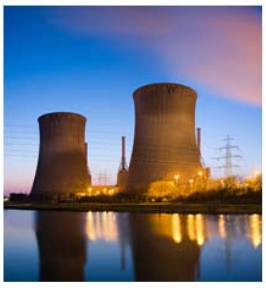
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

ERO Reliability Risk Priorities

RISC Recommendations to the NERC Board of Trustees

November 2016

RELIABILITY | ACCOUNTABILITY

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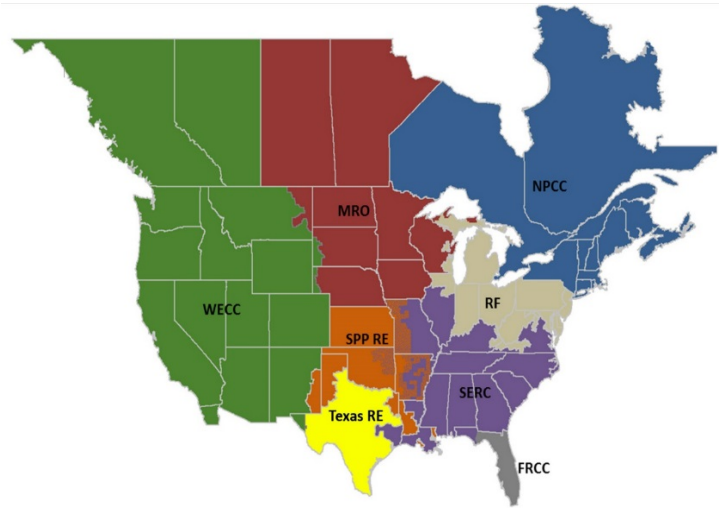
Preface

The North American Electric Reliability Corporation (NERC) is a not-for-profit international regulatory authority whose mission is to assure the reliability of the bulk power system (BPS) in North America. NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the BPS through system awareness; and educates, trains, and certifies industry personnel. NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico. NERC is the electric reliability organization (ERO) for North America, subject to oversight by the Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada. NERC's jurisdiction includes users, owners, and operators of the BPS, which serves more than 334 million people.

The North American BPS is divided into eight Regional Entity (RE) boundaries as shown in the map and corresponding table below.



FRCC	Florida Reliability Coordinating Council
MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
SPP RE	Southwest Power Pool Regional Entity
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

The Reliability Issues Steering Committee (RISC) is an advisory committee to the NERC Board of Trustees (Board). The RISC provides key insights, priorities, and high-level leadership for issues of strategic importance to BPS reliability. The RISC advises the Board, NERC standing committees, NERC staff, regulators, REs, and industry stakeholders to establish a common understanding of the scope, priority, and goals for the development of solutions to address emerging reliability issues. The RISC provides guidance to the ERO Enterprise and the industry to effectively focus resources on the critical issues to improve the reliability of the BPS.

This 2016 report presents the results of the RISC's continued work to strategically define and prioritize risks to the reliable operation of the BPS and thereby provide recommendations to the Board regarding the approach that NERC should take to enhance reliability and manage those risks.

Chapter 1: Background and Introduction

Background

This 2016 annual report documents the results of the RISC's continued work to identify key risks to the reliable operation of the BPS. This report proposes relative priorities and management effort pacing and provides input to the Board on recommended actions.

The RISC's obligations are based on the NERC Board's resolutions on the initial 2013 recommendations:

> *RESOLVED, that the Board hereby accepts the report of the Reliability Issues Steering Committee (RISC), expresses its appreciation to the RISC for the excellent report, and endorses continued work by the RISC on a gap analysis on the high-priority and then the medium-priority issues and requests continued reports to the Board.*
>
> *FURTHER RESOLVED, that the Board hereby directs NERC management to continue to work with the RISC to consider how the priority rankings should be reflected in the development of the ERO's business plan and in the work plans of NERC committees.*
>
> *FURTHER RESOLVED, the Board hereby directs NERC management to work with the RISC and, as appropriate, NERC committee leadership to consider how NERC should utilize a data-driven reliability strategy development process that integrates with budget development and overall ERO planning (e.g., Standing Committee planning, department, and employee goal-setting).*

There are important links between the risk priorities and the recommended actions for the ERO Enterprise and industry. The RISC acknowledges and appreciates the increased reliance of the NERC Board and ERO Enterprise leadership on this report as an input for the ERO's multiyear Strategic Plan and its Business Plan and Budget.

The RISC participants include representatives from the NERC standing committees, the Member Representatives Committee (MRC), and "at large" industry executives. The observations, findings, and guidance presented in this report include input from industry forums, trade associations, and other industry groups. RISC also received feedback through policy input to the NERC Board of Trustees and an industry webinar.

The 2016 report builds on the comprehensive initial assessment of ongoing efforts and corresponding recommendations to the Board made in February 2013, which have been updated and refined annually. This report and recommendations reflect discussions with representatives from technical and standards committees, industry dialogue through a series of focused executive leadership interviews, the FERC Reliability Technical Conference, and technical reports and assessments. These results were presented to the ERO executive management group for integration in the development of the 2017–2020 ERO Enterprise Strategic Plan. The final report will be presented to the Board in November 2016.

Introduction

The RISC has carefully reviewed numerous inputs on BPS reliability from various stakeholders, and this report reflects the top priorities of the industry leadership represented on the committee. The RISC reviewed and assembled information from ERO Enterprise[1] stakeholders, policy makers,[2] and focused executive leadership interviews to develop a composite set of risk profiles and a graphic depiction of the key risks to the system. The

[1] ERO Enterprise is interpreted to mean NERC, the Regional Entities, and the necessary technical committees.

[2] Policy makers is interpreted to mean any entity that can impact the legal or regulatory framework in place at various levels, including local, state, federal, and provincial governmental authorities in addition to various trades and lobbying organizations.

depiction presents the likelihood of occurrence, the expected impact on reliability, and the trajectory of the associated risks.

The individual risk profiles have been categorized as High, Moderate, or Low. High-risk profiles present not only a possible severe impact on reliability but also a level of uncertainty. The High risks are evolving and the likely impact and necessary mitigation are often less clear. Thus, High risks require a larger amount of industry attention and resource focus to better understand and address impacts to the system. Moderate risks still represent a large potential impact to the BPS, but there is consensus that the industry understands the risk and necessary steps to improve reliability. Low risks do not mean that possible reliability impact is small, but rather the profiles are understood with clearly identifiable steps that can be taken to manage risk. Thus, even risks that are well understood and have measures in place for risk mitigation are included as risk profiles because the industry must remain vigilant in addressing these Lower or Moderate risks in order to prevent the profiles from being escalated higher.

A Low or Moderate ranking in this report does not mean the risk covered in the profile is not a threat to the system. These risks still require monitoring and action to mitigate or reduce the likelihood of instability, uncontrolled separation, or cascading outages that adversely impact the reliability of the BPS. Accordingly, the risk profiles were categorized as follows:

High Risk Profiles

- Cybersecurity Vulnerabilities
- Changing Resource Mix
- BPS Planning
- Resource Adequacy

Moderate Risk Profiles

- Loss of Situational Awareness
- Physical Security Vulnerabilities
- Extreme Natural Events

Low Risk Profiles

- Asset Management and Maintenance
- Human Performance and Skilled Workforce

Format of the Report and Method of Analysis

A majority of this report is comprised of risk profiles that detail the evolving status and mitigation efforts to address each specific risk. These profiles outline a summary of the risks and the potential impact to the BPS. Through the profiles, the RISC recommends activities to manage the risks in the near-term, mid-term, and long-term. The ERO Enterprise and industry can use the composite risk profiles and the risk map for baseline and recurring evaluation of reliability risks.

Where appropriate, the RISC identified the group or entity that should take mitigating action; however, some recommendations did not present a clear owner or responsible party. In these cases, the recommendation is presented as a more generalized action item that can apply to numerous entities, including policy makers, industry, and the various organizations in the ERO Enterprise.

The primary objective of this report is to highlight risks that merit a continued level of attention and recommended actions that align with the multidimensional aspects of the risk. This report differs from other ERO reports, such as the annual *State of Reliability,* in that it is forward-looking view of the BPS. The *State of Reliability* reviews data from previous years to draw objective conclusions.

Additionally, the committee evaluated risks based on impact to the BPS regardless of the source of the risk. In order to evaluate key risks to the system, the committee had to recognize various emerging issues in different areas of the grid and resources such as distributed energy resources. Operators and planners of the BPS are aware of the need to have a wide-area view to provide an understanding of external conditions that can affect them; therefore, the profiles note several risks where the BPS can be impacted at interfaces (*e.g.,* distributed resources, gas delivery, telecom, etc.). RISC determined it is important to shine a light on external factors that increase BPS risk and offered recommendations to address them. Given the changing nature of the system and acceleration of integrating distributed energy resources, the RISC is obligated to raise areas of concern since impacts from distributed resources may require mitigations at the BPS level.

Other inputs to the Risk Profiles

FERC Technical Conference

On June 1, 2016, FERC conducted a commissioner-led technical conference on reliability. The purpose of the conference was to discuss policy issues related to the reliability of the BPS. As part of its review of emerging risks to the reliable operation of the BPS, RISC used the inputs and active discussions at this conference to supplement its development of the risk profiles. The technical conference addressed three main topics: the 2016 State of Reliability, Emerging Issues, and Grid Security. These topics were addressed in four panel sessions:

- The first panel focused on the **2016 State of Reliability.** The participants of this panel affirmed several of the risks identified by the RISC. The panelist identified the most significant risks to the BPS as coordinated physical attacks on the system, interdependencies from other industries, extreme weather events, gas dependency, adequacy of models (past N-1), and aging infrastructure. This panel also highlighted necessary actions to address the adequacy and modeling of the distribution system. Panelists discussed the need for better modeling and increased visibility of the system. In addition, panelists noted a need to identify the difference between the distribution and transmission operator responsibilities.
- The second topic, **Emerging Issues,** was divided into two panels. The first panel provided an international perspective to the grid's emerging issues, and panelists from the European Union and Mexico added several perspectives. Market features were discussed that could improve reliability, such as protocols for buying capacity and markets designed around a reliability objective. The second panel continued the first panel's discussion on emerging trends and risks, but concentrated the discussion on distributed resources, vulnerability to natural gas fuel deliverability, and microgrids. The rapid acceleration of the changing resource mix and need to identity metrics around essential reliability services (ERS) was discussed. Additionally, the reliability concerns from the Aliso Canyon natural gas leak exemplified the challenges in the West. This panel stressed the need for better planning and the need for flexibility in order to mitigate risks from the changing resource mix.
- The final panel, addressing **Grid Security,** highlighted the need to share threat information and to support industry coordination. In addition, the need to develop a culture of cyber-awareness among the workforce was identified along with the suggestion the industry could invest in neutral ground-blocking devices.

Pulse Point Interviews

In order to expand the consideration of potential reliability risks from a strategic perspective, the RISC conducted one-on-one interviews with key industry executives and leaders to gain their insight. The goal was to focus on important reliability risks from different vantage points among regulators and utilities and to ensure that key areas

of reliability concern and relevant priorities were adequately identified for consideration by the RISC. A summary of these interviews are described below.

Several interviews validated the concerns presented in the risk profiles. The profiles of Changing Resource Mix and Cybersecurity Vulnerabilities were the most common themes in all of the interviews. In addition, several industry executives voiced concerns over fuel dependency and the greater reliance on natural gas. Many utilities commented that natural gas currently serves as the baseload fuel for their areas, heightening the need for greater focus on gas infrastructure in order to identify potential risks to the BPS.

Although several industry leaders acknowledged that NERC has no jurisdiction over markets, there is a growing concern that the existing markets do not accurately reflect products necessary to support the new resources being integrated today. For example, several markets may not include ancillary services necessary to support reliability when relying on more distributed resources. Several executives also expressed concern over the current rate structure where large investments to augment or maintain the system are precluded.

A continued theme from 2015 is some leaders are concerned about a workforce shortage, such as protection and control engineers. The aging workforce has been a consistent theme throughout the years, and some leaders provided support for continuing to monitor this risk.

A few leaders encouraged the ERO to place a stronger emphasis on the electro-magnetic pulse (EMP) threat, particularly with high altitude devices capable of causing widespread outages. Also one leader suggested changing the focus to constructing a more resilient distribution system to support reliability as more renewables and other resources are being added to the distribution system.

The following list identifies recommendations provided during the pulse point interviews. Policy makers should recognize the need to support the costs needed to manage, operate, and maintain system assets as these activities are part of an organization's ability to maintain and improve system performance and the reliable operation of the power system.

- The industry and the ERO Enterprise should collect more detailed data from larger areas ("bigger data") to support better analytics and larger studies.
- The industry should consider updating studies and not rely on just N-1 scenarios. This may entail fully studying the distribution system.
- RTOs/ISOs should consider studies beyond three years out in order to assess certain reliability needs.
- Expedite research and development to bring advancements to market sooner, specifically fuel and energy storage and fuel cell technology.
- Entities should have a clear communication protocol both internally and externally in the event of coordinated attacks or coincident events.
- Entities should begin considering how to build a new generation of back-up systems for natural disasters and extreme events.
- The industry must expand or introduce a true "security culture" to small electric utilities.
- The industry should collaborate on a common software platform for distribution management systems.

Focus Areas and Recommendations from the Risk Profiles

Outlined here are the highest priority focus areas identified in the 2016 risk profiles. Concentrated effort by the Industry on these areas, as well as inclusion of goals within the ERO Strategic Plan and the associated Business Plan and Budget, should improve BPS reliability. Additional detail can be found in the associated Risk Profiles.

Cybersecurity Vulnerabilities (Risk Profile #9)

- The ERO Enterprise and the industry should adopt a nimble, multipronged approach to address the continually evolving cybersecurity threat. Examples of nimble tools include increased Electricity information sharing and analysis centers (E-ISAC) participation and products, peer reviews and assistance visits to move to a best-practice model, and guides and recommendations for new and less-defined threats.
- The E-ISAC, the Telecommunications, and Natural Gas Information Sharing and Analysis Centers should enhance communications. Expand the use, availability, and value of cybersecurity threat and vulnerability information sharing, analytics, and analysis.
- The ERO Enterprise and all utilities should foster development of a security culture among their employees.

Changing Resource Mix (Risk Profile #1)

- The ERO Enterprise should:
  - Assess the risks associated with single points of disruption of natural gas as well as the uncertainty of supply.
  - Use special assessments and studies to inform and educate policy makers, regulators, and the industry of reliability effects and interconnection requirements.
  - Gather data and insights on distributed energy resources in an effort to improve visibility, predictability, and the dispatchability needed to support BPS reliability.
  - Continue to provide independent technical assessments on reliability issues stemming from proposed regulatory rules or statutes as well as any significant tariff rules related to the changing resource mix.
  - Further develop lessons learned based on operational experience with variable energy and distributed energy resources.
- To address the impact on ERS, NERC should benchmark and support technical studies on frequency and inertia response, voltage support, short-circuit analysis, and inter-area oscillations.

BPS Planning (Risk Profile #2)

- The ERO Enterprise should:
  - Coordinate with the industry, manufacturers and developers of asynchronous resources to develop and make available accurate dynamic models.
  - Identify the type and frequency of information needed from distributed energy resources.
  - Create guidelines and best practices for developing and maintaining accurate system, dynamic and electromagnetic models that include transmission, resources, load, and controllable devices for use in long-term and operational planning.
  - Continue to assess ERS performance to develop necessary guidelines and to determine if Reliability Standards are required.

- NERC should continue to collaborate with Planning Coordinators to expand development of interconnection-wide models commensurate with expected dispatches. This collaboration will support the ability to conduct more effective long-term planning assessments.

Resource Adequacy and Performance (Risk Profile #3)

- The ERO Enterprise should:
  - Continue to improve modeling and probabilistic methods with industry to evaluate resource adequacy to include impacts from ERS, unit retirements, and load and resource variability during different time frames (including shoulder months).
  - Assess and develop mitigation recommendations to address single points of disruption, such as fuel contingencies, that will result in large resource outages.
  - Develop new measures of reliability beyond reserve margins, including the sufficiency of ERS.
  - Continue to assess vulnerabilities of fuel availability as part of evaluating resource adequacy and operational capability.
- The industry should evaluate opportunities to develop more accurate short-term load forecast models.
- Analyze data requirements necessary to ensure there is sufficient detail on the capability and performance of the BPS as it is impacted by distributed energy resources. The industry should gather data beyond simple demand forecasts and expand to identify resource capacity, location, and ERS capability.

Themes and Takeaways from the Risk Profiles

In drafting the 2016 risk profiles, no new major risk profiles have been identified. However, several key themes from the profiles show where industry attention is needed.

Resilience and Recovery

Resilience and recovery actions can mitigate exposure from multiple risks. This is particularly important as threats to electric industry infrastructure from cyber and physical attacks are expected to increase, and customers and regulators have increasing expectations on the continuity of electric service. While this report addresses ways to address specific risks, not all possible risks can be anticipated or mitigated. Efforts and resources expended on resilience and recovery can address a wide range of risks and can also limit the extent of extreme or low-likelihood incidents. Resilience assessments in the planning and operating processes should be pursued to support BPS reliability. This was identified as a key recommendation during the 2015 Leadership Summit.

Part of the RISC's role is to identify trends and evolving issues that have the potential to degrade reliability so that actions based on sound technical judgment can be taken. As the character and reliability behavior of the BPS evolves, a wide range of reliability or resilience tools should be identified to guide industry, regulators, and the ERO in effectively managing these risks. The industry must improve forward assessments of reliability and identify resilience activities that anticipate changes.

Key points on resiliency and recovery include:

- In 2015, the top 10 most severe events were related to weather.[3] The ERO Enterprise, the impacted organizations, and the respective forums and trade organizations should perform post-event reviews to capture lessons learned and how to reduce the impact of future events.

[3] See the *State of Reliability* report.

- While the industry operates to the next worse contingency, the industry should be aggressive in identifying single points of vulnerability.
- Continue to leverage the North American Generator Forum (NAGF), North American Transmission Forum (NATF), Electric Power Research Institute (EPRI), and other industry-practice-sharing forums to enhance resilience and recovery.
- Leverage data sources such as event analysis, near miss databases, the Transmission Availability Data System (TADS), the Generating Availability Data System (GADS), the Demand Response Availability Data System (DADS), relay misoperations, EOP-004/OE-417 reports, and ac equipment failures to identify patterns and risks.
- Highlight applicable metrics in the *State of Reliability* report as benchmarks for resilience and recovery.
- Continue to include resilience goals in the ERO Enterprise's Strategic Plan.

The ERO Enterprise must have a complete understanding of the changing nature of, and associated risks to, the BPS. This includes a more comprehensive analysis of the BPS using NERC's special assessments. Further, markets and other tariffs will influence the changing nature of the reliability behavior of the power system and can provide the full complement of services required for the continued reliable operations of the BPS. The work on ERS is vital to understand the minimum requirements surrounding frequency response, voltage, and ramping resulting from the acceleration of the changing resource mix.

Adequate Data Visibility

Data is needed to understand the performance of and risks to the BPS. This includes information regarding distributed energy resources. Several profiles recommend the ERO Enterprise and industry use "bigger data" from multiple sources and larger areas to identify and manage risks. It is imperative that data requirements also include: 1) the data needed from distributed energy resources, including any necessary aggregated forms of data; 2) the entities should provide the data to system operators and planners; 3) logistics for how the data will be exchanged; 4) the frequency of the data updates; and 5) security and confidentiality measures for protecting necessary data.

Accurate Models

Since the rate of change of the resource mix is increasing, planners will place more emphasis on interconnection-wide studies that require improvement to and integration of regional models. In addition, enhancements to models will be needed to support probabilistic analysis to accommodate the energy limitations of resource additions (such as variable renewable resources). Resource adequacy must look beyond the calculation of reserve margins which assume actual capacity available during peak hours. More comprehensive dynamic load models will also be needed. One of the ways in which the industry can understand the system is by monitoring load characteristics and its changing nature due to distributed.

Natural Gas Deliverability

One common underlying risk that can be tied to multiple profiles is the increased use of just-in-time fuel delivery. More specifically, several profiles identify challenges from the single points of failure caused by the increased penetration of natural gas as a base load fuel. Natural gas deliverability and its impact on reliability must be fully studied to identify necessary mitigation strategies, including market, infrastructure, or regulatory solutions. The increased dependency on natural gas as a predominant fuel source presents challenges in real-time to system operators, and situational awareness must now include gas sources, pipeline, and deliverability concerns. Further, any cyber or physical attack on a pipeline highlights the need for increased coordination among pertinent information sharing and analysis centers (ISACs) and the industry to improve response and recovery times due to the interdependency of the gas and electric system. The ability to model and address fuel limitations or shortages in BPS planning is a critical part of system planning. Therefore, there is a need for improved models as well as required data and information to support this planning to ensure the continued reliable operation of the BPS.

Spare Equipment Strategy

Asset management, physical security, and extreme events highlight a need to maintain a focus on a spare equipment strategy. This strategy should encompass identifying critical spare equipment as part of a national or regional inventory. The strategy should also account for the transportation/logistics requirements for replacing critical assets. An improved spare equipment strategy or plan will lead to better planning and possibly faster response times for restoration and recovery.

Chapter 2: Discussion of Reliability Risks

NERC should continue to collaborate with Planning Coordinators to expand development of interconnection-wide models commensurate with expected dispatches. This collaboration will support the ability to conduct more effective long-term planning assessments.

Legend Guide to Figure 2.1

The solid numbered circles in the heat map denote the current state for each risk area, and they are mapped against likelihood and impact scales. The risk trend represents where the committee views the risk to be trending in the near future.

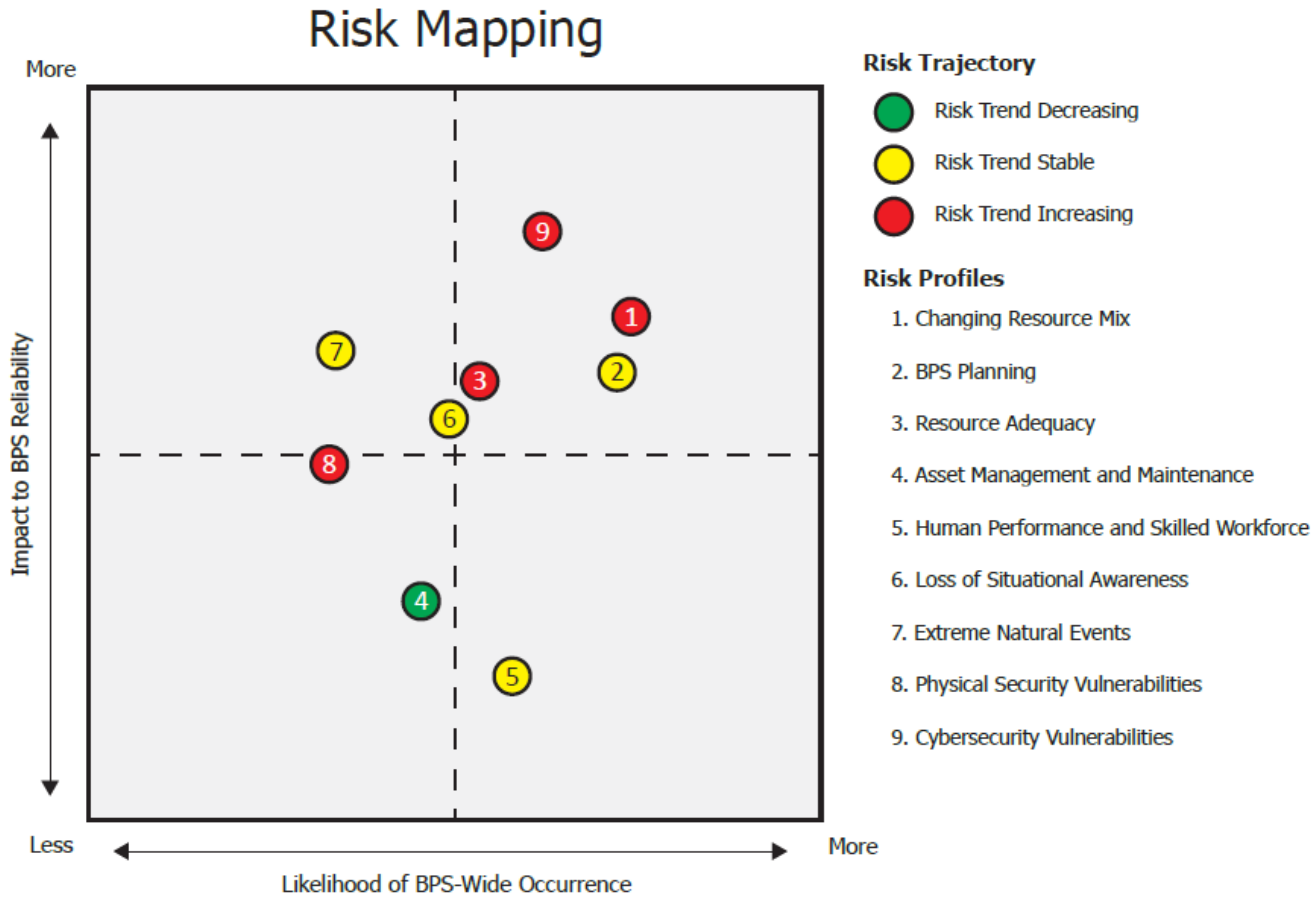


Figure 2.1: Risk Map of ERO Risk Profiles

Risk Groupings

This report provides a framework to categorize risks as High, Moderate, or Low. A Low ranking does not indicate that the risk covered in the profile is not a threat to the system; risks with Low or Moderate rankings still require industry action to reduce the likelihood of instability, uncontrolled separation, or cascading outages that adversely impact the Bulk Electric System. Regardless of the ranking or classification, all risk profiles warrant attention as the rapidly changing BPS can quickly raise the risk. High risks were based on the committee's sense of urgency or where industry focus was needed to fully understand the risks.

High Priority Risks:

- **Cybersecurity Vulnerability**: This risk profile is considered a High risk due to the increasing need for protection against a cyberattack. Cyber threats are becoming more sophisticated and increasing in number. Exploitation of cybersecurity vulnerabilities can potentially result in loss of control or damage to BPS-related voice communications, data, monitoring, protection and control systems, or tools. A cyber-attack can lead to equipment damage, degradation of reliable operations, and loss of load. Further, cybersecurity vulnerabilities can come from several sources, both internal and external, and in some instances the utility may have its cybersecurity fully tested.
- **Changing Resource Mix:** The 2015 risk profile on Regulatory Uncertainty was retired as most of the focus has transitioned to the specifics regarding the changing resource mix. The rapid rate at which fuel costs, subsidies, and federal, state, and provincial policies are affecting the resource mix are creating a new paradigm in which planners, balancing authorities, and system operators are reacting to resource additions and retirements. Further, the integration of new technologies and distributed energy resources are affecting the availability of as well as the ability of operators to see and control resources within their area.
- **Bulk-Power System Planning:** The two planning profiles from 2015 (Ineffective Planning Coordination and Ineffective Resource Planning) were combined into one profile. BPS planning is a risk closely tied to the changing resource mix because planners currently lack the ability to update or create system models and scenarios of potential future states to identify system needs based on the dynamic nature of the system. This changing system makes it increasingly difficult to evaluate BPS stability, including inertia and frequency response, voltage support (adequate dynamic and static reactive compensation), and ramping constraints.
- **Resource Adequacy and Performance:** With the acceleration of the changing resource mix, the risk profile on Generator Unavailability was revamped to include all resources and associated adequacy performance issues. Changes in the generation resource mix and new technologies are altering the operational characteristics of the grid and will challenge system planners and operators to maintain reliability in real time. Failure to take into account these changing characteristics and capabilities can lead to insufficient capacity and ERS to meet customer demands.

Moderate Priority Risks:

- **Loss of Situational Awareness**: This profile expands the profile from 2015 to encompass more than energy management system (EMS) outages. This profile also explains that the loss of situational awareness can be a precursor or contributor to a BPS event. It also highlights emerging challenges with visibility into distributed energy resource impacts on the grid. Loss of situational awareness due to insufficient communication and data regarding neighboring entities' operations is a risk as operators may act on incomplete information.
- **Extreme Natural Events:** Severe weather or other natural events (e.g., hurricanes, tornadoes, protracted extreme temperatures, geomagnetic disturbances (GMDs), floods, earthquakes, etc.) are some of the

leading causes of outages, and the industry must remain vigilant in improving preparation and coordination in order to minimize the effect of such events.

- **Physical Security Vulnerabilities**: Like cybersecurity, there is an increasing and evolving threat profile from physical attacks. Intentional damage, destruction, or disruption to facilities can potentially cause localized to extensive interconnection-wide BPS disruption for an extended period.

Low Priority Risks:

- **Asset Management and Maintenance:** The profile from 2015 on Protection Systems and Single Points of Failure was folded into the Asset Management and Maintenance and the Human Performance profile below. The failure to properly commission, operate, maintain, prudently replace, and upgrade BPS assets generally could result in more frequent and wider-spread outages, and these could be initiated or exacerbated by equipment failures. This profile highlights the need for prudent and timely equipment replacement and sound management of complex protection systems to prevent or mitigate events.
- **Human Performance and Skilled Workforce:** The continued need for skilled workers, such as protection engineers, is needed to prevent both active and latent errors both of which negatively affect reliability.

Perspectives and Conclusions

The preceding summarizes the RISC's conclusions regarding key reliability risks and areas where NERC and the industry should focus to preserve reliability in 2017 and beyond. These observations and conclusions are supported by the collective expertise within the RISC as well as the other inputs outlined in the report. Overall, these inputs provide a strong foundation for the NERC Board of Trustees for consideration as an important input to ERO Strategic Plan as well as the Business Plan and Budget.

Chapter 3: Risk Profiles

Risk Profile #1: Changing Resource Mix

Statement of the Risk

The change to the resource mix is accelerating due to fuel costs, subsidies, and federal, state, and provincial policies. Transmission planners, Balancing Authorities, and system operators of the BPS may not always have sufficient time to develop and deploy plans to mitigate reliability considerations with various resource additions and retirements.

Level of Risk

High Priority

Descriptors of the Risk

1. The rate of change (penetration rates of certain resources) and the type of change (the specific resources) are influenced by economic factors in addition to state, provincial, and federal initiatives, which sometimes impact one region, province, or state more than another. Over time, regulatory initiatives, along with lower production costs, will likely alter the nature, investment needs, dispatch of generation considering the replacement of large rotating synchronous central-station generators with natural-gas-fired generation, renewable forms of asynchronous generation, demand response, storage, smart- and micro-grids, and other technologies. Planners and operators may not have the requisite time to reliably integrate these inputs and make necessary changes.
2. The ability of regulators and industry to foresee and address reliability issues associated with these changes to the resource mix is complicated by:
    a. The lack of ancillary services, such as the ERS (e.g., voltage control and reactive support, frequency response, ramping) on the BPS, which is exacerbated by the retirement of many large rotating synchronous central station generating units.
    b. The integration of large amounts of new resource technologies, distributed energy resources, and behind-the-meter resources; the lack of low-voltage ride through; inaccurate load data to accurately forecast anticipated demand; and the inability to observe and control distributed energy resources.
    c. The need for data and information about the character of resources in the planning, operational planning, and operating time horizons so the system can be planned and operated while accounting for the contributions and implications to reliability of all resources, regardless of their location or configuration.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise and industry should continue to conduct interconnection-wide technical studies, such as frequency and inertia response, voltage support, short-circuit analysis, inter-area oscillation assessments, and electric and gas dependency studies. Also, through a stakeholder outreach and input process, inform and educate policy makers and the industry of reliability effects and interconnection requirements for the changing resource mix.
2. The ERO Enterprise should develop an effective means to gather data and insights into distributed energy resources (i.e., customer, distribution, or otherwise), and formulate plans to achieve the appropriate level of transparency and control such that implications to the BPS can be better understood.

3. Expand the collaboration, through the technical committees, with the Regional Transmission Operators (RTO)/Independent System Operators (ISOs) Council, Balancing Authorities in non-RTO/ISO market areas, other registered entities, and regulators on ERS recommendations for effective implementation as they emerge.
4. The ERO Enterprise should continue to provide independent technical assessments of the reliability impacts from the changing resource mix driven by proposed state, provincial, or federal statues and transmission provider tariffs.

Mid-term (3–5 year time frame):

5. Policy makers should engage in high-level collaboration among market operators (RTOs/ISOs), balancing authorities in non-RTO/ISO market areas, and provinces and states to establish long-term strategies for aligning policies with reliability needs.

Long-term (greater than 5-year time frame):

6. The ERO Enterprise should continue working with industry stakeholders and policy makers on reliability attributes essential to support the long-term reliability of the BPS, including equipment controls that enable system support from variable energy resources, accommodating distributed energy resources such as small end-use customer resources, distributed energy resource performance, and synchronous generation retirements.

Risk Profile #2: Bulk-Power System Planning

Statement of the Risk

BPS planning is transitioning from centrally planned and constructed resources based on forecasted load growth and reliability projects to more reactive, rather than proactive, planning based on the integration of new resources and technologies driven by policies and incentives. Due to the lack of visibility, certainty, and speed that these resources are being integrated in some areas, planners currently may lack the ability to update or create system models and scenarios of potential future states to identify system reliability needs. Planners may not have sufficient time to implement mitigation plans or reliability upgrades to address likely scenarios, driving the need for more real-time operating procedures.

Level of Risk

High Priority

Descriptors of the Risk

1. Planning and operating the BPS is becoming more complex due to:
    a. The increased and accelerated rate of plant retirements, especially conventional synchronous generation, coupled with the increasing integration of renewable, distributed, and asynchronous resources.
    b. Increased risks with the transition from a balanced resource portfolio, addressing fuel and technology risks, to one that is predominately natural gas and variable energy resources.
2. Planners need to evaluate BPS transient, mid-term, long-term, and small-signal stability, including consideration of inertia and frequency response, voltage support (adequate dynamic and static reactive compensation), and ramping constraints due to the timing and dynamic performance of the new resource mix that changes throughout the day. Planners need a complete understanding of all pertinent resources and their characteristics to identify system reliability needs and develop mitigation plans.
3. The ability to perform accurate long-term planning assessments is more difficult due to:
    a. The need for more comprehensive load models.
        i. The uncertainty and lack of visibility into load composition and resource mix along with imprecise or evolving models.
        ii. Complex load model and interaction with power electronics devices on a large scale at the distribution level that may affect BPS operations during disturbances (e.g., fault-induced delayed voltage recovery).
    b. An increasing need for transmission and system planning activities to include distributed energy resources; however, limited data availability, information sharing, enhanced models required for both system and electro-magnetic transients, and a lack of coordination can hinder the ability of planners to complete this analysis.
    c. The increased deployment of distributed energy resources within the distribution or behind-the-meter configurations will impact how the BPS responds.
    d. Uncoordinated integration of controllable device settings and power electronics installed to stabilize the system.
4. Common mode or single points of failure, such as fuel delivery systems, are emerging or have yet to be determined or evaluated.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise should coordinate and work with industry and manufacturers and developers of asynchronous resources to develop accurate dynamic models and make them available.
2. The ERO Enterprise should identify the type and frequency of information needed from distributed energy resources.
3. The ERO Enterprise should develop guidelines and best practices for developing and maintaining accurate system and electromagnetic models that include the resources, load, and controllable devices that provide ERS. This would add the benchmarking of dynamic models with Phasor Measurement Units (PMU) measurements based on actual system response to disturbance.
4. NERC should continue to collaborate with Planning Coordinators to expand development of interconnection-wide models commensurate with expected dispatches. This collaboration will support the ability to conduct more effective long-term planning assessments.

Mid-term (3–5 year time frame):

5. Continue to assess the system performance to determine if the current body of planning Reliability Standards is sufficient to address ERS.
6. NERC should collaborate with Planning Coordinators to assess the impact on reliability from well-head, storage, and fuel delivery issues and how to assess them in long-term planning studies.
7. Improve load forecasting, generator modeling, and coordination between BPS and distribution system planners and operators.

Long-term (greater than 5-year time frame):

8. Encourage vendors of power system simulation software to develop programs to enhance dynamic load modeling capabilities.

Risk Profile #3: Resource Adequacy and Performance

Statement of the Risk

The resource mix and its delivery is transforming from large, remotely-located coal and nuclear-fired power plants, towards gas-fired, renewable energy limited, and distributed energy resources. These changes in the generation resource mix and the integration of new technologies are altering the operational characteristics of the grid and will challenge system planners and operators to maintain reliability. Failure to take into account these characteristics and capabilities can lead to insufficient capacity, energy, and ERS (sometimes called "ancillary services") to meet customer demands.

Level of Risk

High Priority

Descriptors of the Risk

1. The traditional methods of assessing resource adequacy may not accurately or fully reflect the new resource mix ability to supply energy and reserves for all operating conditions.
2. Forecasting BPS resource requirements to meet customer demand is becoming more difficult due to the penetration of distributed energy resources, which can mask the customer's electric energy use and the operating characteristics of distributed resources without sufficient visibility.
3. Conventional steam resources that operate infrequently due to economics may not operate reliably when dispatched for short peak-demand periods during seasonally hot or cold temperatures.
4. Historic methods of assessing and allocating ancillary services such as regulation, ramping, frequency response, and voltage support may not ensure ERS or sufficient contingency reserves are available at all times during real-time operations.
5. Fuel constraints and environmental limitations may not be reflected in resource adequacy assessments.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise and the industry should continue to develop improved modeling and probabilistic methods to evaluate resource adequacy. This includes continued sharing of emerging trends and insights from assessments for effective resource planning and operating models. Adequacy and capacity may include augmenting the measurements of ERS, coordination of controls, balancing load with generation regardless of the location of resources, and energy adequacy in light of installed and available capacity from variable generation.
2. The ERO Enterprise should assess and develop mitigation recommendations as necessary to address single points of disruption, such as fuel contingencies, that will result in large resource outages.
3. The ERO Enterprise and the industry should continue to expand the use of probabilistic approaches to develop resource adequacy measures that reflect variability and overall reliability characteristics of the resources and composite loads, including other than seasonal peak conditions.
4. The ERO Enterprise should generate scenarios for reliability assessments that focus on the location of resource retirements and the impact on ERS.
5. Improve load forecasting, generator modeling, and coordination between BPS and distribution system planners and operators.

6. The ERO Enterprise should develop new measures of reliability beyond reserve margins, including measures on the sufficiency of ERS.
7. The ERO Enterprise and industry should continue to assess vulnerabilities from fuel availability as part of evaluating adequacy and capability to deliver resources.
8. Analyze data requirements necessary to ensure there is sufficient detail on the capability and performance of the BPS as it is impacted by distributed energy resources. The industry should gather data beyond simple demand forecasts and expand to identify resource capacity, location, and ERS capability.

Risk Profile #4: Asset Management and Maintenance

Statement of the Risk

As the system ages and operations are modified, asset management programs also change. Failure to properly commission, operate, maintain, prudently replace, and upgrade BPS assets, such as those nearing their end-of-life, could result in more frequent and wider-spread outages that are initiated or exacerbated by equipment failures or protection and control system failures.

Level of Risk

Low Priority

Descriptors of the Risk

1. A lack of visibility of common-mode failures:
   - Delayed or no industry-wide notice when new issues arise.
   - No trend information readily available.
2. Extended outage time needed to replace major equipment.
3. A lack of sufficient analytics and awareness of inadequately maintained or conditioned equipment at or above minimum standards or requirements.
4. Barriers for proactive equipment replacement programs.
5. A level of awareness and understanding of priority system upgrades.
6. Increasingly complex protection systems that must be managed and maintained to prevent or mitigate events.
7. Protection and control system misoperations exacerbate events, thereby increasing the risk for uncontrolled cascading of the BPS.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. Increase the use of NERC's Alert program to provide more detail on information requests from industry on specific assets, earlier dissemination of detailed reports, and potential follow-up activities involving maintenance and management of assets.
2. The ERO Enterprise, in coordination with industry, should improve data gathering for equipment failure modes and improve the dissemination among equipment owners, manufacturers, and associated vendors.
3. Continue to conduct webinars on equipment event lessons learned, equipment maintenance, and seasonal preparedness.
4. Continue to evaluate performance trends using additional data collected by event analysis to extract insights, issues, and trends for dissemination across industry participants.
5. Industry forums and trade groups should learn from successful asset management programs, maintenance, and lessons learned to gain insights on trends in effective asset maintenance and increase dissemination of best practices.
6. The ERO Enterprise should work with industry experts to develop industry guidelines on protection and control system management to improve performance.

7. Assess system performance to determine whether the current family of protection and control standards needs to be enhanced.

Mid-term (3–5 year time frame):

8. Coordinate with the forums, research organizations, and technical committees to establish sharing of technologies or processes that aid in condition monitoring, failure prevention, spare sharing, and recovery.
9. Coordinate with the US, Canadian, and Mexican energy agencies and industry to support power transformer reserve programs.
10. The ERO Enterprise should provide technical basis for industry to support recovery of upgrade and maintenance costs for reliability purposes.

Long-term (greater than 5-year time frame):

11. The industry should implement best practices from the sharing of technologies or processes that aid in condition monitoring, failure prevention, spare sharing, and recovery.

Risk Profile #5: Human Performance and Skilled Workforce

Statement of the Risk

The BPS is becoming more complex, and as the industry faces turnover in technical expertise, it will have difficulty staffing and maintaining necessary skilled workers. In addition, inadequate human performance (HP) makes the grid more susceptible to both active and latent errors, negatively affecting reliability. HP weaknesses may hamper an organization's ability to identify and address precursor conditions to promote effective mitigation and behavior management.

Level of Risk

Low Priority

Descriptors of the Risk

1. Organizations not implementing improvements based on past events or experiences or keeping an eye on the implementation of new technologies can hinder future operations improvements; gaps in skillsets or organizational improvement must be a priority.
2. Turnover of key skilled or experienced workers (e.g., relay technicians, operators, engineers, IT support, and substation maintenance) will lead to more protection system misoperations.
3. A lack of training programs prevents closing skillset gaps quickly.
4. Inadequate management oversight or controls leads to organizational weaknesses and inefficiencies.
5. Ineffective corrective actions lead to repeated human performance errors.
6. Legacy systems and new technology result in disparity of the skillsets needed for BPS reliability.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The HP groups at the ERO Enterprise and industry forums should expand their communication of insights throughout the industry regarding best practices for increasing HP effectiveness (publishing lessons learned/best practices and supporting the NERC HP conference and other related workshops).
2. NERC should encourage industry and key trade associations to determine the extent of expected skill gaps and develop recommendations to address the skill gaps (e.g., curricula, programs, industry support).
3. The ERO Enterprise, trade associations, and industry should promote expanding training and education programs to include HP and recruitment of the next generation of skilled workers.
4. The ERO Enterprise and the industry should promote the use of NERC cause codes to establish a common understanding of HP triggers, collect and evaluate trends in data, and develop metrics as needed.
5. Explore the development and widespread use of a near-miss database which will leverage data sources such as event analysis, near miss databases, Transmission Availability Data System (TADS), Generating Availability Data System (GADS), Demand Response Availability Data System (DADS), relay misoperations, EOP-004/OE-417 Reports, and AC equipment failures to identify patterns and risk.

Mid-term (3–5 year time frame):

6. Consider and implement high-value recommendations developed to address skills gaps identified in the short-term mitigation mentioned in the 1–2 year time frame.

Long-term (greater than 5-year time frame):

7. Industry should develop and implement a sustainable process to analyze and disseminate best practices for HP.

Risk Profile #6: Loss of Situational Awareness

Statement of the Risk

Information sharing will be vital for visibility and a complete understanding of the impacts and contributions of distributed energy resources to the BPS. Inadequate situational awareness can be a precursor or contributor to BPS events. Loss of situational awareness can also occur when control rooms are not staffed properly or operators do not have sufficient information and visibility to manage the grid in real-time. Additionally, insufficient communication and data regarding neighboring entity's operations is a risk as operators may act on incomplete information.

Level of Risk

Moderate Priority

Descriptors of the Risk

The following items can lead to inappropriate operator response or lack of action:

1. Limited real-time visibility to and beyond the immediate neighboring facilities.
2. A lack of common status information on infrastructures and resources on which operators rely (e.g., gas, dispersed resources, distributed energy resources, and data and voice communications).
3. Information overload during system events.
4. Inadequate tools or fully capable back-up tools to address reliability.
5. Lack of training on the tools and information to assess system reliability at a given point in time.
6. Incomplete data and model accuracy used to feed into real-time operations.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise should develop new measures of reliability beyond reserve margins, including sufficiency of ERS.
2. The ERO Enterprise should develop real-time notification of interconnection anomalies and outliers (e.g., large load or resource losses, large oscillations, large angle changes, low inertia).
3. The ERO Enterprise should continue to perform a root cause or common mode failure analysis of partial and full loss of key EMS capability using events analysis information and provide lessons learned and recommendations to reduce the likelihood of failure.
4. The ERO Enterprise should evaluate whether certain important applications are over reliant on a single service provider and identify mitigating actions to reduce the risk.
5. Work with the forums on an approach for ongoing identification, cataloging, and sharing of good practices related to operating tools.
6. The ERO Enterprise should develop a guideline on situational awareness for the industry to address data modeling and information sharing.
7. The ERO Enterprise should identify the type and frequency of information needed from distributed energy resources for real-time situational awareness.

Mid-term (3–5 year time frame):

8. Develop and implement a set of real-time indicators of interconnection health.
9. The ERO Enterprise should engage industry and trade organizations to develop a list of key tasks and learning objectives for wide-area monitoring as well as assessing status following system events.
10. The ERO Enterprise should engage EPRI to develop a supplement or companion to the Interconnected Power System Dynamics Tutorial that deals with wide-area monitoring under a changing resource mix based on the near-term deliverables above.

Long-term (Greater than 5-year time frame):

11. The ERO Enterprise should engage industry and trade organization and the North American Synchrophasor Initiative (NASPI) to develop a suite of supplemental and back-up tools that use synchrophasor data.
12. Establish a forum with EMS vendors to leverage the near-term and mid-term suggestions for improvement of situational awareness tools.

Risk Profile #7: Extreme Natural Events

Statement of the Risk

Severe weather or other natural events (e.g., hurricanes, tornadoes, protracted extreme temperatures, GMDs, floods, earthquakes, etc.) are one of the leading causes of outages. Severe weather can cause BPS equipment damage, fuel limitations, and disruptions of voice and data communications, which can cause loss of load for an extended period.

Level of Risk

Moderate Priority

Descriptors of the Risk

1. Extreme natural events can damage equipment and limit fuel supplies, which may lead to localized loss of load.
2. Unmitigated GMDs could lead to widespread loss of load due to voltage instability in certain regions.
3. Widespread damage to certain types of BPS infrastructure can extend outages due to unavailability of nearby replacement equipment or specialized capabilities.
4. Physical damage to generation fuel sources, such as natural gas pipelines or storage facilities, can degrade reliable operations of the BPS.
5. Damage to voice and data communications, as well as water supplies, can make certain critical facilities vulnerable and reduce the ability to serve load.
6. The industry does not have full knowledge or coordination in accessing the existing spare equipment inventory.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. Complete the GMD Reliability Standards and start geomagnetic induced currents (GIC) data gathering and analysis.
2. E-ISAC and industry should expand communications among ISACs, including the Telecommunications, Water, and Natural Gas ISACs.
3. Study multiple simultaneous limitations on natural gas deliveries during extreme weather.
4. Participate in exercises that incorporate extreme physical events and implement recommendations from exercise or drills such as GridEx.
5. Incorporate E-ISAC and Electricity Subsector Coordinating Council (ESCC) communications protocols into industry disaster preparedness processes.
6. The industry, trades, and forums should evaluate inventories of critical spare transmission equipment and increase as required.
7. The Department of Energy, the industry, trades, and forums should identify appropriate mitigations to prevent spare equipment gaps and improve transportation logistics.
8. The ERO Enterprise and the industry should leverage best practices and the sharing of lessons learned to expand coordination during extreme weather events among Reliability Coordinators, Balancing Authorities, and Transmission Operators.

9. NERC and industry should plan a workshop that is coordinated with U.S. federal agencies, Canadian, and Mexican governmental authorities to address high-impact low-frequency event response, recovery, and communications vulnerabilities.

Mid-term (3–5 year time frame):

10. Identify and promote specific resiliency best practices to plan for extreme events.
11. The ERO Enterprise should conduct more detailed special assessments that integrate:
    a. Natural gas availability, pipeline capacity, and storage facility impacts on reliability under severe scenarios.
    b. Other interdependencies, such as long-haul communications and water supply.
    c. Analytic data trend insights regarding resiliency under severe weather conditions, identifying preventable aspects for BPS reliability.
12. The ERO Enterprise should apply the severity risk index (SRI), on a more granular regional level to measure system resilience and restoration performance for loss of generation, transmission, and load. These efforts should consider or develop new comparative and descriptive metrics.
13. The ERO Enterprise should perform trend analysis on historical impacts on the BPS of extreme natural events.

Long-term (greater than 5-year time frame):

14. Analyze data from GMD events to further the understanding of GIC effects on Bulk Electric System facilities to support enhancements to models and standards.
15. Institutionalize relationships among ESCC, government, and industry partners to enhance the culture of recognizing and addressing extreme physical event preparedness across industry.
16. Develop a plan to review and improve the trend of SRI as indicative measure of system resilience and restoration performance for loss of generation, transmission, and load.
17. To facilitate preparedness, consider preparing sensitivity analyses to simulate the impacts from the most extreme natural events experienced to date in a planning area.

Risk Profile #8: Physical Security Vulnerabilities

Statement of the Risk

Intentional damage, destruction, or disruption to facilities can cause localized to extensive interconnection-wide BPS disruption potentially for an extended period.

Level of Risk

Moderate Priority

Descriptors of the Risk

1. The increasing and evolving threat around physical attacks.
2. The exposed nature of the grid, which is vulnerable and difficult to protect.
3. Long lead times associated with manufacturing and replacing some equipment, which can increase complexity of restoration after physical attacks that damage BPS equipment.
4. The level of industry knowledge or coordination in accessing the existing spare equipment inventory.
5. Physical damage to generation fuel sources, such as natural gas pipelines, which will degrade the reliable operations of the BPS.
6. Damage to long-haul telecommunications and water supplies, which will make certain critical facilities vulnerable and reduce the ability to serve load.
7. An EMP event, which could lead to widespread loss of load in certain regions.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise should continue to oversee the implementation of NERC's Physical Security Reliability Standard entitled Critical Infrastructure Protection (CIP-014-2).
2. E-ISAC and industry should expand communications among ISACs, including the Telecommunications, Water, and Natural Gas ISACs.
3. The ERO Enterprise should develop effective metrics formulated to understand the trend of physical attacks and potential threats.
4. Assess the risks of physical attack scenarios on midstream or interstate natural gas pipelines, particularly where natural gas availability will impact generation and the reliability of the BPS in NERC's long-term reliability assessments and planning activities.
5. Promote existing and new efforts to improve a spare equipment strategy and prioritization.
6. Develop a catalog of regional/national exercises that incorporate extreme physical events and share with industry, thus supporting increased participation across industry. Whenever possible, expand exercises to include more facilities and industries.
7. The forums and trades should perform the following activities:
    a) Identify and promote specific resiliency and vulnerability assessment best practices with planning for extreme events, including good physical security assessment practices.
    b) Develop an event guideline outlining prevention strategies and event response and recovery protocols for sabotage scenarios.

8. In collaboration with the Critical Infrastructure Protection Committee and industry stakeholders, develop a risk process to address the potential impacts of physical security threats and vulnerabilities.

Mid-term (3–5 year time frame):

9. The industry should review and update restoration plans while accounting for physical security scenarios.
10. Develop performance and metrics reporting on joint E-ISAC and Telecommunications ISAC assessments of potential physical attack disruptions while differentiating from vandalism or theft incidents.
11. Conduct a special regional assessment that addresses natural gas availability and pipeline impacts under physical attack scenarios.
12. The Department of Energy, the industry, trades, and forums should identify appropriate mitigations to spare equipment gaps and transportation logistics.
13. The ERO Enterprise, the industry, trades, and forums should evaluate inventories of critical spare transmission equipment as necessary based on a spare equipment strategy and prioritization.
14. The industry should evaluate mechanisms for cost recovery of implementing specific resiliency strategies by the industry.
15. Industry should work with the technical committees and forums to develop mitigation strategies and physical security assessment best practices.
16. Expand participation in security exercises other than GridEx in order to reflect extreme physical events.
17. Facilitate planning considerations to reduce the number/exposure of critical facilities.

Long-term (greater than 5-year time frame):

18. Institutionalize relationships among ESCC, government, and industry partners to enhance the culture of recognizing and addressing extreme physical event preparedness across industry.
19. Foster the development of methods, models, and tools to simulate system reliability impacts for the planning and operational planning time horizons.

Risk Profile #9: Cybersecurity Vulnerabilities

Statement of the Risk

Exploitation of cybersecurity vulnerabilities can potentially result in loss of control or damage to BPS-related voice communications, data, monitoring, protection and control systems, or tools. Successful exploitation can damage equipment, causing loss of situational awareness and, in extreme cases, can result in degradation of reliable operations to the BPS, including loss of load.

Level of Risk

High Priority

Descriptors of the Risk

1. Cybersecurity threats result from both external and internal vulnerabilities:
   a. Exploitation of employee and insider access.
   b. Weak security practices of host utilities, third-party vendors, and other organizations.
   c. Growing sophistication of bad actors, nation states, and collaboration between these groups.
2. Interdependencies from the Department of Homeland Security Critical Infrastructure Sectors[4] (Communications, Financial Services, Oil and Natural Gas Subsector, and Water) with their own cyber vulnerabilities can impact BPS reliability.
3. Legacy architecture coupled with the increased connectivity of the grid expands the attack surface of BPS protection and control systems:
   a. Increased automation of the BPS through control systems implementation.
   b. Business needs accelerating the convergence of information technology (IT)/operational technology (OT).
   c. IT/OT infrastructure management, out-of-date operating systems, and the lack of patching capability/discipline.
4. Ineffective teamwork and collaboration among the federal, provincial, state, local government, private sector and critical infrastructure owners can exacerbate cyber events.
5. A lack of staff that is knowledgeable and experienced in cybersecurity, control systems, and the IT/OT networks supporting them (historically separate organizations and skillsets), symptomatic across all industries, hinders an organization's ability to detect and prevent cyber incidents.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. Address FERC critical infrastructure protection (CIP) directives in *Revised Critical Infrastructure Protection Reliability Standards*, 154 FERC ¶ 61,037 (2016).
2. Address FERC directives in *Revised Critical Infrastructure Protection Reliability Standards*, 156 FERC ¶ 61,050 (2016) on supply chain risk management.
3. In collaboration with the Critical Infrastructure Protection Committee (CIPC) and industry stakeholders, develop a risk process to address the potential impacts of cyber security threats and vulnerabilities.

[4] https://www.dhs.gov/critical-infrastructure-sectors

4. NERC should continue information sharing protocols among interdependent ISACs.
5. The E-ISAC should continue outreach to industry to increase registration and utilization of E-ISAC portal.
6. The E-ISAC should mature the cybersecurity risk information sharing program (CRISP) and encourage expanded participation.
7. NERC and the CIPC should prioritize lessons learned from regional and national exercises (*e.g.*, GridEx) and publish lessons learned and guidelines as needed.
8. Facilitate planning considerations to reduce the number/exposure of critical facilities.
9. The industry should encourage the development of a peer review process for emerging risks.
10. The industry should create and foster an internal culture of cyber awareness and safety.
11. NERC should develop effective metrics formulated to understand the trend of cyber-attacks and potential threats.

Mid-term (3–5 year time frame):

12. The ERO Enterprise should develop a feedback mechanism from CIP standards implementation to evaluate the standard and lessons learned from technology deployment.
13. The ESCC should operationalize the cyber mutual assistance framework to address issues with recovery after a cyber-attack.
    a. Cross-industry sharing of best practice incident response plans.
    b. Creation and/or expansion of security operations centers that incorporate the BPS (IT/OT convergence areas).
14. Assist industry efforts to address supply chain vulnerability.
15. The ERO Enterprise with industry should develop agreed-upon levels of cyber-resilience suitable for BPS planning and operations.

Long-term (greater than 5-year time frame):

16. The ERO Enterprise and industry should develop methods, models, and tools to simulate cyber impacts on system reliability, enabling BPS planning to withstand an agreed-upon level of cyber resiliency.
17. The ERO Enterprise and industry should develop industry operating guidelines that incorporate an agreed-upon level of cyber resilience.
18. The ERO Enterprise should create and document pathways that enable the integration of new technologies while maintaining or enhancing the agreed-upon level of cyber resilience.