TIP 25h: P37 Electromagnetic Pulse (EMP) Grid Resiliency

Context

EMP refers to a very intense pulse of electromagnetic energy, potentially caused by the detonation of a nuclear or other high-energy explosive device. High-altitude EMP (HEMP) is a nuclear warhead detonated hundreds of kilometers above the earth's surface to produce more widespread effects (areas impacted can be hundreds of kilometers in diameter). HEMP requires a high-altitude delivery device (e.g., a missile) which requires a high level of sophistication and logistics.

Concern has been raised that an EMP, especially HEMP, could damage a significant portion of the electric grid, resulting in months of no electric service. This potential lack of service could result in significant impact on safety, health, and the economic wellbeing of a substantial portion of the population.

Description

Numerous constituencies are pressing to ensure the electric power system is more resilient to a potential large EMP event. However, options to increase resilience through hardening and recovery are not well-defined. Some proposed approaches are high-cost and lack the technical basis to substantiate their viability. This project provides a sound technical basis by which utilities can assess their system and select the most effective approaches needed to increase the resilience of their transmission system to a HEMP event.

This project characterizes the EMP threats, assess component vulnerability, assess methodologies for determining system impact, and assess and/or develop mitigation strategies including hardening and recovery.

The specific tasks in this supplemental project are listed below:

• Threat Characterization – Identify conservative, unclassified HEMP environment(s) to assess the potential impacts on bulk-power system components, and investigate the physics of HEMP propagation and coupling to power system infrastructure.

• EMP Vulnerability – Identify the vulnerability of transmission system and support assets such as, but not limited to: P&C, communications, SCADA, cables, transformers, insulators, etc., exposed to the HEMP threat defined in Threat Characterization

• Impacts – Develop criteria and techniques for performing vulnerability assessments of bulk-power systems exposed to HEMP; Assess impact of sub-system failure on power delivery component performance; Assess impact of loss of generation, distribution, communications, load, water and gas on bulk-power system performance; Assess impact of loss of systems that support power delivery such as GPS, cell phones, transportation, etc.

• Mitigation, Hardening & Recovery – Identify and assess mitigation and hardening approaches that can be employed to reduce effects of HEMP; Identify potential unintended consequences of mitigation and hardening approaches; Develop approaches for mitigating/hardening substation equipment against effects of HEMP; Develop enhanced recovery procedures/plans/capabilities.

• Decision Support – Develop a framework for assessing relative benefits of mitigation approaches; Develop decision support tool(s)

• Trial Implementation – Share effectiveness of HEMP mitigation methods/implementations.

• Benefits and Stakeholder Communication – Report findings via annual conference and webcasts, executive-level communications and technical reports.

Benefits

This project provides the following benefits:

• Increased understanding of EMP propagation inside a substation or control center

• Increased understanding of effectiveness of mitigation technologies, both hardening and recovery

• Provides a technical basis and a decision support framework for the selection and application of technologies to enhance resilience of transmission assets and improve recovery

• Enables prioritization of application of technologies to increase grid resiliency and accelerate recovery

• Helps to protect public and employee health and safety caused by potential power outages from an HEMP event .

Accomplishments

The project determined the EMP event vulnerability of both high-voltage and electronic equipment installed in substations. The effectiveness of mitigation and recovery methods were also assessed. Previously, these issues had not been sufficiently investigated and little quantitative information was available in the public domain.

Deliverables

Through accurate modeling and testing, the deliverables from this project can be summarized as follows:

• Technical assessment of potential transmission system vulnerabilities and mitigation options

• Development and demonstration of transmission resiliency decision support framework

• Annual conference and workshop

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Project Start Date: January, 2018

Project End Date: July, 2019

Reports

High-Altitude Electromagnetic Pulse and the Bulk Power System: Potential Impacts and Mitigation Strategies. EPRI, Palo Alto, CA: 2019. 3002014979

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Participating Organizations

Electric Power Research Institute (EPRI)

Conclusions

This EPRI project was a three-year research effort to determine the potential impacts of a high-altitude electromagnetic pulse (HEMP) on the electric transmission system and to identify potential options for mitigating these impacts. A brief summary of findings from the final report is provided below.

7.1 E1 EMP
Because digital protective relays (DPRs) are arguably the most critical electronics-based asset in a substation, testing primarily focused on these devices. Over 60 DPRs were tested as a part of this research. Testing included:

- Free field illumination testing based on MIL-STD-461G/RS105 to determine the magnitude of the incident E-field that could cause damage or disruption of a device under test (DUT)
- Direct injection testing using a voltage impulse with waveform defined in MIL-STD-188- 125-1 [23] to determine:
  1. the voltage surge magnitude that could cause damage or disruption of a device under test (DUT), and
  2. the performance of potential surge protection devices
- Shielding effectiveness testing of substation control houses based on the MIL-STD-188-125-1 [23] approach to assess the ability of these structures to shield internal components from incident electromagnetic waves.

Testing of DPRs showed that these devices are susceptible to conducted transients, but were found to be mostly resilient to free field illumination of E1 EMP. Limited testing of other devices such as SCADA and communications systems indicated that they could be susceptible to both radiated and conducted threats.
An interconnection-scale E1 EMP assessment was performed to provide a first-order approximation of the potential impacts of E1 EMP on DPRs located within an electrical interconnection. Potential disruption or damage to DPRs assuming exposure to the nominal E1 EMP environment provided by Los Alamos National Laboratory (LANL; up to 25 kV/m at the most severe location on the ground) and baseline soil conditions was found to be moderate, whereas damage from the same environment but scaled so that the maximum peak field at the most severe location on the ground was 50 kV/m was found to be

more of a concern. Based on the assumptions made in the assessments, it was estimated that approximately 5% of the transmission line terminals in a given interconnection could potentially have a DPR that is damaged or disrupted by the nominal E1 EMP environment, whereas approximately 15% could potentially be affected by the scaled E1 EMP environment.

The full report is available at www.epri.com

Next Steps:

BPA facilities has already committed to harden the new Vancouver Control Center for EMP:
Measures will be considered to provide enhanced protection from possible Electro Magnetic Pulse (EMP) and nuclear type events. Possible technologies to be evaluated include:

- Heavy walls
- Locating data center, control center, and critical equipment below grade with sufficient ground cover
- Earth berms
- Providing refractory concrete panels with stainless steel fiber for blast and projectile protection
- Roof covered in refractory material
- Hardening the communications tower
- Copper mesh acting as a faraday cage
- Methods to seal off outside air supply to the facility.
- RF and EMF shields.

Exploring these options will ensure that potential risks are minimized within project expectations and guidelines.