Secure the Grid Coalition

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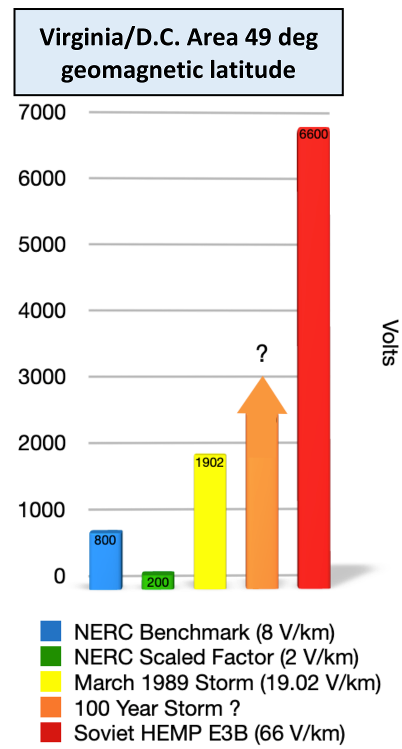
Dear Secretary Granholm and distinguished members of the Secretary of Energy Advisory Board:

The *Secure the Grid Coalition* greatly appreciates the opportunity to voice recommendations to the SEAB for consideration during its June 13, 2022, virtual meeting.

<u>Our Request</u>: We would like to build upon our **previous recommendations, made to DOE for the last 9 years** (and to the SEAB on 25 January) by **urging you to address the vulnerability of large power transformers to ground induced currents** (GICs) produced by solar weather (and nuclear electromagnetic pulse). This urgent recommendation is based on recent peer-reviewed scientific studies that make it clear that the **current protection standards for solar weather are transparently defective and dangerously ineffective** at protecting the electric grid.

<u>A Visual Aid</u>: The graph on the right shows the comparison between the current GMD protection standard and real-world data by applying the different levels (V/km) of induced currents to a 100km transmission line (average length of U.S. transmission lines).



(Note that the voltage level is proportional to the length of the conductor. Thus induced voltages could be much higher than levels noted here since many transmission lines are longer than 100km)

In this case we use an example utility in the Virginia /Washington D.C. area. (a geomagnetic latitude of 49deg). The utility would take the **"benchmark" of 8 V/km**, and apply the **"scaling factor"** (ref. NERC instruction, page 29, TPL-007-4 – Transmission System Planned Performance for Geomagnetic Disturbance Events) to determine a protection level of **2 V/km.**

Contrast this with **real-world data** collected during the **March 1989 Solar Storm** (considered a "40-year" solar storm).

The NERC standard is supposed to bound levels possible for a 100-yr solar storm.

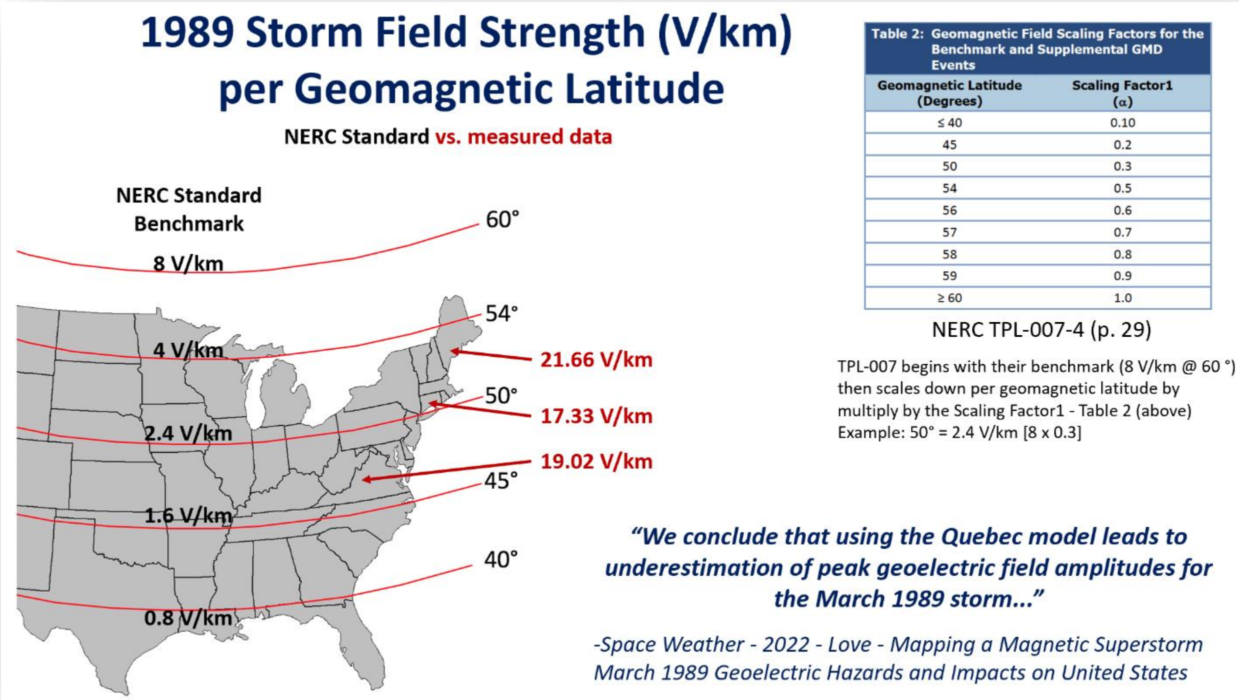
We include an unknown bar for the 100-year solar storm since the last time that occurred (1859 Carrington event) we have no ground voltage or current measurements.

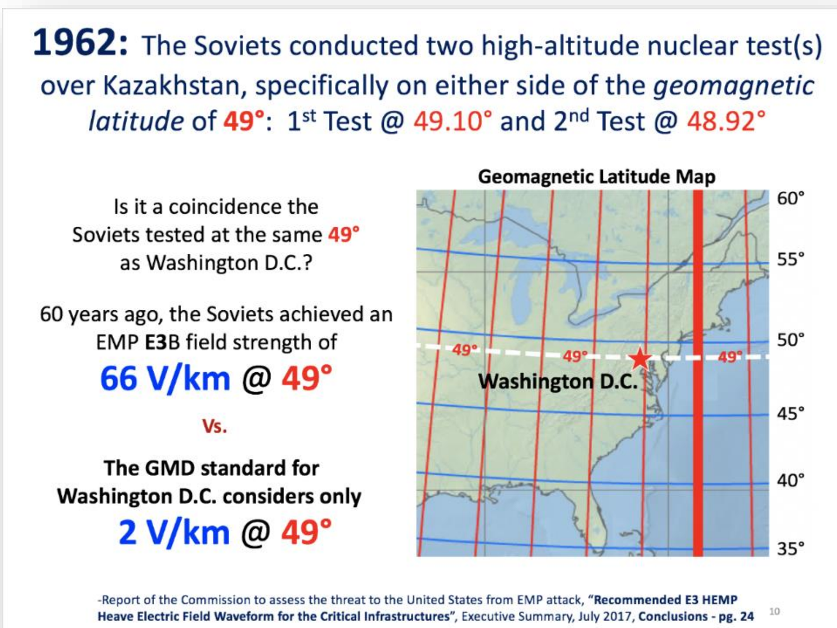
Finally, we provide another example **of real-world data** collected by the Soviets in the 1962 "K-test" of high-altitude electromagnetic pulse (HEMP) effects over what is now considered Kazakhstan. The Soviet tests produced an electric field of **66 V/km** (HEMP E3).

For this reason, the **Congressional EMP Commission recommended protecting the grid to a level of 85 V/km** to guard against both solar weather and HEMP E3. **We concur with that recommendation.**

The pages that follow provide a detailed explanation of the deficiency the current NERC GMD benchmarks. Appendices are also included to provide evidence justifying the need for immediate emergency action to protect the electric grid against GMD and EMP ground induced currents.

Additional Visual Aids: Below are images depicting the differences between the NERC standard "benchmark" and "scaling factor" **(in black)** and actual measured data **(in red)** with an excerpt from page 29 of NERCs TPL-007-4. Also below is a map depicting the specific geomagnetic latitude of the Soviet HEMP test in 1962 over Kazakhstan (which is the same geomagnetic latitude as Washington D.C.)





Background: Since May 2013, the Federal Energy Regulatory Commission (FERC) has required the North American Electric Reliability Corporation (NERC) to set a reliability standard to protect high voltage transformers from the effects of Geomagnetic Disturbances (GMD). For the standard, FERC mandated that NERC set a so-called "Benchmark Geomagnetic Disturbance Event." This benchmark was to establish the maximum 1-in-100-year storm that electric utilities must protect against.

But when the NERC Standard Drafting Team developed the benchmark event, they did not use data on storms impacting North America – but rather used European data on magnetic fields during a 21-year period during which no major storms occurred. Nor did they collect data on past storm effects on critical grid equipment such as high voltage transformers.

Beyond the above manipulation, the Drafting Team spatially averaged their findings which arrived at an insufficient defense-conservative benchmark to protect against only 8 volts per kilometer (8 V/km) beginning at the 60 degree geomagnetic latitude (over parts of Quebec) and then scaled down from there southward into the United States (e.g. only 2.4 V/km for the Washington D.C. area).

This standard, TPL-007, has progressed through four iterations over nearly a decade and its latest version, TPL-007-4, remains critically deficient. This is due to the Drafting Team's spatially averaging their GMD levels to artificially reduce the final "defense-conservative" benchmark to 8 volts per kilometer (8 V/km).

The inadequate benchmark has remained in place despite the science-based criticisms of both the sources and methods employed in its establishment. Specific criticisms that immediately arose upon adoption of this standard follow in **Appendices A and B.**

New Empirical Data from USGS, et.al: In its 2017 report titled "Enhancing the Resilience of the Nation's Electricity System," the National Academies of Sciences pointed out the need for "basic research" and "applied work to develop adequate simulations" to model severe events for the power grid, such as solar weather. **(See Appendix C).**

Two recent research papers published by USGS measuring the most consequential magnetic storms of the past century, the **1921 "Railroad Storm**" and the **1989 "Hydro-Quebec Storm,"** used data collected from magnetometer readings at specified sites.

The first of these is titled, **"Intensity and Impact of the New York Railroad Superstorm of May 1921."** Available at the weblink:
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019SW002250

> This study draws upon magnetometer readings and the failure of telephonic and telegraphic landline systems. This study uses these communications disruptions as a proxy for long-run interconnected conductors, as the electric power delivery topology in 1921 was not interconnected into the bulk power systems we have today. Using the example of the **railroad station that burned down due to overheated telegraph system** in Brewster, Connecticut, the CT160 survey station 27 km north of Brewster reported a geoelectric field of **19.40 V/km**, which is more than 7 times the benchmark of 2.4 V/km per TPL-007-4 for the same geomagnetic latitude.

The most recent of these two studies (May 2022) is titled **"Mapping a Magnetic Superstorm: March 1989 Geoelectric Hazards and Impacts on United States Power Systems."** Available at the weblink:
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021SW003030

> Geomagnetically Induced Currents (GICs) realized during the magnetic storm of March 1989 caused a blackout in Québec, Canada. Highest measured GICs occurred in the Mid-Atlantic and

Northeast United States, where they **caused operational interference for electric-power companies and catastrophically damaged a high-voltage transformer.** (See image below)

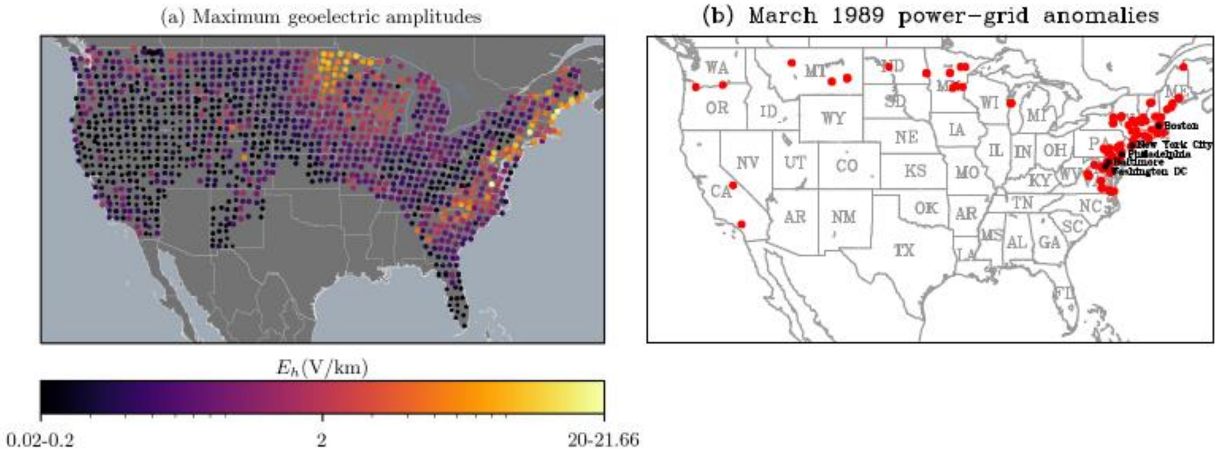
March 1989 magnetic storm damage to a high-voltage transformer at a nuclear power center in Salem, New Jersey.

This study provides guidance where utility companies might concentrate their efforts to mitigate the impacts of future magnetic superstorms. The 1989 storm had its greatest impacts from Ground Induced Currents (GICs) in those regions of lowest earth crust conductivity. These regions are the highly populated Mid-Atlantic states through New England, and the Upper Midwest region. (See image on next page)

This study of 1989 magnetic storm produced field amplitude peaks 1-minute resolution of **21.66 V/km** in Maine and **19.02 V/km** in Virginia and 17.33 in Connecticut. The Upper Midwest region was measured at **12.28 V/km**, at survey site MNB36 in Minnesota.

These data points far exceed the scaled down V/km benchmarks adopted in TPL-007-4.

Comparison of March 1989 geoelectric amplitudes with power-grid operational interference



<u>GMD/ EMP Impacts Will Be Worse Today than 1989:</u> The March 1989 Solar Storm has been deemed by many in the scientific community, including Dr. Love in the most recent USGS Study, to represent a "1-in-40-year" storm.

In the years after 1989, the electric power grid has operated at higher voltage and current levels. Therefore, a solar storm of the intensity of 1989 with identical geospatial and time dependencies would be expected to debilitate the power grid more severely than the 1989 storm. Again, deemed to be a 1-in-40-year storm.

Since the directive of FERC was to establish a benchmark for a 1-in-100-year magnetic storm the need for a higher benchmark is self-evident.

<u>Protecting Against GMD/HEMP Induced Currents Saves Money Annually</u>: Savings to the general U.S. economy on the order of $10B per year can be realized by the implementation of DC-blocking technologies. This is the conclusion of two independent studies into non-spectacular geomagnetic activity. These studies were conducted by **Lockheed Martin, Zurich Services Corp., and NOAA**. See **Appendix D:** "Assessing the Impact of Space Weather on the Electric Power Grid Based on Insurance Claims for Industrial Electric Equipment." See **Appendix E**: "Electric Claims and Space Weather."

<u>Specific Recommendations:</u>

(1) **Establish a Realistic GMD/HEMP E3 Protection Standard**: Our Coalition respectfully recommends that the SEAB take immediate action to raise the benchmark above the current inadequate 8 V/km to the 85 V/km recommended by the Congressional EMP Commission. **See Appendices F, G & H.**

(2) **Immediately Conduct Transformer Testing**: As previously recommended on multiple occasions to DOE and to SEAB, we again recommend the Department of Energy test the multi-million-dollar transformer donated by Duke Energy in South Carolina. Despite numerous requests, we still have no real-world data on the effects of EMP on even one transmission system transformer under load (only modeling from industry-funded studies that are not reliable without

threat level test corroboration). The importance of this testing is made clear in the recent Journal of Critical Infrastructure Policy article titled **"Large Transformer Criticality, Threats, and Opportunities"** co-authored by leading engineers from the **Savannah River National Laboratory**. **See Appendix I** (and **previous recommendations to SEAB** on 25 January 2022.)

(3) Immediately Install GMD/HEMP E3 Protection Technology: Implement the use of Direct-Current-Blocking mitigation hardware devices proven and successful in operation on the live transmission grid for seven years. **See Appendix J.**

Our Coalition is ready to assist the SEAB and can make personal introductions to numerous experts throughout the country who can help DOE act on the above recommendations.

Respectfully submitted by,

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Appendix A provides links to the comprehensive history on the shortfalls of this benchmark standard, as articulated to FERC by the **Foundation for Resilient Societies**, (2013-2017).
https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/Appendix-A-Foundation-for-Resilient-Societies-Testimony-on-GMD-Protection-Standards.pdf

Appendix B is the 2019 testimony of **Dr. George Baker** before the **U.S. Senate Committee on Homeland Security and Governmental Affairs**.
https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/Appendic-C-2019-George-H-Baker-Written-TestimonyFINAL.pdf

Appendix C is a link to a 2017 study conducted by **The National Academies of Sciences**, titled **"Enhancing the Resilience of the Nation's Electricity System."**
http://nap.naptionalacademies.org/24836

Appendix D: "Assessing the Impact of Space Weather on the Electric Power Grid Based on Insurance Claims for Industrial Electric Equipment."
https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/Appendix-E-Space-Weather-2014-Schrijver-Assessing-the-impact-of-space-weather-based-on-insurance.pdf

Appendix E: **"Electric Claims and Space Weather."**
https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/Appendix-F-2015Zurich-ElectricalClaimsandSpaceWeather.pdf

Appendix F: **Examination of NERC GMD Standards and Validation of Ground Models and Geo-Electric Fields**
http://www.firstempcommission.org/uploads/1/1/9/5/119571849/emp_2017_staff_paper_-_gmd_standards_final.pdf

Appendix G: **Electric Reliability Standards for Solar Geomagnetic Disturbances**
http://www.firstempcommission.org/uploads/1/1/9/5/119571849/emp_2017_staff_paper_-_electric_reliability_standards_for_gmd_final.pdf

Appendix H: **Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures**
http://www.firstempcommission.org/uploads/1/1/9/5/119571849/recommended_e3_waveform_for_critical_infrastructures_-_final_april2018.pdf

Appendix I: "Large Transformer Criticality, Threats, and Opportunities" co-authored by Dr. George Baker and leading engineers from the **Savannah River National Laboratory**
https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/LARGE-TRANSFORMER-THREATS-OPPORTUNITIESJCIP-PUBLISHED-VERSION.pdf

Appendix J - Secure the Grid Coalition's Comment Regarding Bulk-Power System EO RFI FR Doc. 2020—14668, pg. 4-6, "**Immediately Protect Large Power Transformers from Direct Current**"
https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/Appendix-D-2020-08-24-excerpt-from-Secured-the-Grid-Coalition-comments-to-DOE-re-Executive-Order-RFI.pdf