

# EPRI Electromagnetic Pulse Research

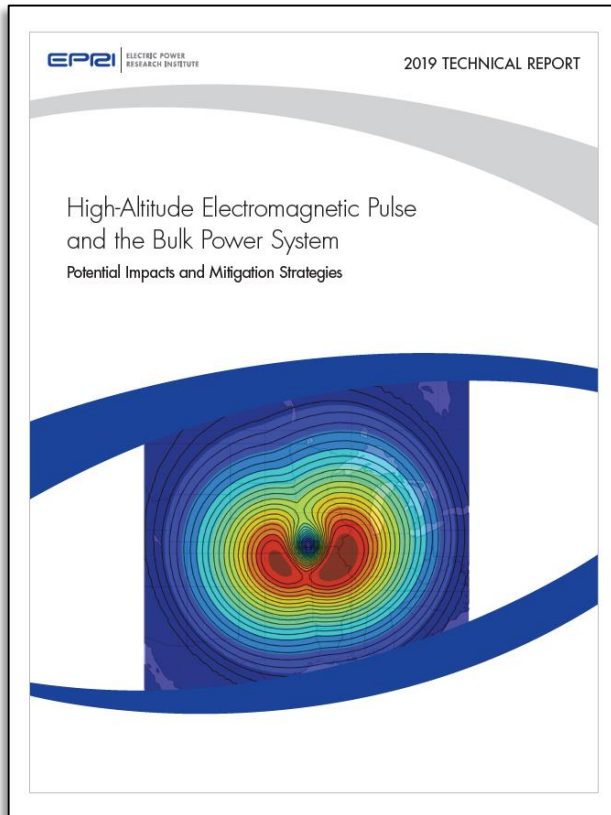
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Senior Program Manager

NERC EMP Task Force Meeting  
Washington, D.C.  
June 12, 2019



# EPRI Final Report

<https://www.epri.com/#/pages/sa/emp?lang=en-US>



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## Electromagnetic Pulse Research

EPRI is conducting research to examine the potential impact of an electromagnetic pulse (EMP) on the electric transmission system. The research is providing critical data to the electricity sector, its stakeholders and the public about potential EMP impacts, as well as methods and technologies to mitigate potential damage.

### High-Altitude Electromagnetic Pulse and the Bulk Power System: Potential Impacts and Mitigation Strategies

The main goal of this research effort was to provide the electric utility industry and other stakeholders with the technical basis for assessing the potential impacts of and EMP on the transmission system, and hardening the system against those impacts.

[READ MORE](#)

### EPRI Analysis Identifies Potential Impacts and Solutions to Mitigate an Electromagnetic Pulse Event on the Electric Grid

EPRI released final results of a three-year research project assessing the potential impacts of high-altitude electromagnetic pulse on the electric transmission system. This industry-wide research project addresses knowledge gaps regarding the potential impacts and ways to minimize potential damage.

[READ MORE](#)

### EMP Video

A high-altitude electromagnetic pulse can be created by the detonation of a nuclear weapon far above Earth's atmosphere. Some stakeholders assert that impacts of such an attack could be catastrophic to the power system infrastructure. However, a science-based approach is needed to assess the true impact of this threat. To address this gap, EPRI has developed a comprehensive research plan, and his video provides an overview of science of high-altitude electromagnetic pulses and EPRI's three-year research plan.

[WATCH](#)

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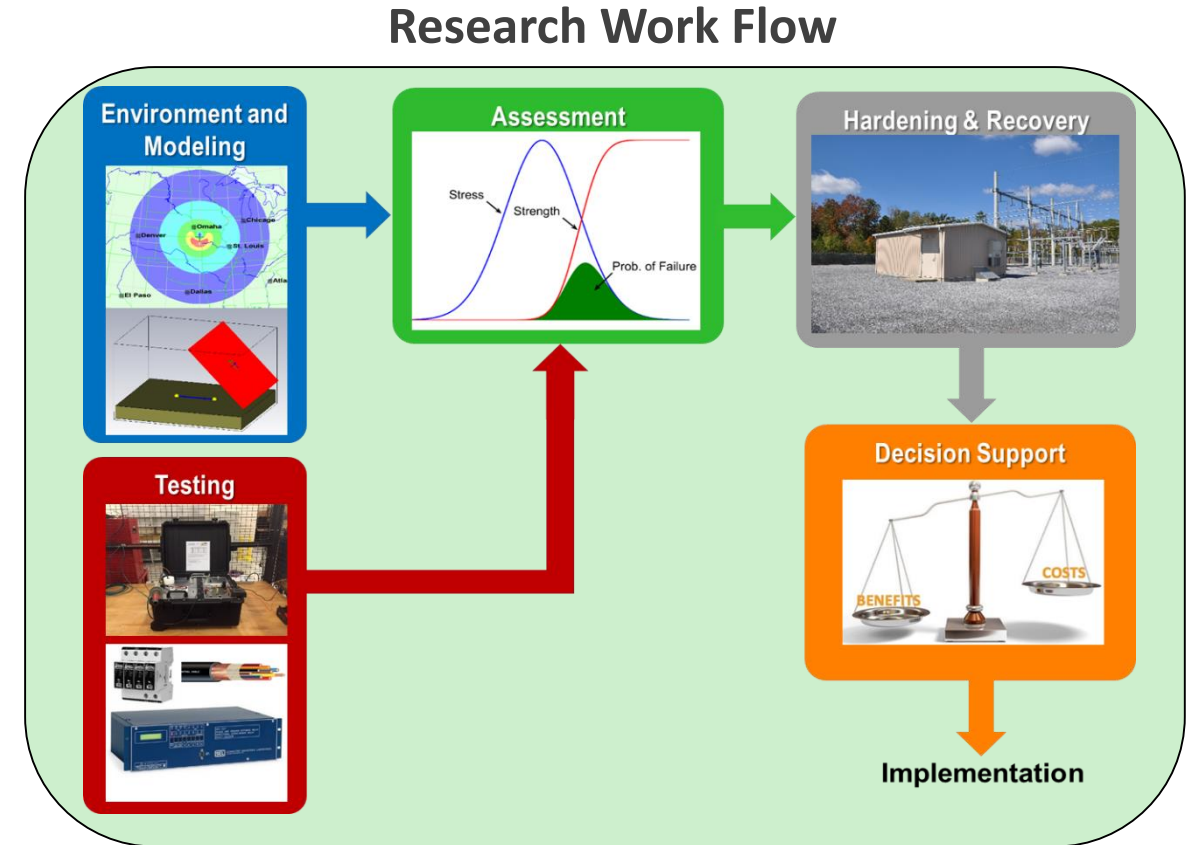
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# EPRI EMP Research Program

- Initial research project focused on switchyards, lines, and substations (Transmission)
- Assessed impacts of E1, E2, E3 and combined E1 + E3
- Answered two important questions:
  - What are the potential impacts of HEMP on the Transmission system?
  - If impacts are significant concern, can they be mitigated in cost-effective ways?



# Collaborative EMP Research

- 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**



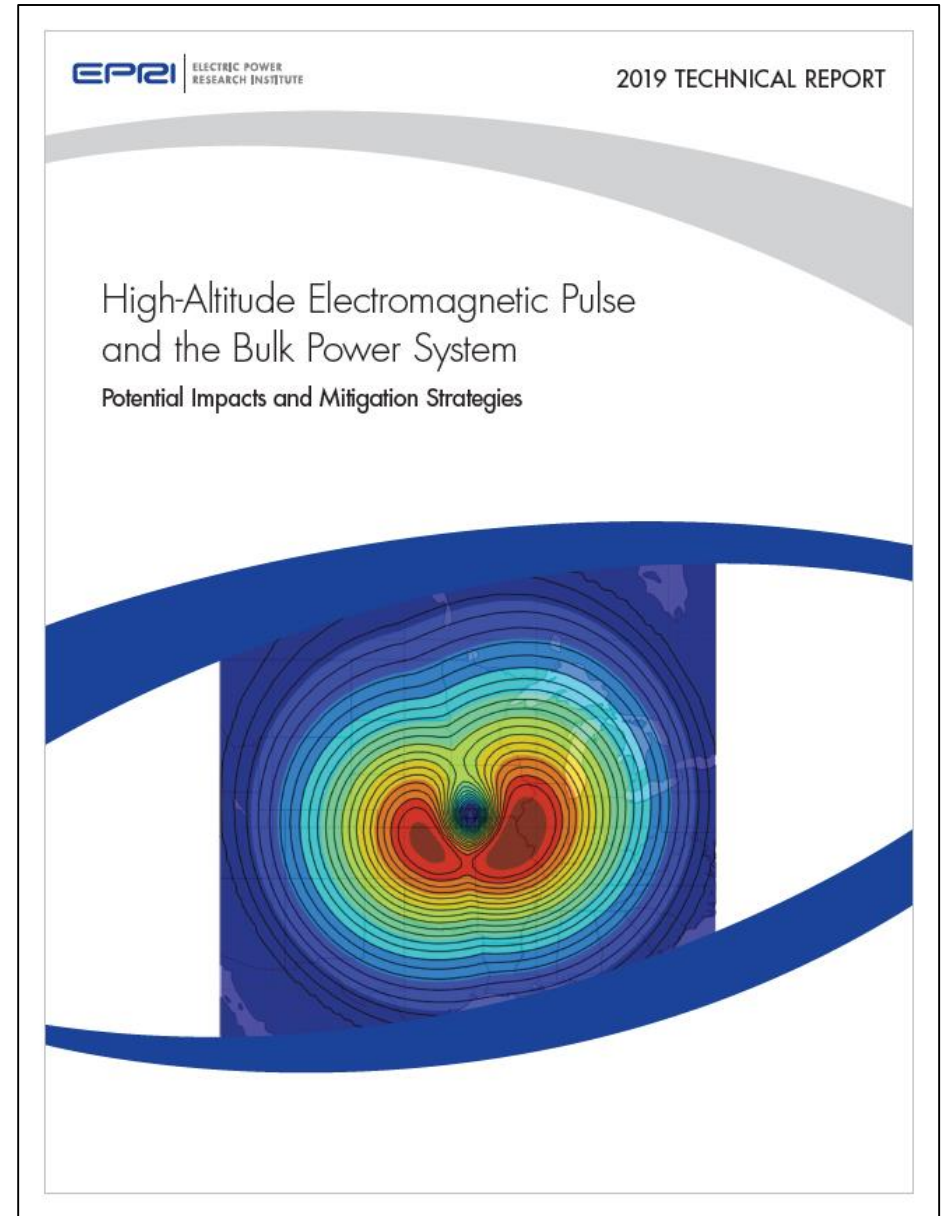
**Lawrence Livermore National Laboratory**

# Summary of Findings

- Extensive modeling, simulation and testing was utilized to assess potential impacts:
  - E1 EMP: Disruption or damage to substation electronics (e.g. digital protective relays) is possible and can be experienced over a large geographic area (electrical interconnection)
  - E2 EMP: Impacts to bulk power system are not expected
  - E3 EMP: Regional voltage collapse is possible; immediate, wide-spread damage to bulk power transformers not expected
- Options for mitigating E1 EMP impacts were tested, but deliberate approach to implementation is recommended to enhance designs, identify/manage potential unintended consequences and improve understanding of cost and long-term asset management
- Two follow-on research efforts are underway:
  - Field trials of E1 EMP hardening at 17+ electric utilities across the U.S.
  - E1 EMP assessment of generation facilities

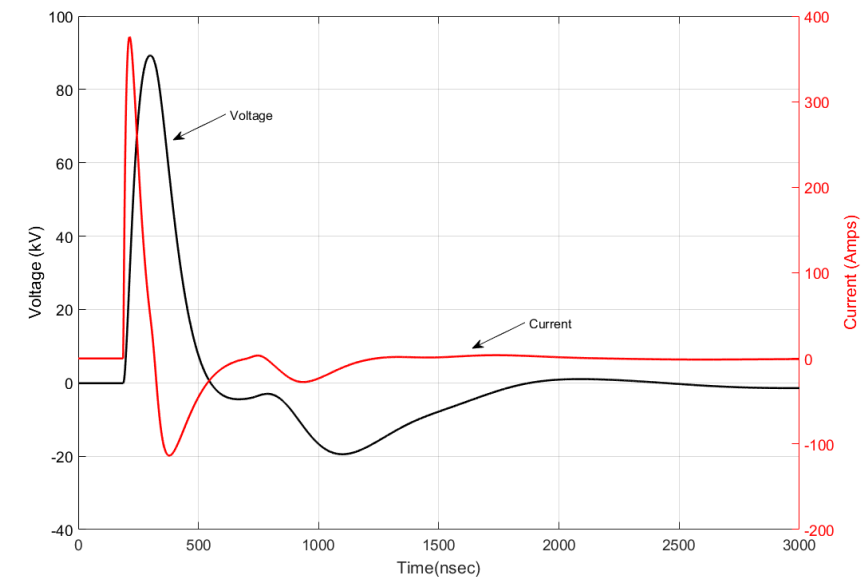
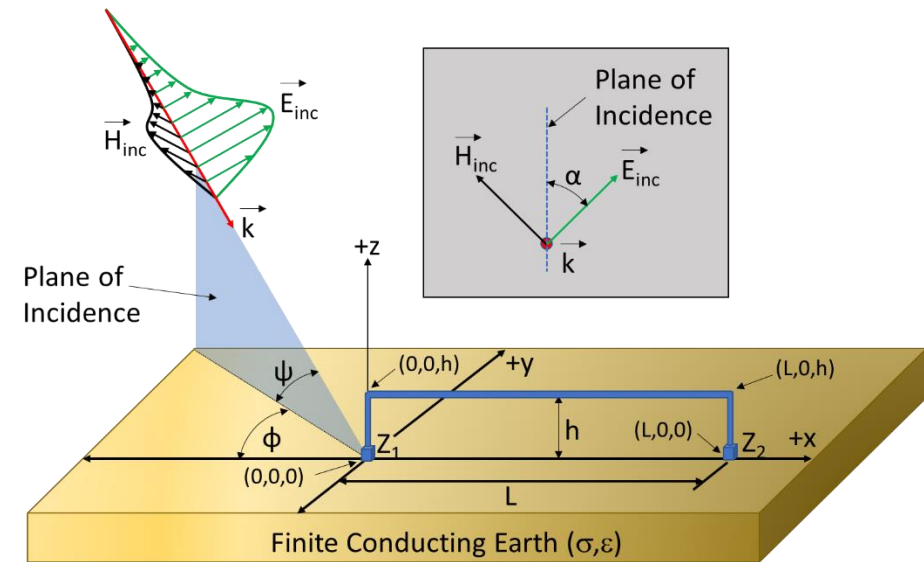
# Chapter 8 of Final Report - Research Needs

- Integrated Energy Network Assets
- Generation Facilities and End-Use Equipment
- Software Tools and Methods for Performing HEMP Assessments
- Equipment Testing
- HEMP Environments
- Field Trials of E1 EMP Hardening of Substations



# E1 EMP Modeling – Individual Substations

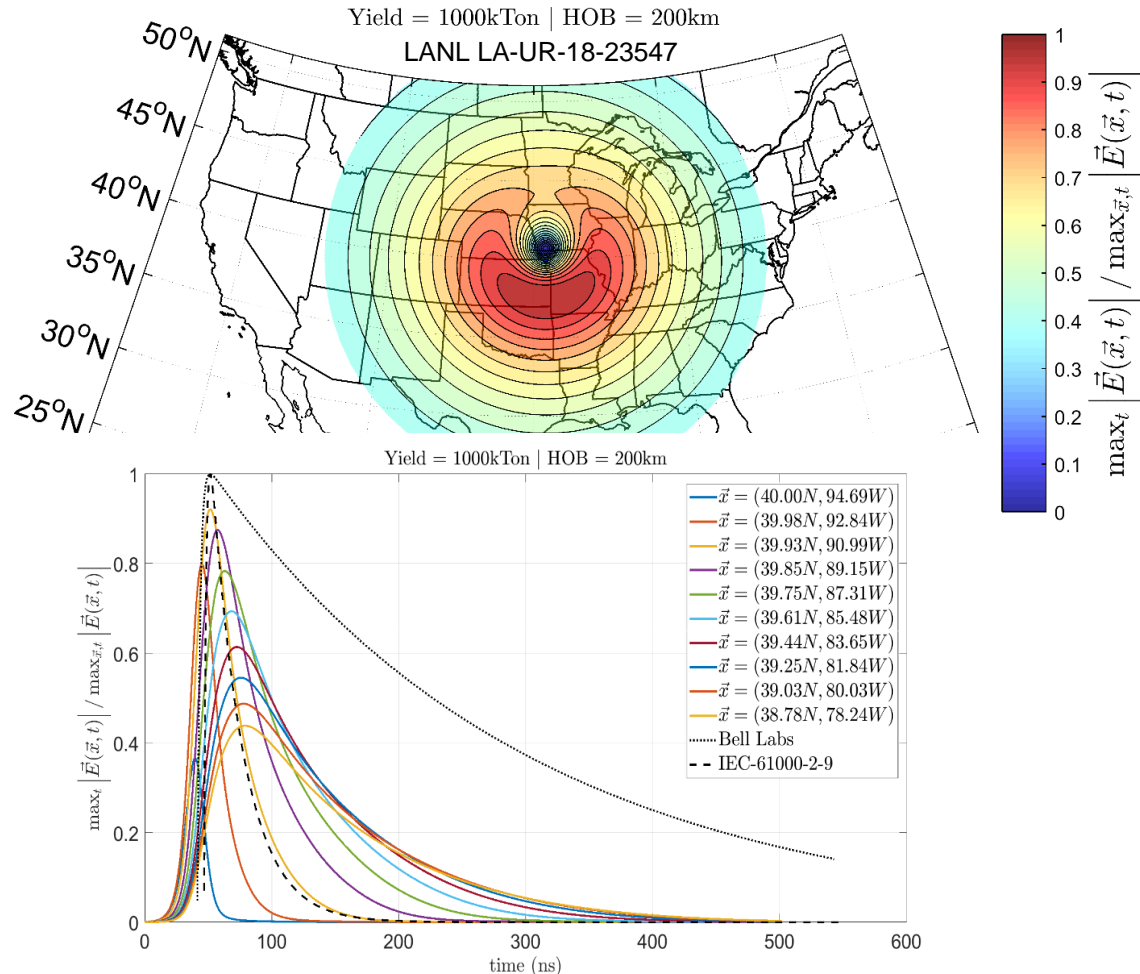
- E1 EMP is considered a plane wave so coupling is different than traditional power system transients
- Only aware of commercial tools that are 3D EM solvers
- EPRI developed and used MATLAB/EMTP based-tools and also CST Studio



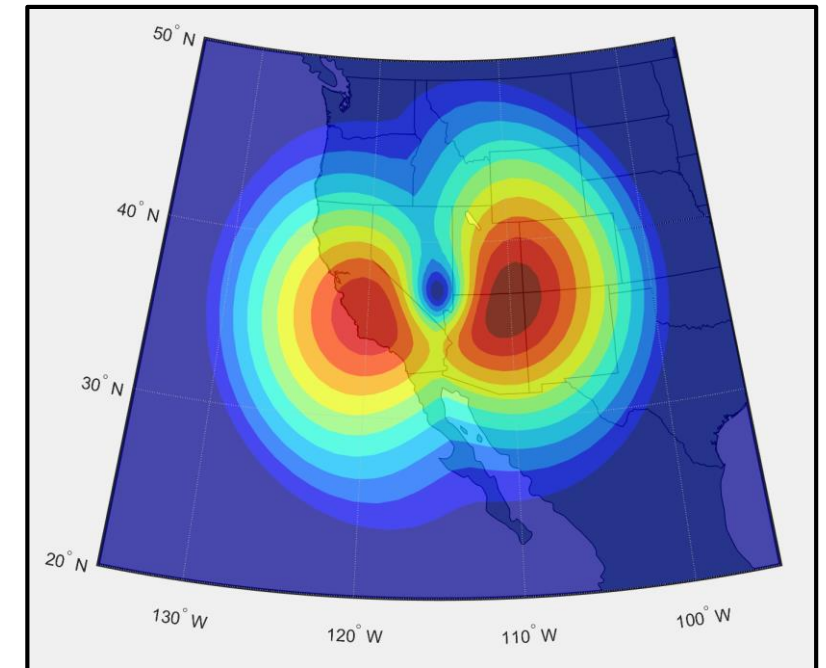
# E1 EMP Modeling – Interconnection Scale

- Requires high-fidelity E1 EMP environment (not publicly available) and ability to perform coupling calculations on 1000's of substations simultaneously

## High-Fidelity E1 EMP Environment



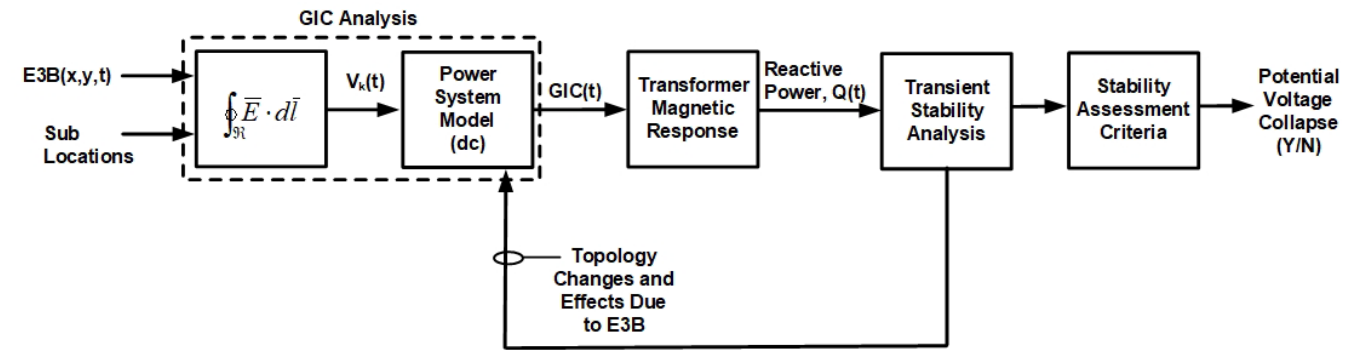
## Notional Coupling Results



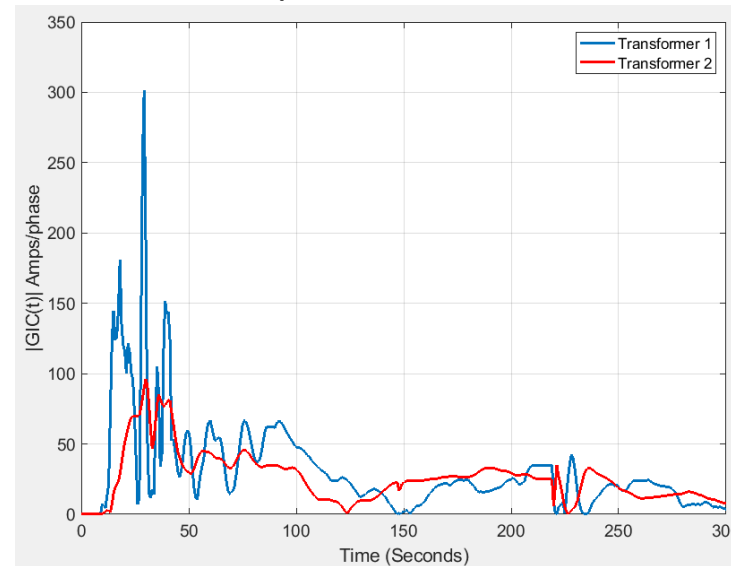


# Voltage Stability Analysis (E3 Only)

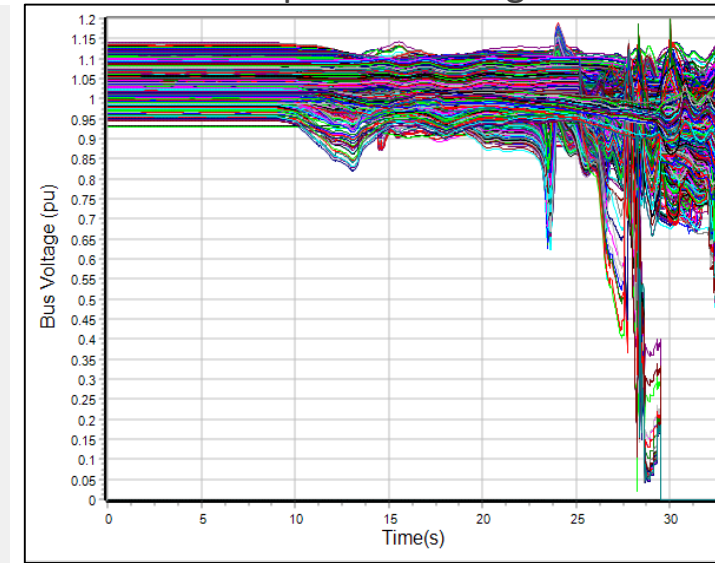
- Because of the nature and duration of the event, transient stability tools are necessary for determining voltage collapse
- Key modeling features include:
  - Dynamic load models
  - Overexcitation limiters
  - Protective relays
  - UV/OV and UF/OF tripping of generators
- GIC analysis requires the use of highly non-uniform E-field that varies spatially and temporally
  - Additional off-line tool in addition to transient stability tool required for higher fidelity environments



Example GIC Waveforms

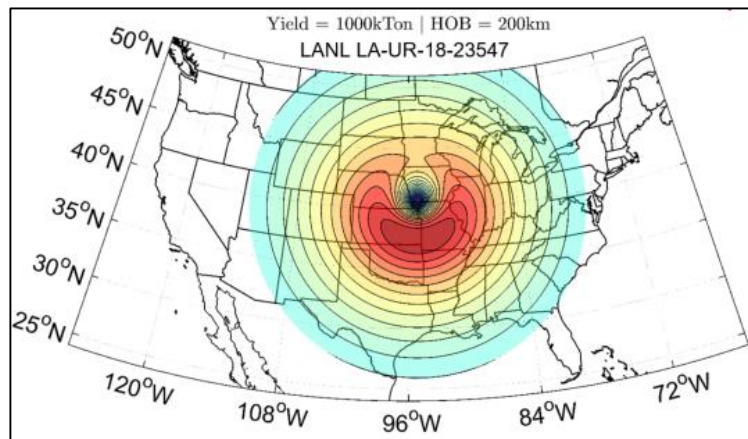
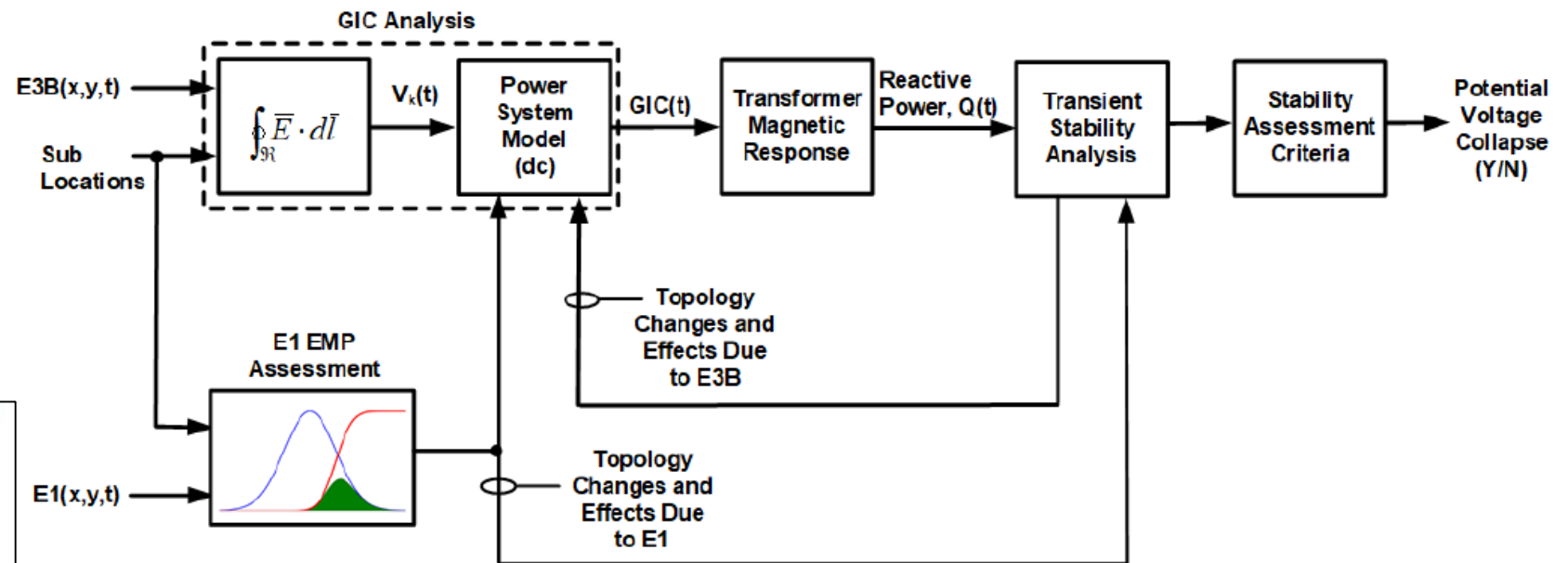
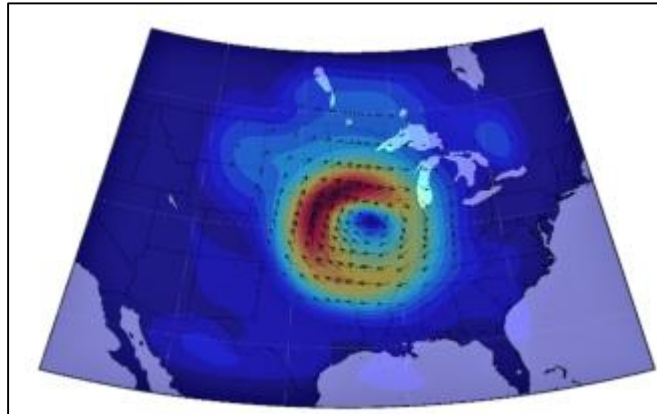


Example Bus Voltages



# Voltage Stability Assessment With E1 Impacts

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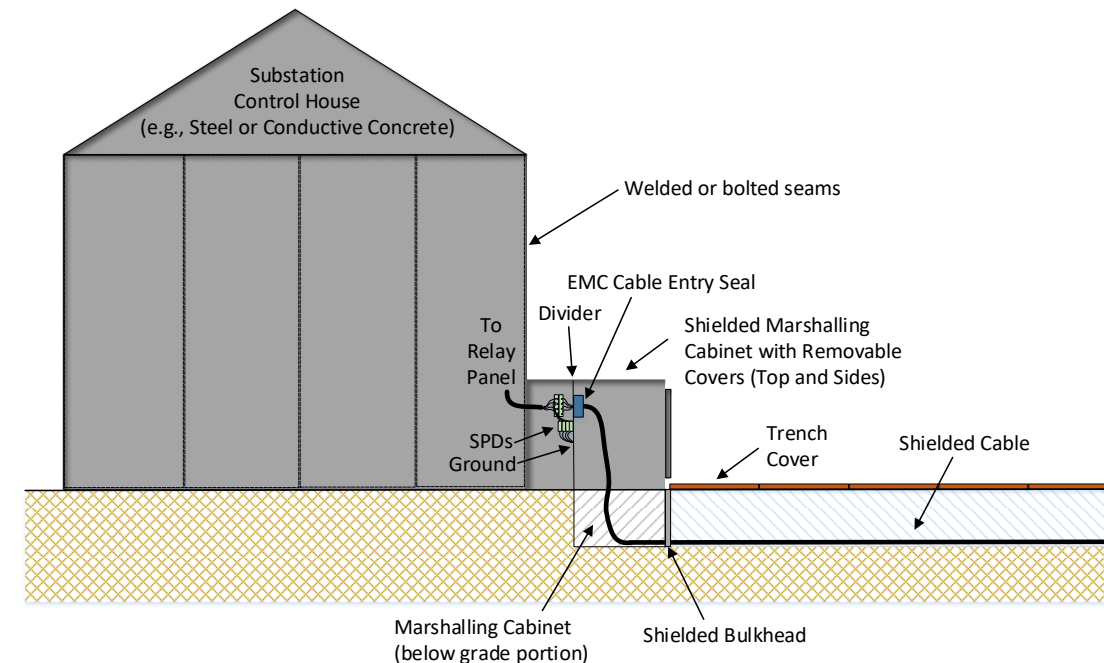
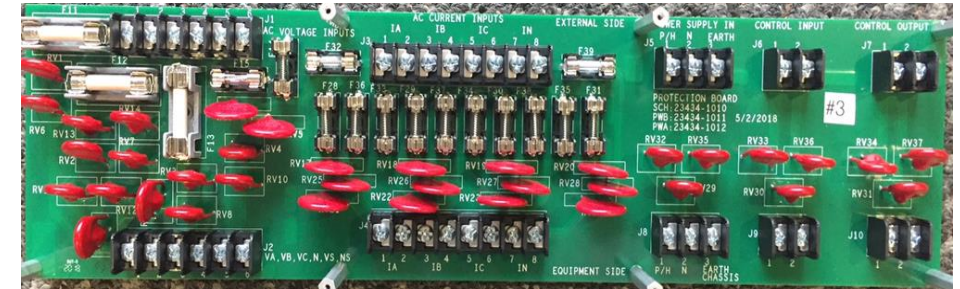
- Interconnection-scale E1 EMP impacts are used to initialize the transient stability tool prior to the E3 EMP event
- High-fidelity E1 EMP and E3 EMP environments are not publicly available
- Currently, no commercial tool(s) exist to perform this analysis

# Field Trials of E1 EMP Mitigation Are Needed

- Potential mitigation options include:
  - Low-voltage surge suppression devices and filters
  - Shielded or fiber optic cables
  - Substation control house design modifications
  - Grounding/bonding enhancements
- Identifying and managing unintended consequences is critical
- Improving designs and understanding cost and long-term asset management also very important

**Currently working with 17 U.S. utilities to evaluate E1 EMP mitigations in substations**

Example of a Prototype Low-voltage Surge Suppression Device



# Together...Shaping the Future of Electricity