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 **[INSERT DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**.

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 e-mail 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, e-mail: Manash.Bagchi@nrc.gov.

SUPPLEMENTARY INFORMATION:

I. The Petition

II. Regulatory Oversight of Electric Power Systems

III. Analysis of Public Comments

IV. NRC Evaluation

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.

<u>Comment NEI-4</u>

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 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."

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

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.

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

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.

[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).

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

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[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).

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 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).

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

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

[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.

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. 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

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

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 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, 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

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

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 12/17/2012 at 8:45 am; Publication Date: 12/18/2012]