Secure the Grid Coalition

A Project of the Center for Security Policy
2020 Pennsylvania Avenue, N.W., Suite 189
Washington, D.C. 20006

November 21, 2025

U.S. Department of Energy
1000 Independence Ave, SW
Washington, DC 20585

Comments of Secure the Grid Coalition on DOE "Speed to Power" RFI (2025-18058)

Dear Department of Energy:

Our Secure the Grid Coalition[1] urges the Department of Energy to act aggressively to protect our nation's electric grid against threats which produce Geomagnetically Induced Currents (GIC). GIC results from regularly occurring solar storms. GIC can also result from the detonation of a nuclear warhead in the upper atmosphere, a so-called High-Altitude Electromagnetic Pulse (HEMP) attack. Fortunately, commercially available, thoroughly validated, and cost-effective technology already exists to protect against both threats—the capacitive neutral blocking device known as SolidGround®.

Whatever you build will stand or fall depending on the firmness of its foundation.

As our comments below will demonstrate, DOE's exciting "Speed to Power" initiative and the future of American energy are at risk of failure due to the lack of a firm foundation protecting our electric grid from **GIC threats that could eventually destroy it.**

Absent protections, the next extreme solar storm could collapse the U.S. electric grid, resulting in millions of deaths—and potential loss of continuity of government. Comprehensive protection against solar storms would also mitigate the long pulse [also known as the "E3 Pulse"] from a HEMP attack.

Thus, nationwide GIC protection will rapidly bolster America's nuclear deterrence against peer adversaries and rogue nations seeking to exploit the asymmetric warfare benefits of a HEMP attack.

Deploying SolidGround® to protect America's roughly 6,000 identified "high risk design" transformers is a one-time cost of ~ $4 billion. This hardware protection will also save the U.S. ~ $10 billion in annual economic losses from GIC effects due to routine solar weather. This is a commonsense investment.

Our present warning and recommendations are a re-addressal of those we voiced previously to DOE in August 2020[2], and to the previous Secretary of Energy in January 2022[3], June 2022[4] and April 2024[5].

While the previous leadership chose not to act, we have firm faith that the present leadership will.

We just hope you will act in time.

---

[1] The Secure the Grid Coalition is a group of policy, energy, and national security experts dedicated to strengthening the resilience of America's electrical grid. It is sponsored by the Center for Security Policy, a 501(c)(3) nonprofit which receives no funding from governments, foreign sources, the electric industry, or any for-profit corporations involved in protecting the grid, including EMPRIMUS, which has developed the capacitive neutral blocking device known as SolidGround®

[2] https://securethegrid.com/wp-content/uploads/2021/02/STG-Coalition-Comments-on-DOE-RFI-24-Aug-2020.pdf

[3] https://securethegrid.com/wp-content/uploads/2025/11/STG-Coalition-Letter_to_DOE_on_Supply_Chain_RFI_Jan_2022.pdf

[4] https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/STG-Coalition-Comments-SEAB-13June2022-Final.pdf

[5] https://securethegrid.com/wp-content/uploads/2025/11/STG-Coalition-Comments-SEAB-9April2024-with_Photos_and_Enclosure.pdf

National Context and Alignment with Executive Order 14262

The Department of Energy's (DOE) Request for Information (2025-18058) cites President Trump's Executive Order 14262 (Strengthening the Reliability and Security of the United States Electric Grid, April 8, 2025) as one of the guiding authorities for accelerating large-scale generation and transmission expansion. That Executive Order recognizes that America's ability to maintain economic, technological, and military superiority depends upon an electric grid that is **both reliable and secure** in the face of surging demand from artificial-intelligence data centers, advanced manufacturing, and semiconductor fabrication facilities.

EO 14262 establishes a clear national policy:

"It is the policy of the United States to ensure the reliability, resilience, and security of the electric power grid… our electric grid must utilize all available power generation resources, particularly those secure, redundant fuel supplies that are capable of extended operations."

In direct support of that policy, DOE is instructed to:

- streamline/systemize use of its emergency authority under § 202(c) of the Federal Power Act,
- create a uniform reserve-margin methodology for all regions, and
- identify and protect generation resources "critical to system reliability."

These provisions make EO 14262 the natural home for actions that address the threat of GICs that are the main impact of both Geomagnetic Disturbances (GMD) and E3 HEMP —phenomena that, if ignored, could abruptly erase the reserve margin and reliability the Executive Order directs DOE to safeguard.

Ultimately, the "Speed to Power" initiative cannot succeed if invisible currents in the earth induced by space weather or from hostile actors are allowed to destroy the very transformers, large power generators and high voltage circuit breakers that make "speed to power" possible.

Existing Reliability Gaps That Undermine the Executive Order's Purpose

A. Regulatory Capture and Reliability Standards Based on Analytical Error

Current electric grid protections against GIC are woefully inadequate, because the threat thresholds in reliability standards developed by the North American Electric Reliability Corporation (NERC) are a small fraction of what has already occurred in the real world. Our detailed technical explanation follows.

The electric field strength of both GMD and E3 HEMP is measured in volts per kilometer (V/km) and directly relates to how large the GIC currents will be.

Our Secure the Grid Coalition's recent report **"*Speed to Power on a Firm Foundation*"** documents in detail how current NERC standards fail to meet EO 14262's requirement for genuine reliability as it relates to the GIC threat.[6]

The Nuclear Regulatory Commission's (NRC) May 7, 2025 decision denying Petition for Rulemaking PRM-50-96 —despite warnings from the Air Force Electromagnetic Defense Task Force, the GAO, EMP Commission, International Electrotechnical Commission (IEC) and the National Academies—epitomizes this institutional blunder. NRC justified its action based on the FERC-approved NERC

[6] The report, "Speed to Power on a Firm Foundation" can be found here: https://securethegrid.com/save/

geomagnetic-disturbance standard (TPL-007-4) and the untrue assertion that "80 percent of EHV transformers are resistant to GICs."

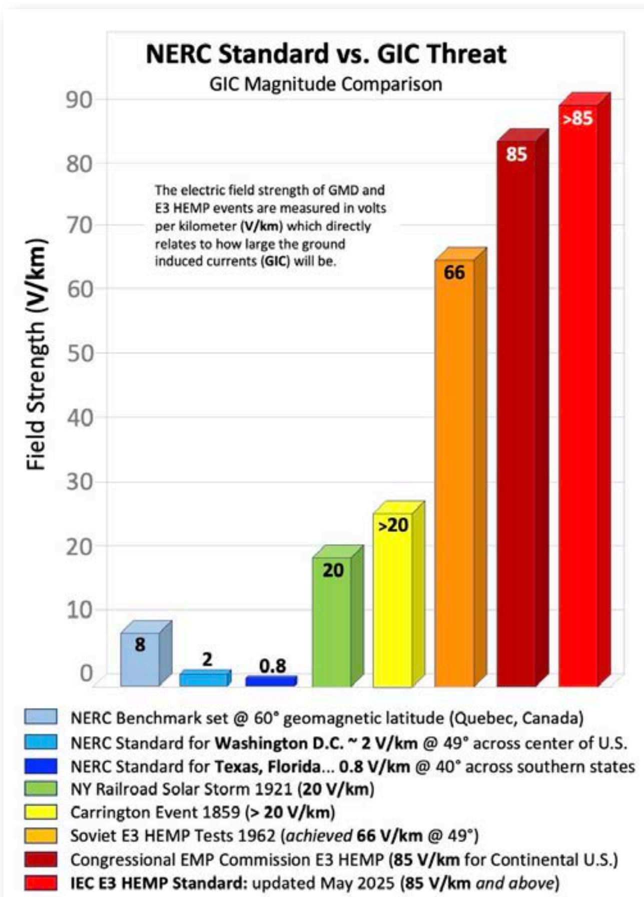
But NERC TPL-007-4 is analytically indefensible. It was specifically designed to ensure that the utility industry could "comply" without actually taking any actions whatsoever to prevent GIC-induced harm to the electric grid. The standard was derived not from U.S. data, but from European magnetometer data collected during 21 years of unusually low solar activity and then spatially averaged to reduce field intensities. The result was a "benchmark storm" of only 8 volts per kilometer (V/km) at 60° geomagnetic latitude over Quebec, scaled down to 4 V/km in the northern U.S., 2 V/km in the central U.S., and 0.8 V/km in the south. These levels of "required protection" in fact require no protection at all from GIC.

Meanwhile, recent empirical research by the U.S. Geological Survey (USGS) shows that this benchmark underestimates reality by more than an order of magnitude. The 1989 Hydro-Québec storm produced field strengths of 19–22 V/km in Virginia, Maine, and Connecticut—**over seven times the NERC benchmark** for those areas.

Such miscalibration leaves the bulk power system unprepared for even moderate recurrence events, let alone a Carrington-class superstorm or an E3 HEMP attack. It is important to note that while the GMD threat often decreases with geomagnetic latitude, the **E3 HEMP works in the reverse with a higher electric field strength at lower geomagnetic latitudes,** due to its generating mechanism.

This means the **southern states will get hit with the most severe GIC from an E3 HEMP attack** with field strengths as high as 85 V/km at 40° geomagnetic latitude (International Standard IEC 61000-2-9) and will be the least prepared anticipating only 0.8 V/km per the NERC standard.

The graphic below shows the NERC Standard versus the real-world GIC threats associated with both solar weather and nuclear E3 HEMP.



Moreover, geomagnetic storm intensity as reported by NOAA and others that study the solar phenomena is measured in nanoteslas (nT) for purposes of comparing events. This does not correctly compare, nor is it the function of solar scientists to compare, the extent of damage that a solar event could inflict on the power grid. The correct measurement to compare the intensities of ground induced currents (GIC) from a solar event is nanotesla per minute (**nT/min**). It is the **rate-of-change** that is the determining factor in the magnitude of ground-induced currents. According to Faraday's Law of Induction, a faster rate-of-change in magnetic flux results in a greater induced voltage. The nT comparison of solar storms is inaccurate and misleading when considering the space weather threat to our power grid. Example: it is the nT comparison that leads some to the belief that the 1989 Quebec Storm was 50% the estimated size of the 1859 Carrington Event when in actuality it was less than 10% the size as it relates to GIC magnitude due to the rate-of-change (nT/min.)

B. The Aging Transformer Fleet Exacerbates Vulnerabilities

Section 2 of EO 14262 calls for "secure, redundant fuel supplies that are capable of extended operations." Yet the very transformers that deliver that fuel are old and fragile. DOE's *own Large Power Transformer and the U.S. Electric Grid* study reported an average transformer age of 38–40 years, with 70 percent over 25 years old. These units were never designed for quasi-DC currents. Their cellulose insulation and dielectric oils degrade with age, magnifying susceptibility to half-cycle saturation, harmonic generation, overheating, and catastrophic failure during GIC events. This informs further the NRC's declaration that "80 percent of EHV transformers are resistant to GICs" is without foundation.

C. Slow Standard Setting Is Not a Solution

The FERC/NERC process averages nearly a decade per standard. Order 779 (2013) directing GMD protections led to TPL-007-1 (2016), then -2 (2018), -3 (2019), and -4 (2020), none of which corrected the fundamental error in the benchmark storm. By contrast, EO 14262 empowers DOE to <u>act now</u> under existing law – an authority that should be exercised <u>before the next solar maximum peaks in 2026–27</u>.

Deploying the Validated Solution: Capacitive Neutral Blocking Technology

A. GIC Mitigation Hardware

A commercially available and cost-effective solution already exists - capacitive neutral blocking devices. The SolidGround® capacitive Neutral Blocking Device (NBD), developed by EMPRIMUS and validated by the Department of War's Defense Threat Reduction Agency (DTRA), Idaho National Laboratory (INL), Oak Ridge National Laboratory (ORNL) and the Department of Energy (DOE) under Contract [No. 89503421PWA001210] automatically blocks GIC (quasi-DC currents) from entering transformers without affecting AC grounding or fault-current handling.

SolidGround® is a closed system (no tampering with existing AC controls) that simply attaches to the transformer's neutral ground cable and automatically <u>blocks GIC at the point of entry</u> whenever detected. The device has been operating for over a decade on our bulk power grid at the 345 kV and 500 kV level in the American Transmission Company (ATC), Western Area Power Administration (WAPA) and Tennessee Valley Authority (TVA) fleets performing as designed without failure. These three utilities have all contributed to the design of SolidGround® and have co-written papers, published articles, written reports and submitted testimony to the U.S. Senate Committee on its performance.

SolidGround® is now being purchased and installed internationally, but there is no regulatory requirement for its mitigative technology in the United States. Foreign nations are purchasing SolidGround® legitimately while it appears that the People's Republic of China has been stealing the intellectual property and is apparently installing a version of it in the Chinese grid.

B. Cost and Scalability

Each SolidGround® unit costs approximately USD $500,000 and is standardized – able to be produced on an assembly line. Nationwide deployment on the estimated 6,000 critical large power transformers identified as "high risk designs" to GIC (the first to half-cycle saturate) would cost ≈ $3–4 billion (including installation)—less than 0.5 percent of the 2021 Infrastructure Investment and Jobs Act [7].

By contrast, routine space-weather losses from low-level GIC entering the power grid already costs the U.S. economy approximately $10 billion annually (Zurich, Lockheed Martin and NOAA study 2015). A single Carrington-class space weather event occurring today is estimated to inflict $0.6–2.6 trillion in losses based solely on the value of lost load (Lloyd's of London 2013)[8].

The benefit-cost ratio exceeds 500:1 in purely economic terms—before considering damaged equipment, national-security losses and human costs – which could be in the tens or hundreds of millions of lives lost. While the solution has been extensively tested and independently validated by both industry and the federal government with the cost and locations defined, it has not been implemented because there is no standard or requirement to install them and utilities will not pay for the cost to protect our grid from GIC if it is not required.

[7] https://centerforsecuritypolicy.org/for-the-cost-of-less-than-1-of-the-biden-infrastructure-bill-we-could-protect-our-electric-grid-from-certain-collapse/

[8] https://centerforsecuritypolicy.org/wp-content/uploads/2022/06/Appendix-E-Space-Weather-2014-Schrijver-Assessing-the-impact-of-space-weather-based-on-insurance.pdf

Metric	Without Mitigation	With Nationwide SolidGround® Deployment
Annual losses from routine GICs (Zurich 2015 → $10 Billion)	Continued $10 B economic loss each year in the U.S. due to GIC harmonics	Reduced/Eliminated
Transformer replacement lead time	3–6 years (Hitachi Energy estimate)	No loss of critical units
Carrington-class storm impact (Lloyd's 2013)	$0.6–2.6 trillion economic loss + potential mass casualties	Contained to minor regional outages
Implementation cost	–	$3 - 4 B (one-time)
Benefit-cost ratio	–	> 500:1

By any metric—economic, environmental, or humanitarian—the cost of inaction dwarfs the cost of implementation. A single year of routine economic losses due to low-level GIC entering our grid exceeds the entire cost of GIC mitigation deployment. Moreover, SolidGround® capacitive neutral-blocking devices enhance the resilience of fuel supply chains, data centers, and defense installations - precisely the critical loads the Executive Order was issued to protect.

Ultimately, effective GIC protection of our nation's grid will only occur once our federal government requires utilities to take action through enforceable requirements and financial incentives.

[See Appendix I – Technical basis: GIC Threat and Transformer Physics]

C. Regulatory Precedent and Funding Mechanisms

FERC's "just and reasonable" standard permits cost recovery for investments that enhance reliability. Therefore, DOE can facilitate rapid deployment of GIC protection through four existing programs:

- **Transmission Facilitation Program (TFP):** DOE should designate SolidGround® capacitive neutral-blocking installations as eligible upgrades to de-risk large transmission projects.
- **Grid Resilience and Innovation Partnerships (GRIP):** DOE should provide competitive grants for transformer hardening with SolidGround® capacitive neutral blocking devices which also provide GIC monitoring.
- **Loan Programs Office (LPO):** DOE should offer low-interest financing to utilities and manufacturers for the mass production and installation of SolidGround® capacitive neutral-blocking devices needed to rapidly deploy roughly 6,000 of these devices nationwide.
- **Defense Production Act Title III:** DOE should support domestic manufacturing of SolidGround® capacitive neutral-blocking devices as a critical-infrastructure component essential to national security.

Implementation Course of Action for the Department of Energy

1. Issue an Emergency Order to Identify GIC-Vulnerable Transformers: DOE should use the authorities granted it under Section 202(c) of the Federal Power Act (16 U.S.C. § 824a(c)), the energy emergency declared in EO 14156 (January 20, 2025), and the direction to use 202(c) authorities provided in EO 14262 (April 8, 2025) to require all ISOs/RTOs to conduct a thorough survey of all large power transformers vulnerable to GIC half-cycle saturation.

The survey would identify those that must be protected against GICs from both GMD and E3 HEMP by using credible GIC scenarios for a 100-year solar storm and E3 waveforms associated with the recently updated international IEC standard (IEC 61000-2-9, Edition 2.0 2025-05), using the standard waveform in Figure A.5, modeling a peak magnetic field strength of 20,000 nT and corresponding electric field of 85 V/km. The emergency order should direct the results of the survey to be submitted within 180 days. The order should then be extended in 6-month increments until the nation produces and deploys the sufficient number of SolidGround® capacitive neutral-blocking devices to protect the electric grid from GIC.

[See Appendix III – Proposed Secretary of Energy Emergency Order on GIC Protection]

2. Deploy SolidGround® Capacitive Neutral-Blocking Devices: DOE should start with federally owned portions of the U.S. electric grid such as the Tennessee Valley Authority (TVA), Bonneville Power Administration (BPA), Western Area Power Administration (WAPA), Southeastern Power Administration (SEPA), Southwestern Power Administration (SWPA), Alaska Power Administration (APA).

Integrating GIC Mitigation into DOE's Reserve-Margin Methodology

Section 3(b) of EO 14262 directs DOE to develop a "uniform methodology for analyzing current and anticipated reserve margins." That methodology must consider not only fuel availability and generation dispatch but also **the risk of generation loss from geomagnetic disturbances and HEMP E3 events**.

Current planning models assume that generation capacity is lost only through mechanical or fuel outages. In reality, a **single severe GMD could simultaneously disable hundreds of transformers, erasing gigawatts of reserve margin nationwide within minutes.**

Therefore, DOE should:

1. **Mandate GIC-inclusive Reserve-Margin Assessment** for all regions regulated by FERC, using credible GIC scenarios for a 100-year solar storm and E3 HEMP waveforms associated with the recently updated international IEC standard (IEC 61000-2-9, Edition 2.0 2025-05)

2. **Identify At-Risk Regions** where modeled reserve margins fall below acceptable thresholds under the same credible GIC scenarios.

3. **Direct Priority Deployment** of SolidGround® capacitive neutral-blocking devices in those regions using TFP/GRIP funding.

4. **Publish a National GIC Hazard Map** analogous to FEMA's flood-risk maps to guide state and utility investment.

Incorporating GIC risk into DOE's reserve-margin model fulfills the Executive Order's mandate to use "all available generation resources" and ensures that the Nation's emergency energy analysis is grounded in physics rather than optimism.

Conclusion

Protection against GIC threats should be an urgent priority. The Administration's recognition of a National Energy Emergency and the President's issuance of EO 14156 and EO 14262 provide DOE with both the authority and the obligation to act.

The evidence presented herein and thoroughly in our November 2025 report **"*Speed to Power on a Firm Foundation*"** demonstrate that existing FERC and NRC policies fall short of the Executive Order's requirements.

If DOE takes the steps recommended herein, the agency will fulfill the clear intent of the above Executive Orders and ensure that America's electric grid remains reliable, resilient, and secure in the face of new industrial demands and old vulnerabilities alike.

Our Secure the Grid Coalition is available and willing to assist DOE as needed in pursuit of our shared goals to Secure the Grid.

Respectfully Submitted,

Lt. Col. Thomas J. Waller Jr. (USMC Ret.)
Co-Director
Secure-the-Grid Coalition
twaller@centerforsecuritypolicy.org

Douglas. Ellsworth
Co-Director
Secure-the-Grid Coalition
doug.ellsworth@usapact.org

Appendix I – Technical Basis: The GIC Threat and Transformer Physics

A. Mechanism of Damage

Geomagnetic Disturbances (GMDs) and E3 HEMP events induce low frequency, quasi-DC currents in the Earth's crust (commonly referred to as ground induced currents or "GIC") that travels the path of least resistance, entering the power grid from the ground through transformer ground connected neutrals. Because transformer cores are designed for pure AC operation, any DC bias (as low as a few amps GIC per phase) drives the core into half-cycle saturation. This produces three cascading effects:

1. **Harmonic generation** that can damage generator rotors, disrupt protective relays, destroy power supplies and customer equipment;
2. **Localized "hot spot" heating** that damages insulation and causes fires; and
3. **Reactive-power losses** that depress voltage across entire regions.

GIC turns large power transformers across the power grid into "harmonic generators" that destroy components all the way to the load, eventually destroying themselves and taking down the grid.

"The half-cycle saturation of the great number of large power transformers on a power system is the source of nearly all operating and equipment problems caused by GIC's during magnetic storms..."
- EPRI TR-100450, 1992

The more severe the GIC the greater the number of transformers half-cycle saturating – simultaneously injecting harmonics into the grid, and the more severe the harmonics levels generated by each transformer. It was the **GIC induced harmonics** during the 1989 Hydro-Quebec event that **collapsed Quebec's grid in 92 seconds during a modest GIC event**.

Following the Quebec event, EPRI working with Minnesota Power, injected DC into the neutrals of large power transformers of various designs at the 345kV and 500kV level to study the levels of GIC required to half-cycle saturate transformers and generate harmonics. **All transformer designs tested saturated at the lowest level of injected DC - 8 Amps/phase** (EPRI TR-100450, 1992).

In 2012, the Department of War's Defense Threat Reduction Agency (DTRA) was interested in the GIC harmonic impact to our power grid and built a substation attached to the live grid at DOE's Idaho National Laboratory to test harmonic levels generated by injecting DC into the neutral of a transformer. As GIC increased, harmonic distortion also increased. Harmonics generated at the high voltage level grow and are further enhanced as they travel towards the load (EPRI 3002002985, 2014).

It is the large power transformers **half-cycle saturating with very low GIC** that are the culprits behind the injected harmonics responsible for the estimated $10 billion in economic loss each year in the U.S. due to common low-level GIC events (Zurich, 2015). There are an estimated **6,000 large power transformers** on the U.S. grid considered "high risk design" that **half-cycle saturate with GICs as low as 2-5 Amps/phase**. This is based on GIC data and is verified by transformer engineers at ABB who have the largest collection of transformer designs that make up the U.S. fleet and have analyzed over 4,000 large power transformers on the U.S. grid as part of the NERC standard.

Golden Rule in GIC mitigation: keep GIC below 6 Amps in the neutral (2 Amps/phase). This prevents the largest "high risk design" power transformers from half-cycle saturating and injecting GIC induced harmonics into the power grid. International utilities have gone to extreme lengths stacking large resistors in series with additional resistors in an attempt to reduce GIC (or stray DC in the ground from HVDC operation) to below 6 Amps to prevent transformer harmonic generation. It is for this reason SolidGround® capacitive neutral blockers for over a decade have been set to begin blocking when GIC reaches 5 Amps in the neutral...just below the 6 Amp threshold. International utilities are now beginning to tear out their large resistors and install SolidGround® which simply blocks GIC bringing it down to zero.

Blocking GIC from entering "high risk design" transformers not only protects those transformers but protects the rest of the power grid and critical components *from* those transformers.

B. The VAR Collapse Mechanism

Operators often counteract voltage depression by spinning up generation and engaging Static VAR Compensators (SVCs) and capacitor banks. This practice is counterproductive and risky during severe GIC events. When saturated transformers consume VARs and harmonics trip SVCs, system voltage plummets and blackout propagation accelerates. The correct solution is not complex operational procedures to chase and react to cascading GIC symptoms (VAR support) but to treat the cause with hardware prevention, namely, blocking GIC from entering the grid. **VAR support in a severe GIC event is dangerous and will only serve to force critical grid components to endure higher levels of GIC and harmonics over longer durations enhancing risk of catastrophic failure of those critical components.** Instead, we must block GIC and allow the power grid to operate as designed through severe GIC events without risk of damage and cascading events related to GIC.

C. Grid Failure from severe GMD and E3 HEMP

The sun has and will produce geomagnetic disturbances much larger than the hypothetical and arbitrarily low NERC TPL-007 standard. If the much larger and historical events such as the "2012 CME near miss[9]" which blasted off the back side of the sun, "1921 Railroad Event", "1859 Carrington event" and even larger "Miyake events" were to happen today, or there is a single nuclear E3 HEMP attack, **our power grid will go down very quickly due to severe levels of GIC induced harmonics - generated by transformers that are half-cycle saturating.**

On July 21, 2016, DOE held an "Electromagnetic Pulse Resilience Action Plan Meeting" with various government agencies, leading utilities in the industry, and major suppliers (DOD, INL, LANL, ABB, Siemens, Dominion, EMP Commission, EPRI, MITRE, STRATCOM, NATF, and others) to discuss our nation's EMP Resilience Action Plan and to identify specific actions "where DOE can help the most" to protect the power grid from EMP. Listed below are a few important takeaways from that meeting:

- **Priority #1 – prevent grid failure**. GIC induced <u>Harmonics</u> from E3 HEMP and severe GMD <u>will cause wide scale grid collapse in just 10's of seconds</u>.
- **Large scale load shedding is not possible**. Equipment is damaged in the shed/reconnect process due to switching transients, and overloading. Shutting down grid is very risky. On and off is when you have problems. It is not realistic.
- **Allowing the grid to fail will damage transformers.** "Switch on/off – there have been transformer failures from trying to put the system back online. Turning back on could cause many problems...when things go down too quickly, things go wrong."
- **Best policy is to protect the grid to operate through a large GIC event**. "Fight to the last breath to keep the system running."
- **Transformers will need E3/GMD protection**. E3 roughly an order of magnitude higher.
- **Neutral blocking device in Wisconsin [SolidGround®] ...working as designed**
- **GIC protection from GMD and E3 HEMP should be addressed concurrently**
- **Transformer protection is a low hanging fruit.**
- **IEC EMP Standard (IEC 61000-2-9) provides useful waveforms**

---

9 https://science.nasa.gov/science-research/planetary-science/23jul_superstorm/

D. Assumptions vs. Data - "Whack-a-mole"

Whack-a-Mole is an assumption that if you block GIC in one location, it will cause GIC to be "re-directed" and spike everywhere else. Example: If you block 10 Amps GIC at one transformer, then 10 Amps GIC (or more) will be shifted somewhere else. In essence - we can't solve the GIC problem.

Fact. Over 10 years of GIC data <u>refutes</u> this assumption. To study this, **DOE under Executive Order 13744 purchased SolidGround® NBDs and installed them on the most GIC monitored grid in the U.S.** This allowed DOE to monitor GIC levels across the grid in real time as SolidGround® operated during many GMD events (of various angles), and to record that data to see the impact of blocking GIC.

DOE Objectives:

- Assess the effectiveness of SolidGround® NBDs to block GIC
- Measure any GICs re-directed to other transformers
- Use data to validate modeling and correct inaccurate assumptions

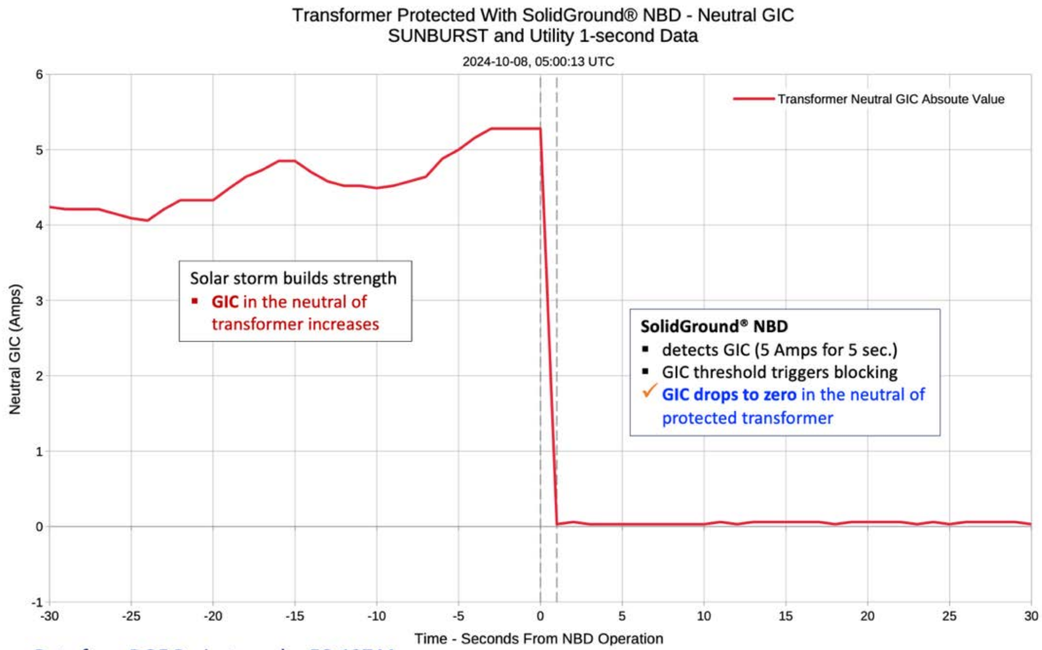
90+ SolidGround® operations analyzed by DOE, EPRI and EMPRIMUS during many GIC events

Results are consistent:

- SolidGround® NBDs operating as designed, no negative effects to power system
- GIC in neutral of protected transformer drops to zero
- Re-directed GIC is minimal and local (**V = IR**)
- **Network GIC** (sum of <u>all</u> GIC monitored on the system) <u>**decreases**</u>

NBD Impact on Protected 500kV Transformer

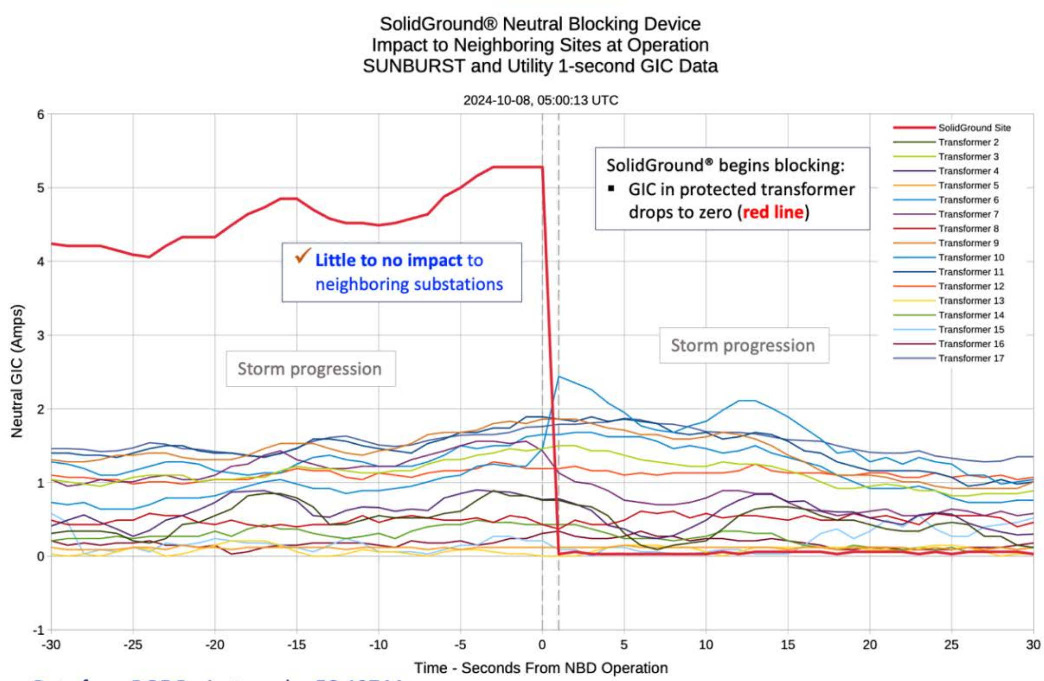
NBD impact can only be measured <u>the instant</u> the NBD changes the GIC circuit



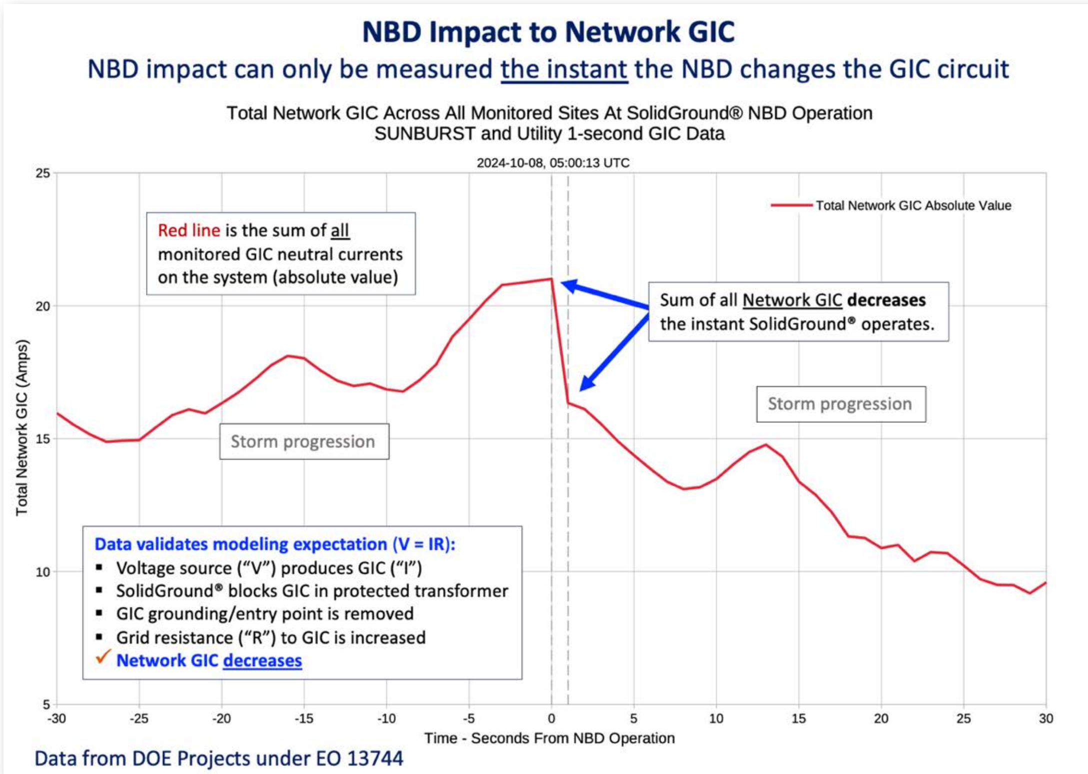
Data from DOE Projects under EO 13744

NBD Impact to Neighboring Substations

NBD impact can only be measured <u>the instant</u> the NBD changes the GIC circuit



Data from DOE Projects under EO 13744



DOE's data consistently shows that **blocking GIC** in the neutral of transformers **decreases Network GIC**. (i.e. GIC is not being re-directed everywhere else, **grid resilience is improving**). The more NBDs installed on the power grid, the more resilient the power grid becomes allowing the grid to operate through severe GIC events. **Modeling assumptions need to be updated to reflect the data.**

% of Transformers with SolidGround® NBDs	% Reduction of Total Network GIC	% Decrease in Reactive (VAR) Consumption
7%	13.7%	14.6%
14%	27.3%	29.3%
21%	41.0%	43.7%

Results derived from PowerWorld ™ modeling of the Wisconsin ATC Power Grid

E. "Re-directed" GIC is a concern today if we do not protect the power grid

GIC will always travel the path of least resistance. During a severe GMD or E3 HEMP event, **the instant high voltage circuit breakers are operated** (intentionally via utility operating procedures or unintentionally due to GIC induced harmonics or E1 HEMP) **the GIC circuit is changed and GIC will be re-directed across the grid** in an unplanned and chaotic manner.

It is important to note that **high voltage circuit breakers** attempting to open (intentionally or unintentionally) during a severe GIC event can be catastrophically destroyed as they require "zero crossings" and **are not designed to break GIC**.

Appendix II – Interagency Coordination and Federal Leadership

• **FERC:** DOE should encourage FERC to revise the TPL-007 benchmark to protect against GICs from both GMD and E3 HEMP by using credible GIC scenarios for a 100-year solar storm and E3 waveforms associated with the recently updated international IEC standard (IEC 61000-2-9, Edition 2.0 2025-05.) While the FERC/NERC process is extremely cumbersome, time consuming, and adversely affected by the utility industry through regulatory capture, the NERC standard does affect how utilities worldwide address the GIC threat. The NERC standard has vastly diminished the preparedness of modern civilizations globally to deal with the GIC threat, so it should be updated no matter how long it takes. If DOE helps set the proper incentives for the electric utility industry to be financially rewarded for properly addressing the GIC threat, the FERC/NERC rulemaking process might occur more rapidly and with better results for the public interest.

• **NRC:** DOE should encourage NRC to ensure that backup power for spent fuel pools and reactor cooling accounts for a long-term grid loss scenarios caused by GICs so that NRC can assist identifying where SolidGround® capacitive neutral-blocking devices should be installed at substations providing power to these nuclear sites.

• **DoW:** DOE should request that Department of War leadership update its (1) Mission Assurance planners [under the "resilience and energy security measures on military installations" as per 10 U.S. Code Section 2920] and its (2) Golden Dome planners to account for a long-term grid loss scenarios caused by GICs so that the Department can assist identifying where the DTRA-validated SolidGround® capacitive neutral-blocking devices should be installed at substations providing power to military bases and defense-critical centers.

• **DOE's Office of Cybersecurity, Energy Security, and Emergency Response (CESER):** CESAR should integrate SolidGround® capacitive neutral-blocking devices into the Energy Sector Lifeline Framework.

• **State Governments**: EO 14262 encourages collaboration "with such executive department and agency heads as the Secretary of Energy deems appropriate." That invitation extends to state energy offices and public utility commissions that can mandate utility resilience plans and allow cost recovery for investments in SolidGround® capacitive neutral-blocking devices. **The National Conference of State Legislatures' August 2025 resolution** urging EMP/GMD hardening provides a ready-made template for state action[10].

[10] https://nationalinterest.org/blog/energy-world/national-conference-of-state-legislators-urges-grid-protection-from-solar-weather-emps

Appendix III – Proposed Secretary of Energy Emergency Order on GIC Protection

Order No. ____

Pursuant to the authority vested in the Secretary of Energy by section 202(c) of the Federal Power Act (FPA) and section 301(b) of the Department of Energy (DOE) Organization Act and for the reasons set forth below, I hereby determine that an emergency exists across the continental United States due to a vulnerability of high voltage transformers to geomagnetically induced currents, also known as ground induced currents (GICs), and that issuance of this Order will meet the emergency and serve the public interest.

Findings

America's electric grid, integral to every aspect of modern life, faces existential threats from solar weather [through coronal mass ejections (CMEs) that cause geomagnetic disturbances (GMDs)] and high altitude nuclear electromagnetic pulse (HEMP), both capable of crippling electric power systems.
The high voltage transformers critical to sustaining the electric grid are vulnerable to geomagnetically induced currents, also known as ground induced currents (GICs), which are induced in the earth by naturally occurring geomagnetic disturbances (GMDs) or the late-time (E3) component of high altitude electromagnetic pulse (HEMP) and enter the electric grid through the ground connected neutral wires of transformers.

The Extra High Voltage (EHV) transformers (345 kV – 765 kV) are the most vulnerable to GIC per their design (as they half-cycle saturate at very low GIC), are also the hardest to replace, many of them custom made with production lead times as long as 4-6 years, and require massive logistical and transportation challenges during their replacement process even during ideal "blue sky" conditions with a fully functioning grid, economy and society.

The GIC threat posed to these critical transformers is dependent on numerous factors, including the transformer's size, design and age, the ground conductivity in the region of the electric grid, and magnetic field produced by GMD or E3 HEMP.

In June 1992, the Electric Power Research Institute found that the aging of power transformers increases their susceptibility to GIC due to degraded insulating oil condition and coil condition (see "EPRI TR-100450, 1992").

In January 2021, The National Security Council recommended "that U.S. electrical systems and other critical infrastructure elements can be assessed for disruption and damage susceptibility up to the benchmark HEMP waveforms characterized by peak electric field strengths of 80 V/km for E3a (blast), and 50 V/km for E3b (heave), respectively," (See "Final HEMP Memo January 12, 2021 – Department of Energy").

In May 2025, the International Electrotechnical Commission (IEC) updated its international standard for E3 HEMP to a peak electric field strength environment of 85 V/km (see "IEC 61000-2-9, Edition 2.0 2025-05").

The current standard established by the North America Electric Reliability Corporation (NERC) to protect transformers and the grid from failure due to GIC, fails to require utilities to consider the design type and age of their transformers, establishes a "benchmark" peak electric field of only 8 V/km in

Quebec, and utilizes a "scaling factor" to allow utilities to "scale down" per their geomagnetic latitude to consider a peak electric field of ~2 V/km across the center of CONUS and only 0.8 V/km across the southern states (while the GMD threat often decreases with geomagnetic latitude, the E3 HEMP threat is higher at lower geomagnetic latitudes due to its generation mechanism), engendering the real possibility of wide-area GIC-caused blackout with transformer and grid equipment failures (see "NERC TPL-007").

ORDER

Given the above circumstances, I have determined that it is necessary and in the public interest for the United States of America that all covered entities conduct a survey of covered equipment to determine vulnerabilities to GIC.

> Covered entities include every electric utility and electric project developer, owner and operator, regardless of ownership or operation by the public or private sector within the state, regardless of whether that utility is subject to the jurisdiction of the North American Electric Reliability Corporation (NERC), and regardless of the regional transmission operators or independent system operators with which it operates.
>
> Covered equipment includes all power transformers with primary voltage of 100 kV or greater and capacity of 25 MVA or greater and all Generator Step-Up (GSU) transformers with secondary voltage of 100 kV or greater and capacity of 25 MVA or greater

Based on my determination of an emergency set forth above, I hereby order:

A. Every covered entity shall conduct a technical assessment survey of all covered equipment within its jurisdiction to determine its vulnerability to geomagnetically induced currents, also known as ground induced currents (GICs), which are induced in the Earth by naturally occurring geomagnetic disturbances (GMDs) or the late-time (E3) component of high-altitude electromagnetic pulse (HEMP).

B. Specifically, covered entities shall use the analytic waveform plotted in Figure A.5 of "IEC 61000-2-9, Edition 2.0 2025-05" in their operating models to determine the susceptibility of their transformers to GICs associated with a peak magnetic field strength environment of 20,000 nT for E3 HEMP, which for a typical low conductivity ground conductivity in the United States will produce a peak electric field environment of 85 V/km, based on the recently updated International Electrotechnical Commission (IEC) international standard. (Evaluating the worst-case E3 HEMP threat to high voltage transformers and the grid will also consider severe GMD threats.)

C. Covered entities shall undertake GIC modeling under the assumption that their transformers are operating fully loaded at the time when the operating environment experiences the GIC insult utilizing the late-time E3 HEMP waveform in IEC 61000-2-9, Edition 2.0 2025-05.

D. Because the aging of power transformers increases their susceptibility to GIC due to degraded insulating oil condition and coil condition, covered entities shall consider the age of the transformers surveyed and de-rate those transformers according to ANSI/IEEE Standard C57.110 and IEEE Standard C57.91 when analyzing transformer susceptibility. After confirming and considering the age, condition, and loading of each transformer, the peak geoelectric operating environment (e.g. 85 V/km), and the ground conductivity profile, covered entities shall identify which transformers would be susceptible to the following effects: (a) Half-cycle saturation (b) GIC induced harmonics; (c) VAR consumption; and, (d) Generation of hot spots in the core or structural elements, (e) oil or insulation degradation, and report the potential impacts of each variable's susceptibility to GIC.

E. No later than 180 days from the passage of this order, and while utilizing strict operational security for Critical Energy Infrastructure Information (CEII), covered entities shall provide a detailed report to (_Insert DOE Recipient__) with copies to their state's public utility commission, to the governor and appointed chief of homeland security, and to the state legislature.

F. The report shall contain the following data for all transformers and substations found to be susceptible to GIC based on the above survey parameters: (a) Transformer Brand (b) Transformer Place of Origin [nation where manufactured] (c) Transformer Design Specifications [i.e. windings and core configuration, winding impedances, winding DC resistances (specify whether assumed or measured), 1 phase vs. 3 phase, capacity (MVA), voltage (kV) (d) Transformer Age (e) Transformer Site Location [redacted for CEII] (f) Transformer Purpose [GSU, Auto, Step-down, Converter] (g) Replacement Lead Time and Replacement Cost.

G. In addition to providing the above data in spreadsheet form, covered entities shall consider how to most expeditiously protect their transformers from GIC, based on the totality of the circumstances (design, purpose, age, replacement lead time, etc.).

H. Covered entities shall not consider "operating procedures" such as load shedding and VAR supply as sufficient forms of GIC protection since adverse GIC effects can occur rapidly (may be no warning with E3) and over large regions that overwhelm operational reaction capabilities, and procedures cannot block GIC from entering an operating electric grid.

I. The report shall also provide the following: (a) Recommended solutions to protect the grid against GIC by preventing or reducing the half-cycle saturation of transformers, (b) Total cost to implement GIC protection of all vulnerable transformers owned and operated by the covered entity and (c) a priority list of transformers considering individual transformer risk, transformers threat to the remaining grid if unprotected (half-cycle saturating and generating harmonics) and associated critical infrastructure/service loss.

J. As part of this report, covered entities shall also provide their recommendations for funding the deployment of this GIC protection, which can include both government grant opportunities and rate recovery.

K. This Order shall be effective from ______ on _____, and shall expire at 00:00 AM EST on ____. Renewal of this Order, should it be needed, must be requested before this Order expires.

Issued in Washington, D.C. at ______________________________________.

____
Chris Wright
Secretary of Energy

cc: FERC Commissioners
Chairman Laura V. Swett
Commissioner David Rosner
Commissioner Lindsay S. See
Commissioner Judy W. Chang