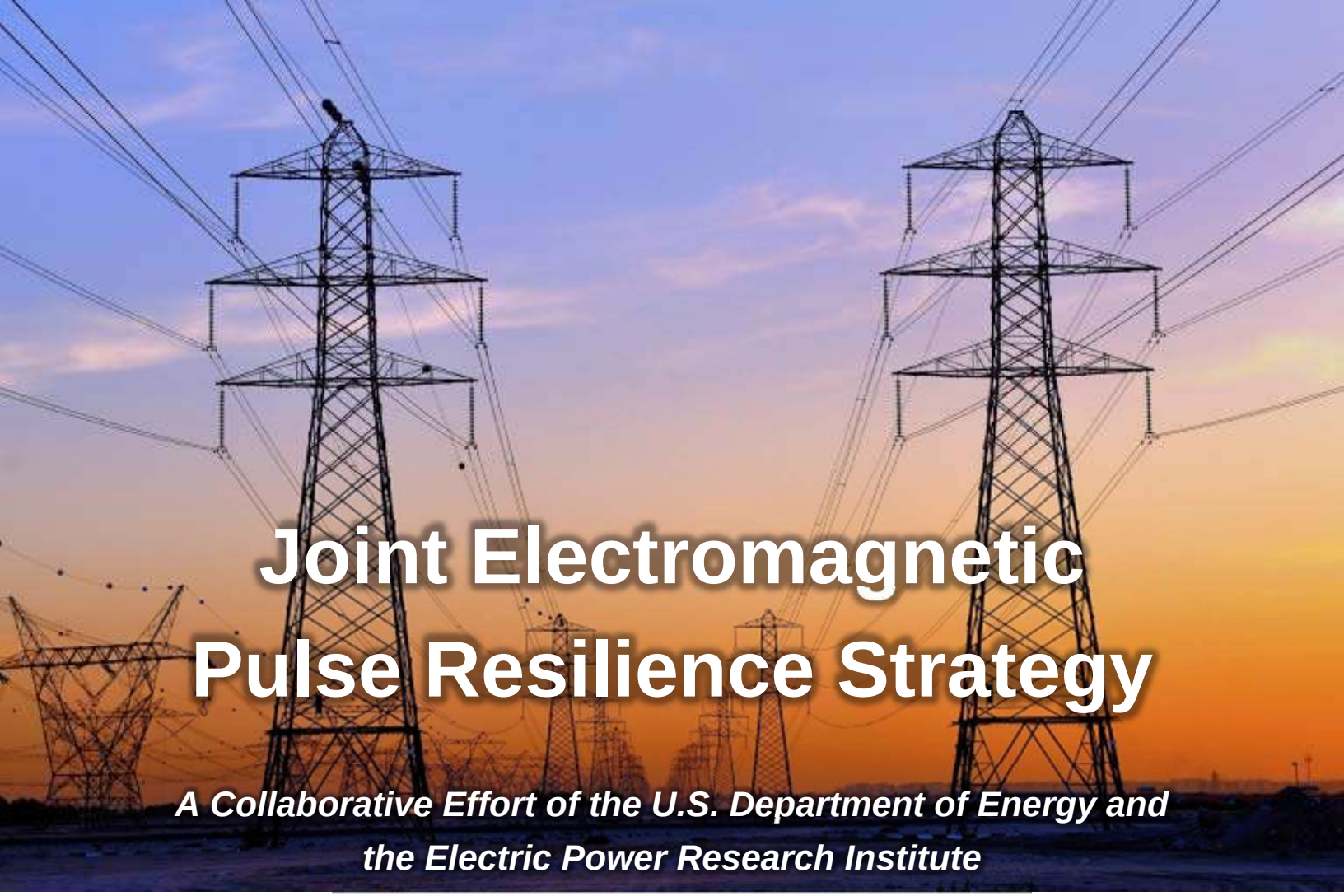

Joint Electromagnetic Pulse Resilience Strategy

A Collaborative Effort of the U.S. Department of Energy and the Electric Power Research Institute

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U.S. DEPARTMENT OF ENERGY

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

For Further Information

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Executive Summary

Electromagnetic pulse (EMP) refers to a very intense pulse of electromagnetic energy, deliberately caused by the detonation of a high-energy explosive device (nuclear or non-nuclear) or generated by a high energy radio frequency (HERF) or directed energy weapon (DEW). High-altitude EMP (HEMP) occurs when a nuclear warhead is detonated hundreds of kilometers above the Earth's surface, impacting areas that may be hundreds of kilometers in diameter. While the United States and other countries are considering defensive/preventative measures to limit the risk of EMP events, reducing vulnerabilities to EMP impacts and improving the response to and recovery from such events are efforts that both DOE and industry can undertake now. Such efforts need to be implemented in a thoughtful and consistent manner and need sound scientific information to guide resource allocation and set priorities.

The *Joint Electromagnetic Pulse Resilience Strategy* (Joint Strategy) is a collaboration between the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI) to enhance coordination, where appropriate and beneficial, and to guide future efforts to help meet the growing demands for EMP guidance.

Following the development of the Joint Strategy, DOE will develop an *Electromagnetic Pulse Resilience Action Plan* (DOE Action Plan) to further refine and direct the Department's efforts to reduce EMP vulnerabilities and improve the energy sector's response and recovery after EMP events through coordination with interagency, national laboratory, industry, and international partners. Similarly, EPRI will be developing an industry-focused plan in coordination with electric utilities and the Electricity Subsector Coordinating Council.

The Joint Strategy lays out five strategic goals to guide DOE and EPRI to minimize EMP impacts and improve resilience:

1. **Improve and Share Understanding of EMP: Threat, Effects, and Impacts.** (Page 4)
2. **Identify Priority Infrastructure.** (Page 5)
3. **Test and Promote Mitigation and Protection Approaches.** (Page 6)
4. **Enhance Response and Recovery Capabilities to an EMP Attack**. (Page 7)
5. **Share Best Practices Across Government and Industry, Nationally and Internationally.** (Page 8)

Additionally, the Joint Strategy identifies the fundamental goals and objectives that both DOE and EPRI members can use to guide their efforts to protect and mitigate critical energy assets from EMP events. It identifies specific initiatives to drive both near- and long-term DOE and industry resilience priorities and ensures that scientifically sound information is available to inform decision-making. This Joint Strategy and the pending DOE and EPRI action plans will facilitate the integration of EMP protection, response, and recovery information into DOE's and industry's risk-management plans to enhance preparedness and critical infrastructure resilience.

Introduction

EMP refers to a very intense, short duration burst of electromagnetic energy that can impact electronic or electrical equipment; EMPs are deliberate actions. An EMP can adversely affect non-protected electronics out many hundreds of miles from its point of origin, depending on the yield of the associated device and the height at which the detonation occurs. An EMP can also potentially disrupt control centers for power systems and for oil and gas networks (and other industries as well). Given the critical importance of reliable electric power and energy supplies for security and economic well-being, it is essential that the United States improve the Nation's ability to protect, mitigate, respond to, and recover from the potentially devastating effects of an EMP.

For the purpose of this Joint Strategy and the associated DOE and industry action plans, the focus is on EMP resulting from a nuclear explosion at high altitude (HEMP), given that such events may have widespread impacts affecting larger portions of the electric grid and other equipment. Other types of EMP producing devices have more limited damage zones associated with them. In terms of impact, this Joint Strategy is focused on high-voltage and other electronic equipment installed in substations, generating plants, and control centers.

Several nation states today possess nuclear weapons which could be used to attack the United States and our allies with EMP. Other nation states and actors may acquire such weapons in the future despite non-proliferation efforts. The nature of a HEMP detonation is such that it can occur with little or no warning, severely limiting the ability of operational-based strategies to limit damage as there is insufficient time to put such strategies in place. Therefore, the response to EMP (particularly HEMP) threats involves measures that harden assets to reduce their vulnerability to damage and improve response and recovery actions to limit the duration of any outage.

The *Joint Electromagnetic Pulse Resilience Strategy* (Joint Strategy) and the forthcoming *Department of Energy Electromagnetic Pulse Resilience Action Plan* (DOE Action Plan) together seek to enhance the coordination of DOE and industry efforts, where appropriate and beneficial, and to guide future effort to help meet growing demands for actionable EMP guidance. Industry will be preparing a complementary action plan in the near future. This Joint Strategy and the pending DOE and industry action plans are intended to drive efforts to reduce EMP vulnerabilities and improve the response and recovery after EMP events, thus minimizing adverse impacts and improving grid resilience.

The Joint Strategy establish goals and objectives to enhance the understanding of risk from, and preparedness for, HEMP events. Many of the goals and objectives outlined in the Joint Strategy can be scaled to address EMP events that are smaller in magnitude. Such events could occur more frequently than HEMP events and can have significant, albeit more localized, effects.

EMP resilience is a global concern as HEMP events can cross borders regardless of the intended area of damage. A few countries are known to have or to be developing defense-based strategies to prevent attacks, while others are focusing on the resilience of their power grids or are focusing on naturally occurring geomagnetic disturbances. Information on many countries hardening and mitigation actions are classified or restricted, limiting the current ability to share this information. This suggests additional international collaboration for government and industry, to find ways to share scientific and testing results if not the actual measures implemented.

Implementation of the Joint Electromagnetic Pulse Resilience Strategy

The goals and objectives that follow recognize two basic principles:

1. **The importance of partnerships.** Public-private partnerships and collaboration are critical to the success of the Joint Strategy, as well as the DOE and industry action plans. Input from EMP experts and industry owners/operators who will make investments in EMP preparedness is necessary for partners to build trust in the resulting data and information. Decisions must be based on sound science and economics about impacts, vulnerabilities, consequences, and costs. DOE and EPRI will work closely with the national laboratories, the Defense Threat Reduction Agency and others in the U.S. Department of Defense (DoD), Department of Homeland Security (DHS), and other companies, associations, and institutes in the electric power industry to develop and share scientific and technical information.

2. **The need for a risk-based approach.** Investments should be made based on a complete understanding of the risk of EMP and the costs and benefits of enhancing mitigation and protection. This will ensure that cost-effective solutions are developed and prioritized with other needed improvements across the industry. A risk-based approach requires that there is a basic understanding of the threat at an unclassified level.

The DOE Action Plan, planned to be released in 2016, details DOE's activities that will be undertaken to implement the Joint Strategy and achieve the five high-level goals, and will include deliverables and timelines. This Joint Strategy acknowledges the challenges associated with planning and preparing for deliberate actions such as HEMP that result from unpredictable terrorist activities; identified activities in the Action Plan should therefore be prioritized considering their cost, feasibility, and risk reduction potential. DOE intends to reevaluate and update the Joint Strategy and DOE Action Plan within four years of the date of publication, or as needed due to changing threats, additional industry participation, or increased availability of scientific information, such as from EPRI's related research program.

Lessons learned through the DOE Action Plan and the complementary industry action plan will have implications beyond the electric industry to protect other electronic and electrical equipment and increase the resilience of other critical infrastructure.

Enhancing National Preparedness and Critical Infrastructure Resilience

This Joint Strategy ensures that EMP risks are recognized and addressed in the context of two Presidential Policy Directives (PPDs): PPD-8, "National Preparedness" (March 30, 2011); and PPD-21, "Critical Infrastructure Security and Resilience" (February 12, 2013). PPD-8 calls for an integrated, all-of-Nation, capabilities-based approach to preparedness for all hazards. The collaboration-based, industry-wide approach encompassed within this Joint Strategy and its accompanying action plans follows this framework.

PPD-21 identifies energy and communications systems as vital due to the enabling functions they provide across all critical infrastructure sectors and instructs the Federal Government to engage with industry and international partners to strengthen the security and resilience of

domestic and international critical infrastructures on which the Nation depends. This Joint Strategy actualizes this collaboration in the area of EMP.

Strategic Goals

This Joint Strategy defines five strategic goals to prepare the DOE and the electric industry to minimize EMP impacts and improve grid resilience. The goals aim to improve the industry's understanding of, protection against, and long-term design and planning for EMP events, specifically HEMP events. (See the Appendix for background on EMP impacts.)

The five high-level goals for DOE and industry research, development, deployment, operations, coordination, and engagement are:

- Improve and Share Understanding of EMP: Threat, Effects, and Impacts
- Identify Priority Infrastructure
- Test and Promote Mitigation and Protection Approaches
- Enhance Response and Recovery Capabilities to an EMP Attack
- Share Best Practices Across Government and Industry, Nationally and Internationally

1. Improve and Share Understanding of EMP: Threat, Effects, and Impacts

Given the level of concern over the EMP threat, DOE and industry need a scientifically sound understanding of what an EMP attack could do to the grid, particularly at substations. Given modern technologies and control systems, a better understanding of the expected severity of damage on different types of equipment is essential. Following that understanding of likely damage, modeling and other information is needed to show how extensive outages potentially could be—and what that might actually mean to our society. Much of the available information on damage is known to be outdated and inapplicable to present technology; moreover, it is not readily available due to classification issues. This also means that there is little or no data on the real cost of additional protection and mitigation measures. To date, there has been a lot of speculation on damages, societal impacts, and costs, but little serious study of the issues. Such information is needed if improvements are to be implemented in a rational way.

Additionally, the realism of the EMP threat needs to be set in context against other threats and hazards that industry must address. This may require more information on the ability to launch an attack and the relative likelihood of such an attack compared to other natural and man-made hazards or other terrorist threats. Lastly, DOE and industry need to understand if there are different magnitudes of EMP events that should be consider in designs, plans, and preparedness efforts. Some EMP events might be considered in or addressed by new designs; for other events, it may be more practical to address the risk through response and recovery plans.

The following objectives should be pursued to better understand EMP and to share that information with industry:

- **Improve assessment, modeling, and prediction of equipment and system vulnerabilities and damage.** A key element of improving resilience to an EMP event is the ability to understand vulnerabilities and predict associated damage to specific types of equipment and thereby systems for different magnitudes of EMP events. Effective prediction of the damages from EMP requires specific scenarios to evaluate and models

that provide reliable and accurate information. If the models produce results quickly, they can also be helpful after an event to understand the full range of damage that likely occurred, even as on-the-ground damage assessments are conducted. This could be especially helpful if communications are lost with one or more electric utility providers.

- **Improve assessment, modeling, and prediction of impacts to society.** The societal impacts of EMP-induced long-duration outages must also be understood to inform the nature and urgency of implementing appropriate mitigation and protection measures. To ensure appropriate and effective protection, mitigation, response, and recovery actions are taken, it is important to understand the likely impacts of such events on infrastructure and other systems on a regional or even national basis—both directly and as a result of extended outages. Improvements in understanding societal impacts will require assistance from other Federal agencies, the National Laboratories, academia, and others.

- **Develop a more complete and current understanding of the threat.** While it is not possible to precisely predict the occurrence of an EMP attack, it is possible to understand what it would take to successfully deploy such an attack and whether or not one or more nation states actually have that capability and possible intent. Knowing which country or which mechanism is not important to industry, just the realism of different EMP scenarios—in terms of possible areas of damage that could be expected based on the voltage experienced. Thus, there is a need for realistic scenarios that DOE and industry can use to guide their individual and joint decision making efforts. This should include the identification of the most likely types of assets that industry needs to protect, given the range of EMP scenarios.

- **Disseminate results to industry.** Collaboration is key to addressing the EMP threat. Government decision makers need scientific information to inform their policies and guidance and industry decision makers need actionable information on threats and societal impacts to inform their resource allocation and preparedness timelines.

- **Expand industry collaboration.** DOE and EPRI developed this Joint Strategy to guide initial efforts in managing EMP risks to some of the most critical electric power infrastructure. Successful approaches to managing the overall risks to the Nation from EMP will require much broader representation from other portions of the electric industry—and from other infrastructure sectors.

2. Identify Priority Infrastructure

Effective protection, mitigation, response, and recovery all depend on prioritizing resource allocation to ensure that essential equipment, assets, and systems receive attention first. It is important to identify which functions are most critical and then determine which components are essential to keeping those functions operational. There is no perfect solution, but having some sense of priorities will enable the implementation of the most effective protection and mitigation strategies and the quickest response and recovery. It is also important to adapt upfront response and recovery prioritizations once actual damages and area of impact are known.

The following objectives should be pursued to identify priority infrastructure for protection, mitigation, response, and recovery:

- **Identify critical infrastructure and functions.** By determining where electric power is most essential, sets of critical functions, assets, systems, equipment, etc. can be created. These functions and infrastructure may be within the grid itself or the infrastructure that depends on the grid. Guidance on determining critical infrastructure under normal conditions should be updated for EMP conditions where outages might persist for extended periods. This objective will need the input of other infrastructure sectors to determine critical infrastructure interdependencies under extended outages.

- **Develop guidance on priority setting.** Having identified the critical infrastructure and functions under extended outage conditions, guidance is needed to ensure that dependencies and interdependencies are considered to determine priorities. Priorities for hardening equipment and for response and recovery should consider not only the infrastructure directly served, but also the importance (and vulnerability to EMP effects) of the equipment and systems to restoring other parts of the grid.

- **Enable sharing of damage assessments to allow refinements in priorities.** Response and recovery priorities will need to be quickly re-examined in light of the severity of the damage and the specific geographic areas involved. If an event is more localized, it may be possible to use alternate service providers (hospitals, banks, food stores, water systems, etc.) in nearby areas rather than immediately focusing on restoring such services in the affected area. In other cases, the electric equipment may be less damaged than expected and a different approach to restoration may be feasible. This adaptive tailoring of priorities is dependent on having a clearinghouse or other mechanism to share damage information across electrical power providers on a near real-time basis.

3. Test and Promote Mitigation and Protection Approaches

An important part of this Joint Strategy is to better understand how critical systems can be protected from EMP and adverse impacts can be mitigated. Given the existing data gaps, this requires analysis, research, and testing. Actionable information must then be made available to owners and operators so they can make fact- and risk-based decisions on reducing the consequences of an EMP attack through hardening and other strategies, rather than focusing only on response and recovery after an attack.

The following objectives should be pursued to improve EMP protection and mitigation:

- **Understand how to best reduce vulnerabilities to EMP.** This will require identifying key gaps in current knowledge about the effectiveness of various protection and mitigation strategies, and designing and conducting the necessary experimentation and testing to determine those approaches that are most feasible and cost-effective for both new and existing facilities/equipment. There should be a plan to share test data with and across industry. Reviews of other government testing efforts (e.g., DoD and the National Laboratories) are important to both reduce duplication and ensure realistic test conditions.

- **Identify new approaches to protection and mitigation.** This involves researching military and international analyses and conducting research and development efforts to identify new approaches. These new approaches will also need to be tested to determine their effectiveness in operational settings.

- **Develop, maintain, and protect stockpiles of vulnerable components.** Inventories of critical components that are susceptible to EMP, too expensive to protect individually, and not likely to be readily available after a widespread loss, could be inventoried for more rapid access after an EMP event. Such stockpiles would need to be fully protected from EMP and processes developed that would govern the prioritized distribution and transport of those components to affected locations.

- **Develop mitigation plans for operational actions when EMP warnings are available.** Should an EMP event occur in one area and indications of additional imminent events be available, it will be necessary to alert industry of the opportunity to implement operations based strategies to limit damage in other areas of the county. Guidance on effective operational strategies based on testing results for both energized and de-energized equipment should be disseminated, and communication channels should be developed and tested (also see Goal 4).

4. Enhance Response and Recovery Capabilities to an EMP Attack

EMP damage could be quite extensive, both geographically and in duration. Except for the protection of certain critical military assets, there are limited protection and mitigation measures currently in place. This makes comprehensive response and recovery capabilities critical to managing EMP risks. Restoring assets and systems that tripped off-line and/or were damaged will be critical to save lives in the short- and long-term and to minimize long-term economic impacts. As with protecting specific assets and systems that are most critical, response and recovery efforts should be prioritized. This may be for the same critical assets and systems or may be for specific equipment where it is more effective to deploy response and recovery measures than it is to harden or otherwise protect the equipment.

The following objectives should be pursued to enhance response and recovery capabilities:

- **Provide guidance for the development, exercise, evaluation, and improvement of both response and recovery plans.** It is essential for electricity providers, reliability coordinators, and system operators to have comprehensive and executable plans (with key decision points) to address a HEMP attack. Guidance should ensure that such plans are comprehensive, outline actions and procedures to be taken regardless of the severity of the attack/event, detail specific measures/actions to be taken depending on the impacts, and are scalable/flexible depending on the severity of the damage and impact rather than assuming a particular set level of damage. Appropriate training on and exercising of such plans is essential to ensure they are effective when needed and that they are improved based on lessons learned from the exercises.

- **Develop a capability to quickly assess damage from an EMP attack.** Electricity providers, reliability coordinators, and system operators must have the plans, tools, and resources in place to be able to quickly assess the damage and impacts from any EMP attack. Using the research and testing results from Goal 1, tools and procedures should be developed that can be shared with industry to enable this capability. Such a capability should identify expected areas of potential damage and include processes to test and evaluate system operations after such an attack.

- **Provide guidance on contingency planning for essential government and industry services.** Preservation of essential government services, personnel movement, and maintenance of infrastructure systems after an EMP event are crucial to minimizing long-term impacts. Government, the private sector, and critical infrastructure entities need guidance on how to respond in a manner that increases the likelihood of maintaining essential operational elements for a prolonged period of time.

- **Provide notification of an EMP attack.** The U.S. Government has sophisticated monitoring systems in place to confirm that a nuclear explosion has detonated over the United States. In order for the electric industry to effectively respond to an EMP attack, they must immediately be informed that such an attack took place so that response plans for EMP attack can be activated and implemented. Appropriate mechanisms for communicating this critical information must be identified, documented, and tested.

- **Ensure the survivability of interoperable communications systems during and after an EMP.** Effective communications systems are essential to gaining and maintaining situational awareness and ensuring unity of effort in response and recovery operations. The effects of EMP on communications systems occur at different timescales and at varying degrees within a single event, depending on the system and the characteristics of the event. Government and private-sector stakeholders need guidance that allows them to maintain communications capabilities (including interoperability) despite an EMP attack. These may be alternate systems that are less vulnerable to the effects of EMP.

- **Set realistic power-restoration priorities and expectations.** Both DOE and industry need to have pre-determined recovery priorities, which can be refined after damage assessments are available, so that the most critical assets and systems are restored first. In addition to overall industry priorities, electrical power providers should develop their own protocols for restoring electrical power after an EMP attack, in coordination with State and local governments.

5. Share Best Practices Across Government and Industry, Nationally and Internationally

Developing the strongest set of technical and scientific data on vulnerabilities and mitigation will benefit from broad-based efforts to collect and share data from around the world, across governments, academia, and industry. Much of the information will be in the form of analyses and testing, but any EMP event that does occur needs to be studied for additional impacts–direct and indirect, regardless of the country in which it occurs. Sharing best practices will also require that ways to share basic information in a way that avoids restrictions and classification is found. Lastly, findings and best practices should be shared across industries as electrical and electronic equipment can be found across all sectors and throughout our society. For instance, not every industry will need to protect transformers, but all deal with communications and control systems.

The following objectives should be pursued to increase broad-based information sharing:

- **Build international support and policies for information sharing.** A prerequisite to enhanced information sharing is high-level support across partner countries to raise awareness of the value of sharing analyses, research, and testing data. This will require

finding alternate ways to present information so that restrictions and classification is not necessary, or is minimized.

- **Share the results of analyses and testing.** Information on the impacts to specific types of systems and the effectiveness of various mitigation strategies should be shared with those with a need to know. Studies should be designed in ways that select results can be shared without disclosing geographical- or company-specific configurations and current vulnerabilities.

- **Investigate and share the findings of any EMP incidents.** Any incident that does occur will have insights that will help other industries and countries use that information to increase their preparedness.

- **Promote a collaborative international approach to preparedness for EMP events.** Infrastructure is interconnected and interdependent, and EMP events could possibly lead to a cascade of impacts across borders and sectors. To mitigate these risks, DOE and industry should work with the international community to facilitate the exchange of information and best practices to strengthen global preparedness for EMP events. DOE should also foster the development of global mutual-aid arrangements to facilitate response and recovery efforts, and should coordinate international partnership activities to support EMP preparedness and response exercises.

Conclusion

EMP has the potential to cause substantial impacts to the Nation's infrastructure, and in particular the electric grid. This Joint Strategy between DOE and EPRI is an important first step to coordinate the industry and government's efforts to address the myriad of challenges presented when managing and mitigating the risks posed by EMP. The five strategic goals and associated objectives support a collaborative approach to developing effective mitigation, conducting targeted research and development, and crafting policies and guidance to reduce infrastructure vulnerabilities to EMP and improve response and recovery through tailored practices and procedures.

Appendix: Background on EMP

The United States is technologically dependent on electricity, and that dependence is growing for critical infrastructure, commercial and residential use, and personal devices. At the same time, the electric power grid is increasingly more complex as smart technologies expand both grid capabilities and create potential vulnerabilities to physical, cyber, and electromagnetic pulse (EMP) threats. EMP refers to a very intense, short duration pulse of electromagnetic energy, deliberately caused by the detonation of a nuclear or other high-energy explosive device. High-altitude EMP (HEMP) occurs when a nuclear warhead is detonated hundreds of kilometers above the Earth's surface, impacting areas that may be hundreds of kilometers in diameter.

The threat of an EMP event is recognized as increasing as more nation states have satellite or missile delivery systems and nuclear devices available. Military capabilities cannot be expected to prevent all possible incidents, leaving the need to reduce vulnerabilities to such attacks and to improve response and recovery capabilities to increase grid resilience.

What do we know about EMP?

The primary threat of EMP is damage to unshielded digital equipment, including Supervisory Control and Data Acquisition (SCADA) systems, control systems, protection relays and systems, communication systems, smart meters, intelligent switches, etc. EMP can induce damaging voltages on electronics that create rapid and total failure. Internal and external insulation may also be at risk, particularly at voltages below 69kV. Although distribution transformer testing indicates that EMP is not likely to fail distribution equipment protected by surge arresters,[1] unclassified data on the impacts on large power transformers is limited. This is of particular concern given the long lead time for construction, transport, and replacement of these larger units. Sufficient testing data exists to determine if the grid is vulnerable, but there is insufficient research, testing and modeling capability to indicate where and how to apply mitigation strategies for optimal protection. In addition, the data that exists are often decades old and were based on tests that did not evaluate many elements of modern grid management technology, including communications systems used to control the grid.

DOE has worked with DHS, DOD, Federal Energy Regulatory Commission (FERC), and the National Laboratories to: 1) understand the potential effects of EMP on power grid equipment and systems; 2) identify gaps in our knowledge base; and 3) identify best practices for mitigation and protection. For example, a recent study by Idaho National Laboratories on behalf of DOE found research gaps that included: EMP impact on modern grid technologies, wireless communications, the understanding of new EMP weapons, protecting and maintaining inventories of spare equipment, and understanding the interdependencies of localized or large-scale restoration and recovery.[2] DOE has also sponsored a study by Oak Ridge National Laboratory to conduct a risk analysis for extreme events, including EMP that will be published later this year. This study will lay out a process for EMP planning for electricity industry companies. The study is expected to be completed in 2016.

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[1] Impacts of a Nominal Nuclear Electromagnetic Pulse on Electric Power Systems: Phase III Final Report, April 1991, Oak Ridge National Laboratory, ORNL/Sub/83-43374/2

[2] *Strategies, Protections, and Mitigations for the Electric Grid from Electromagnetic Pulse Effects,* Idaho National Laboratory, INL/EXT 15-35582, January 2016

The Electric Power Research Institute (EPRI) has initiated a project with its members that will increase the understanding of: 1) overall system impact should an attack occur, 2) power delivery component vulnerability to EMP, and 3) mitigation technology effectiveness, both for hardening and recovery. Deliverables from this study will include: a technical assessment of potential transmission system vulnerabilities and mitigation options; development of a transmission resilience decision support framework; and annual conferences and workshops.

DOE is facilitating industry outreach and coordination through EPRI for the Electricity Subsector Coordinating Council (ESCC), which identified the need for a joint government/industry EMP program at their November 2015 meeting. DOE, the ESCC, and key Federal partners at the Department of Homeland Security and the Department of Defense will form a working group to 1) identify and share current options for mitigating the consequences of an EMP event, and 2) identify additional measures that can be developed, tested, and deployed to address EMP threats in the near future.

How can we reduce EMP risk?

EMP hardening measures could include: hardening equipment to reduce its vulnerability to EMP, replacing certain equipment with alternates that are less susceptible (such as fiber optic cables), developing spare equipment inventories that are protected from EMP, addressing workforce needs in an environment without electricity and all services dependent on that power, and backup communications and transportation plans.