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	**)**	

SUPPLEMENTAL & REPLY COMMENTS OF
THE FOUNDATION FOR RESILIENT SOCIETIES
SUBMITTED TO
THE PUBLIC UTILITIES COMMISSION OF
THE STATE OF MAINE
October 15, 2013

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The Foundation for Resilient Societies appreciates the opportunity for Reply Comments that the Maine Public Utilities Commission has allowed all filers and commentators in Docket 2013-00415.

SOLAR GEOMAGNETIC ACTIVITES OFTEN PEAK FOLLOWING THE SOLAR MAXIMA & POTENTIAL MAN-MADE EMP CAPABILITIES PROLIFERATE: SO TIME IS "OF THE ESSENCE" TO MODEL AND PROTECT ELECTRIC GRIDS.

Some filers in this Docket indicate a preference to defer the deployment of protective hardware equipment until NERC (the North American Electric Reliability Corporation) proposes protective standards, and FERC (the Federal Energy Regulatory Commission) adopts such standards. This could occur at the earliest in January 2015, and might be substantially delayed if the NERC proposed standards are deemed inadequate by FERC, and the standard-setting cycle repeats.

The random and cyclic activities of the sun are not suspended for the convenience of utility regulators or utility operators. The Maine electric grid is becoming a bigger antenna for Geomagnetically Induced Current (GIC) as parallel high voltage transmission lines come online. Installation of these parallel lines is happening under the Maine Power Reliability Program in this decade. And prior assessments indicate that Maine already had above-average risks to electric reliability due to its latitude, geology, adjacency to saline waters, and dependence upon imported power from more northerly latitudes in Canada.

Playing Russian roulette with the sun is a losing proposition. According to William Murtagh of NOAA's Space Weather Prediction Center, the most severe solar storms (e.g. the New York Central Railroad Storm of 1921 and the Carrington Event of 1859) followed periods of below-average solar geomagnetic disturbances (GMDs).

Historical records show that in the first quartile following the solar maxima, there has been a higher frequency of high magnitude solar storms impacting geomagnetic fields on the surface of the earth. (The most recent solar maxima occurred in September 2013.) The most rigorous effort to plot the severity of solar geomagnetic impacts on the magnetosphere of planet earth over roughly the past half century has been conducted by scientists at USGS's Denver, Colorado center, J. J. Love and J. L. Gannon (2009).[1] They fit the geomagnetic data for solar half-cycles for the period 1958-2007, as shown on the following Figure showing the root mean square (RMS) of solar maximal and minimal activities. Their best fit provided a solar half cycle of about 10.5 years. Of particular interest, the dispersal of high intensity solar storms (above 30 NanoTeslas) indicates an historic concentration of high intensity storms in the first quartile, or

[1] J. J. Love and J. L. Gannon, "Revised Dst and the epicycles of magnetic disturbance: 1958-2007," Annales. Geophysicae, 27: 3101-3131 (2009), especially Figure 20.

about 2.65 years following the solar maxima. A severe solar storm can occur at any time. But the probability of significant solar weather causing grid instability appears to be higher than average in the 2 to 3 years following the solar maxima. Hence, the time to deploy Geomagnetic Induced Current (GIC) monitors and to model vulnerabilities and mitigation benefits of protective equipment is now, not several years in the future. Figure 20 from this U.S. Geological Survey modeling effort is reproduced here:

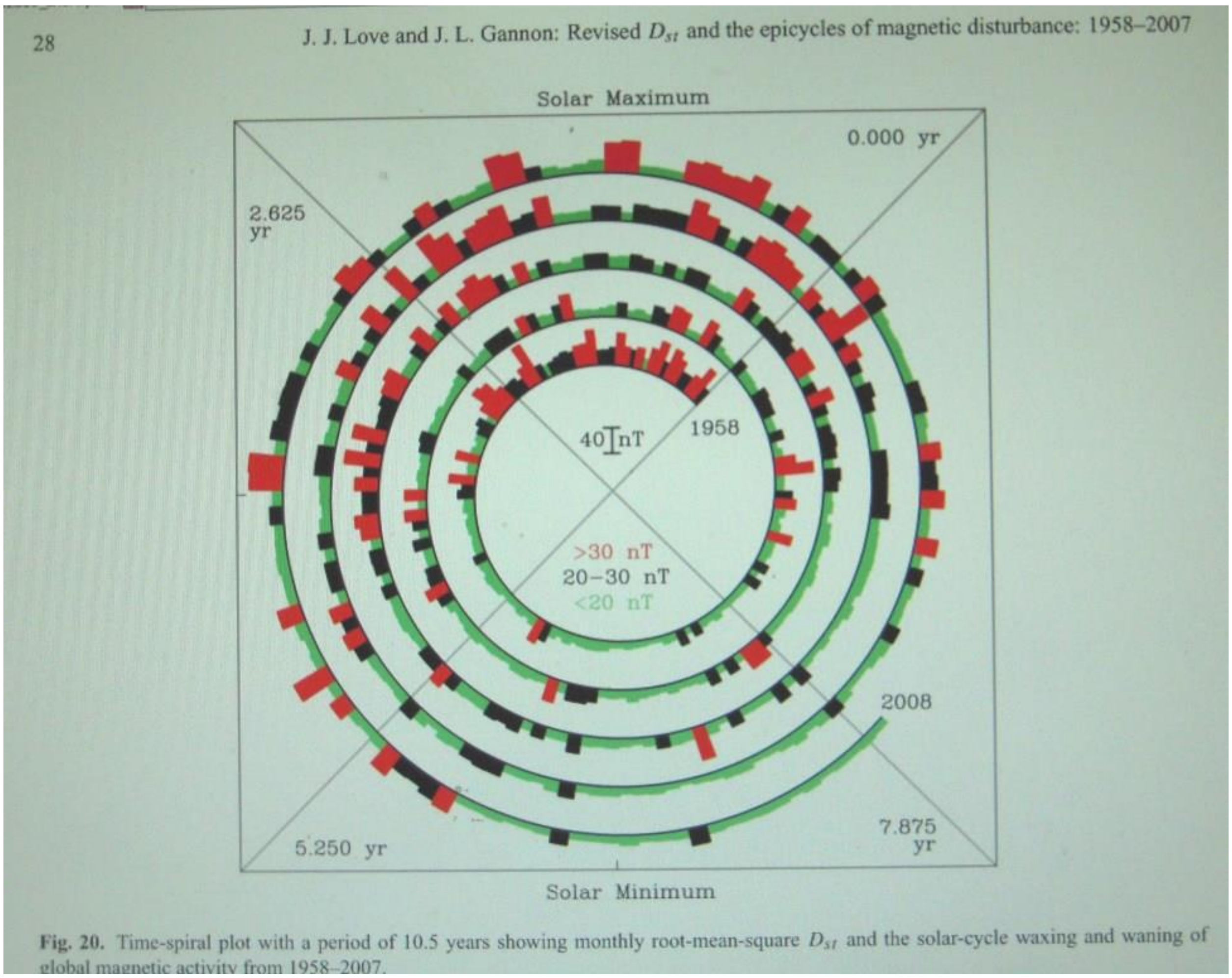

Fig. 20. Time-spiral plot with a period of 10.5 years showing monthly root-mean-square D_{st} and the solar-cycle waxing and waning of global magnetic activity from 1958–2007.

GIC MONITORING AND NEAR-REAL-TIME REPORTING EQUIPMENT IS COMMERCIALLY AVAILABLE AT ABOUT $10,000 PER UNIT, NOT $200,000 PER UNIT.

In preface to our comments on the costs of GIC monitoring equipment, our Foundation wishes once again to commend Central Maine Power for its forthright and voluntary submission of a two decade time series of GIC monitoring data from the Static VAR Compensator site in Chester, Maine. Public availability of these data, recently plotted by John Kappenman of Storm

Analysis Consultants in an analysis within this Docket, assist the Commission in identifying the importance of augmenting the robustness and reliability of the Chester, Maine SVC facility as a key resource to enhance voltage stability of the Maine electric transmission network during solar storms.

Nonetheless, in its Response to MPUC Question 5, Central Maine Power asserted that: The order of magnitude of "GIC monitoring is $200K per site."[2] Perhaps this was the inflation-adjusted cost of installing GIC monitoring at the Chester, Maine SVC facility when installed decades ago.

Our Foundation has queried providers and operators of GIC monitoring equipment, and has determined the following: Advanced Power Technologies of New Jersey indicates they manufacture GIC monitoring equipment, the ECLIPSE system, at a cost of approximately $10,000 per unit. This equipment monitors GIC at the neutral of extra high voltage transformers, harmonics and associated indicators (e.g. dissolved gases & temperature) that allow correlation of GIC variations with indicators of transformer operability and transformer risks. Included in the $10,000 ECLIPSE GIC monitoring systems are programmable SCADA capabilities to automatically report GIC alarm levels, GIC measurements, harmonics, and other transformer performance measures via Ethernet or Internet or otherwise.[3] Emprimus, manufacturer of neutral ground blocking equipment, offers GIC monitoring equipment as an option to purchasers, within a total cost of $250,000 per neutral ground blocking set, or $200,000 per set for volume purchases. Emprimus indicates that GIC monitors by themselves cost about $10,000. GIC monitoring devices may also be purchased as equipment embedded in new extra high voltage transformers.

The Maine grid currently has only one GIC monitor, located at the Chester substation. A single GIC monitor leaves Central Maine Power "blind" to solar storms at certain orientations and puts the citizens of Maine at risk for long-term grid outage. For the approximate cost of a single utility's legal filings on this Maine PUC docket, an additional GIC monitor might already have been installed.

For about $200,000, as many as 20 GIC monitors could be deployed at critical transformer locations within the Maine transmission system. Data could be available to both the sponsoring

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[2] Central Maine Power Response in Maine PUC Docket 2013-00415, October 4, 2013, at p. 4, found in the PDF document at page 5 of 193 pp.

[3] See the Advanced Power Technologies 4-page Spec. Sheet (2013). Certain probes must be separately ordered at added costs.

utility and to ISO New England in near-real-time, reporting by the Ethernet or the Internet or by special purpose communication devices. This could provide early warning to both utility operators and to ISO New England of the need to down-power a transformer, to totally de-energize a transformer, to augment power reserves, or to commence emergency conservation measures in a severe solar storm. Moreover, the early installation of low-cost GIC monitoring equipment could be a vital element to confirm the validity or to improve modeling of the reliability of – and the key vulnerabilities of – the Maine EHV transmission system. Using a network of GIC monitors should accelerate learning from moderate-level solar storms, and associated investments in protective equipment that could help prevent disaster in a major solar storm.

WHY EVEN PARTIAL TRANSMISSION NETWORK PROTECTION CAN IMPROVE RELIABILITY OF EVEN UNPROTECTED EQUIPMENT.

The Foundation urges the Commission and the MPUC Staff to utilize important findings, shared with the Commission via the Emprimus (Faxvog, et al.) filing of October 4, 2013. American Transmission Co. (ATC) has become the nation's first adopter of both system-wide GIC monitoring (23 monitoring sites now operating) and experimental deployment of an Emprimus neutral ground blocking system within an electric transmission network. Figure 1 in the Emprimus filing in this Docket indicates, based on the modeling backed by ATC network GIC monitors, that equipment deployed at the *edges* of a transmission network can reduce overall GIC levels within the transmission system. ATC and Emprimus have reported that the deployment of just 5 hardware protective devices within a network will increase the tolerance levels of solar storms (measured in volts per kilometers) *even for a network that still operates with most of its EHV transformers unprotected.* A preliminary model for the ATC system estimates that, with 5 neutral ground hardware units, the volts per kilometer that would trigger a system collapse increase from 20-21 volts to a higher level, perhaps 23-24 volts. Protecting 10 EHV transformers out of 25 total would, per preliminary modeling,[4] prevent network collapse until an estimated field strength of 26-27 volts per kilometer.

Blocking GIC protects both the specific transformers that are exposed to GIC, and also other EHV transformers in the network, because the overall network operates with reduced GIC flows and adverse harmonic effects throughout the entire transmission network.

Maine will benefit from modeling its own specific transmission network, aided by widespread GIC monitoring within Maine. The specific soil and geoelectric transmission conditions, and the

[4] See Emprimus presentation, "Modeling with GIC and Neutral Blocking," 2013 PowerWorld Client Conference, January 22, 2013, Viewgraph 15 of 32, modeling the American Transmission Company network.

ocean boundary effects upon the intensity of electrojets need to be modeled, monitored, validated, and subjected to open and transparent peer review by experts from any and all sources.

MODELING THE MAINE ELECTRIC GRID IN THE CONTEXT OF ISO-NEW ENGLAND SYSTEM INTER-OPERABILITY

The Foundation for Resilient Societies recommends that the Maine Public Utilities Commission seek voluntary electric utility company participation in a *demonstration project* designed to identify cost-effective means of improving reliability of the Maine electric transmission and distribution system.

This modeling effort needs to be well underway before the Maine PUC files its mandatory report with the Maine State Legislature, due on January 20, 2014. To be successful in this endeavor, the State of Maine will need to obtain expedited but voluntary cooperation of Maine electric utilities subject to MPUC jurisdiction.

Elements of the modeling effort might include:

- Selection of an experienced firm that has an extensive, third-party validated track record to develop a model of the Maine electric grid that takes into account Maine-specific variations in geoelectric soil properties and "ocean effects" GIC near high-saline water bodies. The geoelectric field likely to be experienced consistent with the soil geology, latitude, and geography of Maine during severe solar storms should be explicitly modeled—and model inputs, outputs, and validation against real-world measurements should be publicly disclosed. The safety of the citizens of Maine would not be well-served by allowing a modeling vendor to subjectively assume a geoelectric field for Maine based on general conditions outside of Maine and/or unvalidated models developed for other areas.[5] Expedited deployment of GIC monitoring devices to

[5] It is particularly important that the geoelectric field for Maine be explicitly modeled and publicly disclosed, because of current controversy over the maximum likely geoelectric field likely to be experienced during a severe solar storm. The GMD Task Force of NERC has proposed a maximum design basis geoelectric field of only 5 volts/kilometer during a severe solar storm within the United States, while a geoelectric field of 8 volts/kilometer has already been measured within the United States during a moderate solar storm and a geoelectric field of 50 volts/kilometer might be extrapolated for a severe solar storm. See "Response to NERC Request for Comments on Geomagnetic Disturbance Planning Application Guide, Comments Submitted by the Foundation for Resilient Societies," dated August 9, 2013 and previously filed on this docket.

all Maine electric utilities that are willing to volunteer to employ these monitoring devices, and public disclosure of GIC data to establish a *baseline* for GIC effects before protective equipment is installed.

- Identifying priorities for installation of equipment protection, with one goal being to maximize overall electric grid reliability at a baseline investment; and ultimately to achieve a higher level of system reliability in a cost-effective, incremental effort.[6]
- Investigating potential cost-effective measures to protect Bangor Hydro generation and transmission from *both* E1 (prompt voltage surges from EMP devices) and from E3, so that hydropower resources are available to support "black start" operations in the event of a major regional blackout.[7]
- A solicitation of federal research support for this Maine effort. The federal government has an interest in accelerating understanding of what investments should be supported by equipment reliability standards nationwide, but also to increase the reliability of the electric grid throughout New England. The U.S. Department of Energy, the U.S. Department of Homeland Security, the National Science Foundation, or other federal entities might be able to provide complementary research support for the Maine modeling effort. The Department of Defense has its own needs for reliable power, and also responsibilities to support critical infrastructure protections beyond the resources of each electric utility.

It would be important for the Maine PUC to encourage participation of Maine electric utilities in an *electric reliability demonstration program*. Two elements of this effort would be to model the impacts and cost-effectiveness of *neutral ground blocking equipment*, in parallel to what is underway in Wisconsin; and to model the options for protection of system voltage stability through demonstration of various equipments to: improve the reliability in solar storms of the Chester Maine SVC resource, or the substitution of dynamic VAR compensators that utilize ultra-fast switching equipment not available in prior decades; and alternatives, including the introduction of series capacitors, such as have been utilized in other northern hemisphere electric grids.[8]

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[6] American Transmission Co. has identified priorities for neutral ground blocking protection installations. There may be lessons from Wisconsin that could assist Maine in achieving overall reliability improvements at reasonable cost. There are also significant potential opportunities to increase generator capacity utilization, to reduce transmission congestion, to reduce VAR consumption, and to increase expected life of equipment previously degraded by repeated GIC insults.

[7] Nuclear power plants, such as Seabrook Station, depend upon other "black start" capabilities following mandatory shutdowns, as could be expected by NRC Order preceding a major solar storm. Bangor Hydro and HVDC Interties to Canadian sources of hydropower are both critically important assets for Maine and all of New England.

[8] The Report by Chris Beck, with assistance of others, for the EIS Council, submitted in this Docket on October 11, 2013 should be of particular interest to the Maine PUC because this report highlights efforts of other northern

If the Emprimus-American Transmission Co. demonstration program in Wisconsin has validity for conditions in the State of Maine, even a modest number of hardware demonstrations within Maine might play a significant protective role were a solar storm to come our way over the next several years.

Moreover, without an effort to protect the long-line transmission network from quasi-DC currents, like the E3 currents in nuclear electromagnetic pulses, it will be impractical to harden significant portions of the U.S. electric grid from man-made nuclear EMP weapons.

A PROPOSED MAINE ELECTRIC RELIABILITY INDUCED-CURRENT TRANSMISSION DEMONSTRATION PROGRAM

We would encourage the State of Maine to integrate its reliability enhancement initiatives within a **M**aine **E**lectric **R**eliability **I**nduced-Current **T**ransmission **Demonstration Program**: the **MERIT Demonstration Program.** To best-utilize expertise from throughout the United States, and from any other volunteer experts, this Demonstration Program should operate openly and transparently. To the extent deadlines allow, all modeling should be competitively bid. Draft modeling studies and reports should be publicly accessible, with opportunities for public peer review. Because actions of one electric utility can impact the operating environment of other utilities, all GIC monitoring data should be publicly released and publicly accessible, as is safety information under the auspices of the Nuclear Regulatory Commission.[9]

ENCOURAGING REGIONAL COORDINATION VIA ISO-NEW ENGLAND

What Maine would accomplish in a **MERIT Demonstration Program** would be likely to have a positive effect on electric grid reliability in the ISO New England region. This would mean, ultimately, and perhaps with some delay, cost recoveries for Maine utilities. There might also be lower overall costs for electric ratepayers throughout the region because a more reliable

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latitude nations to protect their electric grids. In Canada, Sweden, and Finland, for example, series capacitors have been installed in extra high voltage transmission systems. These systems block GIC flows, as do neutral ground blocking equipment. But the series capacitors have far higher per unit costs, and need to be assessed for their capacity to protect transmission systems during high magnitude solar storms, storms not as yet experienced.

[9] The practice of treating GIC data as proprietary, or controlled within the SURBURST program of the Electric Power Research Institute has had the effect – intentionally or otherwise – of delaying practical protection of the U.S. electric grid from adverse solar weather. Following the Hydro-Quebec blackout of 1989, GIC data has been collected since the year 1990, without apparent action to reduce vulnerabilities of higher voltage bulk power systems. The FERC effort to accelerate standard setting for geomagnetic disturbances, resulting in FERC Order No. 779, was *sua sponte*, or a self-initiated proposal of FERC following years of industry inaction.

electric grid will make better use of invested capital, and operate at higher levels of capacity utilization.

Central Maine Power has commented that Seabrook Station might be experience higher GIC if only the Maine grid were to be protected against GIC. This is doubtful and unsubstantiated. The American Transmission Co. modeling indicates greater overall regional reliability as vulnerable equipment at system edges is protected from GICs.

In any event, Seabrook Station (operated by a NextEra subsidiary) has a planned replacement of its GSU Transformer (345 kV) scheduled for Spring of 2014. Having monitored GICs at both Seabrook, New Hampshire, and Point Beach, Wisconsin, NextEra is aware of the need to upgrade transformer withstand capabilities.[10]

Coordination with ISO New England will be essential to qualify grid protective equipment for OATTS cost-recoveries.

In conclusion, the Foundation congratulates the State of Maine and its Public Utilities Commission, and its cooperating electric utilities for advancing understanding of opportunities to increase the reliability of electric grids and to serve as a model for the nation.

Respectfully submitted, by

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[10] If NextEra Nuclear does not install a neutral ground blocking device with the new GSU transformer to be shipped from Austria, there will be ongoing opportunities to retrofit such equipment as further research becomes available and as needs are reassessed.