

NERC

NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

EMP Task Force

Strategic Recommendations

November 5, 2019

RELIABILITY | RESILIENCE | SECURITY



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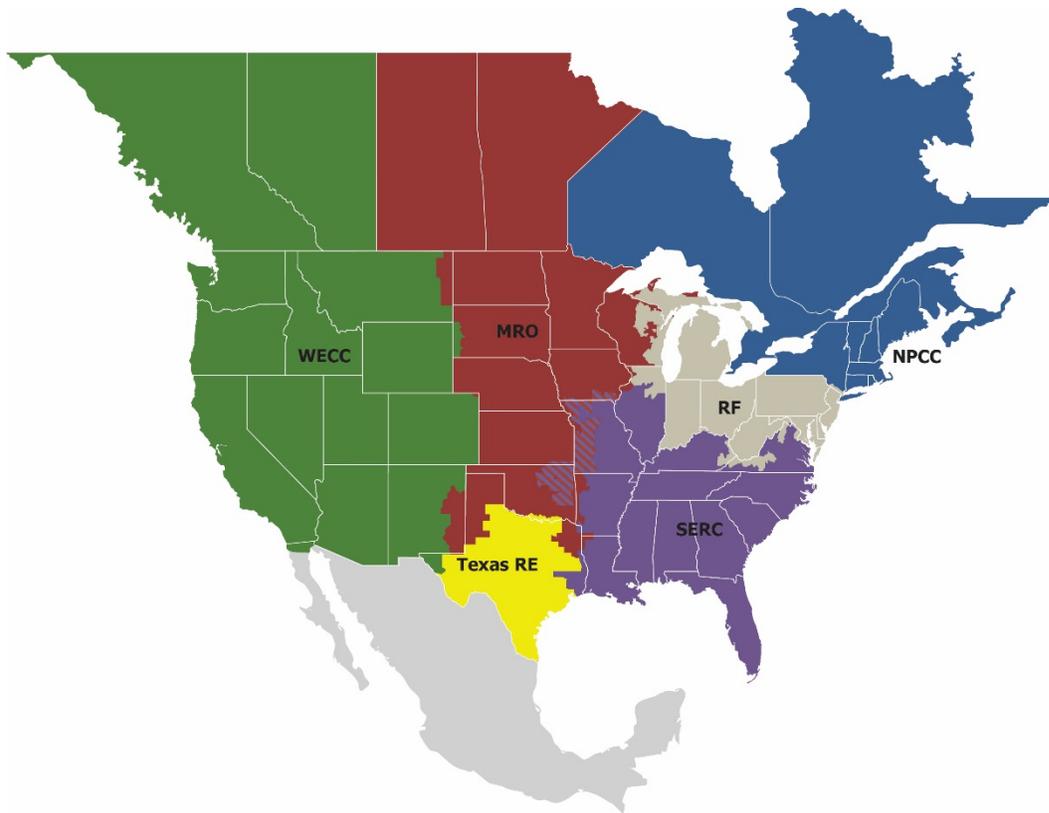
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Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the six Regional Entities (REs), is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is divided into six RE boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Region while associated Transmission Owners/Operators participate in another.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Executive Summary

The Electromagnetic Pulse (EMP) Task Force, formed in March of 2019, is an advisory team that is tasked with collaborating with governmental authorities and applicable industry members. Its charge is to provide front-end, high-level leadership, recommendations, and guidance to the NERC Board of Trustees on next steps based on current research. EMP events may pose a risk to the reliability of the BPS. To understand and address these potential risks, the EMP Task Force has formulated a catalogue of strategic recommendations and policy matters.

Importantly, the ERO Enterprise, in collaboration with industry and governmental subject matter experts, must take the lead determining the desired BPS performance for a predefined EMP event (i.e., one event or multiple events). Based on that information, and with model and simulation development, the industry can evaluate BPS reliability and security concerns for the event and make recommendations towards meeting those expectations. However, several regulatory matters outside of the ERO Enterprise can impact the electric sector's ability to address an EMP event. Those regulatory matters include the need for a cost recovery mechanism and access to classified information regarding an EMP threat.

In this report, the EMP Task Force has identified strategic recommendations for next steps in the following areas:

- [Policy](#)
- [Research and Development](#)
- [Vulnerability Assessments](#)
- [Mitigation Guidelines](#)
- [Response and Recovery](#)

Each strategic recommendation identifies suggested lead organizations with NERC serving a prominent role as the lead or co-lead for most of the items. Certain key items, such as access to classified EMP data/environments and cost recovery mechanisms, must be addressed separately with the appropriate entities. Further, as the research is ongoing, the EMP Task Force should be maintained and expanded to provide guidance for further work, particularly projects undertaken through the NERC technical committees to develop vulnerability assessments, mitigation guidelines, and enhanced response and recovery plans. The timing and sequencing of the recommendations and policy matters in this report are crucial, and the ERO Enterprise should ensure a highly organized and coordinated effort is launched to support EMP resilience.

Introduction

Background

Protecting the BPS and assuring the effective reduction of risks to reliability are integral pieces of the ERO's mission. NERC has launched efforts to identify reliability concerns associated with EMPs and potential methods for promoting resilience to this threat. The EMP Task Force was formed in March 2019 to identify key issues and scope areas of improvement for the industry. As stated above, the EMP Task Force is an advisory team that is charged with providing high-level leadership, recommendations, and guidance to the NERC Board of Trustees, and this guidance is intended to address concerns resulting from high-altitude EMP¹ incidents and the potential impacts on BPS reliability. The EMP Task Force may also recommend the development of future best practices and reliability guidelines to mitigate the impacts of EMP incidents.

Scope of the Report

The EMP Task Force has focused its attention on five areas and have offered recommendations or suggested next steps for each in this report. These were identified after numerous meetings and a technical workshop in July 2019. The following are the five areas of focus:

- [Policy](#)
- [Research and Development](#)
- [Vulnerability Assessments](#)
- [Mitigation Guidelines](#)
- [Response and Recovery](#)

This report is intended to address potential EMP risks to the BPS that involve understanding the interactions among load, generation, and transmission. The recommendations contained in the report are not intended to imply obligations outside of NERC's jurisdiction.

Key EMP Initiatives and Studies Considered by the Task Force

The recommendations and actions are based on unclassified reports and information related to the EMP threat as it may affect the reliability of the BPS as well as the experience and expertise of the EMP Task Force members. Two key documents that are referred to in this report are the EPRI EMP research report *High-Altitude Electromagnetic Pulse and the Bulk Power System*² and the Executive Order *Coordinating National Resilience to Electromagnetic Pulses, Executive Order*.³ Both documents are briefly described below.

EPRI: High-Altitude Electromagnetic Pulse and the Bulk Power System—April 2019

In late April 2019, the Electric Power Research Institute (EPRI) released its *High-Altitude Electromagnetic Pulse and the Bulk Power System* report, which defined the EMP threat to the transmission system, assessed vulnerabilities/risks, and made mitigation recommendations. The EPRI report complements a Department of Energy (DOE) action plan⁴ that was released in January 2017 on EMP Resilience. The action plan identified five goals:

- Improve and share understanding of EMP threats, effects, and impacts

¹ The term EMP includes high-altitude EMPs or HEMPs.

² *High-Altitude Electromagnetic Pulse and the Bulk Power System: Potential Impacts and Mitigation Strategies*. EPRI, Palo Alto, CA: 2019. 3002014979: <https://www.epri.com/#/pages/product/3002014979/?lang=en-US>.

³ *Coordinating National Resilience to Electromagnetic Pulses Executive Order*: <https://www.whitehouse.gov/presidential-actions/executive-order-coordinating-national-resilience-electromagnetic-pulses/>

⁴ *U.S Department of Energy Electromagnetic Pulse Resilience Action Plan*: <https://www.energy.gov/sites/prod/files/2017/01/f34/DOE%20EMP%20Resilience%20Action%20Plan%20January%202017.pdf>

- Identify priority infrastructure
- Test and promote mitigation and protection approaches
- Enhance Response and Recovery capabilities
- Share best practices across government and industry (Some additional information on this work by EPRI is discussed further below.)

The April 2019 EPRI report addressed two key research questions:

- What are the potential impacts of an EMP attack on the modern electric transmission system?
- If impacts are of significant concern, what are possible mitigation options and potential costs and benefits of each?

EMPs are divided into three waveform components:

- E1 EMP: It is an intense, short-duration EMP characterized by a rise of 2.5 nanoseconds and amplitude on the order of tens of kV/m (up to 50 kV/m at the most severe location on the ground).
- E2 EMP: It is intermediate duration with an electric field pulse amplitude of 0.1 kV/m and duration of one microsecond to approximately ten milliseconds.
- E3 EMP: It is a low frequency (below 1 Hz) pulse with amplitude on the order of tens of V/km with duration of one second to hundreds of seconds. E3 EMP is compared to severe geomagnetic disturbances, but an E3 EMP can be much more severe. Also, the E3 event is much shorter in duration than geomagnetic disturbance (GMD) events.

Notably, the most recent EPRI report showed a potential effect on transmission lines, substations, and switchyards from the combined E1, E2, and E3 EMPs that could cause regional voltage collapse and damage to equipment. EPRI also found that digital protective relays were generally very resilient to an initial pulse, but these same relays were susceptible to surges from control and communication cables. More testing is needed, and EPRI is currently working with multiple utilities to pilot a field study.

Presidential EMP Executive Order – March 2019

On March 26, 2019, the president of the United States issued an executive order, *Coordinating National Resilience to Electromagnetic Pulses*. The executive order calls for collaboration and information sharing among government agencies and private industry as appropriate to promote resilience to EMP issues, particularly with regards to threat and vulnerability assessment. The executive order also directed the federal government to provide incentives as appropriate to “encourage innovation that strengthens critical infrastructure against the effects of EMPs through the development and implementation of best practices, regulations, and appropriate guidance.”⁵ Various agencies were assigned different areas of focus. Of particular relevance, the secretary of energy was tasked to perform initial research and development and develop pilot programs that would identify potential failure modes, contingency preparedness, and mitigations with regard to the risk to the electric power grid.

Several agencies were identified with key tasks, and notably this EMP Task Force highlights the following efforts under the secretaries of Homeland Security and Energy:

- Among other things, the Department of Homeland Security (DHS) was charged with serving as a coordinator for addressing the response and recover from an EMP and develop a plan to “mitigate the effects of EMPs on the vulnerable priority critical infrastructure systems, networks, and assets.”⁶ The DHS will also “in

⁵ *Executive Order* at §3 (b).

⁶ *Executive Order* at §6 (e).

coordination with the secretaries of Defense and Energy, and informed by intelligence-based threat assessments, develop quadrennial risk assessments on EMPs.”⁷

- The DOE, among other things, was charged with conducting “early-stage research and development, develop[ing] pilot programs, and partner with other agencies and the private sector, as appropriate, to characterize sources of EMPs and their couplings to the electric power grid and its subcomponents, understand associated potential failure modes for the energy sector, and coordinate preparedness and mitigation measures with energy sector partners.”⁸

Both DHS and DOE are identified in discussions later in this report with regard to strategic recommendations.

GMD vs. EMPs

As the EMP Task Force began to meet, it was clear that stakeholders were confusing the EMP efforts with those that address the GMD. It is important to understand that the level of effort required to develop performance requirements and/or guidelines for enhancing EMP resilience is likely to be more extensive than GMD resilience.⁹ The scientific evidence and basis of analysis for EMP events is not as well advanced, and it is likely to require some time to mature sufficiently to be of practical use. Research conducted so far indicates that the impacts of GMD events tend to remain confined to longer lines, operating at transmission voltage levels, and interfaced to large power apparatus (*e.g.*, generators and transformers). In comparison, the disruptive influence of an EMP event seems likely to span across the full spectrum of power system assets, including the transmission system, the distribution system, the protections and controls hardware, and the command and control infrastructure relied upon to monitor and maintain the power system in a stable operating state. Finally, the impact of an EMP event may extend to customer loads since it remains unclear to what extent loads may be disrupted.

⁷ *Executive Order* at §6 (f) (vii).

⁸ *Executive Order* at §5 (e).

⁹ See *e.g.*, *Grid Security: Protecting against EMPs and GMDs*:

<https://www.eei.org/issuesandpolicy/cybersecurity/Documents/Grid%20Security%20Protecting%20Against%20EMPs%20and%20GMDs.pdf>.

Chapter 1: Policy

Background

The EMP Task Force determined that certain unresolved policy matters will impact industry participation in responding to an EMP event. The EMP Task Force developed a list of policy items that, if defined, will help inform the industry in identifying next steps to address EMP vulnerabilities. The items listed below are largely determined by other entities outside of the ERO Enterprise, but the EMP Task Force highlights these matters in an effort to begin further collaboration with government agencies, industry stakeholders, and policy makers.

Considerations

The policy considerations that the EMP Task Force identified include three recommendations versus identified policy matters to be highlighted as issues that will impact the industry's progress on EMP resiliency. The following three policy recommendations are items that the ERO Enterprise can actively address:

- Policy Recommendation #1: Establishing BPS performance expectations for a pre-defined EMP event
- Policy Recommendation #2: Providing industry and public education on EMPs
- Policy Recommendation #3: Coordination with other Critical Infrastructure sectors on EMP matters

The following three items are highlighted as policy matters that will greatly influence the electric sector response to an EMP threat:

- Policy Matter #1: The high costs of EMP mitigations and the lack of cost recovery mechanisms
- Policy Matter #2: Access to classified information on EMP threats and impact
- Policy Matter #3: Declassification of information for industry use

Each policy recommendation and matter is briefly described below with an accompanying suggested lead organization(s) and support organization(s) that would be responsible for acting on or implementing each of the policy matters. Detailed explanations of the policy matters follow the recommendations, but the suggested lead organizations are outside of the ERO Enterprise. However, these matters should be closely monitored for awareness.

Recommendations

Policy Recommendation #1: Establish BPS Performance Expectations for an EMP Event

The ERO Enterprise, through its authority under the Federal Power Act, should work closely with other agencies to establish performance expectations for all sectors of the BPS regarding a predefined EMP event.

Suggested Lead Organization: [NERC](#)

Potential Support Organization(s): [Department of Energy \(DOE\)](#), [Federal Energy Regulatory Commission \(FERC\)](#), [Department of Homeland Security \(DHS\)](#), [Electricity Subsector Coordinating Council \(ESCC\)](#)

The ERO Enterprise should establish performance expectations (for utilities) as required in response to a predefined EMP event, including parameters such as the following:

- Survivability
- Expectations of ride-through versus recovery
- Restoration time frames
- Permissibility of operations in a reduced protection state

This performance expectation will serve as the basis for industry to evaluate BPS reliability and security concerns with regard to where potential mitigation efforts and capital expenditures should be most focused.

Policy Recommendation #2: Industry and Public Education

Provide consistent/endorsed educational materials about EMPs and their impact to electronic devices and BPS stability to industry and general public.

Suggested Lead Organization: NERC and DOE

Potential Support Organization(s): EPRI, Defense Threat Reduction Agency (DTRA), DHS, DOE Office of Science National Laboratories (National Labs),¹⁰ Nuclear Regulatory Commission (NRC)

Consider publishing educational material about the threats posed by EMPs and the expected impacts to electronic devices and BPS stability. This level of education and outreach supports efforts to better educate the electricity subsector owners and operators and the public about the EMP threat generally and its possible impacts, possible mitigations, and response and recovery options. Better education will also ensure that there is a consistent risk-based understanding based on science that can support more effective collaboration in the identification of mitigations that are cost-effective and prudent. Industry and public education could include, but is not limited to the following:

- Developing, publishing, and distributing unclassified educational material about the EMP threat, possible impacts to the electricity grid, possible mitigation actions, and response and recovery considerations
- Developing, publishing, and distributing unclassified educational material about the threats posed by EMPs and the impacts to electronic devices, equipment, and systems

Policy Recommendation #3: Coordination with Other Sectors

Provide guidance to the electricity industry on how to coordinate with interdependent utility sectors (telecommunications, fuel supply, water) as it relates to an EMP event.

Suggested Lead Organization | NERC and DHS

Potential Support Organization(s) | Asset Owners, Trade and Forum Organizations, ESCC, ISO/RTO Council

Consider providing guidance on how to coordinate with other types of inter-dependent utility sectors like the following:

- Telecommunications
- Fuel Supply/Transportation
- Water/Waste Water

NERC and industry should also continue to engage on national level EMP mitigation policy matters through the ESCC, trade organizations, etc., and communicate with the EMP Task Force for alignment of technical development.

¹⁰ There are currently 17 DOE laboratories: <https://www.energy.gov/science/science-innovation/office-science-national-laboratories>.

Policy Matters

The following policy matters are being addressed outside of the ERO Enterprise; however, these items will greatly impact the ability for industry to implement EMP resilience.

Policy Matters #1: Cost Recovery Mechanisms

Provide industry with clear, consistent cost recovery mechanisms (federal financial support) for planning, mitigation, and recovery plans to ensure the performance expectations as it relates to [Policy Recommendation #1](#) are met.

Suggested Lead Organization | DHS¹¹

Potential Support Organization(s) | NERC, FERC, Asset Owners, DOE, National Association of Regulatory Utility Commissions (NARUC), National Conference of State Legislators (NCSL)

Required effective EMP mitigation will span all portions of the electric sector: generation, transmission, and distribution. The EMP Task Force highlights the importance of this recommendation in light of the variety of cost recovery methods that exist across industry today, ranging from open competitive markets to formula transmission rates to traditional cost of service regulation.

Consider establishing federal cost recovery mechanisms for the electric utility industry to proactively address the performance expectations established by NERC (see [Policy Recommendation #1](#)).

Policy Matters #2 | Industry Access to Classified Information

Provide industry with access to relevant currently classified research by the National Labs, DTRA, and any additional third-party research conducted on electric utility equipment by the Department of Energy.

Suggested Lead Organization | DOE and Department of Defense (DOD)

Potential Support Organization(s) | DHS, DTRA, FERC, National Labs

The use of the best available science is a key principle in establishing the basis for considering mitigation actions and response and recovery plans. Relevant classified information might be critical to performing the appropriate analyses from which investment decisions would be made and would impact on cost recovery actions. Therefore, certain governmental authorities could:

- Support efforts to provide key industry personnel with security clearances (at the appropriate levels) so the industry can gain access to data/information related to research on the threats and impacts of EMP incidents
- Support the potential of having industry personnel, having the appropriate clearances, to engage with the government agencies in the research that is being conducted. This would help bridge any gaps in understanding between the government agencies and the industry about the most critical elements of any research as it might apply to the BPS

¹¹ The executive order states, “[t]he Federal Government shall also provide incentives, as appropriate, to private-sector partners to encourage innovation that strengthens critical infrastructure against the effects of EMPs through the development and implementation of best practices, regulations, and appropriate guidance.” The order also states, “[w]ithin 1 year of the date of this order, the Secretary of Homeland Security, in coordination with the heads of relevant SSAs, and in consultation with appropriate regulatory and utility commissions and other stakeholders, shall identify regulatory and non-regulatory mechanisms, including cost recovery measures, that can enhance private-sector engagement to address the effects of EMPs.”

Policy Matters #3 | Declassification of Information

Work to declassify industry-relevant information on E1, E2, and E3 EMP environments and any other research.

Suggested Lead Organization | DOE and DOD

Potential Support Organization(s) | DHS, DTRA, FERC, National Labs

Access to unclassified EMP environments is essential for assessing the impacts of EMP on the BPS. Several unclassified EMP environments are currently available to the electric industry; however, these environments have very limited usability to the industry mainly because there are many parameters that are not shared with industry. The DOE and DOD could support the following efforts:

- Developing additional unclassified EMP benchmarks in a form that is useful to the industry and can be shared with stakeholders
- Declassifying information related to vulnerability assessment on electric utility infrastructure equipment and other pertinent information
- Facilitating information sharing with electric industry to identify and share vulnerabilities

Chapter 2: Research and Development

Background

While significant work has been done to date by various organizations (EPRI, DTRA, National Labs, etc.), there are still many unknowns in areas crucial to the successful operation of the BPS following an EMP event. Ongoing research activities need to be monitored and their results made available to the utilities. Gaps in existing knowledge and planned research should be identified and additional research activities initiated.

Research Considerations

The key research matters that the EMP Task Force identified in its deliberation include the following:

- Research Recommendation #1: Monitoring current research and report on national initiatives
- Research Recommendation #2: Identification of gaps in research that need to be closed to enable movement toward EMP performance requirements and/or guidelines
- Research Recommendation #3: Develop industry specifications for certain equipment

Research Recommendations

Research Recommendation #1: Monitor Current Research and Report on National Initiatives

Monitor and communicate to the industry research pertaining to EMP and EMP-related national security initiatives that impacts the BPS.

Suggested Lead Organization(s) | NERC, DOE, and DHS

Support Organization(s) | DTRA, FERC, National Labs

- Consider establishing a clearing house for declassified information as it pertains to ongoing research projects sponsored by the Department of Defense and Department of Energy.
- Consider establishing a common communication mechanism to make this information available to electric utility industry stakeholders by setting up a committee or governance structure ensuring the information gets into the right hands.
- Consider publishing a timeline of existing research efforts as many parallel projects are currently underway related to EMP. This would provide visibility and additional collaboration with all industry stakeholders and avoid duplication of efforts.

Research Recommendation #2: Identify Gaps in Research

Additional research is needed to close existing knowledge gaps into the complete impact of an EMP event. This is needed to understand vulnerabilities, develop mitigation strategies, and how to plan response and recovery efforts.

Suggested Lead Organization | NERC

Support Organization(s) | DHS, DOE, EPRI, DTRA

The following are areas that would benefit from additional research:

Generating Facilities

- Consider additional research on generating facilities as they are a crucial element to the operation of the BPS. Large synchronous machines are vital to maintaining steady state voltage on the BPS, and properly functioning black start generation is essential in EMP event recovery:
 - What will be the impact to traditional rotating machines and their control systems, and what mitigations would be effective against adverse impacts?
 - Will these facilities ride through and/or be available for post-EMP recovery efforts?
- Consider additional research on the impact to renewables (inverter-based resources) and their possible mitigations.
- Consider additional research on the impact of E2 to low-voltage auxiliary systems critical to the reliable operation of a generating plant.

Transmission and Distribution Facilities

- Consider additional researching (additional) the impact to transmission and distribution facilities, particularly distribution high voltage configurations that coordinate with transmission substations. Areas to be explored include distribution automation circuit reconfiguration (DACR) restoration systems and advanced meter infrastructure (AMI) systems:
 - Of particular interest is whether an EMP would cause these systems to either temporarily or permanently disrupt operations or be degraded in a manner that leads to misoperations.
 - Work should also be done to determine whether E2 will lead to wide-spread distribution disruptions.
- Assess vulnerabilities to non-microprocessor-based relays (i.e., solid-state and electro mechanical relays).
- Assess performance of auxiliary/instrument transformers during an EMP event.
- Consider validation (by test scenarios) of the coupling models and simulations of E1 EMP to transmission/distribution lines in addition to substation yard wiring.
- Consider defining and analyzing the different circuits within a substation, including current transformers (CTs), potential transformers (PTs), trip/close coils, inputs/outputs, serial communications, etc.
- Consider testing of the complete circuits defined (including yard cables, grounding, control house termination/terminal strips, control house wiring, and panel terminal strips).

End-use Facilities

Consider additional research on impact to end-use facilities. It is crucial to know how loads will be impacted by an EMP as this affects recovery efforts. Knowing the nature and availability of load post EMP is crucial to any successful operations plan to restore the BPS.

Research Recommendation #3: Develop Industry Specifications for Equipment

Undertake efforts to design equipment specifications for the electric sector utility industry around EMP hardening and mitigation strategies.

Suggested Lead Organization(s) | IEEE and NERC

Support Organization(s) | DOE, DHS, DTRA, EPRI, National Labs, CIGRE

- Consider initiating work around EMP technical standards development with existing standards organizations such as IEEE, Underwriters Laboratories (UL), National Electrical Manufacturers Association (NEMA), etc. as it relates to commercial level specifications for equipment, maintenance, and installation.
- Assess the merit of implementing or adopting International Electrotechnical Commission (IEC) EMP specifications as they are not traditionally adopted by the electric utility industry.

Chapter 3: Vulnerability Assessments

Background

In its discussions, the EMP Task Force concluded that a number of knowledge gaps exist with regard to the electric utility industry's ability to conduct EMP vulnerability assessment. These gaps include the following:

- Limited access to unclassified EMP environments for the purposes of performing vulnerability assessment
- Lack of access to open-source or commercially available simulation tools that are needed to couple EMP environments into modern BPS infrastructure and to perform wide-area assessments
- Limited availability of BPS-connected electronic components test results needed to better understand component strength levels (damage thresholds)

In addition, there is absence of well-established methods, procedures, and modeling guidelines needed to conduct assessments. The EMP Task Force further determined that additional gaps exist with regard to research findings presented in publicly available literature as study conclusions vary extensively among technical reports, and thus, there continues to be considerable uncertainty in this area.

These knowledge gaps demonstrate that additional work is needed to improve understanding of the potential impacts of an EMP on the modern BPS and to inform EMP vulnerability assessments performed by the industry. As a result, measures to address the aforementioned gaps were identified by the EMP Task Force and presented in the following sections.

Vulnerability Assessments Considerations

The key vulnerability assessment considerations identified by the EMP Task Force include three recommendations that will impact the industry's ability to successfully perform EMP assessments:

- Vulnerability assessment Recommendation #1: Regular collaboration and coordination with Federal Government to procure and effectively disseminate information needed by industry
- Vulnerability assessment Recommendation #2: Development of EMP vulnerability assessment methods and guidelines
- Vulnerability assessment Recommendation #3: Development of guidelines to identify and prioritize hardening of critical assets

Vulnerability Assessments Recommendations

Vulnerability assessment Recommendation #1: Collaboration and Coordination with Federal Government

Consider maintaining an EMP Task Force within the ERO Enterprise Technical Committees to regularly coordinate and collaborate with governmental authorities to procure and effectively disseminate information needed by industry.

Suggested Lead Organization(s) | [NERC](#) and [DHS](#)

Potential Support Organization(s) | [DTRA](#), [FERC](#), [National Labs](#), [DOE](#), [Asset Owners](#)

- Collaborate with the DHS to obtain the recommended unclassified E1, E2, and E3 EMP environments (i.e., benchmark scenarios) that the industry needs to conduct vulnerability assessment on the BPS. This should be an outcome of the work under the March 26, 2019 EMP executive order. Unclassified EMP environments are expected to be released in March 2020.

- Consider establishing a clearinghouse for EMP study results and equipment test data for use by the industry to conduct EMP impact risk assessments. An objective would be to add new results and data as they become available. Another objective would be to establish an agreed upon/approved set of study results and data that the industry would use in its analyses and assessments.
- Sponsor or participate in inter-agency exercises when appropriate to contribute industry technical perspective and gain understanding of the needs of response planners

Vulnerability Assessment Recommendation #2: EMP Vulnerability Assessment Methods

The ERO Enterprise should develop tools and methods for system planners and equipment owners to use in assessing EMP impacts on the BPS.

Suggested Lead Organization | NERC

Potential Support Organization(s) | EPRI, DOE, DTRA, DHS, National Labs, Asset Owners, and System planners

Consider supporting the development of equipment vulnerability assessment tools and methods for the following:

- Enhancing industry response and mitigation to EMP threats
- Computing geomagnetically-induced current (GIC) flows resulting from E3 EMP

The intent of potential tools and methods are to evaluate the potential for equipment damage due to EMP-induced surges and to provide clear and concise direction to the industry on how to evaluate the potential for an EMP to cause voltage collapse and/or transformer thermal damage. Objectives would be to make available an open-source simulation tool for computing the transient voltages and currents that BPS equipment may be exposed to when subjected to EMP.

In addition, the following should be considered:

- Developing an application guide to provide the industry with best practices and realistic approaches for conducting EMP vulnerability assessment so that EMP impacts can be evaluated and factored into traditional power system planning studies. The guide needs to include theoretical background, modeling parameters, methods, and data considerations needed to perform EMP vulnerability assessments.
- Identifying potential unintended consequences of EMP hardening so that system reliability is not adversely affected.

Vulnerability Assessment Recommendation #3: Critical Assets Identification

Provide guidance to the industry on how to identify and prioritize hardening of assets that are needed to maintain and restore critical BPS operations.

Suggested Lead Organization(s) | NERC and Asset Owners

Potential Support Organization(s) | EPRI, DTRA, DHS, National Labs

- Consider developing a method for identifying critical assets for EMP mitigation solutions in planning, operations, and restoration. As an example, consider establishing criteria related to synchronous and non-synchronous resources and their unique roles in real-time operations and resilience as they have great flexibility in maintaining steady state voltage and reactive power on the BPS
- Develop guidance documents aimed at allowing utilities to identify components and infrastructure likely to be at risk of becoming degraded or failing outright as a consequence of an EMP event, therefore needing to be taken into account when developing system restoration plans

- Develop the range of acceptable response options cover the spectrum, from implementing a prescribed level of hardening for certain zones or particular assets (to avoid being disrupted) while strategically allowing disruptions in other zones subject to advance plans for timely post-event recovery

Chapter 4: Mitigation Guidelines

Background

There are various approaches to EMP mitigation. One approach is to harden individual components while another is to harden an entire facility and install unhardened components within the facility:

- There are EMP mitigation techniques used by the defense sector where facilities have been hardened. This has allowed many mission-critical defense sector installations the flexibility to purchase and obtain any kind of device or component for their applications. This approach seeks to eliminate the threat entirely by shielding the facility rather than hardening the components themselves.
- The electric utility industry often takes a different approach to resilience: historically, the industry has hardened its individual components, allowing flexibility to install them in virtually any environment.

Additional research and vulnerability assessments need to be completed on individual electric utility grade components to understand the gap in resilience. Once this is done, mitigation guidelines can be developed to instruct utilities on adjustments that may enhance system resiliency in a cost-effective manner.

Mitigation Considerations

The EMP Task Force acknowledges that research is continuing, and EPRI is currently conducting field trials in an effort to further study mitigations for utilities. Since the research is ongoing, the EMP Task Force is unable to endorse a particular mitigation strategy at this time for all stakeholders. Work should be done to better understand the EMP threat and identify next steps before specific mitigation strategies are recommended.

Mitigation Guidelines Recommendation

Mitigation Recommendation #1: Develop Guidance on EMP Mitigation

The ERO Enterprise should develop guidelines for industry to use in developing strategies for mitigating the effects of an EMP on the BPS (control centers/plant controls, substations, and power plants).

Suggested Lead Organization | [NERC](#)

Support Organization(s) | [Asset Owners](#), [EPRI](#), [DOE](#), [DTRA](#), [DHS](#), [National Labs](#)

BPS Mitigations (for E3 events)

Evaluate existing GMD mitigation strategies to identify synergies for EMP mitigations where applicable, such as the following:

- Voltage collapse
- Impacts to generation transformers
- Evaluating appropriateness and effectiveness for GIC blocking device applications
- Assessment steps for avoiding unintended consequences
- Protection system Misoperation
- Impact to generator resources

Control Center and Plant Control Room Mitigation (E1 and E2 events)

- Consider developing guidelines for operators of the BPS to mitigate the effects of E1 EMP on components supporting Real-time operations to ensure sufficient monitoring and control of the BPS is achieved to meet the performance expectations established from [Policy Recommendation #1](#).
- Control Facility mitigation guidelines should encompass a wide range of items:
 - Ride through (hardening) versus recovery (sparing) of systems/components
 - Control rooms, associated data centers/ energy management system/generation control systems servers, and associated ancillary vital building equipment uninterruptible power supply, on site generation, mechanical electrical plumbing (MEP) systems etc.)
 - Communication and supervisory control and data acquisition (SCADA) infrastructure used for data and voice needed for control facility BPS operation
- Consideration should be given to the development of recommendations for both retrofitting Control Centers and Plant Control Rooms as well as best practices for new installations.

Substation and Power Plant Equipment Mitigation (E1 and E2 events)

- Consider to what extent mitigations identified by EPRI and others would be included in future guidance.
- Consider unique mitigations associated with generating resources and ancillary equipment:
 - Environmental/Emissions control;
 - Instrument and Control (I&C) systems
 - Water/Wastewater control systems
- Consider developing best practices to help Asset Owners design and build transmission and generation installations.
- Consider assessing the practicality of retrofitting existing substation and power plant equipment versus replacement.

Chapter 5: Response and Recovery

Background

An EMP event can potentially cause a voltage collapse resulting in separation, islanding, or blackout of the system where all or a significant portion of the bulk transmission and distribution system is de-energized but may still be tied together through closed breakers.

This chapter describes high-level strategies to be employed during the recovery and restoration from such an event, including minimum criteria for meeting the objectives of a recovery plan. With the guidance of the entities' Reliability Coordinators, and after assessing the status of the grid within its area, system operators will use their blackstart strategies to facilitate restoring their systems.

Response and Recovery Considerations

Restoration following a disturbance resulting from an EMP event is expected to be significantly more challenging and lengthy than prior industry restoration experiences. An EMP event has the likelihood to leave unhardened protection and control systems in an unknown and potentially damaged state, whether energized or not. Additionally, there is a greater likelihood that portions of unhardened load and generation will be damaged and unavailable to aid in restoring the system. The effects of an EMP can disrupt the atmosphere, rendering even protected microwave and satellite communications inoperable for several hours. Restoration following an EMP event will require significantly more validation to confirm proper functioning of protection and control systems to ensure public safety and reliability during recovery and restoration. Damage to other systems, including communications and transportation systems, and other widespread societal impacts may further complicate and delay restoration following an EMP event.

The essential elements of performing a system restoration following an EMP event are similar to a non-EMP restoration; however, each will be more challenging as noted above. These essential elements include the following:

- Establishing communications (externally with RC, TOP, BA, TOs, GOs, etc., and internally with management, employees, and contractors)
- Assessing system status and equipment conditions and identify damage
- Performing restoration (bottom up via blackstart and/or top down with external assistance)

This section provides recommendations intended to aid in developing effective response and recovery strategies for an EMP event.

Response and Recovery Recommendations

Response and Recovery Recommendation #1: Establish National EMP Notification System

The ERO Enterprise should consider partnering with the appropriate agencies to develop a real-time national notification system for the electric sector to System Operators and Plant Operators pertaining to an EMP event and its parameters.

Suggested Lead Organization(s) | [NERC, DHS, and FEMA](#)

Potential Support Organization(s) | [DOE and USGS](#)

- Consider establishing an early warning threat system as it pertains to the probability of an attack from a foreign threat. This would be analogous to the DHS Terrorism Advisory System or the FEMA National Warning

System (NAWAS). This item includes establishing a warning protocol to grid operators to take action if an EMP is imminent.

- Consider developing a notification system protocol to inform system operators and plant operators immediately after an EMP event has occurred. Knowledge of an event and its location will greatly aid those who have the capability to dispatch personnel to look for damaged equipment in substations or within a plant and will expedite the recovery.
- Consider using the DOE notification system established by the 2015 FAST Act where “a malicious act using electronic communication or an electromagnetic pulse” is already defined as a grid security emergency¹² where System Operators and Plant Operators can be immediately warned or notified after a nuclear missile launch or an EMP has occurred. Knowledge of a pending or actual EMP event and its location will greatly aid and expedite system recovery for those who have the capability to dispatch personnel to prepare the BPS for an EMP event or look for damaged equipment in substations or within a plant after an EMP event.

Response and Recovery Recommendation #2: Coordinated Response Planning

Develop response planning guidelines for electric utility industry members for pre and post-contingency of an EMP event that aligns with the DHS and FEMA.

Suggested Lead Organization | NERC

Potential Support Organization(s) | DHS, FEMA, DOE, Asset Owners and Operators

Defining the criteria for EMP response planning in alignment with DHS and FEMA emergency response planning efforts:

- To ensure aligned expectations across community sectors and responders
- To align electric utility industry and personnel with DHS and FEMA recommendations

Response and Recovery Recommendation #3: Enhance Operating Procedures

Work with industry to develop criteria to incorporate into operating plans and procedures and system restoration plans pertaining to EMP event.

Suggested Lead Organization | NERC

Potential Support Organization(s) | EPRI, DHS, DTRA, National Labs, DOE, Asset Owners and Operators

- Work with industry to develop guidance that can be incorporated into operating procedures on actions that should be taken by grid operators if advance warning of an EMP event is known—in order to lessen the EMP impact:
 - Depending on available time horizon, actions to consider include invoking conservative operations (*e.g.*, returning out of service equipment, carrying additional reserves, and ensuring a distributed generation profile) and possibly disconnecting assets and ensuring certain generation is off-line
 - Guidance should also address aspects, such as securing and protecting supporting equipment and spares (such as relay settings and test equipment) that will be needed in event recovery as well as notification and mobilization of personnel
- Work with industry to develop guidance on how to enhance system operator training and operating procedures to aid system operators in recognizing an EMP event and provide direction that should be taken

¹² See *Fixing America's Surface Transportation Act*, Pub. L. No. 114-94, § 61,003, 129 Stat. 1312, 1773-1779 (2015) (codified at 16 U.S.C. 8240-1) (FAST Act).

by operators during and after to lessen an EMP impact. Training should include transmission system vulnerabilities, vulnerabilities of RTU's and protection system components.

- Work with industry to develop guidance on how to enhance generator operator and plant operator training and plant procedures to aid generation personnel in recognizing an EMP event and provide direction that should be taken by generator operators and plant operators during and after to lessen an EMP impact. Training should include generating unit vulnerabilities, vulnerabilities of instrument and control systems, protection systems, and environmental control components.
- Work with industry to develop guidance on elements to add to revised system restoration plans (SRPs) related to an EMP event. Examples include steps to address anticipated communications difficulties, actions to confirm functioning protection and control equipment, adjustments to SRPs to prioritize hardened blackstart units, cranking paths, and other assets, and adjustments to account for load uncertainty.

Response and Recovery Recommendation #4: Incorporate EMP Events into Industry Exercises and Training

Develop training for system and plant operators about EMP events and what to anticipate and incorporate EMP events in industry exercises to test response planning and system restoration recovery efforts.

Lead Organization | NERC

Potential Support Organization(s) | Asset Owners, ISO and RTOs, FEMA, DHS

- Develop an industrywide shared understanding to explain an EMP event. This includes standardized operator awareness training for the industry to explain an EMP event, the impact of an EMP on the electric system, what operators in control rooms might experience, and unique challenges operators will face in restoration following an EMP event.
- Consider developing and hosting EMP event exercises around hazard simulation as it relates to DHS efforts under the Executive Order.
- Consider EMP risk and mitigation actions as regular topics of discussion at NERC-hosted security and reliability conferences and workshops, such as GridSecCon, technical committee meetings, and other events.

Response and Recovery Recommendation #5: Strategies for Supporting Recovery

The ERO Enterprise should provide guidance to industry for supporting systems and equipment (including spare equipment strategy) needed for BPS recovery post-EMP event.

Lead Organization | NERC

Potential Support Organization(s) | Asset Owners and Operators, RTOs/ISOs, FEMA, DHS

To support effective recovery from an EMP event, industry must ensure needed personnel and equipment will be available. To this end, industry should develop best practices for the following:

- Communication mechanisms are in place to mobilize employees not at work.
- Communications mechanisms are in place to communicate with field personnel and to contact local emergency agencies.
- Identification of the recovery data and information that is needed post EMP is completed.
- Relay settings are stored in a hardened asset and protection and control test and setting equipment is protected.

- Needed company critical information, including personnel contacts and procedures and required spares, are housed in a hardened asset.
- Plans are in place for housing and feeding employees involved in the recovery effort.
- Vehicles and transportation will be available.

Chapter 6: Conclusion and Next Steps

Given the complex nature of addressing the risks associated with an EMP event, many of the recommendations outlined in this report are interrelated. The timing and sequencing of the next steps for industry are contingent on many of the policy items highlighted to be addressed outside of the electric sector or outside of the ERO Enterprise.

Challenges to Moving Forward

Clear expectations must be defined with regard to the acceptable levels of performance for the BPS for a pre-defined EMP event. NERC should take the lead on identifying and communicating these expectations with industry stakeholders. In tandem, progress on the following items will enable industry to prepare and understand the breadth of an EMP threat:

- Industry must be provided access to classified data, and there must be some level of declassification in order to share the appropriate information with stakeholders.
- A federal cost recovery mechanism must be identified for implementing EMP mitigation.
- Research should continue on any identified gaps in EMP knowledge and mitigation strategy.
- Effective EMP mitigation for the electric infrastructure requires the development of guidance (on technical issues, policy, and rate recovery) across multiple jurisdictions (state, federal, and different regulatory authorities/agencies), and
- The development and enhancement of tools and methods for assessing the vulnerabilities of the BPS to EMPs is required.

The EMP Task Force acknowledges that resolving some of these items are outside the authority of the ERO Enterprise, though the organization can influence directions. The EMP Task Force also acknowledges that some of these items are unable to be addressed by a single entity/governmental authority. Nevertheless, work must advance in these areas to support effective EMP mitigation strategies.

Next Steps

The EMP Task Force should be maintained in order to monitor, inform, and facilitate any further actions stemming from the recommendations listed in this report. Due to the magnitude of this threat and the numerous items detailed in this report, membership on the EMP Task Force should be expanded, and the NERC technical committees should commence most, if not all, of the initiatives for research, vulnerability assessment, mitigation guidelines, and the items listed for response and recovery. In addition, NERC will continue to work with the DOE and EPRI to clearly understand EMPs, their effective mitigations, and the proper ways to engage industry.

Chapter 7: EMP Task Force Roster

Chair	Aaron Shaw	AEP
Vice-Chair	Rey Ramos	Southern Company
Members	John Babik	JEA
	Kenneth Braerman	Exelon Corporation
	Brian Evans-Mongeon	Utility Services
	Barry Gustafson	Xcel Energy
	Jason Marshall	Wabash Valley Power Association
	Arun Narang	Hydro One
	Thomas Popik	Resilient Societies
	Joe Sowell	GTC
	John Stephens	City Utilities
	Micah Till	Dominion Energy
	Randy Crissman	NYPA