NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

2024 State of Reliability Overview

June 2024

[2024 SOR Infographic]

[2024 SOR Technical Assessment]

[2024 SOR Video]

Assessment Overview of 2023 Bulk Power System Performance

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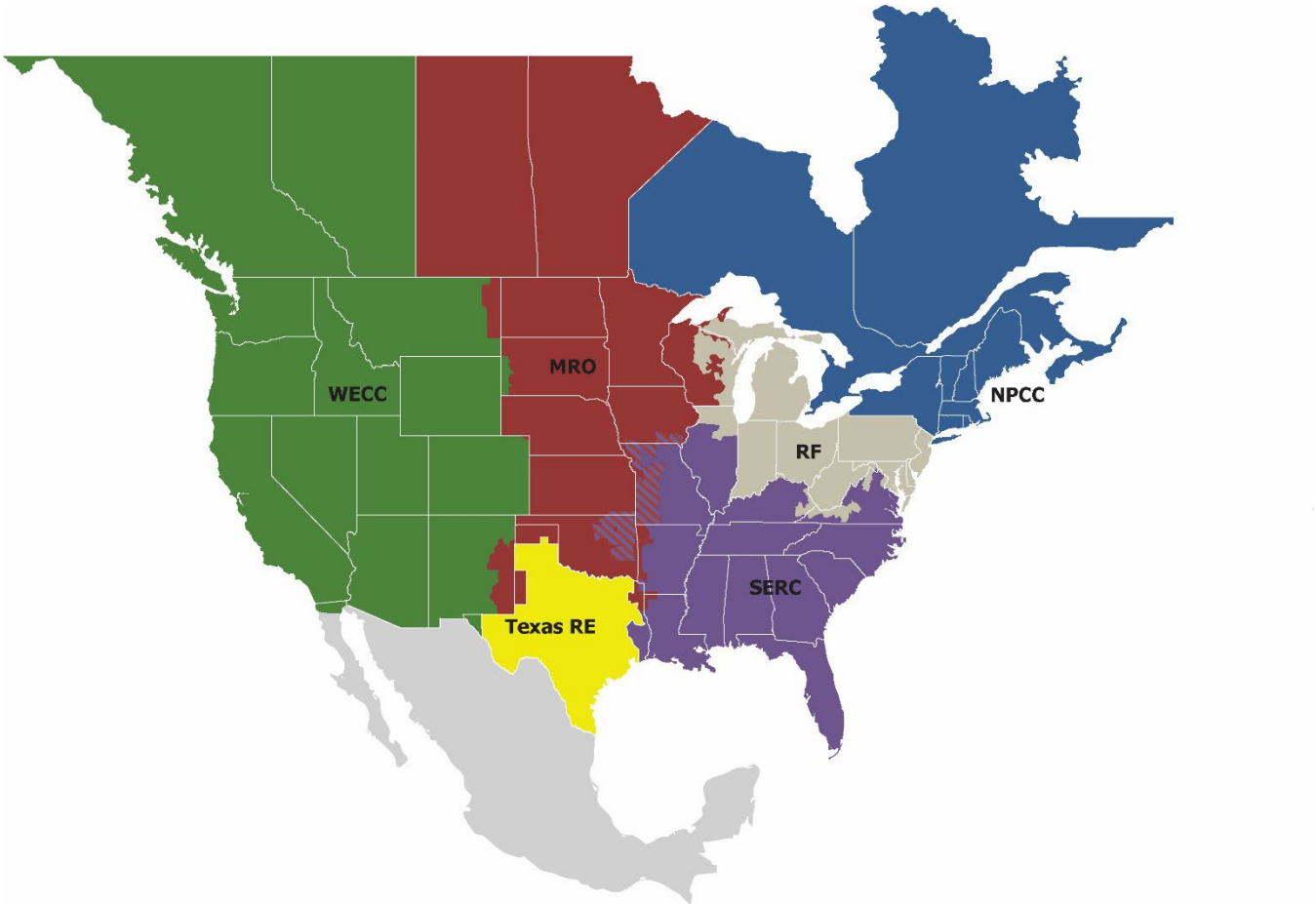
Preface

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

Reliability | Resilience | Security

Because nearly 400 million citizens in North America are counting on us

The North American BPS is made up of six Regional Entities as shown on the map and in the corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity while associated Transmission Owners/Transmission Operators participate in another.



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

About This Overview

This year's *State of Reliability* (*SOR*) report is comprised of two publications: this *2024 SOR Overview*, which is a high-level summary of the Technical Assessment, summarized by key findings, and the *2024 SOR Technical Assessment*,[1] which provides NERC's comprehensive annual analytical review of BPS reliability for the 2023 calendar year. This analysis fulfills a key role in NERC's mission by providing an unbiased, data-driven look at BPS reliability, identifying ongoing challenges and informing future-looking assessments. This overview seeks to inform regulators, policymakers, and industry leaders on the most significant reliability risks facing the BPS and describe the actions that the ERO Enterprise has taken and will take to address them.

The *2024 SOR Overview* replaces the key findings previously found in the Technical Assessment.

Development Process

ERO staff developed this overview and the corresponding *2024 SOR Technical Assessment* with support from the Performance Analysis Subcommittee. It draws conclusions from an established set of reliability indicators and mandatory information reported by industry to the Transmission Availability Data System (TADS), the Generating Availability Data System (GADS), the Misoperation Information Data Analysis System (MIDAS), voluntary reporting into the Event Analysis Management System (TEAMS), Bulk Power System Awareness monitoring and processes, and the Institute of Electrical and Electronics Engineers (IEEE) Distribution Reliability Working Group.

Considerations

- Data in the *SOR* represents the performance for the January–December 2023 operating year unless otherwise noted.
- Analysis in this report is based on data from 2019–2023 that was available in Spring 2024, and it provides a basis to evaluate 2023 performance relative to performance over the last five years. All dates and times shown are in Coordinated Universal Time (UTC).
- To properly demonstrate key trending information, this year's report evaluates generation data dating back to 2014.
- The *SOR* is a review of industry-wide trends and not a review of the performance of individual entities.
- When analysis is presented by Interconnection, the Québec Interconnection is combined with the Eastern Interconnection unless specific analysis for the Québec Interconnection is shown.

[1] https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2024_Technical_Assessment.pdf

Key Finding 1: Response to Severe Weather Events Confirms the Overall Resilience of the BPS

Over the past several years, a handful of extreme weather events has increasingly been the largest challenge to BPS reliability, and the unprecedented magnitude of these events has dominated reliability trends. In 2023, the absence of such anomalous events in the United States showed that the BPS performed well based on the more routine (but still severe) weather events (see Figure 1).

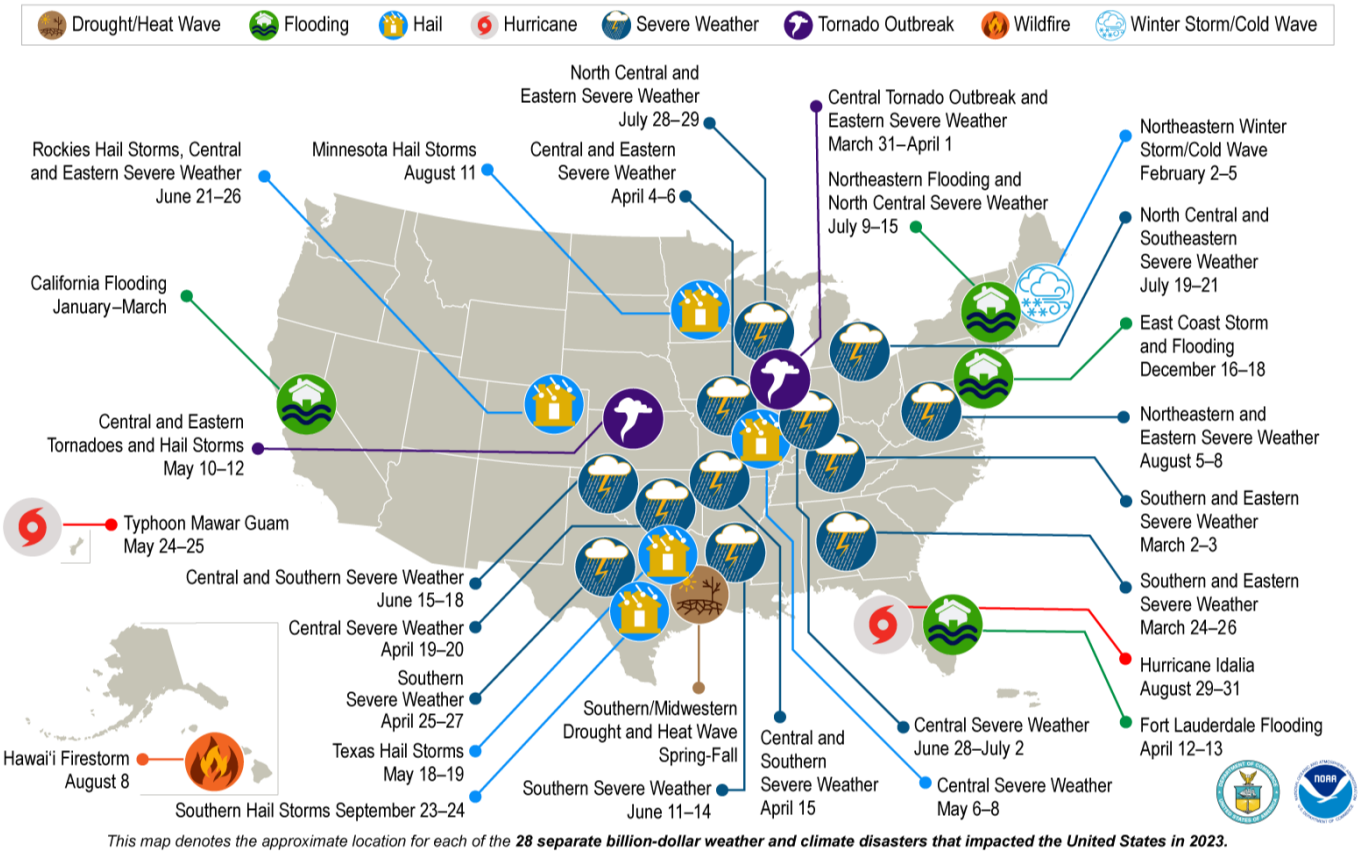


Figure 1: 2023 U.S. Billion-Dollar Weather and Climate Disasters[2]

Canada experienced record-setting wildfires throughout 2023. Transmission metrics were disproportionately impacted by the short-duration outages associated with these wildfires, specifically within the Québec Interconnection. However, due to operator actions as well as the fires' varied timing and geographical locations, the actual impact on BPS reliability was minimal (see Figure 2).

[2] NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2023). https://https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73

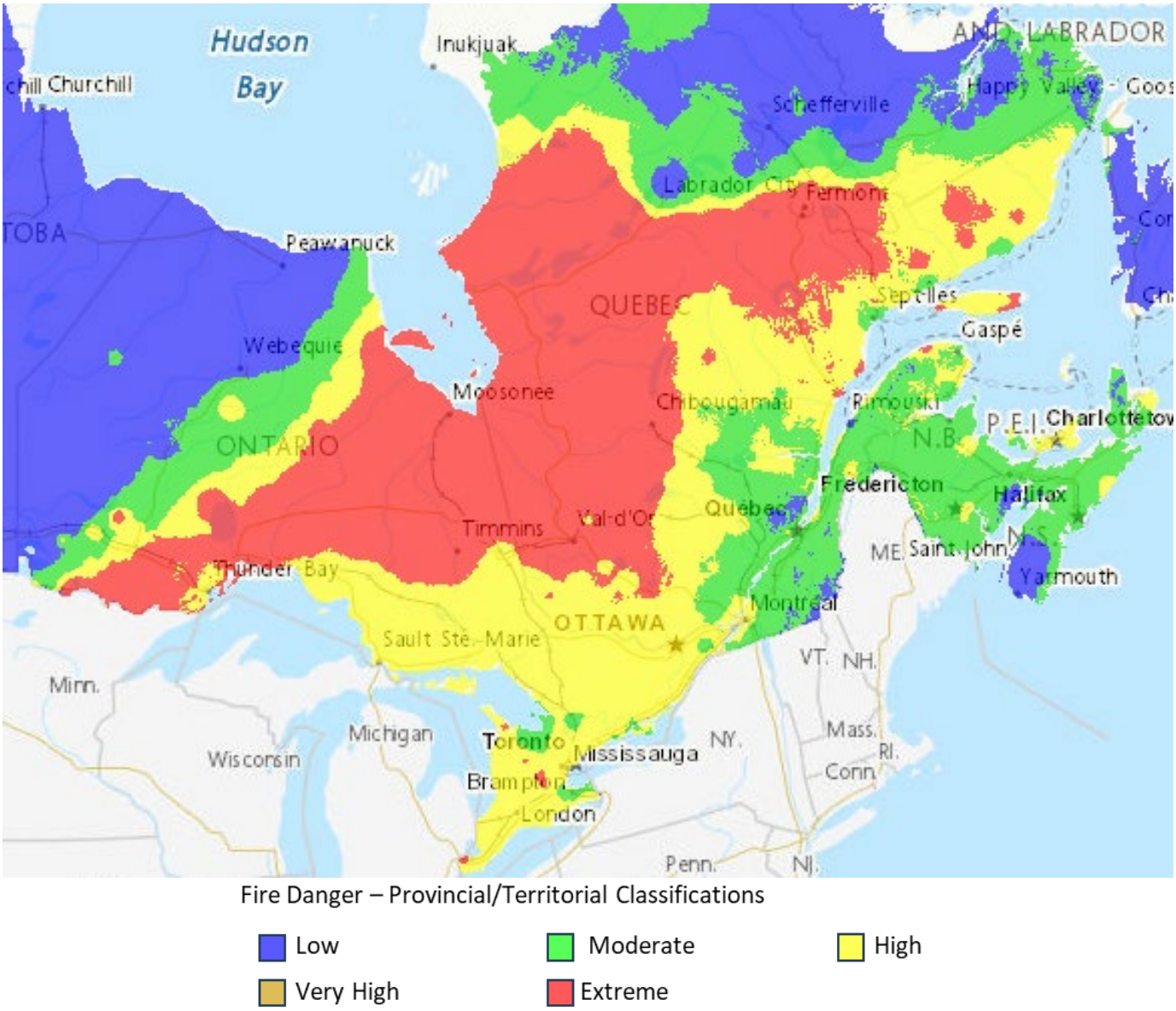


Figure 2: Fire Danger in Canada, June 20, 2023[3]

Overall, the worst-performing days (as measured by the severity risk index) showed significantly better performance than the worst-performing days observed in prior years (see Figure 3). Following these more routine, severe events in 2023, restoration times of transmission system outages were 10–20% better than in most prior years, and no load loss associated with Level 3 Energy Emergency Alerts occurred.

[3] Natural Resources Canada, June 20, 2023

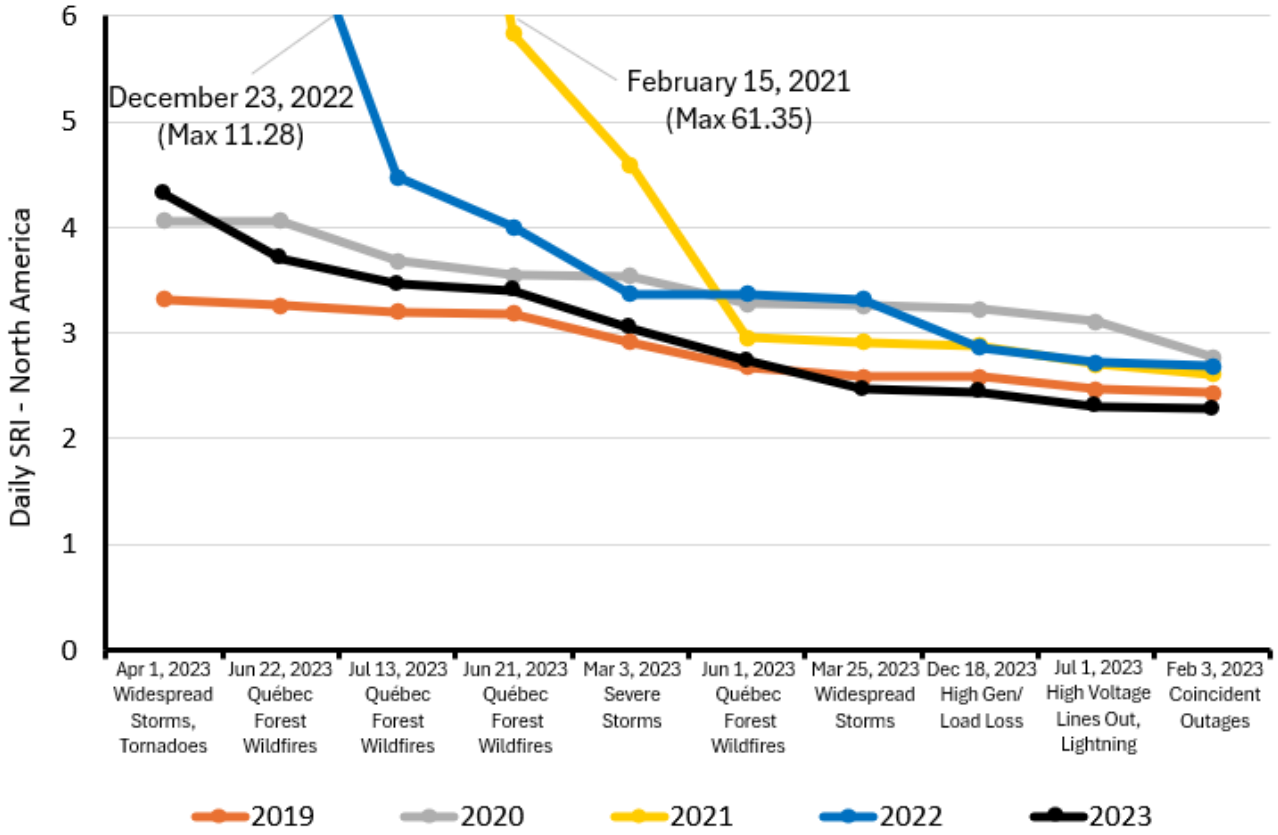


Figure 3: Top Annual Daily SRI Days Sorted Descending

This finding highlights the ability of the BPS to withstand severe weather events, demonstrating the importance of advanced preparation, active management engagement throughout the duration, and rapid restoration following an event.

Resultant Actions

- Increased ERO Enterprise focus on periods of extreme and abnormal weather conditions, through inquiries and other event analyses, has produced recommendations for revisions to Reliability Standards, increased cold weather alerts, and additional data collection to monitor performance.
- EOP-011-2[4] was issued to address the effects of operating emergencies by ensuring that each Transmission Operator (TOP), Balancing Authority (BA), and Generator Owner (GO) has developed plans to mitigate operating emergencies and that those plans are implemented and coordinated within the Reliability Coordinator area as specified within the requirements. This standard became enforceable in 2023.

[4] EOP-011-2

Key Finding 2: Generation Forced-Outage Rates Continue to Increase

Conventional and wind generation forced-outage metrics remain at historically high levels, exceeding rates for all years prior to 2021. Despite no major events comparable to Winter Storms Uri or Elliott, the weighted equivalent forced-outage rates (WEFOR) of baseload coal and cycled natural gas units[5] remained high in 2023 (see Figure 4), remaining the primary drivers for the high conventional generator outage rates. While performance of any fuel type may vary during a single event, the annual WEFOR for natural gas units has remained relatively consistent. Although hydro generation also experienced relatively high forced-outage rates for this class of resource, these plants represent a much smaller portion of the conventional fleet and do not contribute as much to the WEFOR.

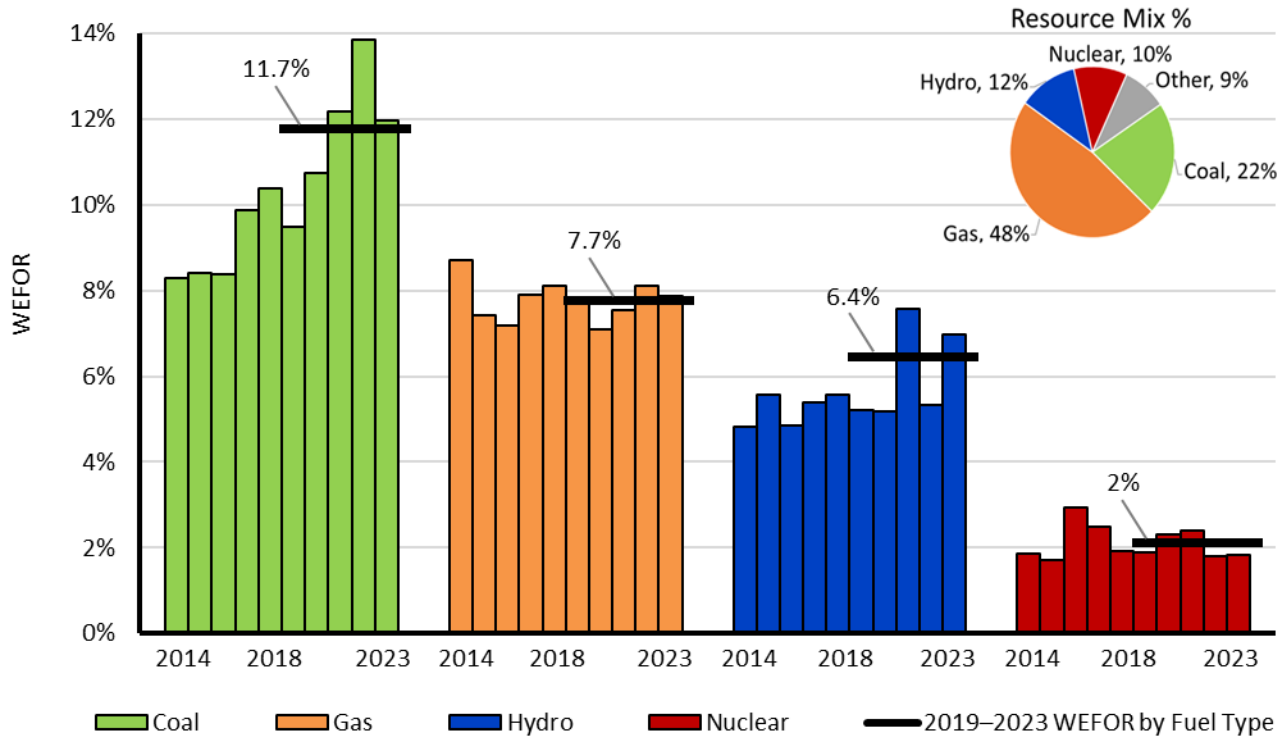


Figure 4: 10-Year Annual Coal WEFOR 2023 Resource Mix by Net Maximum Capacity

Due to year-over-year variability, coal generation most closely correlates to the overall WEFOR, despite more energy being produced by both natural gas and nuclear power in 2023 (see Figure 5). There is a slight correlation between the age of coal units and WEFOR; however, the WEFOR of coal units is affected more by an increase in maintenance and a reduction in service hours than an increase in forced outages.

As baseload coal units continue to be retired and require more maintenance, they are increasingly being replaced by a mixture of inverter-based resources (IBR) and periodically run gas turbines. Industry statements related to reduced investment in maintenance and abnormal cycling, which are being adopted primarily in response to rapid changes in the resource mix, are negatively impacting baseload coal unit performance. This aligns with analysis showing that baseload coal units operating below a 60% capacity factor experience a disproportionate increase in outage rate.

[5] Figure 4 presents all generators for a given fuel type. Frequently cycled natural gas generation shows a higher WEFOR; however, overall natural gas generation's WEFOR has remained relatively stable.

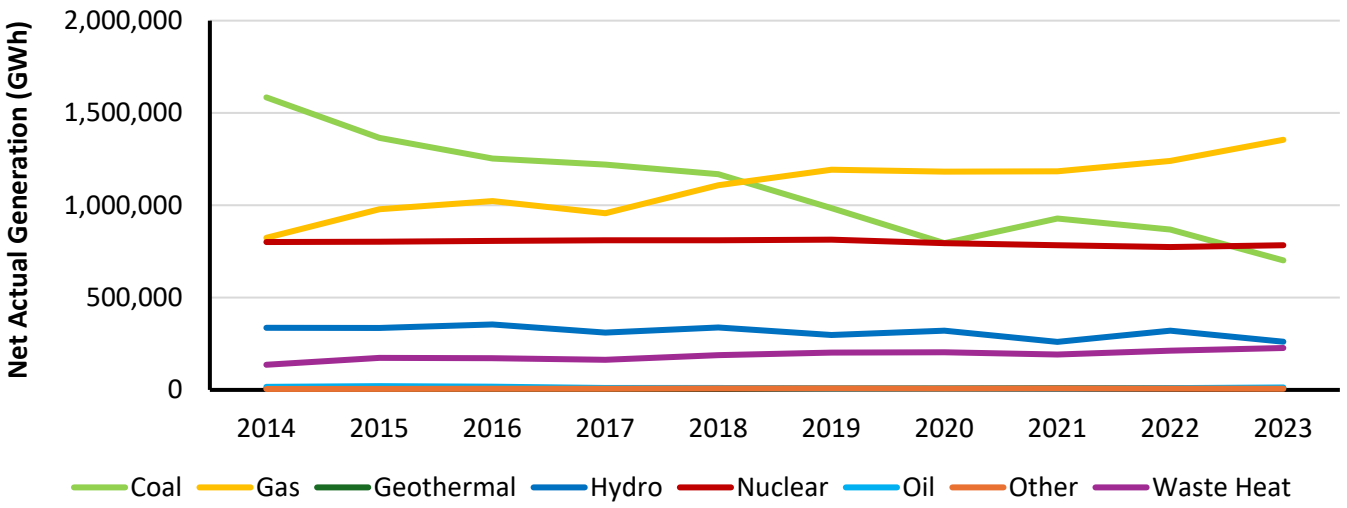


Figure 5: 10-Year Annual Conventional Net Actual Generation (GWh) by Fuel Type

The weighted resource forced-outage rate continues to increase for wind generation, up to 18.9% overall compared to 18.1% in 2022. While not an exact comparison to the WEFOR used to measure performance of conventional generating units, the continued increase is of concern given the growth in wind generation over recent years. New and expanded reporting requirements for conventional and renewable generation went into effect in 2024. This will allow for expanded analysis of the performance of IBRs in future reports and more detailed analysis of conventional generating units.

Resultant Actions

- Decreasing baseload coal generation reliability, in combination with increasing variable resource generation, will necessitate increased reserve margins.
- As the BPS becomes more reliant on energy-constrained and variable resources, traditional capacity-based planning methods and strategies might not identify energy-related risks to reliable system operation. To address these concerns, NERC standards BAL-007-1[6] and BAL-008-1[7] have been prioritized for release in 2024. These standards will require operating entities to assess the risks associated with energy emergencies in the near-term and seasonal time horizons and take appropriate actions.
- The *Long-Term Reliability Assessment* (*LTRA*), *Summer Reliability Assessment*, and *Winter Reliability Assessment*[8] continue to analyze a variety of possible future scenarios and identify preventive measures. In recent years, NERC has enhanced the risk analysis in the summer and winter reliability assessments by incorporating deterministic risk scenarios involving generator forced-outage rates under typical and more extreme conditions. NERC's *LTRA* includes a probabilistic assessment (ProbA) of supply shortfall risk, considering hourly profiles of demand, variable energy resource performance, and generator outages. The ProbA identifies expected amounts of unserved energy and load-loss risk that could otherwise go unaddressed by peak hour reserve margin resource adequacy analysis.
- NERC and industry continue to develop enhanced approaches to assessing resource adequacy as the resource mix evolves. The NERC Reliability and Security Technical Committee (RSTC) created the Energy Reliability Assessment Working Group (ERAWG) to support wide adoption of technically sound approaches to energy assessments by BPS planners and operators. Working group projects and activities are described on the ERAWG page.[9]

[6] BAL-007-1
[7] BAL-008-1
[8] Reliability Assessments
[9] ERAWG

Key Finding 3: Performance of Inverter-Based Resources[10] Continues to Impact the BPS

IBR events continue to challenge BPS reliability, especially since IBR disturbance response is no longer limited to solar facilities. The southwest Utah disturbance in April 2023 and the California battery energy storage disturbances in March and April 2022 indicate this, and an upcoming NERC–Texas RE joint report will identify similar impacts to wind. The unexpected loss of generation and lack of ride-through support from these types of resources create system stability challenges. ERO Enterprise oversight and mitigation of these risks should be highly prioritized as IBRs grow in magnitude and increase as a share of the generation mix, especially in the Texas and Western Interconnections.

A second 2023 event occurred in the same southwest Utah area in September 2023, involving 90% of the same facilities. Software updates that were implemented in coordination with equipment vendors improved system disturbance response, reducing the generation loss by nearly 50% from the April event. This reduction demonstrates that the issues can be (at least partially) addressed through software updates.

Resultant Actions

- Inverter software upgrades to affected facilities in California increased the threshold for dc bus unbalance tripping, faster activation of stronger dc balancing, and low-voltage ride-through mode.
- California Independent System Operator (CAISO) updated the technical requirements of its pro forma large generator interconnection agreement (LGIA), requiring the plant controller to be coordinated with the inverters so that that the plant controller does not restrict inverter reconnection following the clearance of a low-voltage transient.
- NERC issued a Level 2 Alert on Inverter-Based Resource Performance Issues[11] to collect data and provide specific recommendations to industry to reduce the systemic performance issues identified in multiple disturbance reports. The data collection effort included responses from 521 generation facilities and 15 inverter manufacturers, representing over 53,500 MW of solar capacity. The Federal Energy Regulatory Commission (FERC) issued an order in Docket RD22-4,[12] Registration of Inverter-Based Resources. NERC is working with industry to make changes to the Rules of Procedure to specify registration requirements for IBRs.
- FERC Order 901[13] directed NERC to develop new or modified Reliability Standards that address reliability gaps related to IBRs in data sharing, model validation, planning and operational studies, and performance requirements. Multiple IBR-related high-priority standards projects are slated to be completed in 2024, including new IBR performance requirements.
- FERC Order 2023[14] requires interconnection customers requesting to interconnect an asynchronous generating facility to provide the Transmission Provider with the models needed for accurate interconnection studies. Additionally, interconnection customers must maintain power production at pre-disturbance levels as well as dynamic reactive power to support system voltage during transmission system disturbances. The rule also requires that all newly interconnecting large generating facilities provide ride-through capability consistent with any standards and guidelines that are applied to other generating facilities in the BA area.
- Section 1600 data collection to collect GADS performance and event data from IBR wind, solar, and battery energy storage system (BESS) resources begins in 2024. This data will be used to further analyze IBRs and refine performance trends and metrics.

[10] IBRs include solar photovoltaic (PV), Type 3 and Type 4 wind, BESS, and fuel cell.
[11] NERC Level 2 Alert Focused on Inverter-Based Resource Performance Issues for Generator Owners, March 14, 2023.
[12] FERC Docket RD22-4-000 (Docket No. RM22-12-000), Registration of Inverter-Based Resources, November 17, 2022.
[13] FERC Order No. 901, Final Rule Reliability Standards to Address Inverter-Based Resources, October 19, 2023.
[14] FERC Order No. 2023, Improvements to Generator Interconnection Procedures and Agreements, July 28, 2023.

Key Finding 4: Texas Interconnection Reliability Performance Improves While Facing New Challenges

Despite reliability challenges posed by integrating variable generation and new technologies, the Texas Interconnection has demonstrated a high level of improvement to reliability by using BESS to support frequency (Figure 6).15 Additionally, the Texas Interconnection showed statistically significant improvement to its misoperation rate in 2023, compared to the prior four years (see Figure 7).[16] The Texas Interconnection experienced relatively normal generation and transmission outages in comparison to prior years.

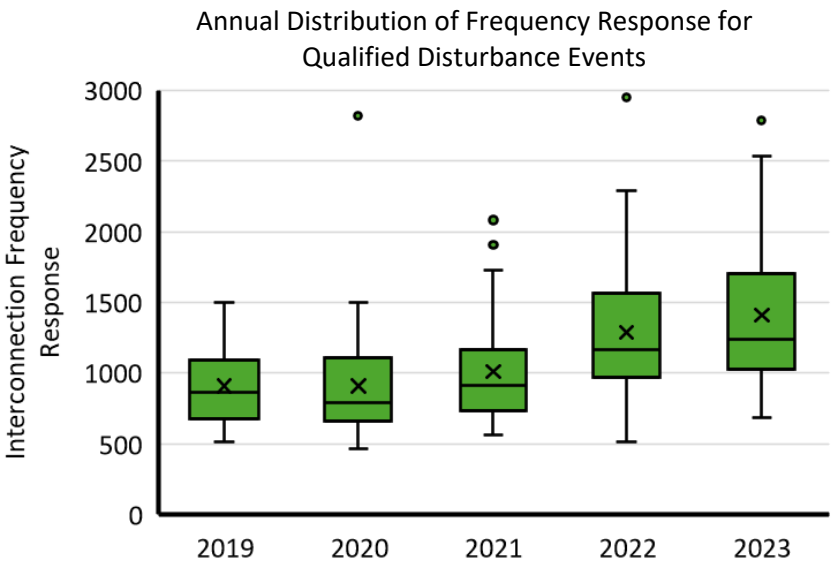


Figure 6: Texas Interconnection Frequency Response (M4) by Operating Year (2019–2023)

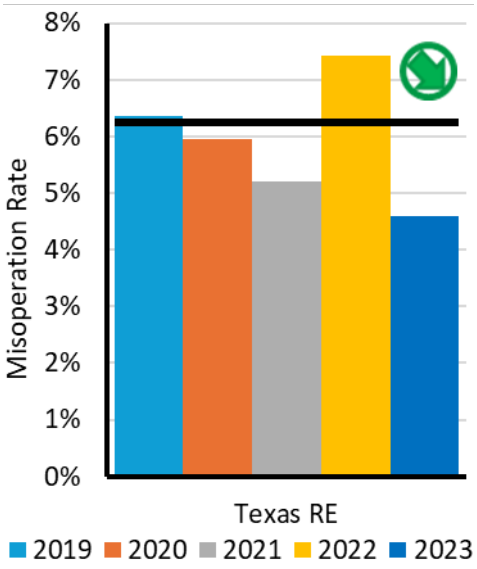


Figure 7: Changes and Trends in the Annual Misoperations Rate

As reported in NERC reliability assessments[17] and the *2023 SOR* report,[18] the Texas Interconnection can no longer meet summer and winter peak demand with only conventional generation and has demonstrated how these challenges can be successfully managed while at the same time encountering new ones. BESS also provided valuable energy and ramping support to help manage the September 6, 2023, energy emergency Level 2 alert that occurred during the rapid down-ramp of solar generation that evening.[19]

Resultant Actions

- Electric Reliability Council of Texas, Inc. (ERCOT) has proposed changes to the ERCOT Nodal Operating Guides to incorporate performance requirements for IBRs. These changes are being reviewed through the ERCOT stakeholder process.

[15] M-4 Interconnection Frequency Response
[16] M-9, Protection System Misoperations Rate
[17] NERC Reliability Assessments
[18] 2023 State of Reliability Report
[19] Electric Reliability Council of Texas filing to the Texas Public Utility Commission on the September 6, 2023, Energy Emergency Level 2 Event.

Acknowledgements

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NERC Industry Group Acknowledgements	
Group	**Officers**
Reliability and Security Technical Committee	Chair: Rich Hydzik, Avista Vice Chair: John Stephens, City Utilities of Springfield
Performance Analysis Subcommittee	RSTC Sponsor: Darryl Lawrence, PA Office of Consumer Advocate Chair: David Penney, Texas RE Vice Chair: Heide Caswell, Oregon Public Utilities Commission
Events Analysis Subcommittee	Chair: Chris Moran, PJM Vice Chair: James Hanson, WECC
Generation Availability Data System User Group	Chair: Danny Small, City Utilities Vice Chair: Ken Sabourin, Sunflower Energy
Electric Gas Working Group	Chair: Mike Knowland, ISO New England, Inc. Vice Chair: Daniel Farmer, Entergy
Misoperations Information Data Analysis System User Group	Chair: Thomas Teafatiller, ReliabilityFirst Vice Chair: Stony Martin, SERC
Transmission Availability Data System User Group	Chair: John Idzior, ReliabilityFirst Vice Chair: Nick DePompei, SERC
Resources Subcommittee	Chair: Greg Park, NWPP RS Vice Chair and NPCC: Bill Henson, ISO-NE
Real-Time Operating Subcommittee	Chair: James Hartmann, Electric Reliability Council of Texas, Inc. Vice Chair: Timothy Beach, California Independent System Operator (RC West)
Reliability Assessment Subcommittee	Chair: Amanda Sargent, WECC Vice Chair: Vacant
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