From Doomsday to Reality

EPRI Research to Inform Smart Decisions on High-Altitude Electromagnetic Pulses

By Chris Warren

Perspectives on what might happen to society in the aftermath of a high-altitude electromagnetic pulse (HEMP) range from "doomsday" scenarios to minimal impacts.

In one prediction, hundreds of large power transformers at substations around the country overheat and fail, resulting in blackouts lasting months or even years. In Congressional testimony in 2015, Peter Pry—executive director of a Congressional advisory board called the Electromagnetic Pulse Task Force on National Homeland Security—ominously warned that the prolonged damage to the grid could result in the death of 90% of Americans "through starvation, disease, and societal collapse."

At the other end of the spectrum: In a 2015 article, Sharon Burke and Emily Schneider of the Washington, D.C.–based think tank New America Foundation contend that severe weather and other natural hazards pose much greater risks to the grid. "Odds are you have far more to fear from nut-obsessed squirrels than nutty extremists when it comes to the reliability of your electricity," they wrote.

This divergence in views regarding potential HEMP attacks points to a lack of publicly available, scientifically credible information about the true dangers. Given the sensitive national security issues involved, rigorous research on HEMP threats is classified or otherwise unavailable for public scrutiny.

"The only thing settled is that nothing is settled," said Randy Horton, an EPRI senior program manager.

Filling the HEMP Knowledge Void

In 2016, EPRI launched a three-year project to investigate HEMPs, including threat assessment, mitigation, and recovery. The research parallels similar but distinct work at the U.S. Department of Energy and is meant to provide utilities, federal and state regulators, and policymakers with information to guide policy and investment decisions.

"EPRI's mission is to conduct research for the benefit of the public, and this drives our long-standing commitment to address anything that threatens grid reliability and safety, including HEMPs," said Rob Manning, EPRI vice president for transmission and distribution.

"EPRI wants to provide the public, utilities, and regulatory and legislative decision-makers with unbiased technical results," said Andrew Phillips, EPRI director for transmission and substations. "They can consider our findings as they evaluate the risks posed by HEMPs, including the possibility of widespread power failures."

Credible information is particularly important when it comes to protecting the electric grid. Though well intentioned, policies mandating that tens of thousands of substations and transformers nationwide be equipped with the same level of protection as missile launch sites—at a cost of tens of billions of dollars—may be an overreaction to the risks.

"Even utilities that have already taken steps to harden their facilities recognize that they don't have all the answers and need a more scientific basis for investment decisions," said Horton.

EPRI's first HEMP report, published in September of 2016, covers the state of knowledge and research gaps, drawing from 70 publicly available papers and interviews with utilities on their hardening and mitigation practices. It describes the three components of a HEMP:

- E1: A high-magnitude, short-duration pulse
- E2: A short-duration pulse similar to lightning
- E3: A pulse similar to naturally occurring geomagnetic disturbances

Each HEMP component may impact the electric grid in different ways. Prior research has pointed to the potential vulnerabilities of electronic components as a result of elevated voltages and currents associated with E1 and E2.

"They have the potential to cause electronics to fail or malfunction," said Phillips. "The ones we worry about in substations are the relays controlling the circuit breakers that protect and control the grid. Without those relays, the grid can no longer operate." An additional concern is the potential effects to control centers and energy management systems that operate the electric grid.

The E3 pulse has the potential to overheat and damage transformers, which play a critical role in bulk power system operations. Some transformers increase voltage so that electricity can be transmitted across long distances while others reduce voltage so that it can be sent to consumers. Because designing and building large power transformers can take up to 18 months, the loss of many of them could result in long-term blackouts.

"During an E3 event, transformers consume a lot of reactive power," said Phillips. "That reactive power can cause voltage collapse, and some are concerned that the voltage collapse could result in large-scale blackouts across the United States."

The report points to a lack of specific guidance to help electric utilities protect their assets from a HEMP attack and notes that an early detection system could potentially help the grid withstand its impacts.

Utility plans and actions underway include installation of high-frequency filters, grounding and surge protection devices to guard against E1 pulses, and storage of spare equipment in HEMP-protected warehouses. "Some utilities are building HEMP-proof control rooms," said Phillips. "Control rooms contain the computers and electronics for managing grid operations. They cost tens of millions of dollars, and making them HEMP-proof increases that price significantly."

Can a HEMP Destroy Hundreds of Bulk Power Transformers?

A second EPRI report published in February evaluates the threat posed by an E3 pulse to the bulk electric system in the continental United States. Many worst-case HEMP scenarios, such as long-term blackouts, stem from the potential effects of E3 on transformers.

“The fears about the E3 pulse are based on the belief that it would cause many transformers to fail,” said Horton. “We thought it was important to start our research with E3 and figure out how likely that was. This can inform utilities and regulators in making fact-based decisions about hardening and mitigation investments.”

Past research on E3 impacts did not accurately account for both the magnitude and duration of the geomagnetically induced currents resulting from E3. For example, one study concluded that an E3 pulse wouldn’t damage transformers because the duration of the resulting currents was so short. But the study did not use thermal models to assess how increased temperatures would impact the transformers, calling the conclusions into question. Another study only evaluated the magnitude of the geomagnetically induced currents, concluding that widespread transformer damage as a result of E3 was likely.

“Think about duration like this: You can run your hand through a candle and nothing happens,” said Horton. “But if you hold your hand over the flame for any significant time, you will burn it. Same principle applies here.”

To quantify E3 impacts on larger power transformers, EPRI developed thermal models based on transformer data from laboratory and field tests along with 3D simulations. For instance, EPRI and a transformer manufacturer injected DC current into a transformer, observed the resulting temperature changes, and incorporated the results into the thermal models. EPRI’s models are more accurate than those used in prior research because they factor both the magnitude and duration of the geomagnetically induced currents.

“The limiting factor is that we do not have a model for each transformer, but our generic models are conservative,” said Horton. “That means that they should yield hotspot temperatures that are as high or higher than those that would be experienced in the field.”

EPRI concluded that while an E3 pulse could generate significant currents in hundreds or thousands of transformers, only 3 to 14 units (depending on the location of the nuclear blast) were at risk of thermal damage, indicating a low likelihood of widespread, long-lasting blackouts. This finding alone isn’t meant to dictate policy or investment decisions, but it should dampen a temptation to act hastily. “It says that we don’t need to panic and buy hundreds of spare transformers,” said Phillips.

EPRI’s methodologies are presented in detail in the report. “We came up with a defensible technical basis that can be scrutinized by others,” said Phillips. “The report provides all the information needed to evaluate our approach.”

Future research will build on the findings of the first two reports. Later in 2017, EPRI plans to publish a report examining the potential for an E3 pulse to cause a voltage collapse or blackout. This work is distinct from the recent findings, which focused on thermal effects of E3. Then researchers will examine impacts of E1 and E2 pulses on substations. This will include modeling the electrical interactions with control cables, overhead conductors, and other infrastructure, along with testing of components to determine the pulse levels that they can withstand.

“We are beginning to test grid components, such as relays and microprocessor-based devices, to see what pulse levels they can handle,” said Horton. “By combining the results of those tests with the modeling results, we can determine the probability of failure and the impacts to the grid.”

The goal of this research is to develop a thorough understanding of all the possible impacts of a HEMP attack to inform smart decisions on how to defend the grid. “At the end of this research, we will put all the pieces together and know the full range of potential impacts for E1, E2, and E3,” said Horton.

Key EPRI Technical Experts

Randy Horton, Andrew Phillips