FOUNDATION FOR RESILIENT SOCIETIES, INC.

FIRST-STAGE APPEAL TO THE DIRECTOR OF STANDARDS OF THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION (NERC) PURSUANT TO THE NERC STANDARD PROCESSES MANUAL REV. 3, SEEKING AMENDMENTS TO A NERC-PROPOSED RELIABILITY STANDARD NERC STANDARD TPL-007-1, TRANSMISSION SYSTEM PLANNED PERFORMANCE FOR GEOMAGNETIC DISTURBANCE EVENTS

Submitted on January 4, 2015
to
Valerie Agnew, Director of Standards, NERC

Foundation for Resilient Societies
52 Technology Way
Nashua NH 03060

January 4, 2015

Ms. Valerie Agnew
Director of Standards
North American Electric Reliability Corporation
3353 Peachtree Road, N.E.
Atlanta, Georgia 30326

Dear Ms. Agnew:

The following is a First Stage Appeal of the NERC-proposed Standard TPL-0071, Phase 2, relating to "Transmission System Planned Performance for Geomagnetic Disturbance Events" adopted pursuant to FERC Order No. 779.

Amendments to the proposed standard, together with responsive comments relating to November comments in prior balloting and supporting documentation, were posted on the NERC website on December 5, 2014. The proposed standard does not adequately address the risks posed by harmonic production, VAR consumption, vibration hazards, and other omissions or inactions specified below.

In accordance with the NERC Standard Processes Manual, Revision 3, adopted by the NERC Board of Trustees on June 26, 2013, the Foundation for Resilient Societies, Inc. [hereinafter "Foundation" or "Resilient Societies"] has thirty days from the date of standard changes and publication to file an Appeal or asserted errors of commission.

Per our discussion and a telephone message you left for me in December 2014, the deadline for a timely appeal for errors of commission in standard development would be January 4, 2015. You indicated, however, that because January 4th is a Sunday, the filing of an appeal on January 5, 2015 would be deemed timely-filed. Resilient Societies is filing its First Stage Appeal to you, as NERCs Director of Standards, electronically on Sunday, January 4, 2015, thereby averting any challenge that might occur were we to file on January 5th.

We note that our Appeal asserts there are a set of *inactions or omissions* in proposed Standard TPL-007-1 (Phase 2). These are:

- Failure to include in the Benchmark Model supporting Standard TPL-007-01 risks posed by harmonic production in transformers and impacts other grid critical equipment;

- Failure to include in the Benchmark Model supporting Standard TPL-007-1 methods to estimate VAR consumption, and to estimate effects of VAR requirements, or swings in VAR consumption and their effects on voltage instability, inadequacies of regional spinning reserves, separation risks, and risks of cascading outages;
- Failure to include effects of quasi-DC current injections upon *magnetostriction* and other vibrational risks to high voltage transformers, stators, and turbines, among other equipment;
- Failure to establish standards for mandatory installation and operation of *geomagnetic induced current* (GIC) monitors at sites of high voltage transformers within the Bulk Power System;
- Failure to require of NERC-registered entities or to propose that FERC require public data release of GIC monitor data now or in the future available, including crossings of critical thresholds, or more general public release of GIC data from all GIC monitors now or in the future deployed within the U.S. Bulk Power System, thereby raising concerns that the NERC-proposed standard facilitates wholesale market manipulations and antitrust violations by market traders with preferential access to non-public GIC data or GIC data networks; and
- Failure to validate the NERC Benchmark Model for geomagnetic disturbance assessments against actual historical GIC data within the United States so that as a result the NERC GMD model might discourage and serve as an effective barrier to needed hardware protection of the North American bulk power system from severe solar geomagnetic storms;
- Failure to perform cost-benefit analyses of *averted costs* of (higher) redispatch of power; reductions in need for and costs of reactive power (VAr) production during solar storms; reductions in reduced generation and transmission system income due to off-cost sales due to regional grid congestion; reduced capacity utilization rates; reduced grid outages; and reduced losses of capital equipment; and
- Failure of essential "quality control" by the Office of Standards and the Director of Standards to assure that the essential goals and mandates of FERC Order No. 779 are met by the proposed NERC Standard TPL-007-1.
- Failure of essential "quality control" by the Office of Standards and the Director of Standards by allowing Standard Drafting Team use of a modeled GIC limit of 75 amps per phase for thermal assessment of transformers when the source for this 75 amp limit is an unapproved IEEE standard still in process.
- Failure to fully address our prior comments about the above issues submitted in NERC standard-setting.

Resilient Societies asserts, per NERC's Standard Processes Manual, Revision 3 [hereafter "SPM_Rev3"] that the above asserted inactions or omissions to fulfill the obligations under the SMP_Rev3 are timely made, whenever filed. Because there is no time limit when seeking remediation of inactions to perform essential components of a reliability standard. Specifically, the NERC Standard Processes Manual explains, at Section 8.0 (Page 34): "Appeals shall be made in writing within 30 days of the date of the action purporting to cause the adverse effect, except appeals for inaction, which may be made at any time." (Process for Appealing an Action or Inaction).

Resilient Societies appreciates the opportunity to participate in the NERC-FERC standard-setting process. We have participated in NERC's Geomagnetic Task Force since the year 2012; we have filed comments with both NERC and FERC in advance of FERC Order No. 779 and in the Phase 1 and Phase 2 standard setting process. When FERC explained (July 2014) that their docket record did not show the locations of GIC monitors deployed as of the year 2014, we performed research and filed with FERC the locations of 102 GIC monitors that, if properly utilized and publicly reported, could significantly offset modeling defects in the NERC Benchmark model and would encourage deployment of hardware-protective equipment that is likely to generate net income for electric utilities operating within the bulk power system.

Our Summary Appeal explains why we are an aggrieved party; why the actions and inactions of NERC cause significant adverse effects upon the ability of our Resilient Societies to perform its mission, and upon the bulk power system and its electric customers; and why NERC quality controls have been inadequate in the development of standards to mitigate solar geomagnetic storms.

We include as Appendices to this Appeal (as part of the Appeal record) the following documents:

1. Group Comments submitted to NERC on Standard TRP-007-1 on November 21, 2014;
2. Separate Comments to NERC of the Foundation for Resilient Societies submitted on November 21, 2014;
3. Comments to NERC by John Kappenman in November 21, 2014 on the significant incompatibility and underreporting bias deriving from latitudinal scale factors causing the NERC model to under-report actual GIC impacts on the Maine electric grid by a factor of about 4X to 5X; and explaining why interpolation from data at different sites in scientifically valid and far more reliable than a NERC model that is widely incompatible with empirically measured geo-electric fields in the United States.
4. Report on GMD event modeling with specific analyses of the Maine grid, submitted by the EIS Council, based on its contracted analyses by John Kappenman, showing that the

unvalidated NERC Benchmark model is not compatible with empirical measurements from Chester, Maine; and why interpolation of data is scientifically valid and far more reliable than the NERC benchmark model that significantly under-estimates volts per kilometer geoelectric field for the Maine electric grid (found in Maine PUC Docket 2013-00415, Report of the EIS Council submitted to Maine PUC, October 4, 2013);

5. Central Maine Power Final Report to the Maine PUC, December 2014 in Maine Docket 2013-00415, demonstrating that the NERC benchmark model effectively exempts Maine electric utilities (and hence most likely will exempt electric utilities in all of the other 47 FERC-jurisdictional states of the U.S.) from alleged need for transformer protections; but contrasts this model with other criteria indicating benefits of installing various levels of GIC blocking devices;
6. Emprimus Final Report to the Maine PUC, in Docket 2013-00415, January 2, 2015, as Corrected January 5, 2015, which shows that the NERC model, when compared to the Chester, Maine time-series of GIC readings, may underestimate geoelectric fields and which shows that blocking devices at 12 locations in Maine and 4 locations in New Brunswick, Canada would significantly improve the stability and protection of the Maine and ISO-New England electric grids.

Respectfully submitted by:

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SUMMARY OF APPEAL
SUBMITTED BY THE FOUNDATION FOR RESILIENT SOCIETIES TO THE DIRECTOR OF STANDARDS
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION
WITH RESPECT TO NERC PROPOSED STANDARD TPL-007-1 (PHASE 2)

1. FOUNDATION FOR RESILIENT SOCIETIES IS AN AGGRIEVED PARTY.

The Foundation for Resilient Societies in an independent, non-profit, 501(c)(3) research and education organization, incorporated in year 2012 in the State of New Hampshire. It is composed of Board members from New Hampshire, Arizona, California, Massachusetts, South Carolina, and Virginia. The mission of the Foundation is to perform research and education in support of greater resiliency for critical infrastructures of 21st century societies. Resilient Societies commenced its organizational efforts in year 2011, and one month before the tsunami and nuclear power plant disaster at Fukushima-Daiichi, Resilient Societies organizers submitted to the Nuclear Regulatory Commission a Draft Petition to enhance on-site backup power resources at U.S. licensed nuclear power plants. This Petition was adopted for further assessment by the Nuclear Regulatory Commission in December 2012.

Directors of the Resilient Societies have expertise in the mitigation of electromagnetic pulse (EMP), specifically high altitude EMP. One of our Directors served as Chairman from year 2001 through year 2008 of the Congressionally-designated Commission on Electromagnetic Pulse. That Commission that produced several reports, some unclassified, on the hazards of man-made electromagnetic pulse events. In April 2008 that Commission produced a detailed review of the risks to critical infrastructures, and emphasized the benefits of protecting roughly 2000 extra high voltage transformers in the United States, in part because of the dependency of all other critical infrastructures on the electric grid, and in part because of the long-lead times to replace high voltage transformers if a substantial proportion of these transformers were not protected by appropriate hardware. Another of the Resilient Societies' Directors was for many years the principal standards developer for the U.S. Department of Defense to protect critical national assets, defense assets, and operating capabilities of the U.S. government from man-made electromagnetic pulse.

In FERC Order No. 779 (May 2013), the Federal Energy Regulatory Commission determined to restrict its Order to mitigate naturally occurring electromagnetic pulses also known as geomagnetic disturbances. (GMDs). The decisions of the NERC Standards Drafting Team to develop a "benchmark model" for solar geomagnetic storms, to select a benchmark event that is substantially less severe than the Carrington event of 1859 or the New York Central Railroad Storm of May 1921, and to disregard a time series of GIC records from the State of Maine has the cumulative effect of creating a standard for hardware protection assessment that may relieve all electric utilities in all of the 48 states subject to FERC jurisdiction from any duty to install any blocking device or other transformer protection hardware.

How do the NERC Standards Drafting Team assumptions, the benchmark event selections, and the disregard of empirical data on historical GMD events in the U.S. affect Resilient Societies' interests and the ability of its Board to apply the Board's expertise in advancing protection of the North American electric grid from high altitude electromagnetic pulse risks? The answer is simple: if there is no protection of the long transmission lines and associated high voltage transformers from severe GMD events, the lack of hardware protection (whether neutral ground blockers or series capacitors) will make it impossible to also protect against the so-called E3 surges that also threaten the viability of high voltage transformers during a man-made EMP event. IF NERC promulgates and FERC adopts the benchmark model for GMD mitigation, there will be no practical way for the President, or the U.S. Congress to initiate parallel protection of the electric grid from man-made EMP events. It makes no financial sense to block E1 pulses while failing to protect against concurrent E3 pulses that occur in parallel, even if they arrive milliseconds later. Hence, our Board will of necessity fail in its designated mission to enhance the resiliency of critical infrastructures in 21st century societies. So we are aggrieved by what NERC has done with its mandate under FERC Order. No. 779.

Our Resilient Societies is further aggrieved by its dependence upon the electric grid and commercial telecommunications powered by the commercial grid among Directors in six different states to perform our research and to review our proposed filings, etc. Our activities, in short, depend upon the reliability of the electric grid, which is essential to support reliable telecommunications. This reliability is threatened by a NERC proposed standard that may create liability protection for electric utilities without enabling hardware protection of long-replacement-time grid equipment. If the electric grid is to remain unprotected from severe solar GMD events, hence also from man-made EMP events, we will be unable to fulfill with reliability our mission in the future. So far, Israel, South Korea, and India have initiated programs to protect their electric grids from man-made EMP events. All of our Board members, however, reside and work in the United States, and we are aggrieved if, however

inadvertently, NERC and its Standards Drafting Team leave our nation unprotected and our Foundation unable to fulfill its purposes because of NERC's proposed Standard TPL-007-1.

2. FAILURE TO INCLUDE IN THE NERC GMD WHITEPAPERS BENCHMARKS FOR HARMONIC PRODUCTION ARISING FROM SOLAR GMD EVENTS.

See the comments of Smart Sense.Com, Inc. submitted in November 2014. We concur that understanding the extent, duration, and magnitude of harmonic productions is essential to understand thermal impacts, and reactive power impacts on grid stability, separation risks and cascading outages. See also the Emprimus Report of December 2014 to the Maine Public Utilities filed in Maine PUC Docket 2013-00415.

3. FAILURE TO PROVIDE METHODS TO ESTIMATE VAR (REACTIVE POWER) CONSUMPTION ARISING FROM SOLAR GMD EVENTS.

A March 2013 review of the Maine and ISO-New England grid under condition of solar storms (found at www.resilientsocieties.org) identified the likelihood that spinning reserve or other prompt generating reserves would be unlikely to maintain a balanced electric load in New England, absent some protective equipment. The Emprimus Report of December 2014 prepared for the Maine PUC does estimate VAR requirements under different assumptions about solar storms, the appropriate K-factor to utilize in modeling the Maine grid, etc. The failure of the NERC whitepapers to address VAR requirements could result in an underestimation of grid instability risk. Further, the absence of financial analysis in the NERC modeling effort has the effect of concealing the significant financial benefits that result from significantly reducing VAR consumption as a result of selective installation of blocking devices that reduce VAR demand.

4. FAILURE TO INCLUDE MAGNETOSTRICTION AND OTHER VIBRATIONAL RISKS TO OPERABILITY OF TRANSFORMERS, STATORS, TURBINES AND OTHER GRID EQUIPMENT.

In December 2011 to January 2012 Resilient Societies compared databases of transformer outages or fires to databases of solar geomagnetic storms in North America. This resulted in a more intense review of the concurrency of (1) a solar geomagnetic storm that occurred in North America on November 8-9, 1998, and (2) the melting and loss of the Phase A (115 kV) unit of the 345 kV transformer at Seabrook Station on November 10, 1998. Resilient Societies filed a Report of what happened at Seabrook Station in November 1998, to the NERC GMD Task Force in January 2012. Without any GIC monitoring, nor awareness of the mechanisms by which magnetostriction during GMD events can cause vibration-related equipment damage, the

Public Service of N.H. engineers at Seabrook station initially concluded that a 4 inch stainless steel bolt had randomly lo0osened, dropped into the low voltage Phase A GSU transformer winding, and caused a 12.2 day outage of Seabrook Station. Because as of January 2012, Seabrook station had not yet installed GIC monitoring equipment, that was the initial assessment of NextEra Nuclear engineering staff in January 2012. They reviewed with Mr. Harris the actual language of the November 1998 event records, which indicated the root cause of the outage was a deformed stainless steel bolt. But this was most unlikely. The 3-phase GE transformer, manufactured in 1981, and installed in 1986, had operated at full power since August 1990. Why in roughly 3000 days of operation did not the stainless steel bolt cause overheating and melting of the low voltage (24.5 kV) end of the Phase A transformer? Why did the defective stainless steel bolt shake loose, or relocate into the low voltage winding, and cause severe overheating on November 10, 1998.

The overtaking of a north-to-south GMD event of November 8, 1998 by a south-to-north GMD reversal caused a "sudden impulse " GMD event on November 9, 1998. Merely because engineers who could not observe an invisible GMD event did understand it does not mean it did not happen. While the "root cause" of the outage at Seabrook Station was a defective stainless steel bolt, the *proximate cause* of the 12.2 day transformer outage, power redispatch, and replacement of the Phase A transformer, etc. was a cannibalizing solar storm of November 8-9, 1998. The averted costs, had there been a neutral ground blocker in place, would have more than paid to install GIC blockers at all of ISO-New England's high voltage GSU transformers. The NERC Task Force has improperly omitted *magnetostriction* and other vibrational hazards from its benchmark modeling. Why?

If vibrational hazards are to be addressed, it is more likely than not that neutral ground blockers are the least-cost solution. They cost less than most series capacitors. Studies at Idaho National Laboratory in 2012-2013, and testing observed by members of the GMD Task Force, demonstrated that relatively low harmonic productions into a 138 kV transmission system caused severe vibration and associated noise. When a neutral ground blocker was activated, the vibration and nose disappeared. These experiments are reported in publications from INL and SARA in year 2013. Wishing away a hazard to transformer resiliency is not enough. The NERC GMD Task Force needs to amend its model to include vibrational risks, and report on the lowest cost solutions, such as neutral ground blockers.

Is it unusual that engineers at Seabrook Station would rather not accept that a GMD event was the cause of a multi-million dollar outage in November 1998? Not at all. In January 2012, an engineer at Seabrook Station proposed that GMD could not have been the cause of the transformer damage, because GMD would enter through the high voltage end of the

transformer, but the melting was at the low voltage end of the transformer. This was an argument worth exploring. A check with John Kappenman in Duluth, Minnesota, a national expert on transformer vulnerabilities, resulted in re-examination of photos of the Salem 1 transformer loss during the Hydro-Quebec solar storm of March 13, 1989. The GICs had entered through the high voltage end of the GSU transformer, but had migrated to the low voltage windings, which had melted to destruction. So we have an expensive example of why psychological resistance to empirical evidence of transformer damage needs re-examination, whether at specific sites of transformer damage or by the Standard Drafting Team and the Director of Standards at NERC.

The Standard drafting Team needs to consider the findings of C. J. Schriejver and S. D. Mitchell, "Disturbances in the US electric grid associated with geomagnetic activity," J. Space Weather Space Clim. 3 (2013), A 19. This article highlights a combined NERC and Department of Energy database from the period 1992 through year 2010. About 4 percent of electric grid disturbances are attributed entirely or partially to severe space weather. Yet at the time, most of these events are otherwise attributed – as happened at Seabrook Station in November 1998. The odds ratio that an event among the 4 percent of outages associated with space geomagnetic weather are attributable to solar GMD events entirely or partially rather than to random outages is a ratio of 32 to 1.

The Standard Drafting Team and the Director of Standards at NERC should insist upon inclusion of vibrational hazards as a significant cause of loss or significant damage to transformers and other grid equipment. This change would increase understanding that vibrational hazards require remediation; and that the same equipment that protects against thermal stress also protects against vibrational risks. This improved modeling would be likely to accelerate voluntary commitments to deploy neutral ground blocking equipment.[1] The arbitrary exclusion

[1] The Interim GMD Task Force Report of February 2012 did note that, due to GMD events, there could be "increased mechanical vibrations and torsional stress [within generators] due to increased negative sequence currents." (GMD Task Force Report, Feb 2012, at p. 58). See also Marius Cloutier and Mark Houghton, "Case Studies of Fiber Optic Accelerometer Used for End-winding Vibration Monitoring on Turbo-Generators," CIGRE SC A1 & EPFL Colloquium on Large electrical Machines, Lausanne, 7 Sep 2005; Mike Hoffer and Andrew Tesla, "Stator Bar Vibration Sensors and Fiber-Optic accelerometers," EPRI03 (2003); Jackson Lin, "Applying Stator End-Winding Monitoring Technology at JH Campbell Generation Plant," Conf, San Antonio, Texas, June 2002; Yuxing Wang and Ming Jin, "Finite Element Modelling of the Vibration of a Power Transformer," Proc. Acoustics, 2-4 Nov 2011; B. Garcia, et al, "Transformer tank vibration modeling as a method of detecting winding deformations, Part I," IEEE Trans. Power Del. 2006, v. 21:157-163. Overheating in bolts, such as the stainless steel bolt that dislodged at Seabrook Station in 1998, can result from GMD-induced vibrations or other vibrations. See J. Turowski, "Overheating hazard in flanged bolts of transformers," Proc. ISEF, 1985: 271-274, and Juan Carolos Olivares-Galvan, et al., "Reduction of Stray Losses in Flange-Bolt Regions of Large Power Transformer Tanks," IEEE Trans. Industrial Elec. V. 61: 44554463 (Aug. 2014). Some utilities that have upgraded their GIC monitoring capabilities already utilize sensors for "tank wall vibration" of high voltage transformers. See Richard A. Becker of Bonneville Power Administration, "GMD/GIC Activities," presented at NERC GMD Task Force meeting, July 25, 2013,

of vibrational hazards from the GMD Benchmark Model causes inappropriate dismissal of the value of blocking equipment; and allows transmission operators to avoid even assessment of GMD hazards, at generating sites and transmission systems that have experienced loss of transformers due to vibrational hazards, some the result of moderate level solar GMD events.

5. FAILURE TO ESTABLISH RELIABILITY STANDARDS FOR MANDATORY INSTALLATION AND OPERATION OF GEOMAGNETIC INDUCED CURRENT (GIC) MONITORS.

The FERC Commissioners in FERC Order No. 779 (May 2013) asked NERC to consider deployment of GIC monitors as part of the mitigation process for solar GMD events. It is a failure of quality control for the Director of Standards at NERC to fail to require consideration of this option. As the "Additional Facts" filing of Resilient Societies demonstrated in August 2014 [See FERC Order No. 779-A], there are at least 102 deployed GIC monitors in the United States, generally attached to the neutral of high voltage transformers. The locations of these GIC monitors appear to correlate to above average risks of equipment damage during or following GMD events. The costs of harnessing these GIC monitors to improve the NERC Benchmark model, and to improve the utility of operating procedures, and to aid utilities in decision-making relating to hardware protection equipment, are modest.

Estimating the total of high voltage transformers in the U.S. Bulk Power system at 2100 to 2300 systems, and using the Central Maine Power cost-estimate for purchase and installation of GIC monitoring units ($36,000 per unit),[2] the costs to instrument all high voltage transformers in the U.S. would be in the range of just $75 million to $83 million dollars. Taking into account the text of FERC Order 779 on GIC monitoring, it is a failure of quality control for the Director of Standards at NERC to avert consideration of reliability standards for GIC monitors, and the cost-benefit review of timely assessment and opportunity for pre-disaster mitigation, through use of GIC monitors. Further, commercial neutral blocking devices come equipped with GIC monitors as a standard component. Standards and benefits of GIC monitors should have been and need to be addressed.

6. FAILURE TO REQUIRE PUBLIC RELEASE OF GIC MONITOR LEVELS, OR DESIGNATED GIC WARNING THRESHOLD LEVELS, SO AS TO PRECLUDE MARKET MANIPULATION AND

"Transformer Monitoring," Slide 3 of presentation. A series of studies of vibrational hazards to transformers in the high voltage (500 kV) Chinese transmission network are addressed in: Liu, Li, and Pirjola, "Analysis of Increases of noise of 500 kV transformers," (n Chinese), High Voltage Engr. 31(4): 85-87 (2005); Liu, C.M., Liu, L.-G., and R. Pirjola, "Geomagnetically induced currents in the high voltage power grid in China," IEEE Trans. Power Delivery 24(4): 2308-2374 (2009); and Liu, Li, and Pirjola, "Observations and modeling of GIC in the Chinese large-scale high-voltage power networks," J. Space Weather Space Clim. 4 (2014), Paper A03.

[2] Central Maine Power, Final Report to the Maine PUC, December 2014, for cost estimates of GIC Monitors purchased and installed.

POTENTIAL ANTITRUST VIOLATIONS RESULTING FROM NERC RELIABILITY STANDARD-SETTING.

Presently, there are at least 102 active GIC monitoring units deployed in the U.S. electric grid. With some exceptions,[3] the 16 Reliability Coordinators do not operate GIC monitors, and their current access to GIC data is on a voluntary basis from entities that do operate GIC monitors.

Those who are allowed to participate in the EPRI-sponsored SUNBURST network have access to the entire network's GIC data. Those who are not owners or operators of GIC monitors, and those who do not have access to GIC network data are disadvantaged in the wholesale auction bidding for same day and day ahead electric auctions.

Does the NERC coordinated process for creating reliability standards inadvertently or intentionally favor certain large generator owner-operators and certain SUNBURST network participants over others in electric markets that are intended to be nondiscriminatory, just, and in the public interest? If so, this NERC Rulemaking process is a candidate for the opening of an antitrust investigation by the Antitrust Division of the U.S. Department of Justice.

Resilient Societies respectfully proposes that the NERC Director of Standards re-evaluate the consequences for fair and competitive electric markets if: generator operators need not participate in mitigation of GMD hazards, per the Phase 1 standard-setting; and generator operators and owners need not share their own GIC data with others; and if wholesale electric market participants who are not members of the SUNBURST GMD monitoring network or other electric market traders are disadvantaged by being excluded from the "GIC monitoring club" as it might be named.

In the now defunct Enron operations selling power into the CAISO market, it was a common practice to withhold electric generation, or to accelerate grid congestion; or to offer day-ahead electric power, and then be paid for withdrawing the contractual right of delivery. More recently, some participants in electric markets have made offers of power at negative prices, and then have been paid for not delivering unneeded power the following day.
At almost every meeting, NERC posts reminders about potential antitrust practices that should not be undertaken. But has NERC, perhaps unintentionally, creates a market of "haves" and "have nots" when it comes to the utilization of U.S. taxpayer-funded space warnings of potential or actual GMD events that might disrupt market activities within the bulk power system? The "haves" are able to combine the NOAA issued space weather warnings with

[3] For example, PJM Interconnection LLC operates a GIC monitor.

knowledge of GIC conditions at a wide range of power grids. The "have nots" only have access to the NOAA space weather warnings.

NERC has a duty to conduct its electric reliability standard-setting so as not to exacerbate disparities of knowledge, and disparities of trading opportunities in wholesale electric markets. Without a remedy proposed by NERC when it submits its GMD reliability standard to FERC, NERC can fairly be accused of favoring some wholesale market participants above the others, causing discriminatory, unjust, and unfair opportunities in wholesale electric markets.

Back in June 1999, the Assistant U.S. Attorney heading the Antitrust Division of the U.S. Department of Justice, Joel I. Klein, gave the Western Systems Coordinating Council (WSCC) limited and conditional approval to proceed with reliability standard setting as allowable under the antitrust laws of the United States.[4] The proposed reliability standards did not, at that time, "appear to raise significant risks to competition."

NERC 's Director of Standards, in consultation with appropriate legal staff, should consider the benefits to marketplace competition on a level playing field if GIC monitoring data is to be ordered to be shared with all market participants and with the public.[5] Otherwise, NERC risks antitrust review of what appears on its face to be an anticompetitive practice, in designing GMD operating procedures and hardware protection assessments that expand inequality of access to significant electric market factors in day ahead markets, and perhaps other markets, if GIC monitoring data is to be shared with the "haves" and withheld from the "have nots."

7. FAILURE TO VALIDATE THE NERC BENCHMARK MODEL FOR GEOMAGNETIC DISTURBANCE ASSESSMENTS AGAINST ACTUAL HISTORIC GIC DATA WITHIN THE U.S.

The NERC Standards Drafting Team cited three sets of published articles in response to our Group Concerns that the NERC benchmark model was essentially defective and unreliable because NERC made no effort to validate the findings by comparison with historic time series of data for GIC monitoring and transformer performance in the United States.

We ask the Director of Standards to mandate a comparison of how the NERC GMD Benchmark standard compares with actual historical data from the United States, on geo-electric fields and

[4] See U.S. Department of Justice, Justice Department Approves Procedures to Establish and enforce Electric Power Reliability Standards," Jun 19, 1999, available at http://www.justice.gov/atr/public/press_releases/1999/2497.htm

[5] It is notable that the Bonneville Power administration has placed GIC monitoring data for multiple GIC monitors on its website, where anyone can view the last four days of data. We commend BPA for their transparency in this regard.

claims of diminished GIC effects – by as much as an order of magnitude – below some unsubstantiated threshold.

We objected to the use of a model of the electric grid for Finland and associated Baltic States as the basis for modeling risks and benefits of hardware protective equipment for the United States and Canada. Nonetheless, the NERC Standards Drafting Team cites as their pillar of reliability the multi-authored assessment by Pulkkinen, Bernabeu, Eichner, Beggan, and Thomson, "Generation of 100-year geomagnetically induced current scenarios," Space Weather, 10, S04003 (2012). The foundation for this model is the Finnish electric grid, where major urban centers of electric demand are in the 60˚ to 62˚ latitude range. At that latitude, there appears to be comparability between geoelectric fields in Finland and geoelectric fields in Canada.

However, as John Kappenman demonstrates, the quick fall-off of geoelectric field strength below the southern regions of Finland is not replicated when observing actual GIC readings and when interpolating geoelectric fields in the 40˚ to 45˚ latitude regions of the northern United States. See the Kappenman & Rasdasky (July 2014) and Kappenman-Birnbach (Nov. 2014) submissions to the GMD Task Force. See also the submission of the EIS Council to the State of Maine on October 4, 2013.[6]

The Kappenman analysis takes a specific GMD event from year 1998 and compares the actual GIC readings in Maine with the model derived from the Pulkkinen, et al. geo-electric field for the latitude of Chester, Maine. More recently, in December 2014, both Central Maine Power and Emprimus completed assessments of vulnerabilities and protection options for the Maine electric grid, pursuant to a state law that took effect in June 2013. These assessments are also filed, and with revisions to be filed in Maine Docket 2013-00415.

Both of the Maine study sponsors were asked to validate their models of GMD effects by using actual State of Maine historical data. It is our understanding that roughly one decade of GMD data from the early phases of EPRI's SUNBURST modeling effort were lost as a result of computer crashes without data backup.[7] Hence, it is our understanding that the Chester, Maine time series of GIC data, and the "tripping" of the Chester Static VAR compensator during just moderate solar storms, is the longest continuous time series of GIC available for any location within the United States.

[6] This paper, prepared by John Kappenman of Storm Analysis Consultants, for the EIS Council under contract, was submitted to and is an on-line retrievable document filed in Maine PUC Docket 2013-00415, with the filing date being October 4, 2013.

[7] We have been so advised, but find no acknowledgment of historic data losses posted on the SUNBURST website.

Central Maine Power, though requested by members of the Maine legislature to compare their use of the NERC GMD Benchmark model with real Maine GIC data, did not make that comparison before filing their report in December 2014.

Emprimus, also asked to compare their model of GMD hazards and criteria for installation of protective equipment, did make those comparisons. The Emprimus assessment of November 12, 2014, as updated in December 2014, determined that the GIC data for Chester, Maine may be higher than the NERC GMD model used by Central Maine Power would project.
A modeling error could have disastrous impacts on the survivability of long-replacement-time equipment needed to operate the U.S. electric grid.

The CMP utilization of the NERC Benchmark model projected just 4.53 volts per kilometer geoelectric field in Maine. Relying on the NERC model, it is likely that no utility in the State of Maine would be required to install any hardware protection equipment, including neutral ground blocking devices.

Because the Emprimus utilization of PowerWorld modeling produces results that would encourage installation of neutral ground blocking devices, the risks of grid collapse are not significantly increased even if their model under-predicts GIC intensity. This is because neutral ground blockers will keep harmonics resulting from geomagnetic induced currents out of high voltage transformers, and will protect against overheating and vibration, even if the actual GICs are higher than forecast.

In contrast, the NERC Model, adopted by Central Maine Power for their baseline assessment, will fail disastrously if the actual GICs are higher than the NERC model would predict.

We refer the NERC Director of Standards to the following assessments, all of which tend to invalidate the NERC benchmark model as a prudent basis for solar storm mitigation: the Kappenman-Radasky White Paper of July 2014; the Kappenman-Birnbach White Paper of November 2014; the EIS Council analysis of the NERC geoelectric field biases when applied to North America and not Finland and Baltic states, filed in Maine on October 4, 2013; and the two December 2014 assessments submitted to the Maine Public Utilities Commission (CMP and Emprimus), retrievable online from Maine PUC Docket 2013-00415.

Another paper cited by the NERC Standards Drafting Team is that by Ngwira, Pulkkinen, Wilder and Crowley, “Extended Study of Extreme Geoelectric Field Scenarios for Geomagnetically Induced Current Applications,” Space Weather v. 11:121-131 (2013). Relying upon the DST

network, with its equatorial weighting and risk of under-reporting of more northerly-centered solar storms, this study concedes it may be in error by an order of magnitude. The December 2014 Emprimus analysis of how the NERC GMD Benchmark model stacks up when applied to the Maine electric grid suggests that the NERC GMD benchmark model underreports actual GIC data, such as the mean of GICs experienced at Chester Maine.

A third reference cited by the NERC Standards Drafting Team does utilize 28 European observatories to assess historical, and one in 100 year and one in 200 year solar weather hazards. Once again, this is a model for *Western Europe* and not for *North America.* Even if this modeling effort is accurate for Europe, there is no prudent basis for its application to the geoelectric fields of the United States. Especially when other modes correlate better with the actual data.

Moreover, the meltdown of a transformer in southern New Jersey (at the Salem Unit 1 powerplant) during a modest solar storm centered in Canada, on March 13, 1989 provides a case study of why assumptions about rapidly declining geoelectric fields by latitude in the mid-Atlantic region are dangerous and imprudent, and not appropriate to fulfill the FERC mandates in Order No. 779. If the geoelectric field declines by roughly an order of magnitude, why did the Salem 1 GSU transformer windings melt in March 1989?

Hence, we request that the Director of Standards compare the modeled geoelectric currents in the NERC model to the historical data for Maine, and for historical data in the as yet publicly undisclosed SUNBURST database.

Finally, we note that the NERC Standard Drafting Team objects to the interpolation, using geomagnetic intensity from different observatories, and interpolating and estimating field strength of geomagnetic storms based on geospatial relationships is suspect.

We suspect that the NERC Standards Drafting Team objects to interpolation – widely used in many solar weather and grid assessments over decades – primarily because the NERC benchmark model fits so poorly with historically-recorded geomagnetic induced current data.

We cite, and request that the Director of Standards at NERC review a peer-reviewed paper that analyzes the value and limits of interpolation to estimate geoelectric fields at the surface of the earth. This paper is: Lisa H. Wei, Nicole Homeier, and Jennifer L. Gannon, "Surface electric fields for North America during historical geomagnetic storms," Space Weather 11: 452-462 (2013). The lead author utilized this modeling effort in conjunction with a Lloyd's of London assessment of claims for electrical equipment and other insurance losses; and Ms. Gannon is an

experienced scientist at the USGS facility in Boulder, Colorado. There is a sound basis for interpolation.

To paraphrase John Kappenman, in his analysis of NERC geoelectric field bias submitted by the EIS Council to the State of Maine (October 4, 2013), studies that *interpolate* using real historical data are more reliable than models whose sponsors *refuse to compare their model to the historic time series of data for the region for which they propose reliability standards.*

We ask the NERC Director of Standards to compare the modeling projections for the United States with the time series of actual data for the United States. Otherwise, the NERC model may merely provide liability protection while leaving the U.S. electric grid entirely unprotected from severe solar geomagnetic storms. This outcome would defeat the purposes of FERC Order No. 779. The quality control required by the NERC Standard Processes Manual requires a higher standard of care.

8. FAILURE IN QUALITY CONTROL AND FAILURE TO CONSIDER TECHNICAL OBJECTIONS IN OUR COMMENTS TO A MODELED GIC LIMIT OF 75 AMPS PER PHASE FOR EXEMPTION OF TRANSFORMERS FROM THERMAL IMPACT ASSESSMENT

In our comments in NERC standard-setting, we commented:

> The most recent version of the "Screening Criterion for Transformer Thermal Impact Assessment"[8] whitepaper uses measurements from limited tests of only three transformers to develop a model that purports to show all transformers could be exempt from the thermal impact assessment requirement. It is scientifically fallacious to extrapolate limited test results of idiosyncratic transformer designs to an installed base of transformers containing hundreds of diverse designs.

The Standard Drafting Team did not appropriately respond to our comment and did not present technical evidence that a 75 amp limit is supported, other than to reference a standard-setting at IEEE that is still in process.

9. FAILURE TO PERFORM COST-BENEFIT ANALYSIS OF GRID PROTECTION OPTIONS

[8] "Screening Criterion for Transformer Thermal Impact Assessment," NERC Standard Drafting Team (October 2014) available at http://www.nerc.com/pa/Stand/Project201303GeomagneticDisturbanceMitigation/GMD_Thermal_screening_Oct27_clean.pdf.

FERC Order No. 779 encouraged cost-benefit analysis of grid protection measures. The NERC Standards Drafting Team, by failing to itemize the categories of cost and cost-avoidance through mitigation measures, has the effect of discouraging investments in grid protection. This runs contrary to the purpose of FERC Order No. 779, which was to protect the electric grid from severe solar weather. It was not to provide a shield from liability without providing any practical protection for operation and recovery of the electric grid during and after severe solar storms.

We ask the NERC Director of Standards to review the two recently filed Reports to the Maine PUC, the December 2014 Report by Central Maine Power, and the December 2014 revised Emprimus Report, also to the Maine PUC. Both of these reports provide options for protection of electric transmission and transformer equipment.[9] We request that the NERC Director of Standards utilize these reports to identify mitigation options, and to compare costs of alternative or complementary mitigation options.

IN CONCLUSION:

The Foundation for Resilient Societies asks the Director of Standards at NERC to review the NERC proposed standards to mitigation solar geomagnetic disturbances, to correct deficiencies that we have cited or enumerated, and to better reconcile the NERC proposed standard TPL-007-1 with the purposes and requirements of FERC Order No. 779.

Respectfully submitted by:

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[9] Resilient Societies wishes to thank Justin Michlig of Central Maine Power for identifying in his December 2014 Report some grid protective options that have not been widely discussed within the NERC GMD Task Force.