

Bulk Power System GMD Impacts

Next Steps in Addressing Space Weather Science and Modeling Gaps

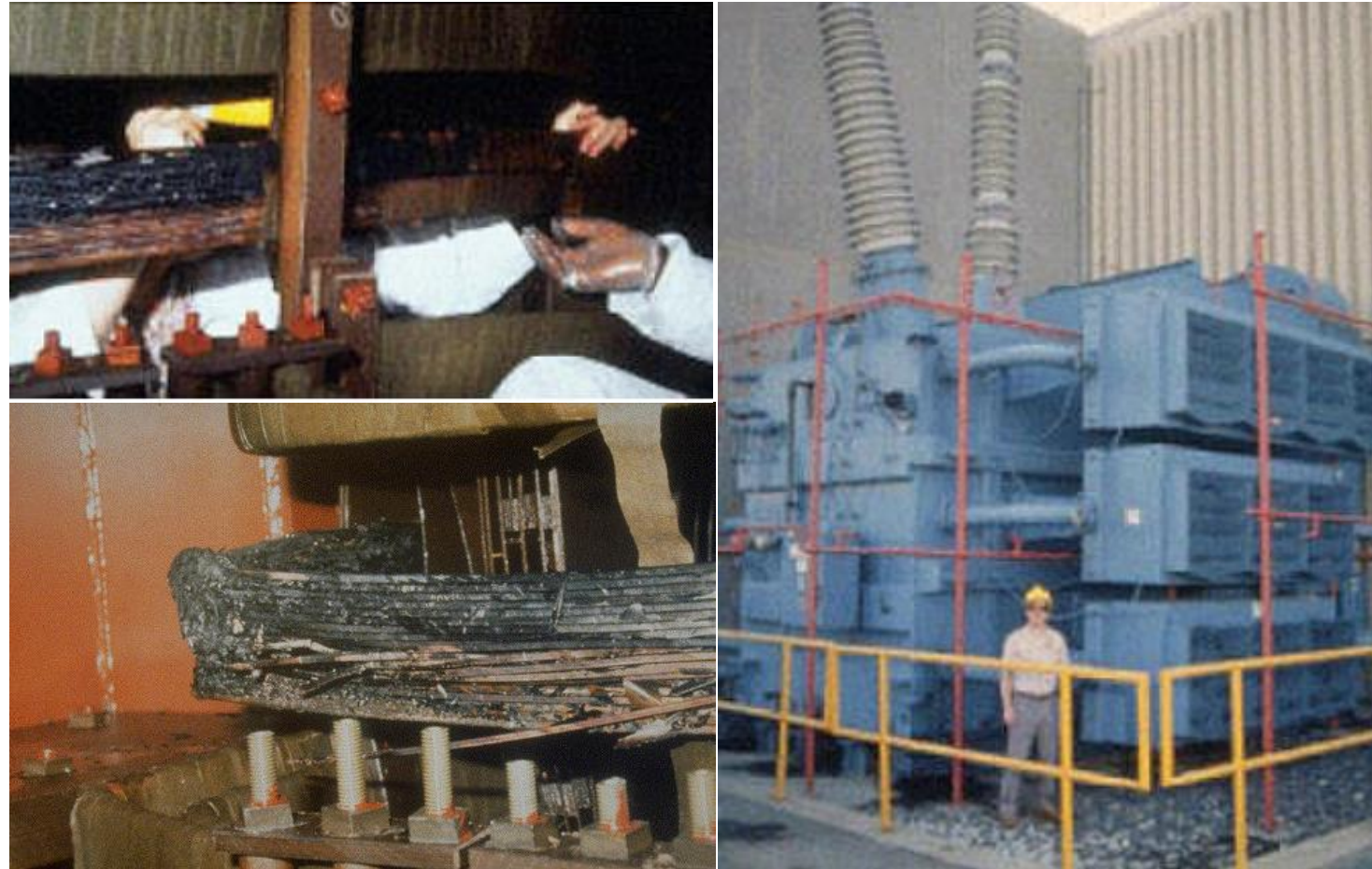


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NASA Space Weather Council (SWC)
February 22, 2024

Industry Questions

- What do we prepare against?
 - How big of a storm can we have?
 - How likely is this event?
- How soon can we know if a big event is happening?
- Do we know the impacts?
- Are we doing everything we can?



Salem Nuclear Plant GSU Transformer damaged by the GMD event of March 1989. (Photos courtesy of PSE&G.)

Do we know everything we need to know?

Background

- Extreme space weather has demonstrated its capability to disrupt normal power delivery.
- EPRI has been performing GMD-related research since the late 1970's.
- Research areas include:
 - GIC Calculation and System Modeling
 - Software Tools
 - Vulnerability Assessments
 - Mitigation Measures
 - Measurement (EPRI SUNBURST Network)

The collage features several EPRI documents:

- Mitigation of Geomagnetically Induced Currents in Transformers**: A white document cover with the EPRI logo and title.
- GMD News and Observer**: A newsletter cover with the title "Your View into EPRI Research on Geomagnetic Disturbance Vulnerabilities, Impacts, and Mitigation" and a row of five small images.
- Research Findings for Geomagnetic Disturbance Research Work Plan**: A white document cover with the EPRI logo and title, including a "Summary Report" section.
- Quick Insight Brief: Space Weather Activity and Transmission System Impact: February 2023**: A white document cover with the EPRI logo and title, featuring a large image of a power transmission tower against a red and orange sky.

Text from the "Quick Insight Brief" document:

RESEARCH QUESTION
What lessons can be learned from the space weather activity observed during the February 2023 solar storm?

KEY POINTS

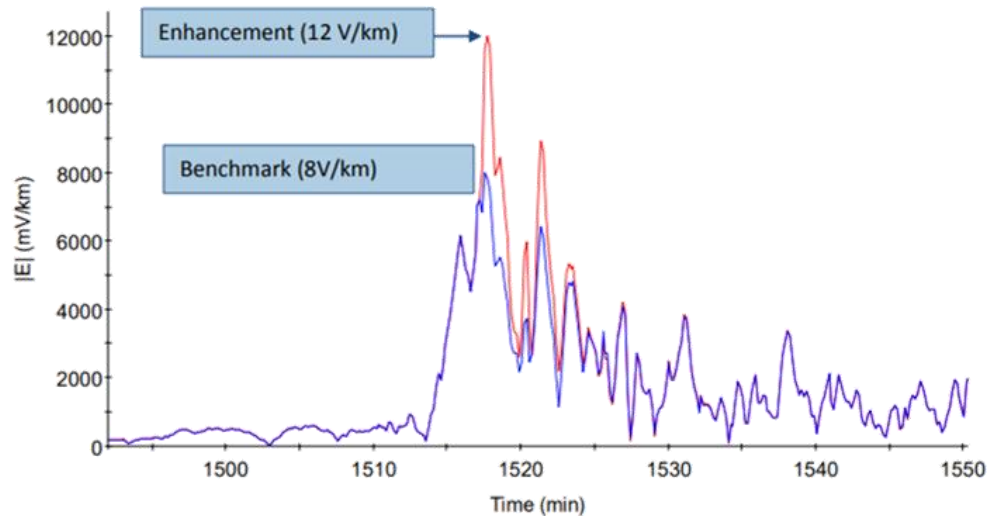
- In late February 2023, the National Oceanic and Atmospheric Administration's (NOAA) Space Weather Prediction Center reported significant activity on the sun's surface. An active sunspot region unleashed several solar flares, and multiple coronal mass ejections (CMEs) with Earth-directed components from the sun, on February 24-25, 2023. The leading edge of these CMEs arrived at Earth at approximately 19:25 UT on February 26, 2023.
- NOAA issued a Sudden Impulse Alert shortly after arrival, indicating a deviation in the magnetic field of 34 nanoteslas (nT) at the Federal Energy Grid Observatory in Carbon, Virginia. According to NOAA, Earth experienced G3 geomagnetic storm conditions (where G5 is the maximum) on February 27, 2023, from 06:00 to 18:00 UT (Universal Time).
- Geomagnetically induced currents (GICs) were measured flowing in the transmission grid. Three of the EPRI SUNBURST Project monitoring sites recorded GICs exceeding 10 amperes (A), making this a moderate level SUNBURST GIC event. In addition to the three sites experiencing GICs exceeding 10 A, five additional sites recorded GICs between 5 A and 10 A and 18 others recorded GICs between 1 A and 5 A.
- The geomagnetic disturbance (GMD) event was categorized as a Kp-7 (where Kp-9 is the maximum); no significant impact on the North American bulk-power system has been reported to date.
- Earth is entering a solar maximum during which more solar events are expected. The February storm is a reminder that large-magnitude GMD events can occur at any time, but have higher probability of occurrence during a solar maximum.

BACKGROUND
GMDs are the result of coronal mass ejections (CMEs) from the sun's surface that impact the earth's ionosphere and magnetosphere. These disturbances induce the flow of low-frequency currents, known as GICs, in the earth and in conducting infrastructure such as transmission lines and transformer windings. Wire-grounded transformers provide a path for GICs through transmission lines, transformer windings, and the ground. GICs have the potential to cause thermal stresses to the transformer and voltage collapse due to the generation of harmonics and reactive power absorption.

What do we prepare against?

How big of a storm should we prepare against?

- NERC TPL-007 – GMD Vulnerability Assessment – Regulatory Compliance
 - GMD Vulnerability assessment begins with 1-in-100-year GMD Storm Definition



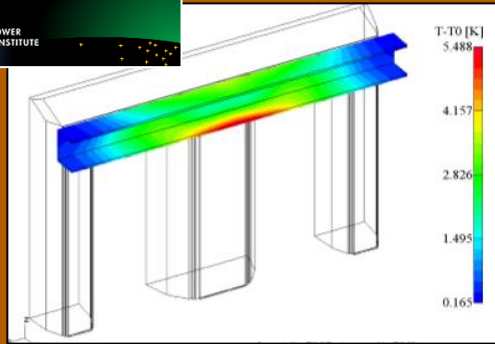
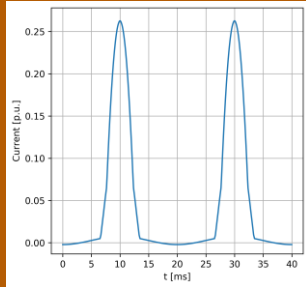
How soon can we know?

- Long-term (>2hrs ahead) and short-term forecast capabilities
 - Increase time to assess the system
 - Time to implement safe-posturing



Do we know the impacts?

Harmonic/Thermal Analysis



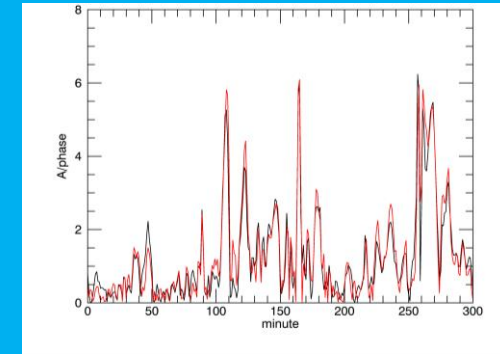
Predicting harmonic/
thermal responses

Monitoring



Obtaining GIC monitor
data from planning area

Model Validation



GIC and magnetometer
data to validate models

Answering Key Compliance Requirements for the 1-in-100-year Event

Do we know the impacts?

- GMD Modeling tools

ETT v1.0

Test Data	
L _{dc} (A)	T (C)
1	10
2	20
3	40
4	50
5	100
6	200
7	
8	

Curve Fitting Results

Structural Parts Asymptotic Response

Temperature (°C) vs I_{dc} (A)

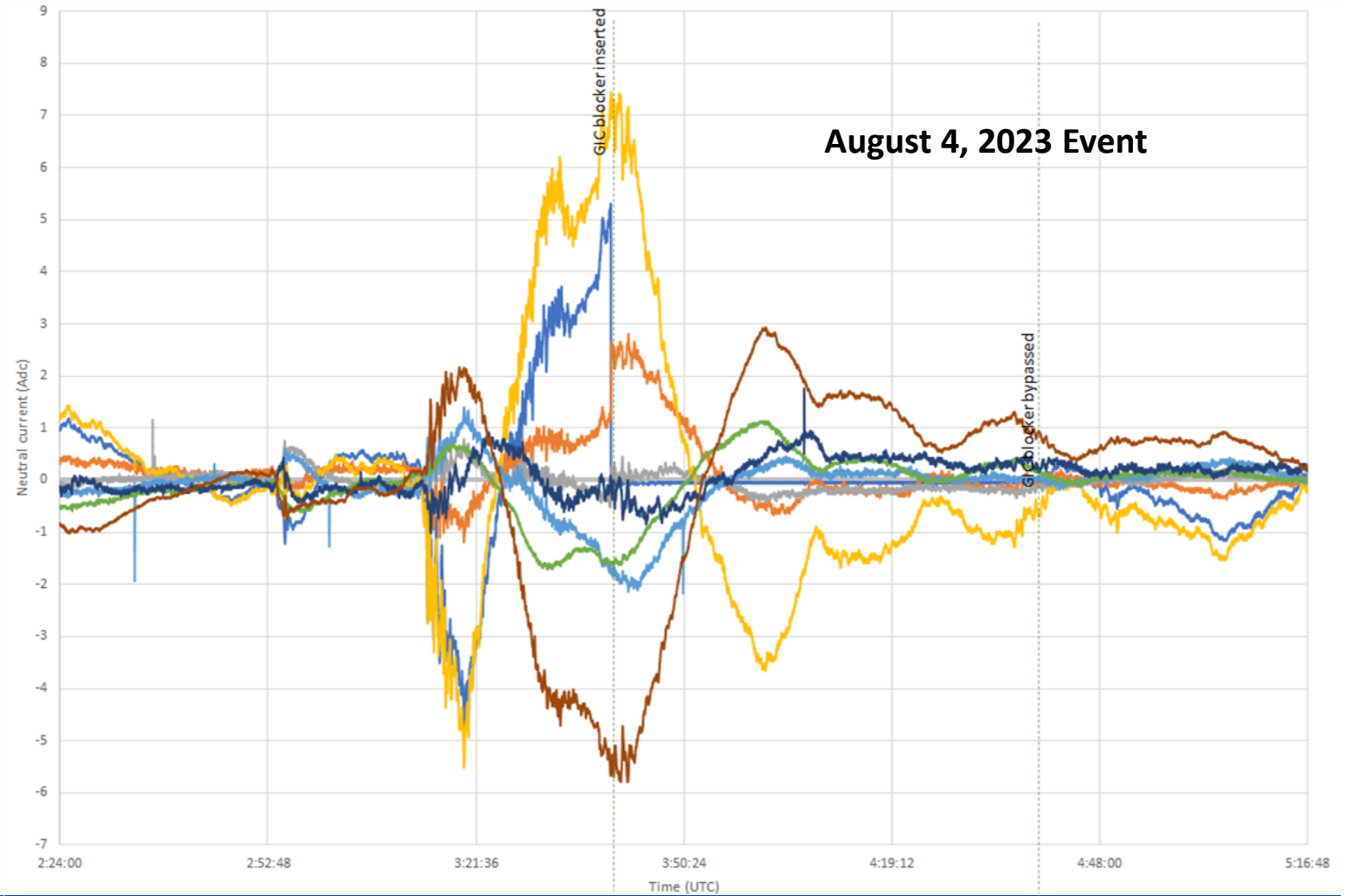
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GIC harm

PSS®E

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Are we doing everything we can?



GIC Blocker Field Demonstration

Are we doing everything we can?

- Collaborative Research
- Industry meetings
- NERC's GMD Meetings
- NASA Engagement
- DOE Engagement
- NSF Engagement
- NOAA Collaboration



Continued Engagement is Critical in GMD Preparedness



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