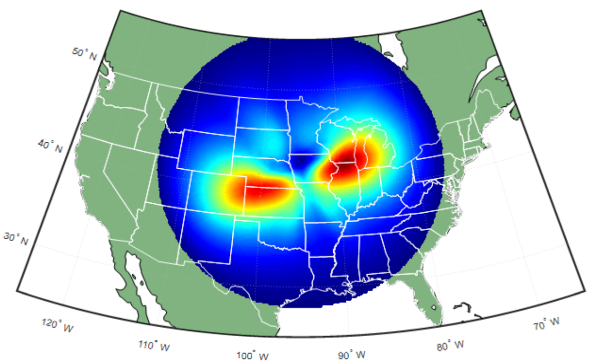
ELECTRIC POWER RESEARCH INSTITUTE

Assessment and Mitigation of High-Altitude Electromagnetic Pulse Impacts on Distribution Systems



Project Highlights:

- Technical guidance and tools for assessing the potential impacts of HEMP on distribution systems
- Options for mitigating the potential impacts of HEMP on distribution systems
- Improved understanding of the costs and potential unintended consequences associated with employing HEMP hardening of distribution systems

Background, Objectives, and New Learnings

The detonation of a nuclear weapon at high altitude or in space (~30 km or more above the earth's surface) can generate an intense electromagnetic pulse (EMP) referred to as a high-altitude EMP or HEMP. The resulting HEMP is characterized by three hazard fields, denoted as E1 HEMP, E2 HEMP, and E3 HEMP that are capable of causing damage and disruption to ground-based technological systems such as the electric power grid and telecommunication systems.

The early time hazard field component (E1 HEMP) is an intense, short-duration electromagnetic pulse characterized by a rise time on the order of a few nanoseconds and amplitude up to 50 kV/m. E1 HEMP is an electromagnetic plane wave that propagates through the air and couples to overhead conductors and cables. This coupling process generates voltage and current surges which can disrupt or damage sensitive electronic equipment such as digital protective relays, smart meters, supervisory control and data acquisition (SCADA) systems and can cause flashover of medium-voltage insulation. Because of the high-frequency nature of E1 HEMP, it can also propagate through enclosures such as control cabinets and damage or disrupt electronics. Prior EPRI research[1] has shown that E1 HEMP has the potential to disrupt or damage substation-based electronics over large geographic areas. Preliminary research into distribution systems has also shown the potential for E1 HEMP to cause wide-scale damage and/or disruption of electronics and medium-voltage insulation systems that are used in distribution systems.

The intermediate time component (E2 HEMP) is considered an extension of E1 HEMP and has an amplitude on the order of 100 V/m and duration of one μsec to approximately ten msec. E2 HEMP couples to overhead lines and unshielded cables in a manner that is similar to a lightning strike. Due to the basic impulse level (BIL) ratings of transmission components, prior EPRI research[1] has shown that E2 HEMP would have negligible impacts. However, the potential impacts to lower BIL systems, such as distribution systems, is an open research question.

The late-time component (E3 HEMP) is a very-low frequency (below 1 Hz) pulse, similar to a geomagnetic disturbance (GMD) event, but with considerably higher amplitude and shorter duration. The amplitude of the E3 HEMP pulse is on the order of tens of V/km with duration of one second to hundreds of seconds. The resulting E3 HEMP induces low-frequency, geomagnetically-induced currents (GIC) in transmission lines and transformers. The flow of GIC in transformers causes part-cycle saturation which results in increased reactive power consumption and the generation of harmonic currents.

The combined effects of the three HEMP components is a primary concern. Prior EPRI research on the bulk power system indicated that regional voltage collapse with impeded system recovery is possible when effects are considered in aggregate. To date, the potential impacts of HEMP on the modern distribution system and system resiliency have not been explored.

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

The primary objective of this project is to assess the potential impacts of HEMP on distribution systems and to identify mitigation options that can be utilized to improve system resiliency against such impacts. Initial focus will be on E1and E2 HEMP effects. Ongoing work in the transmission area to assess and harden against the effects of HEMP will be highly leveraged in this work.

Benefits

This project can potentially provide the following benefits:

- Technical guidance and tools for assessing the potential impacts of HEMP on the distribution system and developing engineering solutions for mitigating the impacts.
- Improved understanding of the costs and potential unintended consequences associated with HEMP hardening of distribution systems.

Project Approach and Summary

This project will leverage prior and ongoing R&D in the transmission area to determine the potential impacts of HEMP on distribution systems and assess options for mitigating the potential impacts. Specific tasks include:

- Modeling of representative distribution systems to assess E1 HEMP impacts on medium voltage equipment such as insulators, transformers, reclosers, and electronics that are utilized for protection, control, and automation.
- Laboratory testing of medium voltage equipment to improve understanding of their ability to withstand the E1 HEMP and E2 HEMP threat.
- Modeling of a representative transmission and distribution system to assess the potential impacts of E3 HEMP on distribution systems. Effects from both GIC and the harmonics that are generated by part-cycle saturated transformers will be considered.
- Identify and assess options for mitigating the identified impacts through laboratory testing and/or modeling, as appropriate.

Deliverables

- Technical guidebook for assessing the potential impacts of HEMP on distribution systems as well as step-by-step guidance on developing engineering solutions to mitigate the potential impacts.
- Software tool to aid engineers in modeling and assessing the potential impacts of E1 HEMP and E2 HEMP on distribution systems.
- Annual Workshop and periodic update WebEx meetings.

The non-proprietary results of this work will be incorporated into EPRI's Distribution Systems R&D program, and made available to the public, for purchase or otherwise.

Price of Project

Pricing is tiered based on the participant's annual distribution throughput (GWhr). The cost is $70k for utilities with >20,000 GWhr/year distribution throughput and $30k for all others. The project qualifies for tailored collaboration (TC) or self-directed funding (SDF). Funding can be split over three calendar years.

Project Status and Schedule

The project is expected to start in Q3 2021 and last for 24 months.

Who Should Join

Asset owners responsible for the resiliency, reliability, and security of distribution systems.

Contact Information

For more information, contact the EPRI Customer Assistance Center at 800.313.3774 (askepri@epri.com).

Technical Contact

Randy Horton, Ph.D., P.E. at 205.515.7303 (rhorton@epri.com)

Member Support Contacts

Brian Dupin at 650.906.2936 (bdupin@epri.com)
Barry Batson at 704.905.2787 (bbatson@epri.com)
Chuck Wentzel at 618.320.0011 (cwentzel@epri.com)
Tim Anderson at 704.595.2054 (tanderson@epri.com)

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com