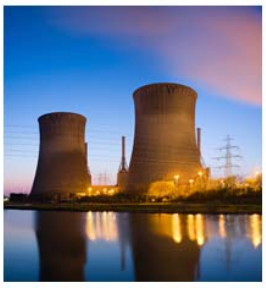
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

ERO Reliability Risk Priorities

RISC Recommendations to the NERC Board of Trustees

February 2018

RELIABILITY | ACCOUNTABILITY

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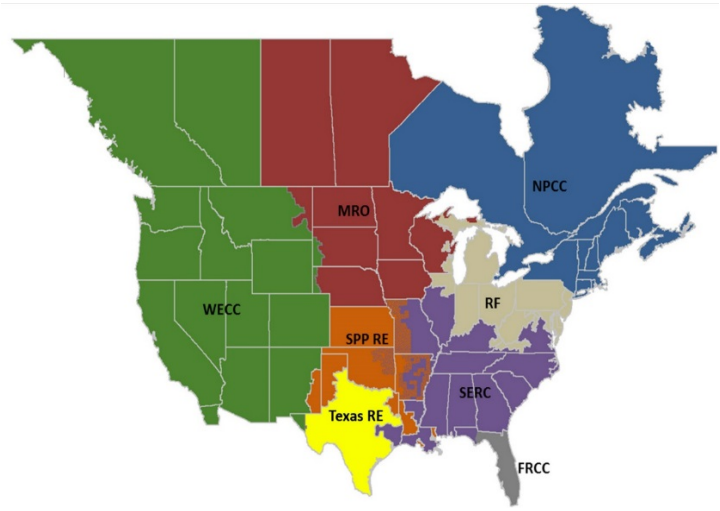
Preface

The North American Electric Reliability Corporation (NERC) is a not-for-profit international regulatory authority whose mission is to assure the reliability and security 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[1] and the industry to effectively focus resources on the critical issues to improve the reliability of the BPS.

This ERO Reliability Risk Priorities report (RISC 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.

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

Preamble

The RISC has identified a number of key observations regarding emerging risks to the reliability of the BPS to focus the industry's efforts. These key observations are:

1. The fast pace of change of the resource mix;
2. Interdependence between the energy and communication sectors;
3. Increased complexity of the power system's automated control systems due to the increased use of power electronics and digital controls, and the risks of negative interaction between those control systems;
4. Ongoing evolution and complexity from determined actors using cyber technologies;
5. Changing workforce skills needed to reliably implement the new control facilities involved in the power system; and
6. Addressing BPS impacts associated with emerging reliability risks is placing increased demands for coordination among policy makers and regulatory authorities, including the need for increased coordination among provincial, federal, and state regulatory authorities, with due consideration of jurisdictional boundaries.

These key observations were used to identify linkages and coordinate the recommendations across the RISC report's risk profiles. By identifying risks, whether associated with the planning and operation of generation, transmission, or distribution[2] facilities, the RISC recognizes that not all of the recommendations are within the ERO's jurisdiction.

[2] Distribution facilities are not within the BPS however there is expected to be a greater dependence on distribution systems for achieving reliable operation of the BPS as the transition to distributed resources continues.

Chapter 1: Background and Introduction

Background

This report documents the results of the RISC's continued work to identify key risks to the reliable operation of the BPS and provide recommendations to mitigate those risks. This report includes recommendations regarding relative priorities to further assist the Board and NERC management.

The RISC's efforts are both responsive and in support of the Board's resolutions in connection with the initial 2013 RISC recommendations[3]:

> *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 linkages between the risk priorities and the recommended actions for the ERO Enterprise and industry. While the individual risk profile recommendations in this report are presented individually, there are interdependencies between many of the risks that present unique challenges to the electricity industry. The RISC acknowledges and appreciates the increased reliance of the Board and ERO Enterprise leadership on this report as an input for the ERO Enterprise's Long-Term Strategic Plan, Operating Plan, and Business Plan and Budgets.

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. The RISC also received feedback through stakeholder comment periods and during open MRC meetings.

This report relies on and extends the comprehensive initial assessment and corresponding recommendations to the Board made in February 2013, which have been updated and refined annually. This report and recommendations also reflect discussions with representatives from the NERC technical and standards committees, industry dialogue through a series of focused executive leadership interviews, the discussion with leaders at the NERC Reliability Leadership Summit, the FERC Reliability Technical Conference, and many technical reports and assessments. These results were presented to ERO Enterprise executive leadership for integration into the ERO Enterprise strategic and operational plans.

[3] *See* minutes from the Board's February 7, 2013, meeting: http://www.nerc.com/gov/bot/Agenda%20highlights%20and%20Mintues%202013/BOT%20-%20February%207%202013%20Minutes.pdf

Introduction

The RISC has carefully reviewed numerous inputs on BPS reliability from various stakeholders. On October 25, 2017, an initial draft of the report was posted for stakeholder review and comment.

This report reflects the collective opinion of the RISC regarding the priorities. The RISC reviewed and assembled information from ERO Enterprise stakeholders, policymakers,[4] and focused executive leadership interviews to develop a composite set of risk profiles and a graphic depiction of the key BPS reliability risk. The depiction presents the RISC's views on the likelihood of occurrence, the expected impact on reliability, and the trajectory of the associated risks.

The individual risk profiles have been mapped against the likelihood and impact, which indicates the unmitigated or inherent risks of each risk profile as determined by the RISC. While all of the identified risks 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, the RISC recommends the highest priority be given to those risk profiles that have been identified as having the higher likelihood/higher impact. Regardless of the categorization, all risk profiles warrant attention. Accordingly, the risk profiles were categorized as follows:

Higher Likelihood, Higher Impact

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

Higher Likelihood, Lower Impact

- Increasing Complexity in Protection and Control Systems
- Human Performance and Skilled Workforce

Lower Likelihood, Higher Impact

- Loss of Situational Awareness

Lower Likelihood, Lower Impact

- Physical Security Vulnerabilities
- Extreme Natural Events

Format of the Report and Method of Analysis

The primary objective of this report is to highlight risks that merit 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 a forward-looking view of the BPS in contrast to the *State of Reliability* report which reviews data from previous years to draw objective conclusions.

[4] Policymakers is used generally to mean any organization 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.

A majority of this report is comprised of risk profiles that detail the evolving status of each risk and the mitigation efforts to address each risk. These profiles outline a summary of the risks and the potential impact to the BPS. Through the risk profiles, the RISC recommends activities to further understand and mitigate these risks in the near-term (1–2 years), mid-term (3–5 years), and long-term (greater than 5 years). The ERO Enterprise and industry can use the composite risk profiles and the risk map for baseline and recurring evaluation of reliability risks.

The RISC also significantly reduced the number of recommendations from the initial draft report by eliminating or consolidating overlapping recommendations and removing recommendations that reflect activities which, while important, are already well underway and part of the three-year ERO Enterprise Operating Plan and applicable NERC standing committee plans. An example of this includes the work being undertaken by the Electricity Information Sharing and Analysis Center (E-ISAC) and Critical Infrastructure Protection Committee (CIPC) in furtherance of the E-ISAC Long-Term Strategic Plan, which was recently approved by both the Members Executive Committee (MEC) of the Electricity Subsector Coordinating Council (ESCC) and the NERC Board.

Where appropriate, the RISC identified the group or organization that it believes should lead the mitigating action; however, some recommendations do 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 policymakers, industry, and the various organizations within the ERO Enterprise.

Additionally, the committee evaluated risks based on impact to the BPS regardless of the source or location of the risk. To evaluate key risks to the system, the RISC recognized emerging issues emanating from different areas of the grid (e.g., resources such as distributed energy resources (DER) that may not be located or directly connected to the BPS). Operators and planners of the BPS are aware of the need to have a wide-area view of changes to the system 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, resources located on the electric distribution system, gas delivery system, telecom system, water system, etc.). RISC determined it is important to shine a light on external factors that increase BPS risk and offered recommendations to address those risks. Given the changing nature of the system and acceleration of penetration of DER on the distribution system, the RISC is obligated to raise areas of concern since impacts from DER may require mitigation actions at the BPS level.

Other inputs to the Risk Profiles

Reliability Leadership Summit

On March 21, 2017, NERC and the RISC hosted a Reliability Leadership Summit (Summit) with leaders of the reliability community, including top industry executives, state and federal regulators, and NERC and Regional Entity senior leadership. The Summit included moderated panels focused on identifying and discussing challenges around three main topics: (1) challenges in operating the BPS; (2) resilience and security; and (3) emerging risks to reliability. Common themes and takeaways from the Summit included the following:

- The RISC report accepted by NERC's Board in 2016 does not appear to have any gaps in identified risks, though their pace has accelerated.
- Risks related to DER was a prominent theme during the Summit, including the influence of digital-based systems, lack of situational awareness, planning methods and forecasting models, overlapping regulatory responsibilities and inconsistent policies, and jurisdictional limitations. The work and recommendations of the DER Task Force should be reviewed and leveraged accordingly.
- DER and changing technologies imply large amounts of new data, resulting in data management burdens and its protection as a risk. Despite the risks related to data protection, there are also risks related to not sharing data for situational awareness and learning purposes.

- Cybersecurity threats continue to evolve and escalate, posing an increasing level of threat to the BPS.
- The RISC report should recognize the international aspect of policymaking.
- The "skilled workforce" risk profile may be more appropriately titled "changing workforce." The skills required are evolving, including responsibilities related to compliance.
- Risk mitigation mechanisms for smaller utilities need to be explored.
- Gas dependency and other common mode failure events involving telecommunications and water-related systems continue to be prominent risks.
- Addressing BPS impacts associated with emerging reliability risks is placing increased demands for coordination among policymakers and regulatory authorities, including the need for increased coordination among provincial, federal, and state regulatory authorities, with due consideration of jurisdictional boundaries.

FERC Technical Conference

On June 22, 2017, 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 four main topics: overview of the state of reliability, international perspectives, potential for long-term and large-scale disruptions, and grid security. These topics were addressed in four panel sessions:

- The first panel focused on an **Overview of the State of Reliability.** The participants of this panel affirmed several of the risks identified by the RISC. The panelists identified the most significant risks to the BPS as impacts from integrating DER, retirement of base-load resources, jurisdictional gap between federal and state/provincial regulations, cyber-system supply chain risks, increased variable energy resources, resource adequacy, and risks from the accelerated pace of technology integration such as smart inverters having unintended consequences. This panel also highlighted the need for review of NERC's standards to ensure they are effective, and eliminate those requirements that are not addressing important risks to BPS reliability.
- The second panel focused on **International Perspectives** from Canada, Mexico, and the European Union on the grid's emerging issues, including the changing resource mix, introducing and expanding markets, improving transmissions planning across international borders, and expanding pipeline infrastructure to facilitate additional gas-fired generation.
- The third panel focused on the **Potential for Long-Term and Large-Scale Disruptions**, which continued the first panel's discussion on emerging trends and risks, but concentrated on the impact of the reliance on a single gas storage facility, electromagnetic pulse (EMP), and resilience of the grid.
- The final panel, addressing **Grid Security,** highlighted controls to mitigate cybersecurity risks to the BPS, particularly in light of the 2015 and 2016 cyber-attacks on the electric grid in Ukraine. In addition, the need to develop a culture of cyber-awareness among the workforce was identified.

Pulse Point Interviews

In order to expand the identification and 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.

Challenges discussed during the pulse point interviews were generally focused on four areas: changing resource mix and technology, economic considerations, cyber and physical security, and regulatory policy.

Several interviews validated the concerns presented in the risk profiles. The profiles of the Changing Resource Mix and Cybersecurity Vulnerabilities were the most common themes in all of the interviews. In addition, several industry executives voiced concern over lack of fuel diversity and 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. Further, interviewees discussed resilience and a concern about how changes to the grid are reducing resilience. A few interviewees encouraged the ERO to place a stronger emphasis on the EMP threat, particularly with high altitude devices capable of causing widespread outages. Also, one industry 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.

Although several interviewees 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.

A continued theme is some interviewees 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.

Several executives expressed concern about whether regulators and policymakers would support the cost recovery needed to address these challenges to maintain system performance and the reliable operation of the power system.

Department of Energy Grid Study and Recent FERC Order Initiating New Proceeding

In August 2017, the Department of Energy (DOE) published a study, *Staff Report to the Secretary on Electricity Markets and Reliability,*[5] aimed at evaluating the present status of the electricity system and exercising foresight to help ensure a system that is reliable, resilient, and affordable long into the future. The study included four key chapters (Power Plan Retirements, Reliability and Resilience, Wholesale Electricity Markets, and Affordability) and eight policy recommendations. These recommendations were related to reliability and resilience, as well as wholesale markets, and were generally consistent with the direction the RISC is advocating. On January 8, 2018, FERC issued an order terminating a proceeding to address a proposed DOE rule on grid reliability and resilience pricing and initiated a new proceeding to examine resilience of the BPS in regions operated by regional transmission organizations (RTOs) and independent system operators (ISOs) and direct each RTO and ISO to submit information on certain resilience issues and concerns identified in the order to enable FERC to examine the resilience of the BPS holistically[6]. In this order, FERC, referencing the National Infrastructure Advisory Council, set forth its preliminary understanding of resilience to mean "the ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event."

Focus Areas and Recommendations from the Risk Profiles

While all of the identified risks require monitoring and action to mitigate the risks to the reliability of the BPS, the RISC recommends the highest priority be given to those risk profiles that have been identified as having the higher likelihood of BPS-wide occurrence and higher impact to BPS reliability. Outlined here are those risk profiles that

[5] https://energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf
[6] See *Grid Resilience in Regional Transmission Organizations and Independent System Operators*, 162 FERC ¶ 61,012 (2018): https://www.ferc.gov/CalendarFiles/20180108161614-RM18-1-000.pdf

should be given the highest priority, along with their near-term recommendations. Concentrated effort by the industry on these areas, as well as inclusion of goals within the ERO Enterprise Operating Plan and the associated Business Plan and Budgets, should mitigate the risk to BPS reliability. Additional detail can be found in the associated risk profiles.

Cybersecurity Vulnerabilities (Risk Profile #9)

1. In collaboration with the CIPC and industry stakeholders, develop a risk process to address the potential impacts of cybersecurity threats and vulnerabilities.
2. The E-ISAC should continue information sharing protocols among interdependent information sharing and analysis centers (ISACs) to increase the visibility into cyber and physical security threats.
3. Facilitate planning considerations to reduce the number and exposure of critical cyber facilities to attack.
4. The ERO Enterprise and the E-ISAC should develop metrics regarding the trend of cyber-attacks and potential threats.
5. The industry should develop focused training and education programs and/or share best practices to address the shortage of skilled and experienced cybersecurity professionals, as well as IT professionals with BPS operations experience.

Changing Resource Mix (Risk Profile #1)

1. The ERO Enterprise and industry need to provide more effective guidance to evaluate and improve controllable device settings[7] and how the interaction between these devices can affect BPS reliability, particularly during transient conditions.
2. The ERO Enterprise should augment new systems being developed to gather data and insights into DER (i.e., customer, distribution, or otherwise), and Reliability Coordinators should 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 RTOs/ISOs Council, Balancing Authorities in non-RTO/ISO market areas, other registered entities, and regulators on essential reliability services (ERS) recommendations for effective implementation as they emerge.
4. Based on assessments on the reliability impacts of the changing resource mix, policymakers should promote and 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.
5. NERC should ensure that the Inverter-Based Resource Performance Task Force (IRPTF) completes its scope of work on schedule and implements the recommendations needed to maintain reliability. The recommendations should include addressing any gaps in NERC Reliability Standards.

BPS Planning (Risk Profile #2)

1. The ERO Enterprise should identify the type and periodicity of information needed from DER to improve load forecasting and generator modeling and address coordination requirements between BPS and distribution system planners and operators to account for the uncertainty introduced by integration of variable generation, including the impact of weather on these resources.

[7] For example, inverter based resources, protective relay schemes, remedial action schemes, static synchronous compensators (STATCOMs)/static VAR compensators (SVCs), generation distributed control systems, power system stabilizers, etc.

2. NERC, working with the industry and forums, should develop guidelines and good industry practices for developing and maintaining accurate system and electromagnetic models that include the resources, load, and controllable devices that provide ERS, including the addition of benchmarking of dynamic models with Phasor Measurement Units (PMU) measurements based on actual system response to disturbance.

Resource Adequacy and Performance (Risk Profile #3)

1. NERC should assess the recommendations from the *Bulk Power System Impacts Due to Disruptions on the Natural Gas System*[8] special assessment and make recommendations on mitigation strategies to address the reliability issues identified.
2. 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 non-peak system conditions.
3. Improve load forecasting that takes into account behind-the-meter resources, generator modeling, and coordination between BPS and distribution system planners and operators by analyzing data requirements necessary to ensure there is sufficient detail on the capability and performance of the BPS as it is impacted by DER. The industry should gather data beyond simple demand forecasts and expand to identify resource capacity, location, and ERS capability. Regulatory support for common interconnection standards will be important for planning and analysis.
4. The ERO Enterprise and industry should continue to assess vulnerabilities from fuel availability as part of evaluating adequacy and capability to deliver resources.

Themes and Takeaways from the Risk Profiles

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

Learning from Events and the Sharing of Information and Practices

The ERO Enterprise and industry has a number of ongoing activities, such as the E-ISAC, NERC Alerts, event analysis processes, and peer reviews where information is shared about risks, lessons learned, and improvements to operating and maintenance practices. Many of the recommendations within the risk profiles recommend continuing or expanding these activities to leverage the knowledge across the industry.

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.

Spare equipment strategy is an important aspect of restoration and recovery. The strategy should encompass identifying critical spare equipment as part of a national or regional inventory. The strategy should also account for the transportation and 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.

[8] http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SPOD_11142017_Final.pdf

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 resilience and recovery include:

- In 2016, the top Severity Risk Index days were a combination of many smaller local events, indicating that BPS resilience to the events during the year was high.[9] 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.
- While the industry operates in anticipation of 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 long-term strategy and operating 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.

FERC's recent order launches an information gathering effort by FERC with the RTOs and ISOs to:

1. Vet its proposed definition of Resilience
2. Determine how RTOs and ISOs assess threats to resilience
3. Identify how RTOs and ISOs mitigate threats to resilience

Responses from the RTOs and ISOs are due to FERC in 60 days of the order (March 9, 2018). The information submitted to FERC should be useful to both NERC and other interested stakeholders and provide an ongoing framework for future discussions and consideration of this topic.

Adequate Data Visibility

Data is needed to understand the performance of and risks to the BPS. This includes information regarding DER. 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

[9] See *2017 State of Reliability* report*:*
http://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/SOR_2017_MASTER_20170613.pdf

DER, 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 that 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 DER.

Natural Gas Deliverability and Other Co-dependencies

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 fuel supply and its deliverability impacts reliability and 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, gas storage, infrastructure maintenance, compressor station location and failures, and deliverability concerns. Further, potential cyber or physical attack on a pipeline highlights the need for increased coordination among pertinent 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.

The BPS is also becoming more dependent on other sectors such as telecommunications for visibility and control. Coordination between sectors should be enhanced to mitigate vulnerabilities that significantly impact the reliability and resilience of the BPS.

Chapter 2: Prioritization of Inherent Reliability Risks

Figure 2.1 shows each of the identified inherent risk profiles mapped against likelihood and impact scales, which indicates the unmitigated or inherent risks of each risk profile as determined by the RISC. The risk map shows the RISC's assessment of how the inherent risks of the profiles have changed from the previous report. The colored numbered circles show the RISC's current assessment of inherent risks. For those risks that have shifted, the shaded numbered circles represent the location from the previous report, with an arrow showing the movement for the current report. Profiles 1, 7, and 9 are the only ones that moved. Profile 4 has also moved, but does not show movement with an arrow, as the profile was redrafted from Asset Management and Maintenance to focus on Increasing Complexity in Protection and Control Systems. All other risks remained in the same location as in the previous report.

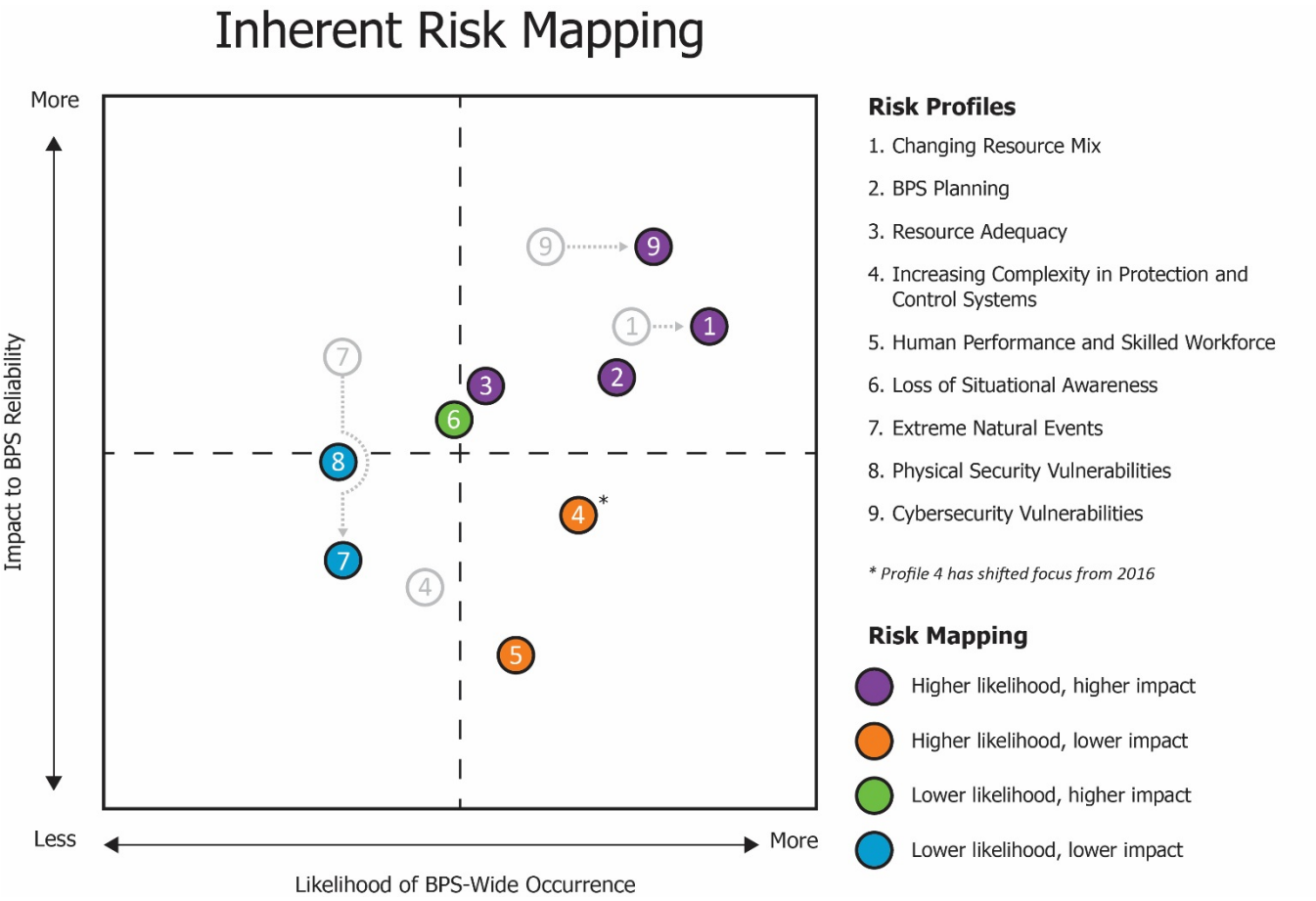


Figure 2.1: Risk Map of ERO Risk Profiles

Risk Groupings

Higher Likelihood, Higher Impact Risks:

- **Cybersecurity Vulnerability**: The likelihood of this risk increased, while impact to reliability remains the same as the last review based on the judgment of the RISC. Cyber threats are becoming more sophisticated and increasing in number, based on experience from attacks in other countries and on other industries. Exploitation of cybersecurity vulnerabilities can cause loss of control or damage to BPS-related voice communications, data, monitoring, protection and control systems, or tools. A large cyber-attack can result in equipment damage, degradation of reliable operations, uncontrolled cascading of the BPS, and loss of load. Further, cybersecurity vulnerabilities can come from several sources, both internal and external and any one or combination of these threats has the potential to leave the utility in a compromised condition.
- **Changing Resource Mix:** The probability of this risk has increased, while the impact remained the same. 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 DER 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 likelihood and impact from BPS planning remained the same. It is closely tied to the changing resource mix as planners 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:** The likelihood and impact from this risk remained the same. The changing resource mix and the integration of new technologies are altering the operational characteristics of the grid. Failure to take into account these changing characteristics and capabilities can lead to insufficient capacity and ERS to meet customer demands. This profile focuses on the development of better tools, metrics, and analysis to assess resource adequacy and performance.

Higher Likelihood, Lower Impact Risks:

- **Increasing Complexity in Protection and Control Systems:** The profile from the last report regarding Asset Management and Maintenance was revised to focus on the increasing complexity in protection and control systems to support integration of new technologies. The need to properly design, coordinate, commission, operate, maintain, prudently replace, and upgrade BPS assets is increasing to prevent the potential for more frequent and wider-spread outages. These disruptions could be initiated or exacerbated by protection and control system misoperations or failures. Asset management strategies are evolving to include cybersecurity, resilience, and recovery from high impact, low frequency events.
- **Human Performance and Skilled Workforce:** There continues to be a need for skilled workers, such as protection engineers, to prevent both active and latent errors both of which negatively affect reliability.

Lower Likelihood, Higher Impact Risks:

- **Loss of Situational Awareness**: This profile 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 DER 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.

Lower Likelihood, Lower Impact Risks:

- **Extreme Natural Events:** The impacts from these events have not lead to instability, uncontrolled separation, or cascading outages that adversely impact the reliability of the Bulk Electric System (BES). The effects on power delivery of these events have been contained to the local area experiencing the natural event, though the likelihood of occurrence remained the same. The RISC believed the impact is better characterized as "decreasing" from last year's report because although there have been more severe weather events, the grid has responded well. Severe weather or other natural events (e.g., hurricanes, tornadoes, protracted extreme temperatures, geomagnetic disturbances (GMDs), flooding, earthquakes, forest fires, extreme icing, 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 range from localized to extensive interconnection-wide BPS disruption for an extended period.

Perspectives and Conclusions

The preceding sections summarize the RISC's conclusions regarding key reliability risks and areas requiring focus to preserve reliability in 2018 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 for consideration as an important input to future updates to the ERO Enterprise Long-Term Strategy and Operating Plan, as well as ERO Enterprise resource planning and allocation.

Chapter 3: Risk Profiles

Risk Profile #1: Changing Resource Mix

Statement of the Risk

Today's resource mix has continued to evolve with the addition of emerging technologies like inverter generation based resources, improving storage techniques, and federal, state, and provincial renewable favoring policies. Transmission Planners, Balancing Authorities, asset owners, and system operators of the BPS may not have sufficient time to develop and deploy plans in response to reliability considerations resulting from the new resource mix.

Risk Mapping

Higher Likelihood, Higher Impact

Descriptors of the Risk

1. The intensity and pace of change (penetration rates of certain resources) and the types of change (the specific resources) are influenced by policy and economic factors in addition to state, provincial, and federal initiatives, which sometimes influence one region, province, or state in a certain direction more than another. Since the BPS is interconnected, these effects cannot be isolated to stay within political boundaries. Over time, regulatory initiatives, along with expected lower production costs and aging generation infrastructure, will likely alter the nature, investment needs, and 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 be challenged to 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. Ancillary services, such as the ERS (e.g., voltage control and reactive support, frequency response, ramping/balancing, blackstart) on the BPS, that could be further eroded by the retirement of many large rotating synchronous central station generating units.
    b. The integration of large amounts of new resource technologies, DER, 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 DER.
    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.
    d. The interaction and performance of control systems during transient events that may result in new common-mode failures that may not have been anticipated, (e.g., the inverter performance as demonstrated during the Blue Cut fire event).

Ongoing Activities

The ERO Enterprise and industry are engaged in a number of activities in connection with this risk, including but not limited to:

- Placing stronger emphasis on review and analysis of power system events, including those that are lower impact, to discover potential reliability trends early in their lifecycles;
- Conducting interconnection-wide technical studies and assessments, such as studies and assessments of frequency and inertia response, voltage support, short-circuit analysis, and inter-area oscillation;
- Conducting electric and gas inter-dependency studies to identify BPS reliability risks and solutions, including opportunities for more resilience-producing coordination between electric and gas industries; and
- Providing independent technical assessments of the reliability impacts from the changing resource mix driven by proposed state, provincial, or federal statutes and transmission provider tariffs.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise and industry need to provide more effective guidance to evaluate and improve controllable device settings[10] and how the interaction between these devices can affect BPS reliability, particularly during transient conditions.
2. The ERO Enterprise should augment new systems being developed to gather data and insights into DER (i.e., customer, distribution, or otherwise), and Reliability Coordinators should 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 RTOs/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. Based on assessments on the reliability impacts of the changing resource mix, policymakers should promote and 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.
5. NERC should ensure that the IRPTF completes its scope of work on schedule and implements the recommendations needed to maintain reliability. The recommendations should include addressing any gaps in NERC Reliability Standards.

[10] For example, inverter based resources, protective relay schemes, remedial action schemes, static synchronous compensators (STATCOMs)/static VAR compensators (SVCs), generation distributed control systems, power system stabilizers, etc.

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 may lack the ability to timely update or create system models and scenarios of potential future states to identify system reliability needs. Planners may be challenged to implement mitigation plans or reliability upgrades to address likely scenarios, driving the need for more real-time operating procedures.

Risk Mapping

Higher Likelihood, Higher Impact

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. Incomplete information exists to perform BPS transient, mid-term, long-term, and small-signal stability studies, including consideration of interaction of BPS and resource controls, inertia/frequency response, voltage support (adequate dynamic and static reactive compensation), and ramping/balancing constraints due to the timing and dynamic performance of the new resource mix that changes throughout the day.
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 DER; 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 DER within the distribution or behind-the-meter configurations that will impact how the BPS responds.
    d. Uncoordinated integration of controllable device settings and power electronics installed to stabilize the system.
    e. Changing and uncoordinated regulations of policymakers and regulatory authorities complicated by jurisdictional boundaries.
4. Common mode or single points of failure, such as fuel delivery systems, that are emerging or have yet to be determined or evaluated.

Ongoing Activities

The ERO Enterprise is working with planning coordinators to expand the development of interconnection-wide models with expected dispatches to support effective long-term planning assessments. The ERO Enterprise and industry are also working to improve modeling capabilities, including working with manufacturers and developers of asynchronous resources to develop and make available accurate dynamic models, as well as encouraging vendors of power simulation software to develop programs to enhance dynamic load modeling capabilities. These activities consider the increasing reliability and security interdependencies between the U.S., Canada, and Mexico.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise should identify the type and periodicity of information needed from DER to improve load forecasting and generator modeling and address coordination requirements between BPS and distribution system planners and operators to account for the uncertainty introduced by integration of variable generation, including the impact of weather on these resources.
2. NERC, working with the industry and forums, should develop guidelines and good industry practices for developing and maintaining accurate system and electromagnetic models that include the resources, load, and controllable devices that provide ERS, including the addition of benchmarking of dynamic models with PMU measurements based on actual system response to disturbance.

Mid-term (3–5 year time frame):

3. The ERO Enterprise 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.
4. NERC should coordinate with Planning Coordinators to continually review existing and identify new planning methods and tools needed to respond to the changing system.

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, DER, and other emerging technologies. 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. Failures to take into account these characteristics and capabilities can lead to insufficient capacity, energy, and ERS to meet customer demands.

Risk Mapping

Higher Likelihood, Higher Impact

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 DER, 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.

Ongoing Activities

The ERO Enterprise is working closely with stakeholders to develop improved modeling and probabilistic methods to evaluate resource adequacy. This includes assessments of emerging trends and insights for resource planning and operating models. Resource adequacy review will also include evaluation and augmentation of the existing and new measurements of ERS, coordination of controls, balancing load with resources, and resource adequacy in light of installed and available capacity from variable generation and DER.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. NERC should assess the recommendations from the *Bulk Power System Impacts Due to Disruptions on the Natural Gas System*[11] special assessment and make recommendations on mitigation strategies to address the reliability issues identified.
2. 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 non-peak system conditions.
3. Improve load forecasting that takes into account behind-the-meter resources, generator modeling, and coordination between BPS and distribution system planners and operators by analyzing data requirements necessary to ensure there is sufficient detail on the capability and performance of the BPS

[11] http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SPOD_11142017_Final.pdf

as it is impacted by DER. The industry should gather data beyond simple demand forecasts and expand to identify resource capacity, location, and ERS capability. Regulatory support for common interconnection standards will be important for planning and analysis.

4. The ERO Enterprise and industry should continue to assess vulnerabilities from fuel availability as part of evaluating adequacy and capability to deliver resources.

Risk Profile #4: Increasing Complexity in Protection and Control Systems

Statement of the Risk

Failure to properly design, coordinate, commission, operate, maintain, prudently replace, and upgrade BPS control system assets could negatively impact system resilience and result in more frequent and wider-spread outages initiated or exacerbated by protection and control system misoperations or failures. Asset management strategies are evolving to include greater amounts of digital network based controls for substation assets that introduce cybersecurity risks.

Risk Mapping

Higher Likelihood, Lower Impact

Descriptors of the Risk

1. Extended outage time needed to recover from compounding equipment outages.
2. A lack of sufficient analytics and awareness of inadequately maintained or conditioned equipment at or above minimum standards or requirements.
3. Increasingly complex protection and control systems that must be properly designed, coordinated, managed, and maintained to prevent or mitigate events.
4. BPS remedial action scheme failures as well as protection and control system misoperations that exacerbate the impact from events, which significantly increases the risk for uncontrolled cascading of the BPS.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. Industry forums and trade groups should share successful asset management programs and lessons learned to gain insights on trends and increase dissemination of good industry practices.
2. NERC should work with industry experts and the forums to promote the development of industry guidelines on protection and control system management to improve performance.
3. The ERO Enterprise should determine whether enhancements are required to the current family of protection and control (PRC) standards or related NERC guidance materials.

Mid-term (3–5 year time frame):

4. The ERO Enterprise should encourage industry forums, research organizations, and technical committees to share technologies or processes on condition monitoring, failure prevention, spare sharing, resilience, and recovery.
5. The ERO Enterprise should provide the technical basis for BPS resilience enhancements.

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

6. Recognize the risks of shorter technology lives for protection and control system components and the need to implement replacement programs that do not impact BPS reliability.

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. The addition of significant internal procedural controls needed to maintain compliance with reliability and CIP compliance requirements has brought additional complexity to many skilled worker positions. 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.

Risk Mapping

Higher Likelihood, Lower Impact

Descriptors of the Risk

1. Organizations not implementing improvements based on past events, experiences, good industry practices, or keeping an eye on the implementation of new technologies that can hinder future operations improvements; gaps in skillsets or organizational improvement must be a priority.
2. Significant increase in operational complexity resulting in more extensive training needs associated with new technology and related compliance control strategy.
3. Turnover of key skilled or experienced workers (e.g., relay technicians, operators, engineers, IT support, and substation maintenance) that will lead to more protection and control system misoperations.
4. Complicated new multi-discipline control and protection schemes that are beyond the skillset of the existing workforce.
5. A lack of training programs that prevent closing skillset gaps quickly.
6. Inadequate management oversight or controls leads to organizational weaknesses and inefficiencies.
7. Ineffective corrective actions lead to repeated HP errors.
8. 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 ERO Enterprise and industry forums should expand their communication and encourage sharing of good industry practices for increasing HP effectiveness (publishing lessons learned/good industry practices and supporting the NERC and NATF HP conference and other related workshops).
2. NERC should encourage industry and trade associations to identify skill gaps and develop recommendations to address them (e.g., curricula, programs, industry support, and educational pipeline programs), including those which may be associated with protection and control schemes.
3. 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.
4. The industry should develop a near-miss database to leverage data sources such as event analysis, 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.

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

5. Industry and trade organizations, such as NATF, should develop and implement a sustainable process to analyze and disseminate good industry practices for HP.
6. Industry standards and regulatory rules should consider the human skill set changes and training needs as part of their development.

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 DER 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.

Risk Mapping

Lower Likelihood, Higher Impact

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, DER, 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.
7. Dependency on telecommunications systems for situational awareness.

Ongoing Efforts

The ERO Enterprise uses events analysis information to work with industry in performing root cause and common mode failure analysis of partial or full loss of key Energy Management System (EMS) capability and provide lessons learned and recommendations to reduce future risk in this area.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise should evaluate whether key applications are over reliant on a service provider and identify mitigating actions to reduce the risk.
2. The ERO Enterprise should identify the type and frequency of information needed from DER for real-time situational awareness.

Mid-term (3–5 year time frame):

3. NERC, in concert with industry and trade organizations, should improve its set of real-time indicators of interconnection health.
4. NERC should work with industry to 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.
5. The industry, trade organizations, and other industry groups such as the North American Synchrophasor Initiative (NASPI) should develop a suite of supplemental tools that use synchrophasor data (e.g., state

estimator, contingency analysis, etc.) to improve situational awareness, provide early warning for operators regarding deteriorating conditions, and assist in recovery from disturbances.

6. Evaluate the risks of private telecommunication systems as compared to use of public systems for Supervisory Control and Data Acquisition (SCADA) systems.

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

7. The ERO Enterprise should engage with industry and trades organizations to identify options for the delivery of data critical for situational awareness in situations where EMS systems are down for extended periods.
8. The ERO Enterprise should work with industry and EMS vendors to establish forums to identify options for improving situational awareness tools utilizing EMS data including the integration of synchrophasor data.

Risk Profile #7: Extreme Natural Events

Statement of the Risk

Severe weather or other natural events 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.

Risk Mapping

Lower Likelihood, Lower Impact

Descriptors of the Risk

1. Lack of preparation for GMD events could lead to widespread loss of load due to voltage instability in certain regions.
2. Widespread damage to certain types of BPS infrastructure can extend outages due to unavailability of nearby replacement equipment or specialized capabilities.
3. Physical damage to equipment and fuel supply sources, such as natural gas pipelines or other energy storage facilities including hydro.
4. Damage to voice and data communications, as well as water supplies, can make certain critical facilities vulnerable and reduce the ability to serve load.
5. The industry does not have full knowledge, shared documentation, or coordination in accessing and assessing compatibility of the existing spare equipment inventory across geographical and political boundaries.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. Study multiple simultaneous limitations on natural gas deliveries during extreme weather.
2. NERC and industry should plan a workshop that is coordinated with U.S., Canadian, and Mexican federal agencies and governmental authorities to address high-impact low-frequency event response, recovery, and communications vulnerabilities.

Mid-term (3–5 year time frame):

3. NERC should conduct detailed special assessments that integrate:
   a. Interdependencies in addition to fuel-related, such as telecommunications and water supply.
   b. Analytic data trend insights regarding resilience under severe weather conditions, identifying preventable aspects for BPS reliability.
4. Better understand the interdependence of the telecommunication infrastructure and electric infrastructure during a natural disaster.

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

5. Analyze data from GMD events to further the understanding of geomagnetically induced current effects on BES facilities to support enhancements to models and standards.
6. 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.

Risk Mapping

Lower Likelihood, Lower Impact

Descriptors of the Risk

1. Evolving threat around physical attacks, including EMP.
2. The exposed nature of parts of the grid makes it 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. Incorrect assumptions on availability of replacement equipment.
5. Physical damage to generation fuel sources, such as natural gas pipelines, which will degrade the reliable operations of the BPS.
6. Damage to necessary telecommunications and water supplies, which will make certain critical facilities vulnerable and reduce the ability to serve load.

Ongoing Activities

Industry considers exposure to attacks on critical facilities in its planning activities.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. The ERO Enterprise should develop performance metrics measuring and prioritizing potential physical attacks that will result in system disturbances while differentiating them from vandalism or theft incidents.
2. 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.
3. Based on recommendations and identified risks outlined in EPRI's EMP report[12] and soon to be released results for EMP shielding requirements, determine the need to develop Reliability Standards, reliability guidelines, industry webinars, or additional analysis to address EMP events as necessary.
4. NERC should seek input from water, telecommunications, and gas ISACs in the development of physical security Reliability Standards.

Mid-term (3–5 year time frame):

5. Conduct a special regional assessment that addresses natural gas availability and pipeline impacts under physical attack scenarios.

[12] See *Magnetohydrodynamic Electromagnetic Pulse Assessment of the Continental U.S. Electric Grid: Geomagnetically Induced Current and Transformer Thermal Analysis*: https://publicdownload.epri.com/PublicDownload.svc/product=000000003002009001/type=Product

6. National government agencies (e.g., Department of Energy, Natural Resources Canada, Secretaría de Energía (SENER)), industry, trades, and forums should identify appropriate mitigation strategies to fill spare equipment gaps and transportation logistics shortcomings.

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.

Risk Mapping

Higher Likelihood, Higher Impact

Descriptors of the Risk

1. Cybersecurity threats result from exploitation of both external and internal vulnerabilities:
    a. Exploitation of employee and insider access.
    b. Weak security practices of host utilities, third-party service providers and vendors[13], and other organizations.
    c. Unknown, undisclosed, or unaddressed vulnerabilities in cyber systems.
    d. Growing sophistication of bad actors, nation states, and collaboration between these groups.
2. Interdependencies from the critical infrastructure sectors, such as Communications, Financial Services, Oil and Natural Gas Subsector, and Water, where sector-specific 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. The trend towards increased integration of IT operating systems may increase in the attack surface and associated attack risk.
    c. IT/operational technology (OT) control system infrastructure management, out-of-date operating systems, and the lack of patching capability/discipline.
4. Technologies and services
    a. Increased reliance on third party service providers and cloud-based services for BPS operations and support.
    b. Cybersecurity risks in the supply chain: software integrity and authenticity; vendor remote access; information system planning; and vendor risk management and procurement controls.
5. Ineffective teamwork and collaboration among the federal, provincial, state, local government, private sector and critical infrastructure owners can exacerbate cyber events.
6. A lack of staff that is knowledgeable and experienced in cybersecurity of control systems and supporting IT/OT networks (historically separate organizations and skillsets). This risk is symptomatic across all industries and is a risk because it hinders an organization's ability to prevent, detect, and respond to cyber incidents due to organizational silos.
7. The rapid growth in sophistication and widespread availability of tools and processes designed to exploit vulnerabilities and weaknesses in BPS technologies and in connected IT networks and systems.

[13] *See* Reliability Standard CIP-013-1, Supply Chain Risk Management: http://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-013-1.pdf.

Ongoing Activities

With the support and ongoing oversight of the NERC Board and the MEC of the ESCC, the E-ISAC has developed and is executing a long-term strategy for the E-ISAC to improve cyber and physical security information-sharing and risk analysis and increase engagement within the electric sector, as well as with other ISACs. The ESCC has also directed the formation of the Cyber Mutual Assistance Program, which builds on industry's culture of mutual assistance and is informed by lessons learned from major disruptive cyber incidents overseas, as well as by exercises held in North America, such as GridEx.

Recommendations for Mitigating the Risk

Near-term (1–2 year time frame):

1. In collaboration with the CIPC and industry stakeholders, develop a risk process to address the potential impacts of cybersecurity threats and vulnerabilities.
2. The E-ISAC should continue information sharing protocols among interdependent ISACs to increase the visibility into cyber and physical security threats.
3. Facilitate planning considerations to reduce the number and exposure of critical cyber facilities to attack.
4. The ERO Enterprise and the E-ISAC should develop metrics regarding the trend of cyber-attacks and potential threats.
5. The industry should develop focused training and education programs and/or share best practices to address the shortage of skilled and experienced cybersecurity professionals, as well as IT professionals with BPS operations experience.

Mid-term (3–5 year time frame):

6. The ERO Enterprise should develop a feedback mechanism from CIP standards implementation to evaluate the standard and lessons learned from new technology deployments.
7. 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):

8. 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 resilience.