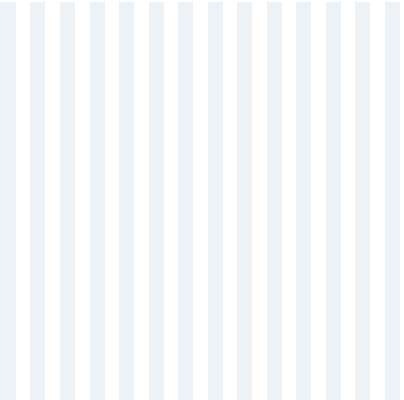


# WINTER 2025-2026



## RESILIENCE OF THE ELECTRIC GRID IN NORTH DAKOTA

**NORTH DAKOTA  
TRANSMISSION AUTHORITY**

The North American Electric Reliability Corporation (NERC) produces a seasonal grid reliability assessment for winter and summer seasons. This reliability assessment covers the United States and Canada.

Similarly, the **Midwest Reliability Organization (MRO)** produces a seasonal grid reliability assessment for the Midwest region, covering the central states from northern Texas to Canada, including Saskatchewan and Manitoba. This region includes North Dakota. The MRO's Winter 2025-2026 Reliability Assessment was released November 25, 2025. The full report is included in this document.

MRO's annual winter assessment projects that the region will have sufficient electricity supply to meet demand during the upcoming winter months (December 2025 through February 2026) under normal peak demand conditions with typical maintenance and forced outages. For the first time in several years, the entire region is also expected to meet operating reserve requirements under extreme peak demand scenarios, despite record demand levels set last year.

The assessment also identified significant improvements in winter weather operations following severe winter storms Uri (2021) and Elliot (2022), due in part to revisions to winter weather reliability standards and increased winterization outreach efforts.

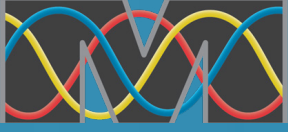
MRO's 2025 Regional Winter Assessment provides key stakeholders with critical insights into potential reliability challenges and recommends actions to mitigate risks. The report also highlights bulk power system performance trends specific to the MRO region to inform long-term system planning.

North Dakota generation and transmission owners & developers continue to build out transmission and generation assets. Both cooperative generation and transmission entities and investor-owned utilities see opportunities to develop natural gas generation in North Dakota to meet capacity requirements (dispatchable generation) and recognize that North Dakota also has rich wind resources that can be appropriately leveraged to meet energy requirements. Fortunately, the coal industry has received regulation reprieve, allowing coal generation facilities to plan for a more robust future. Solar projects offer valuable capacity attributes for summer peaks, with peak production aligning with summer peak consumption. Hydropower, though a small segment of the generation mix, is a dependable and flexible generation asset. Nuclear energy holds promise, particularly in the small modular reactor realm; however, like coal, the development and construction of a facility requires several years.

What about the future? The recent transmission capacity and large-load impact study for North Dakota shows that generation and transmission will need to be developed in tandem to capture new large load opportunities. The Midcontinent Independent System Operator (MISO) and the Southwest Power Pool (SPP) have aggressive transmission expansion plans. Our generation utilities are building or have plans to add generation including large natural gas facilities, wind farms, battery storage and some solar generation.

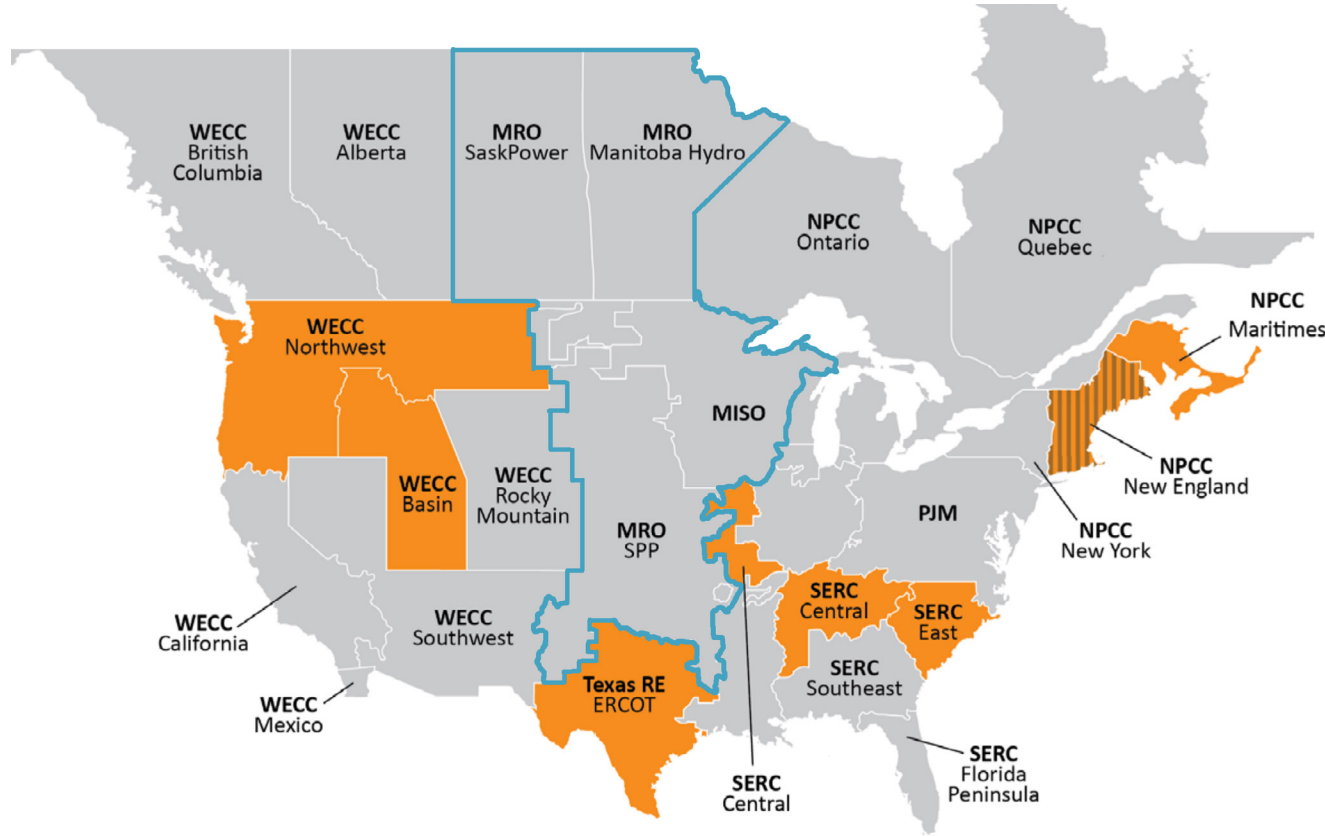


Claire Vigesaa, Executive Director  
North Dakota Transmission Authority



# 2025 Regional Winter Assessment

December 2025 through February 2026



■ High Risk during Extreme Weather  
■ Elevated Risk during Extreme Weather

    Risk to Natural Gas Pipeline Capacity  
■ Normal Risk  
    MRO Region



Sufficient resources are anticipated to meet operating reserve requirements under both normal and extreme peak demand conditions in MRO's Region.



The bulk power system performed much better during the January 2025 arctic events than in prior winter storms (like Uri and Elliott), due in part to improved cold weather preparedness measures.



The performance of wind and gas generation is crucial for maintaining reliability during periods of high demand and extreme cold weather this upcoming winter season.



Reportable transmission outages and protection system misoperations are both trending downward. Forced outage rates for conventional generation, however, are trending upward - suggesting component fatigue from frequent ramping to compensate for lower intermittent resource output.

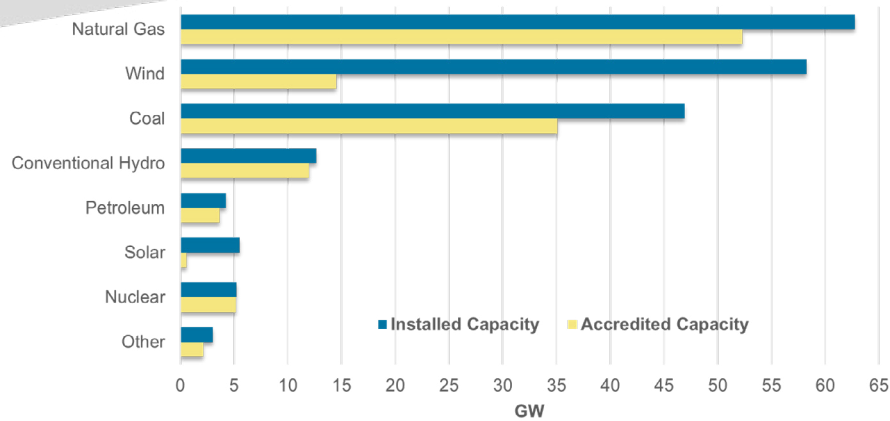


Read the [2025 Regional Winter Assessment](#)

# Ongoing Seasonal Focus Areas

## Risk monitoring and reduction

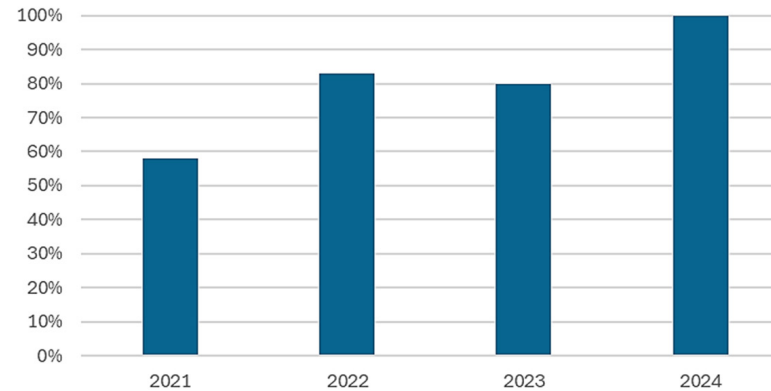
### Generation Resource Mix



- Natural gas and wind are significant components of the regional generation mix, making the performance of these resources crucial to reliability during periods of high demand.
- Variable generation resources (wind & solar) do not provide the same amount of accredited capacity as Natural Gas or Coal, complicating resource planning and operations.
- The inverters used to connect variable resources to the grid pose reliability challenges. The ERO Enterprise is mitigating this risk through new/revised standards for inverter-based resources.
- As the resource mix evolves, the ERO Enterprise is establishing new ways to assess energy availability on an hourly basis in long-term planning.

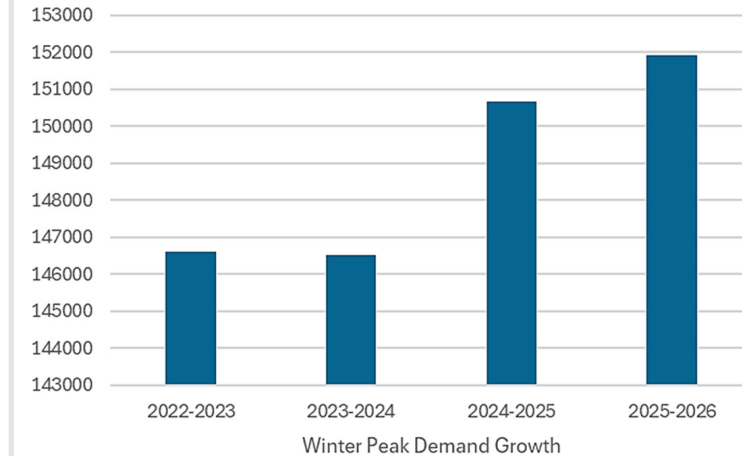
### Extreme Weather

GWP Participants with Winterization Plans



- Frequent and longer-lasting extreme cold weather continues to pose significant challenges to the regional power grid.
- Winter storms Uri (2021) and Elliot (2022) resulted in revised cold weather standards, that along with significant outreach, have improved reliability of the system during extreme winter weather events.
- MRO's [Generator Winterization Program](#) helps utility companies prepare for cold weather by sharing recommendations and best practices.
- NERC's [Guideline on Generating Unit Winter Readiness](#) is another helpful resource.

### Increased Demand



- Uncertainty in potential large loads (data centers and industrial facilities) complicates system planning and peak and hourly load forecasting.
- Development timelines for new power generation and transmission infrastructure don't align with those associated with large loads.
- The ERO Large Loads Task Force (LLTF) is working to mitigate potential reliability risks from interconnecting large loads to the bulk power system.



MIDWEST  
RELIABILITY  
ORGANIZATION



# Regional Winter Assessment

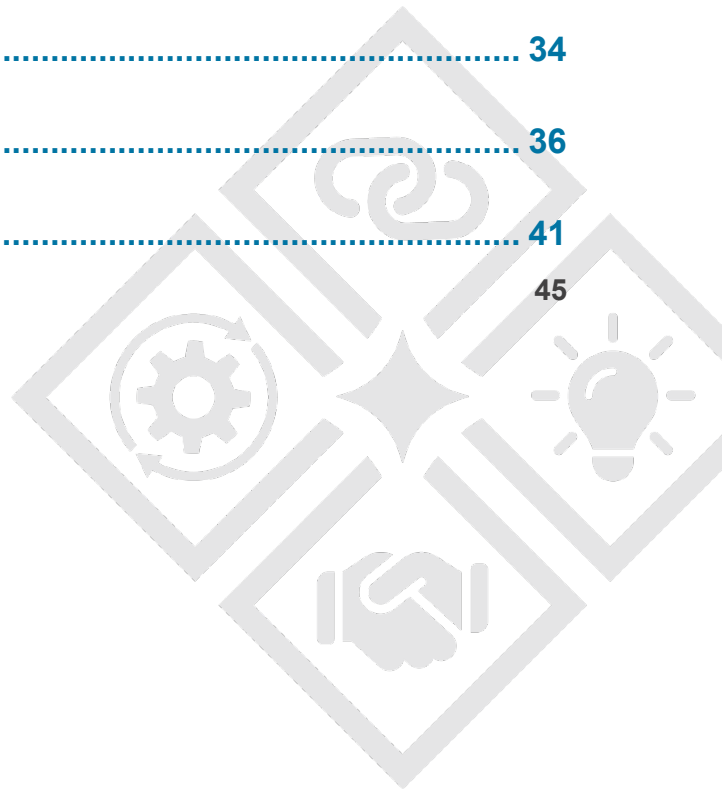
November 2025

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# Preface

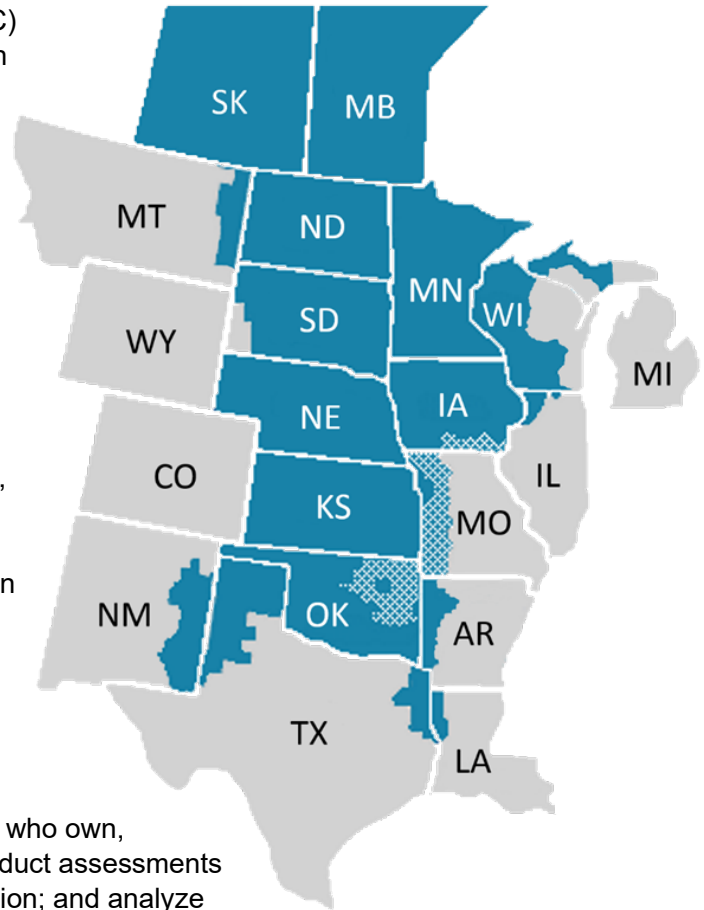
## ABOUT THE ORGANIZATION

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, of which MRO is one. 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 more than 260 organizations that are involved in the production and delivery of electric power, including Canadian utilities, cooperative and municipal utilities, investor-owned utilities, along with federal power marketing agencies, generator power marketers, and transmission system operators.

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 and provides outreach across the region to discuss important topics related to addressing risk and improving reliable operations of the bulk power system.



## Executive Summary

This annual assessment provides information and raises awareness of regional bulk power system challenges and trends, helping industry stakeholders and decision-makers reduce risk and maintain electric reliability during the winter season. The 2025 Regional Winter Assessment (RWA) provides critical insights for the upcoming winter season, specifically the months of December through February. In developing the 2025 RWA, MRO staff analyzed data from the four Planning Coordinators (PCs) operating in the region to determine if adequate electricity generation and transmission is available to meet projected peak winter demand. The four PCs in MRO's region are: Manitoba Hydro, Midcontinent Independent System Operator, Saskatchewan Power Corporation, and Southwest Power Pool.

Additionally, this report incorporates quarterly data from over 260 registered entities (users, owners, and operators of the bulk power system) to assess the regional grid's performance during previous winter seasons. This helps identify key trends and emerging risks. Information on the identification, registration, and certification of these entities is available in [Appendix A](#).

This report complements NERC's North American Winter Reliability Assessment by providing a more detailed analysis of reliability concerns specific to the MRO region.

## KEY FINDINGS

- Despite peak demand records set last year, anticipated resources should be sufficient to meet operating reserve requirements under normal peak demand conditions with typical maintenance and forced outages.
- For the first time in several years, sufficient resources should also be available to meet operating reserve requirements under extreme peak demand, coupled with extreme weather conditions. This change in expected resource availability is due to:
  - An increase in Midcontinent Independent System Operator's resource availability above its minimum resource adequacy target, and a decrease in scheduled maintenance and anticipated forced outages from improved winter performance.
  - A decrease in Saskatchewan Power Corporation's expected number of hours with operating reserve deficiencies.
  - An increase in Southwest Power Pool's resource availability and a decrease in anticipated extreme resource derates from improved winter performance.
- Interruptions to fuel supply, combined with higher penetration of variable energy resources could create unique operational challenges. The increased penetration of wind in the MRO region makes the performance of wind generation during periods of high demand crucial for whether the electricity supply will be sufficient to meet system demand.
- The arctic events in January 2025 showed marked improvement in BPS operations over previous extreme winter storms, like Uri and Elliot. Although there was a total of 71,022 MW unplanned generator outages across the Eastern and Texas Interconnections, no firm load was shed. This improvement is attributed to the winter preparedness efforts of the ERO Enterprise, including MRO.



## WINTER SEASON TRENDS

- Weighted Equivalent Forced Outage Rates (WEFOR) for conventional generation continue to trend higher than the five-year moving average, suggesting component fatigue from frequent ramping to compensate for uncertain intermittent resource output.
- Reportable automatic transmission outages last winter were two-thirds lower than the five-year average.
  - Over the past five years, failed AC Circuit Equipment has been the leading contributor to sustained transmission line outages during winter months.
- Even though protection system misoperations decreased markedly in 2024 compared to previous winters, this remains a leading attribute of system outages in the MRO region.
  - Human error accounted for one third of last winter’s misoperations, with over half of these resulting from as-left personnel errors.
  - Although misoperations did not result in significant loss of generation or load, this remains an area of concern that MRO is closely monitoring.

## RECOMMENDATIONS

MRO recommends the following actions to mitigate risks of energy shortfalls on the regional bulk power system this winter:

- Reliability Coordinators (RCs), Balancing Authorities (BAs), Transmission Operators (TOPs), and Generator Operators (GOPs) should maintain heightened situational awareness of unplanned generation or transmission outages, extreme weather conditions, and periods of low wind forecast.
- These organizations should implement operating procedures as needed to ensure resource adequacy.
- RCs, BAs, and Generator Owners (GOs) should develop protocols to ensure sufficient generation resource availability before the winter season.
- State and provincial regulators should be prepared to support grid operators by approving environmental and transportation waivers and the issuance of public appeals to conserve electricity, both before and during the winter season.
- Registered entities should review [NERC Alerts](#) and guidelines related to cold weather preparedness, and participate in MRO’s voluntary [Generator Winterization Program](#).



# Chapter 1: Assessment Overview

## PROCESS

MRO's [Reliability Assessment](#) staff independently review, evaluate, and report to NERC the reliability of electricity supply and demand, transmission system adequacy, and key issues and trends that could affect bulk power system reliability in the region. This work is conducted in accordance with the [MRO Regional Delegation Agreement](#), the [NERC Rules of Procedure](#) Section 800, and the [ERO Reliability Assessment Process](#).

Each year, MRO collects and assesses data from regional RCs and PCs to identify key reliability challenges, risks, and uncertainties affecting adequate electricity supply. PCs are responsible for integrating transmission facilities, service plans, resource plans, and protection systems in their analyses to ensure reliable power within their specific footprints. These organizations collaborate with Transmission Planners (TPs) to assess the reliability impact of resources and transmission outages within interconnected areas. RCs, who are responsible for the real-time reliable operation of the BPS, have a wide-area view of the system and hold the highest level of operational authority within their designated footprints.

In addition to the four PCs in MRO's region, there are three RCs: Midcontinent Independent System Operator (who also serves as the RC for Manitoba Hydro), SaskPower Corporation, and Southwest Power Pool.

NERC's reliability assessment process covers all of North America and is a coordinated evaluation effort between the NERC [Reliability Assessment Subcommittee](#), NERC staff, and the six Regional Entities.<sup>1</sup> MRO's RWA is an independent assessment that leverages some of the same data used in NERC's [2025 Winter Reliability Assessment](#) with a more targeted focus on the MRO region. By evaluating past seasonal performance, the assessment identifies reliability concerns, trends, and emerging region-specific risks.

## AREA STUDIED

MRO's RWA covers two Canadian provinces and all or parts of 16 U.S. states. Notably, the Midcontinent Independent System Operator footprint spans three Regional Entities: MRO, Reliability First (RF), and SERC Reliability Corporation (SERC). MRO is responsible for collecting and reviewing resource and transmission system adequacy data for the entire Midcontinent Independent System Operator area and coordinates with RF and SERC during preparation of NERC reliability assessments. However, MRO's review of Midcontinent Independent System Operator's historical performance data is limited to the MRO region. Additionally, MRO gathers and analyzes performance data and NERC reliability assessment information for the entire Manitoba Hydro, SaskPower Corporation, and Southwest Power Pool footprints.

The sources used for this assessment include NERC's 2025 Winter Reliability Assessment and MRO's [Performance Analysis \(PA\)](#) data from the ERO Generating Availability Data System (GADS), Transmission Availability Data System (TADS), Misoperation Information Data Analysis System (MIDAS), and Event Analysis (EA).

<sup>1</sup> <https://www.nerc.com/AboutNERC/keyplayers/Pages/default.aspx>



Figure 1.1 illustrates the North American assessment areas, and Figure 1.2 shows the boundaries of the North American Regional Entities, which do not align precisely with the assessment areas.

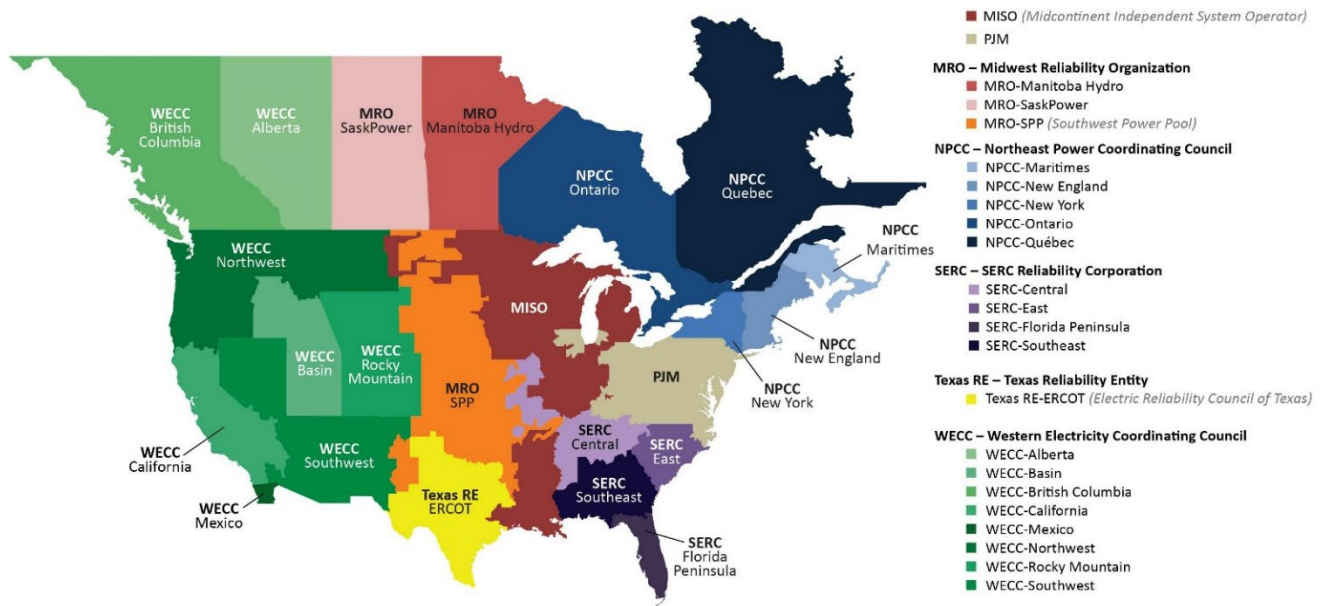


Figure 1.1: NERC Assessment Areas

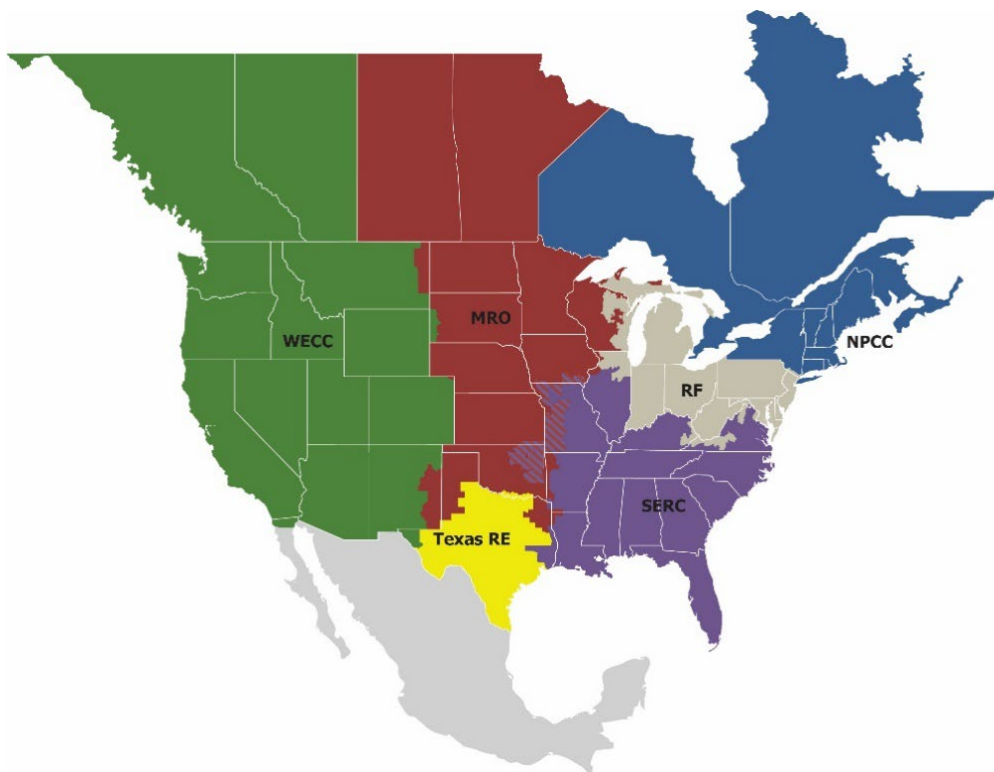


Figure 1.2: Regional Entity Boundaries



## Chapter 2: 2025 Winter Outlook

Changing climate conditions have made seasonal load forecasting increasingly complex and difficult. The uncertainty associated with seasonal load forecasting has elevated winter reliability risks for the BPS. Extreme cold temperatures and severe weather stress the grid and can cause electricity demand to deviate significantly from historical forecasts. Underestimating demand may lead to ineffective operational planning and insufficient scheduling of resources, while overestimating demand can lead to adding excessive resources at consumers' expense. Additionally, generator performance and fuel supply issues are more likely to arise when generators are required to operate on short notice, exposing BAs to potential resource shortfalls.

In coordination with the ERO Enterprise (collectively NERC and the Regional Entities) and industry, MRO conducts seasonal generation and load forecasts to assess reliability risks. Details from the 2025 Seasonal Winter Forecast can be found in [Appendix B](#). Based on this information, the projected reliability conditions for each assessment area in the MRO region for the 2025 winter season are outlined below.

### BY ASSESSMENT AREA

#### Manitoba Hydro

Manitoba Hydro's Anticipated Reserve Margin (ARM) increased from 12.3% last winter to 13.7% this winter due to an increase in resource availability. However, this is coupled with slightly higher demand from economic and population growth and electrification of transportation and space heating. Also contributing to the ARM increase are more High Voltage Direct Current (HVDC) losses based on higher outage assumptions. Manitoba Hydro's Installed Capacity (ICAP) Planning Reserve Margin Requirement (PRMR) remains unchanged at 12%.

Manitoba Hydro does not anticipate any emerging reliability issues for the 2025 winter season, but continues to monitor extreme weather events, drought, and asset health that includes the HVDC system. Although water conditions are well below normal for this time of year, the Manitoba Hydro system was designed for extreme drought conditions and operating plans ensure reliability can be maintained should drought conditions persist. Manitoba Hydro stress tests the robustness of its operating plans using a cold snap scenario that includes multiple days of high load driven by extreme cold combined with other contingencies.

#### Midcontinent Independent System Operator

Midcontinent Independent System Operator's ARM decreased from 55.1% last winter to 49.5% this winter, driven by economic development that is outpacing previous forecasts. However, the ICAP PRMR for the 2025 winter season also decreased from 49.4% last winter to 38.6% this winter, resulting in an increase in resource availability. This decrease was due to winter generator performance improvements, specifically with respect to decreases in generator maintenance and lower forced outages driven by extreme cold temperatures. The company projects that sufficient capacity will be available for the 2025 winter season under normal weather conditions and typical outage scenarios.

Some risk for the upcoming winter season is possible in a high generation outage and high winter load scenario. Reliability is expected to be maintained through Load Modifying Resources, non-firm energy transfers into the system, energy-only resources that do not have a must-offer requirement for the winter but may still offer into the energy markets, or internal transfers that exceed the Sub-Regional Import/Export Constraint between the Midcontinent Independent System Operator North/Central and South regions.



Continued coordination with neighboring RCs and BAs to improve situational awareness and assess any needs for firm or non-firm transfers will help address extreme system conditions.

Midcontinent Independent System Operator is part of a well-connected transmission system, with ample resource availability, an effective reserve margin, a varied fuel mix, and a well-run market system that allows it to maintain reliability and respond successfully to real-time concerns.

### Saskatchewan Power Corporation

SaskPower's ARM decreased from 37.7% last winter to 35.1% this winter because of growth in the residential and power class sectors. Contributing factors include population growth in the province, expansion projects, reduced self-generation in the industrial sector, and increased electrification across various customer groups. SaskPower's seasonal energy analysis also shows a much lower than expected number of hours with operating reserve deficiencies this winter compared to previous years. SaskPower's ICAP PRMR for the 2025 winter season remains unchanged at 15%.

Peak load is typically experienced during the winter months due to extremely cold weather. Based on planned maintenance, typical forced outages from historical data, and expected renewable generation under the normal and extreme demand conditions, SaskPower Corporation does not anticipate any reliability issues this winter.

Demand response programs, short-term power transfers from neighboring utilities, maintenance rescheduling, and/or short-term load interruptions would be used to manage extreme winter conditions.

### Southwest Power Pool

Southwest Power Pool's ARM increased from 44% last winter to 56.5% this winter due to additional natural gas and wind generation. Southwest Power Pool's ICAP PRMR remains unchanged at 19% coincident peak and 15% non-coincident peak demand.

While reliability issues are not anticipated, an extreme event could occur that needs to be managed. Southwest Power Pool's robust transmission system, resource availability, effective reserve margin, diverse fuel mix, and efficient market system allows it to maintain reliability and respond successfully to real-time concerns.

Southwest Power Pool has maintained reliability despite experiencing extreme weather across its footprint during each peak season (summer and winter). Although extreme weather events and weather forecast errors can disrupt planned real-time operations, comprehensive procedures are in place to help mitigate this risk.

Recognizing that coal transport could be an emerging reliability issue, the company provided GOPs with reporting thresholds and a minimum supply that must be maintained. The Market Monitoring Unit has been involved in coal conservation and recently approved an Opportunity Cost Calculator during abnormal fuel supply or transportation limitations. To this point, Southwest Power Pool has experienced lower coal stock at a number of plants because of railroad system challenges.



## Chapter 3: Historical Seasonal Trends

The following data was used to analyze system performance and identify seasonal trends:

- Bulk Electric System (BES) Event Analysis
- Energy Emergency Alerts
- Generation Availability Database System (GADS)
- Transmission Availability Database System (TADS)
- Misoperation Information Data Analysis System (MIDAS)
- Historical Winter Load Forecast

Performance data from GADS, TADS, MIDAS, and Event Analysis (EA) are collected and analyzed by MRO staff for the regional footprint. Resource and transmission system adequacy reviews are conducted by the Planning Coordinators (PCs) in the region within each respective area.

### BULK ELECTRIC SYSTEM EVENT ANALYSIS

MRO staff studies events and system disturbances pursuant to [NERC Rules of Procedure](#) Section 800, that include significant losses of load or generation, significant BPS disturbances, or other emergencies on the BPS. Using the [Event Analysis Process](#) established by the ERO Enterprise, MRO works with registered entities to perform a root cause analysis of the event, develop a brief report, and document recommendations or lessons learned that can be shared with electric power industry stakeholders.

### Transmission System Events

Twenty Category 1a transmission events occurred on the system in MRO's region between January 2024 and September 2025, with four occurring during the 2024 winter months. Equipment failure and protection system misoperations were identified as contributing causes. A Category 1a event results in an unexpected outage, contrary to design, of three or more BES Facilities caused by a common disturbance. (The NERC Addendum for Determining Event Category can be found at [NERC Addendum for Determining Event Category](#).)

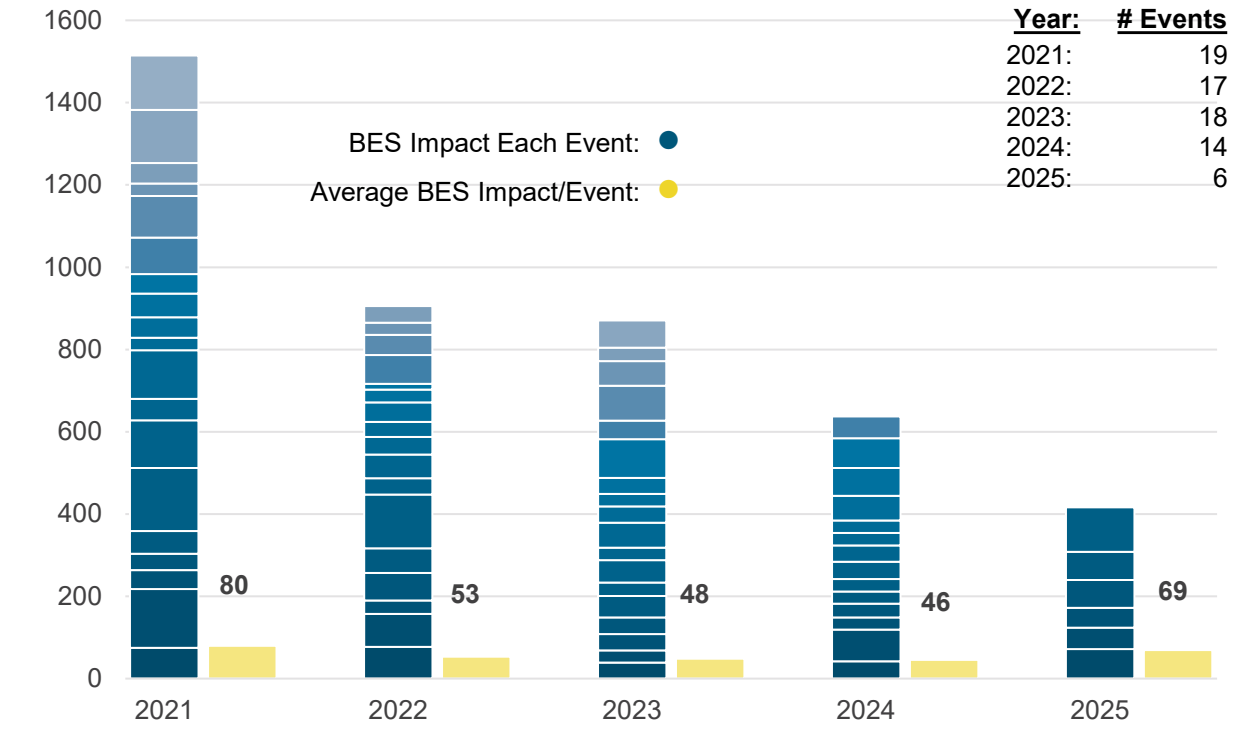
MRO has published numerous lessons learned and two white papers addressing root causes identified through performance and event analyses to reduce misoperation risk. The Protective Relay Subgroup (PRS) is working to revise the white papers considering more recent challenges and mitigation strategies. MRO staff continues to collaborate with industry experts on the PRS to reduce protection system misoperations.

Figure 3.1 illustrates MRO's Event Severity Index that includes all BES events and allows for comparison of the impact that each event had on the BES. Each section of the bar represents the calculated impact of the event using the number of elements lost, amount of generation lost, and amount of load lost. As an example, the event impact number for an event with 100 MW of load shed, 120 MW of generation lost, and 8 BES elements taken out of service will be higher than the impact of an event with a low number in any of the named categories. The yellow bar is the average annual impact of all events, which MRO uses as a general indicator of how entities are limiting the impacts of events on the BES in the region.

MRO's primary focus is to limit large-impact events, especially those that may lead to a broad cascading event or outage. The total number of events over the five-year period shown on the chart has remained consistent year-over-year, while the average impact has been trending downward.



A summary of BES events that occurred during the 2024 winter season in MRO’s region, including the event category, number of BES facilities lost, MW of generation lost, and MW of load lost, is included in [Appendix C](#).



**Figure 3.1: MRO Event Severity Index as of September 2025**

### Energy Management System Events

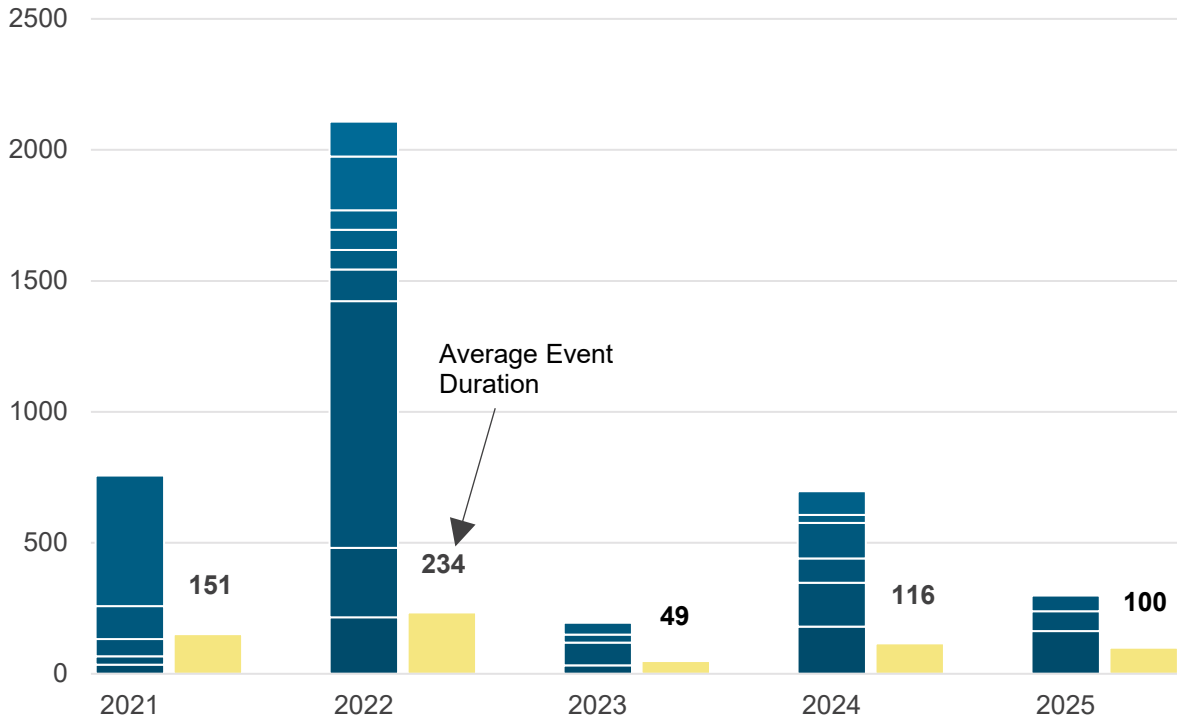
In 2024, six Category 1h Energy Management System (EMS) events occurred within the MRO region. So far in 2025, there have been three EMS events. One of these events took place during the 2024 winter season timeframe with a duration of 163 minutes. The average duration of the 2024 Category 1h events was 116 minutes, and the 2025 year-to-date average is 100 minutes. A Category 1h event results in the loss of monitoring or control at a control center such that it significantly affects the entity’s ability to make operating decisions for 30 continuous minutes or more. (The NERC Reference Guideline for 1h events can be found at [Reference Guideline for Category 1h Events](#).)

A common factor among these events is that they occurred either during or shortly after a routine maintenance procedure. The number of EMS related events has decreased over the last five years, possibly due to mitigation recommendations in NERC lessons learned, webinars, and other outreach efforts. NERC’s [Event Analysis Subcommittee \(EAS\)](#) provides registered entities the opportunity to engage in discussions around significant events impacting the BES, event causal factors, the event analysis process itself, as well as supporting the development of lessons learned.

MRO encourages entities to participate in these initiatives as they provide the opportunity for industry-wide information and knowledge sharing.



Figure 3.2 compares the loss of EMS events that took place during the last six years. Each section of the blue bar represents the duration of each event in minutes. The yellow bar is the average duration of all the events for each year.



**Figure 3.2: Loss of EMS Event Time Duration**

## ENERGY EMERGENCY ALERTS

An Energy Emergency Alert (EEA) occurs when a BA or load-serving entity exhausts all available resource options and cannot meet its expected load and operating reserves. EEAs are issued by RCs and are governed by NERC Reliability Standard [EOP-011-4](#) to ensure that TOPs and BAs have coordinated operating plans to mitigate emergencies.

The MRO region experienced one EEA level 2 event during the 2024 winter season. A summary of the event is included in [Appendix C](#).

## GENERATOR AVAILABILITY

Generating Availability Data System (GADS) is a program that collects information about the performance of electric generating equipment to assist with analyzing generation outages. [GADS data](#) has been reported since January 1, 2013, and includes information on more than 8,000 conventional generation units across North America. It is a valuable source of information on reliability, availability, and maintainability of generating units and includes unit design data, monthly performance data (including hours of availability and power produced), and event data. The ERO Enterprise has been capturing wind generation performance data in a separate GADS Wind application since 2018, which has now been retired. GADS Solar data was first collected in 2024, which was the first year for reporting events for GADS Wind in the new data collection portal. This newly reported data is not included in this report but



will be added once more information becomes available. Due to a change in GADS data reporting format in 2024, Manitoba Hydro data is not included in this report.

Generation unavailability can have a substantial impact on reliability. Useful metrics for generator unavailability are the equivalent forced outage rates (EFOR)<sup>2</sup> and megawatt Weighted EFOR or WEFOR. Long-term trends indicate increasing WEFOR rates due to component fatigue and an aging fleet. Given higher penetrations of intermittent resources, conventional generation is being cycled (ramping up and down) to follow load and operating at minimum output more often, increasing the number of forced outages due to component failures.

### Key Findings

- The increase in 2024 and 2025 WEFOR is attributed in part to difficulties with spring and fall maintenance.
- Winter events had a slightly greater impact on the BES year over year, though less than the calendar year 2024 as a whole.
- WEFOR rates for generation continued to trend upward in the 2024 winter season. (Rates so far in 2025 are artificially high due to sampling the most impactful portion of the year and are anticipated to decrease as more data is collected. MRO is monitoring increases in WEFOR rates closely.)
- Fossil steam and simple cycle gas turbines contributed to higher event impacts and increased WEFOR percentages during the 2024 winter season.

Based on forced outage rates for fossil-steam and simple cycle gas turbines, MRO closely monitors the performance (and identifies the failure risk) of these types of resources. Higher forced outage rates of fossil-steam and simple cycle gas could impact generation resource availability during extreme winter peak demand and increase the number and duration of EEA events. Maintaining a robust and reliable fleet of balancing resources is critical to meeting energy needs at all hours when integrating renewable resources. More details on generation impacts are provided in [Appendix D](#).

## TRANSMISSION AVAILABILITY

[Transmission Availability Data System \(TADS\)](#) is used to track the availability of AC/DC transmission circuits and transformers operating at 100kV and above. [TADS](#) also collects detailed information about individual outage events, that when analyzed both regionally and North American-wide, provides useful data in reliability analyses. Momentary outages of less than one minute are only reported for elements at or above 200kV, while sustained outages of one minute or longer are reported for elements at 100kV and above.

### Key Findings

- There were 165 AC circuit outages reported for the 2024 winter season. This is only 66% of the five-year average of 249. The month of February had only 24 AC circuit outages reported, which is the lowest number of outages for a month ever reported for a seasonal assessment.
- Other (30%), Failed AC Circuit Equipment (20%), and Weather, Excluding Lightning (17%) are the leading contributors to sustained outages.

<sup>2</sup> The hours of unit failure (unplanned outage hours and equivalent unplanned derated hours) given as a percentage of the total hours of the availability of that unit (unplanned outage, unplanned derated, and service hours) - Alexander Eydeland and Krzysztof Wolyniec (2003). Energy and Power Risk Management. John Wiley and Sons. p. 109. ISBN 9780471455875



- Two small winter storms (December 26, 2024, and January 5, 2025) caused 45 outages, accounting for 27% of all outages during the 2024 winter season.

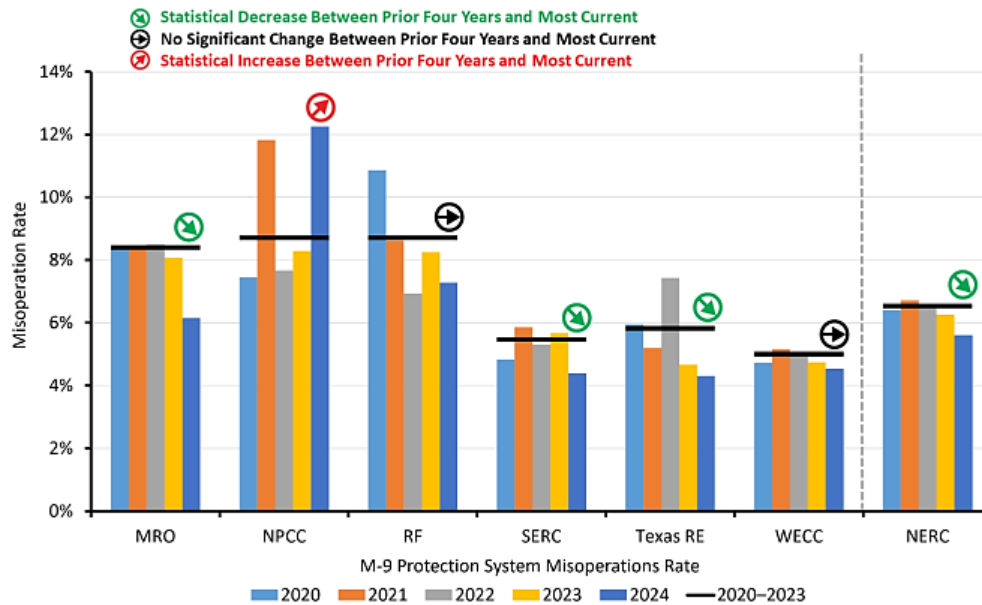
Additional details on transmission outages are provided in [Appendix E](#).

## PROTECTION SYSTEM MISOPERATIONS

A properly functioning protection system is critical for maintaining reliability of the BES. Proper operation of protection systems is instrumental in preventing cascading events and large disturbances. A protection system misoperation is summarized as a failure of a composite protection system to operate as intended for protection purposes (the full definition can be found in the [NERC Glossary](#)).

Reporting of misoperations allows for causal analysis, overall trending across North America, and an opportunity to improve the effectiveness of mitigation measures. TOs, GOs, and Distribution Providers are required, per the NERC Rules of Procedure Section 1600 data request process, to report protection system operations and misoperations through MIDAS. A common measure using MIDAS data is a misoperation rate [misoperations]/(total operations), which provides an industry measurement of protection system performance.

The annual ERO Enterprise misoperation rate is shown below in Figure 3.3 from the [2025 NERC State of Reliability](#) report.



**Figure 3.3: Changes and Trends in the Annual Misoperations Rate by Regional Entity**

There were 3,094 operations and 189 misoperations reported in the MRO region in 2024 for a misoperation rate of 6.11%. Figure 3.4 shows the misoperation rate<sup>3</sup> has been trending nearly flat since 2020. 2024 showed a marked decrease in the misoperation rate. Forty percent of the decrease can be attributed to a decline of misoperations caused by “relay failures/malfunctions.” Another 30% can be

<sup>3</sup> The misoperations rate data shown in Figure 3.4 was updated in 2024 to reflect final misoperation rates submitted through MIDAS for the five-year period. This resulted in nominal changes in the data reflected in this report compared to previously published seasonal assessments.



attributed to a decline of misoperations caused by “other/explainable”. The ‘other/explainable’ category is applied to misoperations that have an identifiable cause that doesn’t fit into the other categories (see Figure 3.9 for categories). ‘Other/explainable’ includes environmental issues such as damage due to water from a leaking roof, animal intrusion, temporary changes in network topology that, because of their low probability of occurrence, are not accounted for in the design of the protection system, or IEC 61850 errors.<sup>4</sup>

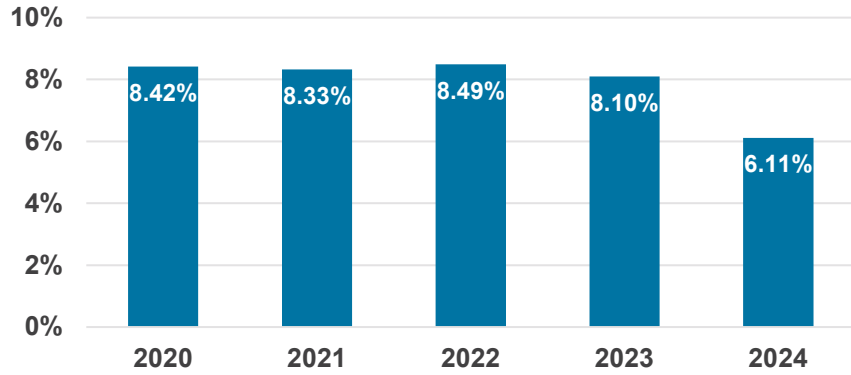


Figure 3.4: MRO Misoperation Rate by Year

Figures 3.5 and 3.6 provide context for the misoperation rate for 2024. Total protection system operations increased by about 4% in 2024 from the previous year, and total misoperations decreased by approximately 22%, resulting in a markedly lower misoperation rate. Overall, Figures 3.4 and 3.5 show that 2024 was slightly above the five-year average for total operations and well below the five-year average for number of misoperations.

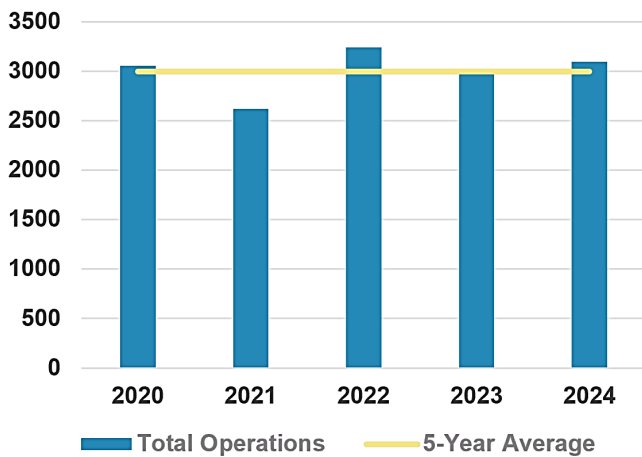


Figure 3.5: Yearly Protection System Operations

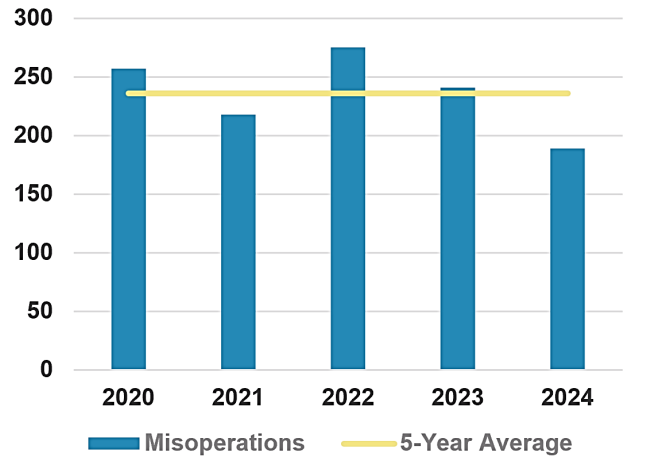


Figure 3.6: Yearly Protection System Misoperations

<sup>4</sup> IEC 61850 is an international standard for substation automation systems and defines the communication between substation devices.



MIDAS reports are completed and reported by entities quarterly. The first (January-March) and fourth (October-December) quarters of the year align closest to the winter season (December- February) for this assessment.

As shown in Figure 3.7, more relay system operations occur on the MRO system in the spring/summer vs. autumn/winter. MRO attributes this disparity to more BES faults caused by stronger and more frequent summer weather events when compared to winter weather.

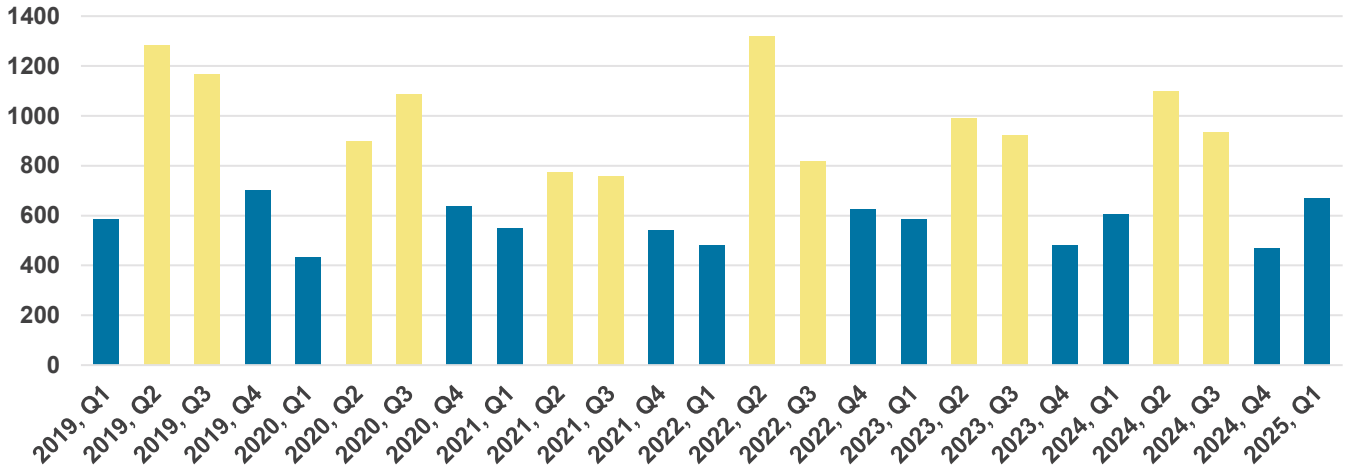


Figure 3.7: Total Operations (Spring/Summer vs. Autumn/Winter)

As shown in Figure 3.8, many misoperations are not associated with a fault. Non-fault-associated misoperations have a smaller annual variance than misoperations associated with a fault and do not vary with the number of correct protection system operations. Therefore, these misoperations would have a larger impact on the overall misoperation rate if the total number of protection system operations is low.

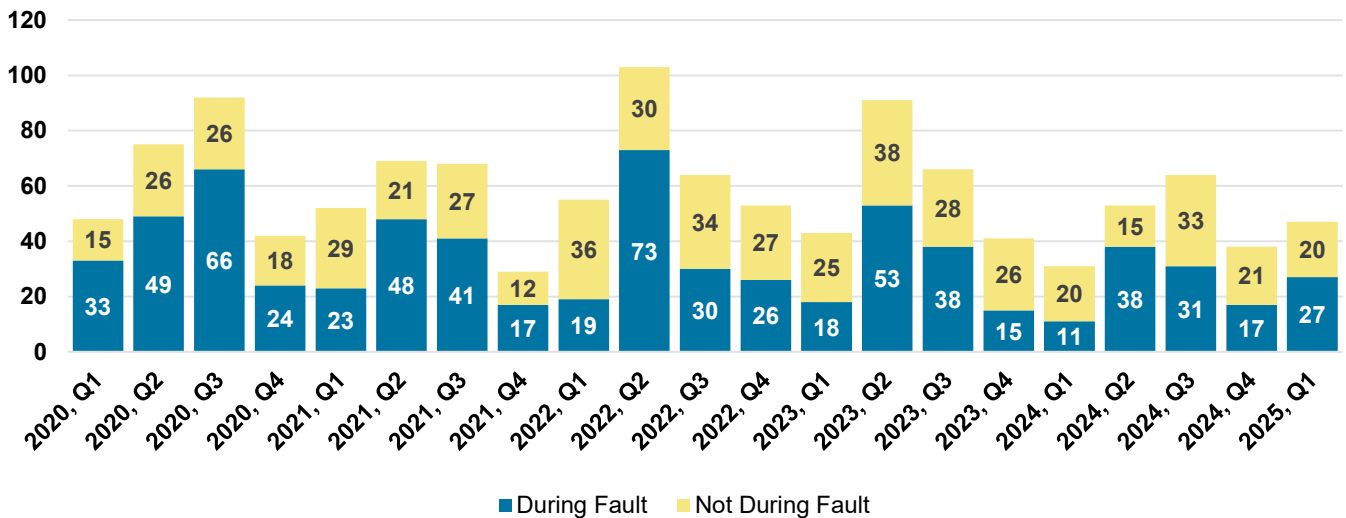


Figure 3.8: Fault Associated and Non-Fault Associated Misoperations

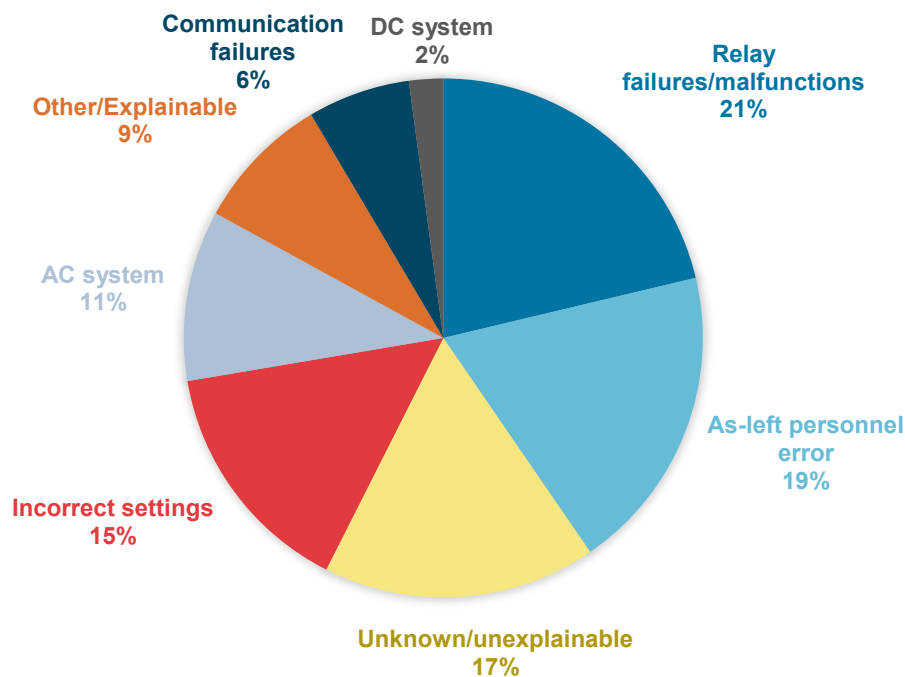


There were a total of 47 misoperations that occurred in the MRO region between December 1, 2024, and February 28, 2025. Examining these misoperations reveals several areas for improvement. As illustrated in Figure 3.9, of the 47 misoperations that occurred during this time, 34% were attributed to human errors (i.e., as-left personnel errors, design errors, incorrect settings, and logic errors) and an equivalent 34% to equipment failures (i.e., relay failures/malfunctions, AC system, and DC system). The 21% attributed to relay failures or malfunctions mark a change from the previous winter, when no misoperations were attributed to this cause.

This trend underscores the importance of ongoing equipment maintenance and testing and reviewing obsolescence plans to ensure system reliability over time. With the higher number of protection system operations in spring/summer seasons, higher relay failure/malfunction rates during those seasons may coincide with the increased operational demand.

Although misoperations on the BPS stemming from human error have declined in past years, a significant portion of misoperations in the MRO region remain attributed to human error causes. The following efforts help to reduce human error-related misoperations:

- Commissioning best practices and challenges are being discussed by MRO's Protective Relay Subgroup, which is an industry-led group comprised of utility companies and MRO staff.
- NERC hosted a third annual BES Protection System Misoperation Reduction Workshop at MRO's headquarters on October 7-8, 2025.



**Figure 3.9: Winter 2024 Misoperations by Cause**



## HISTORICAL WINTER LOAD FORECAST

To account for weather effects as accurately as possible, entities provide a forecast based on normal weather or assumed temperatures consistent with approximately the past 30 years of meteorological data. This is also referred to as the 50/50 forecast, which means that each year, the probability of the projected peak load being exceeded is 50%, while the probability that the actual peak load would be less than predicted is also 50%. A 90/10 forecast is a worst-case, extreme weather scenario that can be reasonably anticipated. It means there is only a 10% probability of the projected peak load being exceeded and there is a 90% chance that the actual peak load would be less than predicted. In other words, the forecast would exceed, on average, only once every ten years.

Figure 3.10 shows the five-year historical winter normal (50/50) and extreme (90/10) forecasts, actual and all-time winter peak load for each assessment area in the MRO region.

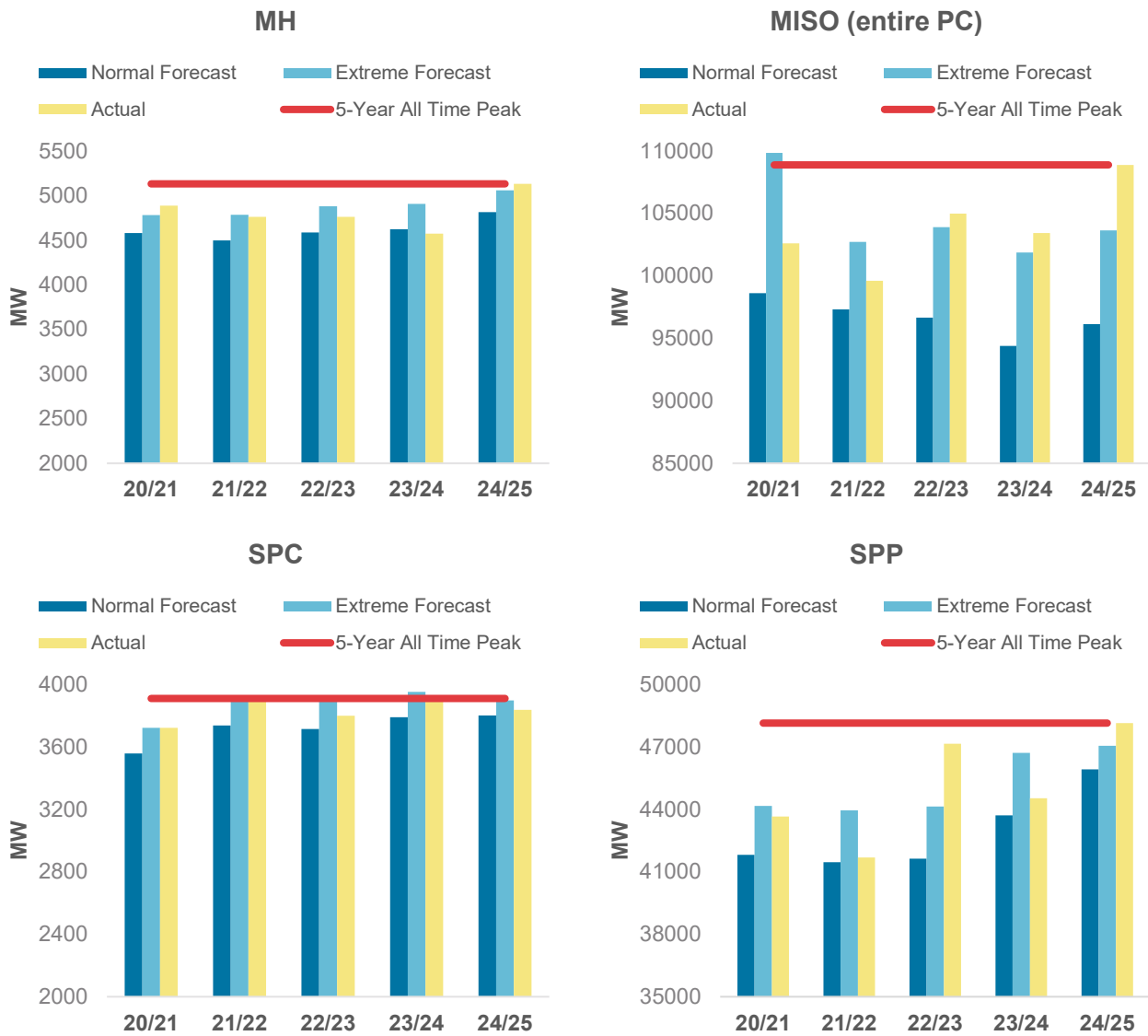


Figure 3.10: 5-Year Historical Winter Load Forecast



New all-time peak demands were recorded last winter for Manitoba Hydro, Midcontinent Independent System Operator, and Southwest Power Pool.

The extreme peak load forecast for the upcoming winter season is:

- Manitoba Hydro: 5,146 MW
- Midcontinent Independent System Operator: 102,215 MW
- SaskPower Corporation: 3,968 MW
- Southwest Power Pool: 48,435 MW

The highest historical all-time winter hourly average demand recorded is:

- Manitoba Hydro: 5,132 MW in January 2025
- Midcontinent Independent System Operator: 108,888 MW in January 2025
- SaskPower Corporation: 3,910 MW in December 2021
- Southwest Power Pool: 48,142 MW in February 2025

Actual weather conditions that occurred at the time of peak load can then be compared to the forecasted weather prediction to determine if any adjustments are warranted at the forecasted peak. This is particularly important for Midcontinent Independent System Operator and Southwest Power Pool, whose BA footprints span from the Canadian border to the Gulf of Mexico and can experience significant weather diversity on any given day.



## Chapter 4: Emerging Risks

### LARGE LOAD GROWTH

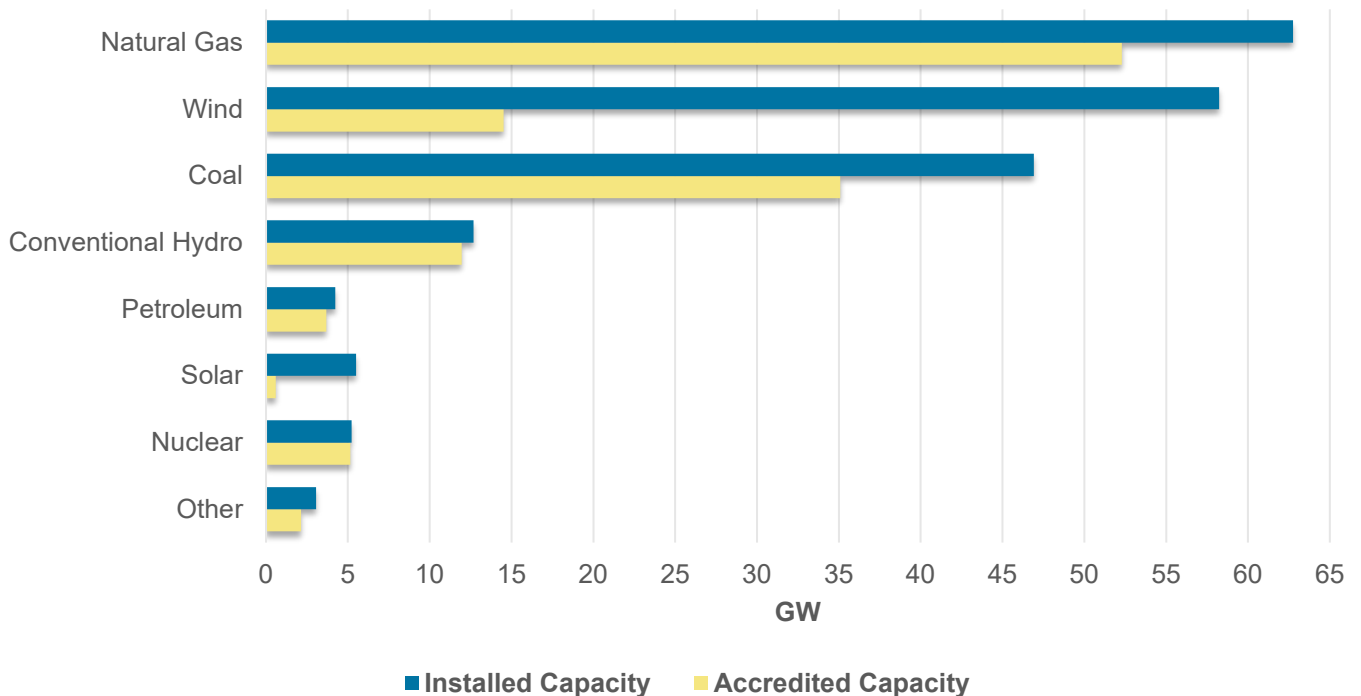
Growth in large load parcels like data centers and industrial facilities pose various challenges for system planners and operators. Large parcels of load on the system increases uncertainty in peak and hourly load forecasting. Moreover, determining how much of the current forecasted load will be installed further complicates planning efforts.

Large load development timelines are often much shorter than the timelines for building new power generation and transmission infrastructure. If data center and industrial facility growth rates surpass that of area resources, the likelihood of load loss increases.

### GENERATION RESOURCE MIX

MRO's 2025 winter peak installed and accredited capacity reflects a diverse mix of fuel types, as shown in Figure 4.1. The largest single contributor by peak capacity in the region is natural gas, with approximately 64% of installed capacity located in the southern portion of the region. Coal plants and wind turbines make up the next largest portions of the generation mix.

Conventional generation, such as coal, steam, hydro, and combustion turbines, which have a large rotating mass capable of providing essential reliability services like frequency and voltage support, is gradually being retired.



**Figure 4.1: MRO 2025 Winter Peak Installed and Accredited Capacity by Fuel Types**

The growing share of intermittent resources, such as wind and solar, is adding operational complexity in resource commitment and dispatch. Forecasting inaccuracies can lead to larger, unexpected energy shortfalls or excesses in real-time operations, making it difficult to predict ramping changes.



## Wind

The MRO region has approximately 58 GW of existing installed wind capacity, with 15 GW (26%) as accredited for the 2025 winter peak season. Multiple proposed projects in the Midcontinent Independent System Operator and Southwest Power Pool generation interconnection queues could add approximately 26 GW of installed wind capacity by winter 2035. Operational challenges related to large amounts of wind power include difficulties in accurately forecasting wind output, impacts on conventional resource cycling, transmission capacity or voltage constraints, and limited reactive support capability of older wind turbines compared to conventional generation.

## Solar

Utility-scale solar photovoltaic (PV) installations are rapidly increasing in the MRO region and are projected to become the second most prominent renewable energy source after wind. Approximately 27 GW of solar projects are being proposed in the Midcontinent Independent System Operator and Southwest Power Pool interconnection queues by winter 2035. Operational challenges related to large amounts of solar resources include managing daily ramping changes at sunrise and sunset.

## SUMMARY OF RISK

Not every project in the interconnection queue will be constructed, as some may be withdrawn after completion of system impact studies, which determine transmission upgrades required for project integration. The transition from conventional generation to intermittent resources requires BAs to maintain flexible resources that can ramp quickly in response to fluctuations in output from intermittent sources and load variability. Conventional steam units, especially those designed for base load, generally have lower ramp rates, and were not built to handle frequent cycling, which can increase forced outage rates and maintenance needs.

These factors elevate the risk of insufficient resources to serve load during periods when renewable output falls short of forecasts. This challenges control room operators, especially when there is high uncertainty in intermittent resource output and significant ramping events. As a result, BAs are forced to carry additional operating reserves to manage forecast uncertainties for wind and solar, as well as load forecasting errors.

Moreover, with more intermittent resources in the mix and the retirement of conventional generation, it is becoming increasingly difficult to schedule planned outages for conventional generating units. The higher unpredictability of intermittent resource output means BAs rely more heavily on conventional resources during off-peak maintenance periods. This introduces scheduling complexities for planned maintenance that typically use the same labor resources, while at the same time need to ensure reliable load service. Additionally, increased ramping of conventional units due to intermittent resource challenges accelerates maintenance requirements, further complicating maintenance scheduling and labor resource utilization for these resources.



## CHAPTER 5: MITIGATING ACTIVITIES

### MRO GENERATOR WINTERIZATION PROGRAM

Severe winter storms continue to challenge the reliability of the Bulk Electric System. Analyses of events dating back to 2011 show that extreme cold weather can significantly disrupt generation resources. To help mitigate this risk, [MRO's Generator Winterization Program \(GWP\)](#) focuses on assessing cold weather preparedness and generator performance.

The GWP is not a compliance or enforcement program. Instead, it provides a collaborative platform for sharing knowledge, identifying best practices, and offering recommendations to help entities strengthen and improve winter readiness. The program is designed to support reliable generator performance and reduce cold weather-related outages, derates, and failures to start.

#### Program Progress and Expansion

From 2021 through 2024, more than 35 entities across ten states and one province have participated in the GWP. MRO has conducted site visits at a diverse set of generating resources, including fossil and nuclear steam plants, simple- and combined-cycle combustion turbines, black start units, dual-fuel facilities, hydroelectric plants, and wind farms. This diverse mix of facilities and locations provide valuable insight into cold weather practices across different climates and technologies.

#### 2025 GWP Initiatives

MRO published a [Generator Winterization Program General Findings Report](#) that compiles best practices identified and observed during the GWP site visits. The report highlights strategies that strengthen overall winter preparedness and specific cold weather protection measures implemented at generating facilities. The report provides practical recommendations to help entities reduce winter weather risks, improve generator performance, and enhance reliability during extreme cold events.

The 2025 GWP will include at least seven generator site visits focused on natural gas fired simple- and combined-cycle units. Generator owners or operators can participate in the 2025 program by responding to the [GWP survey](#), which is a benchmarking tool for MRO, and receiving feedback on the responses.

MRO has enhanced outreach, industry engagement, and participation in the GWP through presentations at regional and national forums.

#### 2025 – Weathering the Storm

During the [January 2025 arctic events](#) which included winter storms Blair, Cora, Demi, and Enzo; unplanned generator outages peaked at 71,022 MW across the Eastern and Texas Interconnections and no firm load shed was required. This marks an improvement in generator availability compared to past cold weather events where Winter Storm Uri (2021) saw 61,305 MW of outages and 23,418 MW of firm load shed, while Winter Storm Elliott (2022) saw 90,500 MW of outages and 5,400 MW of firm load shed. The assessment team noted that improved generator performance reflects strengthened winterization practices, better coordination with natural gas systems, and enhanced operational procedures.



## Ongoing Commitment

Cold weather remains one of the significant risks to reliable generation performance in MRO's region. The GWP encourages adoption of the seven key components in [NERC's Guideline on Generating Unit Winter Readiness](#) and emphasizes the importance of proactive planning and preparation. Both MRO and the broader ERO Enterprise remain committed to supporting industry efforts to prepare for extreme cold events. Additional resources and program updates are available on the [MRO Generator Winterization Program](#) webpage.



## CHAPTER 6: SUMMARY

### FOCUS AREAS FOR 2025 WINTER

MRO's independent evaluation of the generation and transmission systems for the 2025 winter season has identified the following key focus areas and potential operational concerns:

- **Wind Generation Performance:** With the increased penetration of wind (and solar) in the MRO region, the performance of wind generation during periods of high demand is crucial in determining whether the electricity supply will be sufficient to meet system demand.
- **Conventional Generation Outage Rates:** WEFOR for conventional generation in 2024 remained higher than the five-year moving average. Long-term trends show increasing forced outage rates, partly due to the cycling of conventional generation beyond its original design limits, driven by higher penetrations of intermittent resources. This cycling can lead to component failures.
- **Sustained Transmission Outages:** For the past five years Failed AC circuit equipment has continued to be the leading contributor to sustained transmission line outages during winter months.
- **Protection System Misoperations:** Protection system misoperations remain a leading cause of major events in the MRO region. Human error accounted for one third of last winter's misoperations, with over half of these resulting from as-left personnel errors



# Appendix A: Registration and Certification

## REGISTRATION

There are 256 entities registered in the MRO region ([NERC Compliance Registry \(NCR\)](#)) as of the date of this publication. These users, owners and operators of the BPS are deemed material to reliability because they meet specific criteria or perform certain functions. The number of registered entities on the NCR fluctuates with the addition of new entities and/or changes to existing entities' operational structure and functions. Which mandatory NERC Reliability Standards and requirements are applicable depends on how an entity is registered and the functions it performs. Registration information is fundamental to reliability assessments in that certain functions pose greater risk to reliability of the BPS.

The functional relationships identified in the NERC Rules of Procedure, Reliability Standards, and important entity relationships are part of an entity's registration record. All BAs and TOPs are required to be under the responsibility of one RC. Transmission facilities must be the responsibility of one TP, PC, and TOP. Loads and generators shall be the responsibility of one BA. RCs, BAs, and TOPs, along with GOs and GOPs, have an important role in maintaining reliability during normal and complex weather operations. These entities provide accurate operational data for ERO event analysis. Generator modeling data provided by GOs and GOPs utilized by TOPs, BAs and RCs is critical for use in operations planning and real-time analysis of the BPS.

Registration growth over the past five years has predominantly been with the GO and GOP functions. The increase in entities registered as GOs and GOPs is due to the decline of vertically integrated utilities and the deregulation of the supply side of the industry, combined with an increase in renewable resources. With the increasing integration of Inverter Based Resources (IBRs), NERC's category 2 registration criteria were established and implemented to register owners and operators of BPS-connected IBRs with a nameplate rating of 20 MVA or more connected at 60kV and above.

The registration of category 2 generation owners and operators began in August 2025. The [NERC Inverter-Based Resources Work Plan](#) (phase 3) identifies all candidates found to meet category 2 criteria that shall be registered by May 2026. NERC's [May 2025 IBR Registration Workplan update](#) identified over 100 BPS-connected IBR assets subject to registration in the MRO region.

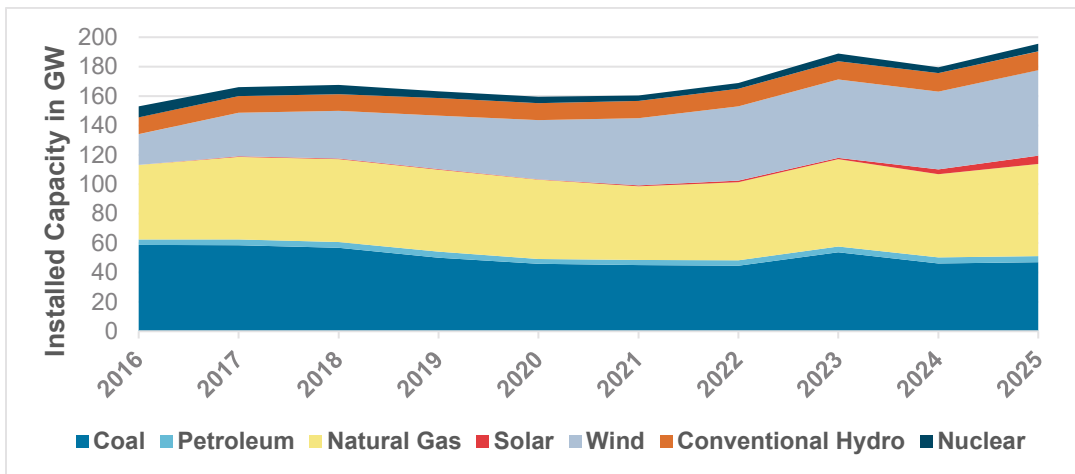


Figure AA1: MRO Historical Resource Mix by Fuel Types



## CERTIFICATION

Real-time actions of RCs, TOPs, and BAs impact the reliable operation of the BPS. [ERO Enterprise Certification](#) activities provide regional assurance that the processes, procedures, tools, and training a registered entity uses to perform its functions have the capacity to meet the reliability obligations of its registration. A registration candidate is required to complete the certification process for any new BA, RC, or TOP registered function. Material changes to already certified and operational registered entities require a review of conditions by the Regional Entity. The decision to certify changes to an already operating and certified registered entity is a collaborative decision between MRO and NERC.

During the first half of 2025, MRO completed five certification program activities. Currently, MRO has over 20 certification program activities initiated and active. In addition to these active/in progress activities, MRO is evaluating nine submissions of change events. MRO anticipates more submissions before year end due to EMS modifications related to the industry changes required by FERC order 881 and the commission's approved extensions.

The Certification Program includes activities (Certifications and Review of Conditions) to identify issues that if not resolved may lead to inadequate performance of duties and responsibilities applicable to the function. Fifty-seven functional registrations in the MRO region are applicable to the Certification Program.

This seasonal reliability assessment was developed based on data collected during performance analysis, event analysis, and situational awareness activities and directly focuses on RCs, TOPs, and BAs. The assessment provides reliability insight for the certification program and its activities. The roles fulfilled by the three functions (RC, BA, and TOP) are critical to the functional relationships within and between electric areas.



## Appendix B: WINTER Seasonal Forecast

The 2025 winter seasonal forecast includes the months of December 2025 through February 2026.

### ANTICIPATED WINTER RESOURCE AND PEAK DEMAND SCENARIO

Peak demand (or load) is the highest electrical power demand that occurs over a specific period and is typically characterized as daily, seasonal, or annual. The changes in demand levels are generally predictable and have daily, weekly, and seasonal patterns. The annual peak of hourly, daily, and monthly demand typically occurs during the summer or winter due to higher cooling or heating needs. Figure AB1 illustrates the 2025 anticipated, and the nine-year historical generation by fuel type at the time of winter peak for each of the PCs in the MRO region.

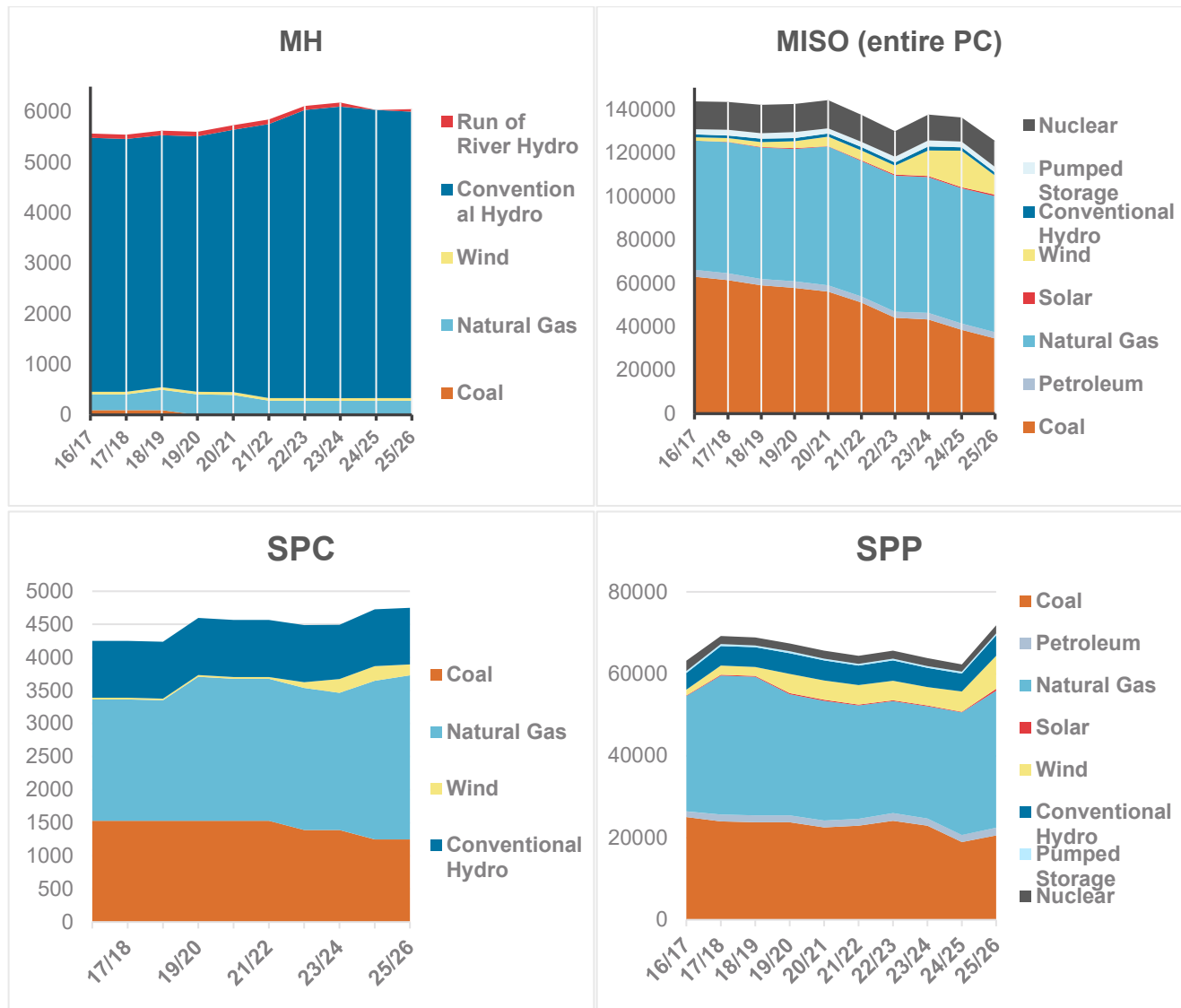


Figure AB1: Generation by Fuel Type at Time of Winter Peak



Each PC has a different resource mix. While Manitoba Hydro is predominantly conventional hydro, the resource mix in Midcontinent Independent System Operator, SaskPower Corporation, and Southwest Power Pool consist primarily of coal and natural gas with increasing amounts of wind in Southwest Power Pool. Because intermittent resources like wind and solar are weather dependent, forecasted on-peak wind and solar capacity contributions are based on historic average values and can be substantially less than ICAP.<sup>5</sup> Midcontinent Independent System Operator and Southwest Power Pool wind and solar capacity accreditation is significantly lower than the total existing ICAP values for this reason. As penetration of intermittent resources increases, forecast errors in the output of intermittent resources available in the short-term (hours or days) can have a greater impact. BAs may need to increase operating reserves to account for the uncertainty in short-term resource output.

Rooftop solar, battery storage, and other distributed, behind-the-meter generation resources are having a dramatic impact on the load shape and the ability to forecast net demand (total demand less behind the meter resource output). When coupled with the anticipated increase in demand (e.g., electric vehicle charging, cryptocurrency mining, data centers, hydrogen production, and other electrification efforts), future load forecasts and patterns will likely change dramatically from what they are today.

Fossil-steam, combined/simple cycle gas power plants, and wind turbines are susceptible to extreme cold temperatures if not properly winterized for these conditions. Wind turbines may also go offline due to ice buildup on blades, which require the ice to melt before the turbines are brought back online. The extreme peak demand scenarios in Tables AB3 and AB4 examine how extreme or prolonged cold temperatures over a large area could impact generation resource adequacy. Resources throughout the extreme scenarios are compared against expected reserve margin requirements based on peak load and normal weather. The effects from low-probability events are also factored in through additional resource derates. For example, maximum historical outages minus the average of both maintenance and forced outages for non-intermittent resources or low-output scenarios (such as a wind resource output adjustment due to low-wind), and additional load based on extreme weather conditions.

The [90/10 peak load](#) weather forecast methodology is used to model the reliability risk of the actual system peak exceeding the forecasted [50/50 peak load](#) due to load forecast uncertainty. The industry uses this traditional methodology and assumption to ensure energy availability through increased dispatchable resource capacity so that adequate resources are available during higher than anticipated peak demand. However, recent increases in extreme weather events and unavailability of energy during off-peak hours (e.g., low wind production) presents new challenges, in part due to the retirement of dispatchable resources and the rapid growth of fuel sources that are weather dependent and inherently less predictable (like wind and solar).

As a result, a new ERO Enterprise cross-functional working group comprised of experts in multiple industries within the energy sector, including representatives from fuel supply and delivery chains (e.g., fuel oil and natural gas) and the electric grid will report to NERC's Reliability and Security Technical Committee. The Energy Reliability Working Group will serve as an informational stakeholder forum open to cross-sector organizations to facilitate ongoing assessment of energy-related risks to the balance of supply and demand on the BPS. This working group will also develop documents to clarify energy reliability issues and

<sup>5</sup> The maximum amount of capacity a generator can produce. ICAP can be considered in two different ways: Nameplate capacity rating in MW or seasonal net dependable capacity rating that accounts for ambient temperatures and humidity during the season.



best practices for assessing energy risks and identify potential responsive measures associated with unassured energy supplies.

The electric power industry needs to develop new and enhanced forecasting methods and new metrics to evaluate energy availability required to support reliable and secure operations of the BPS at all times.

The following definitions are used for the risk scenario analysis:

- **Anticipated Resources:** Existing resources plus Net Firm Transfers plus Planned resources in MW.
- **Typical Maintenance Outages:** Historical average of generator maintenance outages in MW for specified period/conditions, (e.g., average of maintenance outages for December through February weekdays, over the past three years) or area-specific methodology for determining anticipated maintenance outages.
- **Typical Forced Outages:** Historical average of forced generator outages in MW for a specified period/conditions (e.g., average of forced outages for December through February weekdays, over the past three years), or area-specific methodology for determining anticipated forced outages for non-intermittent resources (e.g., thermal, hydro).
- **Normal Peak Load:** Peak hour demand forecast in MW based on normal weather. This is also referred to as the 50/50 peak load forecast.
- **Reserve Margin:** The amount of generation capacity in MW available above projected load to reliably meet expected demand.
- **Extreme Resource Derates:** Reduced capacity contribution in MW due to generator resource performance in extreme conditions (e.g., temperature-based derates; or based on severe historical events).
- **Extreme Peak Load:** Sum of Normal Peak Load and seasonal load adjustment in MW for extreme weather conditions (e.g., 90/10 peak load forecast; or based on severe historical events).
- **Extreme Low Generation:** Anticipated Resource minus Typical Forced Outages and Extreme Derates in MW.

Several risk factors and criteria are used when determining the risk levels (low, medium, and high) for an assessment area that is likely to issue EEAs. This includes meeting the reference margin levels, the loss of load expectation and the availability of sufficient operating reserves under normal and extreme peak demand. The anticipated resources for conventional generators are based on ICAP, which represents physical generating capacity adjusted for ambient weather conditions. While intermittent renewables, such as wind and solar, capacity contributions are based on historic average values. Table AB2 displays anticipated reserve margins with normal peak load projections for each assessment area. The normal peak load projections are based on 50/50 weather forecasts and are provided on a coincident<sup>6</sup> basis for the assessment areas. Manitoba Hydro, Midcontinent Independent System Operator, SaskPower Corporation, and Southwest Power Pool have sufficient resources to meet their PRMR under normal peak winter conditions.

<sup>6</sup> Sum of two or more peak loads that occur in the same hour.



Assessment Area	Anticipated Resources	Normal Peak Load	Anticipated Reserve Margin	PRMR	Likelihood to Issue EEAs
MH	5,575	4,903	13.7%	12.0%	Low
MISO	144,993	96,999	49.5%	38.6%	Low
SPC	5,262	3,894	35.1%	15.0%	Low
SPP	72,129	46,077	56.5%	19.0%	Low

**Table AB2: Anticipated Reserve Margin Percentage with Normal Peak Load**

Manitoba Hydro, Midcontinent Independent System Operator, SaskPower Corporation, and Southwest Power Pool anticipate reserve margins that reflect robust amounts of excess capacity, there is still potential risk of energy shortfall based on past performance during extreme weather events.

Based on the normal peak load forecast with typical maintenance and forced outage scenario shown in Table AB3, Manitoba Hydro, Midcontinent Independent System Operator, SaskPower Corporation, and Southwest Power Pool have sufficient resources to meet their operating reserve requirements under normal peak winter conditions with typical maintenance and forced outages.

Assessment Area	Anticipated Resources	Typical Maintenance and Forced Outages	Anticipated Resources with Typical Outages	Normal Peak Load	Anticipated Reserve Margin with Typical Outages	Likelihood to Issue EEAs
MH	5,575	113	5,462	4,903	11.4%	Low
MISO	144,993	26,317	118,676	96,999	22.3%	Low
SPC	5,262	238	5,024	3,894	29.0%	Low
SPP	72,129	12,500	59,629	46,077	29.4%	Low

**Table AB3: Reserve Margin Percentage with Typical Outages and Normal Peak Load**

The scenario shown in Table AB4 considers typical maintenance and forced outages combined with extreme winter peak load forecast. For this scenario, Manitoba Hydro, Midcontinent Independent System Operator, SaskPower Corporation, and Southwest Power Pool have sufficient resources to meet operating reserve requirements under extreme peak winter conditions with typical maintenance and forced outages.

Assessment Area	Anticipated Resources with Typical Outages	Extreme Peak Load	Reserve Margin Under Extreme Peak Load	Likelihood to Issue EEAs
MH	5,462	5,146	6.1%	Low
MISO	118,676	102,169	16.2%	Low
SPC	5,024	3,968	26.6%	Low
SPP	59,629	48,435	23.1%	Low

**Table AB4: Reserve Margin Percentage with Typical Outages and Extreme Peak Load**

The worst-case scenario for winter 2025 considers increased resource outages and derates combined with an extreme peak load forecast as shown in Table AB5.



Assessment Area	Anticipated Resources with Typical Outages	Extreme Resource Derates	Extreme Low Generation	Extreme Peak Load	Reserve Margin Under Extreme Resource Derates and Extreme Peak Load	Likelihood to Issue EEAs
MH	5,462	0 <sup>††</sup>	5,462	5,146	6.1%	Low
MISO	118,676	12,775	105,901	102,169	3.7%	Low
SPC	5,024	418	4,606	3,968	16.1%	Low
SPP	59,629	3,000	56,629	48,435	16.9%	Low

**Table AB5: Reserve Margin Percentage with Extreme Resource Derates and Extreme Peak Load**

The extreme low generation in Table AB5 shows marked improvement in expected reserve margin compared to the 2024 winter season.

These scenarios can occur as witnessed in the 2021 and 2022 winter weather events that affected parts of Midcontinent Independent System Operator, Southwest Power Pool, and SaskPower Corporation. The extreme cold-weather events since 2011 indicate that prolonged low temperatures are happening more frequently and can jeopardize the reliable operation of the BPS. Added to this risk is an interruption in fuel supply during extreme cold-weather events.

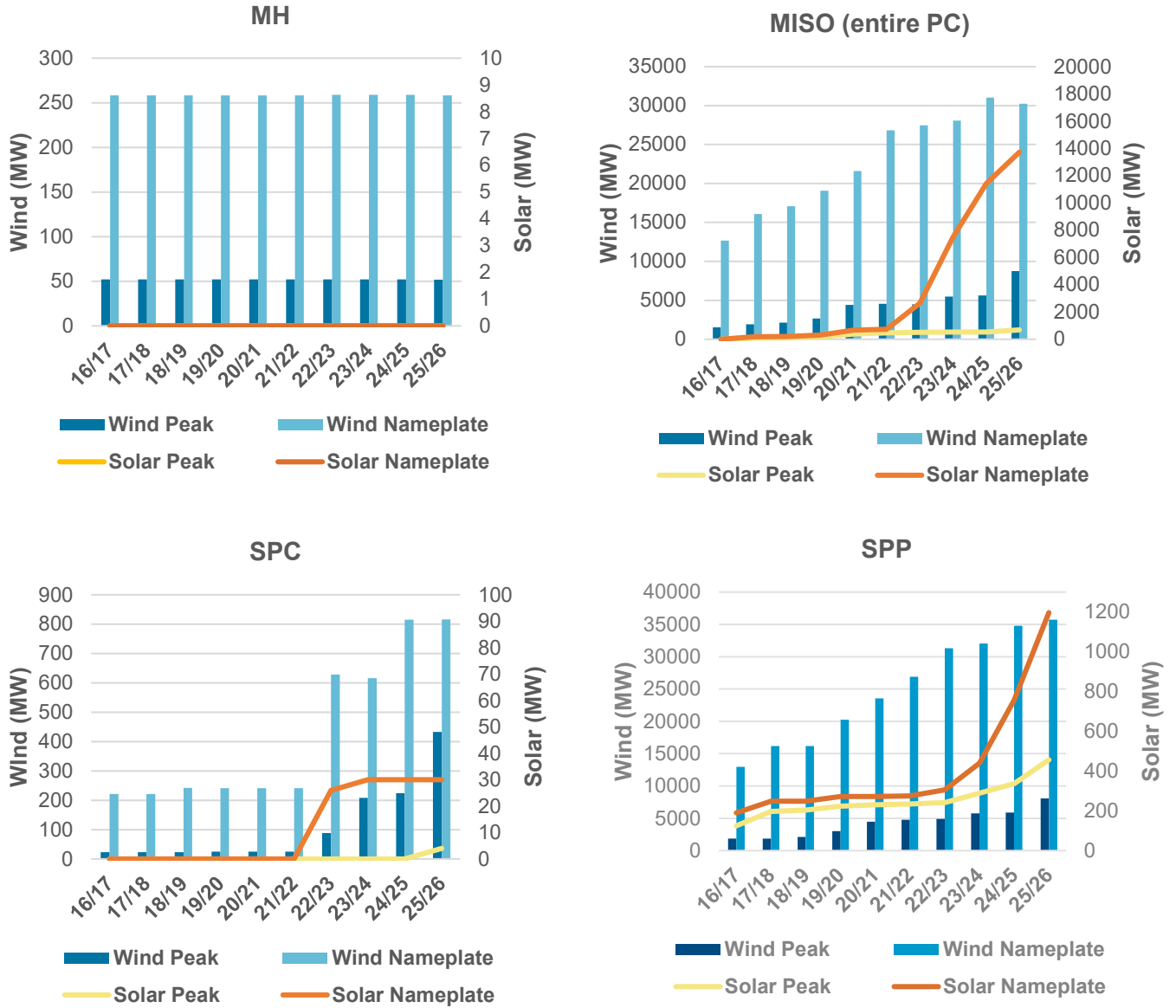
## WIND AND SOLAR RESOURCES

Midcontinent Independent System Operator and Southwest Power Pool continue to see an increase in wind and utility-scale solar photovoltaic penetration in the region. Figure AB6 reflects the winter season wind and solar photovoltaic ICAP and peak capacity for each of the assessment areas. The peak capacity value is the accredited [Effective Load Carrying Capability \(ELCC\)](#) amount of wind or solar available during the period of peak demand. ELCC is defined as the amount of incremental load a particular type of resource, such as wind or solar, can dependably and reliably serve, while also considering the probabilistic nature of generation shortfalls and random forced outages.

The ELCC amount also varies with the resource mix of the system being evaluated. This results in decreasing ELCC values as renewable penetration becomes higher and conventional resources are retired, at times much lower than the ICAP value.

<sup>††</sup> Extreme resource derates has been accounted for in the typical outages, and no additional extreme capacity adjustments needed as part of this assessment.





**Figure AB6: Wind and Solar Photovoltaic Winter ICAP and Peak Capacity**

The rapid growth of inverter-based resources (IBRs) is the most significant driver of grid transformation and poses a high risk to BPS reliability. The new NERC registration criteria for category 2 IBRs will result in an increase in existing and future wind and solar capacity in the MRO region. BPS-connected wind and solar power resources are growing in the MRO region and could reach as much as 115 GW combined by 2035 and continue to challenge grid planners and operators.

When implemented correctly, inverter technology can provide significant benefits for reliability of the power grid. However, it can introduce significant risks if not integrated properly. IBR performance issues, such as wind plants shutting down under extremely low temperatures and solar panels being covered after a heavy snowfall, can have a significant impact on reliability of the BPS.



## Appendix C: BES Event and EEA Details

### December 23, 2024 - Transmission Event

Event Category: 1.a

- Four BES Facilities interrupted
- No generation lost
- 5.3 MW load lost

A 115kV bus differential protection operation tripped four 115kV transmission lines at the entity's substation. A loose connection on the current transformer wiring for one of the transmission lines was determined to be the cause of the event.

A total of 5.3 MW of firm load was impacted for one hour and five minutes during the event.

The loose wiring was fixed, and other nearby circuits were inspected for proper installation.

### January 9, 2025 - Transmission Event

Event Category: 1.a

- Six BES Facilities interrupted
- No generation lost
- 24.9 MW load lost

A 115/12kV transformer was being returned to service. When the 115kV Motor Operated Disconnect was closed, the lockout relay associated with the transformer differential and fast gas relays operated. The lockout relay operation caused two 115kV breakers to trip and a normally open ground switch to automatically close introducing a 3-phase fault onto the 115kV system. This resulted in three 115kV transmission lines and three 115/12kV transformers being tripped. The cause of the event has not been identified. The relays associated with the initiating event as well as relays that misoperated during the event have been identified and tested.

24.9 MW of firm load was impacted for one minute during the event.

### January 24 2025 - Transmission Event

Event Category: 1.a

- Five BES Facilities interrupted
- 38.4 MW generation lost
- 35.8 MW load lost

At 1454 an event occurred during routine switching operations to return one of three generators at the station back to service. The other two generators were online at the time. During switching an error occurred where the operator closed a breaker out of sync resulting in all three generators tripping offline as well as de-energizing a 161kV line, a 69kV line and associated loads.

Design updates are being developed to include a sync check relay to prevent closure out of sync.

35.8 MW of load was impacted during this event for 24 minutes.



**January 20, 2025 - EEA Level 2 Event**

At 1200 the RC declared an EEA 2 due to two units being unavailable, wind generation being affected by cold temperature cut outs, and a converter trip on an additional generator unit. The RC arranged for 150 MW to be supplied from a neighboring RC. A repair crew was dispatched to address the tripped converter. The RC was able to downgrade to EEA 0 within five minutes.

No load was shed during this incident.

**January 31, 2025 - Transmission Event**

Event Category: 1.a

- Three BES Facilities interrupted
- 75 MW generation lost
- No load lost

At 0644 three 115kV transmission lines as well as 75 MW generator relayed out of service as a result of incorrect as-left settings on one of the line relays. The settings error was due to corrupted settings being saved onto the relay after testing software experienced some issues during testing. The corrupted settings were then written back to the relay as the as-left settings.

Testing procedures were updated and reviewed with staff to prevent recurrence.



## Appendix D: Generation Availability details

Generation unavailability can have a substantial impact on power grid reliability. Useful metrics for generator unavailability are EFOR and WEFOR, which measure unavailability of generators as a percentage of all calendar hours.

For the MRO region, the historical annual conventional generator WEFOR for all seasons is shown in Figure AD1 and is trending upward over the five-year span. Winter outage rates are most concerning and merit the outage cause investigation detailed below. The lowest rate was seen in 2020 due to reductions in both total demand and forced outages and derates in simple cycle generation. The steep increase in 2022 WEFOR was driven in part by extreme outage events at the beginning (January and February) and end (December - Winter Storm Elliott) of the winter season as shown in figure AD2. This was also driven by high levels of outages in the fall due to simple cycle gas turbines and a small, but heavily MW weighted increase in WEFOR of fossil steam plants. WEFOR rates were consistent with historical performance until a marked increase in fall outage issues in 2022, which marked the beginning of a trend.

Poor WEFOR performance throughout 2023 began slightly elevated from a difficult 2022 fall maintenance season, and a subsequent challenging winter with high unavailability among simple cycle gas turbines and poor fossil steam performance over the summer. WEFOR in 2024 and 2025 does not currently include any data from Canadian entities, making the data somewhat incomparable. However, 2024 data was largely in line with 2023, suggesting that issues around maintenance outage seasons and elevated forced outage rates were a continuing concern. The 2025 data available at the time of publication is consistent with these findings.

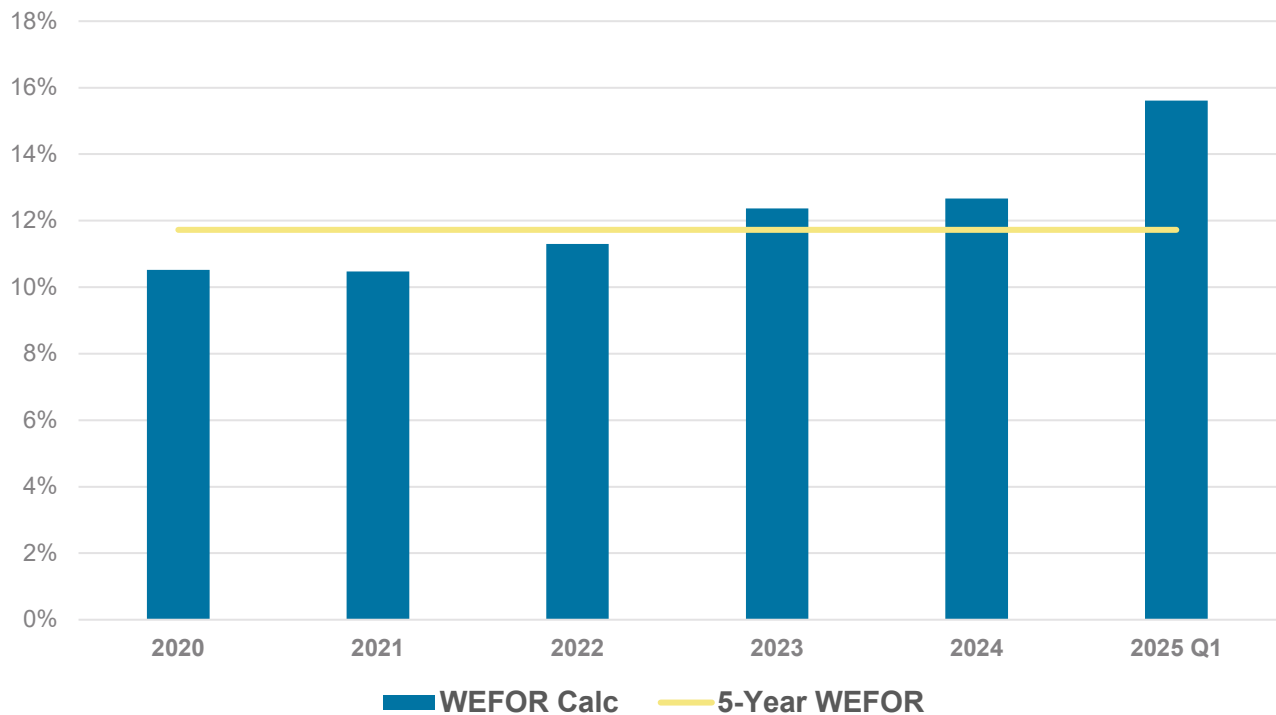


Figure AD1: MRO Annual Generator MW-Weighted EFOR



### MRO WEFOR by Month 2020-2025

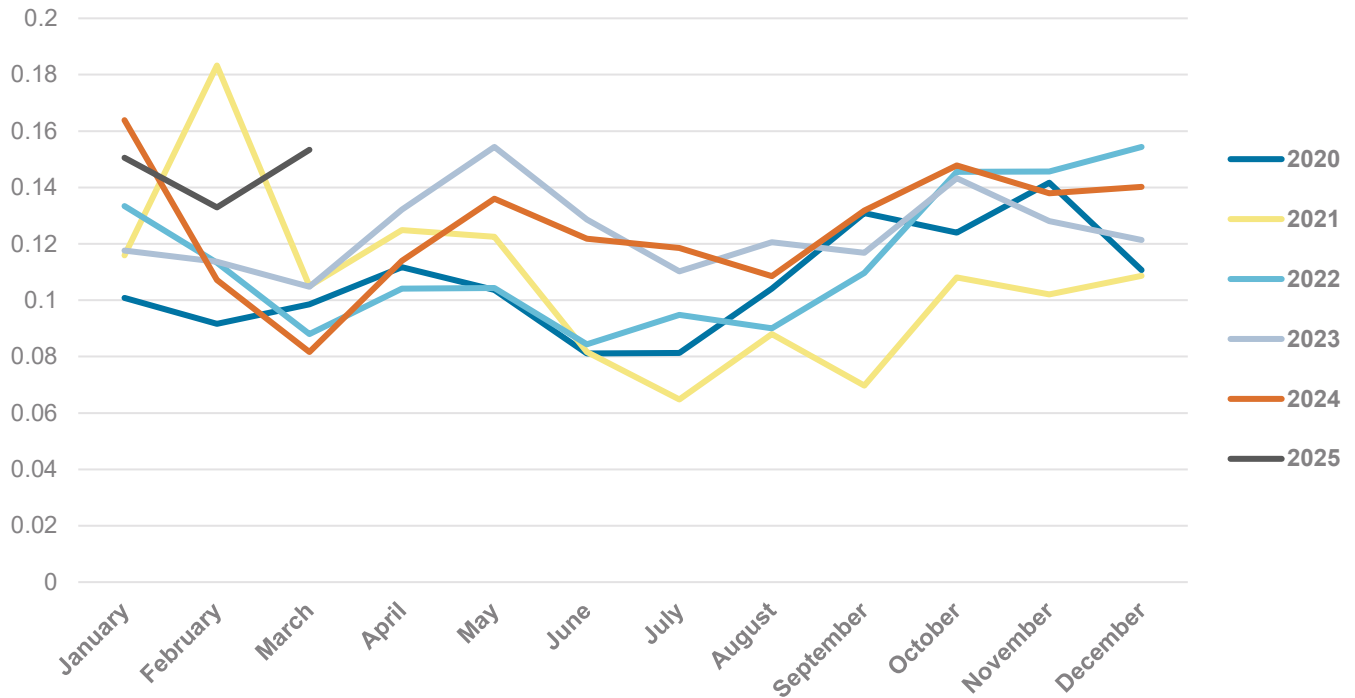


Figure AD2: MW-Weighted EFOR By Month

Table AD3 shows the top five causes for 2024 winter season forced outages, forced derates, and startup failures by MWh loss for fossil-steam plants. Table AD4 shows the top outages in calendar year 2024 and Table AD5 shows this data for the previous five winter seasons.

Cause Type	Portion of lost MWh
Tornado – 1 event	10.6%
Main Transformer – 31 events	6.0%
Waterwall – 22 events	5.9%
Circulating water piping – 2 events	5.2%
Buckets or blades C – 2 events	4.6%

Table AD3: Fossil-Steam 2024 Winter Outages

Cause Type	Portion of lost MWh
Rotor; General – 3 events	11.0%
Buckets or blades C – 4 events	4.5%
Other air heater fouling (heat pipe; plate-type) – 5 events	4.5%
Induced draft fan motors and drives – 41 events	4.0%
Main transformer – 12 events	3.7%

Table AD4: Fossil-Steam 2024 Calendar Year Outage Causes



Cause Type	Portion of lost MWh
Other high pressure turbine problems – 6 events	11.7%
Waterwall (Furnace wall) – 121 events	6.1%
Buckets or blades C – 7 events	4.7%
Storms (ice; snow; etc.) – 43 events	3.1%
Pulverizer mills – 170 events	2.7%

**Table AD5: Fossil-Steam 2020-2024 Winter Outage Causes**

Fossil-steam outage causes for the 2024 winter season deviate from the five-year trends, primarily with high-duration events that dominate seasonal analysis due to the length of impact. Main transformer events were not well distributed in the population, therefore not representing a larger seasonal or generator class concern. Waterwall is historically the most impactful and well-distributed outage amongst fossil-steam units but was only third in the 2024 winter season and sixth overall in calendar year 2024. This is an indicator that less typical events are driving outages, likely due to low incidence, high impact events like natural disasters, or that seasonal effects are extremely pronounced for the generator category.

Winter forced outage rates for fossil-steam units were substantially worse year over year, in large part due to a 17% increase in lost MWh, corresponding to the increases in high-impact events described above, as well as buckets and blades outages. Outside of these high-impact events, there is not a concentration of lost MWh in any category of cause codes, and the portion of lost MWh for individual cause codes is quite low – in the two to three percent range at the high end. This indicates that outages and derates are not being affected by particular risk factors endemic to the region, rather age and maintenance availability are likely the largest driving causes of increases in WEFOR and lost MWh.

Table AD6 shows the top five causes for 2024 winter season forced outages, forced derates, and startup failures by MWh lost for simple cycle gas turbines. Table AD7 shows the same information for calendar year 2024 and AD8 shows the same for five-year historical winter season period.

Cause Type	Portion of lost MWh
Lack of fuel: Contract or Tariff allows for interruption – 244 events	28.3%
Boroscope inspection A – 1 event	8.5%
Other miscellaneous generator problems – 6 events	6.5%
Engine vibration – 1 event	5.9%
Load shaft and bearings B – 1 event	5.1%

**Table AD6: Simple Cycle Gas Turbine 2024 Winter Outages**

Cause Type	Portion of lost MWh
Lack of fuel: Contract or Tariff allows for interruption – 127 events	7.4%
High pressure blades/buckets A – 19 events	6.0%
Fuel nozzles/vanes A – 4 events	5.6%
Other Controls and instrumentation Problems B – 66 events	5.3%
Hydraulic oil system B – 4 events	4.5%

**Table AD7: Simple Cycle Gas Turbine 2024 Calendar Year Outage Causes**



Cause Type	Portion of lost MWh
Lack of fuel: Contract or Tariff allows for interruption – 973 events	22.7%
Engine vibration – 17 events	9.2%
Main transformer – 16 events	6.4%
Other miscellaneous gas turbine problems – 45 events	4.6%
Other miscellaneous generator problems – 19 events	3.3%

**Table AD8: Simple Cycle Gas Turbine 2020-2024 Winter Outage Causes**

Simple-cycle gas turbines have struggled as seen both event impact and WEFOR in the MRO region, particularly in the winter. Historically, as shown in table AD8, lack of fuel, particularly without firm contracts, has been a problem across seasons. These events are more common and more impactful when natural gas supplies are limited during extreme cold events. In the winter 2024 season, only low-incident, high-impact events make up appreciable portions of lost MWhs, indicating that fuel availability is the key point of interest for unit reliability amongst simple cycle gas turbines. The forced outage rates of these units have been high, and MRO is closely monitoring the performance of these resources.

Additional historical five-year and five-year winter season forced outage, forced derate, and startup failure causes for other types of generation is provided below.

Cause Type	Portion of lost MWh
Main stop valves – 1 event	18.8%
Lack of fuel: Contract or Tariff allows for interruption – 17 events	15.7%
Other HP steam system problems – 2 events	15.1%
Other switchyard equipment – external – 3 events	10.5%
Other HRSG tube Problems – 1 event	4.9%

**Table AD9: Combined Cycle Gas Turbine 2024 Winter Outages**

Cause Type	Portion of lost MWh
Cold reheat steam piping up to boiler – 5 events	27.0%
Main transformer – 4 events	16.6%
Other miscellaneous jet engine problems – 1 event	8.2%
Generator output breaker – 2 events	5.1%
Other combustor problems B – 49 events	3.6%

**Table AD10: Combined Cycle Gas Turbine 2024 Calendar Year Outage Causes**

Cause Type	Portion of lost MWh
Stator windings; bushings; and terminals – 3 events	22.7%
Fuel piping and valves A – 25 events	13.5%
Circulating water valves – 2 events	12.2%
Other miscellaneous external problems – 9 events	6.8%
Lack of fuel: Contract or Tariff allows for interruption – 68 events	4.4%

**Table AD11: Combined Cycle Gas Turbine 2020-2024 Winter Outage Causes**



Cause Type	Portion of lost MWh
Lack of fuel: Contract or Tariff allows for interruption – 12 events	20.7%
Main stop valves – 1 event	18.5%
Other HP steam system problems – 1 event	13.3%
Other switchyard equipment – external – 2 events	9.6%
Lube oil system A – 1 event	5.3%

**Table AD12: Combined Cycle Steam 2024 Winter Outages**

Cause Type	Portion of lost MWh
Cold reheat steam piping up to boiler – 2 events	25.5%
Other exciter problems – 10 events	16.5%
Generator output breaker – 3 events	6.7%
Main transformer – 7 events	5.4%
Hot reheat steam piping up to turbine stop valves – 2 events	4.7%

**Table AD13: Combined Cycle Steam 2024 Calendar Year Outage Causes**

Cause Type	Portion of lost MWh
Stator windings; bushings; and terminals – 3 events	20.5%
Other exciter problems – 11 events	9.3%
Fuel piping and valves A – 15 events	8.0%
Circulating water valves – 1 event	7.5%
Other miscellaneous balance of plant problems – 24 events	4.9%

**Table AD14: Combined Cycle Steam 2020-2024 Winter Outage Cause**



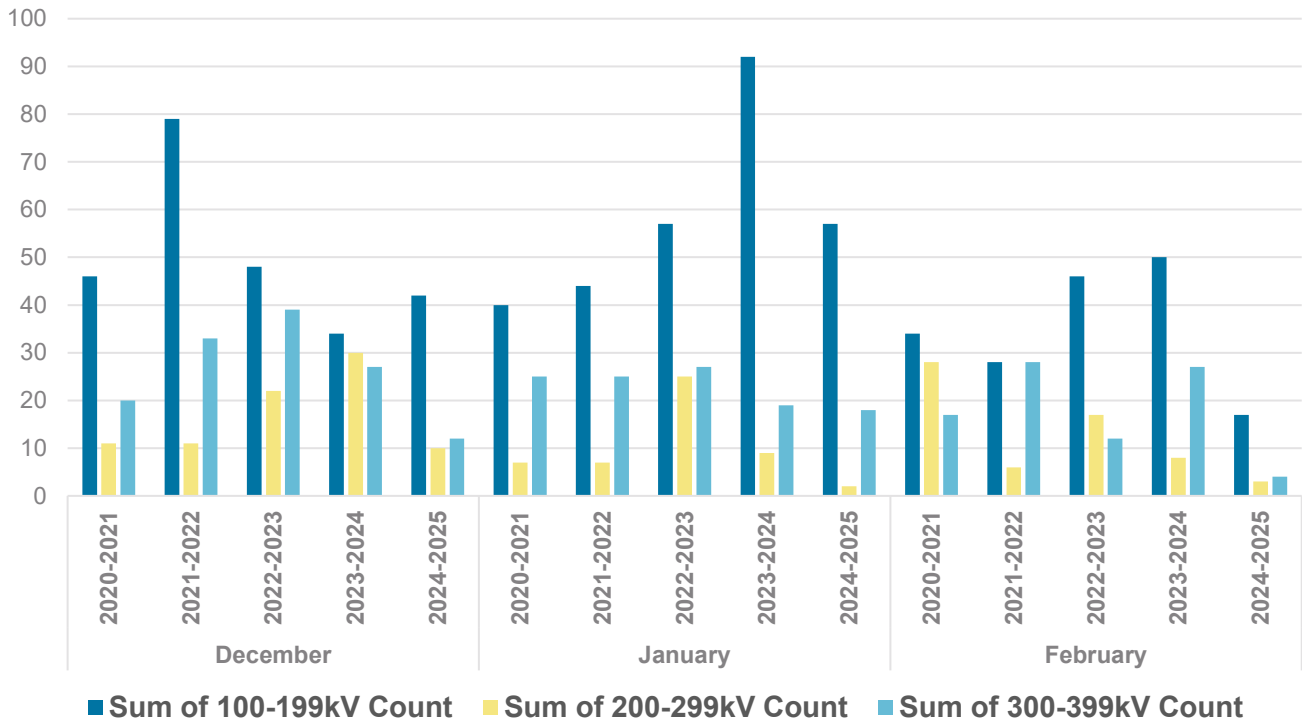
## Appendix E: Transmission Availability details

Table AE1 shows the number of circuits and circuit miles for overhead 100-599kV AC transmission lines within the MRO region. AC circuits in the voltage range of 100-399kV accounted for 90% of the outages during the latest winter season and will be the elements analyzed in the section below.

100-199-kV		200-299-kV		300-399-kV		400-599-kV	
Circuits	Miles	Circuits	Miles	Circuits	Miles	Circuits	Miles
3470	47622	423	14244	529	18723	9	1001

**Table AE1: AC Transmission Circuit Miles**

Figure AE2 shows the number of 100kV and above automatic AC circuit outages that include both momentary (for 200kV and above) and sustained outages for the 2020 through 2024 winter seasons. There was a total of 24 AC circuit outages reported for the month of February in 2025. There were only three 400-599kV outages during the 2020-2024 winter seasons.



**Figure AE2: Winter Automatic Outages by Month**



Figure AE3 shows the top seven causes of momentary outages for the past five winter seasons. The causes are in descending order for the total number of momentary outages over the five-year period. The chart does not include momentary automatic outages for circuits 100-199kV because causes are not reported for momentary outages on circuits less than 200kV. The chart shows that for the most recent period the number of Unknown outages decreased significantly to just two. This is a significant decrease from the 29 that were reported for the 2021 winter season.

For the current period, Weather excluding lighting was the leading cause momentary outages with twelve and failed AC Circuit Equipment was the second leading cause with four reported outages.

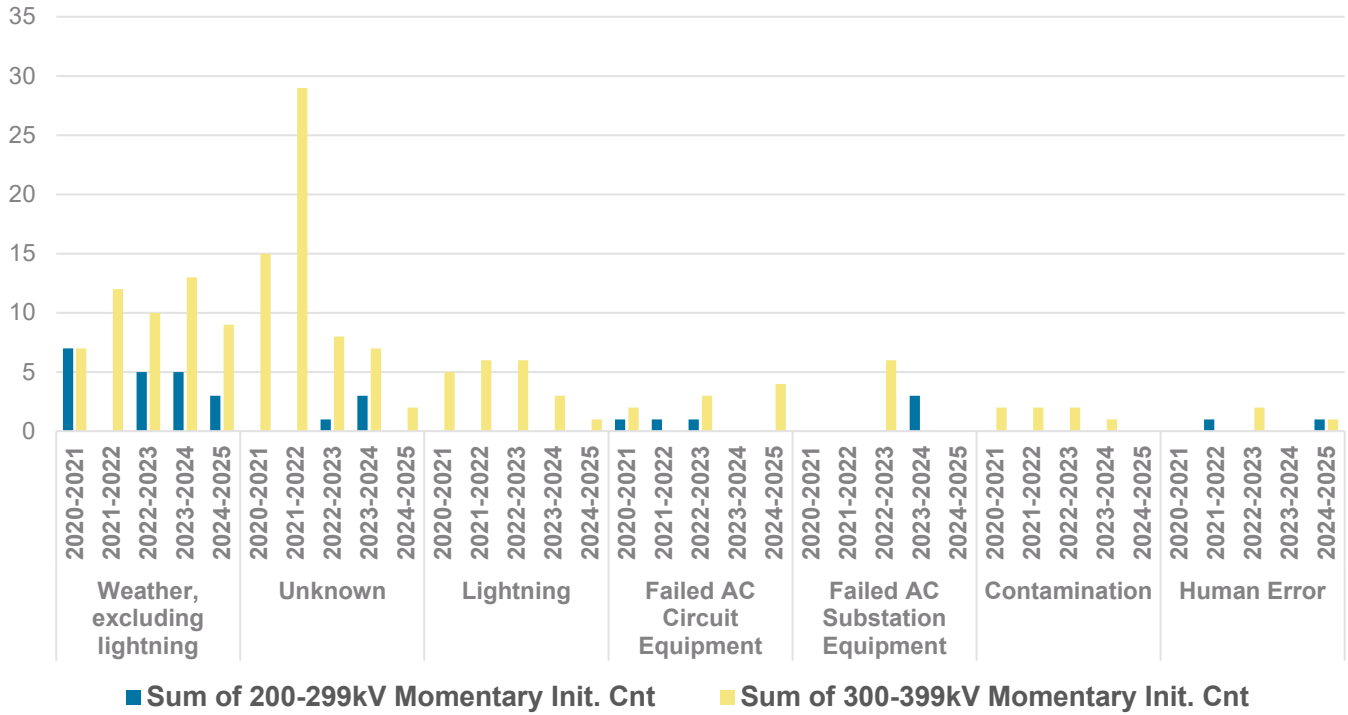
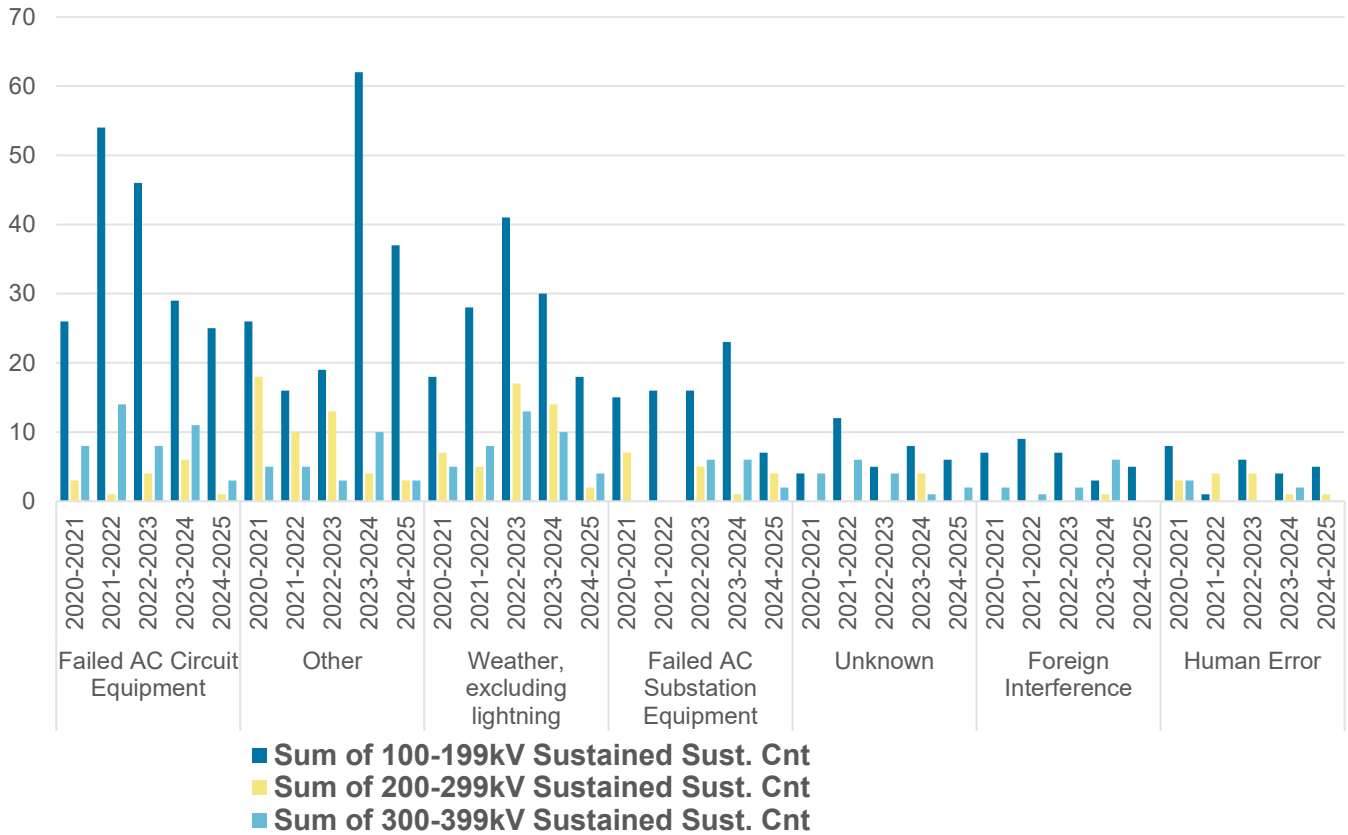


Figure AE3: Winter Momentary Outages by Cause



Figure AE4 shows the top seven causes of sustained outages for the 2020 through 2024 winter seasons. The causes are in descending order for the total number of sustained outages over the five-year period. The chart shows that Weather Excluding Lightning, Failed AC Circuit Equipment, Other, and Failed AC Substation Equipment continue to be major contributors to sustained outages during the winter seasons. For the most recent period, Other was the largest contributor to sustained outages with 43. Followed by Failed AC Circuit Equipment with 29, and Weather, excluding lightning, at 24.

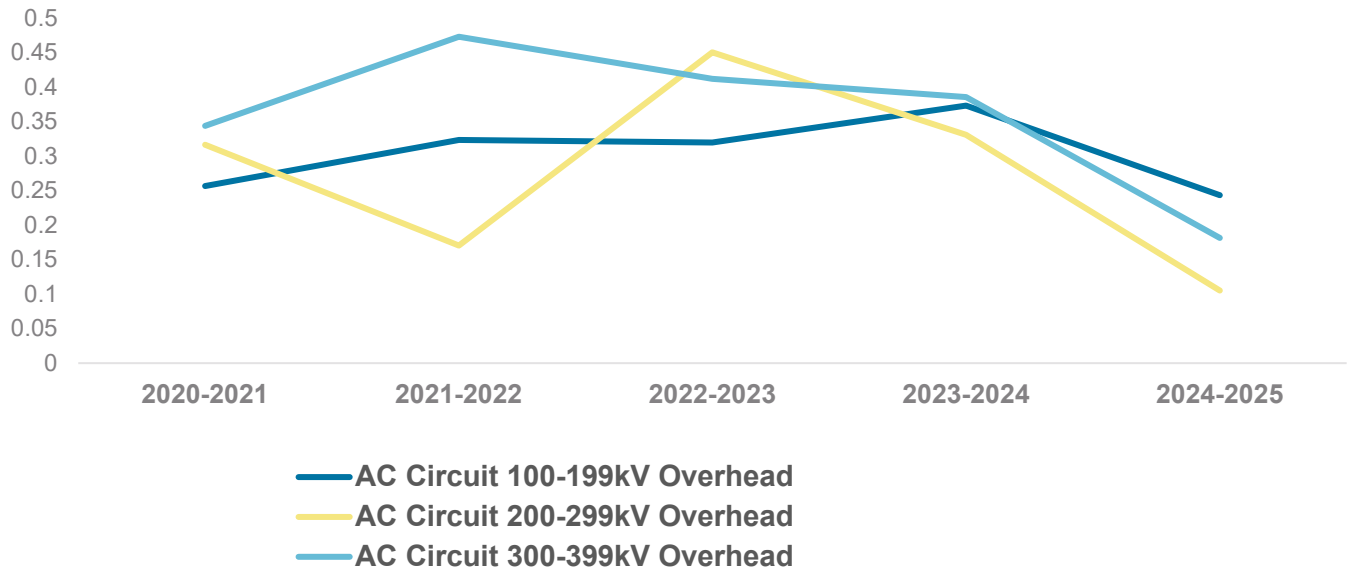


**Figure AE4: Winter Sustained Outages by Cause**

Figure AE5 reflects the yearly winter total outages per 100 circuit miles for 100-399kV circuits. The chart clearly shows a decrease in outages for all the voltage ranges displayed from the previous year.

There were several winter storms that impacted the number of outages in the MRO region for the 2023-2024 winter season. On December 26, 2024, a storm swept through the northern region of MRO. There were 16 outages during that day, which accounts for 25 percent of all outages for the month of December. In addition, 29 outages were reported on January 5, 2025, as a winter storm traveled through the south-central portion of the MRO region, which accounts for 38 percent of the outages in the month of January.





**Figure AE5: Total Transmission Outages per 100 Circuit Miles**



## GLOSSARY

<b>Compliance</b>	Compliance by industry is conforming to NERC Reliability Standards. Strategies by MRO to achieve industry compliance range from education to enforcement and/or sanctions.
<b>Bulk Power System</b>	Facilities and control systems necessary for operating an interconnected electric generation and transmission network (or any portion thereof); and electric power needed to maintain transmission system reliability and serve load. The term does not include facilities used in the local distribution of electric energy.
<b>CMEP</b>	The rules governing compliance and enforcement oversight are included in the Compliance Monitoring and Enforcement Program (CMEP).
<b>Eastern Interconnection</b>	The Eastern Interconnection is a major bulk power system grid in North America. All the electric utilities in the Eastern Interconnection are tied together during normal system conditions and operate at a synchronized frequency that averages 60 Hz. The Eastern Interconnection reaches from central Canada eastward to the Atlantic coast (excluding Quebec) south to Florida and back west to the foot of the Rockies (excluding most of Texas).
<b>Highly Reliable Organization</b>	<p>An organization that avoids sudden, uncontrolled cascading events despite operating in a highly complex environment by adopting a constant state of vigilance resulting in the fewest number of operating errors. These organizations have the following characteristics:</p> <ul style="list-style-type: none"> <li>• Preoccupation with failure • Attention on “close calls” and “near misses.”</li> <li>• Reluctance to simplify interpretations • Solid “root cause” analysis practices.</li> <li>• Sensitivity to operations • Situational awareness and carefully designed change management processes.</li> <li>• Commitment to resilience • Resources are continually devoted to corrective action plans and training.</li> <li>• Deference to expertise • Listens to experts on the front lines (ex. authorities follows expertise).</li> </ul> <p>Refer to <i>Managing the Unexpected-Assuring High Performance in an Age of Complexity</i> by Karl E. Weick and Kathleen M. Sutcliffe.</p>
<b>Industry</b>	<p>Those regulated by MRO include:</p> <ul style="list-style-type: none"> <li>• Investor-owned utilities</li> <li>• Cooperative and municipal utilities</li> <li>• Canadian utilities</li> <li>• Transmission system operators</li> </ul>



	<ul style="list-style-type: none"> <li>• Generator owners and operators</li> <li>• U.S. federal power agencies</li> <li>• Other users, owners, and operators, of the bulk power system</li> </ul> <p>For more information, please refer to the MRO registry (known as “Registered Entities”).</p>
<b>Industry Stakeholders</b>	A person, group or organization that has interest or concern in the industry and in the MRO region.
<b>Intelligence-Led</b>	Using intelligence products based on analytics, root cause analysis, and other mechanisms to inform program areas, such as compliance, around risks.
<b>Registered Entity</b>	An owner, user, or operator who has a material impact on the bulk power system and is on the registry.
<b>Reliable Operations</b>	Operating the elements of the bulk power system within equipment and electric system thermal, voltage, and stability limits so that instability, uncontrolled separation, or cascading failures of such system will not occur as a result of a sudden disturbance, including a cybersecurity incident, or unanticipated failure of system elements.
<b>Responsive Regulation</b>	Responsive regulation is an approach that varies the compliance oversight and enforcement response depending on the registered entity’s individual circumstances. Circumstances that are considered include the participant’s compliance history, function, location, cooperation, and other factors. The aim of the responsive regulators is to return the registered entity to full voluntary compliance. The response is therefore proportional to the risks and consistent for the same type of registered entity in similar circumstances.
<b>Risk</b>	The chance of something happening that has the potential to have an adverse impact on bulk power system reliability. All risks are considered in the context of the potential adverse outcome.

