2023 MRO Regional Risk Assessment

February 2023

MIDWEST RELIABILITY ORGANIZATION

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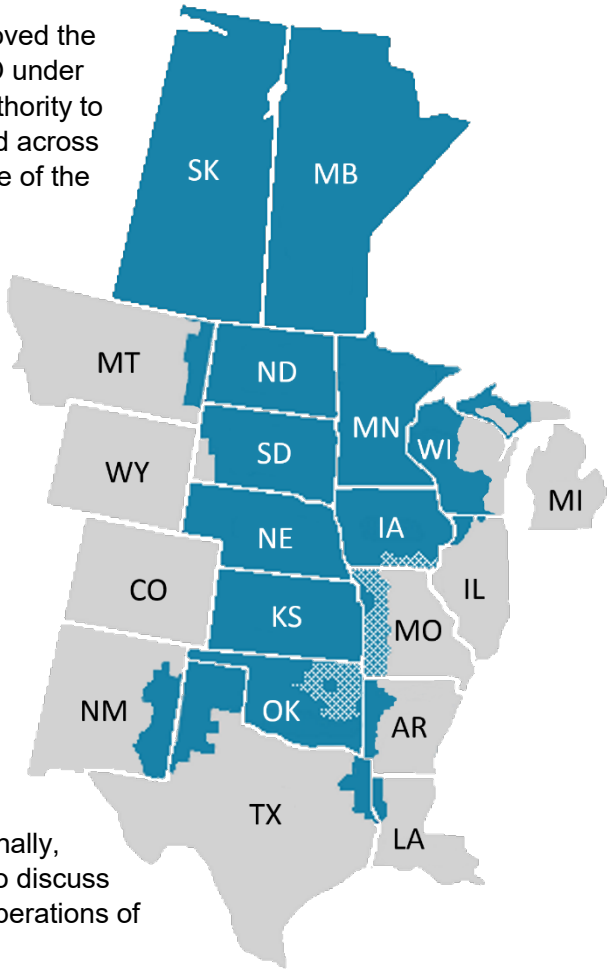
1. PREFACE

Midwest Reliability Organization (MRO) is dedicated to its vision of ***a highly reliable and secure North American bulk power system***. To ensure reliability of the bulk power system in the United States, Congress passed the Energy Policy Act of 2005, creating a new regulatory organization called the Electric Reliability Organization (ERO) to establish mandatory Reliability Standards and monitor and enforce compliance with those standards on those who own, operate or use the interconnected power grid.

In 2006, the Federal Energy Regulatory Commission (FERC) approved the North American Electric Reliability Corporation (NERC) as the ERO under section 215(e)(4) of the Federal Power Act. NERC delegates its authority to monitor and enforce compliance to six Regional Entities established across North America, including MRO. Recognizing the international nature of the grid, NERC as the ERO, along with MRO, established similar arrangements with provincial authorities in Canada.



The MRO region spans the provinces of Saskatchewan and Manitoba, and all or parts of the states of Arkansas, Illinois, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Wisconsin. The region includes approximately 225 organizations that are involved in the production and delivery of electric power, including municipal utilities, cooperatives, investor-owned utilities, transmission system operators, federal power marketing agencies, Canadian Crown Corporations, and independent power producers.

MRO's primary responsibilities are to: monitor and enforce compliance with mandatory Reliability Standards by entities who own, operate, or use the North American bulk power system; conduct assessments of the grid's ability to meet electric power demand in the region; and analyze regional system events. Additionally, MRO creates an open forum for stakeholder experts in the region to discuss important topics related to addressing risk and improving reliable operations of the bulk power system.

2. EXECUTIVE SUMMARY

The purpose of MRO's Regional Risk Assessment is to identify and prioritize risks to the reliable and secure operations of the bulk power system within MRO's regional footprint, which spans all or part of 16 states and 2 Canadian provinces. MRO staff collaborate with industry members serving on three advisory councils (Compliance Monitoring and Enforcement Program, Reliability, and Security) using a wide variety of resources and expertise to conduct this assessment. Identified risks are prioritized by a team of advisory council volunteers and MRO staff using MRO's reliability risk matrix that assesses each risk's impact to bulk power system reliability and likelihood of occurrence.

For 2023, seventeen risks were identified, with the following eight having the highest relative risk:

- Bulk Power Model Assumption Accuracy
- Conservative Practices to Calculate Planning Reserve Margin (PRM)
- Energy Reliability Planning
- Generation Unavailability During Extreme Cold Weather
- Insider Threat
- Overhead Transmission Line Ratings
- Phishing / Malware / Ransomware
- Supply Chain Compromise

Throughout this report, there are common themes and trends identified that underlie these risks and tie them together.

- Conventional, baseload generation is being retired and replaced with dispersed, variable generation, tightening reserve margins.
- New generation resources are largely inverter-based and perform much differently than conventional resources, requiring new modeling assumptions.
- Increasingly bold cyber criminals seek to exploit vulnerabilities in utilities' networks to disrupt normal operations of the bulk power system.
- Extreme weather continues to cause generating resource outages, limiting energy supply at the same time as demand increases.
- The emergence of distributed energy resources connected closer to load results in bi-directional power flows and makes forecasting customer demand more challenging.
- Increasing amounts of generating resources that are physically distant from load is straining transmission capacity and limiting import capability.

MRO is committed to leveraging its unique position to raise awareness, provide guidance, and develop mitigations for the highest risks to reliability and security of the regional bulk power system. Collaboration from multiple stakeholders is needed to manage through the unprecedented pace of change and achieve the goal of maintaining a reliable and secure grid. A variety of solutions from the broad expertise of industry need to be deployed to confront these challenges.

3. INTRODUCTION

The MRO Regional Risk Assessment (RRA or assessment) is a document that MRO staff, with input from industry subject matter experts, prepares annually to identify and prioritize risks to the reliable and secure operations of the bulk power system within MRO's regional footprint. There are several resources used to develop the RRA including event reports, MRO summer and winter assessments, MRO Regional Security Risk Assessment, and ERO Enterprise-wide reports. The following ERO Enterprise-wide risk reports were a resource for this assessment:

- 2021 ERO Reliability Issues Steering Committee (RISC) Priorities Report (RISC report)
- 2022 NERC State of Reliability Report (SOR report)
- 2022 NERC Long-Term Reliability Assessment (LTRA report)
- 2023 ERO Compliance Monitoring and Enforcement Program Implementation Plan (CMEP IP)

Several of the North American-wide risks identified in the above reports can broadly present themselves in any of the ERO regional footprints. However, some of these risks may be more geographic, regional, or registered entity-specific, that is, certain areas, regions or registered entities may have a higher exposure to, or are more susceptible to, a specific risk. Extreme weather conditions or high concentrations of variable generation are examples of these. Therefore, this assessment identifies which risks to the bulk power system may have a higher probability of occurrence within the MRO region or may be regionally unique. This RRA also identifies which risk elements highlighted in the 2023 ERO-wide Compliance Monitoring and Enforcement Program (CMEP) Implementation Plan should be a focus of MRO's CMEP activities for low inherent risk entities.

In developing this assessment, MRO staff leveraged the expertise of the members of MRO's three advisory councils: CMEP, Reliability, and Security. Comprised of industry volunteers from MRO member companies, the advisory councils help to identify and prioritize regional risks.

To the extent possible, recommendations and suggestions for mitigation are presented in this assessment to help registered entities become more aware of, and reduce risk to, their individual systems.

4. CONTINENT-WIDE RISK IDENTIFICATION

4.1 2021 ERO RISC Priorities Report: Risks and Rankings

The 2021 RISC Report[1] highlights forward-looking risks to the North American bulk power system that merit attention and recommends actions that align with mitigating those risks. This biennial report consolidates the identified risks into four high level categories: 1) Grid Transformation, 2) Extreme Natural Events, 3) Security Risks, and 4) Critical Infrastructure Interdependencies.

A. Bulk Power System Planning
B. Resource Adequacy and Performance
C. Increased Complexity in Protection and Control Systems
D. Situational Awareness Challenges
E. Human Performance and Skilled Workforce
F. Changing Resource Mix

A. Extreme Natural Events, Widespread Impact
- GMD

B. Other Extreme Natural Events

A. Physical
B. Cyber
C. Electromagnetic Pulse

A. Communications
B. Water/Wastewater
C. Oil
D. Natural Gas

[1] The charts and figures in this section were taken from the 2021 RISC Report and are shared with permission.

The risks were then ranked by industry stakeholders from highest to lowest. Figure 1 reveals that Changing Resource Mix, followed by Cybersecurity Vulnerabilities, lead industry's perception on the criticality of these risks. This information is useful for industry as a whole to prioritize and dedicate resources and focus.

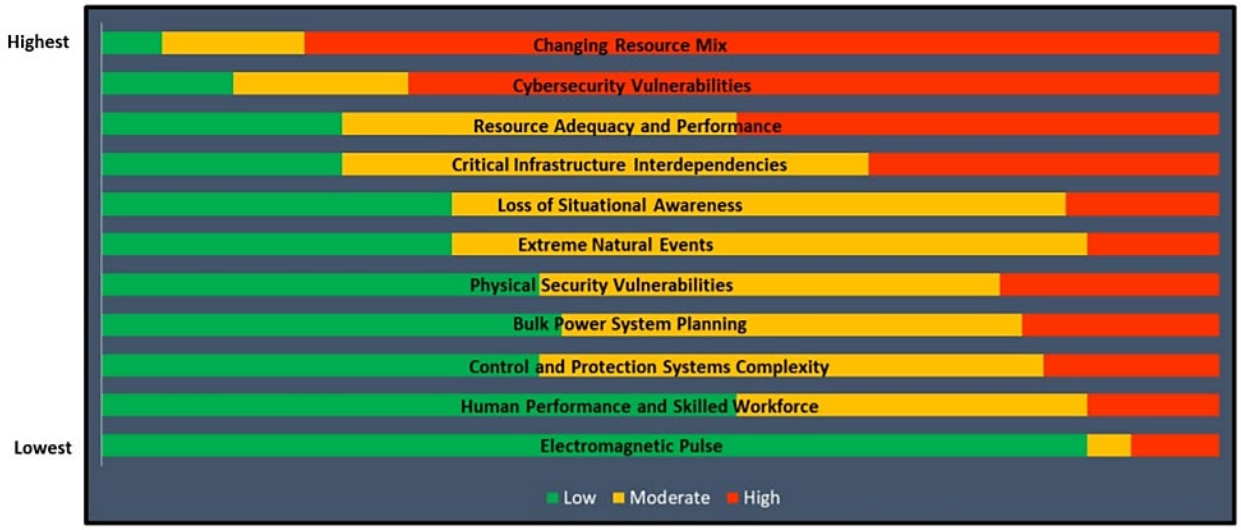


Figure 1: 2021 RISC Risk Rankings per the ERO-Wide Industry Stakeholder Survey

Figure 2 depicts the classification of the identified risks, based on the ranking. Risks identified as "manage" are emerging, imminent, and pose significant threats. Thorough strategic planning and industry collaboration are needed to mitigate these risks. Risks identified as "monitor" are of critical importance to bulk power system reliability, but are being managed with established industry practices to mitigate and lessen potential impacts to reliability. As highlighted in Figure 2, loss of situational awareness and bulk power system planning are two risks that moved from "manage" to "monitor" in 2021.

Figure 2: 2021 RISC Risk Rankings: Manage vs. Monitor

4.2 2022 NERC State of Reliability Report

Analysis of past bulk power system performance provides a backdrop for identifying current system reliability trends. The NERC 2022 State of Reliability Report (SOR Report[2]) provides detailed analyses of past performance while offering technical support for those interested in the underlying data and detailed analytics to:

- Identify system performance trends and emerging reliability risks;
- Report on the relative health of the interconnected system; and
- Measure the success of mitigation activities deployed.

The 2022 report highlights extreme weather challenges, including two notable events, the February 2021 cold weather event in the south central U.S., and the Northwest Heat Dome event in late June and early July 2021. Both events strained the bulk power system's ability to meet customer demand with generation resources. In the case of the February 2021 event, supply could not meet demand resulting in the largest manual load shed event in U.S. history.

Anticipated Reserve Margins indicated in the report for the four assessment areas within the MRO footprint show each system had enough generation resources to meet expected loads in 2021. However, analysis of extreme conditions showed that MISO and SPP would be challenged to meet higher than expected load if there was an atypical number of generation outages. This risk was realized during the February 2021 event.

Data analysis within the report regarding primary frequency response, Interconnected Reliability Operating Limit (IROL) exceedances, protection system misoperation rates, and transmission outages show improving or stable performance.

[2] The charts and figures in this section are from the 2022 State of Reliability Report and included here with permission.

Generator forced outage data from the report, shown in Figure 3, indicates an increase across all fuel types tracked (except nuclear) and are the highest they have been in five years. The Weighted Equivalent Forced Outage Rate (WEFOR) measures the probability that a group of generation will not meet its generating requirements due to forced outages or derates and is weighted to give larger generation more impact to the metric. The increase in 2021 was partially attributable to the outages during the extreme cold weather event in February 2021.

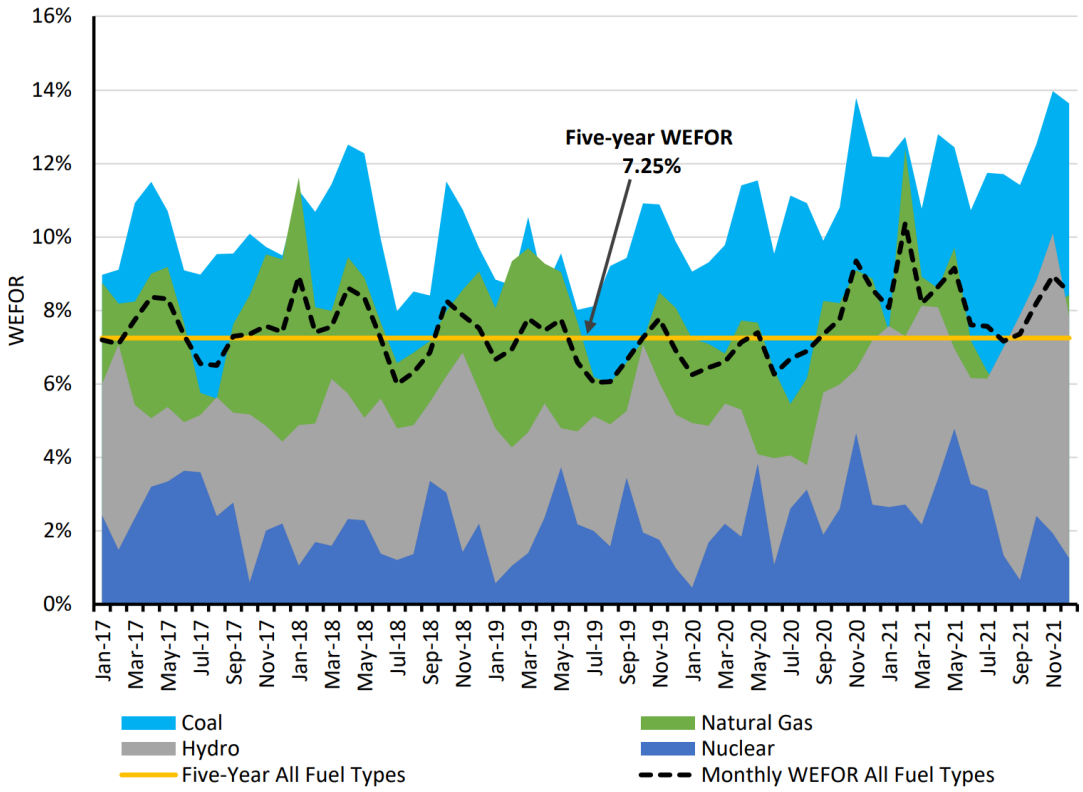


Figure 3: Monthly Capacity WEFOR by Fuel Type from January 2017 to November 2021

Figure 4 shows forced outage data for wind generation over an almost four-year timeframe. The Weighted Resource Equivalent Forced Outage Rate (WREFOR) is the wind generation equivalent to WEFOR. It includes periods when the wind is too low or too high for production from the wind turbines. The data is split by size of the wind generation plant. Data for plants 100-199 MW started being collected in 2019 and for plants 75-99 MW in 2020. The horiztonal lines show the average WREFOR rate, which has risen in 2021 for all plant sizes. The bar graphs are the monthly performance showing an elevated forced outage rate due to the February 2021 event.

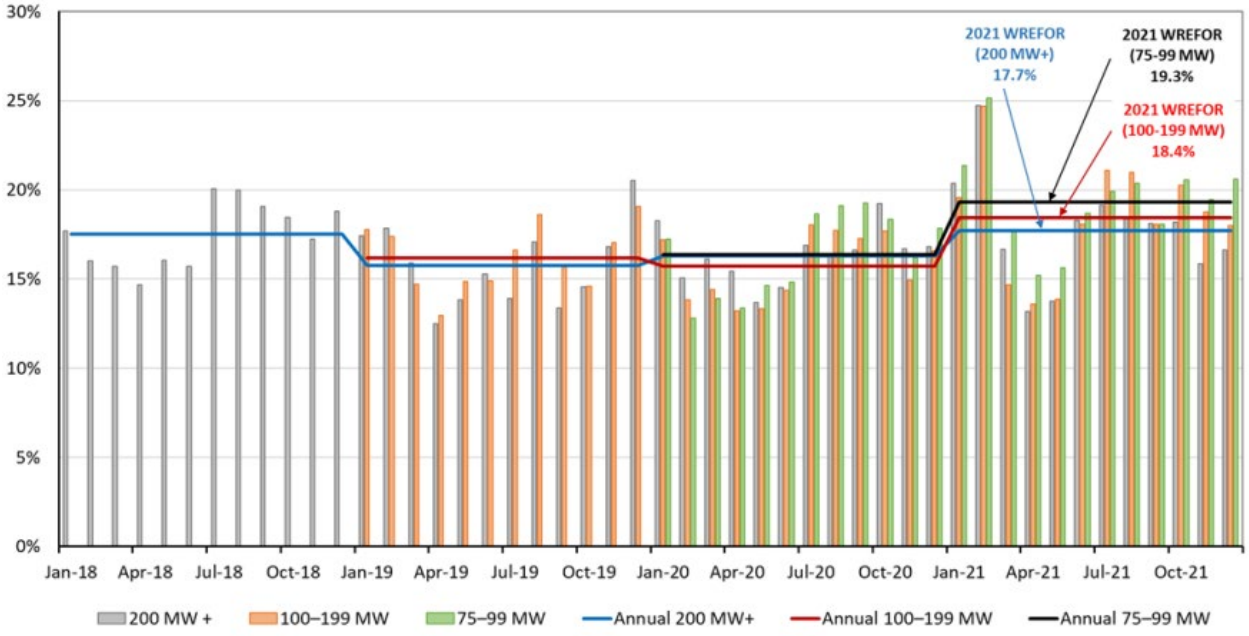


Figure 4: Monthly Capacity WREFOR for Wind Generating Facilities from January 2018 to November 2021

The NERC SOR report included information on the cyber and physical security landscape as it pertains to the utility industry and highlighted several supply chain attacks in 2021. Geopolitical tensions increased in 2021, causing the federal government to launch a 100-day plan to safeguard critical infrastructure. Electric utilities saw an increase in ransomware attacks in 2021 focused on corporate systems. Regarding physical security, the SOR report noted there was only a modest increase in the number of incidents in 2021.

The following six key findings identified in the SOR report call for further attention:

- Extreme cold weather challenges the generation fleet's ability to remain online and supply energy.
- The interdependencies between electricity and natural gas infrastructures exacerbates the above issue.
- Grid resilience is increasingly important to recover from extreme weather events.
- Increasingly bold cyber criminals and geopolitical events coupled with new and changing technologies and vulnerabilities present serious Bulk Electric System (BES) reliability challenges.

- As variable energy resource penetration increases, the response of inverter-based resources to disturbances needs to be addressed.
- Additional data is needed to enable a more complete analysis of grid reliability.

4.3 2022 NERC Long-Term Reliability Assessment Report

NERC's Long Term Reliability Assessment (LTRA) Report[3] is a forward-looking report that assesses the long-term reliability (including planning reserve margins and resource adequacy) of the North American bulk power system while identifying trends, emerging issues, and potential risks during the upcoming 10-year assessment period. The report is not a prediction of future conditions, but rather an assessment of what changes are occurring with respect to resource adequacy and operating reliability. Cyber and physical security risks are not specifically addressed in this assessment.

Trends identified in the NERC SOR report are sustained in the 10-year assessment period of the LTRA. Notably, most assessment areas have adequate supply resources to meet demand forecasts in normal weather conditions. However, several areas are at risk of having insufficient capacity to meet adequacy requirements during long-duration extreme weather events. Further, peak electric demand in many areas is increasing and has the potential to drastically increase with the electrification of the transportation industry and space heating.

Figure 5 reflects the amount of ERO-wide planned resources through 2032 and shows that solar is the predominant planned generation resource with wind, hybrid, and natural gas making notable contributions. It should be noted that not all of these resources will ultimately go online.

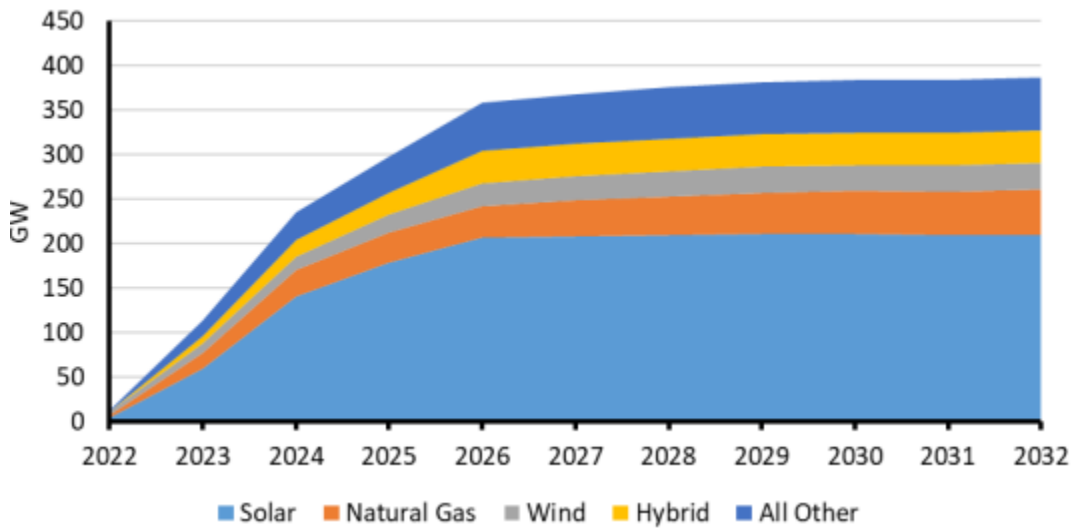


Figure 5: Planned Resources Projected through 2032

[3] Some of the charts and figures in this section are from the Long-Term Reliability Assessment and are included here with permission.

Figure 6 shows the projected generation retirements through 2027 and indicates a steady increase in confirmed and unconfirmed retirements. This, along with Figure 5, illustrate the acceleration of the changing resource mix.

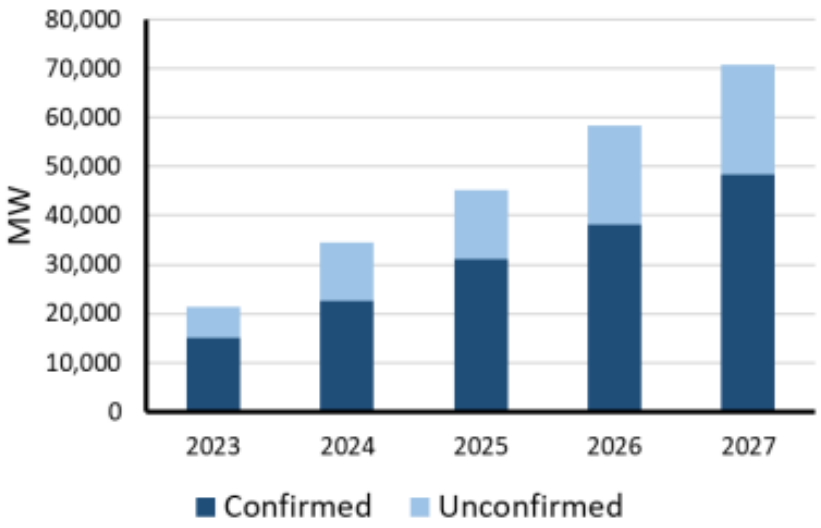


Figure 6: Projected Generation Retirements through 2027

The LTRA reviews specific reliability implications regarding the changing resource mix. As conventional synchronous generation is retired and replaced with more variable generation and inverter-based generation, consideration must be given to maintain essential reliability services like voltage and frequency control and dispatchability. Integration of large amounts of Distributed Energy Resources (DER) is important to maintaining supply and demand balance as forecasts show that more than half of the assessment areas project double the amount of DERs by 2032.

The LTRA identified several key conclusions and recommendations to address expected risks:

- The pace of generation retirements needs to be managed until solutions are in place to continue to meet energy needs and provide essential reliability services.
- Risks from the growing reliance on variable resources and resources with little or no on-site stored fuel need to be mitigated.
- The impact of extreme weather needs to be included in resource and system planning, and resource adequacy needs to be assessed for all hours and seasons of the year.
- Inverter-based resource performance and integration with the grid needs to be addressed.

5. 2023 MRO REGIONAL RISKS AND RANKINGS

The following section summarizes the regional risks identified by MRO staff in collaboration with the MRO advisory council members, utilizing the previously described NERC products as context. Note that some risks identified in this section may apply to the Midwest portion of the continent (which is largely congruent with the MRO footprint), but in other cases, the risk identified may apply only to a functional entity such as an Independent System Operator (ISO) / Regional Transmission Organization (RTO) or a Transmission Owner/Operator (TO/TOP).

5.1 MRO Reliability Risks

The reliability risks in Table 1 were identified as specifically applicable to the MRO footprint. They are listed alphabetically and not according to risk level.

MRO Reliability Risks	
1	Bulk Power Model Assumption Accuracy
2	Changing Sources of Reactive Power
3	Compromise of Sensitive Information **- NEW**
4	Conservative Practices to Calculate PRM
5	Energy Reliability Planning
6	Generation Unavailability During Extreme Cold Weather
7	Inadequate IBR Ride-Through Capability
8	Increased Penetration of Internet-Connected Devices **- NEW**
9	Insider Threat
10	Material and Equipment Availability **- NEW**
11	Misoperations Due to Human Errors
12	Overhead Transmission Line Ratings
13	Phishing / Malware / Ransomware
14	Physical Security Protections from Incidents
15	Tightening Supply of Expert Labor
16	Supply Chain Compromise
17	Vulnerabilities of Unpatched Systems

Table 1: MRO Reliability Risks

Bulk Power Model Assumption Accuracy

Models used for the planning and operation of the bulk power system are the foundation for which new assets are identified and operational strategies are developed. The rapid transformation of the electric grid has posed several challenges to foundational operation and planning methods. Load characteristics are also changing. Increased amounts of DER mean that connections to load are no longer assumed one-directional, which complicates demand forecasting. Increased electrification also complicates demand forecasting as additional devices, such as electric vehicles, connect to the grid and load usage patterns change throughout the day. Shifts away from centralized power supply is changing the size, location, and capabilities of generation on the grid. Power flow patterns have become a market driver to meet demand at the lowest cost, causing traditional interchange assumptions to no longer represent day-to-day operations.

Due to this transformation, traditional assumptions used in the operations and planning models are no longer valid. This risk is reframed from last year's RRA to focus on the accuracy of modeling assumptions rather than simple data accuracy issues. Focusing on modeling assumptions is important in the midst of the grid transformation. Model accuracy is also a subjective term. In this context, an accurate model is one that can reasonably mimic what occurs on the current system and help anticipate the future system. Given the uncertainty of the future system, an increasing number of scenarios need to be analyzed to account for increased variability of load and generation patterns. System models do not currently include the flexibility needed to model the changing grid accurately. For example, models do not adequately capture areas with a high penetration of distributed generation in concert with gross load to cover the range of possible conditions (high production of distributed generation versus low or no production).

The expected surge of purely inverter-based resources (solar generation and Type 4 full converter wind machines) is also creating modeling assumption accuracy risks. While the MRO region has large amounts of wind generation, the majority uses some form of an induction generator that is coupled with the grid, which behaves differently than a purely inverter-based resource that is decoupled. Many times, purely inverter-based resources are being modeled inaccurately. NERC and WECC released a report in August 2020 highlighting deficiencies in accurately representing inverter-based generation in Western Interconnection bulk power models. The key findings identified in the report (using simplified dynamic models, inappropriate dynamics models, and generic values in model parameters) can be extended to the MRO region as purely inverter-based resource interconnections increase. Further, moving to more inverter-based resources will erode the short-circuit strength of the system. Short-circuit models are important to setting protective relays and must accurately capture the reduced short circuit strength and the lack of negative sequence current from inverter-based generation. Failure to do this may cause protective relays to no longer provide dependable and secure fault clearing on the bulk power system.

Changing Sources of Reactive Power

As synchronous generation is retired, reactive capability that synchronous generators inherently provide will also disappear. New generation additions require foresight and proper configuration to provide reactive capability and are typically installed farther from load centers. These factors fundamentally change where reactive power comes from and how it flows through the system to control voltage. The system will become more reliant on non-generation resources (i.e., synchronous condensers, static var compensators, etc.) and inverter-based resources to supply reactive power. While energy and capacity markets have established incentives for generation to be available and

produce real power, there are not strong incentives for the availability and production of reactive power from either generation or non-generation resources.

This risk was expanded from last year's RRA that was focused on reactive capability of inverter-based resources. While it is true that the system will become more reliant on inverter-based resources to provide reactive power, they are not the only resource available to control voltage as highlighted above. Integration of this new mix of reactive resources is not well understood or a current focus of long-term planning assessments. More deliberate planning is needed to better understand the performance of these resources and how they can be deployed to provide needed static and dynamic reactive power to the grid. The deployment of these new resources also needs to account for the range of voltage stability requirements expected as the shift to more variable and less centralized generation creates higher power flows over longer distances.

Compromise of Sensitive Information - NEW

Exfiltration of sensitive data poses a significant threat to organizations and can be combined or exacerbated by other threats. For electric utilities in particular, Critical Energy/Electric Infrastructure Information (CEII) data like operational diagrams, network configurations, login credentials, etc., is the target of threat actors. There is a present threat of bad actors stealing this information in preparation to conduct targeted attacks, extort organizations, or sell to other criminal groups. In particular, compromised data could be used to orchestrate an attack on the bulk power system. Strong data security policies and controls can be cumbersome to manage and depend on many individuals with access to sensitive data abiding by the policies and controls. This is a new risk identified in 2023.

Conservative Practices to Calculate Planning Reserve Margin

Planning Reserve Margins are used as an indicator to gauge whether generation capacity is sufficient to meet peak demand, especially in the planning horizon. RTOs and member companies use Planning Reserve Margins to plan for adequate generation capacity, taking into account planned and unplanned generation outages, derates in generation capability, availability of demand-side management, and load forecasts. The changing resource mix and increase in extreme weather is challenging past assumptions used to calculate Planning Reserve Margins. There is increasing concern that Planning Reserve Margins are overstated and/or required reserve margins are inadequate to address the future generation mix and load characteristics.

This is especially true during winter operations. Uncertainty in natural gas supply for bulk power system generation in the winter season increases risk of gas-fired plants being unavailable. Most demand-side management programs are designed for summer operation, limiting the availability of these resources in the winter. Load has spiked in the winter above 50/50 and even 90/10 forecasts, especially in the south central U.S., due to the predominance of resistive electric heat. Unplanned generation outages due to cold weather have exceeded assumed values in the reserve margin calculation.

Figure 7 shows MISO at risk of insufficient electricity supply under extreme winter conditions as determined by the NERC 2022-2023 Winter Reliability Assessment, which analyzes both normal and extreme operating conditions.

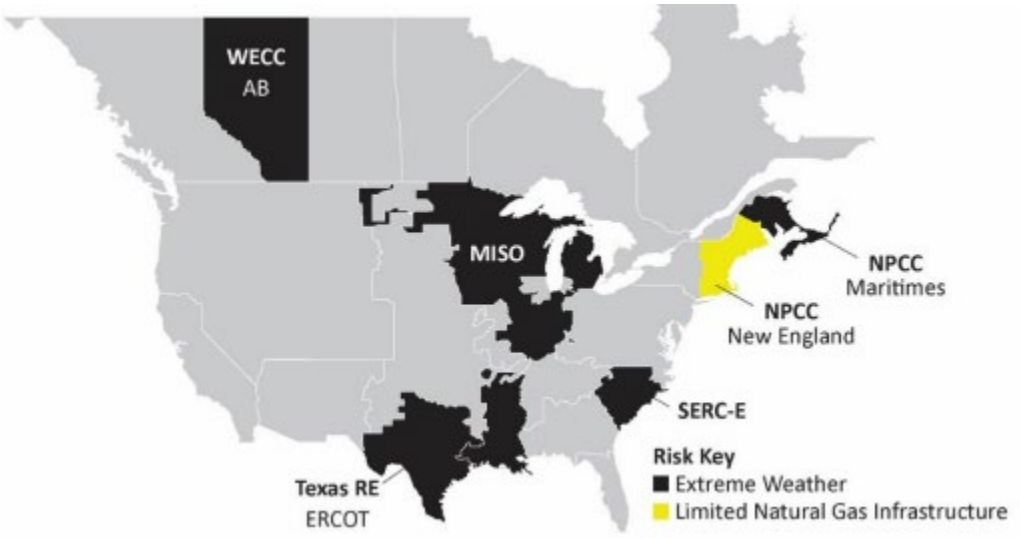


Figure 7: 2022/2023 Winter Reliability Risk Area Summary

However, this concern is not limited to the winter season and so this risk has been revised in this 2023 RRA. The further reliance on intermittent, energy-constrained resources to serve customer demand increases uncertainty of supply availability across all seasons. The 2022 NERC Summer Reliability Assessment showed three of MRO's four assessment areas at either elevated or high risk of insufficient operating reserves in the summer season.

Figure 8 shows the risk classification for the Summer 2022 season, indicating MISO, SaskPower, and SPP at either high or elevated risk.

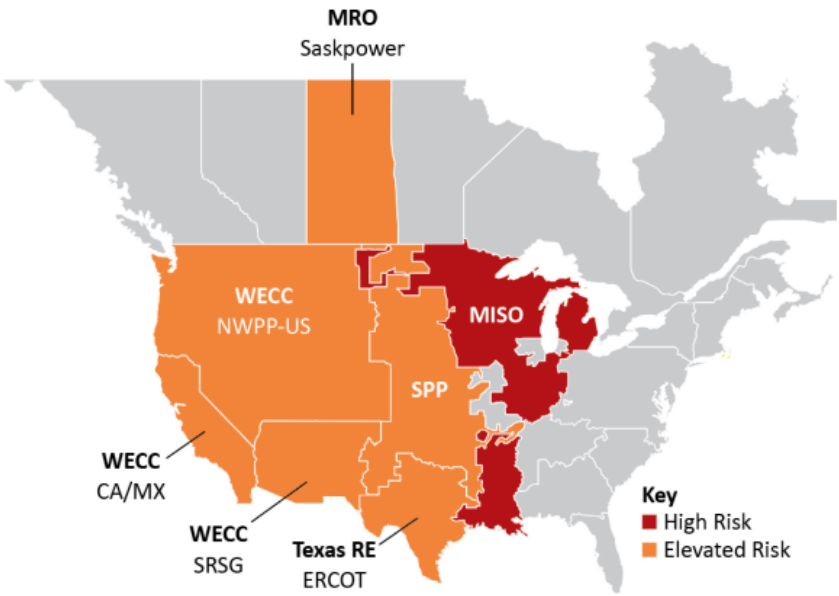


Figure 8: 2022 Summer Reliability Risk Area Summary

MRO-held webinars on summer and winter reliability assessments raise awareness on calculated reserve margins in extreme conditions. These assessments show large differences in reserve margin calculated for normal conditions versus extreme conditions, indicating that assumptions used for these calculations have a drastic impact on the results.

Energy Reliability Planning

Lessons learned from the February 2021 cold weather event and from previous extreme weather events, as well as forward-looking assessments of the grid, all point to energy reliability planning being the top reliability challenge the industry needs to address. Energy reliability planning is the ability to assess whether energy will be available to meet system demands at all hours of the year. There are several interdependent factors challenging the industry's ability to provide consumers with uninterrupted power.

- The changing resource mix is introducing large penetrations of variable resources to the grid at the same time that traditional baseload unit retirements are accelerating, increasing uncertainty and resulting in tighter reserve margins.
- The emergence of distributed resources connected closer to load makes forecasting customer demand more challenging.
- More resources delivering energy farther from load is straining transmission capacity and limiting import capability.
- Electricity use is expanding into new sectors, like transportation and heating; these electrification efforts are the result of state and federal decarbonization goals and are well underway.
- Hybrid and storage assets are a new type of generation that provide fast-ramping resources to the grid, but with limited duration.

Changes to bulk power system supply and demand are happening at an unprecedented rate, requiring industry to rethink how generating capacity, energy supply, and load-serving needs are planned and understood.

The "Lack of Energy Assurance Assessments" risk identified in the 2022 RRA was renamed to "Energy Reliability Planning" to align with the efforts of NERC's Energy Reliability Assessment Task Force (ERATF). The ERATF is an industry task force developing a formal process to address issues ensuring energy adequacy to serve load at any given time, for all hours of the year.

Generation Unavailability During Extreme Cold Weather

The MRO region experiences several forms of severe weather, such as derechos, tornados, lightning storms and damaging hail, ice storms and blizzards, and most recently, extreme cold. Unlike generation facilities in the northern U.S. and Canada, which are designed to operate in extreme cold temperatures, a significant portion of the generation in the southern parts of the region consist of facilities that were not originally winterized to withstand prolonged sub-freezing temperatures and icing conditions. A significant number of generating facilities becoming unavailable during extreme cold temperatures can lead to a shortage of generation across the region, causing an inability to meet load obligations.

The significance of this risk is illustrated by the extreme cold weather event of February 2021. The combined loss of 61,800 MW of generation in the planning footprints of Electric Reliability Council of

Texas (ERCOT), SPP and MISO due to sub-freezing temperatures and lack of generation winterization led to the largest controlled firm load shed event in U.S. history (23,400 MW). More than 4.5 million people in Texas alone were without power, some for almost four days. MISO and SPP directed 2,230 MW and 3,328 MW of load shed, respectively, during the event. The FERC-ERO Cold Weather Inquiry report on the February 2021 event across the south-central U.S. has several findings and recommendations aimed at addressing generation unavailability during sub-freezing temperatures.

MRO initiated a Generator Winterization Program in 2021 to address this risk. The program focuses on bringing awareness to generator winterization best practices and sharing areas for improvement, as well as evaluating the level of readiness and the effectiveness of the entities' programs. MRO sends a survey to select generators in the MRO footprint and conducts site visits each year to gather information. Because of travel restrictions associated with the pandemic, site visits were limited in 2021 to the Minneapolis-St. Paul area. In 2022, MRO expanded the number of visits and the geographic area based on Generation Availability Data System (GADS) data and registered entities' willingness to participate. Six site visits were conducted and three of them in the southern portion of the MRO region.

Inadequate Inverter-Based Resource Ride-Through Capability

The electric utility industry is in the midst of a transition to a new generation mix that includes more renewable generation, like wind and solar. These generation types are typically deployed using power inverters (inverter-based resources or IBR) that convert a DC supply to AC in order to interconnect with the grid. Over the past few years, there have been multiple system disturbances that resulted in the unnecessary loss of generation from inverter-based resources. Most recently, two disturbances in Texas in March 2022 resulted in the loss of 273 MW and 457 MW of wind generation from normal-clearing faults on high-voltage transmission lines. NERC released a report, Panhandle Wind Disturbance: Joint NERC and Texas RE Staff Report, on August 10, 2022, reviewing these events. The results are concerning as the generation resource mix transitions and the system is more dependent on inverter-based resources.

Figure 9 shows the amount of existing and planned solar and wind within the MISO and SPP footprints, which will likely all be inverter-based. Tier 1 resources are those that have a signed agreement or are under construction. Tier 2 resources are those that have completed interconnection study work. Tier 3 resources are those in an interconnection queue that do not meet Tier 1 or Tier 2 requirements. Therefore, while not all of the planned generation will be added, it represents a commitment to drastically increase future amounts of wind and solar connected to the grid.

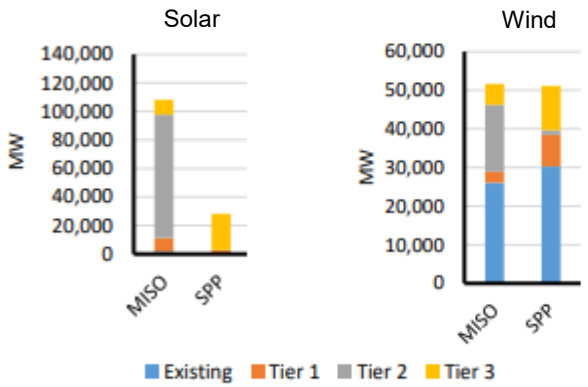


Figure 9: MISO and SPP Existing and Planned Solar and Wind Capacity

As larger penetrations of IBR are deployed, unexpected, momentary losses of IBR generation could severely disrupt the overall generation and load balance. In the 2022 RRA, this risk included a modeling component that has been moved to the *Bulk Power Model Assumption Accuracy* risk in 2023 to provide more focus on ride-through issues.

Increased Penetration of Internet-Connected Devices - NEW

Advancements in technology have led to more internet-connected devices on utility systems. For example, smart meters and DERs increase the amount of data available on customer usage and supply of power and are used to make decisions either by utility operators or customers. The use of Dynamic Line Ratings require the installation of network-connected field devices that ultimately provide data to operational control systems. These connections to intelligent electronic devices are outside of protected substation and generating facilities and are typically internet-connected, greatly increasing the attack surface of the power grid.

If not properly managed, internet-connected devices could be leveraged to manipulate data used to operate the power grid. Furthermore, the internet-connected devices could likely be from a limited set of available manufacturers, thus presenting a common mode vulnerability from the homogenous installed equipment base across a wide geographic area. This may result in a compromise on the power grid, affecting automated tools used for grid operation and disrupting normal function. For example, a compromise of a U.S. water treatment facility in 2021 occurred in part due to a computer system exposed to the internet, and was an attempt to detrimentally affect the water supply. This example illustrates how a similar attack could occur directly on the power grid.

Insider Threat

A person with malicious intent, knowledge and access to proprietary information and/or critical systems poses a substantial threat. A malicious insider may function as an initial access vector for a threat group to further its strategic objectives or act upon the individual's own objectives. The insider threat utilizes legitimate access to critical systems, trusted position, and specific system knowledge to implement various tactics to disrupt operations and create harm to an organization. Insider threats that have a higher impact are typically those with malicious intent, including disgruntled employees, contractors, vendors, or others with knowledge of and access to critical systems. These individuals pose a threat to organizations because they have the ability to go undetected by typical countermeasures and can further modify those defenses to allow expanded, continued, and undetected access. An insider threat enables security-related events of a physical or cyber nature, with the intent to create operational impacts. This risk continues to be a high concern in the 2023 RRA.

As in network security where the perimeter defenses fail to detect malicious activity once the threat is inside, similar logic applies to the human actor once they join the circle-of-trust. In both cases, tools are necessary to detect malicious activity within the trust zone. A method to reduce the human risk of insider threats is through implementation of an insider threat-hunting program. This type of program provides for detection, limiting impact, and limiting movement. It includes concepts such as training on recognizing and reporting signs of insider threat, conducting more frequent and recurring background checks of individuals with access to critical systems, and well-defined access management practices like segregation of duties, least privilege, and the two-person rule for high risk actions.

Preceding its 2022 Security Conference, MRO hosted a full day of training on insider threats. The training started with a presentation by Keith Jones from RWE Renewables on developing an insider threat identification and mitigation program. Dr. Rosie Ward, CEO and co-founder of Salveo Partners, LLC, followed with a presentation focused on employee mental health and the connection to insider threats.

Material and Equipment Availability – NEW

The COVID pandemic resulted in a global supply chain strained beyond its capabilities. An unexpected increase in demand coupled with manufacturing challenges led to extended delivery times for many materials and equipment. Not immune from these challenges, the electric utility industry has suffered from extended deliveries across a spectrum of materials and equipment needed for critical inventory.

Utilities have long relied on partnerships and mutual aid to supplement inventory of spare materials and equipment. As the global supply chain has tightened, overall lack of inventory has affected utilities' ability to leverage those relationships to source materials. This leaves utilities vulnerable to address equipment failures and damage related to severe weather events or physical attacks. Lack of materials to replace failed or damaged equipment and facilities extends outage durations and reduces overall grid capacity. This has the potential to build upon itself if the system is hit with multiple failures or damage within a short period.

Further, lack of materials and equipment also affects planned projects. Delays in projects caused by lack of materials and equipment could mean needed projects are not completed in time to address identified reliability issues.

Misoperations Due to Human Errors

From system protection misoperations reported to the Misoperation Information Data Analysis System (MIDAS) and Event Analysis databases, MRO analyses show that human errors introduced during construction and often identified during commissioning result in latent risk on the bulk power system. The ERO Enterprise (including MRO staff) and FERC jointly launched an effort to investigate this risk and develop findings and recommendations to help registered entities mitigate errors that occur during commissioning. The Joint Review of Protection System Commissioning Programs report was released on November 2, 2021. MRO held a webinar on July 14, 2022, to provide information on the ERO/FERC report and work underway by MRO entities and the Protection Relay Subgroup to reduce human errors.

The risks misoperations present to the bulk power system are not limited to the facilities protection systems are designed to protect. A misoperation can cause unforeseen operations of protection systems that cause a larger number of facilities to outage in order to clear a fault. The MRO 2022 Regional Summer Assessment found that approximately one-third of the misoperations between June 1, 2021, and September 30, 2021, were attributable to human errors. Almost half of the misoperations during the winter 2021 season were attributable to human errors as outlined in the MRO 2022 Regional Winter Assessment. Implementation of proper controls during commissioning to identify human errors will help mitigate this risk. Further controls or best practices implemented throughout the process to design and construct facilities can help as well. Since errors are introduced throughout facility design and construction, the title of this risk was changed from the 2022 RRA to remove references to “commissioning” as that inaccurately focused only on the commissioning process.

Overhead Transmission Line Ratings

Within the MRO footprint, there are varying methodologies for establishing Facility Ratings according to NERC Reliability Standard FAC-008-5 (i.e., ratings for summer and winter seasons and for normal and emergency operation). The FERC inquiry report on the cold weather event of January 17, 2018, recommended Transmission Owners/Operators (TOs/TOPs) conduct analysis, as part of establishing ratings, delineating different ratings for summer and winter seasons for normal and emergency conditions. While not explicitly required within FAC-008-5, use of summer and winter season ratings determined for normal and emergency conditions are a valuable tool for system operation. Without unique ratings for the different seasons or conditions, Reliability Coordinators may make real-time operating decisions using ratings based on assumptions not consistent with real-time conditions, when capacity on those facilities may be most important to reliability.

Most recently, FERC issued Order 881 on December 16, 2021, for Managing Transmission Line Ratings. This order requires transmission providers to implement ambient-adjusted ratings on transmission lines for which they provide transmission service. Additionally, transmission providers must use uniquely determined emergency ratings. This rule recognizes the operational risk presented by using line ratings based on conservative assumptions looking at worst case air temperature and other weather conditions. Implementation of this rule is targeted to increase the utilization of the grid, which overall, benefits reliability. The categorization for this risk increased to “High” in 2023 versus “Medium” in 2022, despite FERC Order 881. This increase in categorization is due to the challenge in implementing the rules introduced by FERC Order 881 and management of the increased data set required for ambient-adjusted ratings.

Phishing / Malware / Ransomware

Phishing is an initial access tactic that uses social engineering and electronically delivered messages, typically emails, that contain maliciously coded links or attachments. A successful phish may then deploy malware and ransomware software used to execute unauthorized actions on the victim's system. Phishing is frequently used to initiate malware and ransomware attacks, which is why it was added to this cyber security risk in 2023. Although phishing is the primary tactic used to deploy malware and ransomware, it is not exclusive. Other vectors exist, such as supply chain, removable media, and drive-by compromises, which rely upon a user to visit an infected website. Ransomware is a type of malware that requires the victim to pay to recover encrypted files or to avoid unauthorized disclosure of sensitive information.

These threats are constantly evolving and could affect critical electric utility systems, resulting in adverse impacts to operations. The ease of deployment and difficulty identifying the attacker makes it a preferred tool for many cybercriminal groups. While this risk is prevalent in Information Technology (IT) systems, Operation Technology (OT) systems may have firewalled connections to IT.[4] The correct configuration of these firewalls is essential; otherwise, a phishing-malware-ransomware event may be the delivery mechanism for an attack aimed at inhibiting the critical functions of the power grid. For example, an adversary could hinder safeguards put in place for reliable operation of the power grid, such as protective relays, or an adversary could inject malicious code that might suppress expected alarms in SCADA systems, leading system operators to be unaware of worsening conditions on the grid during escalated operations. Additionally, attacks on IT systems may indirectly affect OT systems. While OT systems may be isolated from IT by firewalls, the company's operations depend on corporate support functions. Over a longer duration, inhibited corporate functions may cause operations to cease. An example of this was the ransomware attack on Colonial Pipeline, which resulted in a disruption to business operations that affected consumers and airlines on the East Coast.

There are several methods to reduce risk that span from protection to monitoring to response actions. Methods to reduce risk are:

- Implement effective strategies to reduce the risk of initial compromise and manage administrative privileges to prevent code execution.
- Increase the segmentation of your network to limit spread and monitor your network to identify anomalous communications.
- Develop and test an incident response program with preplanned actions and consider using a third party to provide additional resources if an event occurs.
- Consider having system backups that are offline or on a separate network to speed recovery.

[4] In the context of the power grid, Information Technology (IT) systems is in reference to all the equipment and software used to implement corporate functions, while Operational Technology (OT) are the equipment and software used for direct operation of the power grid (e.g., energy management systems, field area networks, substation protection and control, generator controls, etc.).

Physical Security Protections from Incidents

Physical security controls are the first line of protection against unauthorized physical access to critical bulk power system facilities. Unauthorized physical access can be used to conduct a physical attack, or as the initial access tactic for a cyber attack. Geographically dispersed sites incur higher risk because perimeter security measures may not be a viable solution. Dispersed sites may have limited inspections of security controls and may not have infrastructure to enable advanced security equipment, such as video/radar detection. Since perimeter security measures may not be a viable solution to protect dispersed sites, “perimeter” was removed from the risk title in this 2023 RRA.

Most utility security programs have corporate requirements for public deterrence at the asset boundary, with items such as fences, locked gates, card readers, and/or cameras. Denying physical access and deterring damage or theft all help to prevent disruption of bulk power system operations. In the event of an attack, physical boundaries also help limit physical damage to high impact, high cost, and long lead-time equipment, such as transformers or generators.

Unmanned Aerial Systems (UAS), or drones, are used by industry for operational inspections and monitoring of remote assets. UAS may have security vulnerabilities or configurations that could be exploited to steal sensitive information. Threat actors may use UAS to conduct surveillance of substations to gain sensitive information or as weapons to carry explosives with the intent to harm people and industry assets. Non-malicious UAS users may also cause inadvertent damage. Detecting and disabling unauthorized UAS is challenging and there may be little recourse other than reporting to law enforcement.

Supply Chain Compromise

Supply chain compromise affects the end user’s operations because a malicious actor manipulates the hardware, software, or delivery mechanisms before receipt. Supply chain compromises can occur in either IT or OT, and the impact may be broad if the vendor is a market leader in the product or services provided to the utility industry. As an example, in 2020, an adversary compromised a commonly used market leading network-monitoring software to exfiltrate sensitive information. Although this did not happen on U.S. power grid OT systems, the specific software is utilized on those systems. The risk remains categorized as “High” in this 2023 RRA.

To help mitigate this risk, it is important to assess all cyber equipment vendors, implement controls on vendor-related processes, and include controls on procurement processes. Consider applying cyber informed consequence driven engineering in your OT systems, and define consequence-driven response plans that segment OT systems and limit the impact of a supply chain compromise. Diversification of vendors across the industry is another valuable method of reducing the impact of a vendor breach.

Tightening Supply of Expert Labor

From the U.S. Bureau of Labor Statistics data, the number of job openings in the transportation, warehousing, and utilities sector has increased 72 percent since 2020. According to Cybersecurity Ventures, the number of unfilled cyber security jobs has grown 350 percent since 2013 to 3.5 million openings. This rapid increase signals a significant unmet demand for cyber security labor in the utility industry. The risk represents a broader array of the human resources needed to maintain reliable operation of the bulk power system and persists given the competitive job market, low unemployment, and other competing business factors. An insufficient number of trained staff may result in operational impacts and the ability to position the power system to adapt to a number of

rapidly evolving risks. As human resources continue to be scarce, business decisions to prioritize work become even more important because a focus on complying with mandatory NERC reliability standards may compete with developing additional controls required for reliability and security.

Vulnerabilities of Unpatched Systems

Unpatched software or systems creates increased attack surface by allowing known vulnerabilities to exist in both IT and OT systems. This may be due to unavailability of a patch, inability to patch, or lack of awareness of the patch in a timely manner. According to IBM Security's 2021 X-Force Threat Intelligence Index Report, one in three data breaches are a result of unpatched vulnerabilities. Failure to patch vulnerabilities can lead to compromised industrial control systems including protective relays and Energy Management Systems used to operate the bulk power system. For example, the power industry uses legacy applications that may run on unsupported web browsers, thus leaving any newly discovered vulnerabilities without patches. In 2022, hackers exploited unpatched vulnerabilities to attack energy, shipping, healthcare and government systems.

5.2 Correlation Between ERO-Wide Risks and MRO Regional Risks

Figure 10 shows the correlation between the reliability and security risks identified in the 2021 ERO-wide RISC Report and the 2023 MRO Regional Risk Assessment. The MRO regional risks (which are more granular and are shown in the gray boxes) are mapped to the ERO-wide risks in the colored boxes by RISC category. As can be seen, the results of the two analyses are complimentary to one another.

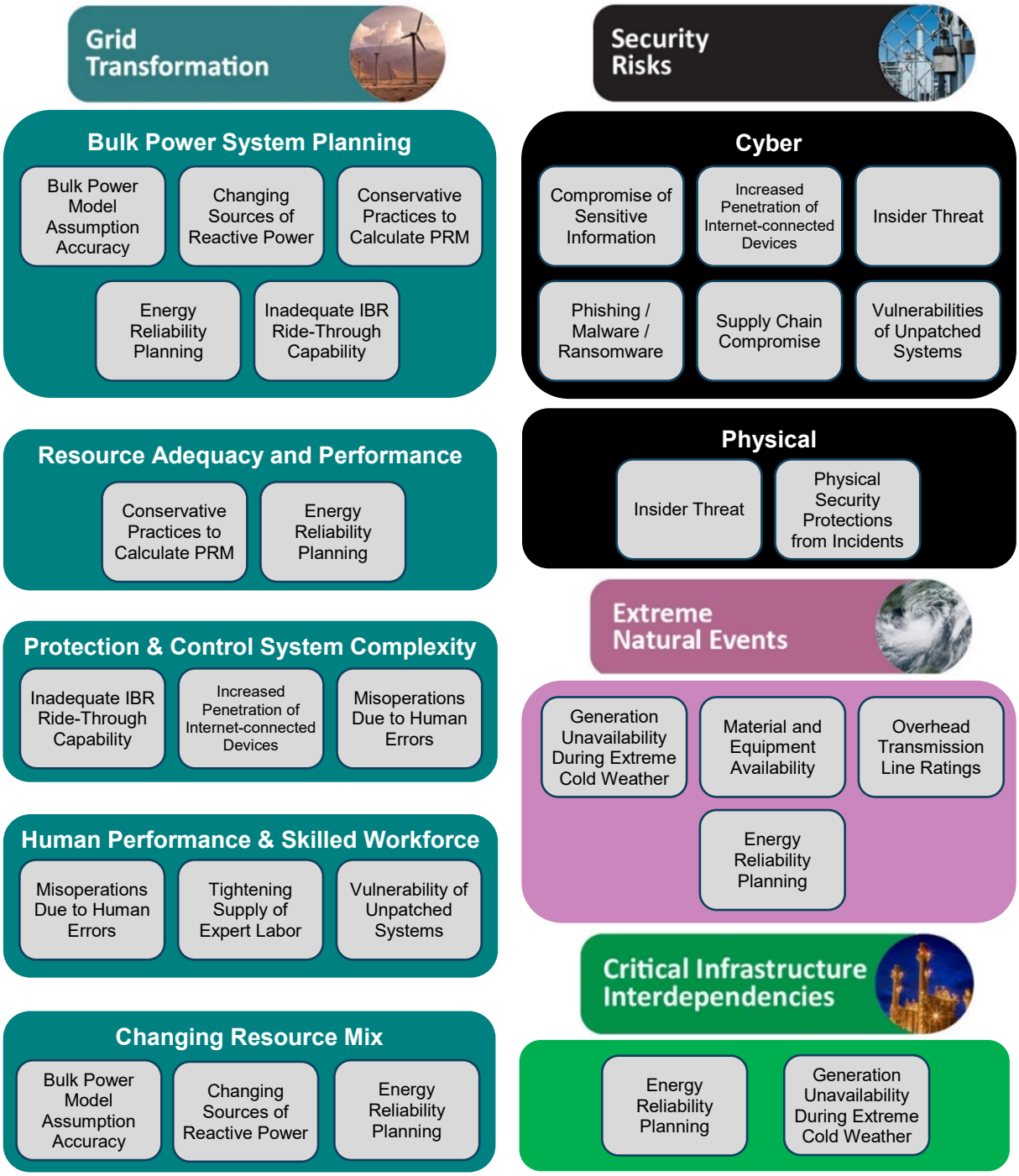


Figure 10: ERO and MRO Reliability Risks Correlation

5.3 MRO Regional Risk Rankings

MRO's Reliability Advisory Council (RAC) developed a reliability risk matrix to provide a relative ranking of the various risks identified by MRO. The relative rank of each risk (location on the matrix) is the result of assessing the likelihood and impact of the risk. Impact is determined based on how widespread an event caused by a risk would be to the bulk power system. Likelihood is assessed by evaluating three criteria:

- Event History - Are there any documented occurrences of the risk?
- Emerging Trends - Are the occurrences (or is the likelihood of occurrence) increasing?
- Mandatory Controls - Is a NERC standard in place to effectively mitigate the risk?

During development of the RRA, industry experts from each of MRO's three advisory councils (CMEP, Reliability, and Security) join MRO staff to rank the risks identified in Section 5.1 through use of the reliability risk matrix. The purpose of the matrix is to identify the highest regional risks and help prioritize risk mitigation efforts. The highest risks also become a focus for MRO staff and the advisory councils, who communicate the findings to industry through outreach, and ultimately work with NERC and industry to develop mitigation strategies by improving the effectiveness of controls where possible.

The ERO Reliability Risk Matrix, shown in Figure 11, is a valuable tool that is repeatable and provides consistent criteria for ranking risk. MRO staff has been working with peers across the ERO Enterprise to use the reliability risk matrix or a similar tool North American-wide.

Reliability Risk Matrix						
Consequence/Impact (C)		Likelihood (L)				
		L1	L2	L3	L4	L5
		Very Unlikely	Unlikely	Possible	Likely	Almost Certain
C5	Severe	Medium	High	High	Extreme	Extreme
C4	Major	Medium	Medium	High	High	Extreme
C3	Moderate	Low	Medium	High	High	High
C2	Minor	Low	Low	Medium	Medium	High
C1	Negligible	Low	Low	Low	Medium	Medium

Consequence/Impact –How could a typical event due to this risk effect BPS Reliability?	
Severe (C5)	Impacts may have widespread effects to the BPS across North America.
Major (C4)	Impacts may have widespread effects to the RC area.
Moderate (C3)	Impacts may have widespread effects to portions of the RC area .
Minor (C2)	Impacts may have effects on the local entity.
Negligible (C1)	Impacts may have small or non-existent effects to the BPS.
Likelihood – What is the reasonable probability that consequences will occur?	
Almost Certain (L5)	Mandatory Controls – No NERC reliability standards in place for mitigation. Emerging Trends – Increasing trends have been identified. Event History – Documented events or widely publicized exploits have been recorded.
Likely (L4)	Mandatory Controls – No NERC reliability standards in place for mitigation. Emerging Trends – Some trends have been identified. Event History – Documented events or generally publicized exploits have been recorded.
Possible (L3)	Mandatory Controls – NERC reliability standards in place for limited mitigation. Emerging Trends – Some trends have been identified. Event History – No documented events, or moderately publicized exploits have been recorded.
Unlikely (L2)	Mandatory Controls – NERC reliability standards are in place for mitigation. Emerging Trends – Some trends have been identified. Event History – No documented events, or minimally publicized exploits have been recorded.
Very Unlikely (L1)	Mandatory Controls – NERC reliability standards are in place for mitigation. Emerging Trends – No known trends identified. Event History – No documented events or publicized exploits have been recorded.

Figure 11: MRO Regional Reliability Risk Matrix

Figure 12 shows the reliability risk rankings after applying the MRO risk matrix:

MRO Reliability Risk Matrix: Risk Rankings						
Consequence / Impact (C)		Likelihood (L)				
		L1	L2	L3	L4	L5
		Very Unlikely	Unlikely	Possible	Likely	Almost Certain
C5	Severe					
C4	Major				4,5,6,16	
C3	Moderate		2	9,12,13	1	
C2	Minor			3,7,8,10,14,17	15	
C1	Negligible			11		

Risk	Risk
1 Bulk Power Model Assumption Accuracy	10 Material and Equipment Availability **- NEW**
2 Changing Sources of Reactive Power	11 Misoperations Due to Human Errors
3 Compromise of Sensitive Information **- NEW**	12 Overhead Transmission Line Ratings
4 Conservative Practices to Calculate PRM	13 Phishing/Malware/Ransomware
5 Energy Reliability Planning	14 Physical Security Protections from Incidents
6 Generation Unavailability During Extreme Cold Weather	15 Tightening Supply of Expert Labor
7 Inadequate IBR Ride-Through Capability	16 Supply Chain Compromise
8 Increased Penetration of Internet-Connected Devices **- NEW**	17 Vulnerabilities of Unpatched Systems
9 Insider Threat	

Figure 12: MRO Physical and Cyber Security Risk Rankings

The eight risks in the orange section of the heat chart identified as having the highest relative risk are:

1. Bulk Power Model Assumption Accuracy
4. Conservative Practices to Calculate PRM
5. Energy Reliability Planning
6. Generation Unavailability During Extreme Cold Weather
9. Insider Threat
12. Overhead Transmission Line Ratings
13. Phishing / Malware / Ransomware
16. Supply Chain Compromise

These eight risks will be focus areas for 2023 mitigation action plans for MRO staff and the advisory councils to help improve or develop controls and increase awareness of these risks within MRO.

Figure 13 shows how risk rankings have changed from the 2022 assessment. Six of the fourteen risks identified in both the 2022 and 2023 assessments changed in either impact or likelihood. Numbered circles in blue are the 2023 risk ranking with an arrow showing the change from 2022 to 2023. Changes include:

- The *Bulk Power Model Assumption Accuracy* and *Energy Reliability Planning* risks both increased to "Likely" largely due to limited mitigating actions since last years' assessment.
- The *Inadequate IBR Ride-Through Capability* risk decreased in impact, but increased in likelihood leaving it in the Medium risk category.
- As previously discussed, the *Overhead Transmission Line Rating* risk increased in impact due to the uncertainty introduced by FERC Order 881.
- The *Tightening Supply of Expert Labor* risk increased in likelihood due to an increasingly challenging job market.
- The *Misoperations Due to Human Errors* risk dropped in both impact and likelihood moving it down to the Low risk category. Guidance provided by an ERO and FERC report on protection system commissioning programs and the limited impact of a single misoperation on the bulk power system are attributed in reducing this risk.

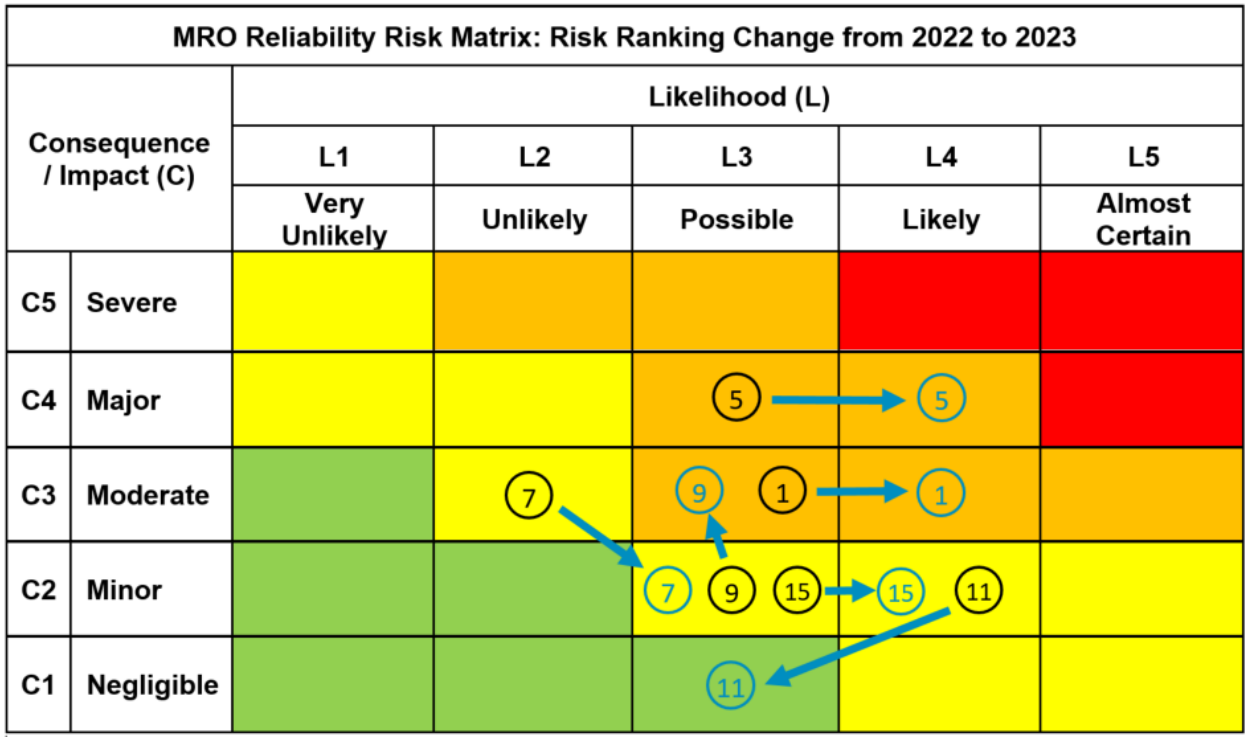


Figure 13: MRO Risk Ranking Change from 2022 to 2023

6. EMERGING TRENDS THAT CAN HELP MANAGE THE RESOURCE TRANSFORMATION

As highlighted in this assessment, the transition from historically available resources like coal and nuclear, to intermittent, renewable resources like wind and solar, needs to be carefully managed in order to maintain reliability. A number of solutions being implemented are designed to meet the needs of the changing energy landscape, some of which are described in more detail here.

6.1 Hybrid Facilities

As Lithium Ion battery technology and other energy storage technology matures and related capital costs decline, these storage technologies will be combined with renewable resources to form hybrid resources. The energy output of a renewable resource can be directed to the grid or to charging batteries located local to the renewable facility. The battery can then be discharged during periods of low wind speeds or at nighttime for a solar plant. This operating flexibility increases resource availability for supply to the bulk power system. Battery storage can also provide essential reliability services (ERS) to the bulk power system, such as voltage support, frequency response, and system inertia, allowing battery storage to help replace the ERS that synchronous resources typically provide.

The storage of variable resource output will help facilitate better management of the increasing penetration of renewable energy and is necessary to maintain reliability of the bulk power system. Hybrid resources have started to populate the interconnection queues. Figure 14 shows the MW amount of hybrid resources entered into the interconnection queues ERO-wide.

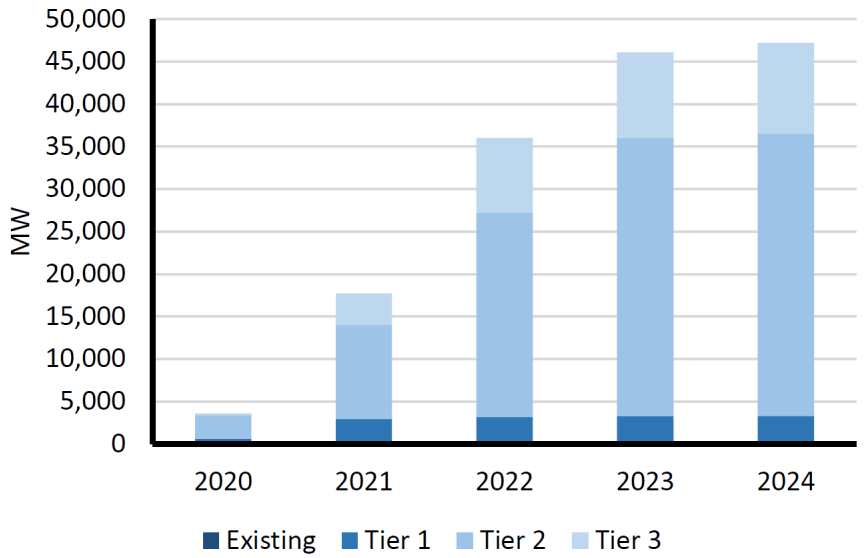


Figure 14: NERC-Wide Hybrid Resources in Generation Queues

6.2 Storage as a Transmission-Only Asset

Lithium Ion batteries can also be used as a transmission asset on the bulk power system. In this application, the primary use of the battery is not to supply energy to balance the grid but to mitigate a transmission performance issue like voltage stability through the injection or absorption of VARs or thermal overload by injecting real power. Batteries can be installed more quickly and economically than traditional wire reinforcements and with fewer issues related to permitting and easements than building new overhead transmission lines. Storage as a transmission-only asset is limited to solving performance issues that occur over a brief period (only a few hours) due to the limited discharge capability of batteries.

An RTO like MISO or SPP may have functional control of the asset to address transmission issues, similar to any other transmission asset. An operating guide would likely be developed for each storage as transmission-only asset specifying operating use consistent with the need identified in the RTO's regional transmission planning process. The owner of the storage asset would follow RTO instructions regarding the state of charge of the battery and charging/discharging cycles. In the right scenario, storage as a transmission-only asset brings increased reliability to an area faced with a short duration challenge in a cost effective manner.

6.3 Participation of Aggregated Distributed Energy Resources (DER) in RTO Markets

On September 17, 2020, FERC issued a final rule (Order 2222) that requires RTOs to revise their tariffs to facilitate the participation of distributed energy resource (DER) aggregations in organized wholesale electric markets. Participation in markets streamlines possibilities for this growing asset class to help address resource adequacy challenges by allowing large-scale dispatch of DERs under normal and emergency conditions. Aggregated DERs can be a mix of energy supply and load resources enabling load reduction, generation supply, or both to respond to imbalance conditions on the grid.

Much of today's DERs net with load from the utility's perspective, which blurs situational awareness and the ability to accurately forecast load. Another benefit of Order 2222 is that it provides RTOs visibility into the capabilities and performance of DER by requiring certain information, data, metering, and telemetry. This will make it easier to separate DERs from traditional loads, therefore improving future load forecasting. Impacts of changing weather patterns on DERs will also be better understood with an increase in the data available. Information obtained through the aggregated DERs will ultimately be incorporated into bulk power planning models, which will improve model accuracy and assessment capabilities to understand the impact of DER on transmission power flows.

Acquiring the visibility of aggregated DERs will require developing new methods of communication across the transmission/distribution boundary. Some utilities promote DER in the form of solar gardens. This allows distribution customers to purchase a portion of a community solar garden site (typically between 1-5 MW aggregate), as compared to installing them on their own roof or property. This physical aggregation of DERs allows the local utility to provide real-time data to the RTO. Aggregated DERs will also likely include Demand Side Management programs, such as price-based or time-of-day electric vehicle charging. This will further provide operational flexibility to manage real-time operations.

RTOs are proactively collaborating with relevant state agencies and members to prepare for FERC Order 2222. MISO has developed a public document titled *MISO and DER: Ensuring Grid Reliability Through Visibility and Communication* that provides a comprehensive discussion on this topic.

6.4 Small Modular Reactors

A new type of nuclear power technology called small modular reactors (SMRs) is under development in a range of countries, including the U.S., Canada, South Korea, Argentina, and several countries in Europe. The U.S. government has not yet approved the reactors, but U.S. national labs are actively participating in research and development of this new technology. SMRs have been hailed as a way the U.S. could help boost the nation's production of nuclear power, which emits no carbon dioxide, and provides operational flexibility that is similar to the current baseload units (coal, oil) that are being retired.

Since SMRs are modular, they can be manufactured off site and then shipped to a location for installation. This modular aspect is expected to reduce manufacturing time as well as the cost of the units. Typically, each modular reactor is expected to range from about 30 to 300 MW and could be grouped together to form a larger power plant. These units would have fast-ramping and load following capabilities, which would complement variable generation and help ensure energy adequacy throughout the entire year.

Safety is a major focus of SMR development. Traditional reactors use pumps to maintain a constant flow of water to cool their cores and are equipped with backup diesel generators to keep that process going in the event of a power outage. SMRs rely on the natural forces of heating and cooling that combine with gravity to circulate water through its system, eliminating the need for pumps as a failure point, in addition to multiple layers of safety features.

The Nuclear Regulatory Commission (NRC) is currently in the process of reviewing several SMR designs. NRC approval is required before a manufacturer can license out its design for construction.

6.5 Electrification

Electrification is the process of replacing technologies that use fossil fuels with technologies that operate by using electricity. In the days of Nikola Tesla and Thomas Edison, electrification was producing light via electricity versus traditional methods of gaslights and candles. Today, there is a strong push to electrify transportation and space heating to further decarbonize our society.

Electrification of transportation and space heating will have profound effects on the electric demand needing to be served by utilities. A National Renewable Energy Laboratory report from 2018 estimates electric load could be 20-38% higher by 2050 driven by electrification load growth. This represents a return to an annual demand growth rate not seen since 2005. Load curves (daily and seasonal) are also likely to change and be less predictable. The use of electric heat pumps for heating could shift some peak loads to the winter season.

The increased load and variability will make it more difficult to balance supply and demand. However, the increase in assets that are electrified also present an opportunity to leverage demand-side management tools to maintain balance. Systems and incentives to charge electric vehicles in periods with abundant electricity supply can help offset the challenges with variable resources.

7. 2023 ERO COMPLIANCE MONITORING AND ENFORCMENT PROGRAM (CMEP) ACTIVITIES AND RISK ANALYSIS

The following sections discuss Compliance Monitoring and Enforcement Program (CMEP) activities and how these activities relate to the risks identified in this RRA. This section has been revamped from previous RRAs, which included an overview of NERC Reliability Standards and observed compliance trends, to focus on particular risks outlined in this document. MRO staff and advisory councils will communicate a broader selection of compliance trends through other methods throughout the year.

7.1 Oversight of "Risks in Aggregate"

Each year, MRO conducts a series of self-certifications targeting those entities where individual inherent risk is low, but may be impactful to bulk power system reliability when evaluated in aggregate with other entities for common-mode risks. As part of the ongoing refinement of risk-based compliance, MRO monitors aggregated risks across multiple low inherent risk registered entities. The intent of the initiative is to identify any critical Reliability Standards that, when evaluated across multiple low inherent risk registered entities, rise to a level that supports active monitoring. This risk in aggregate concept primarily affects those entities whose Compliance Oversight Plans (COPs) do not presently include any standards or requirements for monitoring.

Some examples of the types of risk MRO has observed that are elevated when evaluated in aggregate include voltage control and ride through, protection system settings and maintenance, frequency response and ride through, and response to operating instructions.

MRO's evaluation of aggregated risk considered for oversight in 2023 includes seven focused risks:

1. Cyber Security for Low Impact Bulk Electric System (BES) Cyber System (BCS)
2. Generator Performance During Events
3. Under Frequency Load Shedding (UFLS)
4. Protection System Maintenance
5. Generator Operation for Maintaining Network Voltage Schedules
6. Response to Operating Instructions
7. Generation Availability During Severe Cold Weather

<u>Cyber Security for Low Impact BCS</u>

- Reliability Standard CIP-003-8 Attachment 1 (Security Management Controls, Cyber Security Plans for Assets Containing Low Impact BES Cyber Systems)
  - Section 2 – Physical Security Controls

    Monitoring of this section of the standard addresses the *Physical Security Protections from Incidents* risk identified in this RRA. Denying physical access can augment technical means for controlling access to information and infrastructure. Though on the surface, an individual asset's weak security does not present a risk, in aggregate the possibility of widespread geographic targeting of an entity with systemically weak low

impact security perimeters could be problematic. In the professional judgement of MRO staff, an entity's security program should be evaluated for the following:

  - Continuity of the perimeters used to protect the low impact BES Cyber Asset (BCA)
  - Physical access point process including technical and procedural controls
  - Controls on access revocation

- Section 3 – Electronic Access Controls

  Monitoring of this section of the standard addresses the *Remote Connectivity* risk element identified in the Compliance Monitoring and Enforcement Program (CMEP Implementation Plan report. A leading indicator of risk for entities is the presence of Inter-Control Center Protocol (ICCP) connections to organizations that are not NERC registered entities subject to mandatory security requirements. For example, wind turbine generators often have communications links to the turbine manufacturer for the purposes of maintenance monitoring. The protocol link is indicative of a common mode vulnerability that originates at one of the several turbine suppliers that have assets deployed across the continent at low impact generation sites. In the professional judgement of MRO staff, an entity's program should be evaluated for the following:

  - Permit only necessary inbound and outbound electronic access as determined by the Responsible Entity
  - Verify that firewall configurations are appropriate to this requirement
  - Controls over remote access
  - Controls over access revocation

- Section 5 – Transient Cyber Asset (TCA) and Removable Media (RM) Malicious Code Risk Mitigation

  Monitoring of this section helps to address both the *Insider Threat* and *Phishing / Malware / Ransomware* risks identified in this RRA, and *Supply Chain* risks identified in the last three versions of CMEP IP and in this RRA. Although the compliance requirements only address a small subset of possible threat vectors, in MRO staff's professional judgement, an entity's program should be evaluated for the following:

  - Controls that guarantee that TCA and RM are mitigated for malicious code prior to connecting to an applicable system
  - Controls that guarantee the system used to scan TCAs and RM has up to date signatures
  - Additional options to run active malicious code mitigation on applicable systems

MRO anticipates that a future revision of Reliability Standard CIP-003 will address *Supply Chain* and *Remote Connectivity*. The Risk In Aggregate program will be updated when the new standard becomes effective.

Generator Performance During Events

Ride-Through Capability

A lack of ride-through capability for a single, small generating resource would pose only minimal risk to the bulk power system, but widespread errant settings could significantly worsen the outcome of a frequency or voltage collapse event and lead to cascading outages. Monitoring of this section helps address the *Inadequate IBR Ride-Through Capability* risk. Three types of generating resource ride-through characteristics are addressed in the standards and requirements listed below; frequency, voltage, and fault ride-through.

- Reliability Standard PRC-024-3 (Frequency and Voltage Protection Settings for Generating Resources)
  - R1. Addresses frequency ride-through capability, and;
  - R2. Addresses voltage ride-through capability

- Reliability Standard PRC-025-2 (Generator Relay Loadability)
  - R1. Addresses fault ride-through capability

Frequency ride-through, in particular, is a significant aggregate risk as frequency excursions generally affect a large area or even an entire Interconnection at the same time, whereas voltage issues tend to be limited to local areas, especially in the Eastern Interconnection.

Frequency Response Modeling

Because major frequency-excursion events are rare, there is limited opportunity to observe the ability of generating resources to respond to frequency changes. Accurate modeling of generating resource frequency response is therefore critical to gaining assurance that generating resources are set to respond optimally to frequency events. It is the responsibility of the Planning Coordinators and Transmission Planners to perform these studies that demonstrate generating resources frequency response across wide areas; however, the assumptions and accuracy of the models used in those studies requires verification work that is performed by the Generator Owners.

- Reliability Standard MOD-027-1 (Verification of Models and Data for Turbine / Governor and Load Control or Active Power / Frequency Control Functions)
  - R2. Addresses model verification and transmittal of frequency control models

UFLS

The proper functioning of a UFLS program across a wide area requires provision of UFLS relays with specified settings from a large number of entities. Some of these entities are large utilities with higher inherent risk, but many of the UFLS entities are small and have a low inherent risk. Individually, these low-risk entities do not pose significant risk during a frequency event, but there is a higher aggregate risk.

- Reliability Standard PRC-006-5 (Automatic Underfrequency Load Shedding)
  - R9. Addresses providing automatic tripping of load for a UFLS program

Protection System Maintenance

The generator ride-through and UFLS protection system settings described above are all subject to protection system maintenance and testing requirements that help ensure correct and reliable functioning of these systems. The same aggregate-risk concepts described for generator ride-through and UFLS highlight the importance of maintenance and testing.

- Reliability Standard PRC-005-6 (Protection System, Automatic Reclosing, and Sudden Pressure Relaying Maintenance)
  - R3. Addresses time-based maintenance programs of protection systems,
  - R4. Addresses performance-based maintenance programs of protection systems, and;
  - R5. Addresses efforts to correct identified maintenance issues

Generator Operation for Maintaining Network Voltage Schedules

Individual small generating facilities that fail to maintain specified voltage schedule do not typically pose significant risk to the bulk power system. However, in the MRO footprint, there are significant pockets of high wind generation penetration where a failure of many facilities to regulate voltage could lead to local voltage collapse and potential cascading outages. Wind generation is highlighted here because the owners and operators of those plants tend to have lower inherent risk as they typically own smaller fleets of generation facilities.

- Reliability Standard VAR-002-4.1 (Generator Operation for Maintaining Network Voltage Schedules)
  - R1. Addresses operating in automatic voltage control mode,
  - R3. Addresses notifying TOP of status changes to operating in automatic voltage control mode,
  - R4. Addresses notifying TOP of reactive capability changes, and;
  - R6. Addresses changing step-up transformer tap positions

Response to Operating Instructions

During certain extreme events that occur on the bulk power system, MRO forecasts the possibility that numerous operating instructions could be issued to low inherent risk entities for time-critical tasks such as load shedding. A failure to act on an operating instruction by a single low-risk entity may not pose significant risk, but a large number of such failures during a major event would likely worsen the outcome. Many low-risk Generator Operators and Distribution Providers do not receive operating instructions on a regular basis. Verifying compliance with Reliability Standard COM-002-4 R3 can help ensure that the appropriate personnel at low-risk entities are prepared to receive and process operating instructions.

- Reliability Standard COM-002-4 (Operating Personnel Communications Protocols)
  - R3. Addresses training of personnel on proper three-part communication

Generation Availability During Extreme Cold Weather

The loss of a single generating resource during extreme cold weather poses minimal risk to the bulk power system as there are typically other resources in reserve to pick up for the lost resource. However, the loss of numerous generating resources over a short period of time due to severe cold weather can outstrip the available reserves or diminish available capacity such that the bulk power system is no longer capable of meeting load obligations. Failure of individual entities to prepare their generating resources for extreme cold weather can have a cumulative effect causing a large amount of generating capacity being unavailable. Monitoring of this section helps address the *Generation Unavailability During Severe Cold Weather* risk from this RRA and CMEP IP *Cold Weather Response* risk element.

- Reliability Standard EOP-011-2 (Emergency Preparedness and Operations, effective 4/1/2023)
  - R7. Addresses generating resource cold weather preparedness plans, and;
  - R8. Addresses training for generating resource maintenance or operations personnel on cold weather preparedness plans

7.2 Compliance Activities Addressing Risks

There are several ongoing activities intended to address identified risks to the bulk power system. This section is a summary of those activities as they are applicable to the highest risks identified by this RRA. This is not an all-inclusive list of activities, but highlights activities that MRO expects to have the largest impact on a risk.

NERC Project 2020-02 Modifications to PRC-024 (Generator Ride-through)

A draft Standard Authorization Request (SAR) proposing to retire PRC-024-3 and replace it with a performance-based ride-through standard that ensures generators remain connected to the bulk power system during system disturbances is under review. This SAR is a result of numerous events related to the *Inadequate IBR Ride-Through Capability* risk presented in this RRA. These events indicate that PRC-024-3, with its focus only on voltage and frequency protection, is not adequate to address the tripping and output reductions of inverter-based resources. The SAR proposes the new standard not be limited to voltage and frequency protection settings, but rather any generator protection or control system that could result in the reduction or disconnection of a generating resource during a system disturbance.

Information relating to this project can be found at Project 2020-02 Modifications to PRC-024.

NERC Project 2020-06 Verifications of Models and Data for Generators

A review by the NERC Inverter-based Resource Performance Task Force (IRPTF) in 2020 identified issues with the MOD-026-1 and MOD-027-1 standards that make them not applicable to inverter-based resources. A NERC group developed a SAR proposing to revise these standards to clarify requirements related to IBRs and require sufficient model verification to ensure accurate representation of IBR dynamics. This project will help address the *Bulk Power Model Assumption Accuracy* risk by providing clarity to Generator Owners on modeling parameters that are necessary for the Generator Owners to validate and provided to Transmission Planners to accurately depict

bulk power system dynamic response. Information relating to this project can be found at Project 2020-06 Verifications of Models and Data for Generators.

NERC Project 2021-07 Extreme Cold Weather Grid Operations, Preparedness, and Coordination

As referenced in Section 7.1, the EOP-011-2 standard becomes effective April 1, 2023, with new requirements for Generator Owners/Operations to have cold weather preparedness plans. This standard change was part of a project initiated in 2018. This supplemental project was created in 2021 in response to the findings from the FERC, NERC, and Regional Entity Joint Staff Inquiry into the February 2021 Cold Weather Grid Operations report and relates to the *Generation Unavailability During Severe Cold Weather* risk. This project has been broken into two phases, with phase 1 culminating on October 26, 2022, with the NERC Board of Trustees adopting a revised EOP-011-3 and a new EOP-012-1 standard.

Phase 1 moves newly added Generation Owner/Operator requirements from EOP-011-2 to a new standard, EOP-012-1. New requirements in EOP-012-1 include Generator Owners implementation of freeze protection measures to operate at a defined extreme cold weather temperature for the unit for a specified continuous duration depending on the commercial operation date of the unit. Generator Owners will also be responsible for calculating the extreme cold weather temperature every five years and updating preparedness plans or creating corrective action plans accordingly based on the new calculated temperature. These requirements should help mitigate the *Generation Unavailability During Severe Cold Weather* risk by setting clear expectations of winter generation performance and mandating action plans to address any deficiencies.

Information relating to Phase 1 of this project can be found at Project 2021-07 Extreme Cold Weather Grid Operations, Preparedness, and Coordination. Phase 2 of the project should commence once FERC approves the Phase 1 standards.

NERC Project 2022-02 Modifications to TPL-001-5.1 and MOD-032-1

This project includes a series of SARs aimed at addressing the impacts of the rising number of inverter-based resources and distributed energy resources on planning assessments. This project helps to address the *Bulk Power Model Assumption Accuracy* risk. Both the NERC Inverter-Based Resource Performance Task Force (IRPTF) and System Planning Impacts from Distributed Energy Resources Working Group (SPIDERWG) contributed SARs to this project.

The IRPTF SAR for TPL-005-5.1 recommends language changes that include the uniqueness of inverter-based resources from planning assessments. The SPIDERWG SAR for TPL-001-5.1 targets the need to consider the performance of DER, in particular dynamic behavior, to ensure accuracy of transmission planning assessments. Subsequently, the SPIDERWG SAR for MOD-032-1 seeks to address gaps in data collection to adequately model aggregate levels of DERs in planning assessments.

Information relating to this project can be found at Project 2022-02 Modifications to TPL-001-5-1 and MOD-032-1.

NERC Project 2022-03 Energy Assurance with Energy-Constrained Resources

In December 2020, NERC published a whitepaper, Ensuring Energy Adequacy with Energy Constrained Resources, outlining the need for a new method of assessing resource adequacy to ensure energy availability for all hours of the year. This project was born from that whitepaper and includes two SARs–one for the planning horizon and one for the operations/operations planning horizon. Both SARs have the same objective: to require entities to perform reliability assessments evaluating energy assurance by analyzing the expected resource mix availability and fuel availability. The intent of the project is to create a consistent approach for how to conduct these analyses. A drafting team has begun work on this effort. This target of this project is to address the *Energy Reliability Planning* and *Conservative Practices to Calculate PRM* risks.

Information relating to this project can be found at Project 2022-03 Energy Assurance with Energy-Constrained Resources.

NERC Project 2022-04 Electromagnetic Transient (EMT) Modeling

Continuing with projects associated with bulk power system modeling, the EMT Modeling project identifies the need for more detailed studies to address the increase in inverter-based resources on the grid. As with other modeling projects, this intent of this project is to help address the *Bulk Power Model Assumption Accuracy* risk. Traditional load flow based transient stability studies are good for analyzing low frequency electromechanical effects on the power system. However, since inverter-based resources used electronic converters with no electromechanical elements, traditional studies cannot accurately represent the fast-acting controls and response of these resources. The SAR for this project proposes to require collection of EMT models from entities and for planners to conduct EMT studies where needed.

Information relating to this project can be found at Project 2022-04 EMT Modeling.

FERC Order 881

In December 2021, FERC issued Order 881 to improve the accuracy and transparency of transmission line ratings. A subsequent order, Order 881-A, issued in May 2022 clarified the original order but left the main tenets intact. At the center of Order 881 is the requirement to implement ambient-adjusted ratings and seasonal ratings as well as uniquely determined emergency ratings. This order directly addresses the *Overhead Transmission Line Ratings* risk. Utilities will have three years to develop and document their programs to comply with Order 881.

8. CONCLUSION

The 2023 MRO Regional Risk Assessment analyzes key risks identified in ERO-wide assessments and reports to determine how these risks affect the MRO region. In addition to assessing which ERO-wide risks may be more prevalent for the MRO region, MRO staff leveraged the expertise of the three MRO advisory councils (CMEP, Reliability, and Security) to identify any additional risks that the MRO region may be susceptible to experiencing.

From these analyses, the top 8 risks were prioritized, which are repeated below.

1. Bulk Power Model Assumption Accuracy
4. Conservative Practices to Calculate PRM
5. Energy Reliability Planning
6. Generation Unavailability During Extreme Cold Weather
9. Insider Threat
12. Overhead Transmission Line Ratings
13. Phishing / Malware / Ransomware
16. Supply Chain Compromise

These risks highlight the challenges facing regional grid owners, operators, and planners as they work to address:

- the impacts of the changing generation resource mix,
- increasing use of inverter-based resources,
- extreme weather,
- evolving demand uncertainties, and
- the threat of cyber and physical attacks.

MRO's mission is to not only identify and prioritize risks, but also assure effective and efficient mitigation of risks to the reliability and security of the North American bulk power system. Involvement from various stakeholders within the industry, including MRO staff, MRO advisory councils, MRO member entities, the ERO Enterprise, and policy makers is essential to fulfilling this mission. MRO has developed projects and goals to raise awareness of the highest risks, provide guidance to manage the risk, or develop mitigations to reduce the risk. Specifically, MRO staff incorporate the results of this assessment into their annual goals to address the highest risks. Similarly, MRO advisory councils focus on the highest risks as they build their annual work plans and activities. MRO staff also stay engaged with efforts within the ERO Enterprise to help mitigate risks.

The electric utility industry is seeing changes at an unprecedented pace. To prepare for the future grid, industry must take actions now to address the risks presented in this report. Innovative ideas and collaboration amongst stakeholders is critical to address these risks and ensure the reliable and secure operation of the bulk power system. MRO will continue to leverage its unique position and expertise to identify and prioritize risks and work with its members and entities to develop mitigation strategies for risks.

9. REFERENCES

1. 2021 ERO Reliability Risk Priorities Report
https://www.nerc.com/comm/RISC/Documents/RISC%20ERO%20Priorities%20Report_Final_RISC_Approved_July_8_2021_Board_Submitted_Copy.pdf
2. 2022 NERC State of Reliability Report
https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2022.pdf
3. 2022 NERC Long-Term Reliability Assessment
https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf
4. 2023 ERO Compliance Monitoring and Enforcement Program Implementation Plan
https://www.nerc.com/pa/comp/CAOneStopShop/ERO%20CMEP%20Implementation%20Plan%20v1.0%20-%202023.pdf
5. NERC Event Analysis Program
https://www.nerc.com/pa/rrm/ea/Pages/EA-Program.aspx
6. 2022 MRO Regional Summer Assessment
https://www.mro.net/wp-content/uploads/document-library/MRO-2022-Regional-Summer-Assessment.pdf
7. 2022 MRO Regional Winter Assessment
https://www.mro.net/wp-content/uploads/document-library/MRO-2022-Regional-Winter-Assessment.pdf
8. NERC-WECC Joint Report on Inverter-based Resource Modeling Report
https://www.nerc.com/comm/PC/InverterBased%20Resource%20Performance%20Task%20Force%20IRPT/NERC-WECC_2020_IBR_Modeling_Report.pdf
9. NERC 2022-2023 Winter Reliability Assessment
https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_WRA_2022.pdf
10. NERC 2022 Summer Reliability Assessment
https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2022.pdf
11. NERC/FERC January 17, 2018 Cold Weather Event Inquiry Report
https://www.ferc.gov/legal/staff-reports/2019/07-18-19-ferc-nerc-report.pdf
12. MRO Generator Winterization Program
https://www.mro.net/program-areas/reliability-analysis/generator-winterization-program/
13. Joint NERC and Texas RE Staff Report on the Panhandle Wind Disturbance
https://www.nerc.com/pa/rrm/ea/Documents/Panhandle_Wind_Disturbance_Report.pdf
14. FERC, NERC, and RE Joint Review of Protection System Commissioning Programs
https://www.ferc.gov/sites/default/files/2021-11/Protection%20System%20Commissioning%20Program%20Review%20Project.pdf
15. FERC and NERC Staff Report on the South Central United States Cold Weather Event of January 17, 2018
https://www.ferc.gov/news-events/news/ferc-and-nerc-release-report-january-2018-extreme-cold-weather-event-0

16. FERC Order 881 Managing Transmission Line Ratings
https://www.ferc.gov/news-events/news/ferc-rule-improve-transmission-line-ratings-will-help-lower-transmission-costs
17. U.S. Bureau of Labor Statistics Job Openings and Labor Turnover Survey
https://www.bls.gov/jlt/
18. Cyber Security Ventures Cybersecurity Jobs Report
https://cybersecurityventures.com/jobs/
19. IBM Security X-Force Threat Intelligence Index 2022
https://www.ibm.com/downloads/cas/ADLMYLAZ
20. MRO Reliability Risk Matrix
https://www.mro.net/wp-content/uploads/document-library/ERO-Reliability-Risk-Matrix-Final-2021.pdf
21. NERC Reliability Guideline on BESS and Hybrid Power Plant Performance Modeling Studies
https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_BESS_Hybrid_Performance_Modeling_Studies_.pdf
22. FERC Order 2222 Participation of DER Aggregations in Markets Operated by RTOs and ISOs
https://www.ferc.gov/news-events/news/open-access-order-no-2222
23. MISO and DER: Managing Grid Reliability through Transparency and Communication
https://cdn.misoenergy.org/MISO%20and%20DER%20-%20Visibility495365.pdf
24. Project 2020-02 Modifications to PRC-024
25. Project 2020-06 Verifications of Models and Data for Generators
26. Project 2021-07 Extreme Cold Weather Grid Operations, Preparedness, and Coordination
27. Project 2022-02 Modifications to TPL-001-5-1 and MOD-032-1
28. Project 2022-03 Energy Assurance with Energy-Constrained Resources
29. Project 2022-04 EMT Modeling