Eastern Canada play a critical role in assuring hydropower imports to Maine and other ISO-New England recipients.

NERC has apparently[5] eliminated a previously in-process Equipment Monitoring standard that could assist Regional Coordinators (RC's), including ISO-New England), or the President of the

[4] NERC Draft Standard 2012-03 for Geomagnetic Disturbances – Operating Procedures, Sep. 2013.

[5] While elimination of NERC Project 2012-01, Equipment Monitoring and Diagnostic Devices, was proposed to the NERC Standards Committee, and a vote on its elimination held, inadequately disclosed meeting minutes do not

United States in mandating the de-energizing of unprotected grid-critical equipment during a severe solar geomagnetic storm.

Although widespread electric blackouts remain rare, the expansion of extra high voltage transmission networks has the unintended consequence of making the electric grid more vulnerable. Localized electric grid outages are increasingly common and already carry an estimated economic cost of $120 billion annually in the United States. More worryingly, while blackouts encountered to date almost exclusively stem from natural disasters – expected events with predictable consequences – the EMP/GMD threats have potentially far more serious consequences for the power grid, and for almost all other critical infrastructures that rely upon the 24/7 availability of reliable electric power.

4. Identify additional potential mitigation measures that could be implemented to decrease the negative impacts of GMD or EMP;

EMP Mitigation Measures

Transformer EMP protection can be accomplished using transient voltage surge suppression (TVSS) devices including metal oxide varistors or spark gaps on the transformer terminals. Generators may be protected by installing TVSS devices on their terminals. Communication and SCADA systems may be protected by shielding critical electronics, treating communications/data line shield penetrations with overvoltage protection devices, and using optical fiber instead of copper lines wherever possible.

GMD Mitigation Measures

Hardware protective devices for solar storms include series capacitors and neutral current blocking devices. These devices eliminate the root cause of solar storm damage—transformer half-cycle saturation—and eliminate transformer heating, reactive power consumption, harmonic production, and most severe vibrations associated with equipment damage.

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. According to Advanced Nuclear Fusion, LLC, dynamic VAR compensators will be available as prototype equipment starting in year 2014.

Installation of monitoring devices for Geomagnetically-Induced Current (GIC) would allow utilities to de-energize vulnerable equipment during slow-moving solar storms. Currently, ISO-New England has near-real-time access to only one GIC monitoring device located at the

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specifically state that this specific standard proposal was eliminated, but only disclose that a number of proposed standards were eliminated.

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.[6] United Illuminating Company in Southern Connecticut also has four GIC monitoring stations, but this data has not been 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 a Maine PUC requirement within the Maine Power Reliability Program.

5. Estimate the costs of those potential mitigation measures to decrease the negative impacts of GMD or EMP (please include low-cost, mid-cost and high-cost measures);

Costs of EMP Mitigation Measures

Protection of EHV transformers and generators against EMP (E1 pulse) has minimum costs on the order of $10K per unit of equipment protected.

Based on U.S. Department of Defense experience, protection of control centers against EMP effects is 3% to 5% of new facility costs. A nuclear power plant control center in Texas has been recently retrofitted to cope with EMP hazards at a cost of about $8.75 million dollars.

Costs of GMD Mitigation Measures

The Foundation for Resilient Societies performed a cost analysis of solar storm GMD protection for the Maine grid. The analysis found that electric utilities could install neutral current blocking devices for approximately $300,000 per substation. With nine existing high voltage substations in Maine, and another five substations planned as part of the MPRP, the estimated cost to protect the Maine grid would be $4.2 million, or only one-third of one percent of the MRPR cost. The cost to protect the Maine grid from solar storms would be an estimated $1.52 per household per year. This cost projection assumes that the costs of adding protective equipment to the Maine Power Reliability Program will be spread over a five year period.

In projecting the costs and benefits of programs to strengthen the reliability of the Maine electric grid, the Maine PUC and its supporting contractors should take into account the economic benefits of diverting most of the G*eomagnetically Induced Currents* (GICs) from entering the EHV transmission networks of Maine and ISO-New England.

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[6] In the submittal of ISO New England on October 4, 2013 in Maine PUC Docket 2013-00415, Step 1.4 of current ISO-NE operating procedures, as revised through June 19, 2013, involves the solicitation of current GIC readings by telephone. ISO-NE recognizes benefits if field readings of GIC can be more reliably reported. See page 16 of the 113 pp. ISO-NE submittal.

Among the components of economic benefits are the following:

- Reducing the costs of providing *reactive power* to stabilize voltage within the Maine transmission and distribution system;
- Reducing the percentage of wholesale power dispatched at "off cost" prices due to grid congestion during moderate or severe geomagnetic disturbances;[7]
- Reducing downpowering of electric generating facilities to prevent damage from Geomagnetically Induced Current;
- Higher capacity utilization within the Maine electric utility industry, at least theoretically resulting in reduced wholesale prices for electric generation, even in deregulated markets;
- Increased throughput of electric power (increased imports and increased exports) of Maine transmission entities, reducing the cost per kilowatt hour for more efficient use of the same capital equipment.
- Potential macroeconomic benefits to the State of Maine if Maine becomes a first mover in providing more reliable electric grid services, thereby attracting data center construction and employment, or location of other industries that require highly reliable electric power to achieve corporate goals.; and
- Benefits of "averted costs" through protection from severe, widespread, or long-lasting electric blackouts in event of a major GMD , measured in savings of life , avoidance of environmental contamination, and preservation of economic activity.

Due to overlap of FERC and Maine PUC regulatory jurisdiction, staff off the Maine PUC and the Maine Public Advocate may find it necessary to appear in ISO-New England tariff proceedings and FERC tariff reviews to obtain partial recoveries of Maine ratepayer financed capital improvements to the Maine Power Reliability Program or other reliability-enhancing programs.[8] We also recommend equipment to monitor GIC, and to correlate GIC and harmonic saturation reductions with "benefits" accruing to downstream transmission and distribution customers

[7] See published studies of Kevin Forbes and Chris St. Cyr, indicating substantial losses in transmission revenues due to even moderate geomagnetic induced currents within the bulk power system. E.g. the PJM Interconnection system for the 25 month period April 1, 2002 through April 30, 2004.

[8] Transmission system upgrades for the portions of the Maine electric grid within the ISO-New England service area are eligible for cost-recovery tariffs if the upgrades are cost-effective and contribute to improved ISO NE system reliability. ISO New England pool supported "Project Transmission Facility" cost sharing is covered by a review process that varies depending upon cost thresholds. ISO New England has assisted the Maine PUC by including these planning procedures for cost-sharing and tariff recoveries in its October 4, 2013 submittal in this docket: "Planning Procedure No. 4, Procedure for Pool-Supported PTF Cost Review," found at pp. 88-109 of 113 pp.

within ISO-New England, including ultimate electric customers outside the State of Maine. See answer to Question 11.

6. What are the positive and negative effects of adopting a policy to incorporate mitigation measures into the future construction of transmission lines and the positive and negative effects of retrofitting existing transmission lines to incorporate mitigation measures?

Positive and Negative Effects of Adopting EMP Mitigation

EMP mitigation would provide protection from man-made threats such as nuclear EMP and intentional electromagnetic interference. In the long-term, the electric grid and its transmission lines should be protected against EMP. However, retrofit of existing transmission would be more costly than designing protection into future transmission upgrades.

Positive and Negative Effects of Adopting GMD Mitigation

Installation of hardware blocking devices on only future transmission lines would divert GIC into existing transmission lines and not substantially protect the Maine transmission system. Instead, hardware blocking devices should be installed for both existing and future transmission lines.

The same hardware blocking equipment that is available for retrofit application within the State of Maine is available in other states and regions.

To be assured that Maine does not adopt technical standards that are inconsistent with the experience and knowledge of federal regulators, the Maine PUC should instruct its staff and contractors to coordinate closely and to seek technical assistance from the Staff of the Federal Energy Regulatory Commission (FERC). The FERC Commissioners, supported by FERC Staff, unanimously adopted FERC Order No. 779 in May 2013, requiring development of standards for GMD operating procedures and hardware protection of the bulk power system. It is part of FERC's mandate to assist the states in enhancing the reliability of their electric grids, and regional electric grids so these operate harmoniously and consistently with federal standards and federal standard-setting now under development.

By coordinating its assessments and proposed initiatives with FERC staff, the Maine PUC can assure that Maine has access to the studies, assessments, and staff expertise of FERC as Maine proceeds with its own reliability initiatives.

Our Foundation estimates that at least 14 to 16 EHV transformers in the State of Maine would benefit from prompt hardware protection.[9] Upgrades or replacements of static VAR compensators are also options to consider as dynamic VAR compensators become available to commercial customers in the near future.

If Maine retrofits the existing transmission network within the state to provide higher reliability for the existing electric infrastructure, it makes sense to include designs for enhanced reliability in new additions to electric generation, electric transmission, and electric distribution.

Additional benefits to Maine may accrue as Maine works with regional states served by ISO-New England and the relevant electric utilities operating in New England. If, for example, Seabrook Station, a known GIC "hotspot", were to install hardware designed to protect a replacement GSU transformer scheduled for installation in year 2014, this hardware upgrade would potentially benefit downstream transmission lines to Maine and Maine ratepayers by assuring a more reliable source of baseload power in a region that is increasing its share of intermittent electricity, such as wind power.

Beyond essential retrofits to existing Maine electric infrastructure, the Maine PUC can amend its Maine Power Reliability Program to keep GICs out of the bulk power system throughout the state.

What are some of the benefits of adopting standards to include reliability enhancements for all future equipment that is vulnerable to GMD?

Positive Effects:

a. Building protection in at the outset of new system build is less expensive than retrofit protection.

b. Protecting Maine's electric power infrastructure will allow the State to "keep the lights on" during a GMD catastrophe avoiding a long-term blackout, avoiding disastrous consequences that will be experienced by unprotected States.

c. Improved "black start" capabilities where the grid is in collapse and most control areas are blacked out. If just one state, such as Maine, is protected from GMD within a regional grid, then it is much easier to repair damage and restore electric power in neighboring states.

[9] See the Foundation website, www://resilientsocieties.org for the text of the March 2013 Foundation review of reliability enhancing opportunities for Maine and ISO-New England.

d. Saves operating costs by eliminating the need to reduce the operating power of transformers during solar storms, or to depower essential equipment entirely.

e. Enables control rooms to "operate through" GMD events so operators will maintain awareness and positive control of the system

f. Extends the operational lifetime of transformers

g. Reduces harmful harmonics caused by transformer saturation. In some cases, harmonics can damage customer equipment (e.g. uninterruptible power supplies, motor controllers). Enables customer homes and commercial facilities/plants to keep running, i.e. operate through GMD events.

h. If Maine demand a higher level of grid reliability, without waiting for federal solutions still over the horizon, these states will be at competitive advantage in attracting large data centers and other enterprises that require high levels of grid reliability.

<u>Negative Effects</u>:

a. There will be upfront cost for protection – but this will be offset by cost savings associated with averted reactive power costs, higher capacity utilization, longer equipment life, and reduced costs of blackouts.
b. Regulatory costs for Maine PUC staff to appear in ISO-New England tariff cases and FERC rulemaking to recover a fair share of reliability upgrade costs that also benefit downstream customers in other states
c. Small amount of additional space needed for transformer protection devices.

7. What are any potential effects of the State adopting a policy under 6 above on the regional transmission system?

While protection of only the Maine portion of the ISO-New England control area would not prevent blackout or transformer damage in other states, Maine generation and transmission resources protected from GMD damage would provide a black start resource for adjoining states and aid in system recovery.

Maine's approach to grid protection will likely set the standard for other States, and may be adopted by FERC for nationwide protection of the grid. Regarding black starting the grid, if long-distance transmission is in collapse and much of the Eastern Interconnection is blacked out, black start procedures will be much easier if they are developed on a regional basis with some control areas protected. The more states that are protected, the easier it will be to repair damage and restore electric power to the ISO-New England control area.

8. What would be a reasonable time frame for the adoption of any additional mitigation measures?

Timeframe for EMP Mitigation Measures

Transient voltage surge suppression (TVSS) devices including metal oxide varistors or spark gaps on the transformer terminals are commercially available and have been used for many years in Department of Defense systems. Ultra-fast protective switches to cope with EMP/E1 are in development, but have not yet been commercially adopted.[10]

Timeframe for GMD Mitigation Measures

Commercially available protective equipment to mitigate hazards of GMD has been independently tested and is commercially available. Hardware blocking devices are commercially available from Emprimus and might be installed within a year. Idaho National Laboratory has performed independent testing of these devices. (Other suppliers may offer blocking devices as well.)

Dynamic VAR compensators are in the prototyping phase within Advanced Fusion Systems, LLC. Commercially available dynamic VAR compensating capacitors may be available in the period 2014-2015.[11] To sum up, Preliminary cost recovery rule-making may take one to two years to achieve at the state and federal levels. The uniform adoption of appropriate GIC and related monitoring equipment could expedite voluntary adoption of protective equipment -- demonstrating cost-savings to utility executives. Rule-making for cost-sharing could evolve over a period of years as more definitive data on operating experiences become available to regulators.

9. Provide any recommendations regarding the allocation of costs to mitigate the effects of geomagnetic disturbances or electromagnetic pulse on the State's transmission system and identify which costs, if any, should be the responsibility of shareholders or ratepayers?

Allocation of Costs to Mitigate GMD

Initial costs of EHV transformer protection, even if amortized over just five years, will be less than one tenth of one percent of transmission reliability enhancement costs. Such a low share of transmission system reliability enhancement should be included in the ISO-New England

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[10] For a summary and image of an ultra-fast switch to protect against EMP, see the October 4, 2013 submittal in this Docket by Advanced Fusion Systems, LLC. This company has offered to supply protective switches to other vendors, including its competitors, due to the public interest to be served. Certain switches are subject to export controls.

[11] See the October 4, 2013 submittal in this Docket by Advanced Fusion Systems, LLC, section on "DVAR Systems."

reliability program costs. These are subject to review and approval by FERC, for the parts of Maine that are included within the ISO-New England control area.

Maine rate-payers pay about 8 percent of the ISO-New England transmission reliability enhancement costs, because the total reliability program costs allowed are allocated to all New England rate-payers by their proportion of system utilization.

Nonetheless, it is important that efforts be made to install equipment to monitor GIC flows, and the blockage of GIC entry into the bulk power system; and to perform cost-benefit analyses of these regional system enhancements. If Maine is to pioneer a more reliable electric grid, the state needs to apply principles of equity so its rate-payers do not bear an undue burden of costs while other downstream electric users also obtain benefits of reliability enhancements.

Parts of the Maine electric grid are not connected to, nor subject to reliability tariffs imposed by ISO-New England. But most of the Maine electric grid is connected to the ISO-New England portions of the bulk power system. Any allocation of initial costs to rate-payers in the ISO-New England system, even if approved by ISO New England and, upon review, by FERC, should include a proviso that, as monitoring equipment and analyses better define the allocations of costs and benefits, that both ISO-New England and FERC should provide an equitable "look back" period to consider whether some rate-payer relief is both just and reasonable and an appropriate incentive to reward those who have taken the lead towards a more reliable electric grid.

Our Foundation does not have current cost data for dynamic VAR compensators that might replace the static VAR compensator at Chester, Maine. The benefits of operating the Chester facilities without risk of loss of 2,700 MW of transmission capacity clearly extends to all electric consumers within the ISO –New England region. Equitable cost allocation ought to be an element of decision-making at both the state and federal levels in considering whether the Chester equipment should be retrofitted, replaced, or left as it is.

Among the primary beneficiaries of transmission reliability enhancements may be the merchant generating companies that supply electricity in largely deregulated markets under various FERC Orders and the Energy Policy Act of 2005. In theory, if these generating entities have reduced transmission congestion downstream, they can avert most "off-cost" sales and increase net operating income. If some of the protection for GSU transformers, while physically within generating facilities, are eligible for cost recovery to enhance the reliability of the bulk transmission system, these capital costs may be recoverable under ISO-New England tariffs that FERC later approves.

How will Maine rate-payers benefit? If there is adequate competition in electric generating markets, a more energy efficient and less congested transmission system ought to result in bids to sell generated electricity at lower costs. The Maine PUC, which has limited the share of allowable generating in some Maine sub-markets that may have imperfect competition, needs to monitor the benefits of keeping GICs and associated harmonics out of transmission systems within the State of Maine. If GMD protection for GSU transformers does not show, over time, benefits for Maine rate-payers, the Maine PUC and FERC may need to reconsider whether reliability upgrades to be included initially in ISO-New England tariffs are in fact benefitting rate-payers and not merely utility investors.

If Maine is to pioneer in enhancing electric grid reliability, it is important to identify both the costs and benefits and the fair allocation of costs and benefits to all of the regional rate-payers – not just those in Maine.

10. Discuss the relationship of any possible mitigation measures that might be undertaken by the State of Maine to measures that might result from the FERC rule. Specifically, is it possible that if Maine implements mitigation requirements in advance of NERC and FERC that such requirements might result in additional costs that might not have been necessary if mitigation requirements were not imposed on Maine T &D utilities?

Pending FERC Rule for GMD Mitigation Measures

The existing energy regulatory system encourages coordinated but overlapping regulatory initiatives by states and the feral government. The State of Maine has good cause to protect its existing and future transmission systems, taking into account risk factors that include its northern latitudes, susceptibility to boosted Geomagnetically-Induced Currents conducted through high salinity waterways, expansion of extra high voltage transmission systems, and dependencies upon electricity imported from Canada. By coordinating research, assessments, and proposals for mitigative standards with FERC, the Maine PUC can reasonably expect to avert significant conflicts between future state and federal reliability standards.

Because Section 215 of the Federal Power Act, as amended in year 2005, provides NERC the exclusive right to propose standards to FERC, it is possible that NERC will fail to produce acceptable standards, and that FERC will delay any standard approvals beyond the deadlines originally set in FERC Order No. 779.

A ballot on NERC-proposed "operating procedure" standards will close on October 18, 2013. The draft standard excludes as responsible parties generation operators that own GSU transformers--equipment at special risk of damage. The draft standard excludes Balancing Authority responsibilities for GMD operating procedures, which raises questions about Maine's ability to import emergency power from Canadian provinces during severe solar geomagnetic storms.

Fortunately, a growing scientific consensus has demonstrated, over more than a decade of rigorous assessment, that commercially available equipment is available to mitigate both GMD and EMP threats to electric grid reliability. Some firms, e.g. Metatech and Storm Analysis

Consultants, and various DOE laboratories have extensive track records of analytic capability. Other firms, such as PowerWorld, offer the opportunity to model impacts of selective installation of neutral blocking devices.

Experience shows that standard-setting at NERC, including coordination with FERC, moves at a snail's pace that cries out for concurrent state reliability initiatives. For example, it took 10 years for NERC to approve a reliability standard for "vegetation management" (also known as "tree-trimming") and 5 years to pass rudimentary cyber protection standards. Twenty-four years after the Hydro-Quebec Blackout caused by GMD, NERC has yet to even propose a reliability standard for hardware-based protection against GMD. Waiting for NERC to pass a GMD protection standard might result in Maine being unprotected for another decade or even indefinitely—and the risks and costs of GMD hazards would be imposed on Maine's most vulnerable citizens—hospital patients, nursing home residents, and anyone else that depends on reliable electric power.

While there is currently a FERC Order for GMD standards development, NERC and its electric utility members can take a variety of actions to delay enactment of a standard and to make selected geographies and utility networks exempt from any requirement for installation of hardware protective equipment. For example, as part of the standards-setting process, the NERC GMD Task Force has drafted an " Geomagnetic Disturbance Planning Application Guide" that proposes complicated, iterative, and subjective procedures for electric utilities to establish a geoelectric field "threshold" at which adverse equipment and system impacts might occur. By progressively altering modeling assumptions until the estimated geoelectric field is below this "threshold," electric utilities might erroneously conclude no GMD protection is necessary. In fact, the draft "Application Guide" reads as an instruction manual for electric utilities to "game" equipment and system impact studies; page 14 of the Application Guide in the subsection titled "Integration of Equipment Impact and System Impact Studies" (lines 35-37) reads, "If equipment considerations require mitigating measures, reduce the magnitude of the geoelectric field to the point where there are no equipment issues." For further details, see Attachment 1, "Response to NERC Request for Comments on Geomagnetic Disturbance Planning Application Guide," Comments Submitted by the Foundation for Resilient Societies on August 9, 2013.

Successful implementation of reliability enhancements for the State of Maine will require: Maine PUC coordination with FERC staff; Maine coordination with other ISO-New England states, and coordination with Canadian regulatory authorities having jurisdiction over Canadian interties and electric imports. Also, the Maine PUC may participate in in the setting of modified tariffs for capital programs that improve the reliability of ISO-New England transmission systems; so the costs and benefits of reliability enhancements can be fairly and equitably apportioned.

Working within the concurrent federal and state regulatory system, utilities within the State of Maine and the Maine PUC have protected Maine rate-payers in past reliability upgrades. Maine rate-payers are obligated for only eight percent (8%) of the Maine Reliability Program that was initially approved in the year 2007 and that is ongoing in future years. Other New England states will have positive incentives to coordinate with Maine's initiatives so the entire New England grid becomes more reliable in cost-effective phased steps.

If the Maine initiatives result in fair returns on investment for the utility companies, plus some share of the benefits for Maine ratepayers, we might see the Maine precedent sweep the nation at the state level.

11. Discuss whether there are any jurisdictional bars to Maine's adoption of mitigation measures;

FERC has primary regulatory jurisdiction over the bulk power system. Were Maine to adopt reliability standards that would impair the reliability of the bulk power system or were to conflict with preemptive FERC standard setting, FERC, and federal courts of appeal would have authority to enjoin Maine's inconsistent regulatory program.

By fully coordinating its draft assessments and any proposals for standard-setting with the FERC staff, the Maine PUC should be able to avert inconsistencies with prospective FERC standards. Because GMD/EMP mitigative equipment is sold in interstate commerce – though in some instances with export controls impacting foreign sales – the same protective equipment that will work in Maine will work in other states and within the FERC regulated bulk power system.

Parts of the Maine electric distribution, and parts of the Maine electric generating system are not connected to ISO-New England, and are exclusively regulated by the Maine PUC.

All of the nuclear power plants licensed by the Nuclear Regulatory Commission (NRC) are subject to preemptive safety-setting standards adopted or to be adopted by the NRC. The NRC has authority to require "backfitting" of licensed facilities to achieve needed safety standards. Any equipment that would be required for NRC-licensed power plants within the State of Maine or serving Maine customers from New Hampshire would require concurrent review and approval by NRC if safety issues arise. In general, NRC would be a primary beneficiary of grid protections from common mode failures, such as GMD or EMP events, because nuclear fuel safety and expedient "black restart" for NRC licensees depend upon minimization of the geographic scope and duration of any electric blackouts.

12. Provide information regarding any other state's adoption of mitigation measures related to GMD and EMP, including citations to the relevant statutes and rules;

Maine's L.D. 131, enacted on June 10, 2013 makes Maine the first state in the nation to mandate assessment of protective measures to mitigate geomagnetic disturbances and electromagnetic pulse hazards. [12]

Other states have recognized the need to improve the reliability of their electric grids but have not enacted legislation that specifically addresses the challenges of geomagnetic disturbances and electromagnetic pulse risks.

The State of Arizona on April 5, 2013 adopted Arizona SR 1324[13], which encourages the coordination of critical infrastructure information but exempts from public disclosure critical infrastructure information relating to natural disasters and emergency response plans.

The State of California on September 23, 2012 adopted Assembly Bill A. 1650[14], requiring Emergency and Disaster Preparedness of California Public Utilities. This legislation requires the development of state standards for disaster preparedness plans of electric utilities.

The State of Connecticut on June 15, 2012 adopted Connecticut Senate Bill S. 23.[15]
This legislation requires the preparation of emergency plans and operating procedures but does not mandate assessment of hardware protection for Connecticut electric utilities.

The State of Kentucky in year 2013 enacted H.B. 167, which requires both identification of risks and assessment of potential responses to threats of terrorism, including cyber-terrorism, and specifically threats of electromagnetic pulse attack. Hazards of solar storms are not specifically addressed.[16]

In the 113th Congress, two bills of interest are under consideration that may be relevant to Maine's pending assessment of coordination between federal and state reliability initiatives.

H.R. 2417, introduced on June 18, 2013, now with 24 cosponsors, known as the SHIELD Act, would strengthen the authority of FERC to establish reliability standards for geomagnetic disturbances and electromagnetic pulse risks without depending upon prior initiation of standard proposals by NERC.

H.R. 271, the Resolving Environmental and Grid Reliability Conflicts Act, would enable electric utilities that must comply with U.S. Department of Energy temporary interconnection orders in

[12] Legislation sponsored by Rep. Andrea Boland and others commenced as Maine H. 106, Resolve 45.
[13] Arizona Acts of 2013, Ch. 69.
[14] California Acts of 2012, Ch. 472.
[15] Conn. Public Act 12-148
[16] Acts of 2013, ch. 21, adding to Kentucky Revised Statutes ch. 39G.

an emergency [per Section 202 (c) of the Federal Power Act]to avert otherwise mandatory violations penalties under the federal Clean Air Act.[17] Neither of these bills has passed either house of the Congress at the time these comments are submitted.

These references to recently enacted state legislation and to bills pending before the U.S. Congress are provided for background information only. The Foundation for Resilient Societies does not endorse any federal or state legislation. The Foundation operates as a non-profit organization undertaking research and education on the protection of critical infrastructure.

13. Provide any comments filed by the T & D utility at NERC regarding Phase 1 of the FERC GMD rulemaking1; and

See Attachment 1, "Response to NERC Request for Comments on Geomagnetic Disturbance Planning Application Guide," Comments Submitted by the Foundation for Resilient Societies on August 9, 2013.

See "Project 2013-03 Geomagnetic Disturbance Mitigation," "Comments Received" at

http://www.nerc.com/pa/Stand/Pages/Project-2013-03-Geomagnetic-Disturbance-Mitigation.aspx

14. Provide, to the extent information is available, information on the extent or frequency of GMD or EMP events in Maine and the extent of any damage to the transmission system caused by those events.

Examples of GMD events and resulting damage to electricity generation and transmission in Maine and the ISO-New England control area include:

1. 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.

2. 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

[17] The Department of Energy has mandated temporary interconnection of electric utilities on six occasions. For highlights, see H. Rept. 113-86, issued on May 20, 2013.

equipment. The proximate cause of the Seabrook GSU transformer was Geomagnetically-Induced Current and resulting transformer vibrations during the solar storm.

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

4. 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

5. 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."

Excerpts from Power Reactor Status Reports on October 29, 2003

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.

Experience of Central Maine Power with GMD Impacts and Operating Procedures

Upon request of the Energy, Utilities and Technology Committee of the Maine State Legislature, Central Maine Power voluntarily released on March 21, 2013 twenty-four years of GMD impacts on its system and twenty-two years of GIC data at its Chester, Maine substation.[18] Central Maine Power should be commended for this voluntary and good faith release of data which has substantially expanded public knowledge of GMD and its impact on electric grids. The Central Maine Power GMD event disclosure is reproduced in full in Appendix 1 of this comment. Central Maine Power also disclosed its GMD Operating Procedures.

No GIC monitors were installed in the Central Maine Power system at the time of the March 1989 solar storm that caused the Hydro-Quebec Blackout. However, these system impacts were observed, according to the disclosure:

- All Orrington capacitors tripped
- Orrington capacitors would not close back in
- Yarmouth 4 and “MY” Generator VARs went over 300+ MVAR each

By the June 5, 1991 solar storm, a GIC monitor had been installed at the Chester, Maine substation. Below is a summary of the top 10 GIC events from June 1991 to March 2013, ranked by maximum GIC readings.

[18] No GIC readings or GMD impacts were provided by Central Maine Power for the period between 9/8/1994 and 5/4/1998. It is not clear from the disclosure whether no significant GMD occurred during this period, or whether the data are missing.

Top 10 GMD Events for Central Maine Power—1991 to 2013

GIC Rank	Maximum GIC Reading in Amps	Impact Category	GMD Event Dates	Central Maine Power Comments
1	173.4	No Known Impact	06/21/2001	May be an anomaly – one time spike with very little activity before or after spike
2	98.0	No Known Impact	10/24/2003 to 11/05/2003	NKI; 10/29/03 Very large GIC flow but no impacts seen by CMP
3	96.9	SVC Trip	08/24/2005	Chester SVC Filter banks tripped
4	89.9	SVC Trip	11/24/2001	Chester SVC filter banks trip
5	88.0	No Known Impact	11/07/2004 to 11/10/2004	NKI; 11/9/04
6	83.1	No Known Impact	05/15/2005	NKI
7	81.7	SVC Trip	04/06/2000	SVC filter banks trip; distribution customers UPS's not functioning properly in North Coastal areas
8	76.2	Generator Trip	03/30/2001	MIS G1 trip but think it was due to faulty control board – no other evidence for trip
9	76.0	Capacitor Trip	07/15/2000	MS2 declared by ISO; Orrington KC3 trip; 7kV swing on 345kv system; many Auto xfmr LTC operations
10	74.3	Capacitor Trip	05/04/1998	2 caps tripped at Orrington; Orrington Bus @ 328kV

Note: NKI stands for No Known Impact. SVC stands for Static Var Compensator.

As the above table shows, the Central Maine Power system has experienced multiple capacitor and Static Var Compensator (SVC) trips during GMD events. In fact, of the top 10 GMD events over a twenty-two year period, 50% resulted in SVC or capacitor trips. SVC and capacitor trips are caused by production of harmonics within half-cycle saturated power transformers. While transformer manufacturers are now beginning to specify transformers resistant to overheating when subjected to GIC, this data from Central Maine Power shows that harmonic production by transformers is another important GMD effect that must be addressed by system operators. The disclosed GMD impacts also show that harmonics prevented Uninterruptable Power Supplies (UPS) at customer sites from functioning properly during at least one solar storm.

SVC trips were the immediate cause of voltage collapse for Hydro-Quebec in March 1989, a system geographically adjacent to Central Maine Power. The Hydro-Quebec Blackout occurred during an induced electric field of approximately 2 volts/kilometer. According to an estimate by John Kappenman of Storm Analysis Consultants, a 1-in-100-year solar storm of intensity equivalent to the 1921 Railroad Storm or 1859 Carrington Event would produce an electric field of approximately one order of magnitude greater.

Central Maine Power and its regional balancing authority, ISO-New England, currently rely on Operating Procedures to protect against solar storms and associated GMD. Operating procedures for ISO-New England were first implemented on February 13, 2003. Nonetheless, these Operating Procedures did not prevent the Chester SVCs from tripping during the August 24, 2005 solar storm.

The current GMD Operating Procedures of Central Maine Power appear to concede that tripping of SVCs and capacitor banks is still likely during solar storms. Section 4.2.2 of the Central Maine Power System Operations Common Control Room Procedure states:

4.2.2 The following actions will be evaluated between ISO-NE and their LCC operators and performed as appropriate to posture the grid accordingly either pre-SMD event or post-SMD event (Note: ISO-NE initiates discussion of below actions at Kp7 or greater, per their SOP-RTMKTS.0120.0050):

- Inhibit the Unbalance protection of the Chester SVC to prevent trips caused by harmonics.

  …

- Take pre-contingency measures for the loss of the Chester SVC and/or Orrington capacitors.

In summary, this disclosure by Central Maine Power shows that solar storms and associated GMD have had major effects on its system, with significant SVC and capacitor trips during relatively minor solar storms producing GIC of less than 100 amps. ISO-New England Operating Procedures implemented in 2003 did not prevent tripping of the Chester SVC during a 2005 solar storm. Central Maine Power compensates for the inability of Operating Procedures to mitigate harmonics by requiring unspecified “pre-contingency measures” for tripping of equipment. Additionally, in a grid posturing action whose prudence could be questioned, normally-needed system protection—such as “unbalance protection”—would be inhibited by their GMD Operating Procedures.

When considering this recent disclosure of GMD impacts by Central Maine Power, and the track record of its Operating Procedures, one must remember that Maine has not experienced a truly severe solar storm during the time period of recorded GIC readings—such as the 1921 Railroad Storm or the 1859 Carrington Event. Such a storm is likely to produce GIC of magnitude 5-10 times greater than the March 1989 storm, with greater potential for production of harmonics, equipment tripping, cascading blackout, and permanent damage to critical equipment.

In addition, we request that ISO-NE and Northern Maine Independent System Administrator (NMISA) provide any information about their own operating procedures that would help to address the above issues. We also ask ISO-NE and NMISA to discuss the procedures under which it would review any design features or hardening devices that might be used to mitigate the effects of EMP or GMD on the transmission system and what standard it would apply in such reviews. Finally, any interested person is welcome to file comments on any of the issues outlined in this Notice of Inquiry and in the Resolve.

See attachment 2, "Comments of the Foundation for Resilient Societies, FERC Docket No.RM12-22-000, Submitted to FERC on December 24, 2012"

See Attachment 3, "Comments of the Foundation for Resilient Societies, FERC Docket No.RM12-22-000, Submitted to FERC on April 1, 2013."

See Attachment 4, "Comments of the Foundation for Resilient Societies, FERC Docket No.RM12-22-000, Submitted to FERC on May 14, 2013."

These comments are respectfully submitted, by

Thomas S. Popik, Chairman of the Board

William R. Harris, Secretary and Board Member, and

George H. Baker, Board Member,

For the

Foundation for Resilient Societies
52 Technology Way
Nashua, NH 03060
www.resilientsocieties.org