Foundation for Resilient Societies

COMMENTS
ON ADVANCE NOTICE OF PROPOSED RULEMAKING (ANPR) OF THE NUCLEAR REGULATORY COMMISSION RELATING TO THE PREVENTION AND MITIGATION OF STATION BLACKOUT

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Submitted by

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The Foundation for Resilient Societies, incorporated as a non-profit corporation in Nashua, N.H., appreciates this opportunity to comment on Proposed Rulemaking to Prevent and Mitigation Station Blackout.

OUR FOUNDATION'S FIRST INITIATIVE – TO IMPROVE ON-SITE POWER RESILIENCY FOR PUBLIC SAFETY AND LONG-TERM VIABILITY OF NUCLEAR POWER.

Our Foundation is committed to research and education aimed at ensuring greater resilience for the critical infrastructures of modern society. To this end, our first research and related policy initiative (submitted in March 2011, as PRM-50-96) identified opportunities to enhance the endurance and protective design of on-station backup electric power systems that would cope with long-term Loss of Outside Power (LOOP). Specifically, we addressed common-mode failure risks that could occur when solar coronal mass ejections (CME) cause geomagnetic disturbances (GMD) and increase risk of widespread blackouts and LOOP that could persist for months or even years.

We concentrated our analysis in PRM-50-96 on Commission-licensed nuclear power plants, because CME events that could take down the bulk electric power system, nationally or regionally, would, if not previously mitigated, place at risk spent fuel assemblies in pools that depend upon continuous electric power for cooling, instrumentation, and water makeup.

SUPPORT FOR AUGMENTED ON-SITE BACKUP POWER SYSTEMS AND GREATER ELECTRIC GRID RELIABILITY TO ACHIEVE RISK REDUCTION AND REVENUE ENHANCEMENT.

Our Foundation endorses analytic consideration of our Petition for Rulemaking (PRM-50-96) within the broader context of revisions to Station Blackout Rulemaking. Our Board of Directors has the goal of research and related policy initiatives that would be cost-effective for a more resilient, modern society. Taken in the context of NRC rulemaking, concurrent consideration of design improvements and revenue implications is more likely to result in findings of: cost-effectiveness, appropriateness for newly-licensed systems, and appropriateness for "backfitting" requirements, and to achieve a wider set of public safety goals.

The same on-site backup electric power systems that can be designed to withstand solar geomagnetic storms should be enabled, at varying and increasing levels of capacity, to support, despite loss of outside power: the pumps required to cool spent fuel assemblies; the electricity for instrumentation to monitor and report (including remote relay reporting to offsite monitoring centers) the condition of spent fuel assemblies, and water levels surrounding them); the operation of hydrogen recombination equipment and containment power venting fans (to prevent hydrogen gas explosions) within reactor containment structures and within buildings holding spent fuel assemblies; reactor instrument and control monitoring equipment; site safety and security monitoring equipment; and recharging of onsite batteries

THE RESUPPLY AND USEABILITY OF DIESEL FUEL REMAINS OF CONCERN FOR PROLONGED LOOP CONDITIONS.

In our earlier Petition (PRM-50-96), we indicated that the Commission staff should consider on-site solar powered systems as a complement to Emergency Diesel Generators. These Emergency Solar Generators (ESGs) would purposely not be connected to the long lines of the bulk electric system, to protect against both geomagnetic storm impacts and high altitude EMP risks. Our concerns about the availability and reliability of workable diesel fuel remain undiminished. Low sulfur diesel fuels, unlike their predecessor formulations, have diminished shelf-life. Depending upon conditions of storage and filtering, these fuels require turnover, so EDGs will operate reliably when needed.

Moreover, in a prolonged regional or national station blackout condition – which could result from a severe solar storm– the shutdown of diesel fuel production facilities could result in unexpected looting, or black market sales, or other unplanned risks to receipt of diesel fuel that is under firm contract for delivery to nuclear power plants. So diesel fuel deliveries may become uncertain, and previously refined diesel fuels may become stale. Under the Defense Production Act of 1950, as amended, the Secretary of Defense and the President have emergency planning authority to requisition essential supplies. But it is more prudent to design robust on-station backup power capabilities that can operate through a prolonged LOOP event that could affect an entire region and not just a single Commission-licensed power plant.

STANDARDS ARE NEEDED FOR HARDWARE PROTECTIVE EQUIPMENT TO *PREVENT* ELECTRIC GRID OUTAGES AND RESULTING STATION BLACKOUT, NOT MERELY TO MITIGATE STATION BLACKOUTS WHEN THEY OCCUR.

The NRC and federal government would be remiss if they were to only address the means of mitigating the conditions that arise during prolonged station blackout, at a single NPP, regionally, or nationally. Research on the technical and financial aspects of “neutral current blocking devices” that are likely to *prevent* electric grid outages and widespread station blackout conditions show that high priority should be given to the development of (a) geomagnetic withstand standards for newly licensed facilities; (b) standards for conditions of relicensing of existing NRC-licensed generating facilities; and (c) standards for backfitting of existing, previously licensed nuclear power plants, to prevent the uptake of dangerous levels of *geomagnetically induced currents* (known as GICs) into the bulk power system of North America.

HARDWARE AND MONITORING SYSTEMS EXIST TO BLOCK THE ENTRY OF HIGH GICS INTO CRITICAL GSU TRANSFORMERS AND INTO THE BULK ELECTRIC TRANSMISSION SYSTEM.

In November 2011, representatives of two hardware-protection manufacturers presented their approaches to neutral ground blocking and series capacitor resistors at a meeting sponsored by the North American Electric Reliability Corporation (NERC). This equipment (together with monitors of GICs within the nearby earth, and GICs within generation step-up transformers) can block significant GICs from entering the bulk power grid via step up transformers. We know from an insurance industry study that in a year with high GICs entering the bulk power systems in North America and Europe, year 2000, loss claims for transformer failures were four times the claims in four surrounding years with lower levels of geomagnetic disturbance. We also know that the claims data indicated that GSU transformers were even more vulnerable to failure and insurance loss claims; their failure rate in the year 2000 was more than six times the average claims rate in surrounding years (in inflation adjusted dollars). Protecting most of the GSU transformers in each region is a key element in *preventing* station blackouts, and *reducing the duration* of station blackouts that may occur.

Most of the extra high voltage transformers can be protected against the uptake of harmful GICs and resulting harmonic effects upon bulk transmission systems. An industry-wide initiative could either prevent altogether large regional blackouts, or, if cascading blackouts occur, then reduce the duration (time) and scope (geospatial impact) of station blackouts. If the *duration* of loss of outside power can be shortened from years or months, to days or hours, then under most circumstances the existing diesel generators can allow generation facilities to avert “station blackout” conditions altogether.

MODELING SYSTEM-WIDE EFFECTS OF TRANSFORMER HARDENING AND REDUCED INTAKE OF GICS VIA GSU TRANSFORMERS SHOULD BE EXPEDITED; MANDATORY GIC MONITORING AND REPORTING SHOULD BE REQUIRED VIA NRC AND FERC.

At the recent FERC hearing on April 30, 2012 (AD12-13-000), representatives of the electric power industry, Mr. Cauley of NERC, and Mr. Naumann of Exelon (representing the Edison Electric Institute), cautioned that any system-wide adoption of neutral ground blocking equipment needs to be modeled. This modeling effort should be expedited, and combined with system-wide GIC monitoring and recording – including mandatory system-wide monitoring and recording of earth-based and transformer-based GICs at all NRC-licensed nuclear power plants, *inter alia.* If done in time to assess system operations during the current *solar geomagnetic maxima*, in and around the year 2013, the Commission's ability to reduce the likelihood, scope, and duration of GMD-driven station blackouts would be significantly enhanced.

RELYING UPON SPACE WEATHER WARNINGS, AND SHUTTING DOWN ALL NRC-LICENSED POWER REACTORS ARE PRESENTLY INFEASIBLE MITIGATION STRATEGIES.

What is the best mitigation strategy if a severe solar geomagnetic storm reaches the earth at an orientation that will produce major geomagnetic disturbance of the North American electric grid? What is the best course of action if 2000 extra high voltage transformers, including those at non-nuclear plants, remain hardware-unprotected at the time of arrival of such a solar geomagnetic storm?

One of the Commission's Senior Electrical Engineers, "Singh" Matharu, addressed that challenge, at the April 30th FERC Staff Technical Conference, assuming that the beyond-design-life ACE satellite at the L1 LaGrange point remains in operation during such a storm.[1] This space satellite, or, with Congressional funding, a more modern replacement with IOC in year 2014, could allow an assessment of likely risk to NRC licensed power plants. The likely levels of geomagnetically-induced current would only be known 20 to 30 minutes before a high velocity solar storm reached the earth's surface.

Given standard NRC procedures to safely shut down reactor power in advance of an impending hurricane or other severe weather, Mr. Matharu postulated that the NRC might recommend shut down of all NRC-licensed nuclear power plants that could be affected by the impending solar storm. But this mode of mitigation could, by itself, create grid instability and risks of cascading grid failures. There must be a more prudential and more cost-effective strategy to *prevent* station blackouts, or to drastically limit their duration or impact upon EHV transformers with long replacement times – measured in months or years.[2]

[1] In the Webcast of FERC AD12013-000, relevant observations of the NRC's staff representative, Gurchuran "Singh" Matharu, are found at minutes 247-249 and 252 of 257.

[2] At the April 30, 2012 FERC Staff Technical Conference, senior NERC executives admitted that the much heralded Spare Transformer Equipment Program (STEP) Program, which inventories reserve transformers available to the bulk power system, does not include generation step-up (GSU) transformers for extra high voltage systems, usually 345 kV or higher. The STEP program was designed to cope with loss of one or a limited number of transformers in a post 9/11 terrorist attack. The STEP Program was not designed to mitigate near simultaneous loss of GSU transformers across many regions or in large numbers. At the present time, there is no significant U.S. manufacturing of GSU transformers, but in future years, the U.S. will again participate in GSU transformer production, starting in Tennessee.

THE COMMISSIONERS HAVE AUTHORITY TO REQUIRE HARDWARE PROTECTION OF CRITICAL GSU TRANSFORMERS, INCLUDING MANDATORY BACKFITTING THAT IS COST-EFFECTIVE.

Does the Nuclear Regulatory Commission have the authority to require neutral ground blocking of GSU transformers installed for newly licensed nuclear power plants? Apparently so. Does the Commission have the authority to require "backfitting" of GSU transformers with neutral ground blocking equipment as a condition of relicensing? Apparently so. Does the Commission have the authority to require "backfitting" protection of existing GSU transformers at NRC licensed nuclear power plants that are already relicensed? The Commission has the authority to require such backfitting hardware protections, but in its discretion the Commission may require that a cost-effectiveness standard be met. We expect that such a standard can be met.

A CASE STUDY OF OUTAGE COSTS AT SEABROOK STATION INDICATES THAT GSU HARDWARE PROTECTION IS A BETTER BUY THAN "DOWNRATING" GENERATION UPON SOLAR STORM WARNINGS.

We wish to bring to the attention of the Commissioners and Commission staff our Foundation's Case Study of the 12.2 day outage of the NRC-licensed Seabrook Station during a moderate-level two-phase geomagnetic storm that impacted the U.S., Canada, India, and China on November 7-9, 1998. Because of prompt FLIR imaging of Seabrook Station's GSU transformer on November 10, 1998, it was possible to repair and not replace this 345 kV General Electric transformer. Relying upon cost estimates provide by Seabrook's own engineering staff, and converting to year $2012 dollars for a comparable current-day outage, we estimate that the purchase of neutral ground blocking devices, with appropriate GIC monitors, plus protection against high altitude EMP (HEMP) E1 and E3 voltage surges, plus shipping, installation, and staff training would cost about $275,000. Would this purchase be cost-effective as a "backfit" for Seabrook Station's existing General Electric 25 kV / 345 kV GSU transformer that was built about 31 years ago and partially rebuilt in 1998? Would this purchase be cost-effective as a component of a replacement transformer due for installation at Seabrook Station in April 2014?

We estimate that the purchase, shipping, installation and training costs, as a capital expense, would pay its own way in just 40 hours during a solar storm warning, if the "downrating" from generation at 100 percent of rated capacity (1260 MW or thereabouts) to 80 percent of rated capacity lasted just 40 hours or more. A positive return on investment would result from additional savings: extending the life of an existing or new GSU transformer; avoiding revenue losses during extended repair outages such as occurred at Seabrook in November 1998; avoiding environmental cleanup costs in event of a transformer fire; and of far greater financial benefit: reducing needless VAR (voltage-ampere-resistance) consumption if unprotected/unfiltered quasi-DC currents result in off-cost dispatch of power (reducing revenues to sellers), uncontracted dispatch of power (with power flowing to lowest voltage lines, whether under contract or not), or other transmission congestion costs.[3]

STUDIES OF MIS-OPERATION, CONGESTION, AND OFF-COST DISPATCH INDICATE COMPELLING FINANCIAL RETURNS TO HARDWARE-PROTECTING INVESTMENTS.

A series of careful studies by Professor Kevin Forbes of Catholic University and Christopher St. Cyr of NASA – studies that have been under-utilized or not utilized at all within the NERC GMD Task Force – demonstrate that the U.S. electric utility industry may be unintentionally suppressing net operating income for the entire industry. By relying on "downratings" and "off-cost" transmission work-arounds, and mis-operations of bulk power dispatch during years with significant geomagnetic storms, a substantial share of what might have been net operating income is dissipated in off-cost day-ahead or hour-ahead dispatch; reactive power consumption; transmission line overheating that might be largely averted; inability to transmit and hence inability to generate power for some generation entities; and mis-operation of the bulk power system through dispatch of power via low voltage pathways to receiving sites under no contractual obligation to pay.

The latest of these Forbes & St. Cyr studies (Space Weather, 2012, in press) performs statistical assessments on the PJM Interconnection system that has operated without "neutral current blocking devices" but has instead utilized "operating procedures" that downrate generation facilities during solar storms. This study analyzes the use of "operating procedures" over a two year period of above-average intensity of geomagnetic storms affecting the PJM Interconnection system between April 1, 2002 and April 1, 2004. For this entire two year period, fully 10.6 percent of hours of bulk power dispatch were off-cost.[4] This means that generation and transmission companies were selling blocks of power at prices below what the power would be worth if the system were not so congested by geomagnetically-induced

[3] See William R. Harris, Research Paper, Foundation for Resilient Societies, Seabrook Station Unit 1: Damage to Generator Step-Up Transformer identified 10 November 1998 immediately following Geomagnetic Storm Shocks of November 7-9, 1998. This Paper had been submitted in the Station Blackout Docket as Document NRC-2011-0299-0001, filed on April 28, 2012.

[4] The most recent Kevin Forbes & O. C. St. Cyr study utilizes GIC measurements at the Fredericksburg, Virginia observatory – somewhat southerly of the PJM system center – but its findings are statistically significant at the 0.001 level. See Kevin F. Forbes and O.C. St. Cyr, "Did geomagnetic activity challenge electric power reliability during solar cycle 23? Evidence from the PJM regional transmission organization in North America," Space Weather, accepted March 18, 2012, in press. For a comparative review of in disparate grid systems, see Forbes & St. Cyr, "Solar activity and economic fundamentals: Evidence from 12 geographically disparate power grids," Space Weather, v. 6, S10003 (2008). The NERC GMD "Interim" Task Force Report of February 2012 made no apparent use of the Seabrook Case study, nor of the many rigorous Forbes & St. Cyr grid system analyses that have been published in academic publications over more than a decade.

currents. And these companies were realizing losses over approximately 10 percent of all bulk power sales over a two year period.

REVENUE LOSSES IN THE BULK POWER MARKET FAR EXCEED COSTS TO PROTECT KEY TRANSFORMERS.

We estimate that the lost revenues that are associated with a persistent failure to protect GSU transformers from *geomagnetically induced currents* is roughly an order of magnitude higher than the known revenue losses that result from downrating power production. Hence, the major U.S. investor owned electric utilities, including those operating plants licensed by the NRC, are losing significant shares of net operating income during one or two years of the 10.5 year solar geomagnetic half cycle. Only a small portion of this loss appears to result from the direct revenue losses when downrating generation during solar storm warnings. A series of Forbes & St. Cyr studies, of multiple grid systems around the world, demonstrate significant revenue losses even during days, and months, and years of only modest *geomagnetically induced currents.*

But engineers do not generally read these studies. Nor do Wall Street financial analysts, who might be concerned that *net income for the entire U.S. investor owned electric utility industry has suffered by as much as 6 to 12 percent of total net operating profits during years with more intense solar geomagnetic storms.* The effect of solar storms on electric grid operations has been largely unmonitored, largely invisible to engineers, and almost totally unknown to financial analysts.

THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION (NERC) HAS LOBBIED AGAINST LEGISLATION THAT WOULD REQUIRE GRID PROTECTION AGAINST SOLAR STORMS.

It is ironic that a consortium mostly consisting of electric utility industry representatives, operating as the North American Electric Reliability Corporation, known generally as NERC, has so effectively lobbied to keep Congress from passing legislation that would protect the electric grid from solar storms. Legislative authority for FERC would include authority to require equitable sharing of system protection costs. Bulk power and generation system protections could mitigate the adverse effects of geomagnetically induced currents on electric grid operations and utility profits. FERC authority would even allow electric utilities to recover the investment in protective equipment. By successfully lobbying to prevent adoption of hardware protection for extra high voltage transformers, NERC may have inadvertently delayed opportunities for both generation and transmission entities to increase their net operating income during years with significant solar geomagnetic disturbances.[5]

We do not ask NRC Commissioners and Staff to accept without question our projection that GSU transformer-protective hardware will not only reduce the likelihood, duration, and geospatial scope of “station blackout” risks, but also increase net operating profits of the U.S. electric utility industry. But we do ask that the Commissioners and Staff examine carefully the financial track record of the U.S. electric utility since that industry adopted an “operating procedure” strategy of coping with risks of solar geomagnetic storms. Specifically, we ask the Commission to compare net operating income of major U.S. investor-owned electric utilities during years of significant geomagnetic disturbances (2000 and 2003), and contrast financial performance of the same major U.S. electric utilities (with all data converted into inflation-adjusted year $2011 dollars) during nine other years with lower levels of geomagnetic disturbances at the earth’s surface (years 2001, 2002, 2004, 2005, 2006, 2007, 2008, 2009, and 2010.[6])

By the year 2000, the industry had some utilities that had adopted the practice of “downrating” high-risk generation plants during warnings of imminent geomagnetic storms of high intensity[7]; and

- The electric utility industry, with few exceptions, has decided not to install hardware protection equipment that could both protect GSU transformers and keep geomagnetically-induced currents from entering and degrading operations of the transmission systems; and
- The electric utility industry, via NERC and through other entities, has lobbied successfully to withhold from FERC authority [not presently contained in Section 215(d) of the Federal Power Act], to set reliability standards for geomagnetic disturbance; and
- The electric utility industry has treated on-site measurements of GICs experienced at the transformers as *proprietary data*, thereby delaying independent assessment of the revenue and profit generating potential of hardware-protective equipment.[8]

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[5] At the April 30, 2012 FERC Staff Technical Conference, Mr. Naumann of Exelon, representing the Edison Electric Institute, noted the need for cost recovery authority if electric generation companies are to embrace investments in hardware-protective equipment that benefits other entities within the electric utility industry.

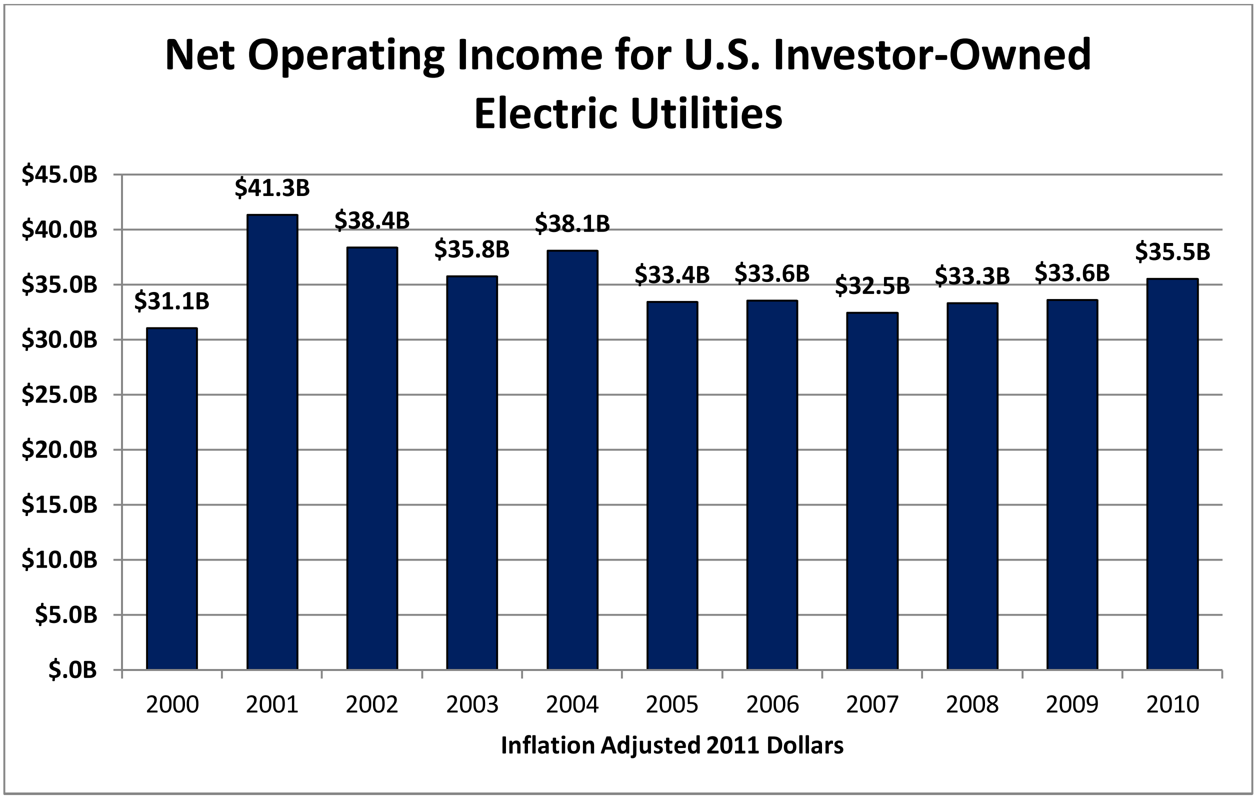
[6] At Comment due date, the U.S. Energy Information Administration has not as yet released data on aggregate net operating profits of the major U.S. investor owned electric utilities, from FERC Form 1s, for year 2011. So we compare data for 2000 through 2010 inclusively.

[7] FERC, which has limited authority over electric generating facilities, has not required timely reports on “downrating” of power output on a plant-by-plant basis. In contrast, the NRC has authority and does require reporting on “downrating” of NPPs under its jurisdiction. The Foundation for Resilient Societies has surveyed NRC databases and identified examples of “downrating” of U.S. nuclear power plants during solar geomagnetic storms since start of 2000, particularly in years 2000 and 2003. See the Appendix to these Comments.

Below is a bar chart displaying annual net operating profits of major U.S. investor owned utilities, for years 2000 through 2010. All net operating profits are shown in year 2011 inflation adjusted dollars, using the Bureau of Labor Statistics online calculator. Major U.S. investor owned electric utilities constitute about 70 percent of the overall U.S. electric utility industry, which includes municipal, cooperative, and other public entities.
Net operating profits are reported by the U.S. Energy Information Administration, using FERC Form 1 quarterly and annual reports. What is striking about the time series of net operating profits is that the industry-touted "operating practices" that are widely viewed as preferable to investments in hardware protective equipment indicate that significant net operating profits may be left on the table by an industry that has advanced at a snail's pace to keep geomagneticially induced currents out of the bulk power system.

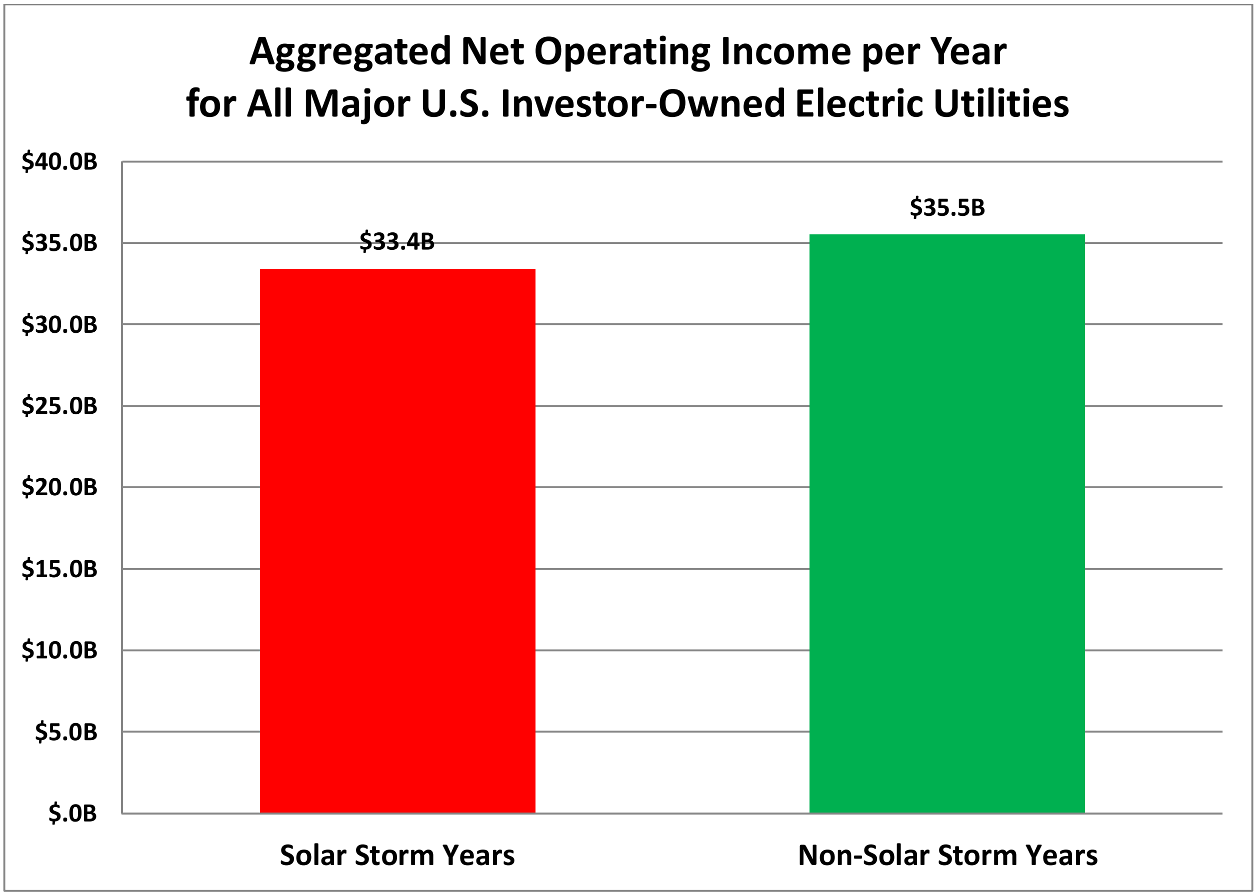
During geomagnetic storms, spot market prices can soar, but whatever profits that are captured appear to be overwhelmingly offset by the inability to sell as if there were no transmission congestion, no power absorption (reactive or VAR power losses), no power that could not be dispatched, no power moving to lowest voltage lines whether or not that power is under contract, no transformer outages (prompt or delayed), and no losses from "downrated" generation. Moreover, electric utilities can incur losses as transformer life is reduced by geomagnetically-induced current and generation plants are taken off line for transformer replacement.

[8] Since the year 1990-91, the Electric Power Research Institute EPRI) has shared with industry participants GIC data for selected participating utility sites, in a program known as SUNBURST. EPRI has also exchanged data with NERC, but the data are not publicly released, even though the physical hazards are comparable to earthquake hazards insofar as they implicate significant risks to public health and safety. The net result has been to delay industry awareness of the needless depression of net operating income industry-wide, persisting from one solar cycle to another.



* In inflation-adjusted year 2011 dollars, using inflation calculator of the U.S. Bureau of Labor Statistics. Data from U.S. Energy Information Administration

The below graph provides a quick comparison of the two sets of profit-years aggregated by times with frequent solar storms—2000 and 2003—as compared to other years with less frequent solar storms.



During a period of virtually no hardware protections for extra high voltage transformers, net operating profits per year in the two high geomagnetic disturbance years (2000 and 2003) averaged $33.43 billion for all major U.S. investor owned utilities. For the nine years with lesser geomagnetic disturbances at the surface of the earth, average annual net operating profits per year were 6.3% higher, or an average of $35.53 billion per year, all data in inflation adjusted year 2011 dollars. (The nine years with reduced GMD intensity had average net operating profits that were 14.3 percent above aggregate net profits for the year with highest intensity GMD, year 2000.)

If all of the reduced profits in high solar activity years could be captured by investments in hardware protective equipment – and we do not fully claim this result – the industry would have a total of $4.2 billion in higher net operating profits in just two years of a 10.5 year half solar cycle with the highest GIC impacts on the electric grid. These profits or just a fraction of the $4.2 billion of higher net income in two of eleven years would more than pay back the total investment in better grid reliability.

FUNDAMENTAL INDUSTRY RE-ANALYSIS COULD ACCELERATE GRID PROTECTIONS AND AVERT THE LIKELY RISK OF PROLONGED STATION BLACKOUT DUE TO SOLAR STORMS.

A fundamental rethinking of hardware protections for extra high voltage transformers could benefit the bottom line of investor owned electric utilities. The cost to protect the 2,000 most critical transformers in the United States would be approximately $1 billion dollars, at a total installed cost of $500,000 per transformer. Some hardware equipment manufacturers offer protective equipment at lower cost per transformer.

The highest priority for the prevention and mitigation of "station blackout" relating to adverse solar weather should be to keep *geomagnetically induced currents* from entering the extra high voltage bulk power system altogether. If leaders in the electric utility industry will reassess their self-interest, and the profit enhancing opportunities they have missed, perhaps they will provide fresh guidance to NERC. Without a fundamental reassessment by the investor-owned electric utility industry, FERC will remain without standards-setting and cost recovery authority, and the U.S. electric grid will remain at needless risk of widespread "station blackout" during and after severe solar geomagnetic storms.

It will be difficult for the NRC to require hardware-protective mitigation for licensees under its jurisdiction, when FERC has responsibility to oversee reliability of the entire bulk power system in the United States. This dilemma will continue if NERC is slow to progress to reliability standard-setting. The most recent NERC strategy has been to call for time-consuming additional study contained in its February 2012 "Interim" Report on geomagnetic disturbances.[9]

The good news is that many NRC-jurisdictional licensees can do their own financial analysis. They can install hardware protections on their own. They need not await the financial endorsement of NERC, because they can improve their bottom line on their own, voluntarily, by better protecting their generation and transmission related hardware. This they can do because they will profit by their diligent efforts, and they will improve the reliability of the North American electric grid by pursuing their self-interest.

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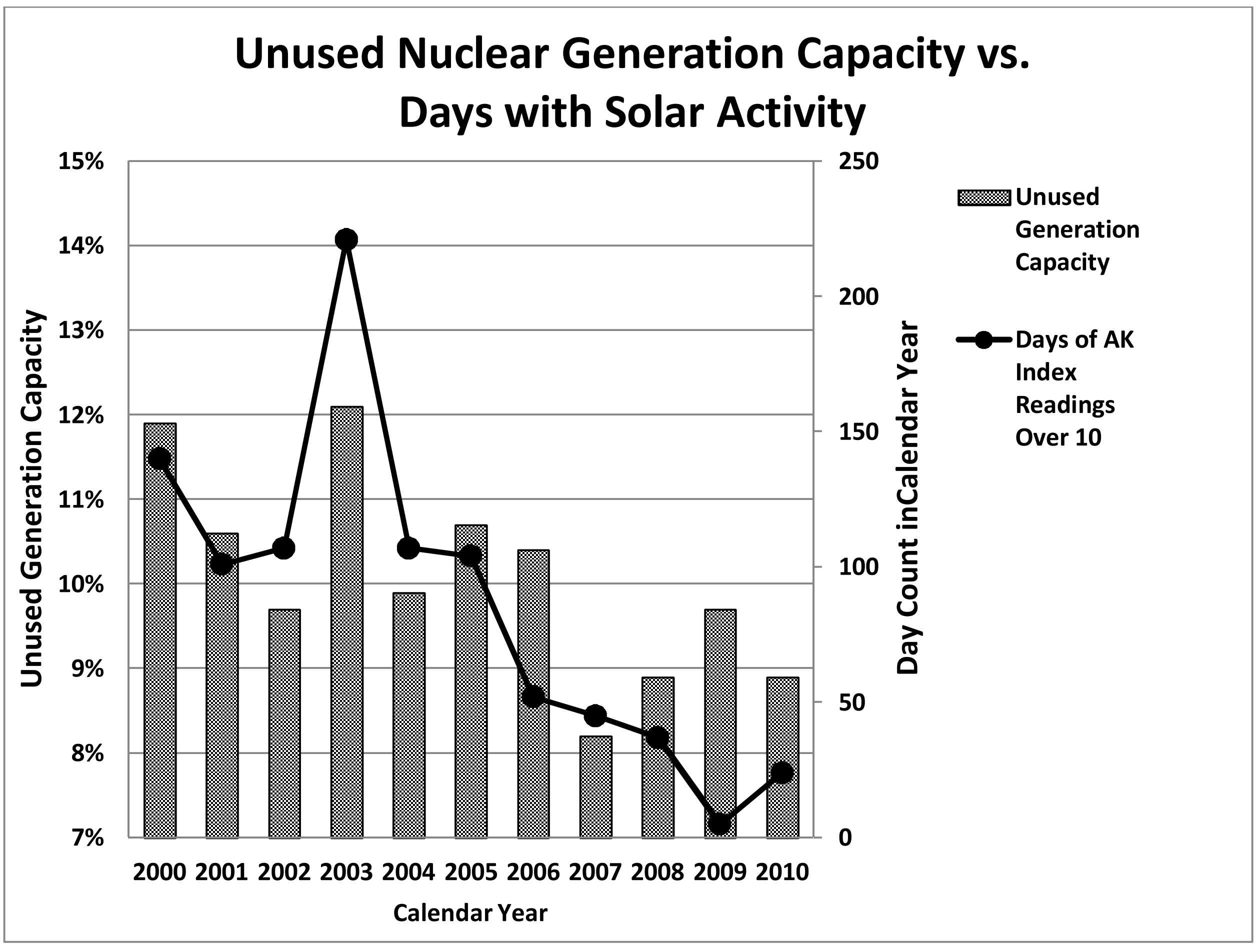
[9] NERC's Interim Report, Effects of Geomagnetic Disturbances on the Bulk Power System Is found at NERC's website: www.nerc.com/files/2012GMD.pdf. For a comparison of the methodologies and deficiencies of the February 2012 NERC "Interim" GMD Report with FERC and other U.S. official assessments of geomagnetic disturbances, see the U.S. Congressional Task Force on National and Homeland Security, Geomagnetic Disturbance Interim Report Assessment: Comparative Analysis of FERC and NERC Reports, docketed with the NRC on April 10, 2012 in Docket PRM-50-96. This Task Force comparative review is incorporated in the present Foundation comments on Station Blackout by reference to the Congressional Task Force Report previously filed and available via NRC's ADAMS database as document ML12101A316.

We offer a last statistical perspective as a reminder to NRC-jurisdictional electric utilities: increased profits are likely to flow from decisions to "backfit" existing or newly purchased GSU transformers. You can: protect the reliability of operations; reduce congestion in transmission lines; increase the share of hourly sales that are cost-based and not congestion-based; and increase the capacity utilization of nuclear power plants, the most expensive generation equipment per kilowatt hour of capacity in the entire electric utility industry.

The Energy Information Administration does make available the generating capacity utilization rates for the entire U.S. electric utility industry for years 2000 through 2010. For other sectors of the electric utility industry, economic conditions affect what share of generating capacity to place on-line. So does weather. But because of the high capital costs and low operating costs, nuclear power plants are utilized at full capacity as much as operating conditions allow. With maintenance scheduled for off-peak seasons, baseload power is available for summer and winter peak demand. So how well does the U.S. nuclear electric utility industry do in operating its baseload nuclear plants as fully as is feasible, during years of frequent geomagnetic disturbance compared to years with less frequent impacts of solar weather?



For the two years within the past eleven years with the most days of geomagnetic disturbances (as measured by days with AK Index over 10)ð 2000 and 2003ð unused nuclear generation capacity was significantly higher than for years with minimal days of geomagnetic disturbance. Might investment in hardware protective equipment lower unused nuclear generation capacity? An increase in nuclear plant utilization rates of only 2 percent could add billions of dollars to the net operating profits of nuclear plant owners.

THE COMMISSION SHOULD REQUIRE GEOMAGNTICALLY-INDUCED CURRENT MONITORING AND PUBLIC REPORTING FOR ALL NRC-JURISDICTIONAL ELECTRIC UTILITIES; THE COMMISSION SHOULD DEVELOP MINIMAL 'WITHSTAND" STANDARDS FOR ALL GSU TRANSFORMERS AT NRC-LICENSED FACILITIES.

We encourage the Commission and its Staff to require GIC monitoring, and to develop standards to prevent and mitigate "station blackout" risks. In parallel, we have confidence that the more astute industry executives will recognize a potential win-win operating environment. They should be able to improve their system reliability during adverse solar storms. They should be able to increase net operating profits – and at the same time improve the reliability of the North American electric grid, so the public interest and national security are better protected.

RESPONSES TO ISSUES PROPOSED IN THE ADVANCE NOTICE OF PROPOSED RULEMAKING ON STATION BLACKOUT (SBO), 77 <u>FED. REG.</u> 16175 (2012).

<u>In General</u>

Today's fleet of nuclear plants was designed with a fundamental assumption—that the electric grid would be highly reliable and any LOOP events would be isolated and of short duration. Fifty years of operating experience has shown this design assumption to be flawed. Even before the events at Fukushima Dai-ichi, the Northeast Blackout of 2003 showed that even a simple cascading blackout could result in simultaneous LOOP for multiple nuclear plants.

Moreover, the assumption that long term blackouts would be infinitesimally rare, and that the frequency of expected LOOPs goes down as the duration of the LOOPs increases, is not necessarily true with evolving electric grid configurations. More non-dispatchable renewable generation—wind and solar—is being added to the grid. Coal-fired plants used for black start are being removed from the grid. In the future, more dispatchable generation will be gas-fired plants—plants which do not store fuel on site, but which are interdependent with natural gas pipelines that increasingly rely on electric pumps and control systems. And finally, we have nuclear plants that are designed to be offline if not connected to a functioning electric grid. Only hydro-electric power is left as reliable and dispatchable power, and many regions lack this resource. All of these factors may combine to make any blackout lasting beyond seven days a long blackout indeed.

If nuclear plants could be designed to produce power from the reactor core while disconnected from the electric grid (even while in a LOOP condition), this would be a near ideal solution to many SBO issues. Currently, the Calvert Cliffs nuclear plant has this capability. If all new nuclear plants were to incorporate this design feature, it would increase electric grid resiliency and reduce the chance of LOOP for plants that must be connected to the grid to produce power. Nuclear power plants would be capable of providing extended generation capability during widespread and severe natural disasters, because nuclear plants in effect store up to 18 months of fuel supply on-site.

Of all naturally-caused events that could result in long-term LOOP, solar storms could have the most widespread impact, with dozens of nuclear power plants being potentially affected. Moreover, Oak Ridge National Laboratory, in a report sponsored by the Federal Energy Regulatory Commission, estimates a 1% annual probability of a solar storm severe enough to damage 300 extra high voltage transformers, resulting in electric grid outage to 130 million Americans and long-term LOOP to over half of licensed nuclear power plants. This LOOP could last 1-2 years, according to the Oak Ridge report. This aggregate LOOP risk from solar storms is greater than more local risks from hurricanes, floods, tornados, and earthquakes. Moreover, in such a scenario, outside assistance to nuclear plants would be in doubt. As a result, the NRC must not eliminate risks due to solar storms in consideration of station blackout rulemaking.

Specific Questions and Responses

Question: Recognizing the uncertainties associated with natural phenomena and in the context of establishing a set of events upon which to base reference bounds for design, should SBO equipment be designed to withstand natural phenomena which the facility is not already designed to withstand, and should SBO mitigation strategies consider such natural phenomena? What severity of natural phenomena should be considered (e.g., length of return period or duration of the phenomena)?

Response: To reduce the risk due to solar storms—a risk which was not fully understood at the time of plant design—backfitting would be required. Any SBO rule should assume that the LOOP duration may extend for the time duration in the Oak Ridge report: 1-2 years. A realistic strategy may be to accept radiation releases from reactor cores that are designed to contain radioactive releases under most conditions, but to largely prevent even larger radiation releases from spent fuel pools, housed in buildings that are not generally designed to prevent hydrogen gas explosions if water cooling fails.

Question: For events that do not fall within the reference bounds for design, but may result in SBO conditions, it may be necessary for licensees to take early action in order to increase the potential for successful mitigation. Recognizing that there are several actions that take time during such events that include, but are not limited to (1) the need to properly identify and diagnose the event or situation, (2) the need to make the decision to implement actions or strategies to mitigate existing or imminent SBO conditions, and (3) the time for licensees to implement the strategies once the decision is made; what time constraints do stakeholders understand to be important in developing SBO mitigation requirements? For example, what should be the coping time with no mitigation for SBO conditions given time constraints that include the time to (1) identify and determine the need to take mitigative actions and (2) implement these strategies under worst case conditions? How long should mitigation strategies be expected to be deployed before the receipt of offsite assistance? If certain mitigation actions must be taken early in the event to avert core damage, how should those actions be determined and how should the time when they must be performed be determined?

Response: Any SBO rulemaking should take into account a scenario where outside assistance never arrives. In such a pessimistic but still realistic scenario, radiation release may be minimized through explicit strategies, including pre-planned and pre-staged onsite capabilities, but not completely prevented.

Question: The current requirements in 10 CFR 50.63 for SBO are ``unit-specific,'' meaning that the total loss of all ac is not assumed to extend to all the power reactors at a given site. Based on the lessons learned from the Fukushima Dai-ichi event, the NRC believes the SBO requirements may need to be expanded to consider an SBO for the entire site (i.e., assume the SBO condition occurs to all the units for multi-unit sites). What are stakeholder views on this matter, and how should it be addressed in the new SBO rule? Please provide the basis for your position.

Response: As events in Japan and during the 2003 Northeast Blackout amply show, total loss of ac power can extent not only to all plants at a given site, but to all sites within a large region.

Question: The current provisions in 10 CFR 50.63 require a facility to withstand, for a specified duration, and recover from an SBO as defined in 10 CFR 50.2. Should the new SBO rule require long-term cooling and water makeup to SFPs during an SBO? Please provide the basis for your position.

Response: The assumption that a facility need withstand a SBO for only a specified duration is fundamentally flawed. Instead, the spent fuel pool mitigation strategy should minimize the risk of radiation release for an SBO of infinite duration. For the full basis for our position, please see supporting materials within Petition for Rulemaking PRM-50-96.

Question: Should the SBO rule address how external events would affect the ``specific duration'' of the SBO and the associated coping time?

Response: Arbitrarily determining a “specific duration” of coping time as a sole design basis is a fundamentally flawed strategy. Instead, the SBO rule should also consider the possibility that the “specific duration” of LOOP will be indefinite or even infinite; under this additional scenario, radiation release could be minimized but not completely eliminated.

Question: If new requirements as discussed in this section should be imposed for existing licensees or with respect to existing certified designs, what sort of benefits or costs do stakeholders estimate could be incurred?

Response: For a complete cost-benefit analysis of spent fuel pool protection under a condition of long-term LOOP, please see PRM-50-96.

Question: What specific objectives should the SBO rule be designed to achieve? a. For example, should the objective of the SBO rule be to significantly reduce the frequency of core damage from a prolonged SBO, or would it be better to focus on the reduction of the frequency of large early release of radiation for low probability external events that result in SBO conditions? Please provide the basis for your position.

Response: Under a LOOP scenario of indefinite duration, core damage might be acceptable, but large scale release of radiation from spent fuel pools could be prevented. See PRM-50-96.

Question: Should the NRC adopt an SBO rule that is more performance-based and which would not specify the events that must be considered in determining the SBO duration or the capability for coping with an SBO of specified duration?

Response: The duration of the SBO is more important than the cause of the SBO. An SBO of indefinite duration should be specifically considered in any rulemaking. An SBO rule should not assume, as the exclusive design basis, that outside assistance will eventually arrive.

Question: Recognizing that the SBO mitigation requirements could address a set of events that fall outside the reference bounds for design of the plant and may lead to SBO conditions, success criteria might be more readily established. Should the rule establish success criteria or requirements that apply as a function of the probability of the events? For example, for the more probable/common SBO events, such as those that 10 CFR 50.63 currently addresses, the current 10 CFR 50.63 requirements could largely remain in place. For the low probability, high consequence, hazard-driven SBOs, a different set of success criteria could be established that recognize the lower probabilities of occurrence of these types of SBOs. Please provide the basis for your position.

Response: For an SBO of indefinite duration, a much lower success criterion should apply. For example, radiation from the reactor core may not be completely prevented, but larger radiation releases from spent fuel pools may be prevented with some statistically acceptable probability.

Question: The NRC would like stakeholder's views on a regulatory approach to SBO mitigation that conceptually follows the NTTF proposal in NTTF Recommendation 4.1. Specifically, do stakeholders believe that the best conceptual approach for SBO mitigation is to establish requirements for an initial coping period (no ac power available), during which time licensees establish mitigation strategies; followed by an interim period during which time the mitigation strategies are employed for a duration sufficient to enable offsite relief to arrive; followed by a final phase where offsite relief has arrived and a stable shutdown condition is established? Alternatively, if stakeholders have alternative approaches or suggested changes to this conceptual approach, please provide the basis for them.

Response: There is no scientific basis to assume that outside assistance will eventually arrive, with a probability of 100%. Therefore, any SBO rule must provide for the possibility that outside assistance will never arrive; under this scenario, radiation releases could not be eliminated, but merely reduced and mitigated post-release.

Question: Relationship Between Existing Station Blackout Requirements in Title 10 of the Code of Federal Regulations, Section 50.63 and the New Station Blackout Requirements… The NRC therefore seeks stakeholder views on which of these options is best suited for implementing new requirements recommended in response to ANPR Sections B, C, and D, above. What is the basis for your position?

Response: In populated areas, lack of electricity will kill large numbers of people quicker and more surely than radiation.[10] Therefore, any new SBO rule should allow practical backfit of nuclear power plants, but should not financially motivate shutdown of existing nuclear plants—large scale shutdowns could destabilize day-to-day operations of the electric grid. Greater SBO risk reductions may be required for new plants, as compared to existing plants.

Our responses to your ANPR are respectfully submitted by the Foundation for Resilient Societies.

[10] See, for example, G. Brooke Anderson and Michelle l. Bell, "Lights Out: Impact of the August 2003 Power Outage on Mortality in New York, NY," Epidemiology 23(2): 189-193 (March 2012).

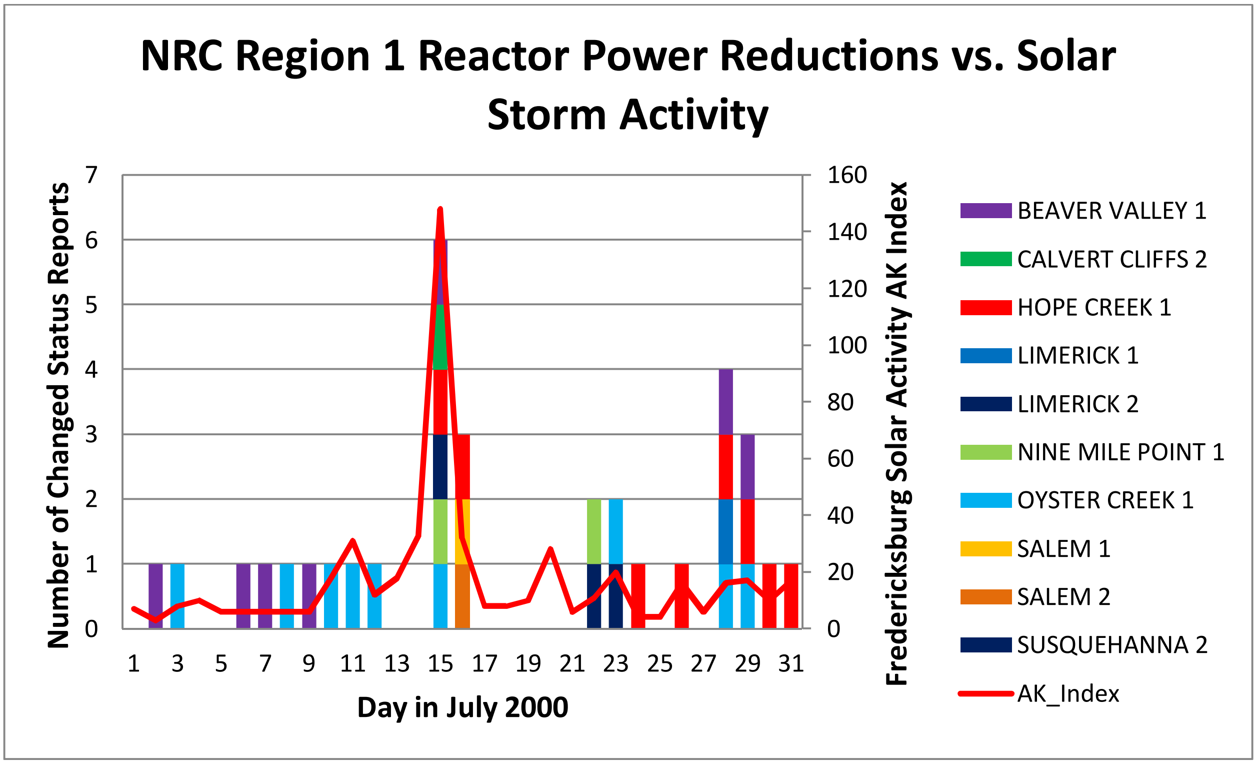
APPENDIX A:

NRC-JURISDICTIONAL PLANTS REPORTING "DOWNRATING" OF GENERATION DURING SOLAR GEOMAGNETIC DISTURBANCES SINCE THE YEAR 2000

During the most recent solar maximum, reductions of power output at some nuclear generation stations during *moderate* solar storms has been substantial, with power reductions of up to 35%. During an *extreme* solar storm, such as the 1859 Carrington Event or the 1921 Railroad Storm, power reductions could be as high as 100% at sites vulnerable to geomagnetic disturbance. While public records for generation and transmission operators are not available in most cases, a limited public data set from the Nuclear Regulatory Commission shows the potential impact of moderate solar storms occurring several times around the last solar maximum.

The below graphs show power reductions for the July 2000 solar storm within NRC Region 1, including some power reductions for maintenance actions other than solar storms, but at the same time as solar storms. NRC Region 1, located in the Northeast, is particularly susceptible to geomagnetically induced currents from solar storms.

The below table shows the magnitude of power reductions at specific nuclear plants, where the "comments" section of the Power Reactor Status Report specifically contains a reference to geomagnetic disturbance or solar activity.


NRC Region 1 Reactor Power Reductions vs. Solar Storm Activity
Number of Changed Status Reports
0
1
2
3
4
5
6
7
Fredericksburg Solar Activity AK Index
0
20
40
60
80
100
120
140
160
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Day in July 2000
BEAVER VALLEY 1
CALVERT CLIFFS 2
HOPE CREEK 1
LIMERICK 1
LIMERICK 2
NINE MILE POINT 1
OYSTER CREEK 1
SALEM 1
SALEM 2
SUSQUEHANNA 2
AK_Index

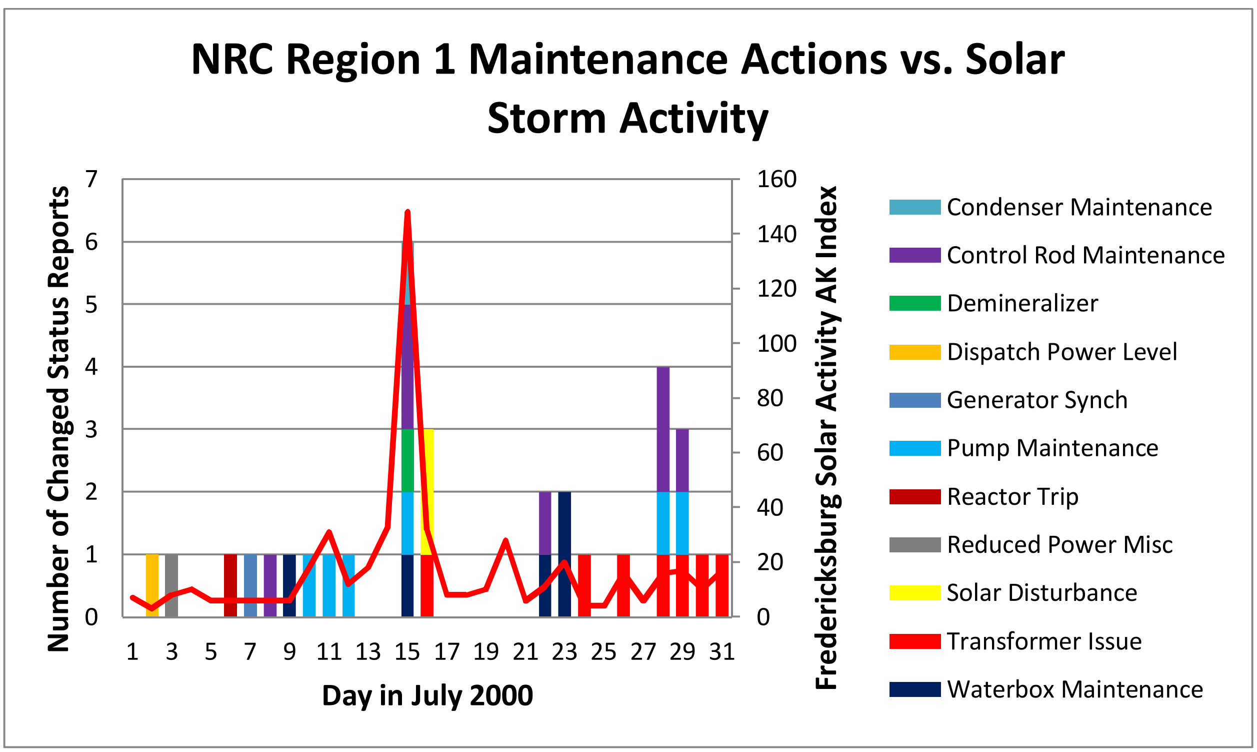

NRC Region 1 Maintenance Actions vs. Solar Storm Activity
Number of Changed Status Reports
0
1
2
3
4
5
6
7
Fredericksburg Solar Activity AK Index
0
20
40
60
80
100
120
140
160
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Day in July 2000
Condenser Maintenance
Control Rod Maintenance
Demineralizer
Dispatch Power Level
Generator Synch
Pump Maintenance
Reactor Trip
Reduced Power Misc
Solar Disturbance
Transformer Issue
Waterbox Maintenance

Table 1. Sample of Power Reductions Due to Geomagnetic Disturbance

Source: NRC Power Reactor Status Reports and NOAA AK Indexes

Date	Nuclear Plant	Power Reduction	Solar Storm AK Index	Reason or Comment
7/16/2000	SALEM 1	20%	32	REDUCED POWER DUE TO GRID DISTURBANCE CAUSED BY SOLAR MAGNETIC DISTURBANCE
7/16/2000	SALEM 2	20%	32	REDUCED POWER DUE TO GRID DISTURBANCE CAUSED BY SOLAR MAGNETIC DISTURBANCE
3/31/2001	HOPE CREEK	35%	115	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE'S
4/1/2001	HOPE CREEK	35%	26	HOLDING POWER DUE TO SOLAR MAGNETIC DISTURBANCE'S
4/2/2001	HOPE CREEK	20%	12	HOLDING POWER DUE TO SOLAR MAGNETIC DISTURBANCE'S
4/12/2001	HOPE CREEK	20%	29	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE
4/13/2001	HOPE CREEK	20%	31	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE
4/18/2001	HOPE CREEK	20%	22	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES ON "C" MAIN POWER TRANSFORMER
10/2/2001	HOPE CREEK	20%	24	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES AFFECTING THE MAIN TRANSFORMER
10/3/2001	HOPE CREEK	20%	26	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES AFFECTING THE MAIN TRANSFORMER
10/4/2001	HOPE CREEK	20%	9	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES AFFECTING THE MAIN TRANSFORMER
11/6/2001	SALEM 1	25%	60	HOLDING POWER AT THIS LEVEL DUE TO SOLAR MAGNETIC DISTURBANCES
11/6/2001	SALEM 2	24%	60	HOLDING POWER AT THIS LEVEL DUE TO SOLAR MAGNETIC ACTIVITY
11/24/2001	HOPE CREEK	22%	76	SOLAR MAGNETIC DISTURBANCE
11/24/2001	SALEM 1	24%	76	SOLAR MAGNETIC DISTURBANCE
11/24/2001	SALEM 2	25%	76	SOLAR MAGNETIC DISTURBANCE
10/29/2003	HOPE CREEK	20%	199	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
10/29/2003	SALEM 1	20%	199	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
10/30/2003	HOPE CREEK	20%	144	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES
10/30/2003	POINT BEACH 1	17%	144	INCREASING POWER FOLLOWING A DECREASE IN POWER DUE TO GRID GEO-MAGNETIC DISTURBANCES
10/30/2003	SALEM 1	20%	144	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES

Table 1. Sample of Power Reductions Due to Geomagnetic Disturbance (cont.)

Source: NRC Power Reactor Status Reports and NOAA AK Indexes

Date	Nuclear Plant	Power Reduction	Solar Storm AK Index	Reason or Comment
10/31/2003	DUANE ARNOLD	6%	73	100% ELECTRICAL CAPABILITY NO D/G OR SWITCHYARD WORK DUE TO SOLAR FLARE RESPONSE
10/31/2003	HOPE CREEK	20%	73	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES - WILL REASSESS HOLD AT 1100 EST AND, IF NO PROBLEMS, ESCALATE POWER
10/31/2003	POINT BEACH 1	16%	73	REDUCED POWER DUE TO GRID GEO-MAGNETIC DISTURBANCES
10/31/2003	SALEM 1	20%	73	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCES - WILL REASSESS HOLD AT 1100 EST AND, IF NO PROBLEMS, ESCALATE POWER
11/8/2004	SALEM 1	23%	116	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE
11/8/2004	SALEM 2	22%	116	REDUCED POWER DUE TO SOLAR MAGNETIC DISTURBANCE
12/15/2006	POINT BEACH 1	2%	48	AFW TESTING IN PROGRESS POSSIBLE REDUCTION IN POWER BY 25% LATER TODAY DUE TO SOLAR MAGNETIC ACTIVITY