UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

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

COMMENTS OF THE FOUNDATION FOR RESILIENT SOCIETIES

Submitted to FERC on December 24, 2012

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

The Foundation for Resilient Societies (or "Foundation") is incorporated in the State of New Hampshire as a non-profit organization engaged in research and education that relates to protecting technologically-advanced societies from natural disasters or breakdowns in human reliability. Its Board of Directors consists of persons residing in New Hampshire, Arizona, California, Massachusetts, and Virginia. Information about the Foundation may be found at www.resilientsocieties.org.

The Foundation seeks to identify and promote cost-effective protection of technologically-advanced societies from infrequently occurring natural and man-made disasters. All technologically-advanced societies rely on critical infrastructures—electric power generation and transmission, telecommunications, transportation, financial services, petrochemical refining, food production, water, and sanitation, to name just a few. Sustained

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

interruption of any one of these critical infrastructures can result in economic, political, and social chaos. The profit incentive, which normally serves society well, provides inadequate protection from disasters which occur infrequently but have high impact and far-reaching impact beyond the responsibilities of any one commercial enterprise. The Foundation seeks to identify these cost-effective opportunities to protect societies and then identify policy initiatives to mitigate or to accelerate recovery from these natural or man-made disasters.

BACKGROUND (I) INITIAL RESEARCH PROJECT OF THE FOUNDATION

The Foundation for Resilient Societies supports the proactive stance of the Federal Energy Regulatory Commission (FERC) Commissioners in proposing to order reliability standards to protect against geomagnetic disturbances. Our Foundation respectfully summarizes its prior Petition for Rulemaking by the Nuclear Regulatory Commission, and recent NRC decision (December 3rd, published December 18th) to proceed to consideration of rulemaking based in part upon our Petition to augment on-site capabilities of NRC-licensed nuclear power plants.

As we have learned of the limited jurisdiction of the Nuclear Regulatory Commission, we have come to recognize that rulemaking by FERC, whose Commissioners have jurisdiction over the entire bulk power system,[2] can significantly enhance the robustness of nuclear power plants, other power plants, and the nation's ability to recover from a severe solar geomagnetic storm. If the proportion of generating facilities and transmission systems that remain operable can be increased through reliability standards to cope with geomagnetic disturbances, operators within the grid seeking reliable "blackstart" of power plants, and seeking to minimize dependence upon on-site facilities to cool radioactive spent fuel, and residents within evacuation zones around nuclear power plants will all have more options and be better protected. This in turn will alleviate elements of the burden otherwise befalling the Nuclear Regulatory Commission.

On March 14, 2011 the Foundation for Resilient Societies filed a Petition for Rulemaking (PRM) to the Nuclear Regulatory Commission ("NRC") proposing that it amend its regulations to

[2] Excepting Hawaii, Alaska, and other intrastate systems.

require that U.S. reactors would have backup spent fuel pool systems capable of operating automatically for two years without fuel resupply. The Petition suggested that an extreme solar storm and associated GMD could cause long-term and widespread commercial grid outage, including Loss Of Outside Power ("LOOP") to nuclear power plants. A draft filing of the petition had been previously made to the NRC on February 8, 2011, a full two months before the tsunami and related Fukushima nuclear disaster in Japan. The NRC docketed the Petition as PRM-50-96.

On December 3, 2012, the NRC determined that "its rulemaking process can appropriately consider a petition on maintaining the safety of used nuclear fuel at U.S. reactors if an extreme solar flare disables the electrical grid."[3] Moreover, in written analysis accompanying its determination, the NRC stated that:

> The NRC's initial evaluation of available information indicates that the likelihood of an extreme solar storm (similar to the 1859 Carrington event 1) is plausible with a frequency in the range of once in 153 to once in 500 years (2E–3 to 6.5E–3 per year). The probability of the petitioner's postulated catastrophic grid failure, given a Carrington-like event, is not known with certainty. However, based on the NRC's review of the existing data, the NRC believes that there is insufficient information for the NRC to conclude that the overall frequency of a series of events potentially leading to core damage at multiple nuclear sites is acceptably low such that no regulatory action is needed. Thus, the NRC concludes that the petitioner's scenario is sufficiently credible to require consideration of emergency planning and response capabilities under such circumstances. Accordingly, the NRC intends to further evaluate the petitioner's concerns in the NRC rulemaking process.

The Foundation for Resilient Societies previously filed a comment in regards to the FERC Staff Technical Conference on Geomagnetic Disturbances to the Bulk-Power System, FERC Docket AD12-13-000. Representatives of the Foundation for Resilient Societies have been active observers of the Geomagnetic Disturbance Task Force (GMD Task Force) and have attended multiple face-to-face meetings at the NERC headquarters in Atlanta, Georgia. Dr. George Baker, a director of the Foundation, recently assisted in the development of event scenarios for the December 13, 2012 NARUC Interactive Lab for Catastrophic Event Resilience

[3] 77 Federal Register 74788-74798 (December 18, 2012), reproduced as Appendix 1 to these Comments.

funded by the U.S. Department of Homeland Security and participated in the lab. Comments submitted to FERC under Docket RM12-22-000 reflect knowledge and perspective gained during the GMD Task Force process, as well as prior research performed in preparation of a Petition PRM-50-96, to the Nuclear Regulatory Commission.

BACKGROUND (II) INTERNATIONAL SECURITY IMPLICATIONS OF FERC COMMISSION CHOICES

The Commission's development of an accelerated timetable for North American Electric Reliability Corporation standards can have an historically significant impact – reversing a long term trend towards increased vulnerability to solar geomagnetic storms. These increased vulnerabilities are, we must assume, inadvertent. Factors include: the deployment of longer transmission lines of higher voltages, hence lower resistance to GMDs and more efficient transfers of GICs in extra high voltage systems; the urbanization and suburbanization of the population of the United States, resulting in greater concentrations of population centers proximate to coastal water bodies, thence increased generation facilities proximate to coastal locations and end-of-line augmented GMD risks; the de-regulation of wholesale energy markets, resulting in higher proportions of long distance dispatch, and greater transmission congestion, aggravating risks of system instability during solar storms.

We concur with John Kappenman, a pioneer of solar geomagnetic research, that the proposed FERC Order proposed in Docket RM12-22-000 is historic in establishing a foundation for a *more* reliable electric grid despite historic trends to the contrary.[4]

We ask the Commissioners to consider, as FERC assesses the scope of its proposed or redrafted Order, both the international context and international security benefits of standards that protect against GMD hazards from all sources. FERC Commissioners and Staff will consider both the issuance of an Order to develop GMD standards, and the responses that are appropriate following any NERC-proposed standards within the context of two significant international developments:

[4] See the introductory sections of Mr. Kappenman's Comments in this docket.

The first of these developments involves yet another round of nuclear weapons development and potential proliferation. The longer that the bulk power system of North America remains vulnerable to man-made electromagnetic pulse, the greater will be the attractiveness of EMP-enhanced weapons for some foreign states that seek leverage from nuclear weapons capabilities, especially weapons capable of inflicting wide-area geomagnetic disturbances (E3 effects) and related prompt voltage surges (E1 effects).

The Draft FERC Order in this Docket has the potential to develop both standards for geomagnetic disturbance hazards and remedies for such hazards that provide a "twofer": protection against solar geomagnetic storms, and, via the same equipment that protects against solar GICs, concurrent protection against the man-made electromagnetic pulses. The government of the United States, together with the government of the Russian Federation, both retains extensive knowledge and hardware-protective experience to cope with man-made electromagnetic pulses. Via a FERC Order and supportive responses from NERC and centers of expertise within the U.S. government and government-contracting laboratories, the United States' public and private sectors can demonstrate to owners and regulators of the other major electric grids of the world that there are cost-effective measures that significantly reduce vulnerabilities to both naturally occurring and man-made geomagnetic disturbances. These solutions can be a model for all the electric grids globally.

The primary need in protecting against man-made electromagnetic pulses is for protection against the long-line hazards to transformers and other critical grid equipment. This is the more expensive equipment that is required for E3 protection.[5] So the same automated hardware protection that blocks GICs from solar storms will also block GICs from man-made

[5] A well-established protection against E1 pulses, which rise in nanoseconds, is a set of varistors (variable resistors) that must be located as close as possible to the equipment requiring protection. Protecting a transformer against E1 surges is substantially less expensive than protecting a transformer from E3 GICs using neutral grounding equipment. Metal oxide varistors (MOVs) are widely utilized in the electric industry as surge protectors against damage during lightning storms. E1 levels derived from high altitude EMP explosions will generally require specialized varistors to protect against higher voltage surges. The relevant varistors are often of the size and shape of a hockey puck, and can be stacked like a stack of hockey pucks, with parallel circuitry. Spare inventories of varistors are needed to replace those that may be damaged during high voltage surges. For some high amplitude and short rise time E1 pulses, varistors may not provide adequate protection; an alternative and more recently developed technology uses power electron tubes which can absorb multiple E1 pulses without replacement.

EMP that can disrupt electric grids over long distances. The secondary need for augmented surge protection equipment is addressed in specific comments that follow.[6]

If the United States takes the lead in protecting its bulk power system against solar geomagnetic storms, with standards that concurrently protect against man-made GICs resulting from nuclear weapons, as well as specially-designed EMP weapons,[7] the incentive to threaten use or actually use nuclear weapons can be significantly reduced worldwide. International cooperation to protect the major electric systems worldwide can help the United States achieve President Obama's declared goal of eliminating nuclear weapons. This has been a goal of all U.S. Administrations since the Baruch Plan under President Truman.

The second of these significant international developments is the potential re-transmission by the President of the United States of the Comprehensive Test Ban Treaty (CTBT) for Senate advice and consent to ratification.[8]

Historically, arms control treaties have achieved higher rates of treaty compliance when accompanied by self-help measures to reduce benefits of noncompliance. FERC Commissioners may wish to consider the precedent set by President Kennedy in supporting a federally legislated and funded Safeguards Program to reduce risks of ratification of a Limited Test Ban Treaty (LTBT) in 1963.[9] The Atomic Energy Commission committed to retain the readiness of its laboratories for a resumption of nuclear testing, if needed, and facilities at U.S. missile test ranges were retained in a high state of preparedness for many years.

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[6] See Section 13 of these Comments.

[7] These GICs are likely to be of higher magnitude than all but the most severe solar GMD storms.

[8] President Clinton initially transmitted the CTBT to the Senate for advice and consent to ratification on September 22, 1997. On January 27, 1998 four former Chairmen of the Joint Chiefs of Staff endorsed treaty ratification conditional upon adoption of six "Safeguard Program" conditions proposed by President Clinton in 1995. At this writing it is uncertain whether President Obama will propose Senate ratification of the CTBT in his January 2013 State of the Union address or at a later date. This policy initiative is likely to be under Senate consideration in calendar year 2013.

[9] The Joint Chiefs of Staff formally adopted a Safeguards Program, and the Congress enacted implementing legislation in 1963-1964. Key policy documents have been declassified and are available at the John F. Kennedy Presidential Library.

Will U.S. Senate consideration of a Comprehensive Test Ban Treaty result in a comparable Safeguards Program that would, as one of its pillars, provide a legislative framework and partial funding to accelerate the hardening of the U.S. electric grid from man-made EMP weapons? Treaty ratification requires a two-thirds vote in the Senate, so there are incentives to achieve a bipartisan solution. If FERC Commissioners have concerns that neither their staff nor NERC has expertise to assure cost-effective E1 protections, they may later identify opportunities through a Treaty Safeguards Program for the Departments of Defense and Energy to provide that support, research, and independent testing, while FERC and NERC together develop standards for E3 protections against geomagnetic disturbances from all sources.[10]

If nuclear weapons are to become truly obsolete, protecting the electric grids of all nations from vulnerability to geomagnetic disturbances must be a building block towards this goal. Hence, as the FERC Commissioners and Staff consider the specific scope of their proposed Order in Docket RM12-22-000, please do not lose sight of the potential benefits for international security if U.S. regulatory policies reduce vulnerabilities to geomagnetic storms of every source – both solar storms and man-made geomagnetic disturbances.

[10] A member of our Foundation Board, George Baker, formerly headed the EMP research and standard-setting group within the Defense Nuclear Agency. Dr. Baker has submitted a Letter, which comprises Appendix 2 of our Comments. His Dupont Summit viewgraphs of December 2012 refute key misconceptions about EMP. These viewgraphs are included as Appendix 3 of our Comments. The text of Dr. Baker's December 2012 presentation before InfraGuard is included in the separate Comments filed in this Docket by Charles L. Manto at pages 33-40 of his filing. Dr. Baker includes a table showing that Varistors (variable resistors) used as surge protectors did prevent equipment damage in certain tests. However, varistors for lightning protection are not generally adequate to cope with many nuclear EMP E1 surges. We consider these issues in Section 13 below.

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1. Model FERC Order on Geomagnetic Disturbance

The FERC Notice of Proposed Rulemaking (NOPR) presents an excellent draft for a FERC Order for reliability standards for geomagnetic disturbances. We propose that the wording of the FERC NOPR might be improved and present a modified version below. Our reasoning for specific retentions and insertions is footnoted and follows in the remainder of this comment.

141 FERC ¶ 61,045

UNITED STATES OF AMERICA

FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part 40

[Docket No. RM12-22-000]

Reliability Standards for Geomagnetic Disturbances

(Issued TBD)

AGENCY: Federal Energy Regulatory Commission.

ACTION: Notice of Proposed Rulemaking.

SUMMARY: Under section 215 of the Federal Power Act, the Federal Energy Regulatory Commission (Commission) proposes to direct the North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization, to submit for approval Reliability Standards that address the impact of geomagnetic disturbances (GMD) from both natural and manmade sources[11] on the reliable operation of the Bulk-Power System. The Commission proposes to do this in two

[11] Rationale for insertion explained in Section 13 Benefits of All-Hazard GMD/E3 Protection.

stages. In the first stage, the Commission proposes to direct NERC to file, within 90 days[12] of the effective date of a final rule in this proceeding, one or more Reliability Standards that require owners and operators of the Bulk-Power System to develop and implement operational procedures to de-energize vulnerable equipment that may be damaged during a severe solar storm, consistent with the reliable operation of the Bulk-Power System.[13] Operating Procedures as exclusive protection shall be an emergency interim measure to protect the Bulk Power System until more reliable protective measures are developed and implemented.[14] As part of implemented Operational Procedures, operators must identify all vulnerable equipment and report such equipment to a database maintained by FERC and accessible to federal authorities in case of emergency in near-real time.[15]In the second stage, the Commission proposes to direct NERC to file, within six months[16] of the effective date of a final rule in this proceeding, one or more Reliability Standards that require owners and operators of the Bulk-Power System to protect the Bulk-Power System equipment and the Bulk-Power System as a whole against the effects of GMD, derived from natural or man-made sources, including but not limited

[12] Rationale for timeline retention explained in Section 3 Original Timelines in FERC NOPR Should Be Adhered To.
[13] Rationale for insertion explained in Section 4 Operating Procedures Should Be an Emergency Measure. Rapid disconnection from the grid may not suffice. De-energizing of critical equipment, or neutral ground blocking of that equipment is essential to protect EHV transformers from damage.
[14] Rationale for insertion explained in Section 4 Operating Procedures Should Be an Emergency Measure.
[15] Rationale for insertion explained in Section 11 Database of Equipment Subject to GIC.
[16] Rationale for timeline retention explained in Section 3 Original Timelines in FERC NOPR Should Be Adhered To.

to equipment overheating and permanent damage, harmonic production, reactive power consumption, equipment vibration, and loss of GPS signaling.[17] The Reliability Standards would require owners and operators to develop and implement plans so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. The Reliability Standards would require owners and operators to develop and implement plans to prevent immediate or delayed equipment damage that would degrade networks beyond a single contingency.[18] These plans cannot be limited to operational procedures or enhanced training alone, but should protect against the potential impact of GMDs without human intervention.[19] Reliability Standards shall be uniform, with a minimum of exceptions or exemptions, and be performance-based.[20] Protective strategies shall be mathematically modeled and[21] could include automatically blocking geomagnetically induced currents from entering the Bulk-Power System, instituting specification and GMD-testing[22] requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to test or retrofit.

[17] Rationale for requirement insertion explained in Section 5 GMD Causes Multiple Failure Modes.
[18] Insertion rationale explained in Section 6 GMD-Induced Failures May Occur After Solar Storms.
[19] Rationale for insertion explained in Subsection 4.5 Warning Time of Space Weather Forecasting Is Insufficient.
[20] Deletion and insertion rationale explained in Section 7 Mathematical Modeling of Protective Measures Is Essential.
[21] Rationale explained in Section 8. Uniform Performance-Based Standards Should Be Required.
[22] Rationale explained in Section 9 Testing of GIC Withstand Should Be Required

This second stage would be implemented in phases, focusing first on the most critical Bulk-Power System assets. Event recording and failure reporting for Bulk Power System assets that may be affected by GMD shall be mandatory and public.[23] To the maximum extent allowed by law, cost-recovery from ratepayers should be authorized for implementation of GMD Reliability Standards.[24]

[23] Rationale explained in Section 12 Mandatory and Public Event Monitoring and Failure Reporting.
[24] Rationale explained in Section 10 Cost Recovery Should Be Allowed.

2. FERC Order on Geomagnetic Disturbance Is Essential for Public Safety

Twenty-three years have passed since a solar storm hit the province of Quebec and amply demonstrated that solar storms can cause electric grid instability, widespread blackout, and transformer damage. After twenty-three years, NERC and the electric utility industry have shown that they are unwilling, or unable, to take the initiative to set a reliability standard on their own. Now the FERC Commissioners are appropriately exercising their authority within the legal framework of Section 215 of the Federal Power Act as amended, and ordering that a standard be set.

No doubt that the FERC Commissioners will receive multiple docket comments from the electric utility industry saying that a reliability standard is not immediately necessary because a GMD threat has not been conclusively established. As example, we quote from the comment early filed on Docket RM12-22 by American Electric Power Service Corporation (AEP):

> AEP has been monitoring the potential effects of GMD across the AEP system transmission system, and has been conducting GMD monitoring activities since 1989. These monitoring efforts have spanned the last three solar cycles. Throughout AEP's analysis, neither imminent threats nor lasting GMD impacts on transformers have been observed. As part of its monitoring efforts, AEP continues to develop models to assess the potential for impact on AEP's system during solar cycles and constructs mitigation plans accordingly. AEP's experience to date indicates that the AEP system and equipment has been capable of withstanding solar storm events without incident.
>
> Based on this experience, as a preliminary matter, AEP agrees with the sentiment expressed in EEI's comments that, without a strong consensus on the technical specification of a GMD event, there is not a sufficient basis for the Commission to conclude that there is a need for a new or modified NERC Reliability Standard on GMDs.

To the extent that an industry consensus on risks of GMD may be lacking, it is due to longstanding non-monitoring and nondisclosure regarding GMD events and electric grid impacts.

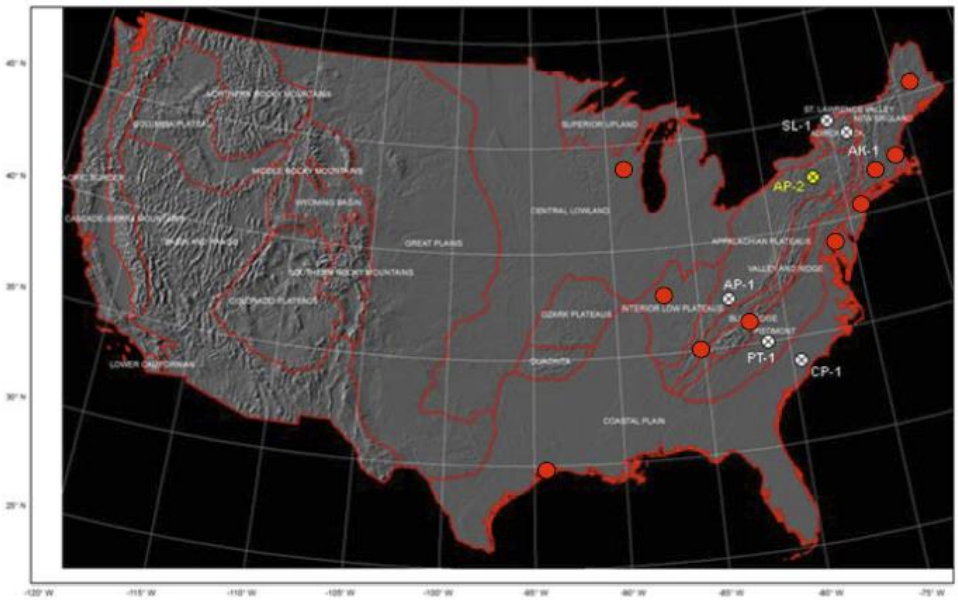
The report of the Oak Ridge National Laboratory, "Geomagnetic Storms and Their Impacts on the U.S. Power Grid," examined over 3,000 Extra High Voltage (EHV) transformers that could be

affected by GMD and concluded that approximately 300 transformers are at risk from a severe solar storm. Slide 14, titled “Existing SUNBURST Nodes” of the EPRI presentation "Geo-Magnetic Disturbances Overview of EPRI Research Activities" given to the GMD Task Force on August 28, 2012 shows only 16 GIC monitoring nodes, with zero nodes in the Western half of the continental United States. The PJM presentation "August 2011 Coronal Mass Ejections PJM GIC Detector Data" given to the GMD Task Force on August 30, 2011 shows 6 GIC monitoring nodes for the PJM network. The Foundation for Resilient Societies filed Freedom of Information Act requests with Bonneville Power Authority (BPA) and Tennessee Valley Authority (TVA) and was able to find another 15 GIC monitoring nodes; 12 for BPA and 3 for TVA. Based on industry discussions, we believe that GIC is also monitored at the Salem and Hope Creek nuclear power plants in New Jersey and the Seabrook nuclear power plant in New Hampshire, accounting for 3 more nodes. Altogether, we estimate only 40 GIC monitoring nodes, out of 3,000 EHV transformers, including 300 high-risk transformers. Therefore, we estimate less than 2% of all EHV transformers are monitored for GIC, and less than 15% of high-risk transformers are monitored.

In regard to AEP GIC monitoring specifically, the webpage “Geomagnetic Disturbances” on the AEP.com website indicates “multiple” GIC monitoring nodes. Slide 2, titled “GMD Membership” of the EPRI presentation "Geo-Magnetic Disturbances Overview of EPRI Research Activities" indicates that AEP is a member of the SUNBURST GIC data consortium. If all of AEP’s monitoring nodes were reporting to SUNBURST, the total number could not be more than the 16 in SUNBURST network, and would likely only be 5 or fewer of the nodes pictured in the central United States:

Existing Sunburst Nodes

Location of 1D Earth Resistivity Models with respect to Physiographic Regions of the USA



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Alternatively, AEP might have more than five GIC monitoring nodes, but not be reporting data for all nodes to SUNBURST. Either possibility is problematic. If AEP has only a handful of GIC monitoring nodes, it could be technically unsound to conclude no imminent threat based on very limited data. Alternatively, if AEP were not reporting all of its GIC data to SUNBURST, it could be in apparent conflict with strong support for SUNBURST and industry monitoring, as expressed by Michael Heyeck, Senior Vice President of Transmission for American Electric Power (AEP), during his testimony at the April 30, 2012 FERC Technical Conference on GMD:

> Second, the industry should expand monitoring to not only capture GIC but also GMD impacts on the electric infrastructure at representative locations, with a specific focus on transformers where the greatest risk from GMD can be expected. Measured system impacts, such as voltage, reactive power, harmonic currents, transformer temperature and dissolved gas analysis (DGA) should then be correlated to GMD severity to better understand the actual sensitivity and vulnerability of equipment performance to GMD

> events. This additional data can then be used to improve modeling and predictive efforts. EPRI's SUNBURST program has been a valuable contributor to the science, capturing GIC data for some time, although it has been among a limited number of industry subscribers. We can enhance the value of such programs by: increasing participants and locations to better represent more of North America; including more correlation between GIC and its impacts such as a harmonics, transformer temperature, voltages and reactive power demand; and reporting findings in as transparent and accessible a manner as practical in order to document true interrelationships between GMD and the power grid.

For clarity on the public record, we encourage FERC to ask AEP, EPRI, and other electric utility industry commenters for backup information, including the number and locations of their GIC monitoring nodes, the dates of operation, any associated GIC readings, and modeling results, as applicable. This information would be helpful in better understanding the perspective that "neither imminent threats nor lasting GMD impacts on transformers have been observed."

The Foundation for Resilient Societies, acting as an observer of the NERC GMD Task Force, asked that utilities represented on the task force disclose GIC data and not a single utility came forward with data. Subsequently, the Foundation for Resilient Societies filed a Freedom of Information Act request with BPA and obtained GIC data for 12 monitoring stations going back to 1993. TVA also indicated willingness to release GIC data, although the technical details of obtaining data are still in discussion. The EPRI SUNBURST consortium has a system of interlocking confidentiality agreements and therefore refuses to release most GIC data.

The persistent concealment of SUNBURST data from independent researchers and non-profit organizations occurs despite EPRI's Charter, its Articles of Incorporation, encouraging information exchange for "all organizations and persons…." Article 3(i) of EPRI's Articles of Incorporation sets this goal:

> "To provide a medium of coordination and cooperation for the <u>exchange of information for all organizations and persons, public or private, concerned with electric power scientific research and development</u>;" (underlining added)

In sum, the vast majority of GIC data, when it is infrequently collected at all, is not publicly disclosed and rarely available to researchers.

GMD impacts to equipment, including transformers, are likewise rarely disclosed and only recently collected in a centralized location. Transformer failures are reported to the Generating Availability Data System (GADS) and Transmission Availability Data System (TADS) databases at the North American Electric Reliability Corporation. The majority of GADS and TADS data are kept confidential, including outage reports. Mandatory GADS data collection started in 2012 and mandatory TADS data collection started in 2009, well after the end of the last solar maximum. Despite extensive participation in GMD Task Force discussions, we are unaware of any research that has attempted to correlate GADS and TADS data with GIC readings.

The Foundation for Resilient Societies specifically asked that PSEG, operator of the Salem and Hope Creek nuclear power plants that experienced transformer failures proximate to solar storms, disclose GIC data and root cause transformer failure reports. PSEG declined to disclose this data.

Because GIC data has been rarely collected and even more rarely disclosed, and because potential GMD impacts to transformers have been only recently collected and are not publicly disclosed, it has been impossible to conduct comprehensive statistical analysis of GMD risks. After 23 years of inattention and nondisclosure, the electric utility industry thereby claims that no imminent threat GMD exists. One cannot help but be reminded of the three proverbial monkeys that *see no evil, hear no evil, and speak no evil.*

Electric utility docket comments claiming no imminent threat to the electric grid, based on incomplete monitoring, undisclosed data, and unperformed or undisclosed analysis should carry very little weight with the FERC commissioners.

In contrast, there are multiple government-sponsored studies that show substantial threat to the electric grid from GMD, including reports by the Congressional EMP Commission (2008), the National Academy of Sciences (2008), the Department of Energy and NERC itself ("2010 High-

Impact, Low-Frequency Event Risk to the North American Bulk Power System"), and the Oak Ridge National Laboratory (2010). All of these reports are well-familiar to FERC staff and require no further elaboration. These government reports conclude a severe solar storm could cause 100 million Americans to be without power for 1-2 years, which undoubtedly would cause causalities in the millions. Any reasonable person would conclude that an immediate FERC order on a reliability standard for geomagnetic disturbance is essential for public safety.

3. Original Timelines in FERC NOPR Should Be Adhered To

Twenty-three years have passed since a solar storm hit the province of Quebec and amply demonstrated that solar storms can cause electric grid instability and widespread blackout. After twenty-three years, the electric utility industry asks for more time. Granting prospective wavier to the deadlines in the FERC NOPR would be rewarding inattention and delay. Instead, NERC and the electric utility industry should show that they are capable of protecting the public interest by making development of a GMD standard a full-time job for dedicated industry personnel and expeditiously moving toward completion. NERC and the electric utility industry need to demonstrate they are deserving of self-regulatory authority—in contrast to woefully slow progress on other critical standards for vegetation management and cyber protection.

Two full years of experience with the GMD Task Force shows that it has become a vehicle for further delay. Task force meetings are proposed then cancelled. Months go by without any update to task force members about next steps. The GMD Task Force Interim Report is widely criticized for lack of rigorous science and unfounded conclusions—and then there are no GMD Task Force meetings for the six months between the report's release on February 29, 2012 and the next meeting August 28, 2012.

Unnecessary delays allow for coordination of nonpublic discussions to forestall a GMD reliability standard. It should be noted that many of the comments filed on Docket RM12-22 indicate explicit coordination among individual utilities, regional entities, and trade groups; not surprisingly, these same comments oppose a reliability standard. The FERC commissioners

should not facilitate coordinated delay tactics at the expense of the public safety; the original timelines in the NOPR should be adhered to.

4. Operating Procedures Should Be An Emergency Measure

After 23 years of intransigence and delay by the electric utility industry, the FERC commissioners are now forced to consider relying on "operating procedures" as a stopgap measure. "Operating procedures" should not be the exclusive measure to provide protection of the electric grid against solar storms. Instead, "operating procedures" should be used solely on an emergency basis, when there would be no other practical means of protecting vulnerable equipment against an exceptionally severe solar storm.

"Operating procedures" that would de-energize vulnerable equipment could be accomplished under Presidential Executive Order using existing laws;[25] this authority might be enhanced by additional federal legislation. For emergency operating procedures to be effective, utilities would be required to participate in nationwide exercises of a national system to de-energize critical energy facilities upon tactical warning of "severe" GMDs. Energy facilities that meet future FERC approved standards would be authorized to "operate through" severe geomagnetic disturbances. Energy facilities that are not protected, and that are projected to pass through harmful GICs to other critical equipment in the bulk power system could, under authority of the President, be disconnected from the grid and de-energized. Long-term use of "operating procedures" on a non-emergency basis would imply that the American public is protected while, in reality, the disruption of "operating procedures" could be substantial; severe economic losses and even widespread deaths could occur.

[25] The President has enumerated Article II Powers and specific statutory powers in event of an "energy supply disruption." Specifically, under Title 42 U.S.C. sec. 5195 (Public Law 93-288) the President has non-delegable authority to order de-energizing of powerplants at onset of a severe solar geomagnetic storm. The President has authority to prohibit any power plant or any other fuel burning installation from using natural gas or petroleum. The Nuclear Regulatory Commission has authority, which it exercises in hurricanes or other emergencies, to require de-energizing of nuclear power plants. Although the President has no specific authority to prohibit use of coal-fueled power plants during a severe geomagnetic storm, under the Defense Production Act, as amended, the President has authority to take temporary control of these and other facilities. See Appendix 4 of these Comments for further discussion.

If FERC were to require prompt updating of a FERC-managed database to support Presidential decision-making in event of a severe geomagnetic storm, data from this federal system should, by regulations, be accessible to insurance and reinsurance companies serving the electric utility industry. Public utilities that have invested in equipment to protect critical electric facilities and regional transmission systems connected to these facilities might be eligible for insurance premium discounts. Electric utilities that insist upon the functionality of "operating procedures" might be subject to higher premiums. In this manner, the insurance industry could protect the capital equipment of insureds, protect public safety, and educate their clients on prudential business practices. The insurance industry, with fuller disclosure by utilities and facilities, plant by plant, could harness market forces to improve grid reliability. This, in turn, would relieve FERC Staff and Commissioners from bearing the full weight of needed reforms.

"Operating procedures" as currently used by few utilities mostly in the Northeast U.S. are premised on increasing reserve reactive power and/or decreasing load from electric utility customers to prevent system instability and transformer damage. These "operating procedures" are untested in severe storms and a potentially ineffective method of preventing critical equipment damage and widespread blackout. The only truly effective "operating procedures" would be proactively de-energizing all vulnerable equipment.

4.1 Currently Used Operating Procedures Have Unclear Goals

While "operating procedures" are in place at several Northeast U.S. utilities, under questioning at GMD Task Force meetings, utility engineers could not clearly state the goals of "operating procedures." On one hand, "operating procedures" could increase reactive power reserves to keep the electric grid operating for as long as possible during solar storms—until catastrophic collapse in a severe storm. One the other hand, "operating procedures" could shed load and therefore protect vulnerable transformers from overheating. Keeping the grid operating for the maximum number of customers is a goal that is inconsistent with the goal of shedding load to protect vulnerable equipment, thereby minimizing the recovery periods to reconstitute a functioning bulk power system. The lack of clearly stated goals shows that currently used "operating procedures" may be of marginal effectiveness.

4.2 "Operating Procedures" Have Not Been Tested or Simulated Under Severe Storm Conditions

Currently used "operating procedures" are a hypothetical solution against an unrealized threat. Because a solar storm of magnitude similar to the 1859 Carrington Event or 1921 Railroad Storm has not occurred when "operating procedures" have been in effect, they are untested in real-world conditions. Nearly every major electric transmission operator has a software-based "state estimator" to determine the effects of equipment failures on their grid. While some transmission operators may have simulated "operating procedures" under conditions of severe solar storms, none has made the results public. Use of "operating procedures" without advance study and mathematical modeling may result in grid instability and/or equipment damage; any advance simulations of "operating procedures" to protect against solar storms should be publicly examined and validated. Without mathematical modeling, the feasibility and effectiveness of "operating procedures" is completely unknown.

4.3 Key Elements of "Operating Procedures" Have Not Been Made Public

A representative of ABB, the world's largest transformer manufacturer, disclosed to the GMD Task Force that his company has supplied graphical curves to electric utilities showing the amount of "load reduction" that would be required to prevent solar storm damage to vulnerable transformers. When the electric grid has little spare generation or transmission capacity, "load reduction" is simply a euphemism for brownouts or rolling blackouts. Because the transformer "load reduction" curves are not published or publicly available, it is not possible to accurately judge how many utility customers might be deprived of power. Nuclear Regulatory Commission (NRC) records for nuclear power plants show power reductions of up to 35% during minor solar storms.

4.4 "Operating Procedures" Depend upon Unreliable Space Weather Forecasting

Terrestrial weather forecasts, supported by an extensive system of satellites and ground observation sites, are often unreliable. In comparison, space weather forecasting is an infant science. In addition to uncertainty about whether a solar storm will directly impact the earth or

pass nearby harmlessly, there is no precise method of predicting damaging currents induced in power grids. Millions of customers could have their power shut off due to forecasts that ultimately prove to be wrong. Alternatively, an unpredicted solar storm could hit the earth and cause widespread electric grid damage and blackouts.

4.5 Warning Time of Space Weather Forecasting Is Insufficient

Accurate space weather forecasting depends on a satellite stationed at the L1 position between the sun and earth. Depending on the exact speed of Coronal Mass Ejections from the sun, the maximum warning time from an L1 satellite would be between 10 and 60 minutes. Within this very short time period, electric utilities would have to make critical decisions about shutting off power to millions of customers. After the 1989 Hydro-Quebec blackout caused by a solar storm, the North American Reliability Corporation published a "NERC Position Statement on Solar Magnetic Disturbance Forecasting." This statement reads, "With the current activity on the sun projected to continue well into the 1990s, NERC believes that a forecasting procedure to provide at least a one hour notice and accuracy of at least 90% is required. This security margin will allow sufficient time to implement special operating procedures." As of the current date, these NERC-recognized conditions to allow effective "operating procedures" are still unmet. Moreover, because there is no cost-effective or technically feasible way of permanently positioning a satellite between the earth and sun, except at the L1 position, an accurate forecast of at least one hour is not possible.

4.6 No Reliable Infrastructure for Space Weather Forecasting

Space weather forecasting depends on only a few satellites stationed millions of miles from earth. These satellites could malfunction at any time and have no immediate replacement. The critical Advanced Composition Explorer (ACE) satellite stationed at the L1 position between the earth and sun is past its designed operational life and has no planned replacement. Sensors on the satellite have malfunctioned during past solar storms. Fuel for the ACE satellite is running low and is being carefully conserved. ACE satellite fuel conservation procedures cause significant periods of radio blackout due to interference from the sun. The ACE satellite is currently a single point of failure for accurate space weather forecasting. While space weather

forecasting has many valuable uses and ACE replacement satellites should receive future funding, forecasting cannot be solely relied upon for electric grid protection.

4.7 Rapid Load Reduction Is Likely to Cause System Instability

Recent events have demonstrated that interconnected electric grids can be extremely sensitive to minor disturbances. In 2003, a tree branch contacted a transmission line in Ohio, causing a blackout through much of the northeastern United States and Canada. In 2011, a technician in an Arizona substation threw a switch that caused a blackout in Arizona, Baja Mexico, and Southern California. Common sense would allow even laypeople to conclude that "operating procedures" dictating turn-off of millions of customers and dozens of power generation facilities within minutes are likely to have unpredictable consequences, including widespread blackouts. Moreover, insurance executives at a June 2012 conference in London have pointed out strong incentives for utility executives not to exercise "operating procedures" that intentionally black out customers: an intentional act other than one executed in response to intervening government order would void insurance coverage under most insurance contracts. So the most important "operating procedures" might be better characterized as "inoperable" procedures that will not be utilized when most needed.

4.8 Effective "Operating Procedures" Could Require Grid Shutdown

The true parameters of electric utility operating procedures and their effectiveness in countering transformer damage have not been publicly disclosed. On July 15, 2000 a moderate solar storm hit the Hope Creek nuclear plant in New Jersey. NRC records disclose the reactor was operating at only 55% power; nonetheless, a main power transformer was impacted shortly after the storm and was taken off-line. In 2003 a Special Agent of the NRC interviewed a worker at the Hope Creek nuclear plant about safety issues. The worker stated, "And we have three main transformers. One is a very good one that we replaced just a couple years ago, and the other two are very old, and they're susceptible to electromagnetic disturbances and are not very good transformers." The worker continued, "…it's an operational risk that we assume by having those transformers in place. We know there may be times where the solar conditions are such that will have to back the units down, and if it gets real bad, *we'll have to shut the*

units down altogether." (Emphasis added.) Shutting down hundreds of vulnerable transformers under extreme solar storm conditions would be essentially the same as shutting down the electric grid.

4.9 Electric Grid Blackstart Procedures Are Risky and Unproven

None of the three United States electric grids has ever been deliberately shut down and there is no assurance that power could be expeditiously restored though blackstart procedures without depending upon neighboring unaffected portions of the United States or interconnected power grid. Grid *blackstart* depends on telecommunications infrastructure and telecommunications infrastructure which in turn depends on the grid power. Battery backup for telecommunications is limited to only a few days. Blackstart procedures have never been tested when the entirety of the United States grid system has been shut down.

We entirely agree with the statement in the NOPR, "Since there could be potential equipment damage resulting from a GMD event, the proposed Reliability Standards should also address operational procedures for restoring GMD-impacted portions of the Bulk-Power System that take into account the potential for equipment that is damaged or out-of-service for an extended period of time."

4.10 Cost-Effective Alternatives to "Operating Procedures" Exist

Hardware-based protection against grid damage from solar storms can be readily installed, including current "blocking devices" for high voltage transformers. In 2010 the Oak Ridge National Laboratory released the report "Electromagnetic Pulse: Effects on the U.S. Power Grid." The report concluded, "Naturally occurring EMPs are produced as part of the normal cyclical activity of the sun...the average yearly cost of installing equipment to mitigate an EMP event is estimated at less than 20 cents per year for the average residential customer." Hardware-based protection would work without time-consuming human intervention, would not be reliant on space weather forecasts, and would have distributed redundancy instead of depending on single pieces of equipment.

4.11 Reliance on "Operating Procedures" Imposes Large Losses on Ratepayers

Each day of reduced generation power because of forecasted solar activity is a potential revenue loss that ultimately can affect utility ratepayers. For example, power reductions at the Hope Creek and Salem nuclear plants during moderate solar storms have typically been in the range of 20%-35%, which correspond to non-trivial revenue losses. When transformers without hardware-based protection do not have power reduced during solar storms, large transformers are at increased risk of failure, both during solar storms and in subsequent years. Multiple reports in the SEC Edgar database show losses in excess of $10 million for transformer failures at power plants when lost revenue, transformer replacement costs, and associated equipment damage is considered. The "downrating" of electric generation during only moderate level geomagnetic disturbances can result in far greater revenue losses than the modest capital costs of neutral ground blocking devices.[26]

4.12 Summary Conclusions Regarding "Operating Procedures"

Currently-used operating procedures are likely to have limited usefulness in protecting hard-to-replace equipment, especially during severe solar storms. In contrast, operational procedures

[26] Seabrook Station 1, situated on a salt marsh in coastal New Hampshire, is illustrative of revenue losses due to operation of a 345 kV GSU transformer without neutral grounding equipment. In November 1998 the GSU transformer and all electric generation were offline for 12 days following a moderate-level geomagnetic storm damaging Phase A of the GSU transformer.

During a recent geomagnetic storm, on July 16, 2012 Seabrook operators downrated electric generation from 85 percent (due to a continuing stator cooling problem) to 68 percent "due to solar magnetic activity causing high circulating current" per NRC daily report, July 16, 2012.

NextEra Energy's Form 10-Q filing with the Securities and Exchange Commission for September 30, 2012 attributes a decrease of $24 million in revenues to reduced generation at Seabrook station for the first nine months of year 2012. This financial report did not partition the losses between the primary cause (damage and delayed opportunity to replace stator cooling equipment) and a secondary cause (susceptibility to GICs at this end-of-the-line facility). If just 2.3 percent of reduced generation revenue of $24 million was attributable to reduced generation because of geomagnetic induced currents, neutral blocking equipment for all four Seabrook 345 kV transformers would have repaid its entire cost, including installation charges, in just the first nine months of year 2012. GIC-protective costs for this facility are assumed to be $250,000 to protect the single 345 kV GSU transformer, plus $250,000 to protect three switchyard transformers that achieve scale economies using just a single neutral grounding system., plus $50,000 of installation costs. The benefit includes protecting these transformers and blocking GICs from entering three 345 kV transmission lines. Protection of the switchyard transformers from GICs may be necessary to prevent entry of GICs into the high voltage transmission system, sometimes known as the "Whack-A-Mole" problem, whereby GICs blocked at one entry site might enter the grid at another nearby site.

For use of a single neutral blocking device to protect multiple transformers, see the Emprimus Comments filed in Docket, RM12-22-000, section on costs at p. 11.

that would de-energize vulnerable equipment are likely to be successful, but at great risk and economic cost, if directed by the President before impacts of a severe solar storm. While de-energizing equipment and selective grid shutdown could be accomplished under existing law using a Presidential Executive Order, more effective operational procedures would require enhancement of Presidential authority by additional legislation and practice drills by both electric utilities and off-grid operators of backup power equipment.

5. GMD Causes Multiple Failure Modes

GMD can cause multiple initiating events in the Bulk Power System, including but not limited to harmonic production and associated relay tripping, reactive power consumption and associated voltage collapse, transformer overheating and premature failure (with attendant chance of fire and/or explosion), circuit breaker malfunction, equipment vibration, and loss of GPS signaling for synchro phasor operation. In turn, these initiating events can cause system instability, uncontrolled separation, and cascading failures. In addition there is the potential for long-term damage to hard-to-replace equipment. Any reliability standards must address all probable failure modes caused by GMD; utilities should not be allowed to address merely transformer overheating from GIC.

6. GMD-Induced Failures May Occur After Solar Storms

It is a fallacy to conclude that GMD-induced failures do not occur because few failures of transformers and other equipment have occurred during solar storms. GIC shortens life of transformers, but does not necessarily result in immediate failure. Indeed, without protective measures, the United States may “ride out” a solar storm, only to experience transformer failures, load shedding, and even outright grid collapse in the days or months following a storm.

7. Mathematical Modeling of Protective Measures Is Essential

The safety of the American public cannot depend on engineering intuition alone. Increasingly, grid modeling tools incorporating GIC capability are becoming commercially available. A

necessary component of any "operating procedures" should be mathematical modeling in advance. Likewise the placement and operation of any series capacitors or neutral ground blocking equipment should be mathematically modeled in advance of installation. To prevent layering of rosy assumptions, mathematical models, including key assumptions, should be subject to external review and audit.

8. Uniform Performance-Based Standards Should Be Required

Reliability standards for geomagnetic disturbance should be uniform and unambiguous. Standards should not allow broad loopholes for "age, condition, technical specifications, or location of equipment," as the current draft of the NOPR would permit.

8.1 Age and Condition of Equipment

Considerations for age and condition of equipment are irrelevant factors for the protection of the public. Whether a new or old transformer fails under GIC conditions, the resulting grid outage will have the same effect. If age and condition of equipment are allowable factors in a reliability standard, it is likely that NERC and the electric utility industry will seek to "grandfather-in" old equipment, much as property owners seek to grandfather substandard dwellings when confronted with newer and safer fire codes. "Grandfather" clauses may be understandable when an entire building must be demolished to achieve compliance, but the electric grid can be cost-effectively protected with ancillary hardware. Accordingly, there should be no reliability standard exceptions for age and condition of equipment.

8.2 Technical Specifications

A "technical specifications" loophole could allow electric utilities to claim their equipment is GIC-resistant, while in reality the equipment could fail, produce harmonics, or consume reactive power under GIC conditions. An example would be the specification of single phase transformers vs. three phase transformers—with three phase transformers purportedly more resistant to GIC. Without actual testing of deployed transformer designs, assertions of greater

GIC resistance are speculative. Reports of a recent test of a three phase transformer at Idaho National Laboratory show that three phase transformers are also vulnerable to GIC.

8.3 Location of Equipment

Most importantly, electric utilities should not be given exemptions to geomagnetic disturbance reliability standards solely because of “location of equipment,” including the factors of latitude, local ground resistivity, depth-based ground conductivity profiles, and proximity to bodies of water. Modeling of GIC flows is a primitive science, based on poorly understood factors. Engineers might have greater scientific understanding if utilities had instrumented their networks for GIC flows and then publicly released data. Unfortunately, utilities have done the opposite—GIC monitors are rarely installed and the rare GIC readings taken have been concealed using interlocking confidentiality agreements within the SUNBURST consortium. Because electric utilities have not diligently taken GIC readings and released the data publicly, they should forfeit any automatic exemption to GMD reliability standards based solely on location of equipment, including latitude.

The operational response of nuclear power plants, as documented in Power Reactor Status Reports available on the NRC website, has not been consistent with the thesis that low-latitude generators or transmission operators should be given blanket exemption to GMD reliability standards. On October 30, 2003, the Salem 1 and Hope Creek nuclear plants in New Jersey reported "REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES." On the same day, the Arkansas 1 and 2 nuclear plants reported "HOLDING OFF ON SWITCHYARD MAINTENANCE FOR SOLAR FLARE RESPONSE" and the Palo Verde 1 and 3 nuclear plants in Arizona reported "T-HOT LIMITED TAKING EXTRA READINGS ON PLANT COMPUTER DUE TO SOLAR FLARE RESPONSE." River Bend 1 nuclear plant in Louisiana reported "NO D/G OR RELAY TESTING DUE TO SOLAR FLARE RESPONSE." Notably, the Arkansas, Palo Verde, and River Bend plants are all in the southern United States.

Multiple peer-reviewed articles describe substantial effects of naturally-caused GIC even at low or mid-latitudes. These articles include “Space Weather and the Vulnerability of Electric Power

Grids, in Effects of Space Weather on Technology Infrastructure,"[27] "Storm sudden commencement events and the associated geomagnetically induced current risks to ground-based systems at low-latitude and mid-latitude locations,"[28] "Transformer failures in regions incorrectly considered to have low GIC-risk"[29] and "Geomagnetically Induced Currents at Mid-Latitudes."[30]

GIC from geomagnetic disturbance caused by nuclear electromagnetic pulse is greater at low latitudes. In contrast, GIC from geomagnetic disturbance caused by solar storms is greater at high latitudes. A uniform protection standard, regardless of equipment latitude, would protect against both sources of geomagnetic disturbance.

Based on developing knowledge of natural GMD effects at low latitudes—as evidenced by peer-reviewed literature—and operational response of nuclear power plants at low latitudes, it would be imprudent for the FERC commissioners to allow automatic exemptions based solely on latitude. Docket comments dismissing the risk of low-latitude GIC outright should be given little weight by the FERC commissioners.[31]

8.4 Effect of Blanket Exemptions

If the FERC commissioners allow rulemaking to proceed with unwarranted considerations for "age, condition, technical specifications, or location of equipment," an entirely predictable sequence of events is likely to occur. First, standards setting will be a long and drawn-out

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[27] Kappenman, J.G., Chapter 14 - Space Weather and the Vulnerability of Electric Power Grids, in Effects of Space Weather on Technology Infrastructure, edited by I. A. Daglis, Kluwer Acad., Norwell, Mass., Vol 176, 2004, pages 257-286.

[28] Kappenman, J.G., "Storm sudden commencement events and the associated geomagnetically induced current risks to ground-based systems at low-latitude and mid-latitude locations, "SPACE WEATHER, VOL. 1, NO. 3, 1016, 2003.

[29] Gaunt, C.T. and Coetzee, G., "Transformer failures in regions incorrectly considered to have low GIC-risk," Power Tech Conference, 2007 IEEE Lausanne, 1-5 July 2007, Dept. of Electr. Eng., Univ. of Cape Town, Cape Town, Page(s): 807- 812.

[30] Koen, J. and C.T. Gaunt, Geomagnetically Induced Currents At Mid-Latitudes, Department of Electrical Engineering, University of Cape Town, South Africa.

[31] Southerly latitudes are more vulnerable than northern latitudes to elevated geomagnetic disturbances from high altitude EMP bursts, resulting in long line voltage surges. Hence, it would be foolhardy to exempt lower-latitude utility companies from protective standards. A rationale for "all hazards" threat analysis is summarized in Comment Section 13 below.

process, as utilities seek to insert the maximum number of exemptions into the reliability standards. Second, once the reliability standards are set, utilities will go to great lengths to qualify for one of the exemptions, first claiming exemption based solely on latitude and using no mathematical modeling whatsoever, and as a backup plan using "GIC assessments." A cottage industry of technical consultants will emerge to provide "on demand" GIC assessments that incorporate multiple rosy assumptions and conclude that no action is required other than vague "operational procedures." (Already a mantra is developing in the industry: "You do an assessment, you show that your equipment would not be impacted by GIC, *and then you're done.*") External audit and public review of GIC assessments will be prevented using confidentiality agreements and the ever-useful excuse of "Critical Energy Infrastructure Information." Lastly, when a large solar storm hits electric utility networks exempted from the standards, utilities will claim immunity from liability claims because they conformed to a government-approved standard. The FERC commissioners should not be complicit in standards ridden with loopholes that will not protect the American public.

One can easily foresee that mitigation using a system of confidential GIC assessments might be ultimately limited to a few locations in the Northeast with high vulnerability; for example, the Salem/Hope Creek nuclear plants, the Meadowbrook substation next to the Alleghany Mountains, and the Seabrook nuclear power plant on the coast of New Hampshire.

8.5 Clear and Understandable Standards

The most clear and understandable standards would be performance-based; for example, utilities must protect all bulk power equipment from the effects of GIC up to the maximum amperage expected in a severe solar storm, the maximum amperage being a reasonable multiple of observed GIC readings in smaller storms, including a safety factor. A reasonable elaboration might include induced voltage per kilometer in transmission lines. The standard could be quickly set, would not require time-consuming and subjective modeling, and would give operators a clear goal for compliance. Operators have little expertise in measurements of geomagnetic disturbance in nanoTeslas/minute, ground conductance modeling using finite element analysis, full solutions of Maxwell's equations, statistical frequencies of solar storm

incidence and duration, etc. Instead, operators need a reliability standard in units and terminology they can readily understand and use: amps and volts.

9. Testing of GIC Withstand Should Be Required

Participants in the GMD Task Force have been repeatedly told by transformer engineers that "shell form" transformers are especially vulnerable to GIC. Now comes Mitsubishi Electric with its comment in Docket RM12-22-000:

> – **NERC standards on GMD should not contain any bias against shell-form transformers. The earlier NERC Interim Report inaccurately suggests that shell-form transformers are categorically more vulnerable to geomagnetically induced currents (GIC) than core-form transformers. This generalization is unsupported. As the Interim Report states elsewhere, GIC vulnerability "cannot be generalized because the [GIC] effects are dependent on design and construction details of the transformer."**

The lives of millions of Americans cannot depend on the subjective, unconfirmed, and conflicting judgments of engineers in the employ of transformer vendors. Even when technical specifications for GIC withstand conform to standards developed under the ANSI system, if the specifications have not been tested, they should not be relied upon for public safety.

10. Cost Recovery Should Be Allowed

At the April 30, 2012 Staff Technical Review Conference, Mr. Naumann on behalf of the Edison Electric Institute emphasized the need for FERC to provide cost-recovery mechanisms if public policy favored accelerated hardware protections of the electric grid. Our Foundation endorses the development of standards that are not merely technically-sound but also standards that are designed to validate and simplify cost-recovery mechanisms.

If an entity participates in the bulk power system, and that entity purchases equipment designed to improve the reliability of the bulk power system, and if that equipment meets NERC-proposed, FERC-approved standards, that equipment should be eligible for cost-recovery.

What if an entity operating a generation station purchases separate neutral ground blocking equipment that both protects its own transformers and filters out downstream geomagnetically induced currents? While the bulk of generation equipment is not to be regulated by FERC, specialized GMD-protective equipment that produces downstream benefits should be eligible for cost-recovery. This equipment is part of the bulk power system that FERC regulates for reliability purposes. Whether the basis for recovery is enhanced reliability, or reduced downstream congestion or VAR power consumption, in either case the equipment should be eligible for cost-recovery.

What about operating procedures that improve the resilience of a generation facility's plant equipment and operations? Here the Commission needs to distinguish a benefit to the (unregulated) generation entity from a potential (but missing) benefit to other transmission facility participants.

The Emprimus comments filed in this Docket explain that some hardware-protective equipment does more than protect the immediate hardware to which the neutral ground equipment is attached. Emprimus asserts, based upon field testing and PowerWorld modeling of network GICs, that by filtering out GICs that would otherwise enter the extra high voltage transmission system, the overall network is more robust. They assert that as the number of transformers with hardware protection from GICs rises, the overall resilience of the grid improves as well. In particular, Emprimus asserts:

> "Recent simulations by PowerWorld show significant increases allowable in field strength for increased number of neutral blocking devices. Specifically, the results show for a typical Bulk-Power System grid configuration: Grid voltages occur at 21.1 V/km (E-W)"
>
> But with 10 neutral blocking devices the voltage collapse thresholds increased an estimated 26 percent to 26.5 V/km (E-W). With 25 neutral blocking devices, collapse thresholds increased by an estimated 29 percent to 27.2 V/km (E-W).

In this example, if validated independently, an investor in protective equipment benefits other grid equipment and overall system reliability. For equipment that increases reliability of the regional grid, by increasing the induced voltage threshold at which equipment is likely to fail,

criteria for cost recovery should be established to encourage investments in protective equipment.

In contrast, if the operator of a generation or transmission system claims to have operating procedures that make that operator's equipment more reliable, this should not be a basis to obtain recovery from other market participants. The system operator is just protecting its own equipment and not enhancing the reliability of the overall grid. No GICs are being removed from the bulk transmission system.[32] No downstream congestion is being averted.

If there are significant benefits to the reliability of the system overall, or financial benefits accruing to counterparties in market trades, then cost recovery should be established. The overall goal should be to enhance system reliability without unjust enrichment.

Finally, what about cost recovery for protections that go beyond the geomagnetic disturbance protections contemplated in the current NOPR? For example, protection against E1 threats from nuclear electromagnetic pulse and non-nuclear intentional electromagnetic interference? In these cases, market incentives for not only cost recovery, but profit generation might be established by FERC or appropriate legislation. Some customers—for example, military bases—might be willing to pay substantially higher rates for E1-protected grid power. Currently utilities are penalized for reliability shortfalls, but rarely compensated for reliability enhancements. The inducement of additional profit would undoubted spur industry innovation and may also reduce resistance to reliability standards designed to protect national security.

[32] Note that Comments in this docket submitted by Exelon Corporation assert, at page 11 of their submission, that the use of blocking devices "while blocking or reducing GICs on transformers to which they are connected, will increase the GIC loading on other transformers." [citing the NERC Interim Report on GMD of February 2012]. In contrast, Emprimus reports in its filing in this same Docket that PowerWorld modeling shows an overall increase in the robustness of regional transformers as additional blocking devices are installed. The NERC GMD Task Force, which excluded public observers from participating in redrafting the last versions of its February 2012 NERC Report, has failed to consider potential benefits of blocking GIC uptake from end-of-line sites with high saline water bodies that may be an alternative medium by which to disperse GICs during severe geomagnetic storms.

11. Database of Equipment Subject to GIC

Currently, there is no integrated federal database of equipment subject to GIC, including long lead time and hard-to-replace EHV transformers. In anticipation of a severe GMD event, federal authorities will lack information necessary to order de-energizing of vulnerable transformers. Were damage to key transformers to occur, information will be lacking in order to manage expeditious replacement. A federal database of equipment subject to GIC, including equipment most at-risk for failure, needs to be a critical element of any GMD reliability standard.

12. Mandatory and Public Event Monitoring and Failure Reporting

Other critical infrastructure that can cause accidents and deaths includes air transport, rail transport, automobile and truck transport, and gas pipelines. Increasingly, these critical infrastructures are subject to federal regulations that require event recording of operations ("blackboxes"); mandatory failure, accident or incident reporting; and public disclosure of these reports. Some examples follow:

Train event recorders:

> 49 CFR 229.135 - Event recorders.
>
> Title 49: Transportation
> Subtitle B: Other Regulations Relating to Transportation (Continued)
> CHAPTER II: FEDERAL RAILROAD ADMINISTRATION, DEPARTMENT OF TRANSPORTATION
> PART 229: RAILROAD LOCOMOTIVE SAFETY STANDARDS
> Subpart C: Safety Requirements: Cabs and Cab Equipment
> 229.135 - Event recorders.
> (a) Duty to equip and record. Except as provided in paragraphs (c) and (d) of this section, a train operated faster than 30 miles per hour shall have an in-service event recorder…

Aircraft event recorders:

> 14 CFR 125.226 - Digital flight data recorders.
>
> § 125.226

Digital flight data recorders.

(a) Except as provided in paragraph (l) of this section, no person may operate under this part a turbine-engine-powered transport category airplane unless it is equipped with one or more approved flight recorders that use a digital method of recording and storing data and a method of readily retrieving that data from the storage medium.

Automobile event recorders:

49 CFR 563.1 - Scope.

§ 563.1

Scope.

This part specifies uniform, national requirements for vehicles equipped with event data recorders (EDRs) concerning the collection, storage, and retrievability of onboard motor vehicle crash event data. It also specifies requirements for vehicle manufacturers to make tools and/or methods commercially available so that crash investigators and researchers are able to retrieve data from EDRs.

Failure reporting for aircraft:

14 CFR 21.3 - Reporting of failures, malfunctions, and defects.

Title 14: Aeronautics and Space
CHAPTER I: FEDERAL AVIATION ADMINISTRATION, DEPARTMENT OF TRANSPORTATION
SUBCHAPTER C: AIRCRAFT
PART 21: CERTIFICATION PROCEDURES FOR PRODUCTS AND PARTS
Subpart A: General
21.3 - Reporting of failures, malfunctions, and defects.
(a) Except as provided in paragraph (d) of this section, the holder of a Type Certificate (including a Supplemental Type Certificate), a Parts Manufacturer Approval (PMA), or a TSO authorization, or the licensee of a Type Certificate shall report any failure, malfunction, or defect in any product, part, process, or article manufactured by it that it determines has resulted in any of the occurrences listed in paragraph (c) of this section.

Accident and incident notification for gas pipelines:

Public Law 112–90, 112th CongressAn Act

To amend title 49, United States Code, to provide for enhanced safety and environmental protection in pipeline transportation, to provide for enhanced reliability in the transportation of the Nation's energy products by pipeline, and for other purposes…

SEC. 9. ACCIDENT AND INCIDENT NOTIFICATION.

(a) REVISION OF REGULATIONS.—Not later than 18 months after the date of enactment of this Act, the Secretary of Transportation shall revise regulations issued under sections 191.5 and 195.52 of title 49, Code of Federal Regulations, to establish specific time limits for telephonic or electronic notice of accidents and incidents involving pipeline facilities to the Secretary and the National Response Center.

Accident and incident data on FAA website:

FAA Home »Data & Research »Accident & Incident Data

Review preliminary accident data

Read final accident data

Look up airline on-time statistics

Search airport data

Research DOT airline data & statistics

Accident & Incident Data

Reports

Preliminary Data

Final Data

Commercial Air Carrier Fatalities

Search Aviation Accident Reports

Office of Accident Investigation & Prevention

Investigation Policies & Forms

Aviation Safety Information Analysis and Sharing (ASIAS)

Runway Incursion Data and Research

Air Traffic Control Tapes

The deaths from a widespread and long-term grid outage after severe solar storm would not be in the hundreds, as for transportation accidents, but would likely be in the millions. In order to better understand GMD impacts and prevent catastrophe, it is imperative that "blackbox" event recorders be required for bulk power system assets, especially EHV transformers. Failure, accident, and incident reporting should be mandatory and publicly releasable. Non-disclosure using the excuse of "Critical Energy Infrastructure Information" (CEII) should not be permitted for Bulk Power System assets that may be affected by GMD.

When a Generator Step Up transformer catches fire at a nuclear power plant, this information is publicly reported as a Licensee Event Report, but the same failure is kept confidential in the GADS database at NERC. CEII as a catch-all for non-disclosure has prevented public understanding of GMD risks to transformers; any GMD reliability standard should remedy this situation.[33]

13. Benefits of All-Hazards GMD/E3 Protection

The FERC Notice of Proposed Rulemaking for Geomagnetic Disturbances addresses all sources of geomagnetic disturbances. Why is this beneficial? First, an "all hazards" approach is preferable because the mitigation measures for man-made GMD and for solar-storm GMD are generally the same, hence there are economies of scale and what economists would call a "joint product." Both high altitude EMP, derived from multi-stage thermonuclear weapons, and severe solar geomagnetic storms produce waves of energy that long line systems, and especially low-resistance long line systems transmit. The magnitude and rate of change of the delayed GICs are generally greater with man-made E3 than with solar storm E3. But the same protective equipment works for both. There are economies in protecting against both hazards concurrently. This is one of the two principal reasons to design for the combined solar GMD/EMP E3 threat rather than to mitigate each, separately.

[33] For an example of a Licensee Event Report involving a transformer fire at the Indian Point 3 nuclear plant, see Adams Accession ML071620122 at NRC.gov; for a summary of transformer failures at nuclear plants see ML090540218.

The second primary reason to design, model, and set reliability standards for the combination of man-made and solar-derived geomagnetic disturbances is the geographic asymmetries of the two threats.

As many of the comments in Docket RM12-22-000 emphasize, the majority of the FERC-jurisdictional electric utilities are of the firm belief, or at least hope, that the only hazards relating to solar geomagnetic storms affect only their sister utilities to the north. While the existing models of solar storms demonstrate higher probabilities of intense GMD events at higher latitude, even the more southern electric facilities would have significant exposure to severe solar geomagnetic storms.

If the FERC Commissioners and Staff insist upon threat modeling, mitigation modeling, and standards development for the combined all-hazards GMD/E3 requirements, these southern-based utilities will soon discover that they are at greater risk of man-made E3 disturbances than their sisters to the north.

The Compton Effect provides an explanation for peak intensities of E3 voltage surges further towards the equator than the direct downward epicenter on earth. A high altitude nuclear weapon might be launched from a barge off either the Atlantic or Pacific Coasts or the Gulf of Mexico. Relative to the possible locus of explosion and the modeling of energy intensity, the more southern latitudes are as exposed and often more exposed than facilities to the north. By adopting the "all hazards" approach to protect the bulk power system, FERC can accelerate the recognition that all jurisdictional utilities need to participate, and that common standards will apply to all, based not on geographic location but on functional requirement.

14. Benefits of All-Hazards E1 Protection

Many utility executives consider that their facilities already have adequate E1 protection, because they have surge protectors to protect equipment from lightning strikes. The recent EPRI summary on Electromagnetic Pulse (EMP), Electromagnetic Pulses (EMPS) and the Power

Grid (September 2012), notes "The rapid, energetic impulse easily overwhelms traditional surge protection used to prevent damage from lightning strikes or sudden line voltage fluctuations."

As Dr. George Baker explains in the parallel filing by InfraGuard, in this same docket, the same varistors that are used as commercial lightning surge protectors can be reconfigured to provide the greater protection needed to cope with E1 pulses, which arrive in a few nanoseconds. The exact location of the varistors is of considerable importance because of the short arrival times of E1 pulses. It would be reasonable to require standards of protection for all E1 threats, because the protective technology is similar and because the incremental costs are modest. Protecting high voltage transformers from E1 surges is important, practical, and not particularly expensive.

Since the current NOPR does not address E1 hazards, the need for protection might be deferred until a Safeguards Program is developed to reduce risks of the Comprehensive Test Ban Treaty, if not accompanied by self-help measures. The E1 hazards might be considered as part of a Safeguards Program, perhaps late in the year 2013. Other equipment than transformers would require protection as well. Preliminary assessments might be better reserved to the Departments of Defense and Energy. By taking an "all hazards" approach, common remedies for the various threats will not be overlooked. Notably, our Foundation is not alone in recommending all-hazards electromagnetic pulse protection. In 2011, the National Association of Regulatory Utility Commissioners passed a resolution recommending protection against both natural and man-made EMP.[34]

15. Concluding Observations

The Foundation for Resilient Societies encourages the FERC Commissioners and Staff to proceed on an expedited track to achieve NERC standards that meet future needs, and encourage cost-recovery for appropriate investments.

[34] NARUC "Resolution Supporting Protection of Utility Infrastructure Against Electromagnetic Pulse Effects," dated July 20, 2011.

Multiple commentators in this docket recommend that FERC await months or years of additional study by NERC before proceeding to standard-setting. Neither FERC nor the society that FERC must protect can afford this leisurely pace.

As John Kappenman has remarked, we are playing Russian roulette with the sun, and, unprotected, we know the sun will win. A solar maxima approaches, and we are still unprepared for a severe solar storm.

Similarly, government decision-makers globally are at a crossroads: will it be nuclear arms control or nuclear proliferation, again? This Commission has an historic opportunity to reduce the incentives to acquire nuclear weapons, or worse, to use them, because our grid is protectable, and because our nation can set a model for others. Protecting against geomagnetic disturbances of any origin is a prudent and necessary policy. Time is of the essence.

Respectfully submitted by:

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Appendix 1 NRC Notice of Consideration on Docket PRM-50-96

Link to Original PDF: [Federal Register Volume 77, Number 243 (Tuesday, December 18, 2012)]

on the importation of pork or pork products from the areas of Italy under consideration for being declared free of SVD.

Therefore, in accordance with § 92.2(e), we are announcing the availability, for public review and comment, of our evaluation of the SVD status of the Regions and autonomous provinces under consideration. The evaluation may be viewed on the Regulations.gov Web site or in our reading room. (Instructions for accessing Regulations.gov and information on the location and hours of the reading room are provided under the heading **ADDRESSES** at the beginning of this document.) The evaluation, as well as the information evaluated, may also be viewed at *http://www.aphis.usda.gov/import_export/animals/reg_request.shtml* by following the link for "Previous regionalization requests and supporting documentation."

After reviewing any comments we receive, we will announce our decision regarding the disease status of the Italian Regions of Lombardia, Emilio-Romagna, Veneto, and Piemonte and the autonomous provinces of Trento and Bolzano with respect to SVD and the import status of susceptible animals and products of such animals in a subsequent notice.

Authority: 7 U.S.C. 450, 7701–7772, 7781–7786, and 8301–8317; 21 U.S.C. 136 and 136a; 31 U.S.C. 9701; 7 CFR 2.22, 2.80, and 371.4.

Done in Washington, DC, this 11th day of December 2012.

Kevin Shea,

Acting Administrator, Animal and Plant Health Inspection Service.

[FR Doc. 2012–30257 Filed 12–17–12; 8:45 am]

BILLING CODE 3410–34–P

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

[Docket No. PRM–50–96; NRC–2011–0069]

Long-Term Cooling and Unattended Water Makeup of Spent Fuel Pools

AGENCY: Nuclear Regulatory Commission.

ACTION: Petition for rulemaking; consideration in the rulemaking process.

SUMMARY: The U.S. Nuclear Regulatory Commission (NRC) will consider in the NRC rulemaking process the issues raised in a petition for rulemaking (PRM) submitted by Thomas Popik (the petitioner) on behalf of the Foundation for Resilient Societies. The petition was dated March 14, 2011, and was docketed as PRM–50–96. The petitioner requests that the NRC amend its regulations to require facilities licensed by the NRC to assure long-term cooling and unattended water makeup of spent fuel pools (SFP).

DATES: The docket for the petition for rulemaking, PRM–50–96, is closed on December 18, 2012.

ADDRESSES: Further NRC action on the issues raised by this petition can be found on the Federal Rulemaking Web site at *http://www.regulations.gov* by searching on Docket ID NRC–2011–0069.

You can access publicly available documents related to the petition, which the NRC possesses and are publicly available, using any one of the following methods:

- *Federal Rulemaking Web site:* Public comments and supporting materials related to this petition can be found at *http://www.regulations.gov* by searching on the petition Docket ID NRC–2011–0069. Address questions about NRC dockets to Carol Gallagher; telephone 301–492–3668; email: *Carol.Gallagher@nrc.gov.*
- *NRC's Agencywide Documents Access and Management System (ADAMS):* You may access publicly available documents online in the NRC Library at *http://www.nrc.gov/reading-rm/adams.html.* To begin the search, select "*ADAMS Public Documents*" and then select "*Begin Web-based ADAMS Search.*" For problems with ADAMS, please contact the NRC's Public Document Room (PDR) reference staff at 1–800–397–4209, 301–415–4737, or by email to *PDR.Resource@nrc.gov.* The ADAMS accession number for each document referenced in this notice (if that document is available in ADAMS) is provided the first time that a document is referenced.
- *NRC's PDR:* You may examine and purchase copies of public documents at the NRC's PDR, O1–F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland 20852.

FOR FURTHER INFORMATION CONTACT: Manash Bagchi or Richard Dudley, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001; telephone 301–415–2905 or 301–415–1116, email: *Manash.Bagchi@nrc.gov.*

SUPPLEMENTARY INFORMATION:

I. The Petition

The petitioner submitted a PRM (ADAMS Accession No. ML110750145), dated March 14, 2011, to the NRC. The petitioner requests that the NRC amend its regulations to require facilities licensed by the NRC under part 50 of Title 10 of the *Code of Federal Regulations* (10 CFR) to assure long-term cooling and unattended water makeup of SFPs. The petitioner asserts that the North American commercial electric power grids are vulnerable to prolonged outage caused by extreme space weather, such as coronal mass ejections and associated geomagnetic disturbances and therefore cannot be relied on to provide continual power for active cooling and/or water makeup of SFPs. Moreover, existing means for providing onsite backup power are designed to operate for only a few days, while spent fuel requires active cooling for several years after removal of the fuel rods from the reactor core. The petitioner suggested rule language with the following requirements:

> Licensees shall provide reliable emergency systems to provide long-term cooling and water makeup for spent fuel pools using only on-site power sources. These emergency systems shall be able to operate for a period of two years without human operator intervention and without offsite fuel resupply. Backup power systems for spent fuel pools shall be electrically isolated from other plant electrical systems during normal and emergency operation. If weather-dependent power sources are to be used, sufficient water or power storage must be provided to maintain continual cooling during weather conditions which may temporarily constrict power generation.

On May 6, 2011 (76 FR 26223), the NRC published a notice of receipt and request for public comment for this petition in the **Federal Register** (FR). The public comment period closed on July 20, 2011, and the NRC received 97 public comments. After reviewing public comments and evaluating other ongoing activities, the NRC performed a preliminary review and analysis to ascertain the validity, accuracy, and efficacy of the petitioner's technical

assertions and proposed amendment of 10 CFR part 50.

II. Regulatory Oversight of Electric Power Systems

The issues raised in this petition span the regulatory domains and oversight of several government agencies and an industry organization. A discussion of the regulatory domains and oversight of the NRC, the Federal Energy Regulatory Commission (FERC), and the North American Electric Reliability Corporation (NERC) is provided to illustrate the complexity and depth of the issues raised in this PRM.

The mission of the NRC is to license and regulate civilian nuclear power facilities and civilian use of nuclear materials in order to protect public health and safety, promote the common defense and security, and protect the environment. An important part of that mission is to ensure public health and safety with respect to the design, construction, and operation of nuclear power plants (NPP).

Commercial NPPs rely on electric power transmission networks to export power and normally use electrical power from the transmission network to safely shut down the plant when required. The NRC's existing regulations consider the historically high reliability of an electric power transmission system in the vicinity of the plants in maintaining the safety of the reactor and fuel stored in SFPs. However, if power from the electrical transmission system is not available, then safety-related backup power systems, typically powered by emergency diesel generators (EDG), are relied on for essential power to safely shutdown the reactor, mitigate accidents, and provide long-term cooling for the reactor core and fuel in the SFPs. These safety-related onsite EDGs are typically maintained with at least a 3 to 7-day supply of fuel and lubricating oil. In addition, NRC regulations require capabilities to withstand a station blackout (10 CFR 50.63, "Loss of all alternating current power") and development and implementation of strategies to maintain or restore core-cooling, containment, and SFP cooling capabilities under the circumstances associated with loss of large areas of the plant due to explosions or fire (10 CFR 50.54(hh)(2)). These requirements are satisfied by equipment typically independent of the electric power transmission network.

The FERC is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. The FERC's main authority in electric power transmission includes the following:

- Regulation of wholesale sales of electricity and transmission of electricity in interstate commerce;
- Oversight of mandatory reliability standards for the bulk-power system;
- Promotion of a strong national energy infrastructure, including adequate transmission facilities; and
- Regulation of jurisdictional issuances of stock and debt securities, assumptions of obligations and liabilities, and mergers.

The NERC's mission is to ensure the reliability of the North American bulk-power system. The NERC is the electric reliability organization certified by the FERC to establish and enforce reliability standards for the bulk-power system. The NERC develops and enforces reliability standards; assesses adequacy of capacity annually via a 10-year forecast, summer forecasts, and winter forecasts; monitors the bulk-power system; and educates, trains, and certifies industry personnel.

The NRC does not have direct regulatory authority over electric transmission systems, but the NRC collaborates closely with FERC and NERC on electric grid reliability, cyber security issues, electromagnetic pulse issues, geomagnetically-induced current (GIC) research, and related activities to the extent that these issues may have impacts on NPPs.

III. Analysis of Public Comments

The NRC received 97 comment submissions on PRM–50–96. Comments both favoring and opposing this PRM were received, and all comments were considered during the NRC staff's evaluation of the PRM. Comments recommending denial of this petition were submitted by the Nuclear Energy Institute (NEI) and are evaluated in the following paragraphs. The majority of comments supporting the petition were in form letter format and did not provided additional technical information. However, one commenter in favor of the PRM did provide technical arguments to support the petition. All of the comments supporting the petition are not discussed here, because it would be premature to discuss these comments in advance of the NRC's decision whether to actually adopt a final rule addressing the issues raised in the PRM. Therefore, comments supporting the petition will be discussed in any proposed rule that addresses one or more of the issues raised in this PRM. If the NRC ultimately determines not to address, by rulemaking, one or more issues raised in this PRM, then the NRC will explain, in a **Federal Register** notice (FRN), why the petitioner's requested rulemaking changes were not adopted by the NRC and addresses comments received in favor of the PRM.

Comment NEI–1

The NRC is separately addressing the long-term spent fuel pool cooling issue raised by this Petition through its near-term task force review of insights from the March 11, 2011 Fukushima Dai-ichi accident. On July 12, 2011, the task force issued recommendations that are currently being considered by the Commission. Several of these recommendations address the topic of long-term spent fuel pool cooling. The Petition raises no unique issues in this area requiring action separate from, or in addition to, those already being taken in response to the task force recommendations. The Commission's ongoing consideration of these recommendations provides ample opportunity to examine the NRC's regulations with respect to long-term spent fuel pool cooling and bolster assurances that the pools remain safe if an extreme event were to challenge cooling capabilities.

The Commission is already conducting a thorough evaluation of the adequacy of these measures in response to the July 12, 2011 recommendations of its near-term Task Force review of insights from the March 11, 2011 Fukushima Dai-ichi accident. This evaluation will further assure that adequate measures are in place to mitigate any potential severe event, not just space weather.

NRC Response

The NRC agrees with the comment that the ongoing review of the Fukushima accident will separately address some safety issues related to the adequacy of long-term SFP cooling at NPPs. These actions are now being evaluated under five different Fukushima Near-Term Task Force (NTTF) report activities like EA Order-12–049, NTTF Recommendations 4.1, 7.2, 8, and 9. They are discussed in further detail in Section V, "Conclusion," of this document.

However, no new mitigating measures have been developed or defined; accordingly, the NRC does not have a sufficient basis at this time to conclude what future actions would be required for resolving issues raised in PRM–50–96.

The NRC has decided to consider and resolve the issues raised in this PRM in a phased manner, given the NRC activities already underway that may have a bearing on those issues. The phased approach would consist of the following activities: to begin with, the

NRC will access the ongoing Fukushima-related activities to assess the degree of additional protection that will be provided by those efforts and if these measures will resolve the petitioner's issues. Specifically, the NRC staff will assess the implementation of Order EA–12–049 (ADAMS Accession No. ML12054A736)—which requires that licensees develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities following a beyond-design-basis external event—and the ongoing enhancements to the station blackout rule being developed under Fukushima NTTF Recommendation 4.1. The NRC staff will also assess possible rulemakings in response to Fukushima NTTF Recommendation 7.2, which could potentially require all licensees to provide Class 1E (safety-grade) electric power to spent fuel makeup systems, and the emergency preparedness activities being developed for prolonged station blackout scenarios under Fukushima NTTF Recommendations 8 and 9.

However, if additional capabilities are judged to be necessary, the NRC will then consider appropriate mechanisms for requiring NPP licensees to consider long-term grid collapse scenarios in their site procedures.

Comment NEI–2

The scenario postulated by the Petitioner, where no offsite response to a nuclear emergency would be available for two years, posits a cataclysmic loss of the nation's infrastructure. In that situation, significant preparedness demands would be placed on all public and private institutions. Prior to assessing any regulatory needs, the credibility of this scenario should first be established in the broader context before more narrow regulatory needs are contemplated. A national assessment of this scenario and the need to prepare for it must first be made before any single regulatory agency begins requiring specific preparedness measures. Indeed the efforts of many different government agencies would need to be carefully coordinated and response priorities set. Otherwise, no action taken by any NRC licensee in response to this petition could be assessed for its adequacy because the availability of any response resources could not be assured absent such coordination. This coordination task would be an extremely significant task to which resources would only be committed once the credibility of the scenario was established. However, there is no such coordination underway because none of the agencies that would be involved have determined that the scenario is credible. In absence of the establishment of the basis for the credibility of this scenario, the petition lacks the basis to determine that there is a valid safety concern.

NRC Response

The NRC agrees with the comment that the long-term grid collapse scenario postulated by the petitioner would necessitate a coordinated response by various government agencies. However, the NRC disagrees with the commenter's assertion that no such coordination is underway or that such coordination does not exist, because the regulatory agencies referred to by the commenter have not determined that the scenario is credible. The NRC is currently coordinating with the National Aeronautics and Space Administration to ensure a common understanding of the technical phenomena associated with solar storms. In addition, the NRC is coordinating with the U.S. Department of Energy (DOE), the FERC, and the Federal Emergency Management Agency (FEMA) to develop both preventative and mitigating strategies to address the potential for a widespread and long-term grid collapse caused by a geomagnetic storm. Consideration of the issues raised by the petitioner necessitates further in-depth analyses. The NRC rulemaking process is a mechanism to look at these events, establish roles and responsibilities, and participate in defining the process for enhanced coordination between government agencies, should the NRC decide to develop and publish a proposed rule for public comment.

Comment NEI–3

The central argument of the petition is the claim that a spent fuel pool accident, namely zirconium ignition, poses a significant safety concern. This claim is based upon the credibility of a Long-Term loss of off-site power event based upon a new initiating event (severe space weather), and the assumption that mitigative actions (specifically diesel fuel resupply from offsite and human intervention) would not be successful in preventing spent fuel pool drain-down and subsequent zirconium ignition resulting from a long term loss of off-site power event. Despite the new information referenced by the Petitioner, the Petitioner offers no data to support the conclusion that a long term loss of off-site power event due to severe space weather is credible. Petitioner has also not established any basis to support the conclusion that actions to mitigate a long term loss of off-site power event could or would not be taken in time to prevent zirconium ignition. In both cases, the Petition is entirely speculative. Thus, the Petitioner has not demonstrated that a new and significant basis exists to challenge the NRC's prior determinations of the safety of spent fuel pools.

NRC Response

The NRC agrees with the comment that the credibility of the event postulated by the petitioner (i.e., a widespread, prolonged grid failure of sufficient magnitude that normal commercial infrastructure would not be available to resupply diesel fuel) must be established before regulatory action is taken. However, the NRC disagrees with the comment's unsupported assertion that the petition is entirely speculative. The NRC's initial evaluation of available information indicates that the likelihood of an extreme solar storm (similar to the 1859 Carrington event [1]) is plausible with a frequency in the range of once in 153 to once in 500 years (2E–3 to 6.5E–3 per year). The probability of the petitioner's postulated catastrophic grid failure, given a Carrington-like event, is not known with certainty. However, based on the NRC's review of the existing data, the NRC believes that there is insufficient information for the NRC to conclude that the overall frequency of a series of events potentially leading to core damage at multiple nuclear sites is acceptably low such that no regulatory action is needed. Thus, the NRC concludes that the petitioner's scenario is sufficiently credible to require consideration of emergency planning and response capabilities under such circumstances. Accordingly, the NRC intends to further evaluate the petitioner's concerns in the NRC rulemaking process.

Comment NEI–4

The Petition does not recognize that the issue of grid reliability and its effects on nuclear safety is already fully and adequately addressed through existing regulation. The NRC has previously made decisions regarding how the issue of grid reliability is addressed within the context of NRC regulatory authority in 10 CFR Part 50, and within the context of protecting public health and safety. The NRC regulatory structure to address grid reliability is best described in Regulatory Information Summary (RIS) 2004–5 "Grid Operability and the Impact on Plant Risk and the

[1] The Carrington event in 1859 is the largest solar storm ever recorded.

Operability of Offsite Power." In summary, issues involving grid reliability are addressed through 10 CFR 50.65, "Requirements for monitoring the effectiveness of maintenance at nuclear power plants;" 10 CFR 50.63, "Loss of all alternating current power;" 10 CFR Part 50 Appendix A, General Design Criteria (GDC) 17, "Electric power systems;" and through nuclear power plant Technical Specifications (TS) on operability of offsite power."

NRC Response

The NRC agrees that the NRC regulations and the NRC regulatory documents cited in the comment address the NRC's current approach to consideration of grid stability with respect to the safety of NPPs. However, the comment does not address the PRM's apparent underlying premise that the regulations and guidance are not adequate, or that the licensing bases for NPPs may be inadequate because they do not address a reasonably foreseeable condition attributable to natural hazards. The comment does not explain how the NRC's regulations, or the regulatory documents referenced, address the matters raised in the PRM in sufficient manner as to prevent the need for further NRC regulatory consideration.

Comment NEI–5

The Petition presents a Probabilistic Risk Assessment to conclude a long term loss of off-site power at a nuclear power facility resulting from severe space weather is a credible event. The Petitioner's assessment is based upon key inputs from the ORNL report regarding the frequency and severity of severe space weather and assumed effects on the commercial power grid. Specifically, the Petition assumes that a once in 100 year severe space weather event results in a probability of 1% per year that a 1–2 year loss of off-site power event would occur. Unfortunately, the Petition has misinterpreted the data presented in the ORNL report. In fact, the ORNL report qualifies its discussion of any potential permanent damage to the power grid, stating that such discussion is only to "provide perspectives * * * of potential level of damage that may be possible to the infrastructure.", and indicating that there is a low level of certainty in the ability to assess what the potential damage could be. Specifically, the report acknowledges the difficulty in determining what would be damaged, the extent of damage, and the complexity and duration for repairing the damage. The myriad of probabilities regarding damage to the grid and length of time a nuclear power plant might be without off-site power quite frankly are not known and likely are extremely small. Therefore, absent further scientific and technical investigation, Petitioners claims amount to nothing more than speculation and the discussion in the ORNL report should not be used to conclude that a once in 100 year severe space weather event would result in a 1–2 year loss of off-site power event. Further, it is important to note that there has never been a long term loss of electric power due to severe space weather. For the worst event of this type in modern history, the commercial power grid was restored to 83% within 11 hours, and permanent damage to transformers and other grid components was extremely small. Effects were extrapolated from this event to the postulated once in 100 year storm, however, it is not possible to determine whether a 1–2 year loss of off-site power event is a realistic consequence. Thus, the ORNL report does not demonstrate that a long term loss of off-site power due to severe space weather is a credible event.

NRC Response

The NRC agrees with the commenter's assertion that the petitioner has not conclusively demonstrated that a long-term catastrophic grid collapse is certain to result from a once-in-100-year storm, but the NRC disagrees with the comment's inference that a long-term loss-of-offsite power due to severe space weather is not a credible event. Although there is a great deal of uncertainty associated with the frequency and magnitude of solar storms, as discussed in Section IV.C, "Frequency of Geomagnetic Storms with Potential Adverse Effects on the Electrical Grid," of this document, the NRC has concluded that the expected frequency of such storms is not remote compared to other hazards that the NRC requires NPPs licensees to consider. The comment addresses the credibility of once-in-100-year storms, whereas the NRC considers initiating events with frequencies of 1E–3 years or less in the licensing of NPPs. The comment also implies that grid restoration time after a severe solar storm would typically be hours or days instead of 1 to 2 years, but the comment provides no supporting analyses of the age and vulnerability of existing transformers installed in the electrical grid to support this implied inference. Accordingly, the NRC believes that it is possible that a geomagnetic storm-induced outage could be long-lasting and could last long enough that the onsite supply of fuel for the emergency generators would be exhausted. It is also possible that a widespread, prolonged grid outage could cause some disruption to society and to the Nation's infrastructure such that normal commercial deliveries of diesel fuel could be disrupted. In such a situation, it would be prudent for licensees to have procedures in place to address long-term grid collapse scenarios. In extreme situations, it is possible that government assets could be called on to facilitate emergency deliveries of fuel to NPP sites before the fuel stored onsite is exhausted. All these issues need further research, review, and analysis before formulating mitigating actions. The NRC rulemaking process is an appropriate mechanism for consideration of the petitioner's issues.

IV. NRC Evaluation

The NRC conducted a preliminary review and analysis of the issues raised in the petition and public comments to reach a conclusion regarding the resolution of this petition. The analysis is described in the following five sections.

A. NRC Requirements for Governing Spent Fuel Pool Cooling and Provision of Electric Power for Accidents

Commercial NPPs are required to have multiple sources of offsite power and safety-related onsite sources of power, typically provided by emergency diesel generators arranged in redundant electrical trains. As specified by GDC 17, "Electric Power Systems," of appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR part 50, "Domestic Licensing of Production and Utilization Facilities," each operating reactor shall have an onsite electric power system and an offsite electric power system that supports the functioning of structures, systems, and components important to safety. The safety function for each system is to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences, and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents.

Commercial NPPs rely on the electric power transmission networks to export power, and NPPs normally use electric power from the transmission network for normal operation of plant equipment, to safely shut down the plant when required, and for accident mitigation. The existing NRC regulations consider the historically

high reliability of an electric power transmission system in maintaining the safety of the reactor and fuel stored in SFPs. However, if offsite power from the transmission network is unavailable, safety-related onsite back up power systems (typically powered by EDGs) are relied on for essential power to safely shutdown the reactor, mitigate any accidents, and provide long-term cooling for the reactor core and fuel in the SFP. These safety-related onsite power sources are typically maintained with at least a 3- to 7-day supply of fuel and lubricating oil. In addition, the NRC regulations require capabilities to withstand a station blackout and the development and implementation of strategies to maintain or restore core cooling, containment, and SFP cooling capabilities under the circumstances associated with loss of large areas of the plant due to explosions or fire. These requirements are satisfied by equipment independent of the electric power transmission network.

The spent fuel pool structure typically consists of a stainless-steel liner covering a steel-reinforced concrete structure several feet thick. The SFP structure is designed to withstand the effects of natural phenomena, including earthquakes, floods, and tornados, without loss of its leak-tight integrity. Consistent with the requirements of GDC 61, "Fuel Storage and Handling and Radioactivity Control," of appendix A to 10 CFR part 50 or similar plant-specific design criteria, SFPs are designed to prevent a significant loss of water inventory under normal and accident conditions. An inadvertent loss of coolant inventory is prevented by design, typically through the absence of drains in the SFP, the location of piping penetrations though the SFP structure well above the top of stored fuel, and the use of design features to prevent siphoning of water. A reliable forced cooling system minimizes coolant evaporation during normal operation and postulated accident conditions. When necessary, operators can provide makeup water to maintain SFP coolant inventory using any one of many makeup water systems, including safety-related systems at most operating reactors. The maintenance of an adequate coolant inventory alone is sufficient to protect the integrity of the fuel, provide shielding, and contain any minor releases of radioactivity that may result from cladding damage.

As the March 2011 events at the Fukushima Dai-ichi site demonstrated, the robust structure of the SFP and the provisions to prevent loss of coolant inventory provide substantial time to implement appropriate methods to makeup coolant inventory lost to evaporation. In most common operating configurations, the existing pool inventory is typically adequate to maintain the fuel covered with water for 1 week or more following a loss of forced cooling. Each facility safety analysis report describes the capability to provide forced cooling and makeup water using installed systems, and these systems may be operated using onsite sources of power. Diesel-driven fire pumps are available at all operating reactors and are among the design capabilities to provide makeup water to the SFP. Beyond these design capabilities, 10 CFR 50.54(hh)(2) requires licensees to develop and implement guidance and strategies intended to maintain or restore SFP cooling capabilities under the circumstances associated with loss of large areas of the plant as a result of explosions or fire. These capabilities required by 10 CFR 50.54(hh)(2) may further extend the time spent fuel can be adequately cooled using on site resources. Thus, assuming an adequate supply of fuel for permanently installed and portable emergency equipment, currently required onsite capabilities would support adequate cooling of spent fuel for weeks following loss of the offsite electric power transmission network.

As directed by the Commission in Staff Requirements Memorandum SECY–12–0025, dated March 9, 2012, (ADAMS Accession No. ML120690347), the NRC staff has undertaken regulatory actions to further enhance reactor and SFP safety as a result of recommendations developed through evaluation of early information from the March 2011 events at the Fukushima Dai-ichi site. On March 12, 2012, the NRC staff issued Order EA–12–051 (ADAMS Accession No. ML12054A679), which requires that licensees install reliable means of remotely monitoring wide-range SFP levels to support effective prioritization of event mitigation and recovery actions in the event of a challenging external event. In addition, the NRC staff issued Order EA–12–049 (ADAMS Accession No. ML12054A736), which requires that licensees develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities following a beyond-design-basis external event. Upon full implementation of these Orders at NPPs, the NRC staff believes that overall protection of public health and safety will be further increased.

B. Geomagnetic Storms and Effects on the Earth

Periodically, the earth's magnetic field is bombarded by charged particles emitted from the sun due to violent eruptions of plasma and magnetic fields from the sun's corona, known as coronal mass ejections (CME).

Solar storms generally follow the sunspot cycle and vary in intensity over the 11-year cycle. The most severe geomagnetic disturbances (GMD) during a cycle have been observed to follow the peak in sunspot activity by 2 to 3 years. Thus, electrical power system disturbances resulting from current cycle 24 are expected to peak in 2013.

Geomagnetic storms are created when the earth's magnetic field captures these ionized particles causing very slow magnetic field variations, with rise times as fast as a few seconds and pulse widths of up to an hour. The rate of change of the magnetic field creates electric fields in the earth that induce current flow in long man-made conducting paths such as power transmission networks, railway lines, and pipelines. These geomagnetically-induced currents (GIC) exit bulk-power systems through neutrals of grounded power transformers and can disrupt the normal operation of the system and even damage the transformers if the transformer core becomes saturated.

Operating experience indicates that there are two risks that result from the introduction of GICs in the bulk-power system:

(1) Damage to bulk-power system assets, typically associated with transformers; and

(2) Loss of reactive power support, which could lead to voltage instability and power system collapse.

The GICs (quasi-direct currents) that flow through the grounded neutral of a transformer during a geomagnetic disturbance cause the core of the transformer to magnetically saturate on alternate half-cycles. Saturated transformers result in harmonic distortions and additional reactive power or volt-ampere reactive (VAR) demands on electric power systems. The increased VAR demands can cause both a reduction in system voltage and overloading of long transmission tie-lines. In addition, harmonics can cause protective relays to operate improperly and shunt capacitor banks to overload. These conditions can lead to major power failures, moving the system closer to voltage collapse.

The immediate and direct impact of geomagnetic storms may be an electrical power outage. The amount of time required to restore the electrical grid

will depend upon the extent of damage to bulk-power system assets. There is a concern about the effects of a long-term power outage over extended portions of the U.S. transmission systems, during which critical services that rely on electrical power may be disrupted. For instance, the petitioner noted that the onsite fuel for backup electric power sources at NPPs would run out in several days to weeks. Furthermore, the petitioner asserted that, since the capability to resupply fuel through gasoline and diesel fuel pumps also generally relies on electrical power systems, a power blackout lasting longer than 2 to 3 days could create long-term implications for interdependent public and private infrastructures. Such a long-term power outage could interrupt communication systems, stop freight transportation, and affect the operations of major industries including fuel (oil and gas) suppliers.

In addition, potential disruptions due to societal stress could significantly hamper the ability to provide fuel resupply deliveries to nuclear power plants.

C. Frequency of Geomagnetic Storms With Potential Adverse Effects on the Electrical Grid

The petitioner references a report prepared for the Oak Ridge National Laboratory ("Metatech report") [2] that uses a frequency estimate of 1 in 100 years (1E–2/yr) for extreme space weather/geomagnetic disturbance to perform calculations that predict the likely collapse of two large portions of the North American power grid. The intensity of the storm postulated in the Metatech report, in terms of magnetic flux density per time, was 4,800 nano-Teslas/minute (nT/min). The Metatech report predicted that over 300 Extra High Voltage (EHV) transformers would be at-risk for failure or permanent damage from the event. The Metatech report concludes that, with a loss of this many transformers, the power system would not remain intact, leading to probable power system collapse in the Northeast, Mid-Atlantic, and Pacific Northwest, affecting a population in excess of 130 million.

The NRC staff investigated the assertion of 1E–2/yr frequency of occurrence of a serious geomagnetic disturbance by conducting a literature review (via Internet) to find relevant information. However, it is difficult to obtain an objective estimate for the frequency of occurrence of a "serious" disturbance, which the Metatech report says can produce magnetic flux density changes on the order of 4,800 nT/min. As noted in a report prepared for the United States Department of Homeland Security (DHS),[3] there is currently no framework for developing a hazard curve (e.g., annual probability of exceeding a given magnetic flux density rate-of-change) for geomagnetic storms.

There are several factors making it difficult to objectively predict the frequency of occurrence of a given level of a geomagnetic event in terms of magnetic flux density change over time (i.e., to produce an appropriate hazard curve), including:

- Paucity of recorded data;
- Relative recentness of monitoring the appropriate parameter (nT/min);
- Lack of correlation between the magnetic flux disturbance intensity (in nT) and its time rate of change (nT/min); and
- Geographical variations that affect how much a given geomagnetic storm impacts a selected location.

The Metatech report provides estimates of the frequency of severe geomagnetic storms. Speculating from observed data, and taking into account that about one-third of the storms would be positioned to adversely impact the United States, Metatech concluded that a storm producing –2400 nT/min could impact the U.S. grid about every 30 years and that a –5,000 nT/min storm could be experienced every 100 years.

An article in *Spectrum* magazine [4] provided annual probabilities of magnetic storms producing more than 300 nT/min in North America. This intensity (rate-of-change of magnetic flux density) is closer to the –480 nT/min experienced by Quebec Hydro in 1989. The annual probabilities set forth in *Spectrum* ranged from 2E–3 at the most vulnerable geographic locations to 2E–5 in the least vulnerable. Most of the northern United States would fall into the 1E–3 annual probability range.

The largest recorded geomagnetic storm, the Carrington event of 1859, may have exceeded 5,000 nT/min. However, this event marked the beginning of scientific observation and data recording of these magnetic storms. In the 153 years since that event, many magnetic storms have been experienced, but none at that level. In order to calculate a meaningful estimate of the return period for such an event, an appropriate time period would have to be assumed. However, there may be a way to estimate the intensity of geomagnetic storms that occurred before the Carrington event. As stated in a *Scientific American* article,[5] ice-core data from Greenland and Antarctica demonstrate sudden jumps in the concentration of trapped nitrate gases, which in recent decades appear to correlate with known blasts of solar particles. The researchers stated that the nitrate anomaly found for 1859 stands out as the biggest of the past 500 years, with the severity roughly equivalent to the sum of all the major events of the past 40 years. Using 153 years as a lower-bound return period and 500 years as an alternative view yields a frequency for experiencing a Carrington-sized event ranging from 2E–3 to 6.5E–3 per year.

Additionally, the NRC establishes its expectation, in GDC 2, "Design bases for protection against natural phenomena," that structures, systems, and components important to safety at nuclear power plants are designed to withstand the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. Solar storms are not specifically identified as natural hazards in GDC 2, but the information currently available to the NRC indicates that the frequency of these storms may be consistent with other natural hazards within the intended scope of the GDC.

Based on this limited analysis, the NRC concludes that the frequency of occurrence of an extreme magnetic storm that could result in unprecedented adverse impacts on the U.S. electrical grid is not remote compared to other hazards that the NRC requires NPP licensees to consider. Accordingly, it is appropriate for the NRC to consider regulatory actions that could be needed to ensure adequate protection of public health and safety during and after a severe geomagnetic storm.

D. Experience With the Effects of Geomagnetic Storms on the Electrical Grid

The Oak Ridge National Laboratory (ORNL) Report ORNL–6665, "Electric Utility Experience with Geomagnetic Disturbances," published in September

[2] Metatech Report Meta-R–319, "Geomagnetic Storms and Their Impacts on the U.S. Power Grid," John Kappenman (January 2010).

[3] "Geomagnetic Storms," prepared by CENTRA Technology, Inc., on behalf of the Office of Risk Management and Analysis, United States Department of Homeland Security (January 14, 2011).

[4] Molinski, Tom S., *et al.*, "Shielding Grids from Solar Storms," IEEE Spectrum, November 2000.

[5] Odenwald, Sten F. and James L. Green, "Bracing the Satellite Infrastructure for a Solar Superstorm," Scientific American (July 28, 2008).

1991,[6] discusses electric utility experience with geomagnetic storms to determine the probable impact of severe geomagnetic storms. The report states, as follows:

> The first reports of geomagnetic storm effects on electric power systems in the United States resulted from the solar storm on March 24, 1940 during solar cycle 17. Disturbances were reported in the northern United States and Canada. The Philadelphia Electric Company system experienced reactive power swings of 20% and voltage surges. In the same period, two transformers in this system and several power transformers on the Central Maine Power Co. and Ontario Hydro system tripped out. The Consolidated Edison Company in New York City also experienced voltage disturbances and dips up to 10% due to the large increase in reactive power on that system. Since that time, power system disturbances have been recorded for geomagnetic storms that occurred during solar cycles that followed. Some of the more severe disturbances occurred on August 17, 1959 (solar cycle 19); August 4, 1972 (solar cycle 20); and March 13, 1989 (solar cycle 22).

Grid Issues: The ORNL Report details circuit breaker failures or inadvertent circuit breaker operations resulting in degradation of transmission systems. Specifically, the report states:

> Past mishaps attributed to GIC include the tripping of circuit breakers from protection system malfunctions. On September 22, 1957, a 230-kV circuit breaker at Jamestown, North Dakota, tripped because of excessive third harmonic currents in the ground relays produced by saturated transformer cores. On November 13, 1960, a severe geomagnetic disturbance caused 30 circuit breakers to trip simultaneously on the 400–220–130-kV Swedish power system. In October 1980 and again in April 1986, a new 749-km 500-kV transmission line linking Winnipeg, Manitoba, with Minneapolis-St. Paul, Minnesota was tripped by protection system malfunctions due to GICs.

The report further discusses malfunctions in capacitor banks and static VAR (reactive power) compensators, which provide rapid voltage regulation and reactive power compensation via thyristor-controlled capacitor banks. Cascading failures of voltage control devices can result in grid instability and eventual blackout. The extent of blackout depends on the magnitude of the GICs and the compensatory actions taken by grid operators. The grid becomes unstable due to false relay operations resulting in unnecessary breaker trips, which cause isolation of transmission lines or voltage support equipment. Transformers may also be damaged when GIC passes through some transformers damaging the insulation and resulting in isolation of associated transmission lines. Isolation of transmission lines can result in grid collapse.

Transformers: The ORNL Report further looks at the impact on large transformers and states, as follows:

> A few transformer failures and problems over the decades have been attributed to geomagnetic storms. In December 1980, a 735-kV transformer failed eight days after a geomagnetic storm at James Bay, Canada. A replacement 735-kV transformer at the same location failed on April 13, 1981, again during a geomagnetic storm. However, analysis and tests by Hydro-Quebec determined that GIC could not explain the failures but abnormal operating conditions may have caused the damage. The failures of the generator step-up transformers at the Salem Unit 1 nuclear generating station of Public Service Electric & Gas Co. during the March 13, 1989, storm probably have attracted the most attention. The 288.8/24-kV single-phase shell-form transformers, which are rated at 406 MVA, are connected grounded-wye. The damage to the transformers included damage to the low-voltage windings, thermal degradation of the insulation of all three phases, and conductor melting. The Salem plant occupies a vulnerable position in the power system network with respect to GICs since it is located at the eastern end of a long EHV transmission system traversing a region of igneous rock (on the Delaware river near the Atlantic Ocean) and is therefore very well grounded. (This position thus acts as a collection point for ground currents since the eastern end of the power network is close to the Atlantic Ocean and that station has a very low grounding resistance.) During the March 13th disturbance, Salem Unit 1 experienced VAR excursions of 150 to 200 MVAR. Additional VARs were consumed by the saturated step-up transformers.

Transformer failures in South Africa are documented in several reports associated with geomagnetic storms. A technical paper[7] entitled "Transformer failures in regions incorrectly considered to have low GIC-risk," by C. T Gaunt and G. Coetzee, cites failures or degradation of large transformers. Specifically, the paper notes:

> After the severe geomagnetic storm at the beginning of November 2003, often referred to as the 'Halloween storm,' the levels of some dissolved gasses in the transformers increased rapidly. A transformer at Lethabo power station tripped on protection on 17 November. There was a further severe storm on 20 November. On 23 November the Matimba #3 transformer tripped on protection and on 19 January 2004 one of the transformers at Tutuka was taken out of service. Two more transformers at Matimba power station (#5 and #6) had to be removed from service.

Recent analysis by Metatech estimates that in a once-in-100-year geomagnetic storm, more than 300 large EHV transformers would be exposed to levels of GIC sufficiently high to place these units at risk of failure or permanent damage requiring replacement.[8] The GICs contribute to the heat-related degradation that may affect transformer insulation. An older transformer design, known as "Shell" type (as discussed in the Salem failure), was susceptible to overheating due to circulating currents. Recent studies indicate that a few isolated cases of premature transformer failures that were attributed to accelerated GIC-related degradation have been limited to this special design. Transformer manufacturers consider modern "core" type transformer designs to not be prone to GIC-related premature or catastrophic failures.[9]

Large transformers are very expensive to replace and few spares are available. Manufacturing lead times for new equipment range from 12 months to more than 2 years. Such large-scale damage to these EHV transformers would likely lead to prolonged restoration and long-term shortages of supply to the affected regions. Prototype rapid replacement transformer concepts are being evaluated but have only had minimal field testing. While promising, there are currently no plans in place to develop the stockpile of such spare transformers that would have to be available, and transformer replacement would still take 6 weeks or longer. Utilities are working to build up quantities of internally managed spares (e.g., by keeping the highest quality replaced units during regularly scheduled replacements), but this will not provide sufficient quantities to alleviate the concern.

Current Industry and Agency Efforts: The electric utilities and Federal agencies (FERC, DOE, NERC, NASA) have expended considerable resources in an attempt to quantify the impacts of the severe geomagnetic storm threats to the U.S. power grid. The efforts are focused on developing models that translate the geomagnetic field environment into specific impacts on the operation of the electric power grid.

[6] Available at *http://www.ornl.gov/~webworks/cpr/v823/rpt/51089.pdf.*

[7] Available at *http://www.labplan.ufsc.br/congressos/powertech07/papers/445.pdf.*

[8] It should be noted that the NERC's Interim 2012 Reliability Assessment report, based on discussions with transformer manufacturers and some technical papers published by industry experts, implicitly concludes that the worst case scenario of long-term grid collapse would not be a likely result of a severe geomagnetic event.

[9] IEEE paper "Effects of GIC on Power Transformers and Power Systems" R.Girgis, Fellow IEEE, K. Vedante, Senior Member IEEE ABB Power Transformers St. Louis, MO, USA; available at *http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06281595.*

The NERC released an Interim 2012 Special Reliability Assessment report entitled "Effects of Geomagnetic Disturbances on the Bulk Power System" NERC Report." [10] Based on an assumed frequency of a once-in-100-year geomagnetic event, the NERC report indicates that potential damage to EHV transformers of recent design is of a low probability, and thus challenges the assertions of the Metatech report that 300 large EHV transformers would be at risk of failure. The report also indicates that GIC-related insulation damage is most likely to result in failure of transformers near the end of their life, or in transformers of earlier designs such as shell-type pre-1972 with brazed windings that may have high circulating currents. The loss of one or two EHV transformers (greater than 345-kV on the high side) would rarely challenge bulk system reliability. Also, the failure or loss of a number of large High Voltage transformers, electrically remote from the EHV system, would not have a significant impact on the bulk-power system capability for an extended duration. The report states: "The most likely consequence of a strong GMD and the accompanying GIC is the increase of reactive power consumption and the loss of voltage stability. The stability of the bulk-power system can be affected by changes in reactive power profiles."

The NERC report implicitly concludes that the worst case scenario of long-term grid collapse would not be a likely result of a severe geomagnetic event. However, the NRC notes that the NERC's concept of a "rare" event for purposes of electrical grid reliability is different from the NRC's when considering the safe design of nuclear power reactors. For example, the NERC report refers to a "severe storm" as once-in-100 years and a "serious storm" as once in 10 years. By contrast, the NRC's requirements regarding consideration of natural hazards for the design of NPPs, as set forth in GDC 2, establish a much more stringent consideration of natural hazards:

Criterion 2—*Design bases for protection against natural phenomena.* Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the *most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated,* (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.

The NERC's implicit conclusion—that grid collapse caused by simultaneous catastrophic failure of multiple EHV transformers is not likely during a large GIC event—must be interpreted with these frequencies in mind. Therefore, the NRC staff does not find that conclusion compelling, absent data or more information on how this assumption has been validated.

The literature on mitigating risk of geomagnetic storm effects on electric power systems is very consistent, focusing on two basic methods of reducing either the vulnerability or the consequences. The first risk mitigation method is to harden equipment to reduce its vulnerability to GIC; the second is to establish operational procedures to reduce the impact of GIC. Electric power utilities can harden their systems against GICs through passive devices or circuit modifications that can reduce or prevent the flow of GICs. Hardening is most effective for critical transformers that play a major role in power transmission, which are very expensive and time-consuming to replace. In response to the March 13, 1989, blackout event when a geomagnetic storm affected Canadian and U.S. power systems, Hydro Quebec, a Canadian utility, implemented hardening measures such as transmission line series capacitors and transformer protection that cost more than $1.2 billion in Canadian dollars. The cost benefits of these measures are indeterminate, because there has not been a storm of similar magnitude to challenge the system, and the uncertainties or variable factors associated with analyzing GICs raise questions about the effectiveness of the measures.

In the U.S., a number of utilities have GMD response operating procedures that are triggered by forecast information and/or field GIC sensors. Existing response procedures generally focus on adding more reactive power capability and unloading key equipment at the onset of a GMD event. The NERC report concludes that more tools are needed for planners and operators to determine the best operating procedures to address specific system configurations. Currently, the FERC has directed the NERC to develop reliability standards that addresses the impact of geomagnetic disturbances on the reliable operation of the bulk power system (77 FR 64935).

Nuclear Power Plant Operation and Shutdown: In the United States, the minimum requirements for electrical power for plant operation and safe shutdown are delineated in 10 CFR part 50, appendix A, GDC 17. The grid provides the offsite or the preferred power source and redundant divisions of onsite power distribution system support plant operation and safe shutdown capability. In the event that offsite power is lost, redundant onsite electrical power sources (e.g., EDGs) are available to support plant shutdown. Geomagnetic storms have the potential to degrade both offsite and onsite power systems. The offsite power system may be lost due to loss of reactive power support or bulk-power system asset damage (e.g., transformer damage). The onsite power system is vulnerable to shortage of fuel oil for EDGs after onsite stored capacity has been depleted.

Nuclear Plant Assets Susceptible to GIC Damage: A typical NPP single unit configuration consists of one fully rated or two 50 percent rated main step up transformers (MT), two unit auxiliary transformers (UAT), and two start up or standby transformers (SAT). During normal plant operation, the MTs are fully loaded and connected to the high voltage transmission network. These MTs are vulnerable to GIC and subharmonics generated in the transmission network. The MTs are fully loaded when the NPP is at-power and they have a grounded neutral that provides a path for GIC, and are therefore susceptible to core saturation and thermal damage. The Salem Nuclear Generating Station transformers, identified in the ORNL report as examples of damage due to GICs, were main step up transformers. From a nuclear safety perspective, the MTs can be used to supply offsite power to plant auxiliaries (via a backfeed scheme) but are generally not the preferred source of power for plant shutdown. The nuclear plant operators (NPO) in areas most vulnerable to GIC-related transformer damage have procedures to reduce plant power output (hence the load on MTs) when solar storm warnings are issued by the National Oceanographic and Atmospheric Administration Space Weather Prediction Center.

During normal plant operation, the UATs supply power to the plant auxiliary system and are connected to the output of the main generator. These transformers, though fully loaded, are not directly connected to the grid, operate at lower voltages, and are "shielded" from GICs by the MTs, which are the interface point between the NPP and the grid. Therefore, these transformers are not expected to be

[10] Available at *http://www.nerc.com/page.php?cid=4%7C61.*

vulnerable to GICs and will be available for plant shutdown as long as the transmission network in the vicinity of the plant is stable.

The source of offsite power required by GDC 17 for plant shutdown is normally through the SATs. During normal operation, these transformers are energized and lightly loaded. The minimum rating of SATs exceeds the total power requirements of safety significant loads. There are a few plants that use the SATs for supplying all station auxiliary loads during normal operation. In these cases, there should be a margin between the normal loading and maximum rating of the transformers to accommodate additional safety-related loads that would be sequenced by an accident signal. Therefore, the transformers should be able to handle some overloading or heating effects related to GICs during normal operation. Though these transformers have grounded neutrals and are connected to the EHV transmission network, they are not expected to be vulnerable to GIC damage, as the heating effects would be minimal due to the light load on the transformers during normal operation. To date, no SAT failures have been attributed to GIC-related damage. Since the SATs are the normal source of offsite power to the NPPs for safe shutdown during postulated accidents and design basis events and since they would not experience significant GIC-related overheating or damage, the offsite power capabilities of NPPs are not expected to be degraded by solar storms.

This generalized evaluation of transformers and offsite power system designs is provided to illustrate the potential system vulnerability to geomagnetic storms. For long-term impact on transformers, the NRC staff is following industry developments for transformers in the bulk-power transmission systems. If the NERC and the FERC mandate that certain types of transformers or certain critical transformers are susceptible to GIC-related failures and that load reduction will reduce the potential for catastrophic failures, then the NRC will take appropriate actions for nuclear plants that operate with startup transformers fully loaded. The NRC staff will review plant-specific designs to establish if any start-up transformers are operating close to their nominal rating during normal plant operation and are susceptible to GIC damage.

The onsite power system EDGs are normally in a standby state and are not expected to be affected by solar storms. In the unlikely event that EDGs are operating in test mode during a solar event, the grounded neutrals of station transformers (UATs or SATs) are expected to drain GICs into the ground, thus shielding the EDGs. The NPOs test EDGs at nominal rating for a few hours during normal plant operation. The EDGs have a nominal rating and a short-term overload capacity. Thus, any GICs that enter the plant's electrical system during EDG operation should not result in excessive overheating of the generator windings. The EDGs are designed for extended operation and have the capability of mitigating the consequences of an accident and supporting spent fuel pool loads. In the event of loss of offsite power, the EDGs automatically start and energize safe shutdown buses of the plant. The design basis of most U.S. plants requires onsite storage of EDG fuel oil capability for 7 days of operation without replenishment. Many plants also have additional fuel oil stored for non-safety significant equipment such as auxiliary boilers that might be available for EDG operation. The NPOs typically have agreements with fuel oil suppliers (in some cases refineries) to support fuel oil deliveries on short notice. If an offsite power blackout lasts longer than 7 days and creates long-term implications for freight transportation and emergency resources of the NPOs, then Federal emergency resources would have to coordinate relief supplies to critical facilities. The relief supplies would include fuel oil for nuclear plants.

Offsite Power Source Vulnerability: The NPP offsite power systems are vulnerable to grid perturbations resulting from GMDs. The scope of protecting transmission networks is beyond the jurisdiction of the NRC. The NRC can recommend protective/precautionary measures that NPPs and grid operators can implement when the magnitude of predicted solar storms is estimated to be potentially damaging to systems in the vicinity of NPPs.

The correlation between the magnitude and duration of geomagnetic storms and the potential degradation of the transmission system is the subject of several ongoing studies between the NERC, FERC, Electric Power Research Institute, and national research institutes such as ORNL. The Metatech report, entitled "Geomagnetic Storms and Their Impacts on the U.S. Power Grid," discusses methods that can be used to comprehensively assess the vulnerability of the U.S. power grid to the geomagnetic storm environment produced by solar activity. These modeling techniques have been used to replicate geomagnetic storm events and perform detailed forensic analysis of geomagnetic storm impacts to electric power systems. It should be noted that these modeling techniques are in a developmental stage. There is no industry standard or model that has been endorsed by a nationally recognized body. The capability may also be applied towards providing predictive geomagnetic storm forecasting services to the electric power industry and specifically to NPOs. The NPOs can then take appropriate actions, based on solar storm warnings, to minimize the risk of damage to nuclear plant assets.

The NERC report considers the most likely outcome of a major solar storm to be grid instability caused by excessive reactive power demand. This scenario results in protective relays separating critical sections of the power grid and potential large scale blackout but limited equipment (transformer) damage within localized areas with highest GIC. Recovery from such an event is expected to be relatively quick (within a day or two) and as such should not be a major concern for nuclear plant safe shutdown capability. In the event that the reactive power demands do not result in separation of the grid system, the cascading effects of the GIC through critical transformers may result in large scale equipment damage and subsequent long-term shutdown of the extra high voltage transmission network due to the long replacement time necessitated by the long lead time for manufacture and installation of large transformers. Nuclear power plants in the blacked out area would require external resources to support shutdown capability and fuel pool cooling for an extended duration.

E. Federal Government Coordination and Emergency Response

A number of different Federal government agencies are involved in assessing the risk to the U.S. power grid from geomagnetic storms. While it is recognized that CME events can pose a serious threat, a sufficient technical basis for the frequency and impact of significant CME events has not been developed to the level typically expected by the NRC for other natural hazards (floods, earthquakes, hurricanes, tornadoes, etc.). The FEMA has promulgated a basis for the development of contingency plans for a significant CME.

The FEMA's planning efforts are captured in the National Response Framework (NRF),[11] which is a guide to how the Nation conducts all-hazards response. It is built upon scalable,

[11] Available at *http://www.fema.gov/national-response-framework.*

flexible, and adaptable coordinating structures to align key roles and responsibilities across the Nation. It describes specific authorities and best practices for managing incidents that range from the serious (but purely local) to large-scale terrorist attacks or catastrophic natural disasters. Within the NRF are annexes that plan the emergency response for various infrastructure sectors. "Emergency Support Function #12-Energy Annex" is the annex relevant to a CME and its effects upon the electrical power grid, and the DOE is the lead agency for coordinating the required Federal response with the NRC as a support agency.

The NRC has an extensive and well-practiced emergency response capability. The NRC response is practiced several times a year in conjunction with inspected licensee exercises. The NRC response organization focuses on protection of the public and the support of NPP needs to mitigate accidents. In the event of a damaged electrical grid, the NRC Operations Center could be engaged in responding to one or more NPPs (and perhaps other licensees) located in the area. Initially, the NPP would only be in the lowest level of emergency because onsite emergency generators are expected to operate and supply power to safety systems. However, as the loss of offsite power continues to the point when fuel supply is challenged, the NRC would consider the need to activate its response capabilities in order to ensure public health and safety with respect to the impacted nuclear plant(s).

The normal progression of emergency response is that the plant operator (NRC licensee) would solve its own logistical needs through commercial arrangements. Should this not be possible due to legalities or degradation of commercial supply capabilities, the licensee would then call upon local offsite response organization support, such as local law enforcement agencies and fire departments. Local authorities might be able to assist with the logistics and/or prioritization of fuel supply, but generally they would not have any transport equipment. When an emergency exceeds local response capabilities, the state is then called upon for assistance. If a geomagnetic storm resulted in a long-term loss of the electrical grid, local authorities would likely require state assistance; this could involve the National Guard and/or assistance from neighboring states or regions to acquire transport equipment and fuel supplies for emergency generators. Local priorities would likely be provided to the state response organization for disposition. Finally, if the emergency situation exceeds state capabilities, then Federal response could be requested through DHS and FEMA.

Throughout any accident at a licensed facility, the NRC would remain in direct contact with the licensee and would be aware of the status of each nuclear plant, including availability of electrical power and fuel oil. Should a licensee need logistical support, the NRC could facilitate that support. Further, nuclear plant licensees can obtain emergency support through corporate, sister plant, and industry assets. As a response to the Fukushima accident, licensees are cooperatively developing regional emergency equipment depots. However, this capability is not in place and may not adequately address fuel supply and transport issues associated with a long-term grid collapse.

The FEMA recognizes the significant impact a CME-induced grid collapse would have on a wide range of infrastructure with public safety concerns and recognizes that nuclear power plants would be one of the many important concerns. To address this concern, the FEMA is considering the potential impact of CMEs as part of an overall concept of addressing all types of impacts on the critical infrastructure.

V. Conclusion

Recent experience and associated analyses regarding space weather events suggest a potentially adverse outcome for today's infrastructure if a historically large geomagnetic storm should recur. The industry and the FERC are considering whether EHV transformers that are critical for stable grid operation should be hardened to protect them from potential GIC damage and whether existing procedures for coping with a GIC event require significant improvements. The transformers required for offsite power for nuclear plants are normally in a standby state or have built-in design margins and are unlikely to be degraded by GICs. The safe shutdown capability of NPPs is not an immediate concern because the onsite EDGs can provide adequate power. In addition, the near-term actions (including a revised station blackout rulemaking (RIN 3150–AJ08, NRC–2011–0299) currently underway in response to the event at the Fukushima Dai-ichi nuclear power plant on March 11, 2011, are expected to include deployment of resources from remote locations to cope with loss of offsite and onsite power for an extended duration. However, in the event of a widespread electrical transmission system blackout for an extended duration (beyond 7 days and up to several months), it may not be possible to transport these and other necessary offsite resources to the affected NPPs in a timely manner. Thus, government assistance (local, state, or Federal) may be necessary to maintain the capability to safely shutdown nuclear plants and cool spent fuel pools in the affected areas. Prior planning is needed to efficiently and effectively use government resources to ensure protection of public health and safety. Current NRC regulations do not require power reactor licensees to undertake mitigating efforts for prolonged grid failure scenarios that could be caused by GICs resulting from an extreme solar storm. Thus, the NRC concludes that the issues and concerns raised by the petitioner need to be further evaluated.

To that end, the NRC will consider the issues raised in the petition in the NRC rulemaking process. The NRC will initiate the rulemaking process for development of a regulatory basis in a phased approach. Initially, the NRC will monitor the progress of several ongoing and potential regulatory activities. The NRC staff will monitor the implementation of Order EA–12–049, which requires that licensees develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities following a beyond-design-basis external event, and the ongoing enhancements to the station blackout rule being developed under Fukushima NTTF Recommendation 4.1. The NRC staff will also monitor possible rulemakings in response to Fukushima NTTF Recommendation 7.2, which could potentially require all licensees to provide Class 1E (safety-grade) electric power to SFP makeup systems, and the activities being developed for prolonged station blackout scenarios under Fukushima NTTF Recommendations 8 and 9. If an assessment of the progress in these areas concludes that the efforts are not likely to address the diesel generator fuel depletion and resupply issue raised by the petition, then the NRC will begin work to develop a regulatory basis to address the extensive grid outage scenario that could potentially be caused by an extreme solar storm.

Preparation of a proposed rule for public comment and publication in the FR would begin only if a viable regulatory basis is developed. If the NRC proceeds with a proposed rule, the NRC will address the comments received in favor of the PRM. In addition, the petitioner's issue of 2 years unattended water makeup of SFPs would be

addressed as part of that rulemaking action.

If the effort to establish the regulatory basis for this rulemaking does not support the issuance of a proposed rule, then the NRC will issue a supplemental FRN that addresses why the petitioner's requested rulemaking changes were not adopted by the NRC and addresses the comments received in favor of the PRM. Finally, with the publication of this FRN detailing the NRC's decision to consider, in a phased approach, the PRM issues in the NRC rulemaking process, the NRC closes the docket for PRM–50–96.

Although outside the scope of this PRM, it should be noted that the NRC, as a part of its core mission to protect public health and safety, is updating its previous evaluation of the effects of geomagnetic storms on systems and components needed to ensure safe shutdown and core cooling at nuclear power reactors.

VI. Resolution of the Petition

The NRC will review and analyze the underlying technical and policy issues relevant to the PRM and the comments submitted in support of the PRM in the NRC rulemaking process, to address the petitioner's requested rulemaking changes and reliable emergency systems capable to operate for a period of 2 years without human intervention and without offsite fuel resupply. If this phased utilization of the NRC rulemaking process results in the development of a regulatory basis sufficient for a proposed rule, then a proposed rule will be prepared for publication and public comment. If a regulatory basis sufficient for a proposed rule is not feasible, then a supplemental FRN explaining this result will be published. Thus the docket for PRM–50–96 is closed.

Dated at Rockville, Maryland, this 3rd day of December 2012.

For the Nuclear Regulatory Commission.

Michael R. Johnson,

Acting Executive Director for Operations.

[FR Doc. 2012–30452 Filed 12–17–12; 8:45 am]

BILLING CODE 7590–01–P

DEPARTMENT OF THE TREASURY

Internal Revenue Service

26 CFR Part 301

[REG–141066–09]

RIN 1545–BL08

Awards for Information Relating To Detecting Underpayments of Tax or Violations of the Internal Revenue Laws

AGENCY: Internal Revenue Service (IRS), Treasury.

ACTION: Notice of proposed rulemaking.

SUMMARY: These regulations provide comprehensive guidance for the award program authorized under Internal Revenue Code (Code) section 7623, as amended. The regulations provide guidance on submitting information regarding underpayments of tax or violations of the internal revenue laws and filing claims for award, as well as on the administrative proceedings applicable to claims for award under section 7623. The regulations also provide guidance on the determination and payment of awards, and provide definitions of key terms used in section 7623. Finally, the regulations confirm that the Director, officers, and employees of the Whistleblower Office are authorized to disclose return information to the extent necessary to conduct whistleblower administrative proceedings. The regulations provide needed guidance to the general public as well as officers and employees of the IRS who review claims under section 7623. This document also provides notice of a request for a public hearing on the proposed regulations.

DATES: Electronic or written comments and requests for a public hearing must be received by February 19, 2013.

ADDRESSES: Send submissions to CC:PA:LPD:PR (REG–141066–09), Room 5203, Internal Revenue Service, PO Box 7604, Ben Franklin Station, Washington, DC 20044. Submissions may be hand-delivered Monday through Friday between the hours of 8 a.m. and 4 p.m. to CC:PA:LPD:PR (REG–141066–09), Courier's Desk, Internal Revenue Service, 1111 Constitution Avenue NW., Washington, DC, or sent electronically, via the Federal eRulemaking Portal at *www.regulations.gov* (IRS REG–141066–09).

FOR FURTHER INFORMATION CONTACT: Concerning the proposed regulation, Meghan M. Howard, at (202) 622–7950; concerning submissions of comments and requests for a public hearing, Oluwafunmilavaio Taylor, at (202) 622–7180 (not toll-free numbers).

SUPPLEMENTARY INFORMATION:

Background

Section 406 of the Tax Relief and Health Care Act of 2006, Public Law 109–432 (120 Stat. 2922), enacted on December 20, 2006, amended section 7623 of the Code on the payment of awards to certain persons who provide information to the Internal Revenue Service relating to the detection of underpayments of tax and violations of the internal revenue laws. Section 406 redesignated the existing statutory authority to pay awards at the discretion of the Secretary of the Treasury as section 7623(a), and it added a new provision regarding awards to certain individuals as section 7623(b). Generally, section 7623(b) provides that qualifying individuals will receive an award of at least 15 percent, but not more than 30 percent, of the collected proceeds resulting from the action with which the Secretary proceeded based on the information provided to the IRS by the individual. Section 406 also addressed several award program administrative issues and established a Whistleblower Office within the IRS, which operates at the direction of the Commissioner, analyzes information received under section 7623, as amended, and either investigates the information itself or assigns the investigation to the appropriate IRS office.

In Notice 2008–4, 2008–1 CB 253 (January 14, 2008) (see § 601.601(d)(2)(ii)(*b*) of this chapter), the IRS provided guidance on filing claims for award under section 7623, as amended. In the notice, the IRS recognized that the award program authorized by section 7623(a) had been previously implemented through regulations appearing at § 301.7623–1 of the Procedure and Administration Regulations. The Internal Revenue Manual (IRM) provided additional guidance to IRS officers and employees on the award program authorized by section 7623(a). The notice provided that the IRS would generally continue to follow section 301.7623–1 and the IRM provisions for claims for award within the scope of section 7623(a), subject to certain exceptions listed in the notice. The notice also provided, however, that the regulations would not apply to the new award program authorized under section 7623(b). Instead, the notice provided interim guidance applicable to claims for award submitted under section 7623(b).

On March 25, 2008, the Treasury Department (Treasury) and the IRS

Appendix 2 Letter from Dr. George Baker

George H. Baker III, Ph.D.
3305 Hemlock Street
Harrisonburg, VA 22801

18 December 2012

FERC Commissioners
Federal Energy Regulatory Commission
Office of Electric Reliability
888 First Street, NE
Washington, DC 20426

Subject: Comments on Notice of Proposed Rulemaking ("NOPR"), Docket No. RM12-22-000

Dear FERC Commissioners:

I enthusiastically applaud your decision to issue the subject Notice of Proposed Rulemaking. I am especially impressed by your explicit requirement for physical protection of the grid to be part of the rulemaking. You are to be commended for your long view of the threat to the North American electric power grid in contrast to human tendency to focus on short-term interests. Industry is understandably swayed by the familiar, the convenient, and the bottom line (like it or not, familiarity and profitability are the touchstones of acceptability – strategic advantage goes to the acceptable). Notwithstanding the lure of procedural solutions, the serious, existential consequences for our national life services and governance argue for hard-pursuit of physical protection solutions advocated in your proposed rulemaking. It is not just the survivability of our electric power infrastructure that is at stake; almost all of our critical infrastructure services will cease should the power grid fail.

It is true that operational procedures will helpful in responding to severe GMD and EMP effects should adequate advance warning be available. However, likely scenarios exist where warning times will be short (minutes) or absent, neutering the efficacy of operational work-arounds. In addition, given the economic loss and liabilities associated with industry-initiated load shedding procedures, utilities are and will be understandably reluctant to execute such procedures. The fact that insurance policies do not cover losses from human initiated load shedding weighs heavily in industry response decision-making here. This reluctance was demonstrated during the August 2003 Northeast blackout.

I encourage you to address both EMP and GMD effects in the rulemaking process. Both EMP and solar storm currents will damage transformers over large regions of the electric grid. These components are expensive, have long lead times, are difficult to move and thus require months to years to replace. Because of its broad-band nature, EMP will also cause failures of grid communication and SCADA systems. Because EMP protection addresses both fast (E1) and slow (E3) GMD-like transients, EMP

protection will also protect the grid against GMD effects. Since GMD protection addresses only slow transients, the converse is not true.

By way of encouragement, we know how to physically protect systems against wide-area electromagnetic effects. EMP protection has been implemented and standardized by DoD on a host of systems. Because of their northerly latitudes, the electric industry in Great Britain, Canada, and the Scandinavian countries have experienced severe solar storm GMD effects and have developed and proved effective countermeasures.

Installation of blocking devices in the neutral-to-ground conductors of large electrical distribution transformers will significantly reduce the probability of damage from solar storms and the slow E3 component of EMP. Transformer protection against E1 overvoltages is achievable by installing common metal-oxide varistors (MOVs) on transformers from each phase to ground.

EMP protection methods for communication and control facilities have been developed and implemented by DoD since the 1960s and are well documented (ref. MIL-STD-188-125-1, MIL-STD-188-125-2, MIL-HDBK-423). The identical methods are applicable for power grid communication and supervisory control and data acquisition (SCADA) systems. Engineering approaches include use of shielded enclosures, provision of backup power, standard grounding techniques, installation of overvoltage protection devices and filters on penetrating conductors, and good cable management procedures. Costs for protecting the power grid are a micro-fraction of the value of the systems and services and risk.

The House Committee investigating the response to Hurricane Katrina reflected on the 9/11 Commission's finding that the most important failure was one of imagination, and found that the Katrina disaster was caused essentially by a failure of initiative. Your Notice of Proposed Rulemaking exhibits both imagination and initiative and is a crucial first step to spur action on the challenging effects of wide-area electromagnetic effects on the North American Power Grid. My hope is that public-private cooperation will prevail in developing low-risk hardware protection of our most critical infrastructure system.

Sincerely,

George H. Baker III, Ph.D.
Professor Emeritus, James Madison University
Principal Staff, Commission to Assess the Threat to the United States from Electromagnetic Pulse
Board of Directors, Foundation for Resilient Societies.

Appendix 3 Presentation: EMP Knots Untied

EMP Knots Untied: Some Common Misconceptions about Nuclear EMP

George H. Baker
Professor Emeritus, James Madison University
Principal Staff, Congressional EMP Commission
Board of Directors, Foundation for Resilient Societies

The author was originally approached to make a presentation to the 2012 DuPont Summit on the benefits of microgrids for mitigating the effects of EMP and solar storms. On reflection, knowing the audience would be an exceptional mix of technical and policy leaders, he suggested that it might be more a propos to lay to rest misconceptions regarding the EMP phenomenon, its effects on systems and the consequences of those effects. The author is grateful that this topic was accepted as part of the DuPont Summit agenda.

The author had no difficulty immediately listing a dozen misconceptions about EMP encountered during discussions with both technical and policy experts, in press reports, on preparedness websites, and even embedded in technical journals. Because many aspects of the EMP generation physics and its effects are obscure and non-intuitive, misconceptions are inevitable.

The wide-area, ubiquitous effects of EMP and the numbers of systems potentially affected makes it convenient to adopt misconceptions that avoid the need for action. Denying the seriousness of the effect appears perfectly responsible to many stakeholder groups. On the other extreme, doomsday hyperbole is also present in some camps.

Misconceptions representing over- and under-emphasizing hyperbole have served to deter action in the past. Downplaying the threat places EMP preparedness on the back-burner compared to other effects. Exaggeration of the threat causes policy-makers to dismiss arguments, ascribing them to the "chicken-little" syndrome.

Given the allotted 15 minute Summit presentation time, the author has limited the present discussion to his perceived highest priority misconceptions, or "EMP knots."

1. EMP will burn out every exposed electronic system.
2. EMP effects will be very limited and only result in "nuisance" effects in critical infrastructure systems.
3. Megaton class weapons are needed to cause any serious EMP effects – low yield, "entry-level" weapons do not engender serious EMP effects.
4. To protect our critical national infrastructure would cost a large fraction of the GNP.

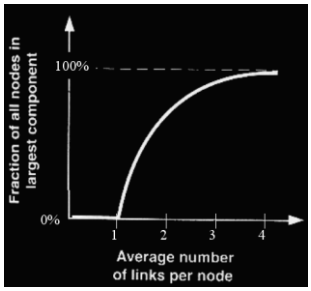
5. Only late-time EMP (E3), not E1 will damage electric power grid transformers.
6. Long-haul fiber optic lines are invulnerable to EMP.
7. Ground burst EMP effects are limited to 2-5 km from a nuclear explosion where blast, thermal and radiation effects dominate.

Misconception 1: EMP will burn out every exposed electronic system.

Based on DoD and Congressional EMP Commission's EMP test data bases we know that smaller self-contained systems that are not connected to long-lines tend not to be affected by EMP fields. Examples of such systems include vehicles, hand-held radios, and unconnected portable generators. If there is an effect on these systems, it is more often temporary upset rather than component burnout.

On the other hand, threat-level EMP testing also reveals that systems connected to long lines are highly vulnerable to component damage, necessitating repair or replacement. The strength of EMP fields is measured in volts per meter. Thus, to first order, the longer the line, the more EMP energy will be coupled into the system and the higher the probability of EMP damage. Because of their organic long lines, the electrical power grid network and long-haul landline communication systems are almost certain to experience component damage when exposed to EMP with cascading effects to most other (dependent) infrastructure systems.

Misconception 2: EMP effects will be very limited and cause only easily recoverable "nuisance" type effects in critical infrastructure systems.



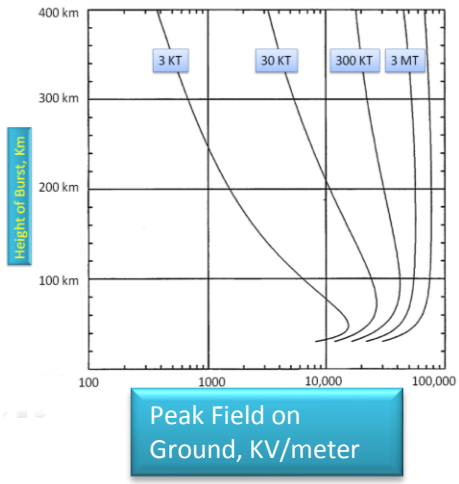
Although EMP does not affect every system, widespread failure of limited numbers of systems, because the interdependency of failed and unaffected electronic systems will cause large-scale cascading failures of critical infrastructure systems and system networks. Paul Erdos' "small world" network theory applies.[35] The graph above illustrates that the fraction of nodes in any network that are connected to single network node changes suddenly when the average number of links per node exceeds one. This means a failed node, where the average links per node is 2, will affect approximately 50% of the rest of the remaining network nodes.

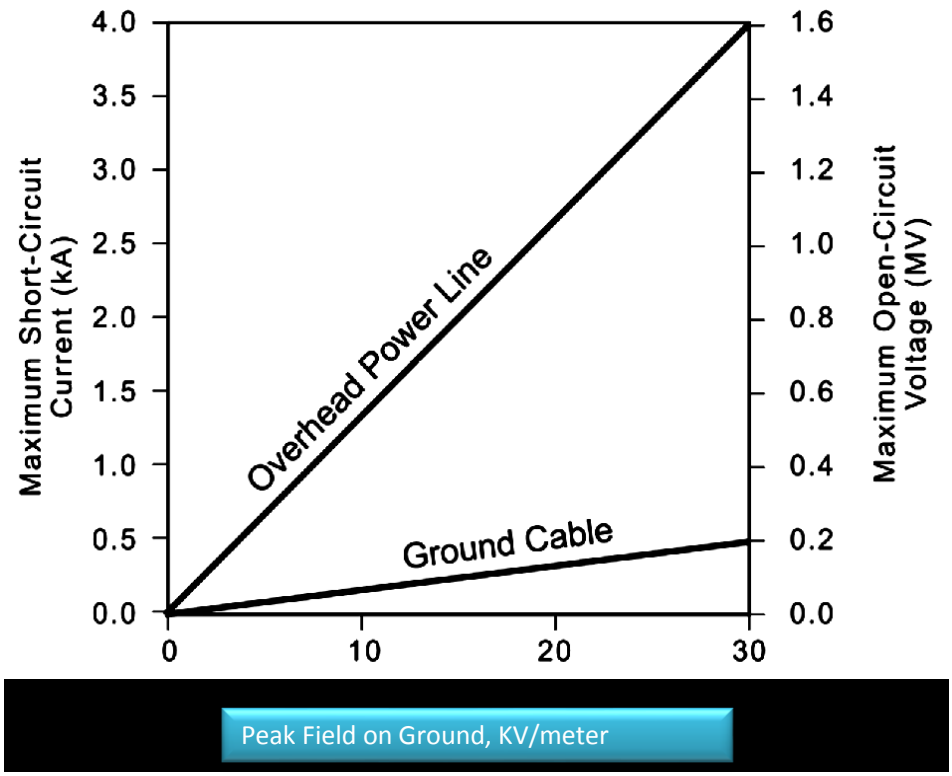
Also, for many systems, especially unmanned systems, upset is tantamount to permanent damage – and may cause permanent damage due to control failures. Examples include:

- Lockup of long-haul communication repeaters
- Upset of remote pipeline pressure control SCADA systems
- Upset of generator controls in electric power plants
- Upset of machine process controllers in manuf. plants

Misconception 3: Megaton-class nuclear weapons are required to cause serious EMP effects. "Entry-level," kiloton-class weapons won't produce serious effects.

[35] Duncan Watts, Six Degrees: The Science of the Connected Age, 2004.





Due to a limiting atmospheric saturation effect in the EMP generation process, low yield weapons altitude produce peak E1 fields of the same order of magnitude as large yield weapons if they are detonated at altitudes in the 50-80 km range. The advantage of high yield weapons is that their field on the ground attenuated less significantly at larger heights of burst.

The first graph above illustrates that, for nominal weapons yields ranging from 3KT – 3MT (a 3 order of magnitude difference in yield), exhibit a range of peak E1 fields on the ground of only a factor of ~3, viz. 15 -50 KV/meter.

With respect to the late time (E3) EMP field, a 30 KT nuclear weapon above 100 km causes geomagnetic disturbances as large as solar superstorms, but over smaller regions.

The second graph above indicates that megavolt levels and kilovolt-level currents are induced in long overhead lines by E1 from kiloton-class weapons.

<u>Misconception 4: to protect our critical national infrastructure would cost a large fraction of the U.S. Gross National Product</u>.

Of the 14 critical infrastructure sectors, EMP risk is highest for electric power grid and telecommunications grid – attention to these infrastructures <u>alone</u> would bring major benefits to national resiliency. These infrastructures are the most vulnerable due to their organic long lines. And they are also the most critical to the operation and recovery of the other critical infrastructure sectors. It is ironic that our most vulnerable infrastructures are also the most vulnerable to EMP.

If we have to pick one infrastructure to protect, the top choice would be the electric power grid. Grid operational behavior is binary – it fails fast and hard over large regions disabling most other critical infrastructures. The grid is the most essential infrastructure for sustaining population life-support services.

Some major grid components take months to replace – years if large numbers are damaged. The primary example is high voltage transformers (an example unit is pictured in the figure immediately above) which are known to irreparably fail during major solar storms and are thus likely to fail during an EMP event. Protection of these large transformers will buy valuable time in restoring the grid and the life-support services it enables.

The unit cost for HV transformer protection is estimated to be $250,000. The total number of susceptible units range from 300 – 3000 (further assessment is required to establish an exact number.) The requirement and cost for generator facility protection are still undetermined but are likely to be in the same ballpark as transformer protection costs. The need for SCADA system protection is moderated by the ready availability of replacement parts and the relative ease of repair. Doing the math, the protection costs for heavy-duty grid components are in the single digit billions of dollars – a small fraction of the value of losses should they fail.

Amortized over twenty years, the protection costs amount to pennies per month for electricity consumers.

<u>Misconception 5: Only late-time EMP (E3), not E1, will damage electric power grid transformers</u>.

XFMR	Shots #@kV	Peak Voltage (kV)	Time to Peak (ns)	Surge Arrester	Notes	Result
ZS1						Pulser calibration
ZS2	1@400	264	618	No	(1)	T-T failure
ZS3	2@400	288	668	No	(2)	HV-LV failure
ZS4	2@400	280	600	No	(1)	L-L failure
ZS5	1@400	272	550	No	(2)	HV-LV failure
ZS6	2@400	290	643	No	(1)	No damage
ZV1	1@400	296	601	No	(1)	No damage
ZV2	1@400	304	592	No	(2)	HV-LV failure
ZV3	2@400	110	100	Yes	(3)	No damage
ZV4	2@500	110	100	Yes	(3)	No damage
ZV4	2@780	116	110	Yes	(3)	No damage
XV1	1@400	272	500	No	(2)	HV-LV failure
XV2	2@400	115	110	Yes	(3)	No damage
ZW1	2@400	292	552	No	(1)	No damage
ZW2	2@400	16	Oscillatory	No	(4)	No damage
ZW3	2@780	100	110	Yes	(3)	No damage
ZW4	2@1000	112	105	Yes	(3)	No damage
ZD1	2@400	120	550	No	(5)	No damage
ZD2	2@400	20	Oscillatory	No	(4)	No damage
ZE1	2@1000	95	100	Yes	(6)	No damage
ZE2	6@780	95	100	Yes	(6)	No damage

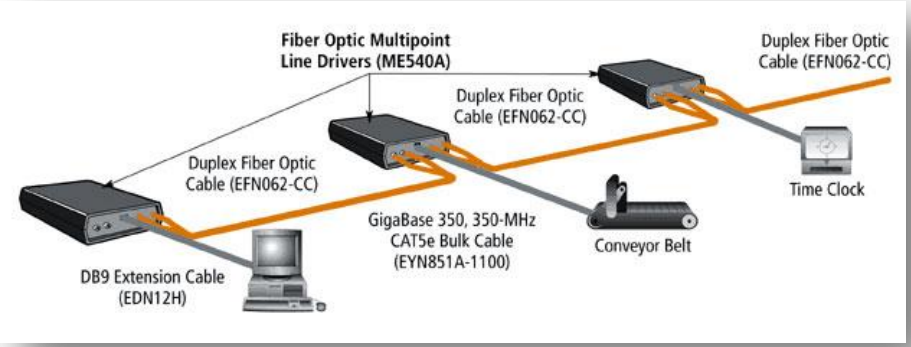
(1) External flashover on HV bushing: T-T failure denotes turn-to-turn failure; L-L failure denotes line-to-line failure
(2) No external flashover; HV-LV failure denotes a high-voltage winding flashover to the low-voltage winding
(3) Surge arrester operation and no external flashover
(4) Surge applied to the low-voltage bushings with no external flashover
(5) Surge applied common mode to both HV bushings with external flashover
(6) Surge applied common mode to both bushings, and both arresters operated

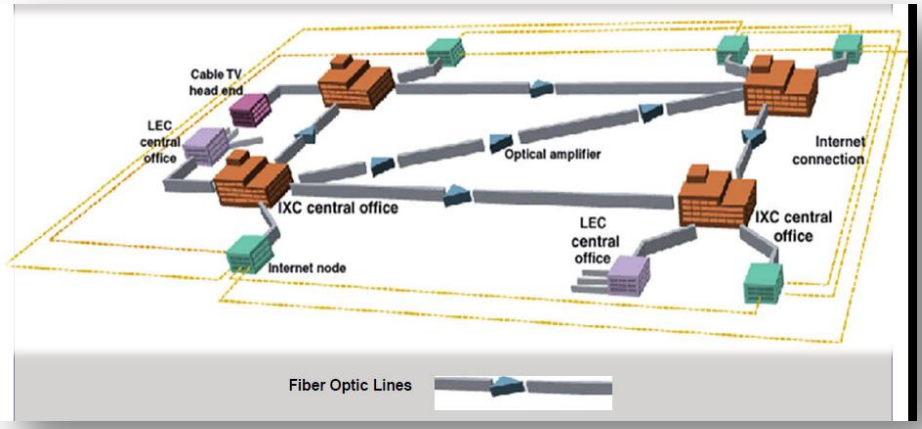
Oak Ridge National Laboratories (ORNL) tests of 7.2 KV distribution transformers caused permanent damage to transformer windings in seven of the twenty units tested. The failures were due to winding damage including turn-to-turn flashover and primary-to-secondary flashover. The results are summarized in the table above.[36]

As an important side-note, transformers with direct-mounted lightning surge arrestors were not damaged during the tests. Similar tests of HV transformers are needed.

[36] W. Radasky et al, The Early-Time (E1) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid, Meta-R-320, Oak Ridge National Laboratories.

Misconception 6: Optical fiber networks are not susceptible to EMP effects.

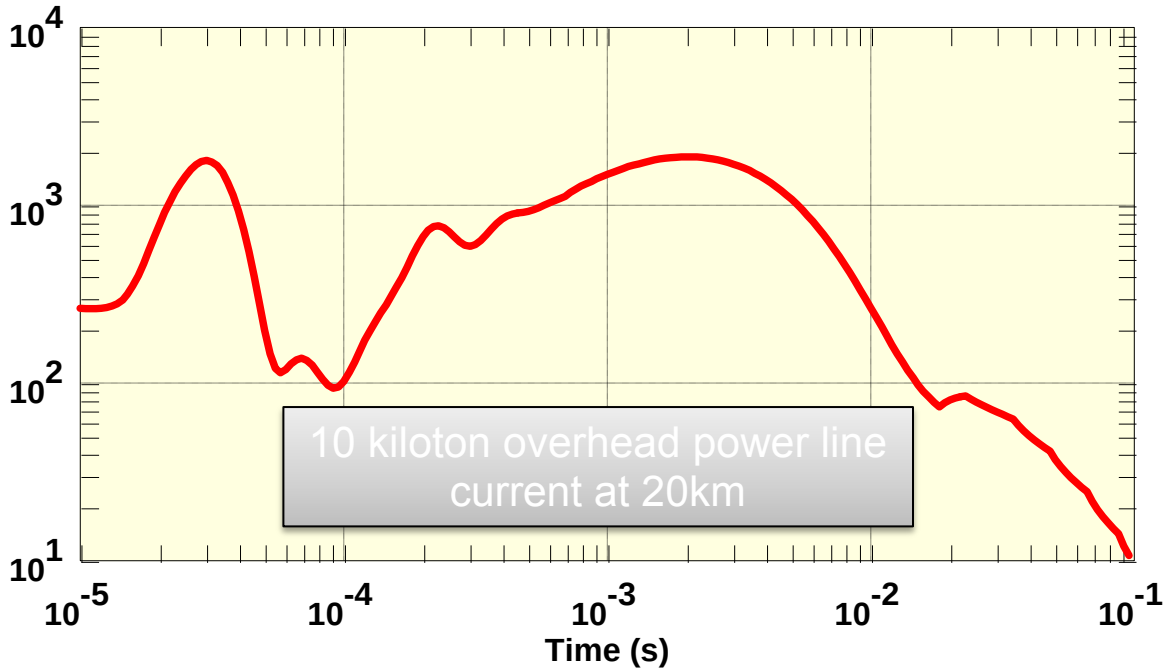




In general optical fiber networks are <u>less</u> susceptible than metallic line networks; however fiber optic line driver and receiver boxes may fail in EMP/E1 environments. Long-haul telecom and internet optical fiber repeaters power supplies are particularly vulnerable. Terrestrial fiber-optic cable repeater amplifier power is provided by the electric power grid and thus vulnerable to grid failure as well as direct EMP/E1 effects. Undersea cable repeater amplifiers are vulnerable to EMP/E3 effects since, because of its low frequency content, E3 penetrates to large ocean depths.

On the plus side, line drivers/receivers and repeaters are relatively easy to protect using shielding, aperture treatment, and power line filters and/or breakers.

Misconception 7: Ground burst EMP effects are limited to 2-5 kilometers from a nuclear explosion in the region where blast, thermal and radiation effects dominate. Thus, ground burst EMP is not a major threat.



Ground bursts couple large currents to long lines running through the nuclear source region that propagate tens of kilometers from the burst location. Destructive source region EMP (SREMP) effects on power and communications infrastructure extend significantly beyond the blast, thermal and radiation effects ranges. As shown in the figure, a nominal 10KT yield ground burst delivers a 2,000 amp pulse lasting for several milliseconds on overhead power line at 20km. A 1 MT ground burst would deliver 150,000 amps at the same distance down the line.

Conclusion.

The seven EMP "knots" addressed here are common misconceptions and arguably the most important to "untie." There are others that should be addressed, but the present list, especially the first four, are crucial to dispel because they have deterred efforts to achieve national preparedness.

From a risk-based priority standpoint, the electric power grid is at the top of the list for EMP protection.[37] Hardening this infrastructure alone would have major benefits for national resiliency, i.e. the ability to reconstitute and restart critical services. It is not just the survivability of our electric power infrastructure that is at stake; almost all of our critical infrastructure services will cease should the power grid fail.

[37] G. H. Baker, "Risk-Based Critical Infrastructure Priorities for EMP and Solar Storms" *Security Analysis and Risk Management Association Newsletter*, October 2011

A major impediment to action has been that government and industry are (understandably) swayed by the familiar, the convenient, and the bottom line. Like it or not, familiarity and profitability are the touchstones of acceptability – strategic advantage goes to the acceptable. Thus the tendency exists to downplay the likelihood of an EMP scenario and its associated consequences (Misconception 2).

By way of encouragement, we know how to protect systems against EMP. EMP engineering solutions have been implemented and standardized by DoD on a host of systems. In the case of the national power grid, the installation of blocking devices in the neutral-to-ground conductors of large electrical distribution transformers will significantly reduce the probability of damage from slow E3 component of EMP and geomagnetic disturbances (GMDs) caused by solar storms. Transformer protection against E1 overvoltages is achievable by installing common metal-oxide varistors (MOVs) on transformers from each phase to ground. Costs for protecting the power grid are a micro-fraction of the value of the systems and services and risk.

EMP protection methods for communication and control facilities have been developed and implemented by DoD since the 1960s and are well documented (ref. MIL-STD-188-125-1, MIL-STD-188-125-2, MIL-HDBK-423). Engineering approaches include use of shielded enclosures, provision of backup power, standard grounding techniques, installation of overvoltage protection devices and filters on penetrating conductors, and good cable management procedures.

Hopefully, this attempt to redress important and pervasive misconceptions concerning EMP will help to spur action on the challenging effects of EMP and public-private cooperation will begin and prevail in implementing low-risk EMP protection of our most critical infrastructure systems.

Appendix 4 Legal Authority to Order Interruption of U.S. Generation

LEGAL AUTHORITY FOR THE PRESIDENT OF THE UNITED STATESTO ORDER INTERRUPTION OF U.S. ELECTRIC GENERATION AND RELATED ELECTRIC GRID PROTECTIONS DURING A SEVERE SOLAR GEOMAGNETIC STORM

William R. Harris

September 18, 2012

The President of the United States holds powers both enumerated and implied by Article II of the U.S. Constitution, and by the President's role as commander-in-chief. Moreover, the Presidential oath of office to "faithfully execute" the laws provide a duty to fulfill a wide array of presidential functions, including the continuity and functionality of the executive branch, aid to the legislative and judicial branches, fulfillment of treaties and other international agreements, and support to state and local governments. Beyond these powers and responsibilities, the President has duties and powers, many of them delegable to Cabinet secretaries, or others.[38] While the police powers are generally reserved to the states (per the 10th Amendment to the federal constitution), the President retains powers granted under the U.S. Constitution and under statutory laws.

A severe solar geomagnetic storm is more likely to affect a region, a nation, or areas of the globe that are international, rather than a portion of one or two states. It is unlikely that a single state will be capable of exercising its police power functions, whether by a state public utility commission, or a governor's office of emergency management, to prevent or even to mitigate severe damage to critical infrastructure from a severe solar geomagnetic storm.

Might the federal government retain the power and duty for preparedness, and with warnings of a severe solar geomagnetic storm, might the President and executive officers to whom the President delegates authority to execute essential federal functions, have the authority and duty to interrupt electric power generation and to protect critical electric infrastructures? Without prompt action supported by the express and implied powers of the

[38] Title 3, section 301 of the U.S. Code provides a general authorization for presidential delegation of functions, excepting specifically non-delegable functions, so long as these acts of delegation are published in the Federal Register. For example, the duty to maintain a domestic industrial base, including national defense resources preparedness, is a delegation by President Obama in March 2012. See 77 FR 16651 (2012).

President, substantial portions of the North American electric grid might not endure, or might not be expeditiously reconstituted after the emergency has passed.

What are some of the presidential powers or powers delegated by the President or Congress to subordinate executive officers of the federal government? Title 42 U.S.C. sec. 5195 (P.L. 93-288, Title VI, sec. 601) explains as a purpose the provision of "a system of emergency preparedness for the protection of life and property in the United States." The Federal Government "*shall* provide necessary direction, coordination, and guidance, and *shall* provide necessary assistance as authorized by the subchapter so that a comprehensive emergency preparedness system exists for all hazards." (italics added). A federal preparedness plan and system to cope with *all hazards* is mandatory, not optional.

Under Executive Order 12656, 77 FR 1665 (March 10, 2012), it is noted that federal preparedness planning requires identification of functions that would have to be performed during an emergency. The federal government has a designated mission to mobilize for, respond to, and recover from: a range of national security emergencies, including (sec. 103) preparedness for "those natural disasters, technologies emergencies, or other emergencies, the alleviation of which is normally the responsibility of … the private sector… [or] State and local governments, and Federal departments and agencies *unless such situations also constitute a national security emergency"* [italics added]. Executive Order 12656 requires development of a system of emergency actions, not just contingency plans. Section 201(4) of this Executive Order requires:

> (a) Development of a system of emergency actions that defines alternatives, processes, and issues
> to be considered during various stages of national security emergencies:
>
> (b) Identification of actions that could be taken in the early stages of a national security emergency or pending national security emergency to mitigate the impact of or reduce significantly the lead times associated with full emergency action implementation;

The Federal government might have multiple sources of confirmation of a severe geomagnetic storm complementing the beyond-projected life ACE satellite (at the L1 LaGrange point) or its prospective replacement satellite: for example, a variety of NRO space assets or other Department of Defense space assets that public sources identify and that might independently confirm an impending solar geomagnetic storm's risks to terrestrial grid assets.

Under Section 701(1) of this Executive Order, the Secretary of Energy shall "develop implementation plans and operational systems for … allocation of all energy resource requirements for national defense and essential civilian needs to assure national security emergency preparedness…." [E.O. 12656, Sec. 701(1)(b)].

The Secretary of Homeland Security has emergency preparedness planning responsibilities for commercial nuclear plants, per Executive Order 12657, 68 FR 10626 (Feb. 28, 2003). The DHS responsibilities apply whenever state or local governments decline or fail to prepare commercial nuclear power plant radiological emergency preparedness plans that are sufficient, and so the state plans are adequate to exercise and use such plans in an actual emergency. There are no indications from the open literature that state or local plans are designed to reliably shut down nuclear generation facilities in anticipation of a severe solar geomagnetic storm. The plant licensees could certify to the Department of Homeland Security, per Section 1(b) of E.O 12657, that the state and local plans do not provide adequate protection and the licensees could delegate authorization to exercise **shutdown** contingency authority to the Secretary of Homeland Security. But for uniform "operating procedures" to take effect, each of the NRC-licensed operators of 104 nuclear power plants would have to authorize this delegation of authority to DHS.

Concurrently, the Nuclear Regulatory Commission (NRC) has authority to require shut down of NRC-licensed power plants as a precautionary measure. This is done routinely for earthquakes and for hurricanes under NRC safety authority. At the April 30, 2012 FERC Technical Conference on geomagnetic disturbances and reliability of the bulk power system[39], an NRC nuclear engineer testified that the prudent course of action in a major solar geomagnetic storm headed for planet earth might be to shut down all NRC licensed power reactors. But since these facilities produce about 19 to 20 percent of national electric supply, their simultaneous shutdown would by itself produces risks of electric grid instability.

In a major solar geomagnetic storm with an inclination likely to cause critical grid equipment losses in North America, does the President have complementary authority to shut down other electric generating plants, if the nuclear-electric plants are to be shut down? The answer is: yes, to a significant extent.

If in future years the North American grid continues to operate extra high voltage transformers without neutral ground blocking devices for transformer protection, in a major solar geomagnetic storm the need to protect transformers from severe or permanent damage extends beyond nuclear facilities. Let us assume that the NRC, or DHS with delegations from nuclear plant operators, has authority to order the uniform depowering of all NRC-licensed nuclear facilities. Without AC energization, the GSU transformers and other EHV transformers are relatively safe from permanent damage from GICs and related harmonics and overheating. The DC currents by themselves are insufficient to produce permanent damage to this equipment. However, these "operating procedures" would remove a vital component of

[39] See FERC Docket AD12-13-000 (2012).

baseload power production in the United States, more than 20 percent of the supply in peak summer months. This would constitute an "energy supply disruption" of substantial magnitude, if a severe solar storm occurred around the time of seasonal power peaks, in summertime.

The Congress has expressly granted to the President the authority to halt, temporarily, the use of natural gas-fired or petroleum-fired electric generation facilities in the United States, under emergency authorization found at Title 42 U.S.C. section 8374. If there is an "energy supply disruption" the President has express authority, by presidential order, to prohibit any power plant in the United States or any other fuel-burning installation "from using natural gas, or petroleum or both for the duration of such [severe energy supply] disruption." 42 U.S.C. sec. 8374. The Congress was anticipating, primarily, an oil supply disruption, but the statutory authority would also apply in event of a nuclear-depowering disruption, including the mandatory shutdown of all nuclear-licensed power reactors in the United States. The President's authority to mandate temporary interruption of electric supply using natural gas or petroleum may not extend to coal-fired plants. These plants were considered the likely sources of emergency electric generation, with presidential authority to waive air quality regulations otherwise enforced by the Environmental Protection Agency. Before considerations of solar geomagnetic storms received substantial Congressional attention, the baseline assumption was that an energy supply disruption was most likely to occur through the loss of imported oil, with a remedy being the suspension of electric generation using natural gas or petroleum, or both, and with coal-fired plants to be brought online to increase the baseload supply of electricity.

An amendment to this statute might make sense, to allow interruption of coal generating facilities, thereby broadening the President's authority to disrupt electric production during a severe solar geomagnetic disturbance, to protect all generation facilities and their extra high voltage transformers throughout the nation.

Given the anticipation of widespread electric blackouts during a severe geomagnetic storm, any federal legislation to broaden authority to authorize temporary cessation of electric power generation via facilities connected to the bulk transmission system might also: provide incentives for "islanding" facilities designed to furnish critical electric supplies to hospitals and other facilities where people now depend upon grid-supplied electricity to power life-support systems and to augment "islanding" electric supply to critical telecommunications systems.

A remaining issue relates to the existence or lack thereof of authority for the Federal Energy Regulatory Commission to authorize cost-sharing between generating utilities and transmission entities. In particular, for any hardware protective equipment that is to be installed, whether at generating facilities or within the regional balancing authorities that

manage wholesale power markets, does FERC have cost-sharing authority? If hardware protective equipment to be installed at generating facilities reduces downstream costs, the frequency of off-cost sales of bulk power, and the magnitude of reactive power consumption within regional transmission markets,[40] a case might be made that the Federal Energy Regulatory Commission already has cost-recovery authority to allocate the costs of installable hardware protections within the "bulk electric system." That system may well include components at generating facilities that improve performance and reliability within the wholesale transmission systems. Protective equipment at generation facilities that enhances reliability, reduces transmission congestion, or that reduces reactive power consumption within the "bulk power system" appears to be eligible for cost-recovery rule-making under FERC's existing Federal Power Act jurisdiction.[41] Many would prefer, however, clarification via amendments to Section 215 of the Federal Power Act to expressly strengthen FERC's reliability enhancing authority and cost-allocation authority.

Either way, there are benefits to improved reliability for critical infrastructure, starting with the reliability of the North American electric power grid, if costs of protective equipment at generating facilities can be allocated to all FERC-jurisdictional beneficiaries. But if there are delays in needed reforms, the President and presidential delegates do retain substantial legal authority to order: temporary shutdown of all NRC-licensed nuclear power plants, and temporary shutdown of all gas-fired and petroleum-fired generating facilities in the United States during a severe solar geomagnetic storm.

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[40] Neutral grounding equipment installed at extra high voltage transformers would, according to manufacturing specs and leading transformer experts, filter out geomagnetic induced currents (GICs). Without such equipment installed, GICs saturate transformers and flow into extra high voltage transmission systems. Studies of regional transmission systems during Solar Cycle 23 indicate that even modest solar geomagnetic storms cause off-cost dispatch of power in more than 10 percent of all hours of dispatch within the PJM Interconnection, Inc. systems between April 1, 2002 and the April 30, 2004. It appears that, in the absence of installed hardware protection equipment at generation facilities, there are significant downstream costs of unfiltered GICs that include: damage to transformers, outages of transformers, loss of sales of electric generation, transmission system congestion, increased consumption of reactive power, and off-contract power dispatch across low voltage lines. Would the installation of hardware protective equipment at extra high voltage generation facilities provide significant benefits to transmission entities? How could such benefits be measured, to develop cost-sharing principles for FERC cost-sharing and state utility rate-making approvals? See in particular recent articles by Kevin F. Forbes and O. C. St. Cyr, "Did Geomagnetic Activity Pose a Challenge to Electric Power Reliability During Solar Cycle 23? Evidence from the PJM Regional Transmission Organization in North America," Space Weather, v. 10, S05001, 14 pp. May 2012, and Kevin F. Forbes and O. C. St. Cyr, "Establishing the Economic Impacts of Space Weather" May 21, 2012, found at http://www.vsp.ucar.edu/Heliophysics/pdf/Forbes_Establishing%20the%20Economic%20Impacts%20of%20Space%20Weather%20MAY%2021%202012.pdf.

[41] See Memorandum, NERC Legal and Standards Departments, Subject: "Use of 'Bulk Power System' versus 'Bulk Electric System' in Reliability Standards", North American Electric Reliability Corporation, April 10, 2012, at http://www.nerc.com/files/Final_BES_vs%20_BPS_Memo_20120410.pdf.

Any such authority ought to be complemented by a rapid upgrade in “islanded” capabilities for off-grid power production, whether by emergency diesel generators, or by electric storage systems and renewable sources of energy production. A temporary shutdown of the North American electric grid would lead to loss of life and extraordinary economic damage. But the costs of inaction appear to be even higher.

Contingency planning and action plans for grid shutdowns will illuminate the benefits of proactive measures, so that most of the electric grid in North America could operate through most foreseeable solar geomagnetic storms. False claims that the President lacks authority to take temporary measures to de-energize, thence to protect the electric grid from more severe and long-lasting damage should be set aside. Plans for partial or total grid shutdowns need to be modeled and refined. Within that context, grid protective hardware and operating procedures need to be assessed, compared, and improved.

Rigorous modeling and planning for emergency contingencies should not be postponed under the false notion that the President lacks authority to act. In times of national emergency, the Supreme Court has shown extraordinary tolerance for emergency presidential actions initiated to protect the nation and to save lives. The President must be prepared to act, under existing constitutional and statutory authorities, and legal precedents. A commitment to proactive measures to protect critical infrastructure requires in advance the exploration of varied contingencies, robust modeling, and development of both contingency plans and actionable remedies.