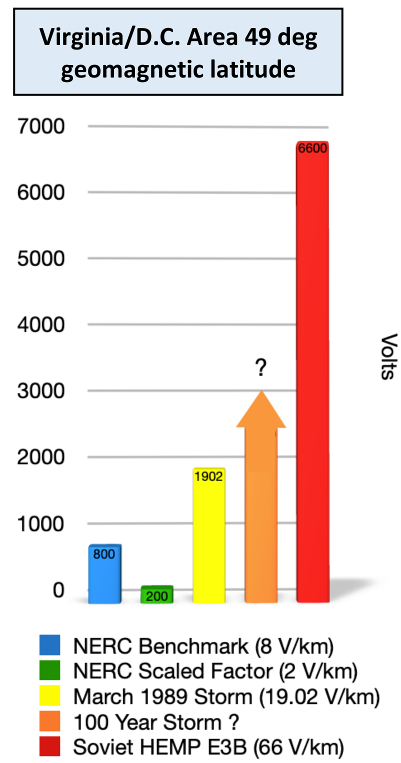
Secure the Grid Coalition

2020 Pennsylvania Avenue, N.W., Suite 189
Washington, D.C. 20006

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 October 25, 2022, in-person meeting.

We would like to **build upon previous recommendations and requests made to SEAB** by our *Secure the Grid Coalition* on June 13, 2022 with the **recommendation that SEAB immediately assess available technologies to mitigate the risks of Solar Weather to our electric grid**.



As we demonstrated in June, **the current standard for solar storm protection of the electric grid is transparently defective and dangerously ineffective at protecting the electric grid**. Included at the right, again, is the visual aid we previously used, showing the current solar weather protection standard in Washington D.C. (green) vs. the types of harmful currents produced by previous solar storms and high altitude EMP (HEMP) tests, using real-world data (yellow, orange, and red.)

The good news is that there is a technology available today that can mitigate not only the catastrophic damage that solar weather can do to irreplaceable transformers, but also the estimated $10 billion of annual economic loss it does to high power users (such as manufacturers, etc.) by producing "harmonics" that pass through transformers and travel down the grid to the end user.

The attached enclosure is a recent presentation from EMPRIMUS featuring information on their SolidGround technology that can protect against these harmful effects of solar weather. **We recommend you review this material** and schedule a demonstration to see how this technology works.

To summarize the material in the attached enclosure:

The largest transformers on our grid (the most critical and difficult to replace) are also the most vulnerable due to their design and are responsible for generating the harmonics (when they half-cycle saturate) due to common low-level GMD events, resulting in the estimated $10 billion in economic loss each year in the U.S.

Neutral Blocking Devices w/ Capacitors (placed in the neutral of high voltage transformers):

- **block GIC (DC Current) from entering the grid and allow AC current to flow.**
- **utilize standard grid components, and**
- **is the most studied/researched mitigation solution.**

The Electric Power Research Institute ***(EPRI) has been studying neutral blocking since the 1980s.***

It would cost the U.S. $4 Billion ***one time*** to pay for and install 6,000 neutral blockers on the most vulnerable HV transformers in our country.

As a reminder, **this U.S. $4 Billion** ***is just 1/3 of one percent of the $1.2 Trillion bi-partisan infrastructure bill*** (and such investments and would be sufficient to protect our grid (our MOST CRITICAL INFRASTRUCTURE) from large and small GMDs as well as HEMP E3, and:

-prevent the estimated $10 billion+ in economic loss every year (see Zurich, Lockheed, NOAA)

-prevent the estimated $0.6 to $2.6 Trillion in economic loss and massive loss of human life from a "Carrington-Level" solar super storm which is a statistical certainty and cannot be deterred (see Lloyd's of London),

-allow for a quicker recover from a HEMP attack, protecting the "backbone of our grid" (HV Transformers, HV Breakers and Generators) from extremely high GICs (see EMP Commission),

-would help deter a HEMP attack

Finally, we want to re-iterate that **the work of our Secure the Grid Coalition** and its sponsor, the non-profit Center for Security Policy, **is strictly in the public interest.** We receive ***no funding*** from companies like EMPRIMUS that can profit from protecting the grid.

As always, our Secure the Grid Coalition is ready to assist the SEAB and can make personal introductions to numerous experts throughout the country who can help DOE take action to protect the grid against solar weather and other known hazards.

Respectfully submitted by,

Thomas J. Waller Jr.
Co-Director
Secure-the-Grid Coalition
twaller@centerforsecuritypolicy.org

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

SolidGround™

Typical Large High Voltage Transformer

emPRIMUS

Emprimus is a research and development company working closely with major utilities, suppliers and various departments of the United States to design, patent, build, test and license complete and effective products to protect the electric power grid against the effects of solar storms/geomagnetic disturbances (**GMD**) and electromagnetic pulse (**EMP**).

Emprimus holds patents and patents pending in the United States and in nations around the world on its methods, circuits, components and software.

For more information, please contact
David Anderson: danderson@emprimus.com
and visit our website: www.emprimus.com

The AC power grid and its major components are not designed for GIC (DC current)

The effects of solar storms (**GMD**s) on the electric power grid are very similar to the "**E3** Pulse" of a high-altitude nuclear electromagnetic pulse (HEMP). They both induce quasi-DC current in the ground (geomagnetically induced current "**GIC**") which invades the electric power grid **through the grounded neutral wires** of high voltage transformers.

Small amounts of GIC from common low-level GMDs are estimated to cause $10 Billion in economic loss *each year* in the U.S.

Lloyd's of London estimates the economic loss of a large Carrington-class solar storm on the North American grid at between $0.6 and $2.6 trillion not to mention the immense loss of human life.

Our AC power grid is extremely vulnerable to EMP and major GMD events.

Mitigation technology <u>must block GIC</u> from entering the AC power grid

We must keep **GIC** (**DC Current**) out of our AC grid to allow critical components to operate as designed and remove the risks of damage, voltage collapse, cascading failures as well as many uncertainties with an EMP **E3** or major **GMD** event.

We suggest neutral blocking as an immediate priority:
to quickly protect the existing critical and hard to replace transformers, high voltage breakers and generators of the bulk power system using tested and available hardware at relatively low cost.

Neutral Blocking will help save $Billions in annual economic loss from small GICs and protect the grid from high GICs due to (intentional) EMP **E3** and (statistical) major **GMD** events.

What GMD/E3 level should the U.S. bulk power grid be protected against?

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

The field strength (**V/km**) of **GMD/E3** events are also dependent on *geomagnetic latitude*

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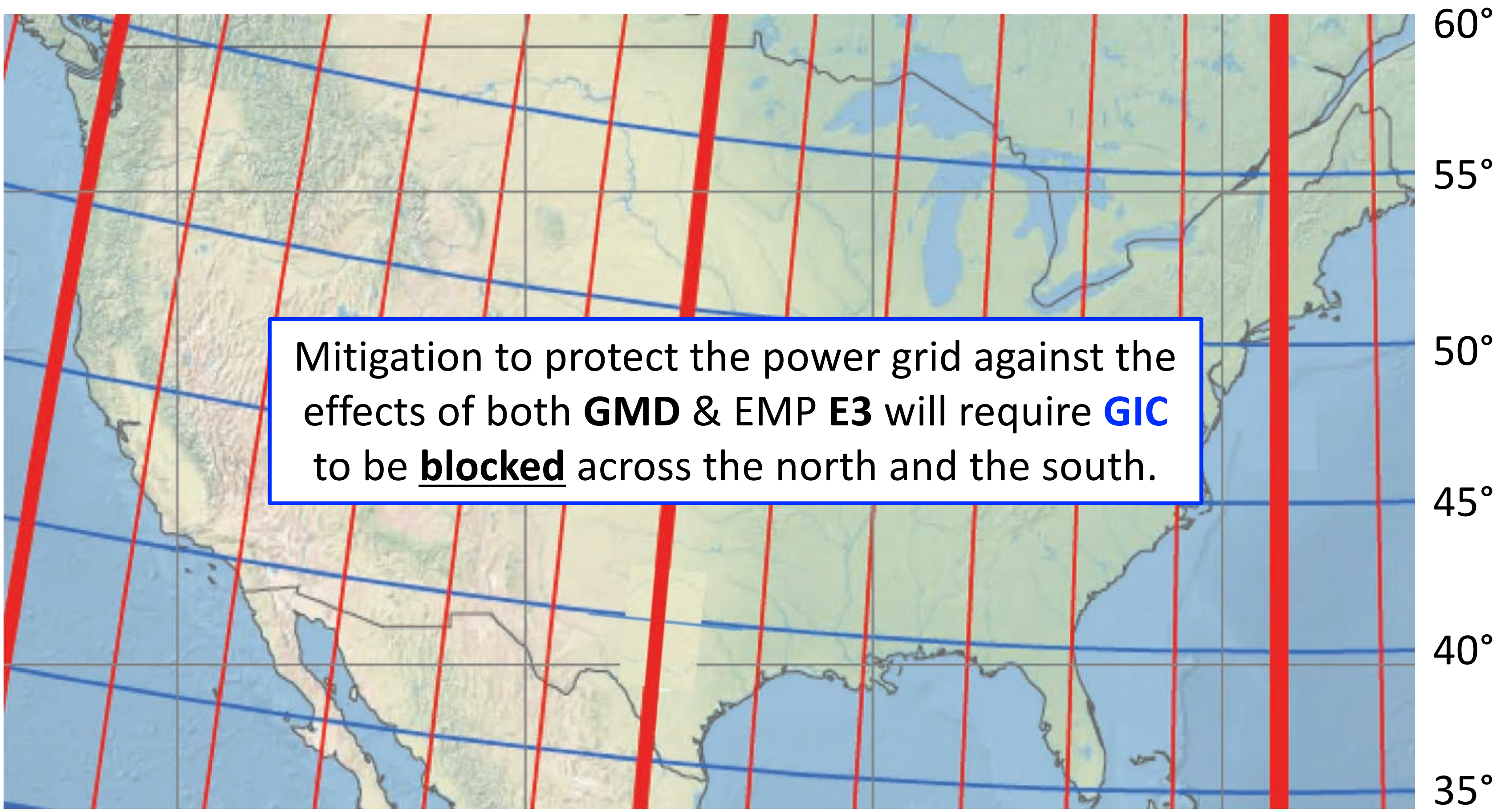
GMD field strength (**V/km**) increases as you get closer to the **<u>POLES</u>** (per TPL-007)



Mitigation to protect the power grid against the effects of both **GMD** & EMP **E3** will require **GIC** to be **<u>blocked</u>** across the north and the south.

EMP **E3** field strength (**V/km**) increases as you get closer to the *geomagnetic* **<u>EQUATOR</u>** (EMP Commission)

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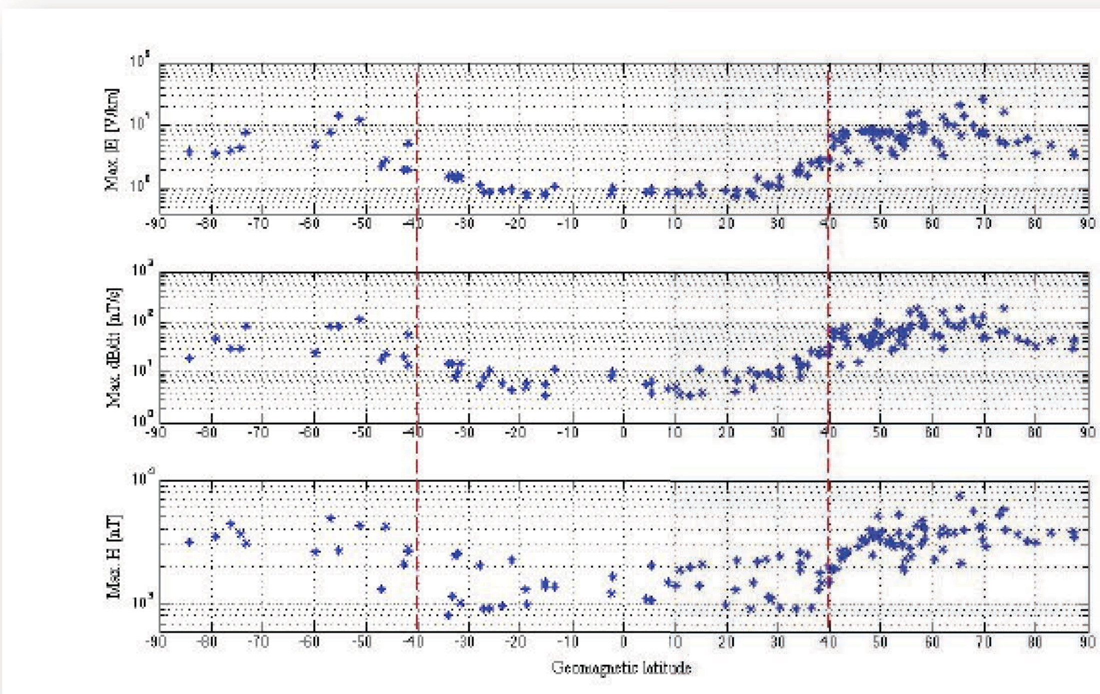
2013, a **NERC** committee of 8 respected space weather scientists estimated a reference **GMD** storm, preliminary results were determined to be a max. geoelectric field of **30 - 40 V/km**

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NASA/CUA

- We are getting 30-40 V/km max. fields (preliminary results)



- Current Science Team composition includes:
  - A. Pulkkinen (NASA/CUA),
  - W. Murtagh (NOAA),
  - C. Balch (NOAA),
  - J. Gannon (USGS),
  - D. Boteler (NRCan),
  - R. Pirjola (NRCan),
  - D. Baker (U. of Colorado), and
  - A. Thomson (BGS/EURISGIC).

1962: The Soviets conducted two high-altitude nuclear test(s) over Kazakhstan, specifically on either side of the *geomagnetic latitude* of **49°**: 1st Test @ 49.10° and 2nd Test @ 48.92°

Is it a coincidence the Soviets tested at the same **49°** as Washington D.C.?

60 years ago, the Soviets achieved an EMP **E3b** (heave) field strength of

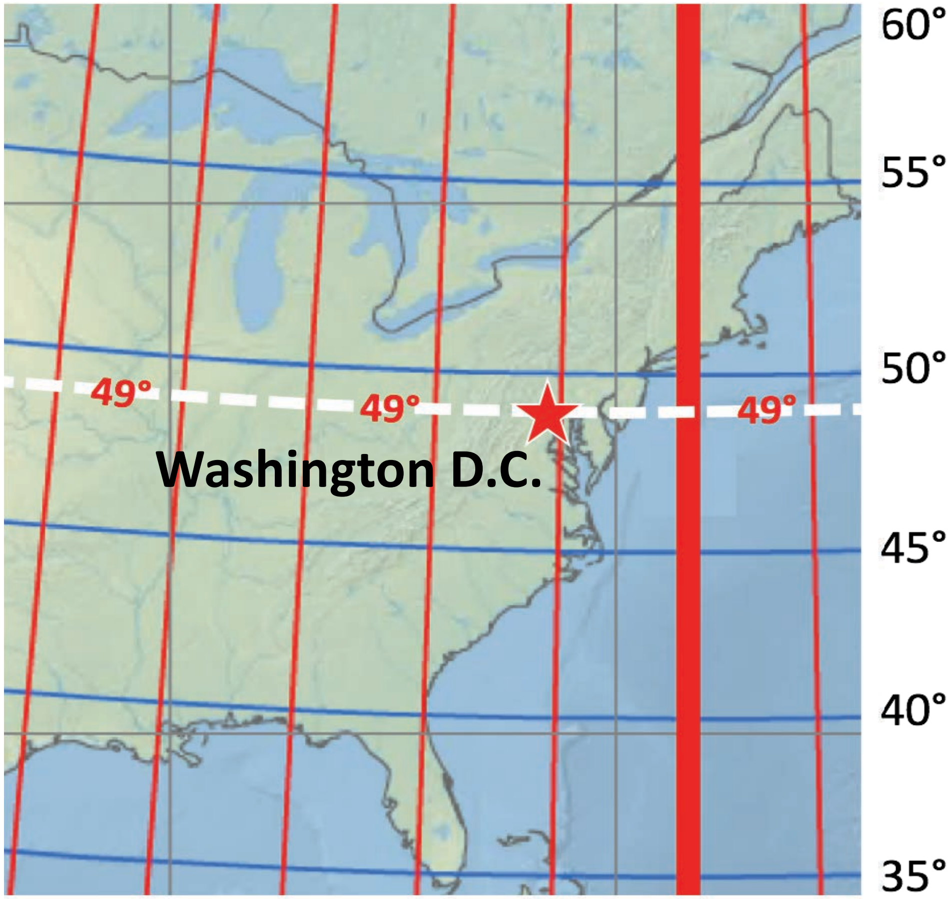
66 V/km @ 49°

Vs.

The GMD standard for Washington D.C. considers only

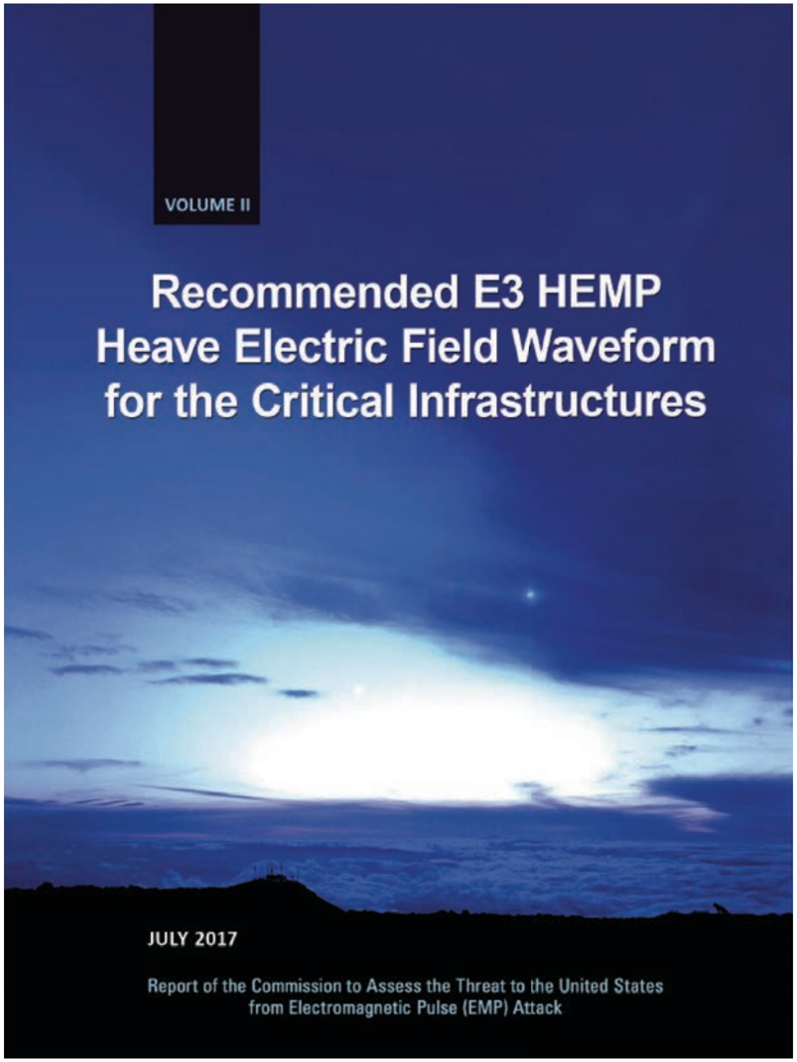
2 V/km @ 49°

Geomagnetic Latitude Map



-Report of the Commission to assess the threat to the United States from EMP attack, "**Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures**", Executive Summary, July 2017, **Conclusions - pg. 24**

April 2018: U.S. Department of Defense cleared an EMP Report of the Commission for open publication



"A realistic unclassified peak level for E3 HEMP would be **85 V/km** [United States] … **102 V/km** for locations nearer to the geomagnetic equator…" (p. ix, 1)

"…measurements are evaluated from two high-altitude nuclear tests performed by the Soviet Union in 1962." (p. 1)

"This report does not claim that the values suggested here are absolute worst-case field levels …" (p. 4)

Mitigation must block GIC to Prevent Transformer half-cycle saturation:

"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, Geomagnetic Storms and Electric Power System Effects, June 1992, p. 6-1

Transformer half-cycle saturation Results in:

- - Generation of harmonics
- - Unwanted extreme reactive flows
- - Power grid instability
- - Thermal damage to the transformer

8 Transformer Designs:
Level of GIC to cause Half-Cycle Saturation

High Risk Design:
These designs begin to **saturate at or <u>below</u> 5A/phase**. MVA size does not matter.

1. Shell Single Phase, 1 Limb
2. Shell 3 Phase, conventional (2 Limb or "D")
3. Shell 3 Phase, 7 Limb
4. Core Single Phase, 2 Limb
5. Core Single Phase, 3 Limb
6. Core Single Phase, 4 Limb
7. Core 3 Phase, 5 Limb

U.S. High Voltage Transformer Fleet:

- **500kV to 750kV** – almost all are of the High Risk designs above (~ 2,000)
- **230kV to 345kV** – ~ 20% are of the High Risk designs above (2,000 to 4,000)

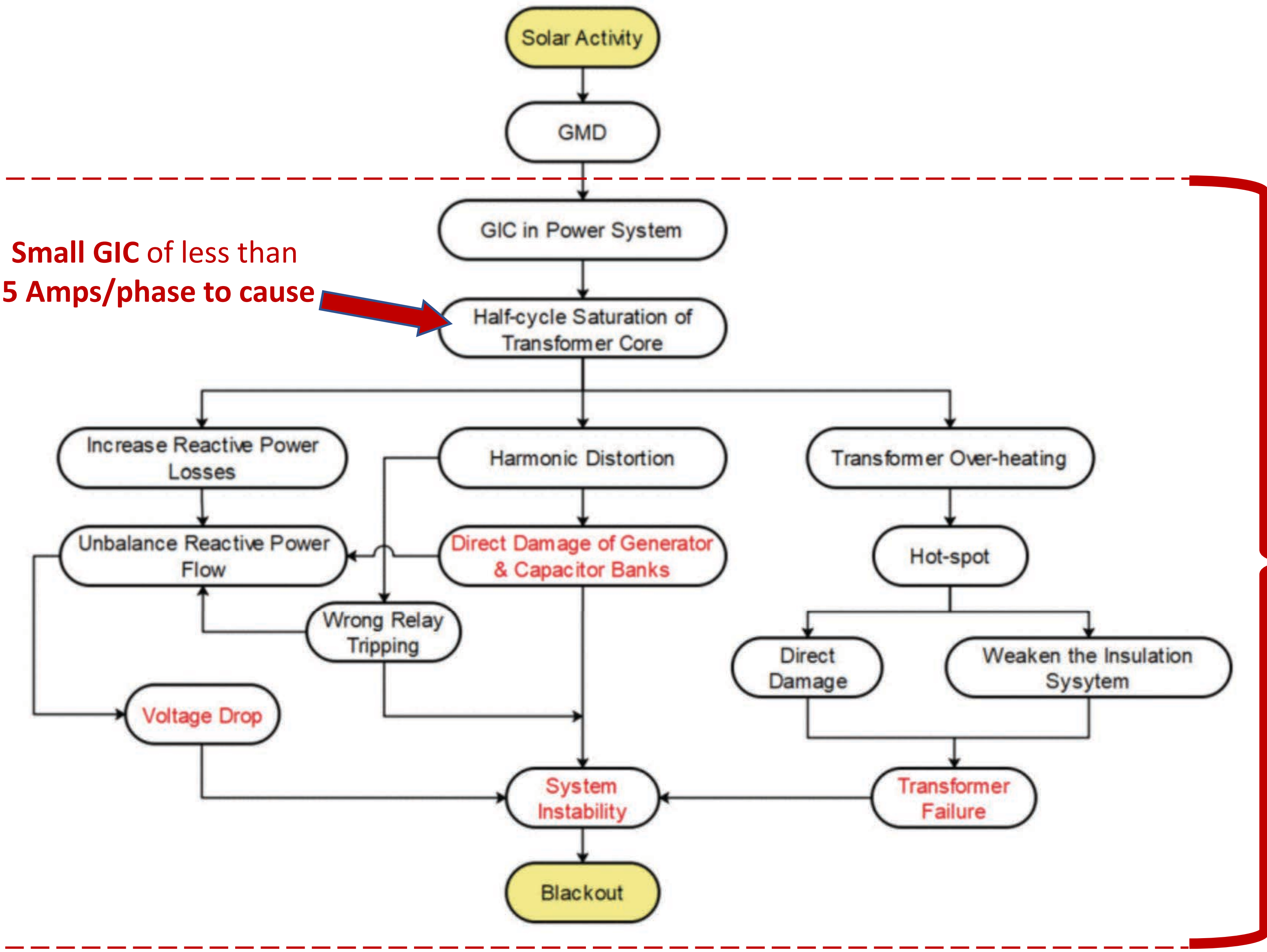
High Risk Design = 4,000 to 6,000 High Voltage Transformers

Only one design is more resilient to <u>small</u> GICs. At 80 MVA this design begins to **saturate at 20A/phase**.

8. Core 3 Phase, 3 Limb

SolidGround™ TRANSFORMER HALF-CYCLE SATURATION

Small GIC of less than
5 Amps/phase to cause



Without Neutral Blocking

A Large GMD/E3 event can create 1,000's of simultaneous issues across large portions of the grid

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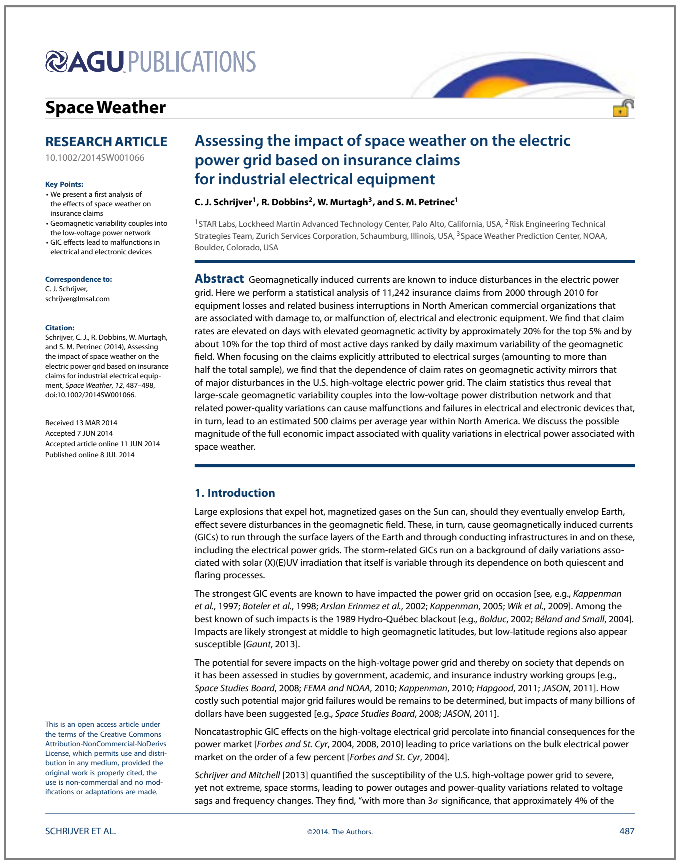
Damage from low-level solar storms

Common solar storms produce low levels of **GIC** (**DC Current**) which invade the AC Power Grid causing high voltage transformers to **half-cycle saturation** and generate **harmonics** which build as they travel into lower voltage distribution.

➢ **$Billion(s)** in business losses ***each year*** in the United States (2000-2010) due to common low-level solar storms.



AGU PUBLICATIONS

Space Weather

RESEARCH ARTICLE

10.1002/2014SW001066

Key Points:
- We present a first analysis of the effects of space weather on insurance claims
- Geomagnetic variability couples into the low-voltage power network
- GIC effects lead to malfunctions in electrical and electronic devices

Correspondence to:
C. J. Schrijver,
schrijver@lmsal.com

Citation:
Schrijver, C. J., R. Dobbins, W. Murtagh, and S. M. Petrinec (2014), Assessing the impact of space weather on the electric power grid based on insurance claims for industrial electrical equipment, *Space Weather*, *12*, 487–498, doi:10.1002/2014SW001066.

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Assessing the impact of space weather on the electric power grid based on insurance claims for industrial electrical equipment

C. J. Schrijver[1], R. Dobbins[2], W. Murtagh[3], and S. M. Petrinec[1]

[1]STAR Labs, Lockheed Martin Advanced Technology Center, Palo Alto, California, USA, [2]Risk Engineering Technical Strategies Team, Zurich Services Corporation, Schaumburg, Illinois, USA, [3]Space Weather Prediction Center, NOAA, Boulder, Colorado, USA

Abstract Geomagnetically induced currents are known to induce disturbances in the electric power grid. Here we perform a statistical analysis of 11,242 insurance claims from 2000 through 2010 for equipment losses and related business interruptions in North American commercial organizations that are associated with damage to, or malfunction of, electrical and electronic equipment. We find that claim rates are elevated on days with elevated geomagnetic activity by approximately 20% for the top 5% and by about 10% for the top third of most active days ranked by daily maximum variability of the geomagnetic field. When focusing on the claims explicitly attributed to electrical surges (amounting to more than half the total sample), we find that the dependence of claim rates on geomagnetic activity mirrors that of major disturbances in the U.S. high-voltage electric power grid. The claim statistics thus reveal that large-scale geomagnetic variability couples into the low-voltage power distribution network and that related power-quality variations can cause malfunctions and failures in electrical and electronic devices that, in turn, lead to an estimated 500 claims per average year within North America. We discuss the possible magnitude of the full economic impact associated with quality variations in electrical power associated with space weather.

1. Introduction

Large explosions that expel hot, magnetized gases on the Sun can, should they eventually envelop Earth, effect severe disturbances in the geomagnetic field. These, in turn, cause geomagnetically induced currents (GICs) to run through the surface layers of the Earth and through conducting infrastructures in and on these, including the electrical power grids. The storm-related GICs run on a background of daily variations associated with solar (X)(E)UV irradiation that itself is variable through its dependence on both quiescent and flaring processes.

The strongest GIC events are known to have impacted the power grid on occasion [see, e.g., *Kappenman et al.*, 1997; *Boteler et al.*, 1998; *Arslan Erinmez et al.*, 2002; *Kappenman*, 2005; *Wik et al.*, 2009]. Among the best known of such impacts is the 1989 Hydro-Québec blackout [e.g., *Bolduc*, 2002; *Béland and Small*, 2004]. Impacts are likely strongest at middle to high geomagnetic latitudes, but low-latitude regions also appear susceptible [*Gaunt*, 2013].

The potential for severe impacts on the high-voltage power grid and thereby on society that depends on it has been assessed in studies by government, academic, and insurance industry working groups [e.g., *Space Studies Board*, 2008; *FEMA and NOAA*, 2010; *Kappenman*, 2010; *Hapgood*, 2011; *JASON*, 2011]. How costly such potential major grid failures would be remains to be determined, but impacts of many billions of dollars have been suggested [e.g., *Space Studies Board*, 2008; *JASON*, 2011].

Noncatastrophic GIC effects on the high-voltage electrical grid percolate into financial consequences for the power market [*Forbes and St. Cyr*, 2004, 2008, 2010] leading to price variations on the bulk electrical power market on the order of a few percent [*Forbes and St. Cyr*, 2004].

Schrijver and Mitchell [2013] quantified the susceptibility of the U.S. high-voltage power grid to severe, yet not extreme, space storms, leading to power outages and power-quality variations related to voltage sags and frequency changes. They find, "with more than 3σ significance, that approximately 4% of the

Electrical Claims and Space Weather: Zurich, June 2015

Insurance Study By Lockheed/Zurich/NOAA:
C. J. Schrijver, R. Dobbins,
W. Murtagh, and S.M. Petrinec
Space Weather Journal, 2014

U.S. Senate Committee on Homeland Security & Governmental Affairs:

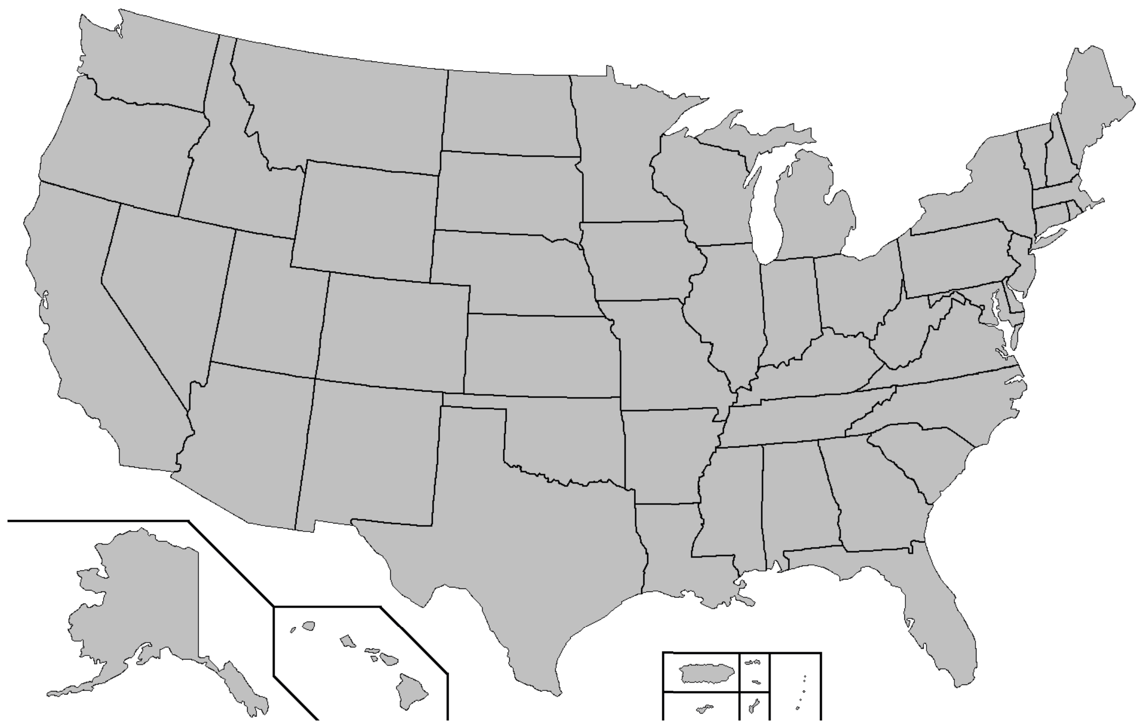
Perspectives on Protecting the Electric Grid from an Electromagnetic Pulse or Geomagnetic Disturbance

February 19, 2019

"I would like to stress that in addition to these extreme events, smaller but more frequent GMDs are estimated to cause an average of $10 billion in damage each year. **Address the major GMDs and we can also protect us from these smaller events.**"

Testimony of Dr. Justin Kasper – **University of Michigan**

"The overall fraction of all insurance claims statistically associated with the effects of geomagnetic activity is ≈ 4%."



"…we are potentially looking at an average impact on the order of $10 billion per year…"

-"**Assessing the impact of space weather on the electric power grid based on insurance claims for industrial electrical equipment**", **Lockheed/Zurich/NOAA**
-Space Weather Journal, 2014 "**Electrical Claims and Space Weather**", Zurich, 2015

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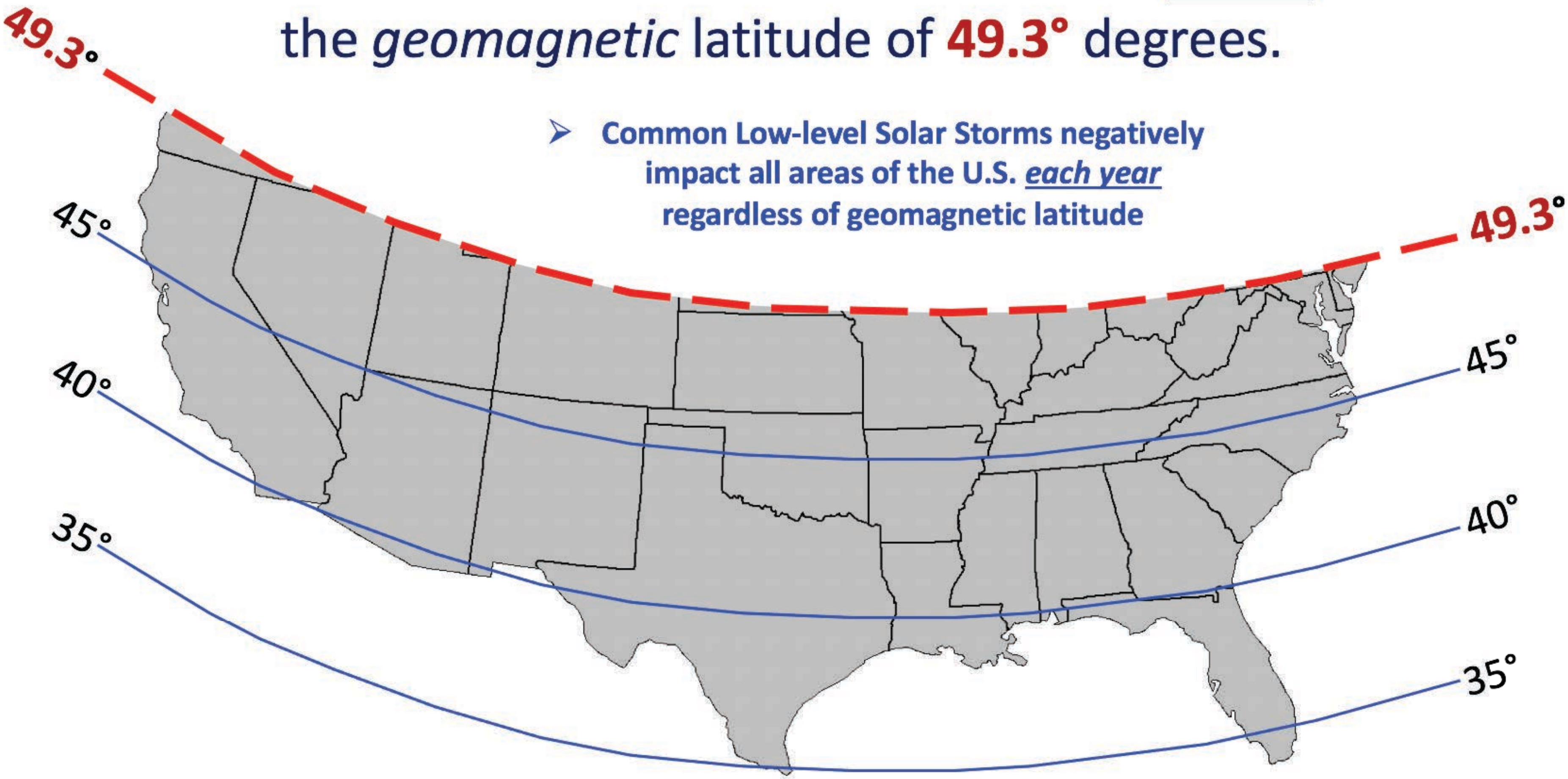
Geomagnetic Latitude

50% of the insurance claims filed were <u>below</u> the *geomagnetic* latitude of **49.3°** degrees.



- **Common Low-level Solar Storms negatively impact all areas of the U.S. *each year* regardless of geomagnetic latitude**

Lockheed/Zurich/NOAA research concluded:

"We find no significant dependence of the claim frequencies statistically associated with geomagnetic activity on geomagnetic latitude."

"Assessing the impact of space weather on the electric power grid based on insurance claims for industrial electrical equipment", Lockheed/Zurich/NOAA

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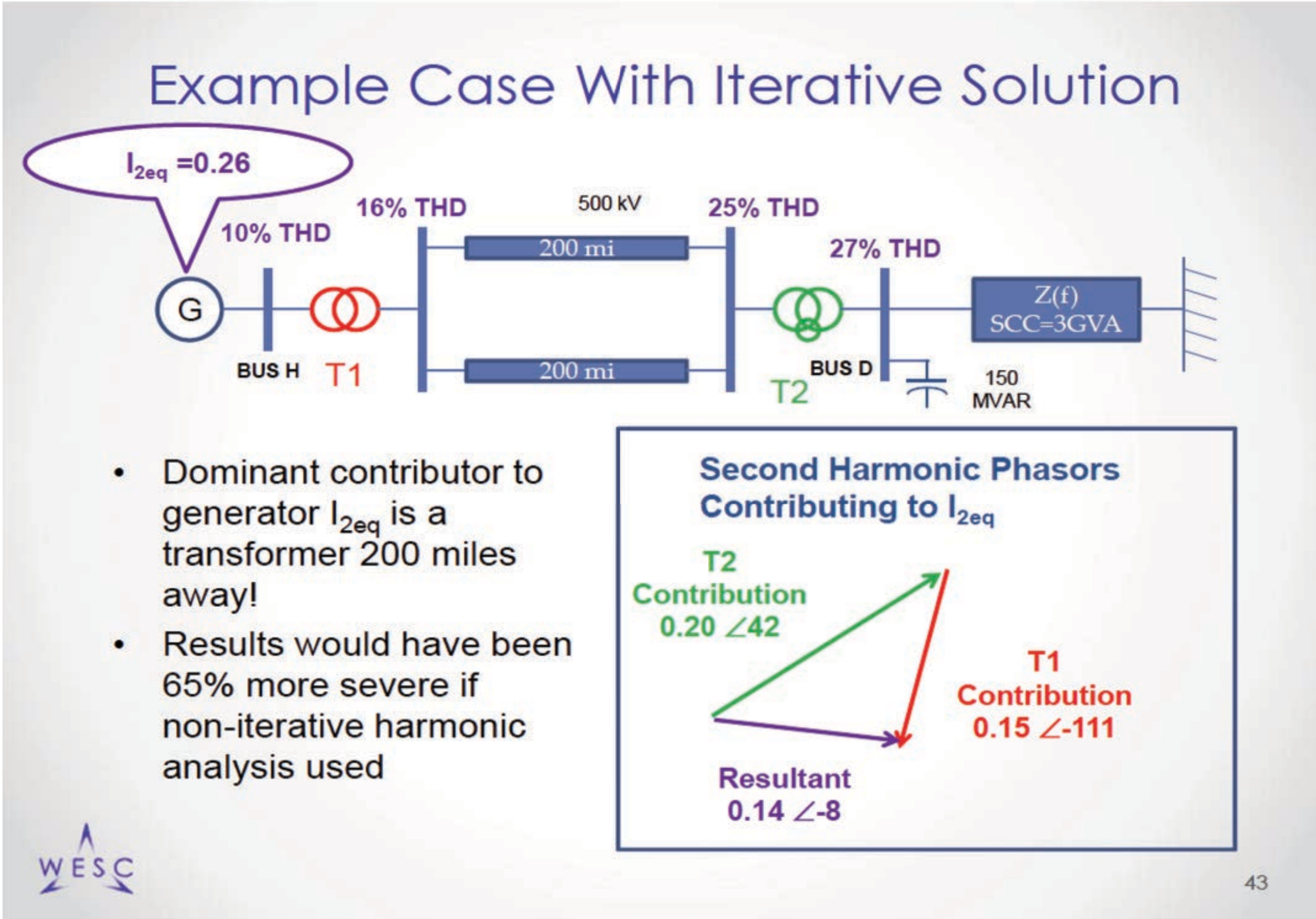
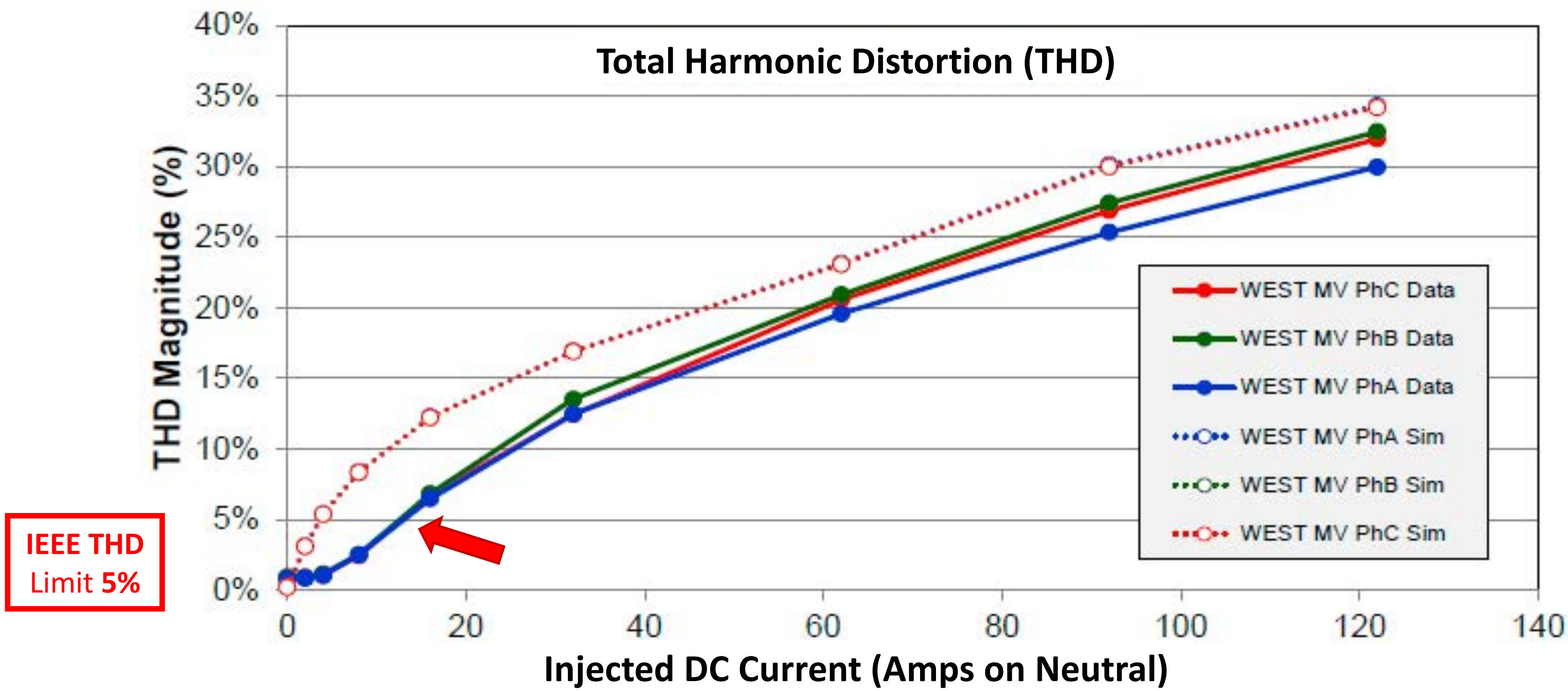
Transformers Half-Cycle Saturating due to small GIC (DC current) induce **Harmonics** which build as they travel into the lower voltage distribution network towards load.



Source: "**GMD Impacts on Generators**", Reigh Walling, pes-psrc.org

Total Harmonic Distortion (% THD) builds as you step down in voltage toward the load.

Secondary Harmonic Trends



At only **5 Amps** DC <u>**per phase**</u> IEEE 519 Std. of 5% Total Harmonic Distortion was exceeded. This data helps explain how small amounts of **GIC** (**DC current**) invading the AC power grid from common low-level GMDs can contribute to the $Billions in economic loss *each year*.

EMP **E3** can induce DC currents of <u>100's to 1,000's of Amps per phase</u> (EMP Commission)

***Graph above is from the U.S. Defense Threat Reduction Agency (DTRA) test results measured during the Idaho National Laboratory Live Grid experiment in 2012.**

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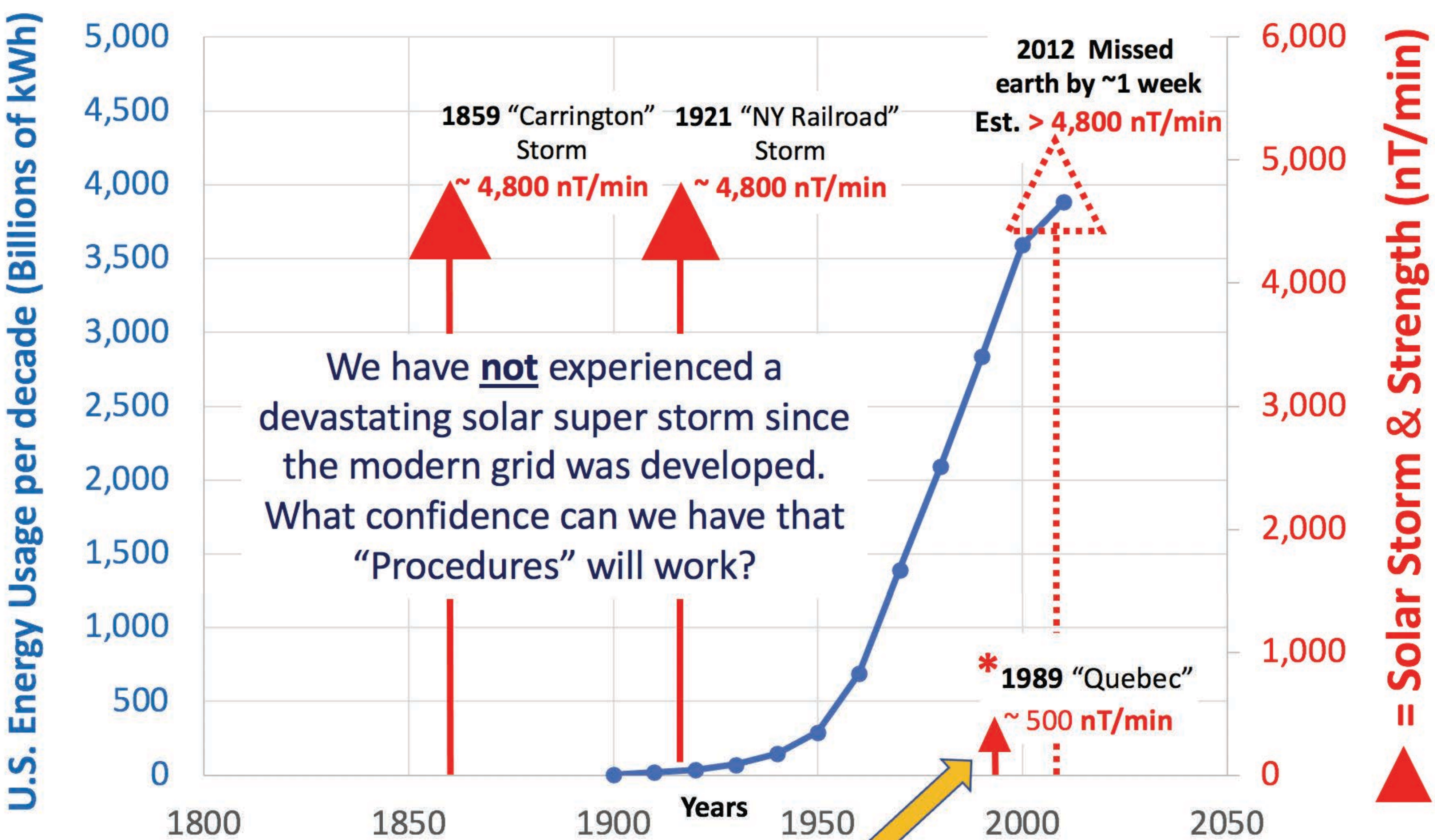
Not reasonable to expect Utilities to respond to common solar storms which occur multiple times each year.

"If we responded to every K alert of level 5 or greater, PJM would have spent over $100 million in excess incremental operating costs … **The ultimate protection against GMD is mitigation**."

-**Solar Magnetic Disturbance: An Operator's Wish List**, Greg A. Gucchi, **EPRI-EPRI TR-100450**

The Result: Small amounts of **GIC** will continue to invade the power grid at the high voltage level each year causing cumulative stress on equipment and generating harmonics. Without mitigation, $Billion(s) in economic loss will continue in the U.S. each year.

U.S. Electrical Grid Development vs. Solar Storms



*1989 solar storm collapsed Quebec's grid in 93 seconds. Only **9 hours** without power **cost ~ $13.2 Billion** in economic loss (Lloyd's of London). This 1989 storm is the basis for our nations GMD standard. The much larger 1859 & 1921 storms are **not** factored into the NERC standard.

Operating Procedures are not sufficient

Operating Procedures

- *Do **not** block **GIC** (**DC Current**) from entering an operating grid*
- *Do **not** prevent half-cycle saturation or the generation of harmonics*
- *Procedures to decrease load on vulnerable transformers **increase risk to HV Breakers***
- *Susceptible to human error - Require minutes to hours after a GMD warning (likely **no warning prior to EMP**).*
- *Attempt to prevent blackouts by finding **replacement VARs** which **are limited** and further complicated by the increased reliance on wind and solar power*
- *Low-level GMD events currently cause **$Billion(s) in economic loss each year** in the U.S.(Zurich/Lockheed/NOAA)*

Vs.

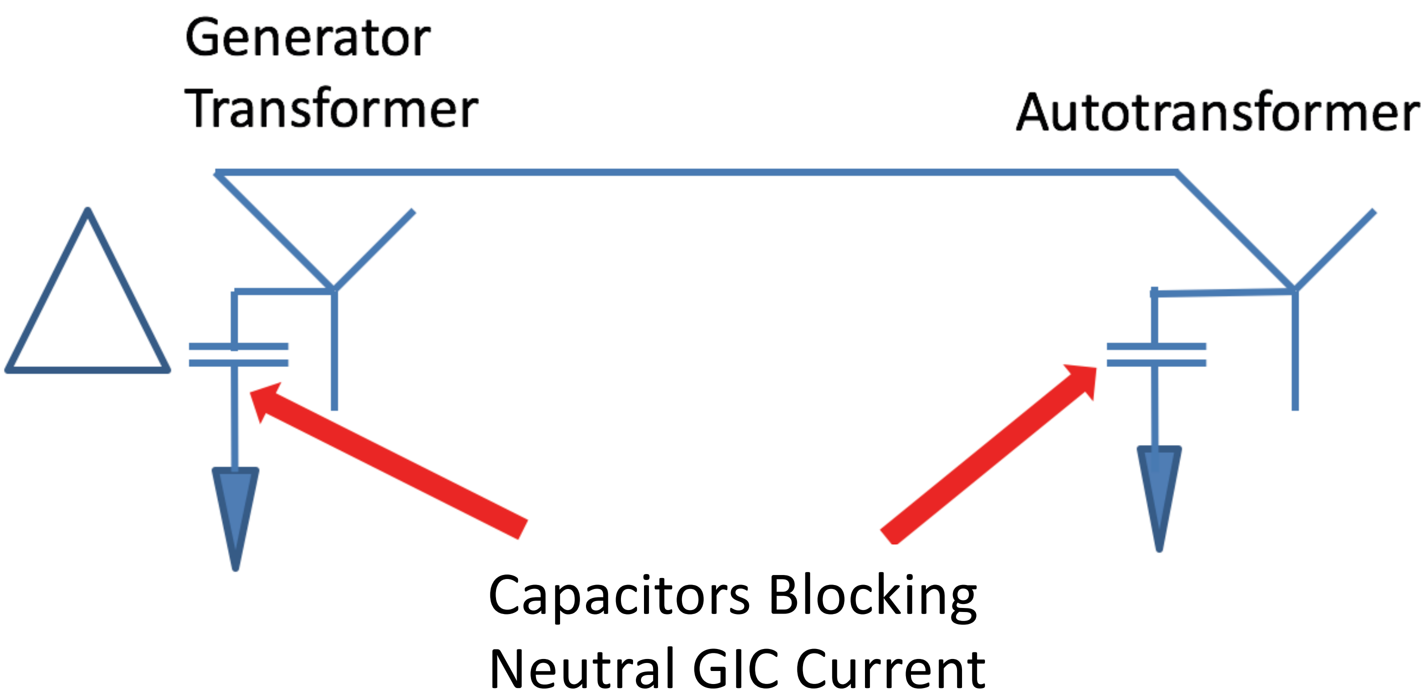
SolidGround™ Neutral Blocker

- ✓ *Automatically **blocks GIC**, prevents half-cycle saturation, prevents harmonics*
- ✓ *Allows Grid Operators to maintain control of the grid w/ **reliable operation of HV Breakers** without GIC across them*
- ✓ ***Operates in milliseconds** when **GIC** or **E1** is detected. Not susceptible to human operational error or delays during event.*
- ✓ ***Prevents voltage collapse (blackouts)** Decreases VAR consumption allowing utilities to operate through a large Carrington level event.*
- ✓ ***Perfect track record** over the last 7+ years blocking GIC from Low-level GMD events each time it was detected*

We must block GIC from entering our AC Grid

The most effective way to block GIC from GMD and EMP E3

GIC Neutral Blocking - **Capacitors** placed in the neutral to ground connection of High Voltage Transformers **block GIC (DC current)** at the point of entry – before it disrupts the system designed primarily for AC.



Capacitors block GIC while allowing AC current to flow

Brief History of Neutral Blocking

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Electric Power Research Institute (**EPRI**)

1983: "A **capacitor** in the neutral of transformers was determined to be the most effective and practical blocking device."

-**EPRI** EL-3295, Project 1770-1 "**Mitigation of Geomagnetically Induced and DC Stray Currents**"

1992: "…inserting blocking devices in neutral leads appears to be the most logical and effective means of preventing GIC flow … the use of ordinary **capacitors** is the best option for a GIC neutral blocking device."

-**EPRI** TR-100450 "**Proceedings: Geomagnetically Induced Currents Conference**"

Capacitors block GIC while allowing AC current to flow

Brief History of Neutral Blocking

Electric Power Research Institute (**EPRI**)

1992: "The Limited Effectiveness of **linear resistance** unless relatively high values of resistance are used, *and the other disadvantages associated with their use*, combine to make them **a less favorable choice for blocking or limiting GIC than capacitors**."

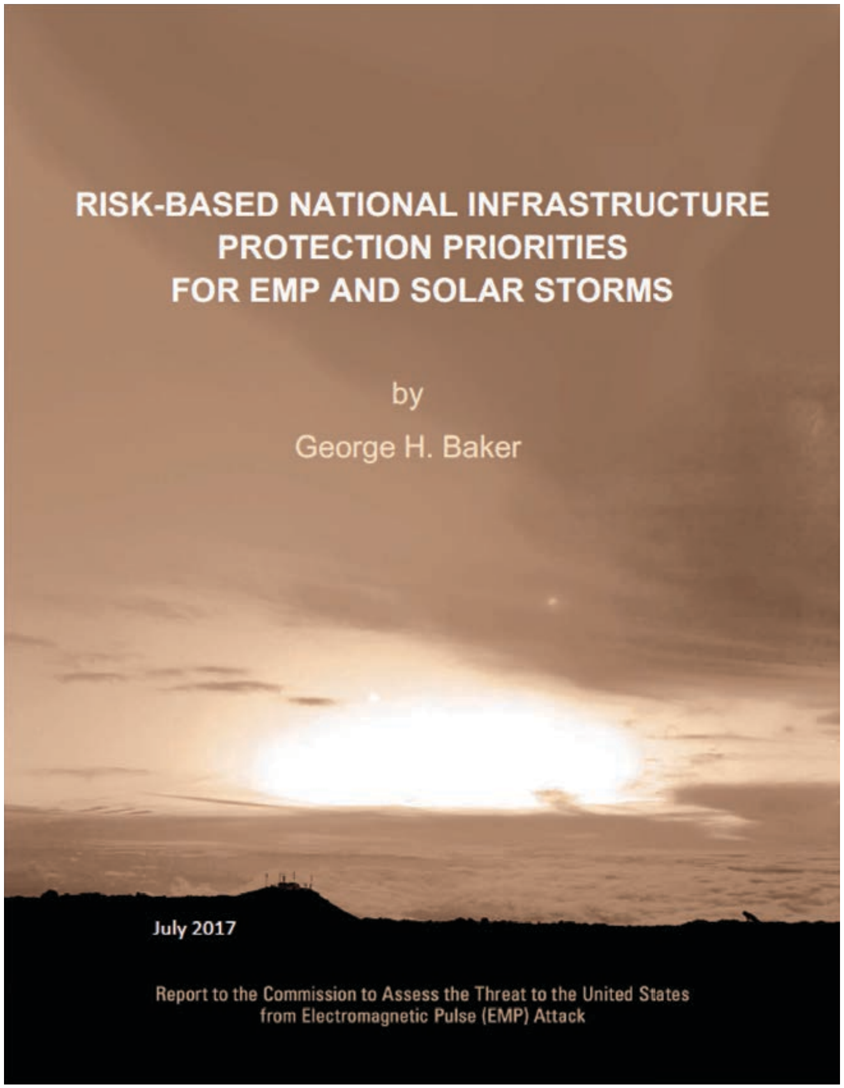
-**EPRI** TR-100450 "**Proceedings: Geomagnetically Induced Currents Conference**", p. 3-8

2019: "The use of **capacitors** in the neutral of grounded-wye transformers…is an effective means of blocking the flow of GIC in transformer windings."

-**EPRI** 3002014979, "**High-Altitude EMP** and the Bulk Power System, Potential Impacts and **Mitigation Strategies**"

Capacitors block GIC while allowing AC current to flow

June 2018: U.S. Department of Defense cleared the EMP Report to the Commission for open publication



"**E3**… **induces currents [GIC] of 100's - 1000's of amperes** in long conducting lines ... that damage components of the electric power grid itself as well as connected systems." (p. 3)

"We have empirical evidence that EMP and solar storms damage transformers within the electric grid…" (p. 8)

"**Installation of blocking devices in the neutral to ground connections of transformers will significantly reduce the probability of damage from solar storms and... EMP E3**." (p. 8)

Neutral Blocking on 10% to 20% of High Voltage Transformers:

- ✓ Significantly reduces Total Network GIC and Harmonics
- ✓ Significantly reduces Reactive Power (VAR) Consumption
- ✓ Minimizes "Whack-a-Mole" effects
- ✓ Reduces the potential for Voltage Collapse

% of Transformers with Blocking	% 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

SolidGround™ NEW STANDARD MODEL

- ✓ **2X more blocking capability**
  - **-8 kV DC (can be upgraded to 20 kV DC)**
- ✓ Same tested circuit with simplified grounding
- ✓ **New SCADA controls**:
  - -**2 automatic modes** of operation
  - -user settable thresholds
  - -**Cyber resistant** controls
  - -manual overrides
- ✓ Improved **EMP Upgrade** capability
- ✓ Protects the grid against **EMP E3** and **GMD** - both large "Carrington level" and common low-level.

SolidGround™ Validation

Simulation and Modeling

Extensively studied by the University of Manitoba and **EPRI**

Report #3002002985, March 2014
Report #109905, February 2018
Report #3002014979, April 2019

High Ground Fault Current Testing at KEMA Labs

Passed <u>repeated</u> high current fault testing

DoD/DTRA - Idaho National Laboratory Live Grid EMP E3 Testing

SolidGround™ met all performance requirements. DTRA co-authored a paper on its performance.

SolidGround™ Currently operating on the Grid

American Transmission Company co-authored & presented a paper on the ongoing performance of SolidGround™.

over 7 years operating on the power grid

"SolidGround™ is ready for deployment"

- Automatically operated, performing as designed without issue, **blocking GIC** during multiple solar storms
- Little to no maintenance, **no operator intervention needed**
- **No negative effects** to the system

U.S. Senate Committee on Homeland Security & Governmental Affairs:

Perspectives on Protecting the Electric Grid from an Electromagnetic Pulse or Geomagnetic Disturbance

February 19, 2019

"**SolidGround™**…has performed according to its design parameters and has not failed…operated automatically to block GIC more than several dozen times and has successfully kept GIC from flowing through the transformer to ground. No adverse operating complications have been experienced on the system due to [SolidGround™] performing its intended function."

Testimony of Jim Vespalec - Director of Asset Planning & Engineering, **American Transmission Company**

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U.S. Senate Committee on Homeland Security & Governmental Affairs

September 13, 2018

"A mature, tested and validated technology has been developed … to protect HV and EHV power transformers from the threat of both GMD's and EMP's … marketed as **SolidGround**™… no signs of unintended consequences introduced into protective relays or other power system components …"

"…there must be a priority to protect the most critical large power transformers in place … estimates are that this would cost **less than $4 billion if we made it a priority to install NBD's [neutral blocking devices]** at our most critical EHV substations…"

Testimony of Scott McBride, Infrastructure Security Manager, National & Homeland Security, **Idaho National Laboratory**

Janney

Janney Report – January 18 - 2018

Grid Resiliency From Electromagnetic Threats; the Infrastructure Plan Provides an Opportunity for Substantial Investment

Billions of dollars from the new Tax Act now available to redeploy into power grid resiliency investments.

"Hardening will likely require a phased approach … focusing initially on protecting the largest, most important transformers … the entire 5,000 [HV Transformers] could be outfitted with state-of-the-art, field tested and proven technology such as **SolidGround**™ GIC/EMP neutral blockers…**"**

emPRIMUS

"Estimating the Cost of Protecting the U.S. Electric Grid from Electromagnetic Pulse"

Foundation for Resilient Societies, September 2020, pg. 63

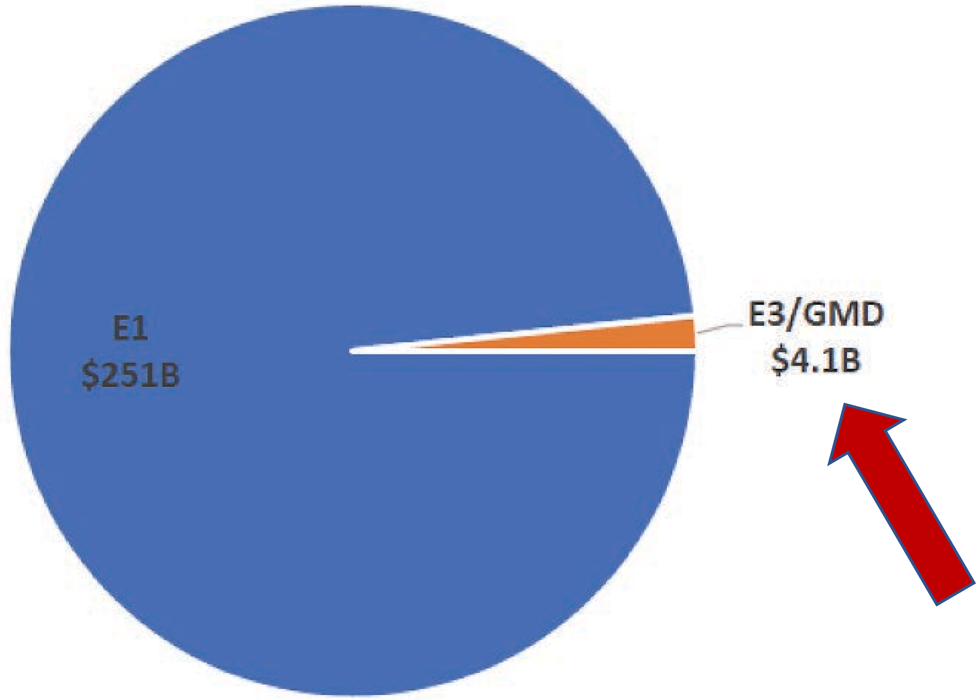

Figure 43: Estimated U.S. EMP Protection Costs by Grid Threat

We find the cost of protection against the E1 pulse is significantly greater than the cost of protecting against E3 and GMD. We allocate the cost of neutral ground blocking devices at substations and generating station to the E3/GMD threat with all other protections allocated to E1. Under this classification, E3/GMD constitutes less than 2% of total protection costs (Figure 43).

E3 and GMD protection should be prioritized because they threaten large power transformers—expensive assets with long lead times—and, GMD is a natural phenomenon that cannot be deterred. Lloyd's of London (Lloyd's) estimates the economic cost of a Carrington-class solar storm on the North American electric grid at between $0.6 and $2.6 trillion based on the value of lost load (VOLL).[8] By this conservative assessment, the value at risk could be over 500 times the cost of E3/GMD hardening.

SolidGround™ Summary

- **Protects the electric power grid** against the effects of EMP **E3** and all levels of **GMD**
- **Automatically Blocks GIC (DC current)**
- **Prevents Half Cycle Saturation** and **Harmonics**
- **Reduces Total Network GIC** and **VAR Consumption**
- Provides a solid metallic *and* effective AC ground
- **Protects HV Transformers, HV Breakers** and **Generators** (the "*backbone of the grid*") allowing utilities to *operate through* large GMD events.
- **Stabilizes grid**, Scalable, **Reduces existing GIC stress** on equipment and provides for rapid payback **preventing *annual* economic loss** from small GICs
- Major components are **industry standard**, provided by **ABB, GE & Schweitzer (SEL)**.
- **New Cyber Resistant Controls** w/ SCADA monitoring
- No Adjustment of protection relay settings required