Society Centennial – 2020 – Washington D.C.

Society of American Military Engineers
Northern Virginia Post

September 9, 2021

Welcome Everyone!

Thanks for joining us

Ed Chamberlayne, PE, PhD, F.SAME
Vice President, WSP USA
Post President

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Pledge of Allegiance

I Pledge Allegiance To The Flag, Of The United States of America, And To The Republic, For Which It Stands, One Nation Under God, Indivisible, With Liberty, And Justice For All

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Today's Agenda

- Upcoming NoVA Programs
- Guest Speaker:
  - Electric Power Research Institute
  - Randy Horton, Ph.D., PE, Senior Program Manager, Electromagnetic Threats and Critical Power, Transmission and Distribution Infrastructure
- Closing

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Upcoming NoVA Programs

- **Sept 16th: Industry-Government Engagement Workshop**
  - **"Improving Cybersecurity & Safety in Smart Buildings & Infrastructure"**
  - **SAME NoVA/DC post and SAME National**
  - **Location: (Crystal Gateway Marriott)**
- **Oct 7th: Business 2 Business Centennial Event**
  - **Location: Nation Museum of the US Army, near Ft Belvoir**
- **Nov 9th: Post Resilience Committee Webinar**
  - **Environmental Security Technology Certification Program (ESTCP) Highlights**
- **November 17-19th: Small Business Conf @ Atlanta**

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Today's Event

This briefing is being held in conjunction with September being National Preparedness Month to raise awareness about the importance of preparing for disasters and emergencies that could happen at any time. The 2021 theme is "Prepare to Protect. Preparing for disasters is protecting everyone you love."

EPRI
Electric Power Research Institute

SAME Strategic Partner for Build and Strengthen Resilient Communities

Randy Horton, Ph.D., P.E.
Senior Program Manager
Electromagnetic Threats and Critical Power Transmission and Distribution Infrastructure

Mitigating the Effects of High-Altitude EMP (HEMP) on the Electric Power Grid

Randy Horton, Ph.D., P.E.
September 9, 2021

About EPRI

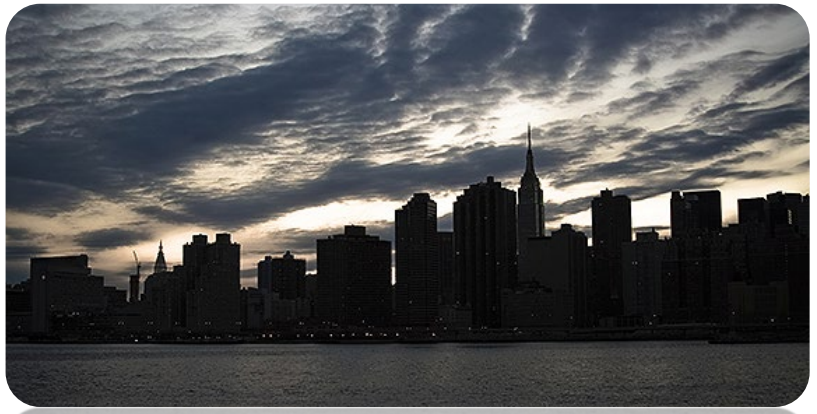
Born in a Blackout

- Founded in 1972 as an independent, non-profit center for public interest energy and environmental research

EPRI Members

- 450+ participants in more than 30 countries
- EPRI members represent approximately 90% of the electricity revenue in the United States
- International members and U.S. Government

Independent, Nonprofit and Collaborative



The Great Northeast Blackout
New York City - 1965

R&D Portfolio Spans the Entire Electricity Sector

Generation to End Use




Generation

- Advanced Coal Plants, Carbon Capture and Storage
- Combustion Turbines
- Environmental Controls
- Generation Planning
- Major Component Reliability
- Operations and Maintenance
- Renewables

Nuclear Power

- Advanced Nuclear Technology
- Chemistry, Low-Level Waste and Radiation Management
- Equipment Reliability
- Fuel Reliability
- Instrumentation and Control
- Long-Term Operations
- Material Degradation/Aging
- Nondestructive Evaluation and Material Characterization
- Risk and Safety Management
- Used Fuel and High-Level Waste Management

Power Delivery & Utilization

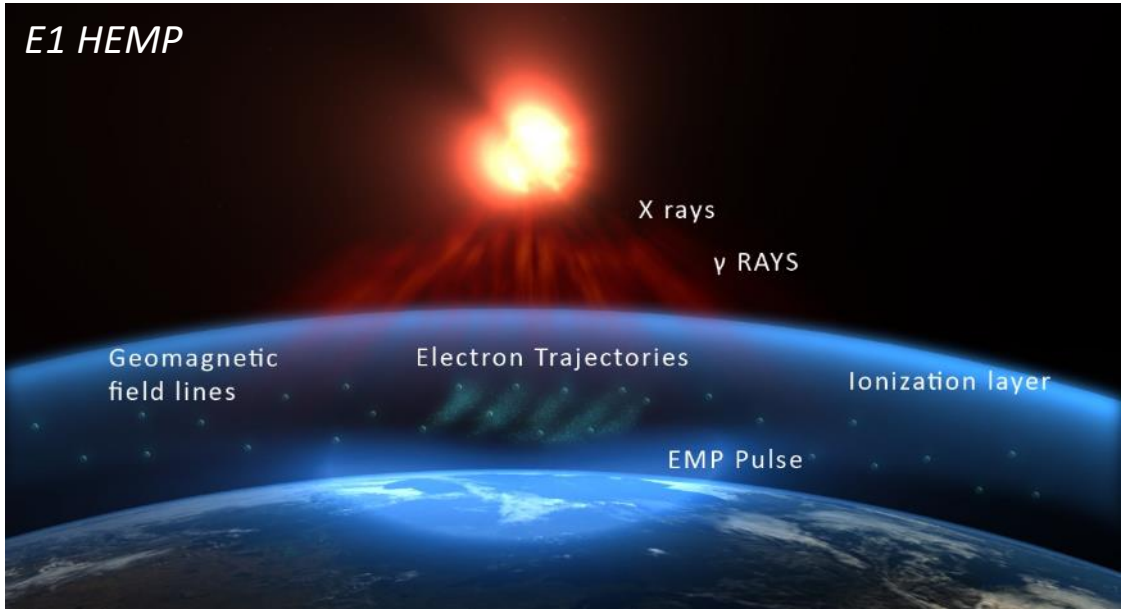
- Transmission Lines and Substations
- Grid Operations and Planning
- Distribution
- Information, Communications, and Cyber Security
- Energy Utilization
- Cross Cutting Technologies
- Critical Power
- Electromagnetic Threats

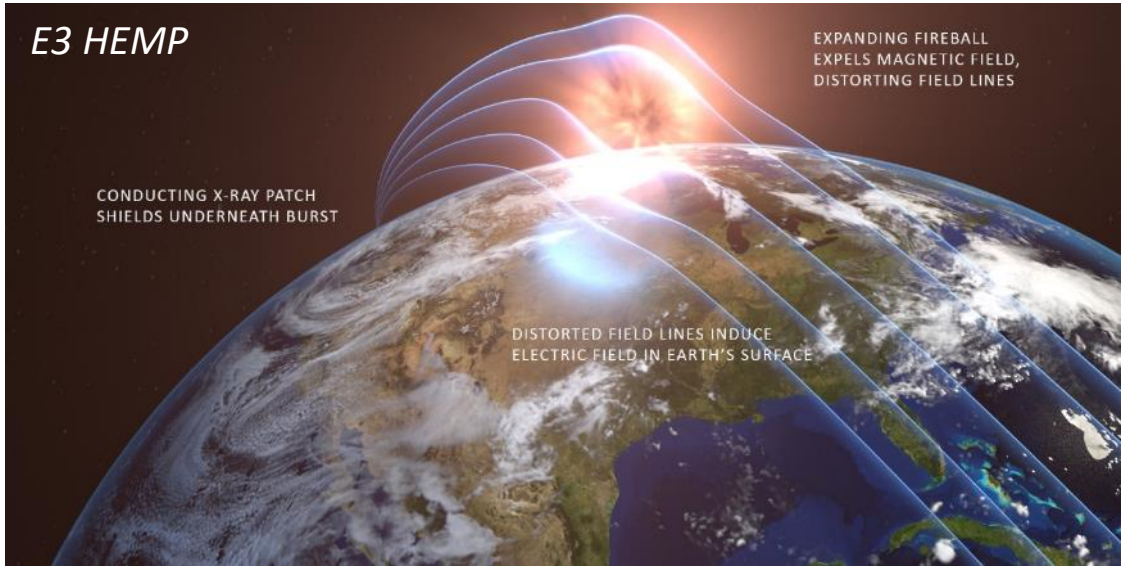
Environment

- Air Quality
- Environmental Aspects of Renewables
- Global Climate Change
- Land and Groundwater
- Occupational Health and Safety
- T&D Environmental Issues
- Water and Ecosystems

What is High-Altitude Electromagnetic Pulse (HEMP)?

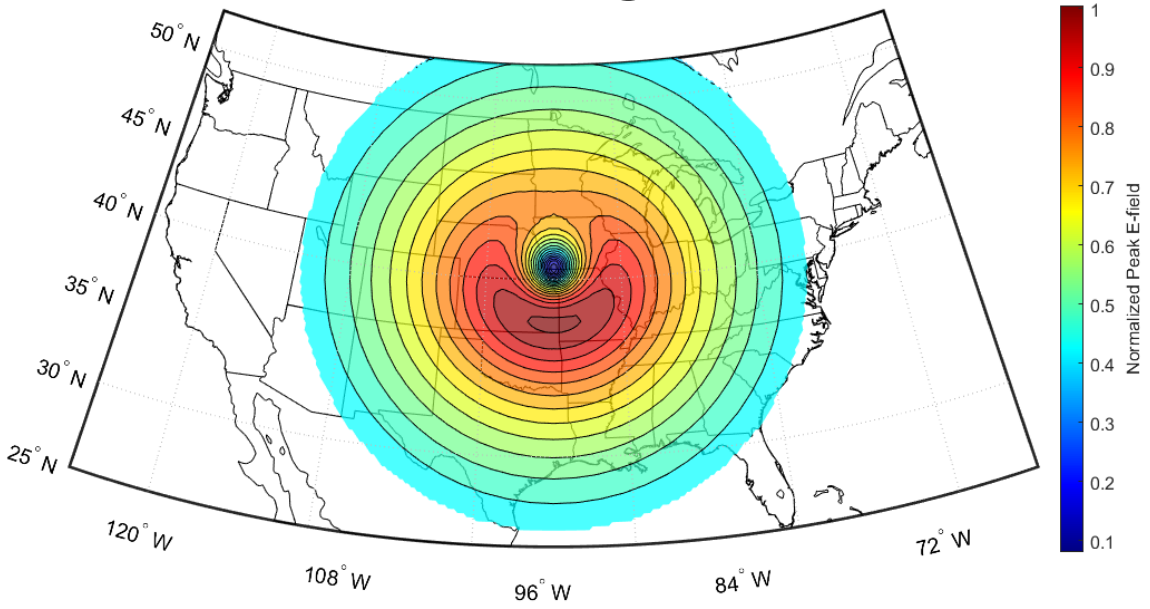
- Created by the detonation of a nuclear weapon at high-altitude or in space
- **E1 HEMP: Early-time Pulse**
  - 10's kV/m, nsec rise times (< 100 MHz)
  - Large geographic coverage (line of sight)
  - Potential impacts to electronics; insulation flashover
- **E2 HEMP: Intermediate-time Pulse**
  - 0.1 kV/m, waveform and effects similar to nearby lightning strike
  - No power grid impacts expected
- **E3 HEMP: Late-time Pulse**
  - 10's V/km; lasts a few minutes
  - Effects similar to severe GMD event; voltage collapse, transformer damage possible



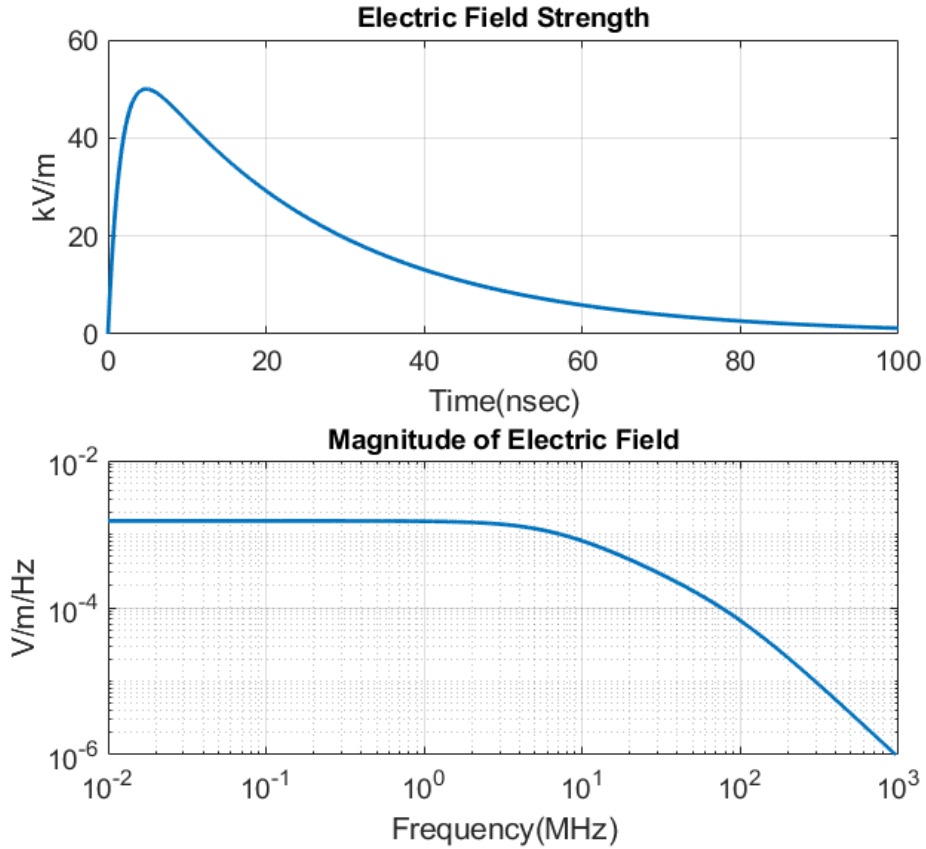


E1 HEMP

Smile Diagram



IEC 61000-2-9
E1 HEMP Waveform



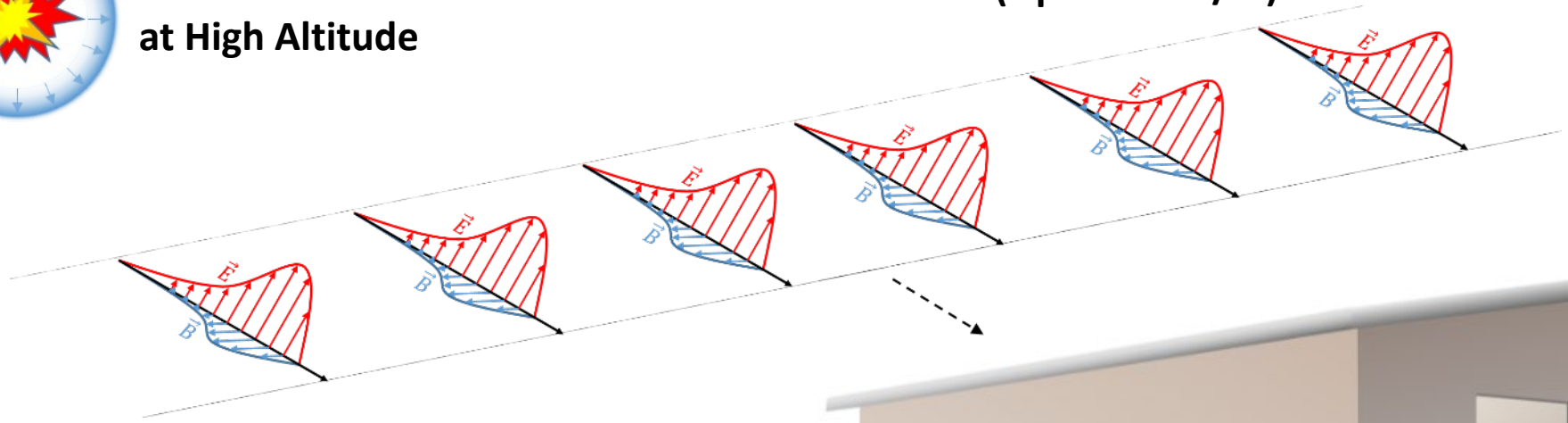
E1 HEMP can impact large geographic areas, but not all areas affected equally

50 kV/m; 99% of the energy is contained between 10 kHz and 100 MHz

E1 HEMP Threat (Conducted + Radiated)

Nuclear Detonation at High Altitude

Incident E1 HEMP Wave (Up to 50 kV/m)



Antenna

Conducted Threat

E-Field (Radiated Threat)

Digital Protective Relays, SCADA, Communications Systems

AC, DC, Control and Communications

Voltage Surge (Conducted Threat)

Phase 1 Project: 2016-2019

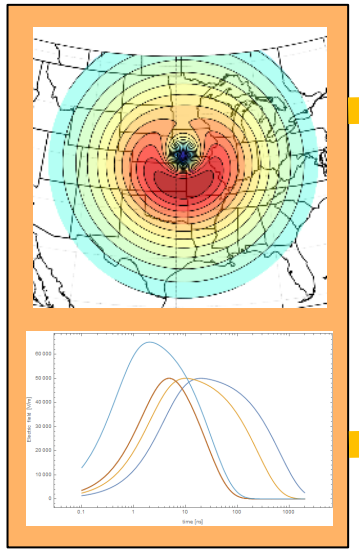
- Transparent, objective EPRI R&D involving numerous energy stakeholders
- Collaboration with 63 U.S. utilities
- Leveraged resources and knowledge from U.S. DOE, National Labs, DoD
- Applied industry-leading expertise to address national security threat

EMP Community Collaboration

Lawrence Livermore National Laboratory

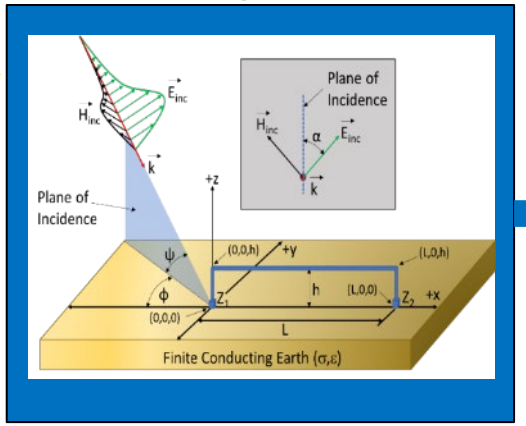
E1 HEMP Assessment Framework

E1 Environments (LANL, LLNL, STDs)

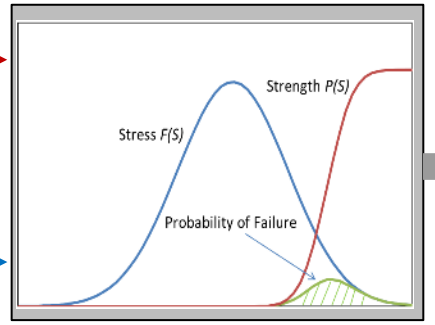


Testing Based on MIL-STDs (Strength)

Modeling (Stress)



Impact Assessment



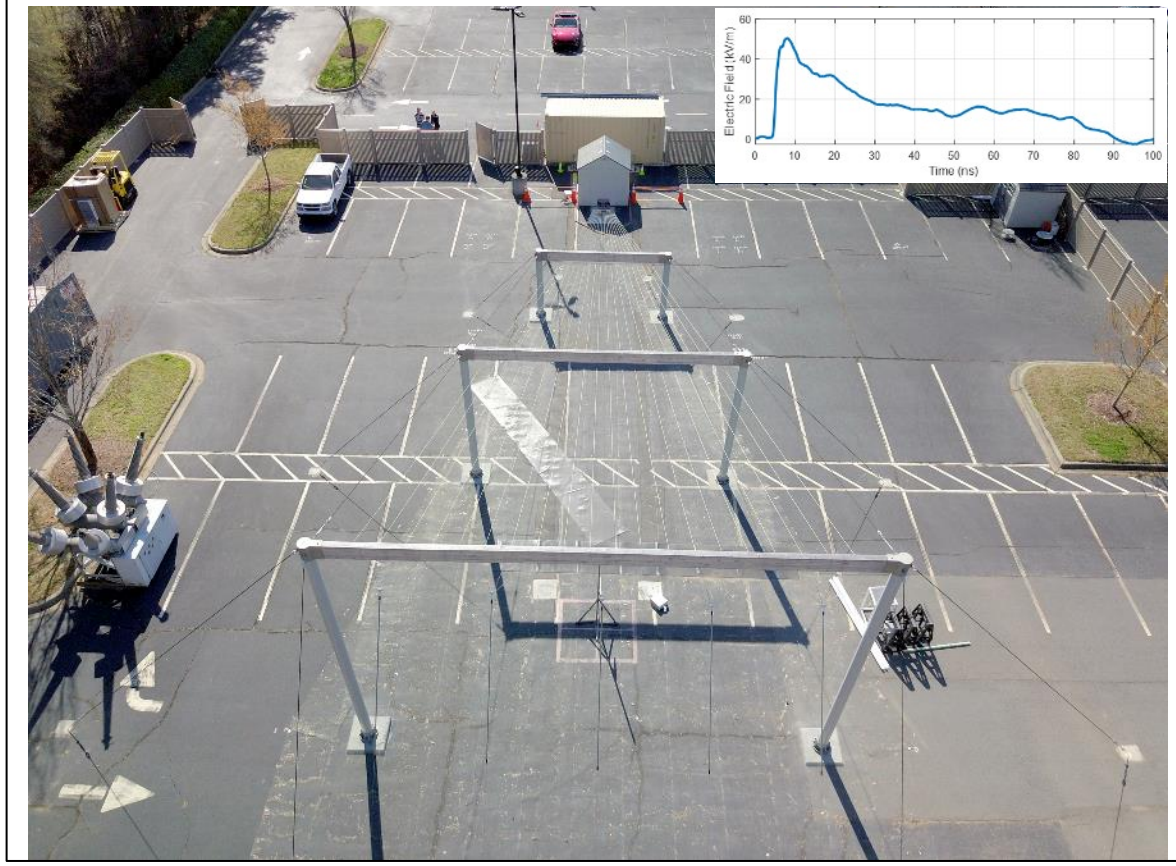
Impacts?

Testing is Only a Part of the Answer

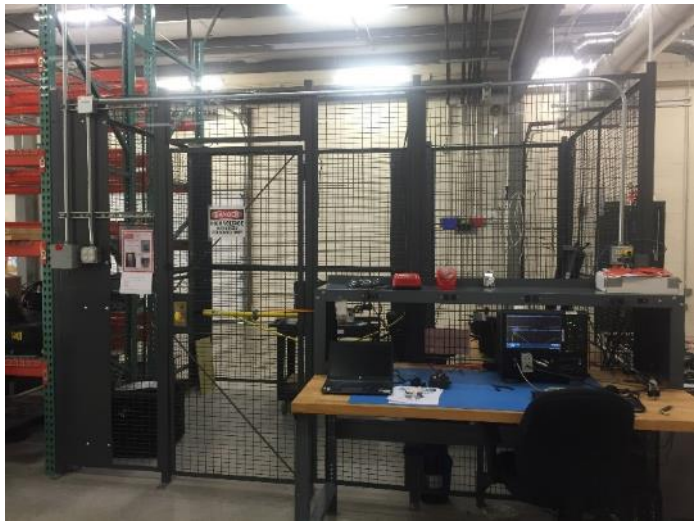
E1 HEMP Testing

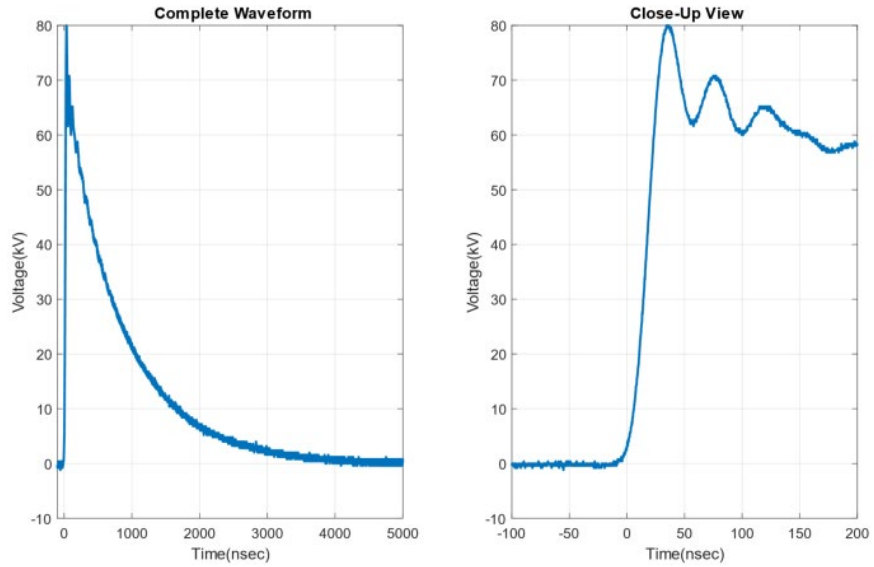
- Guided wave and direct injection testing of equipment is performed to determine strength and identify possible mitigation options

RS105 Testing (Radiated Threat)
EPRI - Charlotte



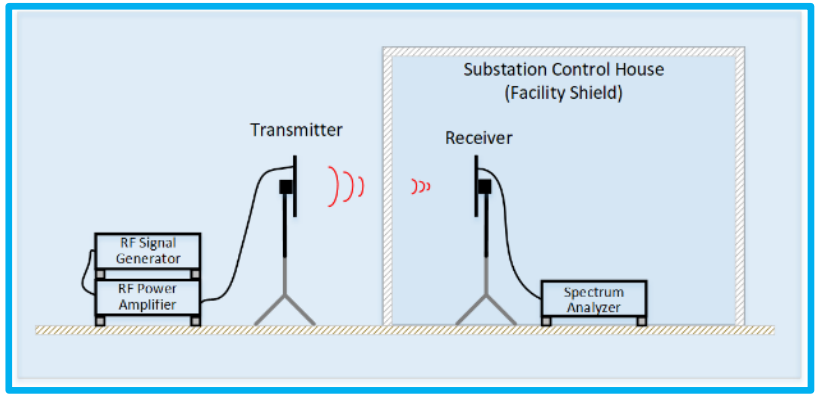
Direct Injection Testing (Conducted Threat)
EPRI - Knoxville





Shielding Effectiveness Testing

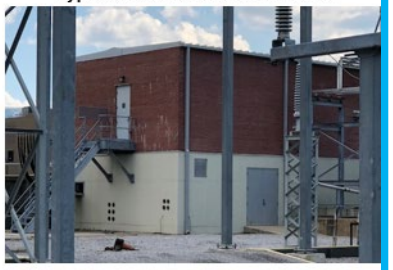
Shielding Effectiveness Test



Typical Control House Designs

Type 1: Concrete Block and Brick

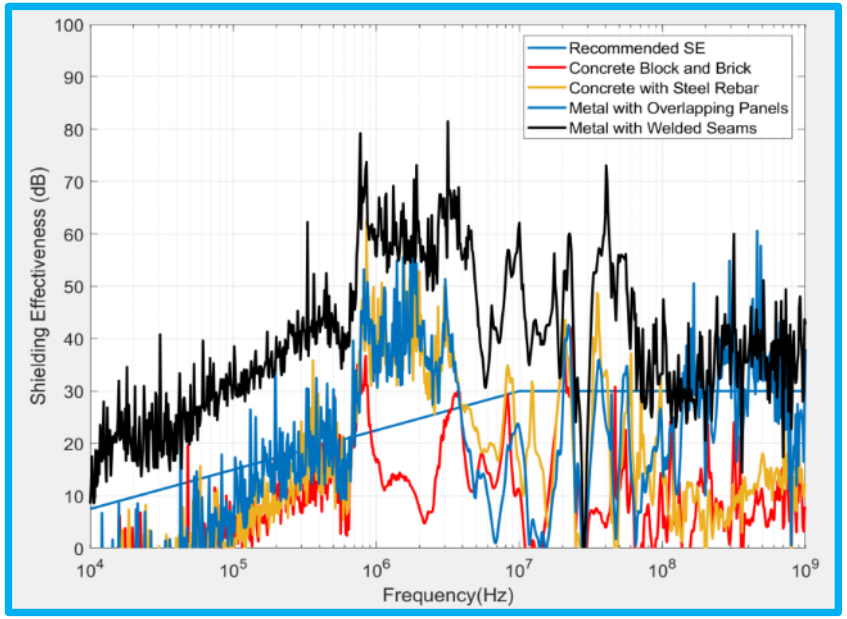
Type 2: Concrete With Steel Rebar



Type 3: Metal with Overlapping Panels

Type 4: Six-Sided Metal with Welded Seams

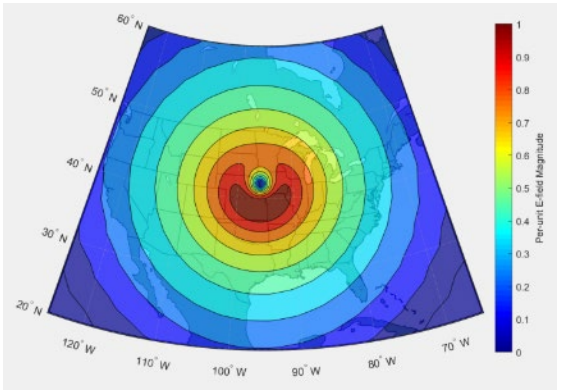
Example Measurement Data



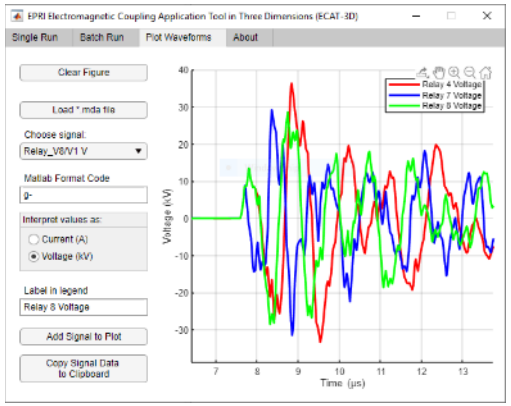
Test is done at very low power levels and can be performed while substation is in service

Advanced E1 HEMP Modeling/Assessment

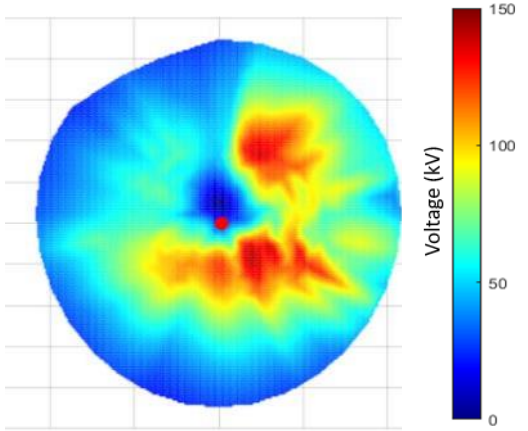
High-Fidelity E1 HEMP Environment

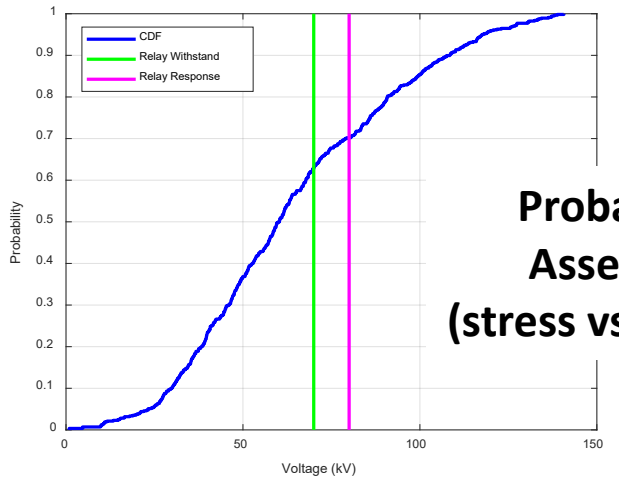


EPRI ECAT-3D (Entire Substation)



Spatial Impacts (Random Sub Location)

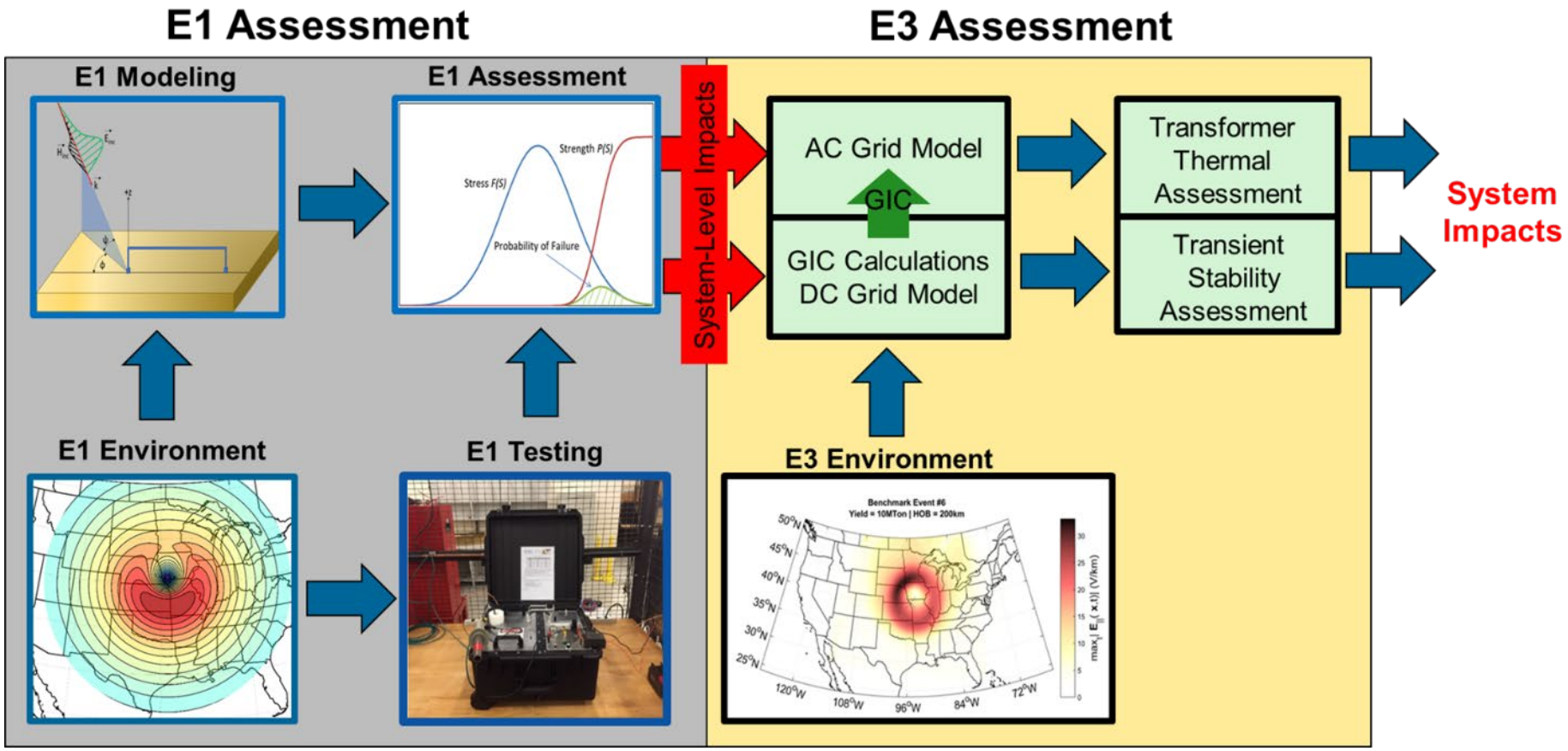




Probabilistic Assessment (stress vs. strength)

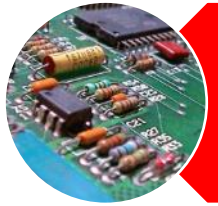
Estimating the probability of upset or failure due to conducted threat is important

E1 HEMP + E3 HEMP Assessment



Voltage collapse possible due to E3 HEMP; E1 HEMP impacts adds additional uncertainty and could hinder recovery efforts

Key Findings From Phase 1 (2016-2019) – E1 HEMP is Most Important

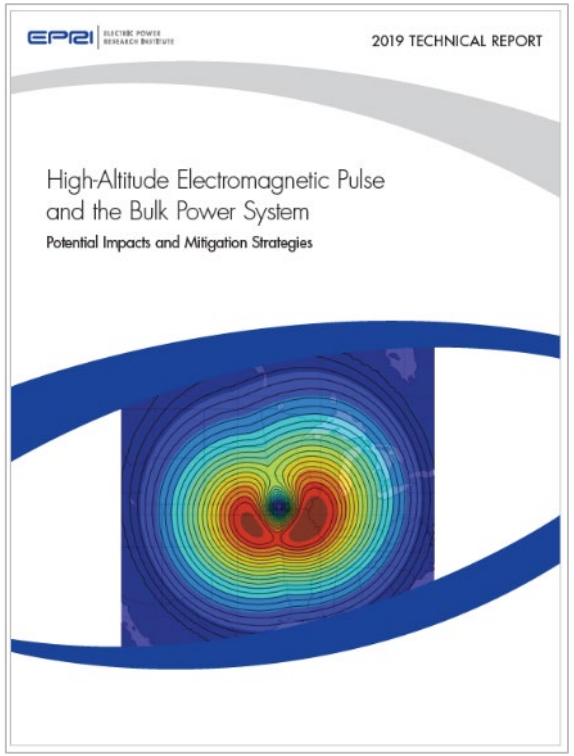


E1 – Damage to electronics possible (conducted threat > radiated threat)

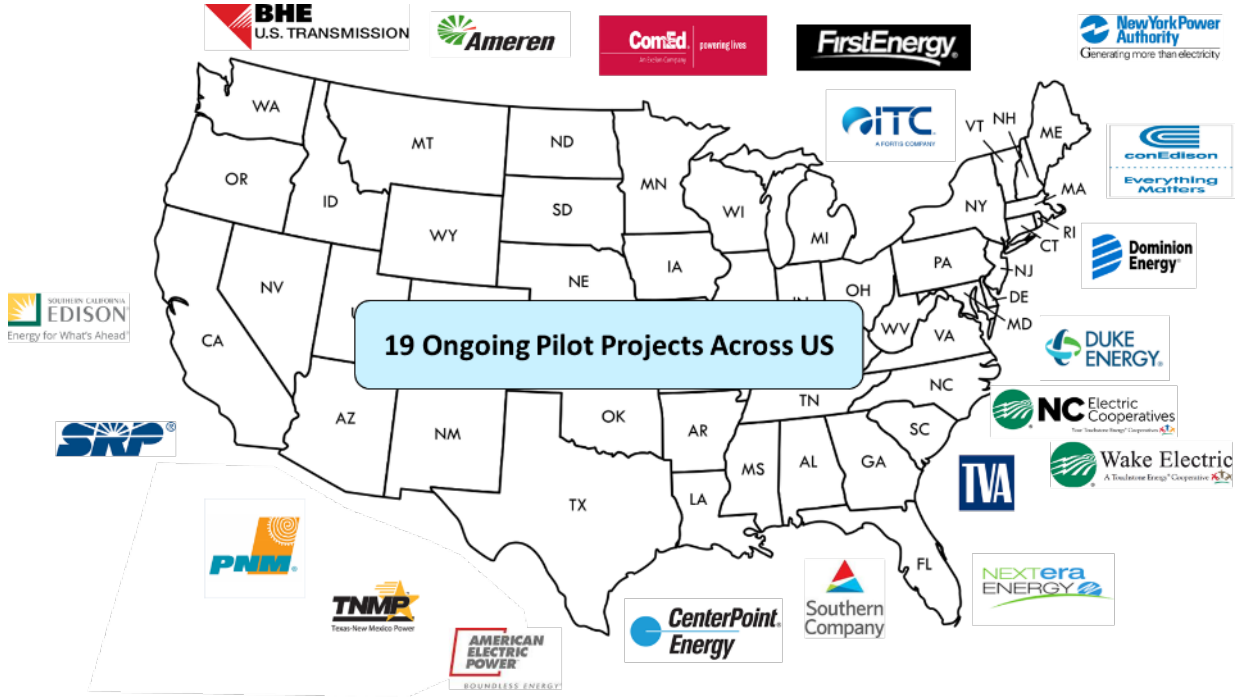
E2 – No impacts expected

E3 – Voltage collapse; limited transformer damage

E1+E3 – Voltage collapse with electronics damage; impacted recovery; uncertainty



E1 HEMP Hardening of T&D Substations – 19 Pilot Projects

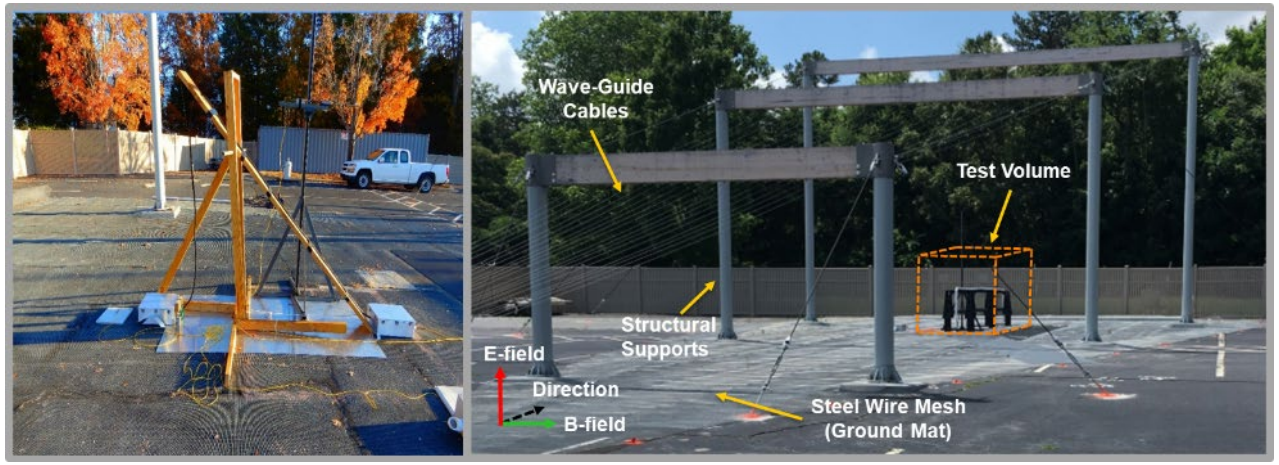


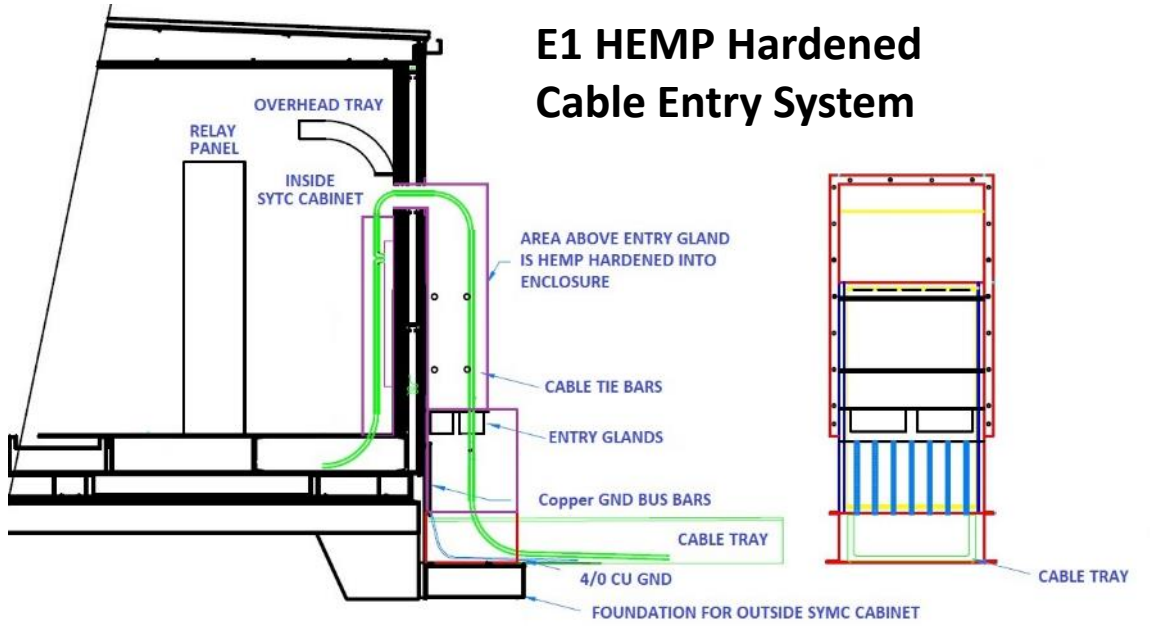
- Each substation design is assessed to determine mods required to harden against 50 kV/m (E1 HEMP)
- Detailed engineering support based on specific substation designs
- Pilot projects are in various stages based on host utility schedules

Developing Detailed Mitigation Designs

- Assessments informing EMP impacts to specific substation designs
- Testing performed to validate mitigation designs (modeling informs testing)
- Implementation of designs in the field

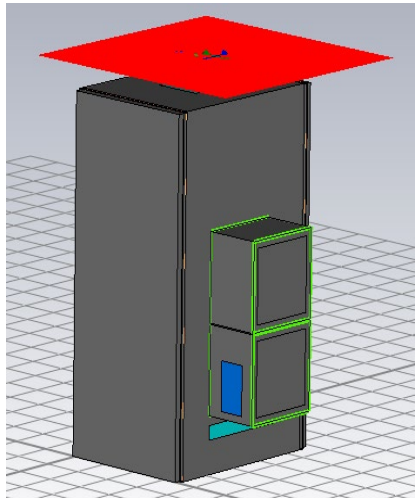
Shielded Cable Testing – EPRI EMP Lab in Charlotte, NC





Example of Completed Pilot Project: E1 HEMP Hardened P&C Module (SE & Fiberoptic based solution)

Laboratory Testing & Assessment

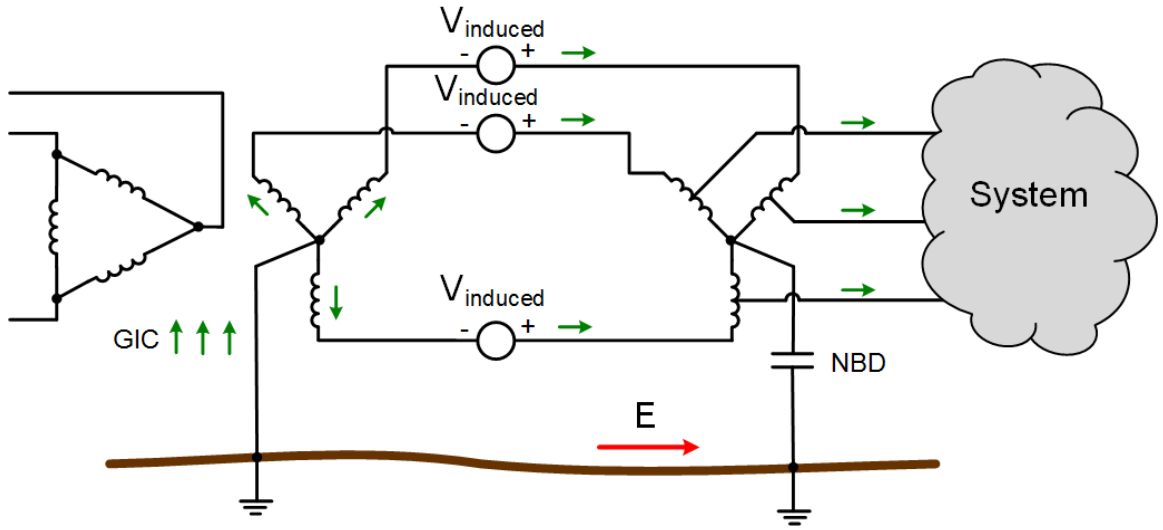


Field Installation

Left: EMP hardened module being tested at EPRI's EMP test facility in Charlotte, NC; Right: 3D E/M simulation of module

E3 HEMP/GMD Pilot Projects

- Geomagnetically induced currents (GIC) generated by E3 HEMP or GMD can be mitigated with capacitive blocking devices or neutral resistors



- Two neutral blocking device pilot projects funded by U.S. Department of Energy (DoE)

- Goal of pilot projects is to develop engineering guidance and obtain field experience with equipment

Assessment of T&D Infrastructure Serving DoD Installations

- EPRI is currently assessing the T&D system serving JBSA as a part of JBSA's and CPS Energy's efforts to harden against electromagnetic threats (HEMP & GMD)
- Performed assessment of a WAPA transmission facility serving a DoD installation
- Assessment efforts being funded by the US Department of Energy (DoE)

Western
Area Power
Administration

Expanding EMP R&D Into Other Critical Areas

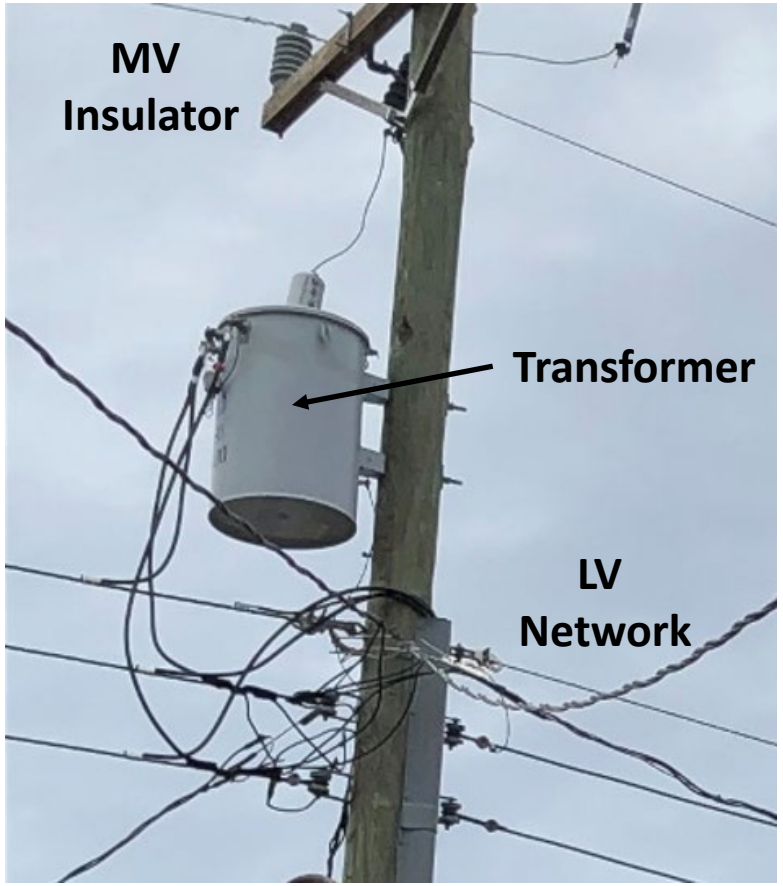
Distribution

Telecom Systems

Generation

E1 HEMP Impacts to Distribution Systems

- E1 HEMP may cause additional impacts to distribution systems as compared with transmission systems
  - Insulation strength of medium voltage insulators and pole top transformers is much less than high-voltage insulators and large power transformers; low-voltage networks even more susceptible
- E2 HEMP could affect MV and LV components
- More work is needed to quantify impacts and identify mitigation options



Key Takeaways From Ongoing R&D and Pilot Projects

- HEMP is a real threat to the electric power grid; impacts can have large geographic footprint; E1 HEMP most important
- Significant testing and evaluation indicates that MIL-STDs not appropriate for substations as they do not account for P&C circuity (voltage/current signals) or existing mfg. requirements
- No “one-size fits all” solutions; standardized approaches possible for future applications
- Limited engineering/technical guidance available for hardening power grid infrastructure; EPRI R&D closing this gap
- OEMs beginning to see opportunity in this space; relevant standards for HEMP mitigation equipment used in electric utility applications are needed
- More work needed to characterize HEMP threat to other areas (G, D, telecom) and identify/develop mitigation options

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Thank you for sticking with NOVA and SAME during these challenging times!

Please watch for emails, our Newsletter and check out our website for future events

https://www.same.org/NOVA