EPRI EMP Report & Grid Security: *Key Messages*

Background

On April 30, the Electric Power Research Institute (EPRI) will release the results of its latest electromagnetic pulse (EMP) report titled, *High-Altitude Electromagnetic Pulse and the Bulk Power System*. The study focuses on the potential combined effects of the E1, E2, and E3 EMP generated by a single, high-altitude nuclear burst. The study also identified and tested potential mitigation options for E1 EMP impacts.

This is EPRI's third and final report focused on the potential impact of a high-altitude electromagnetic pulse (HEMP) on the bulk power (or electric transmission) system. Key collaborators included the U.S. Department of Energy, Lawrence Livermore National Laboratory, Sandia National Laboratories, Los Alamos National Laboratory, the Defense Threat Reduction Agency, and the Electricity Subsector Coordinating Council.

A nuclear explosion above Earth's atmosphere would propel electromagnetic energy toward the surface, generating an initial, short-duration pulse with rise-time of 2.5 billionths of a second (E1); an intermediate pulse with characteristics similar to those caused by nearby lightning strikes (E2); and a late pulse that could last minutes and is similar to a severe geomagnetic disturbance caused by solar flares (E3). Each type of pulse causes a different physical impact to electronic equipment.

EPRI's first EMP report was released in February 2017, and it focused on E3 and the potential for thermal damage to large power transformers resulting from a single HEMP event. The findings suggested that only "a small number of geographically dispersed transformers were found to be at potential risk of thermal damage."

The second report was released in December 2017, and it studied whether a voltage collapse from E3 is possible. The findings suggested that voltage collapse from E3 is possible, but "that service interruption due to late-time pulse or E3 alone would be limited to a regional level and would not trigger a nationwide grid failure." The study also concluded that potential impacts can be mitigated.

This new report on the potential combined effects of E1, E2, and E3 on overhead transmission lines, substations, and switchyards shows that initial E1 and late E3 pulses could trigger a regional service interruption but would not trigger a nationwide energy grid failure. EPRI concluded that "recovery times are expected to be similar to those resulting from large-scale power interruptions caused by other extreme events provided that mitigations specific to the

initial pulse are deployed." Importantly, EPRI also concluded that "possible damage to large power transformers was found to be minimal," with only 3 to 21 large power transformers being at risk.

Specifically, EPRI found that for the initial E1 pulse, "transmission electronic equipment damage or disruption can result from induced voltage surges in connecting cables, as well as by direct exposure to the initial pulse." EPRI also found that "digital protective relays – devices that help detect faults in the electric system – were generally resilient to direct exposure to the initial pulse but were found to be vulnerable to the surges induced on control and communication cables." Supervisory control and data acquisition (SCADA) systems also are at risk of disruption or damage, which "would be expected to degrade recovery efforts and longer-term viability of controlling system frequency."

As part of the study, EPRI also tested mitigation strategies for initial pulse (E1) impacts and found that impacts could be mitigated through various options including:

- Shielded cables with proper grounding;
- Low-voltage surge protector devices and/or filters;
- Use of fiber optics-based communications;
- Enhanced electromagnetic shielding of electric substation control houses; and
- Grounding and bonding enhancements.

EPRI also evaluated strategies for blocking or reducing the flow of geomagnetically induced currents (GIC) that are the root-cause of E3-related impacts, such as voltage collapse and transformer heating.

For next steps, EPRI is working with multiple electric companies to pilot and to field study mitigation options for the initial pulse (E1) at 12-14 substations. This is necessary to identify any potential unintended consequences of any solutions on other components on the energy grid. Electric companies want to ensure that new mitigation strategies do not undermine or conflict with mitigation and protective measures that already are in place.

EPRI also will be launching a new project to evaluate E1 EMP impacts to generation facilities.

EMP Key Messages

In response to the low-likelihood, high-consequence threat of a high-altitude electromagnetic pulse (HEMP) to the energy grid, the electric power industry is working with the Electric Power Research Institute (EPRI) and with our government partners to better understand the impacts of a HEMP. This research helps us to make scientifically informed investment decisions for mitigation measures and to identify ways to leverage existing response and recovery programs and capabilities.

- EPRI launched its research project in 2016 to provide a scientific basis for investments to mitigate EMP threats, inform response and recovery efforts, and develop other partnerships that will help the nation's critical infrastructure providers be better prepared for existential threats to the energy grid. Key collaborators included the Department of Energy (DOE), Lawrence Livermore National Laboratory, Sandia National Laboratories, Los Alamos National Laboratory, the Defense Threat Reduction Agency, and the Electricity Subsector Coordinating Council.

- A nuclear explosion above Earth's atmosphere would propel electromagnetic energy toward the surface, generating an initial, short-duration pulse with rise-time of 2.5 billionths of a second (E1); an intermediate pulse with characteristics similar to those caused by nearby lightning strikes (E2); and a late pulse that could last minutes and is similar to a severe geomagnetic disturbance caused by solar flares (E3). Each type of pulse causes a different physical impact to equipment.

- EPRI released two reports in a series of reports on EMP's impacts on energy infrastructure in 2017 and made these reports available to the public for free. The first report evaluated the potential for a late-pulse EMP (E3) that lasts minutes to cause widespread damage to large power transformers. The second report evaluated whether an E3 pulse could cause regional or nationwide energy grid failure.

- EPRI's latest research studied the potential combined effects of E1, E2, and E3 pulses, and the research shows that initial E1 and late E3 pulses could trigger a regional service interruption but would not trigger a nationwide energy grid failure.

- EPRI's latest report also tested strategies to mitigate the impacts of E1 and identified effective strategies that now will be piloted by multiple electric companies.

- The electric power industry remains focused on mitigation strategies for all EMP threats. EPRI's findings, and the pilot projects that are underway, are helping electric companies to evaluate their systems and to identify and prioritize the most critical components that need protection. It is impossible to protect everything from everything, all of the time.

EMPS and GMDs Are Different

There are important differences between man-made EMPs, such as those from directed energy weapons or nuclear detonations, and naturally occurring GMDs, such as solar flares. Each type of threat must be addressed independently, and appropriate mitigation and protection strategies must be implemented for each.

- Though a GMD wave is similar to a late-pulse EMP (E3), the intensity of a late-pulse EMP can be orders of magnitude more severe and much shorter in duration than GMD events, which can last for several days.

- There are two categories of intentional, man-made EMPs. The first, a high-altitude EMP (or HEMP) caused by the detonation of a nuclear weapon at high altitude or in space, is a high-consequence, low-likelihood threat that could have a potentially catastrophic impact on the nation. EPRI's study focuses on this type of weapon, and, depending on weapon yield and height of burst, how the resulting EMP could impact a large geographical area.

- The second type of EMP, sometimes called a briefcase EMP, is related to the use of a smaller directed energy weapon that would target a single facility or piece of equipment. These types of weapons are not able to produce E2 or E3. EPRI's study did not evaluate this more localized threat.

ESCC and Government Coordination

The Electricity Subsector Coordinating Council serves as the principal liaison between the federal government and the electric power industry, with the mission of coordinating efforts to prepare for, and respond to, national-level disasters or threats to critical infrastructure.

- The ESCC includes electric company CEOs and trade association leaders representing all segments of the industry.
- The National Infrastructure Advisory Council called the ESCC a model for how critical infrastructure sectors can partner with government more effectively.
- The ESCC is focused on multiple areas to improve the security posture of the industry and the energy grid, including:
    - Tools & Technology: Deploying technologies that improve situational awareness and enable machine-to-machine information sharing;
    - Information Flow: Ensuring actionable intelligence and threat indicators are communicated at the right time to the right people in industry and government;
    - Incident Response: Preparing for and exercising to coordinate responses to both natural and malicious threats to energy grid operations; and
    - Cross-Sector Coordination: Working closely with other interdependent infrastructure sectors (communications, downstream natural gas, financial services, and water) to ensure all are prepared for, and can respond to, national-level incidents.

Addressing dynamic threats to the energy grid requires vigilance and a coordinated approach that leverages government and industry expertise and resources.

- To better understand and address the EMP threat, the industry works across the sector and with the ESCC; EPRI; the North American Electric Reliability Corporation (NERC); federal agencies, including DOE, the Department of Defense (DOD), the Department of Homeland Security (DHS), the FBI, and the Federal Energy Regulatory Commission (FERC); and state and local law enforcement agencies.

- With input from the electric power industry, DOE developed the Electromagnetic Pulse Resilience Action Plan that identified five goals: (1) improve and share understanding of EMP threats, effects, and impacts; (2) identify priority infrastructure; (3) test and promote mitigation and protection approaches; (4) enhance response and recovery capabilities to an EMP attack; and (5) share best practices across government and industry, nationally and internationally. DOE's plan was released in January 2017 and is complementary to EPRI's research project.

- Given the interdependencies and potential impacts to multiple critical infrastructure sectors from a range of threats, the ESCC works closely with the communications, downstream natural gas, financial services, and water sectors to ensure all are prepared for, and can respond to, national-level incidents.

- The impact from a HEMP over the continental United States would affect more than just the energy grid. Control and communication systems for water, natural gas, railways, and communications would be impacted. For any one sector's efforts to be truly effective, the interdependencies between critical infrastructure must be considered in national mitigation and recovery scenarios.

- The detonation of a nuclear weapon causing an EMP would amount to an act of war or terrorism, and the federal government has primary responsibility for preventing such an attack as a matter of national security. This role of government, in preventing as well as preparing for, and responding to, such a scenario was acknowledged in the Executive Order on Coordinating National Resilience to Electromagnetic Pulses dated March 26, 2019. The responsibility for protecting the United States from war should fall on the nation's defense intelligence and military services, not on individual critical infrastructure providers.

Resilience and Incident Response

The electric power industry takes a "defense-in-depth" approach to protecting critical energy grid assets from all threats. Developed over many decades of accumulated experience, this risk management program focuses on preparation, prevention, response, and recovery to deal with a wide variety of hazards to energy grid operations.

- Electric companies prioritize risk to enhance protection around critical assets, engineer redundancy to avoid single points of failure, stockpile spare equipment for hard-to-replace

components, and develop other contingencies to minimize impact regardless of the nature of the incident.

- Building on its long history of mutual assistance and partnership to restore electricity after major outages, the electric power industry is expanding equipment-sharing programs—including the FERC-approved Spare Transformer Equipment Program (STEP), SpareConnect, and the Grid Assurance program—to protect the energy grid from a range of threats and to enhance energy grid resilience.

- The electric power industry is working with segments of the transportation sector (rail, trucking, and barge) and the government to improve the coordination and preparation involved in moving large transformers during an emergency.

Electric companies plan and regularly exercise for a variety of emergency situations that could impact their ability to provide electricity to customers. Recent national-level exercises include:

- **National Level Exercise** (FEMA, May 2018) tested the ability of all levels of government, private industry, and non-governmental organizations to protect against, respond to, and recover from a major Mid-Atlantic hurricane. Several local, state, and federal exercises were integrated into the NLE, including **Clear Path VI** (DOE).
- **GridEx IV** (NERC, November 2017) gathered more than 450 organizations and 6,500 participants from industry, government agencies, and partners in Canada and Mexico. GridEx IV also included an executive tabletop exercise where 40 electric sector executives and senior U.S. government officials worked through incident response protocols to address widespread outages.
- **Cyber Guard** (DOD/NSA, June 2017) was a week-long exercise that tested the response capabilities of energy, IT, transportation, and government experts to a major cyber attack. More than 700 cyber operators and critical infrastructure experts participated in the exercise.
- **FEMA Region III** (FEMA, May 2017) conducted a power outage exercise that focused on how federal, state, and local emergency managers would work with the electric power industry to respond to a physical/cyber attack on the Mid-Atlantic region's energy grid.
- **Joint Financial Services—Electric Sector Cyber Exercise** (Treasury, August 2016) examined incident response capabilities and interdependencies between the two sectors.
- **Cascadia Rising** (FEMA, June 2016) was a three-day exercise that tested first responders and government emergency personnel in the immediate aftermath of a significant earthquake.

The electric power industry will participate in several more national-level exercises in 2019, including:

- **ClearPath VII** (DOE, April 2019)
- **Shaken Fury** (FEMA, June 2019)
- **GridEx V** (NERC, November 2019)

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