NERC

2026 State of Reliability

Assessment Overview of 2025 Bulk Power System Performance

June 24, 2026

2026 SOR Snapshot

2026 SOR Technical Assessment

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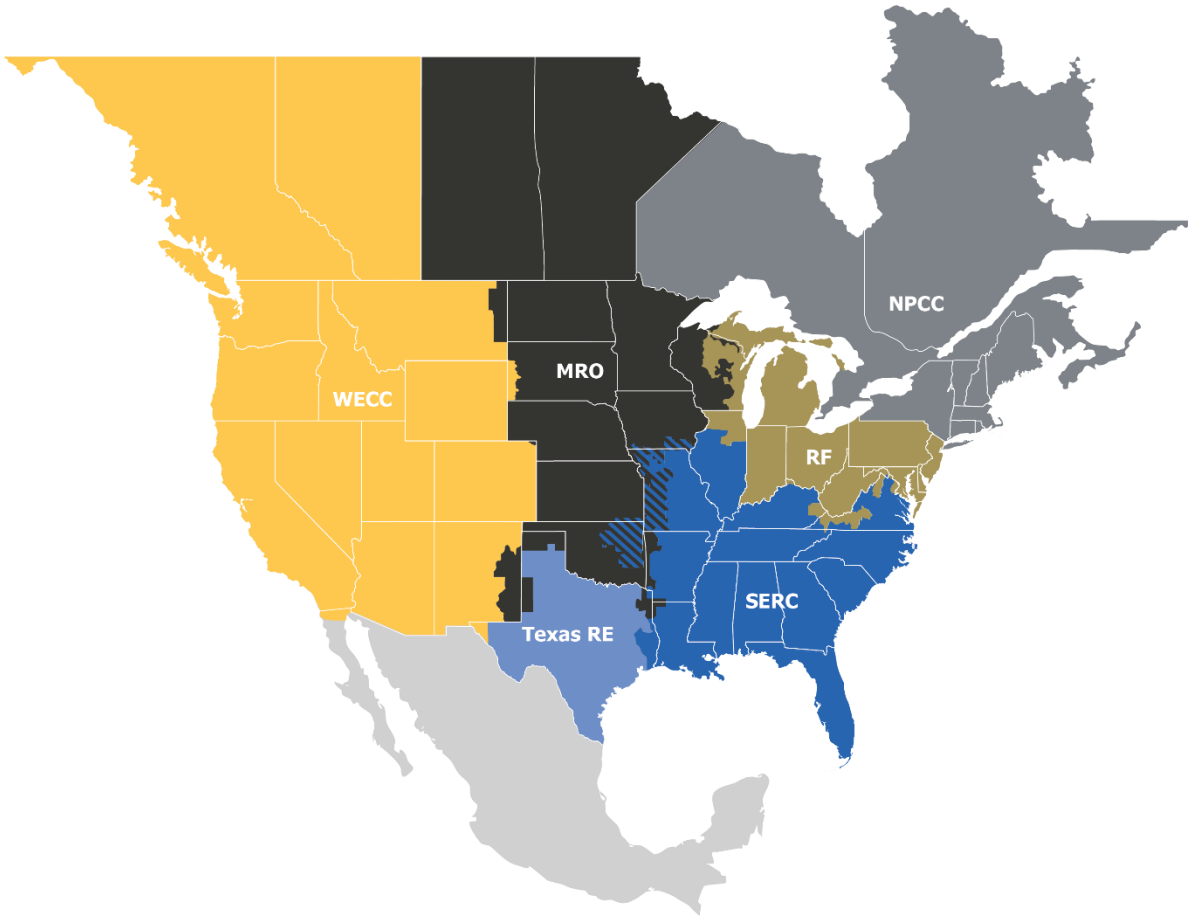
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Preface

Electricity powers our modern life and is the bedrock of our economic wellbeing. The Electric Reliability Organization (ERO) Enterprise—comprised of NERC and the six Regional Entities—is firmly committed to assuring a highly reliable, resilient, and secure bulk power system (BPS) in North America. The ERO Enterprise enables collaborative engagement with industry, regulators, and stakeholders, embracing innovation and supporting the needs of nearly 400 million people.

RELIABILITY | RESILIENCE | SECURITY
POWERING TODAY. PROTECTING TOMORROW.

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/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

NERC delivers the *State of Reliability* (SOR) as a two-part report that consists of the *2026 SOR Overview* and the *2026 SOR Technical Assessment*.[1] The *2026 SOR Overview* serves as a high-level summary of the most important and actionable topics impacting the BPS and how they are being addressed, while the *2026 SOR Technical Assessment* provides NERC's comprehensive annual analytical review of BPS reliability for the 2025 calendar year. The analysis within the SOR report fulfills a key role in NERC's mission by providing an unbiased, data-driven look at the BPS's reliability, identifying ongoing challenges, and informing future-looking assessments. This overview seeks to inform regulators, policymakers, and industry leaders of the most significant reliability risks facing the BPS and describes the actions that the ERO Enterprise has taken, and will take, to address them.

Development Process

ERO staff developed this overview and the corresponding *2026 SOR Technical Assessment* with support from the Performance Analysis Subcommittee (PAS). Both documents draw 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, the Institute of Electrical and Electronics Engineers (IEEE) Distribution Reliability Working Group, and other sources as available.

Considerations

- Data in the SOR represents the performance for the January–December 2025 operating year unless otherwise noted.
- Analysis in this report is based on data from 2021–2025 that was available in Spring 2026 and provides a basis to evaluate 2025 performance relative to performance from the last five years. All dates and times shown are in Coordinated Universal Time (UTC).
- The SOR is a review of industry-wide trends—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] NERC SOR 2026 Technical Assessment

Executive Summary

The North American BPS continues to deliver reliable electric service under increasingly challenging conditions. Key performance indicators remain stable overall even as the system experiences rising demand growth, more frequent extreme weather events, and significantly higher penetrations of inverter-based resources (IBR).

At the same time, the report highlights a critical shift in the nature of reliability risk. Many of the emerging concerns facing the system are no longer driven by single contingencies or localized disturbances but by correlated and system-wide stresses, including energy limitations, operational challenges associated with maintaining reliability in lower-inertia systems, and declining availability of aging combustion generation. Although fuel supply uncertainty and extreme weather exposure were not major drivers in this year's assessment, they remain subject to ongoing monitoring given their continuing potential to affect reliability. The findings emphasize that continued reliability success will depend not only on maintaining infrastructure and resource adequacy but also on improving industry's ability to anticipate, model, and manage these evolving risks before they manifest as reliability events.

While the SOR focuses on historical occurrences in the past year, it is also important to recognize future resource adequacy concerns. NERC's forward-looking *Long-Term Reliability Assessment*[2] and related non-NERC reports[3] continue to highlight that generation development has not and is not expected to keep pace with needs as new projects face delays and cancellations due to supply chain constraints, changing economies, and increasing grid upgrade costs. Similarly, while existing transmission performance continues to improve, its development, particularly of major interstate lines, is not advancing at a pace that can adequately support future reliability needs.

Reliability Indicators

Table 1 provides an overview of key performance measures of the BPS that compares 2025 performance to the previous four years. The results show that while a majority of these measures continue to improve or remain stable, several indicators are identified for monitoring or further attention, highlighting areas that warrant industry focus. The table is intended to contextualize known and emerging trends and areas of operational focus to help stakeholders understand where reliability risks may be evolving or re-emerging as the grid continues to transform.

[2] Long-Term Reliability Assessments
[3] MISO *2026 Reliability Imperative Report*

Table 1: Reliability Indicators[4]			
Improving	**Stable**	**Monitor**	**Actionable**
Frequency Response: Eastern, Texas, and Western Interconnections	**Frequency Response:** Québec Interconnection	**Winter Reserve Margin:** NPCC Maritimes	**Inertia and Rate-of-Change-of-Frequency:** Québec Interconnection[5]
Inertia and Rate-of-Change-of-Frequency: Eastern, Texas, and Western Interconnections	**Protection System Misoperations Rate**	**Transmission-Related Events Resulting in Loss of Load:** Supported by Event Analysis Data	
Energy Emergency Alerts	**Transmission Outages Caused by Failed Protection System Equipment:** AC Circuits	**Interconnection Reliability Operating Limit (IROL) Exceedance**	
Transmission Outages Caused by Failed Protection System Equipment: Transformers	**Automatic AC Transmission Outages Caused by Failed AC Substation Equipment:** AC Circuits	**Transmission Outages Caused by Failed AC Substation Equipment:** Transformers	
Automatic Transmission Outage Events Involving Human Error: AC Circuits and Transformers	**Transmission Element Availability:** AC Circuits	**Transmission Element Availability:** Transformers	
Transmission Outages Caused by Failed AC Circuit Equipment	**Transmission Outage Severity**		
	Transmission Physical Security Metric		

Emerging Trends

While the BPS remains reliable and continues to perform well operationally, underlying reliability risk is increasing and changing in nature; the margin for error continues to decrease while dependence on operational mitigations increases.

NERC's analysis in the SOR report also identifies several important emerging trends:

1. **Conventional generation forced outage rates are up.**
   The report identifies a meaningful increase in conventional generator forced outage rates in 2025, with annual weighted equivalent forced outage rates (WEFOR) increasing to 9.2% compared to historical norms rarely exceeding 8%. Coal and combined-cycle units were the primary drivers of this increase with an increase of over 39.8 TWh and 19.1 TWh of unavailable energy year over year, respectively. In contrast to recent years' generation challenges, operational performance during the

[4] Some metrics are evaluated for multiple sub-topics. These metrics are either listed multiple times, with the different sub-topics beneath the bolded metric name (e.g. different interconnections for Frequency Response), or the criteria driving the overall status is listed (e.g. NPCC Maritimes causing Winter Reserve Margin to have the Monitor status).

[5] The Québec Interconnection has been experiencing low hydraulicity conditions since 2023. In 2025, this resulted in reduced energy exports and increased energy imports. Therefore, fewer hydro generating units were synchronized within the Interconnection, particularly under summer light-load conditions, leading to lower system inertia during this period. These conditions have been cyclical historically and are expected to improve in the coming years.

most challenging winter week of 2025[6] improved as industry winterization efforts continued. Instead, the reduction in availability was distributed throughout the year, suggesting a broader baseline degradation in much of the coal and combined-cycle fleets' performance.

2. **Demand growth and large load integration continue challenging operators.**
   Projected annual energy demand rose to nearly 4.95 million GWh in 2025, while actual summer peak demand in several areas approached or exceeded the normal forecast. Data center and computational loads continued emerging as a major reliability consideration due to their scale, speed of development, and unique operational characteristics. In 2025, two instances of data center customer-initiated load reduction (CILR) exceeded 1,000 MWs, with many more exceeding 100 MWs. NERC continued to work with the electric and data center industries to issue new alerts, host technical conferences, perform standards work, and offer large load guidance activities, reflecting the growing importance of load modeling, operational coordination, and frequency response impacts associated with these rapidly growing loads.

3. **Resource mix transformation is fundamentally changing system operations and reliability management.**
   Solar, wind, and battery energy storage systems (BESS), all IBRs, continued to expand rapidly in 2025, with BESS growth approximately matching solar growth. In several peak demand periods, solar and/or wind production materially exceeded planning assumptions and supported system operations during stressed conditions. Additionally, BESS continued to demonstrate the capability to provide rapid frequency response. At the same time, IBRs are increasing operational complexity associated with inertia, protection systems, dynamic performance, and disturbance response. NERC continued extensive IBR mitigation work in 2025 and early 2026, including new technical requirements related to IBR performance, ride-through capability, and model validation.

4. **Industry mitigation actions are tracking well in many foundational reliability areas.**
   The *2026 SOR Technical Assessment* also documents continued improvement in several important controllable reliability metrics, including overall transmission system outage severity, protection system misoperations, failed protection-system-related outages, and transmission-related loss-of-load events.

[6] Comparisons across winter storm events should be interpreted with caution, as outage risk remains elevated and storm impacts vary significantly by the area impacted, duration, system condition, and event severity.

Conventional Generation Forced Outage Rates Up

Forced outage performance is a foundational indicator of BPS reliability because it illustrates the ability of generating resources to perform daily as well as when they are most needed, during periods of high demand, stressed system conditions, and extreme weather. While reserve margins and accredited capacity metrics provide a static view of resource sufficiency, an analysis of year-over-year forced outage rate changes provides insights into the availability of the conventional resource fleet, revealing trends in outage behavior and emerging reliability vulnerabilities.

Analysis of 2025 Weighted Equivalent Forced Outage Rate

Our 2025 analysis of the conventional GADS[7] revealed an increase in reported units' annual WEFOR[8] to 9.2%, which is higher than the historical norms of 7–8% (see **Figure 2**). This increase was not the result of any particular event but an increase distributed across most months throughout the year, with three months' WEFORs being comparable to the months when winter storms Elliott and Uri occurred. The lack of specific major events is indicative of a more subtle baseline increase in conventional forced outage rates. This, combined with tightening reserve margins[9] in some areas that have continued into 2025 from prior years—as well as performance improvements during the most challenging winter week of the year (January 19–25), highlighted by NERC, the Federal Energy Regulatory Commission (FERC), and industry—emphasizes the overall operational improvements while underscoring the increasingly precarious position of the BPS. As WEFOR increases, planning reserve margins may also increase at a higher rate to accommodate the associated uncertainty[10] (see **Figure 1**).[11]

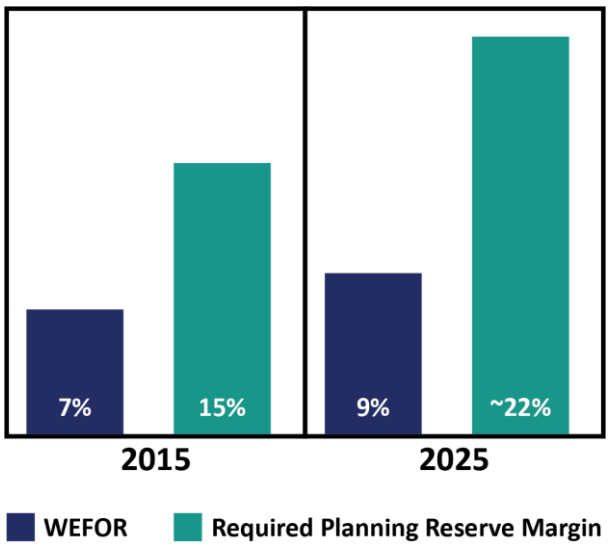


Figure 1: Conceptual Example of Forced Outage Rates Impacting Reserves

[7] GADS reporting is mandatory for units with a capacity >20 MW owned by NERC-registered Generator Owners (GO) per Section 1600 of NERC's Rules of Procedure. The conventional data set is separate from wind, solar, and hybrid energy storage data collection. Standalone energy storage is not currently collected by NERC under a Section 1600 data request.

[8] GADS Data Reporting Instructions - Appendix F Equations - WEFOR is an equation used throughout the electric industry to assess generator reliability by looking at how much units' time and generating capacity is reduced due to forced outages and derates relative to the amount of time they could be generating, weighting that value by each units' net maximum capacity.

[9] Reserve margins refer to the amount of excess generation an area is required to have available as a contingency for major system events to reduce the likelihood of cascading blackouts and load shedding. They are also key to NERC's Reliability Assessments' ability to forecast adequate generation.

[10] Many factors impact reserve margin calculations and vary from season to season throughout the year. Higher impact drivers include forced outage rates, planned maintenance rates, load forecasts, extreme weather outage adders, resource fleet composition, variable energy performance, and resource age.

[11] Figure is for demonstrative purposes. Proportions are not perfectly representative to actual value relations.

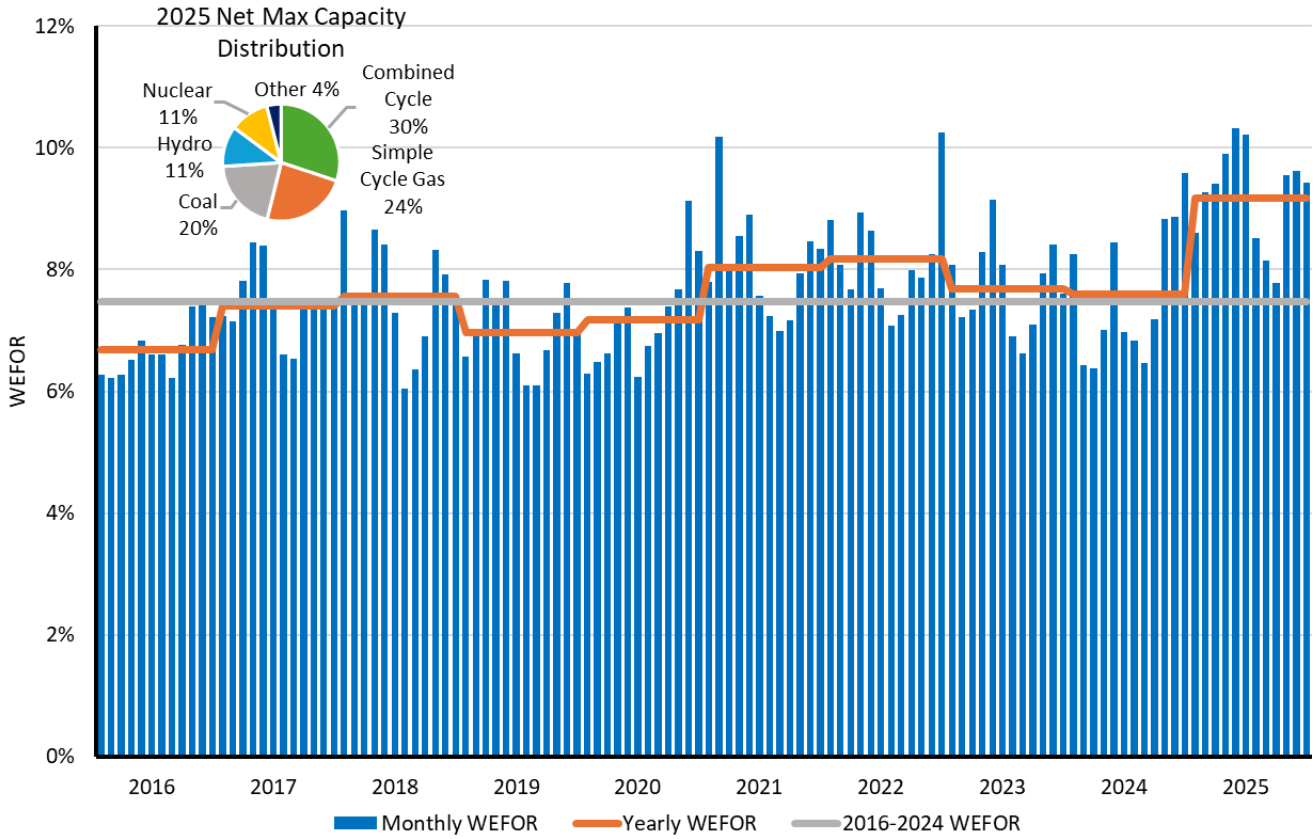


Figure 2: Monthly, Annual, and Five-Year WEFOR

Further analysis (see **Table 2**) identified that the increase in unavailability was primarily driven by a variety of combustion-based generators. The largest year-over-year increases in TWh of unavailability were observed in coal (39.8 TWh increase from 2024 to 2025) and combined-cycle units (19.1 TWh increase from 2024 to 2025). Combining this information with each type of unit's installed net maximum capacity and WEFOR identifies coal-fueled generators as being of more concern than others.

Table 2: 2024 vs. 2025 Year-Over-Year Forced Unavailability Comparison

Primary Fuel Type	Change in GWh[12]	2024 WEFOR	2025 WEFOR
Gas - Steam Turbine	8,772	19.2%	22.4%
Gas - Simple Cycle Combustion Turbine	5,938	20.7%	22.8%
Gas - Simple Cycle w/Heat Recovery Steam Generator (HRSG)	-203	7.7%	7.0%
Combined Cycle	19,154	4.2%	5.7%
Coal	39,835	11.2%	14.1%
Oil - Steam Turbine	1,857	24.6%	25.6%
Oil - Combustion Turbine	2,427	48.2%	69.4%
Hydro	-3,171	8.4%	7.7%
Nuclear	-3,862	2.7%	2.2%
Other	-2,308	11.1%	8.4%
Total/Overall	68,440	7.6%	9.2%

[12] Measured by WEFOR numerator:
$\sum(([Forced\ Outage\ Hours] + [Equivalent\ Forced\ Derate\ Hours]) * [Net\ Maximum\ Capacity])$

To identify possible commonalities, the owners of 41 generators that had a year-over-year increase of at least 1 TWh[13] of unavailability were asked to voluntarily provide additional context to their 2025 GADS data by NERC and the Regional Entities. Of those contacted, responses for 26 generators were provided, which identified several key insights to drive further investigation:

- Sixteen of the units experienced equipment destruction extensive enough to significantly prolong their 2025 outage(s).
- Eight of the units indicated that supply chain constraints significantly prolonged their 2025 outage(s).
  - Constraints were all indicated as occurring at the manufacturer; however, constraints may have occurred deeper into the supply chain unknown to the Generator Owner (GO).
  - Constraints identified included being unable to obtain materials for the repairs, challenges locating part specifications, inexperienced project management, and lack of staff to perform the work.
- Six of the units indicated complete or partial turbine blade release or vibration, which, upon further inspection, would have likely resulted in eventual release.
- Multiple units[14] leveraged the forced outage downtime to perform additional maintenance and inspections. Some indicated that these actions also extended the duration of the outage(s) but resulted in future benefits by either functionally moving up scheduled outages or identifying opportunities to prevent future outages.

After entity responses were evaluated, cause code components were also evaluated by an approximated MWh of forced capacity reduction since 2016. The largest groups were then trended to identify which ones had the largest and/or most consistent increases, with the following component groups being identified:

- **Catastrophe:** Increases over prior year in 2017, 2020, and 2024
  - Largely driven by an increase in use in 2020 because of COVID-19. NERC directed reporters to utilize this code for outages relating to the pandemic at that time prior to the addition of a more appropriate cause code.
  - 2017 and 2024 increases were higher than usual but would not have warranted inclusion on their own.
- **Turbines (High, Intermediate, and Low Pressure):** Increases over prior year in 2017, 2020, 2023, and 2025
  - All three individual turbine component groups were independently identified and represent the largest, most consistently increasing group if combined.
- **Regulatory:** Increases over prior year in 2017, 2018, 2019, 2022, 2023, and 2025
  - Most consistently increasing component group.
  - Initial analysis did not indicate any alignment with a particular policy objective, with both decreases and increases throughout various governmental phases.

[13] Year-over-year variation in MWhs of unavailable generation was used intentionally used in lieu of WEFOR or a single year's MWhs of unavailable generation. This was to focus on units that experienced issues starting in or shortly before 2025 and were most impactful to the overall annual WEFOR. A cutoff was applied to limit overall industry burden and receive a processable amount of input given the timeframe while also being a large enough group to identify common issues. The exact 1 TWh amount provided a clean cut point with a sufficient population but was ultimately arbitrary.

[14] Because this specific information was not directly requested and this is a common industry practice, an exact number of units is not available.

- **Safety:** Increases over prior year in 2018, 2020, 2022, and 2025
- **Nox Reduction Systems:** Increases over prior year in 2017, 2018, 2022, and 2025
- **Boiler Fuel Supply to Bunker:** Increases over prior year in 2017, 2020, 2022, 2024, and 2025

Further data analysis of these component groups and investigation into the underlying cause codes and submitted verbal descriptions are necessary.

The results of this analysis align with, but do not prove, industry assertions concerning coal and combined-cycle units. Most large coal units are over 40 years old and are expected to be retired in the relatively near future. These large coal and combined-cycle units were not designed for regular cycling, which has become an operational requirement in some areas and a necessity to maintain economic viability in others. These factors compound to increase the likelihood of failure over time and act to reduce the incentive to prioritize expensive restoration. Recent Federal Power Act section 202(c) emergency energy orders requested through the Department of Energy (DOE) have also received mixed reception among GOs. These mandates do improve system capacity, but that capacity may not be from reliable units.

Related Actions

Recommendations

- NERC will pursue further analysis and collaborate with the GADS user group (GADSUG) to better understand the causes driving this increase in WEFOR.
- NERC will work with industry to develop specific, measurable reliability indicators for generation performance.
- NERC and the relevant stakeholders should consider adjusting or at least be prepared to adjust reserve requirements to account for lower conventional generation availability.
- GOs should consider bolstering turbine inspection procedures at required intervals. GOs should also consider performing these inspections more frequently or when other major maintenance/outages provide the opportunity.
- Regulators should consider implementing alternative operating requirements during energy emergencies to ensure that regulations do not hinder BPS reliability during critical periods.
- GOs should ensure that manufacturers have capability and plan to replace major components in the event of failure.
- Manufacturers should consider immediately increasing the number of trained technical maintenance personnel to bolster expertise due to the increasing frequency of outages involving major equipment failure and the lack of adequate or sufficiently experienced staff, which was cited multiple times.
- Manufacturers should verify material procurement and processing capabilities.

Demand Growth and Large Load Integration Challenges Continue

Recent events involving data centers and cryptocurrency mining facilities continue to demonstrate the importance of improving industry's understanding of these loads' characteristics and risks as well as the considerations and mitigations needed to reliably integrate them into the BPS.

In a February 2025 event in the Eastern Interconnection, 1,800 MW of data center CILR occurred due to a transmission fault. An additional Eastern Interconnection event in February 2025 resulted in 428 MW of data center CILR. Similar Eastern Interconnection events were observed in March 2025 (227 MW of data center CILR), May 2025 (540 MW of data center CILR), and June 2025 (1,300 MW of data center CILR). ERCOT continues to experience cryptocurrency mining facility CILR events with nine events occurring in 2025 in which at least 100 MW of CILR occurred from computational load facilities.[15] **Figure 3** provides a summary of the Eastern Interconnection and ERCOT data center and cryptocurrency mining facility events.

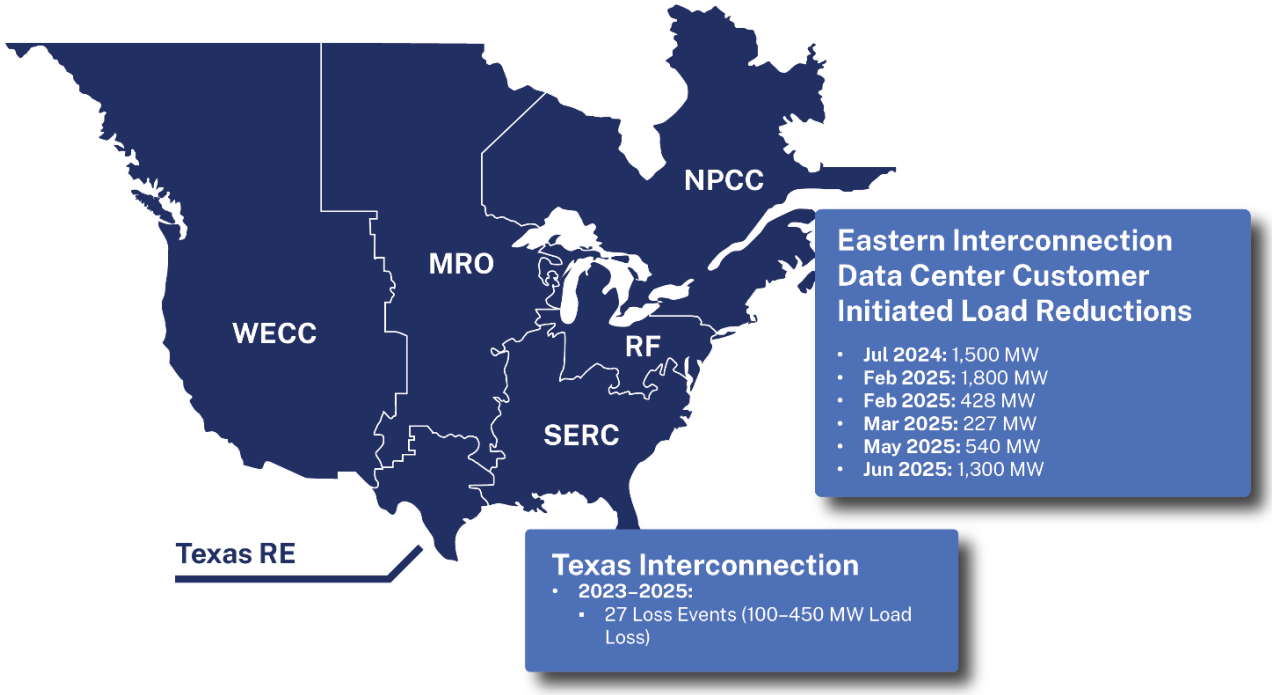


Figure 3: Customer-Initiated Load Reduction Events

Figure 4 provides a breakdown of the large CILRs tracked in ERCOT since 2023. Compared to 2023, the number of events in 2024 and 2025 increased, without indicating improvement. Most events were large computational load events; however, several non-computational load events did occur.

[15] See the Incident Review: Considering Voltage-Sensitive Crypto Load Reductions for an analysis of cryptocurrency mining facility ride-through events in ERCOT.

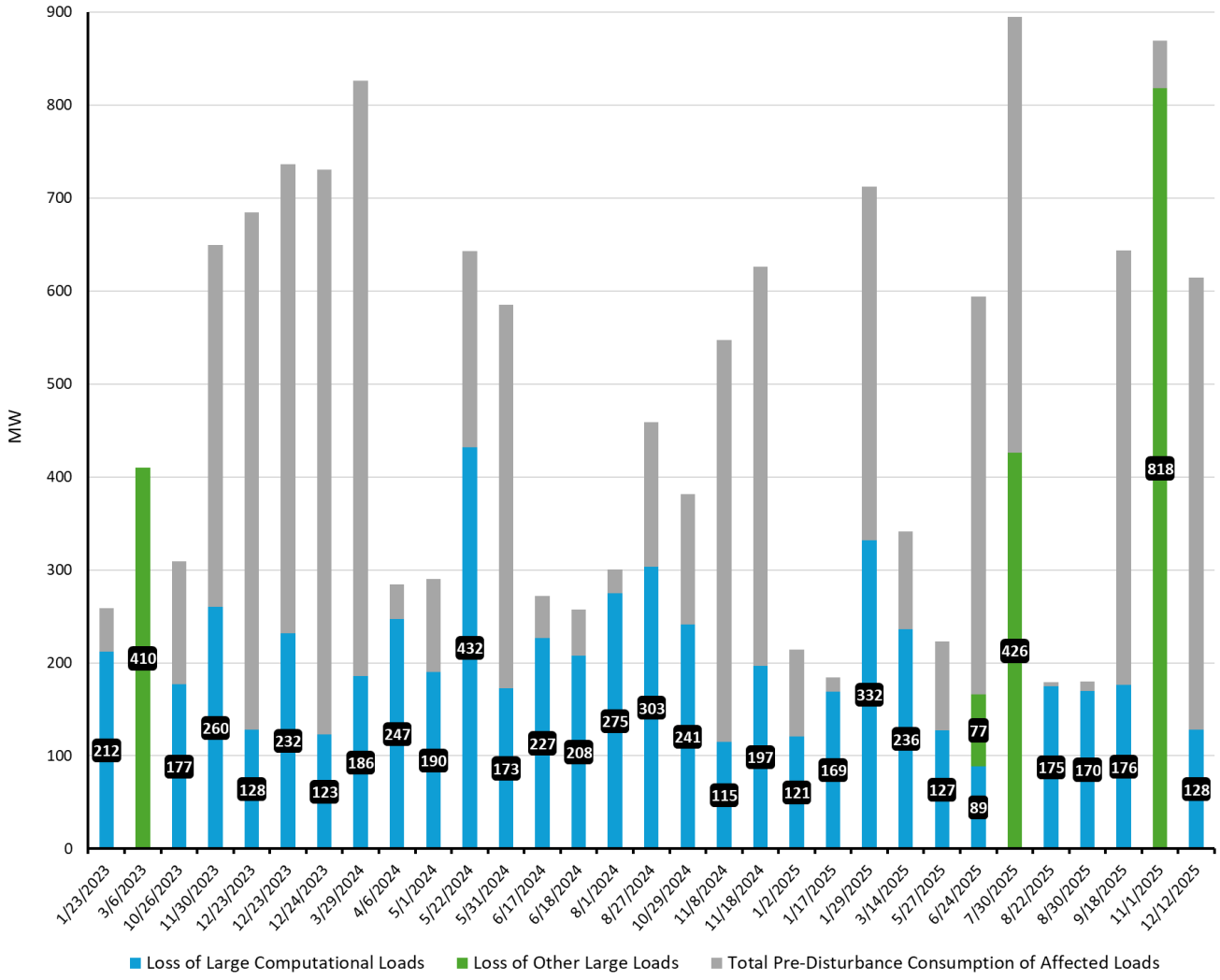


Figure 4: ERCOT Large Load Ride-Through Events

These events demonstrate that the reliability challenges from large loads will increase as these facilities become more prevalent on the grid. As the size of individual large load facilities increases and if large load facilities are located near one another, the sizes of these large load events will likely increase. This could lead to measurable frequency or voltage stability issues. It remains important for grid planners and operators to understand and study the expected performance of the large load facilities during grid disturbances. For the reliability risks to be studied and addressed, load models and study practices that reflect the behavior of the large loads and the risks to the BPS are essential. Continued collaboration between large load facility owners and operators as well as grid planners and operators is essential to ensure the reliable operation of the BPS.

Related Actions

Existing and Ongoing Efforts

- NERC developed a Large Loads Action Plan to address the BPS risks related to emerging large loads.[16]
- The Large Loads Working Group (LLWG) continues to provide technical guidance, industry collaboration, and reliability risk assessment and monitoring for the increasing integration of large loads. The LLWG has published the following white papers and reliability guideline:

[16] Large Loads Action Plan

- A white paper discussing the characteristics of emerging large loads and the risks they pose to the BPS[17]
- A white paper discussing the gaps in NERC Reliability Standards and industry practices related to emerging large loads[18]
- A reliability guideline providing industry with the best practices for mitigating BPS risks related to emerging large loads[19]

- The Load Modeling Working Group (LMWG) continues to address gaps in modeling the dynamic characteristics of the emerging large loads. The LMWG's activities include the following:
  - Developed a technical reference guide for industry on modeling data centers for transient stability studies
  - Endorsed and continues to improve a performance model called Power Electronic Reconnecting and Ceasing (PERC1) for modeling data centers in 2025
  - Continues to educate industry with workshops and by developing tools to help industry develop useful data center models, such as a data center questionnaire[20]
- NERC issued a Level 2 Industry Recommendation Alert to address risks related to large loads.[21]
- Additionally, NERC issued a Level 3 Essential Actions Alert providing specific actions deemed essential to address BPS risks posed by computational large loads,[22] including the following:
  - Transmission Planners and Planning Coordinators developing requirements for computational load modeling data, settings, and parameters
  - Transmission Planners and Planning Coordinators focusing on computational load impacts in system studies
  - Planning Coordinators updating their qualified change definition to reflect the changes that can occur to computational loads
  - Transmission Operators establishing a commissioning process that ensures operational readiness for the integration of large loads
  - Transmission Planners and Planning Coordinators implementing actions to ensure that non-consequential loss of firm computational load does not occur for typically cleared faults
  - Transmission Owners taking actions to capture and share fault recording data for computational load facilities
  - Transmission Operators, Reliability Coordinators, and Balancing Authorities establishing interpersonal communication capabilities and joint operating procedures with computational loads as well as issuing operating instructions to prevent Bulk Electric System (BES) emergencies
- NERC hosted a technical conference focused on the BPS risks posed by emerging large loads and the mitigations needed to integrate emerging large loads into the BPS.[23]

[17] Characteristics and Risks of Emerging Large Loads
[18] NERC LLWG White Paper - Assessment of Gaps
[19] Risk Mitigation for Emerging Large Loads
[20] Data Center Information Collection Questionnaire
[21] Large Load Interconnection, Study, Commissioning, and Operations
[22] Level 3 Computational Load Alert
[23] 02-24-26 Emerging Large Loads Technical Conference

- NERC posted draft updates to the NERC Rules of Procedure for establishing a new registered entity for computational load entities. Additionally, the NERC Standards Committee has launched a standards project to develop Reliability Standards that address the risks posed by computational loads.
- The frequency response metric will continue to be monitored to measure the response to frequency events during large load tripping events.

Recommendations

- The following recommendations are discussed in the LLWG white papers:[24]
  - Registered entities should coordinate with large load entities to address the risks posed by emerging large loads.
  - Relevant NERC Reliability and Security Technical Committee (RSTC) subgroups (including the LLWG, the LMWG, the Security Working Group, and the System Protection and Control Working Group) should continue to assess and address the risks posed by emerging large loads.
  - Regulators should work with utilities to address the risks posed by emerging large loads.
  - Policymakers should review interactions between interconnection requirements, existing state regulations and planning processes, and regional grid operator requirements. Additionally, policymakers should review requirements for large load customers to provide operational data and information to Transmission Owners (TO), Transmission Operators (TOP), Transmission Planners (TP), and other entities.
- NERC registered entities should implement the recommendations provided in the Level 2 Industry Recommendation Alert and the Level 3 Essential Actions Alert.[25]
- NERC will continue incident analysis and lessons learned and share findings with industry.
  - NERC will consider the necessity of mandatory data collection requirements.
- Communication and coordination with the Electric Power Research Institution (EPRI), the Energy Systems Integration Group (ESIG), large load industry groups, and the electric industry at large should be continued.

[24] Characteristics and Risks of Emerging Large Loads, NERC LLWG White Paper - Assessment of Gaps
[25] Large Load Interconnection, Study, Commissioning, and Operations, Level 3 Computational Load Alert

Resource Mix Transformation

The BPS and BES continue to experience a rapid resource mix transformation as conventional generation retirements continue to be replaced primarily by natural gas and increasing IBR penetration. This reduction in conventional resource diversity and increased reliance on variable energy resources continued to pose risks and challenge grid operations in 2025. Additionally, the magnitude of BESS helping to smooth solar generation coming on-line in the morning and going off-line in the evening has increased, with installed capacity roughly matching solar additions last year.

IBR Reliability Considerations

As detailed in NERC's *2025 SOR Overview*,[26] IBR reliability risks remain a priority as these resources continue to grow across the BPS. The primary concern is that some IBRs have unexpectedly reduced or ceased output in response to normally occurring grid disturbances, including generator faults, then rapidly resume output within minutes. These events are driven by a combination of ride-through performance limitations, inverter and plant-level controls, protection systems, and modeling quality deficiencies. Following several major IBR-driven disturbances since 2017, NERC has pursued numerous activities to mitigate related reliability concerns.[27] The *2025 SOR* identified continued unexpected IBR output reductions following normally occurring system disturbances with four events four events exceeding 500 MW reported in 2024 and 16 such events reported since 2020.

Available operational data in 2025 suggests improvements in several key areas. Industry participation in model validation and disturbance review activities increased substantially following implementation of the alert recommendations. While no major widespread disturbance events associated with previously observed common-mode IBR tripping mechanisms were identified during the assessment period, there was a loss of 1,132 MW due to sub-synchronous oscillation protection tripping generation off, a failure mode previously unobserved at this scale. Additionally, rapidly increasing IBR penetration continues to increase operational complexity, particularly in regions experiencing reduced inertia, high renewable penetration during light-load conditions, or rapidly changing power flow conditions. Throughout 2025 and the first half of 2026, several additional major efforts have been undertaken and/or completed as highlighted below.

IBR-Related Actions

Existing and Ongoing Efforts

Level 3 Alert[28]

NERC issued *Level 3 Alert: Essential Actions for Inverter-Based Resource (IBR) Performance and Modeling* to TOs, TPs, Planning Coordinators (PC), and currently registered GOs to enhance technical minimum requirements, study processes, and improve modeling to mitigate risks posed by IBR performance during system disturbances.

- **Essential Action #1**: Each TO and TP, in coordination with their PC, should enhance the existing criteria and policies in their generator interconnection and planning activities, respectively, with additional technical details and IBR-specific performance criteria. These performance-based factors help ensure uniform IBR performance both in normal and post-disturbance operations and include reactive power control, frequency response control, ride-through behavior and post-disturbance performance, and full use of reactive power capability.

[26] 2025 NERC State of Reliability - Overview
[27] Quick Reference Guide: Inverter-Based Resource Activities
[28] NERC Level 3 Alert: Essential Actions for Inverter-Based Resource (IBR) Performance and Modeling

- **Essential Action #2**: Each TP and PC should enhance their modeling and study practices to ensure that sufficient study work and model quality verification are performed and documented to reflect models that are representative of installed, or to-be installed, equipment by establishing model quality and accuracy criteria as well as model performance tests and conformity criteria and by enhancing existing criteria used throughout the generator interconnection.
- **Essential Action #3**: TOs, TPs, or PCs should perform a detailed review of currently operating IBRs on their systems to understand the extent of condition of both real-world performance and accuracy of their models.
- **Essential Action #4**: Each GO should create and implement processes to help ensure that the models used for the evaluation of their design and submitted to TPs and PCs for use in generator interconnection and planning processes are accurate and high-fidelity representations of their IBRs.

To follow up on the Level 3 Alert, the ERO has developed an outreach strategy for 2026 to gather information about why entities are not adopting essential actions or are reporting substandard performance expectations and to address legitimate challenges through clarification of essential actions or, where appropriate, through regulatory processes.

New Standards

Significant reliability gaps associated with modeling are addressed by the updated MOD standards finalized in 2025: MOD-026-2,[29] MOD-032-2,[30] and MOD-033-2.[31] Model validation and verification requirements in MOD-026-2 improve model accuracy and documentation. Enhancements in MOD-032-2 help ensure that validated and verified models are collected and used for both local reliability studies and Interconnection-wide case creation. Improvements in MOD-033-2 allow PCs to assess individual generator performance against their model behaviors as part of system model validation efforts and to remedy discrepancies through MOD-032-2 processes.

Inverter-Based Resource Subcommittee and Electromagnetic Transient Modeling Working Group

The Inverter-Based Resource Subcommittee (IRPS) and Electromagnetic Transient Modeling Working Group (EMTWG) continue to develop reliability guidelines and white papers to share best practices among industry to further reduce IBR risks associated with modeling, studies, commissioning, and testing. Many of these risks can be traced back to poor commissioning and testing of IBRs before they enter commercial operation. These gaps are addressed in the *Draft Reliability Guideline: IBR Commissioning Best Practices*[32] and an upcoming white paper, *IBR Equipment EMT Model Validation*, which aims to provide model validation acceptance criteria, thereby complementing model validation requirements in MOD-026-2 and closing risks posed by inaccurate models.

Category 2 Generator Owner Registration[33]

On May 18, 2023, FERC issued an order approving the NERC Work Plan filed on February 15, 2023, as amended on March 13, 2023, to address registration of IBRs that are connected to the BPS but not within NERC's definition of the BES (referred to hereafter as "Category 2 GO/GOP"). The ERO Enterprise has identified and communicated with 531 IBR facilities that meet the Category 2 GO/Generator Operator (GOP) registry criteria across all the Regional Entities and are, or planned to be, interconnected as of May 15, 2026.

[29] MOD-026-2
[30] MOD-032-2
[31] MOD-033-3 – Further revisions have been implemented in 2026.
[32] Draft Reliability Guideline: Commissioning Best Practices
[33] NERC Files IBR Registration Update, Marking Milestone for Grid Reliability

Beginning on May 15, 2026, entities with identified IBR facilities that meet the Category 2 GO/GOP registry criteria were registered and are now subject to compliance with applicable Reliability Standards, as required by the IBR Order. As part of the Inverter-Based Resource Registration Initiative, NERC staff developed a document identifying the finalized and pending compliance dates for the applicability and enforceability of Reliability Standards applicable to Category 2 GO and GOP registrations. As of May 15, 2026, entities registered as Category 2 GOs or Category 2 GOPs are required to comply with, as applicable, BAL-001-TRE, IRO-010-5, MOD-032-2, PRC-012-2, PRC-017-1, TOP-003-6.1, VAR-001-5, and VAR-002-4.1.

Additional technical conferences will be pursued to assist in identifying which Reliability Standards must be revised to establish applicability to Category 2 IBRs and in which order and grouping they should be developed.

The ERO Enterprise is integrating the new Category 2 GO and GOP registrants into relevant ERO Enterprise efforts, including Compliance Monitoring and Enforcement Program activities related to Reliability Standards applicable to those entities. The ERO Enterprise will continue to identify and register additional entities that meet the Category 2 GO and GOP registry criteria as additional IBR facilities are developed and connected to the BPS.

The completion of the NERC Work Plan represents the conclusion of a substantial three-year ERO Enterprise effort to address the risk to BPS reliability posed by unregistered IBR facilities.

BESS Reliability Considerations

As the BES resource mix continues to rapidly evolve, BESS penetration has rapidly increased over the past several years (see **Figure 5**) to approximately match solar growth in 2025. This growth is projected to continue, requiring observation and analysis of this resource's capabilities.

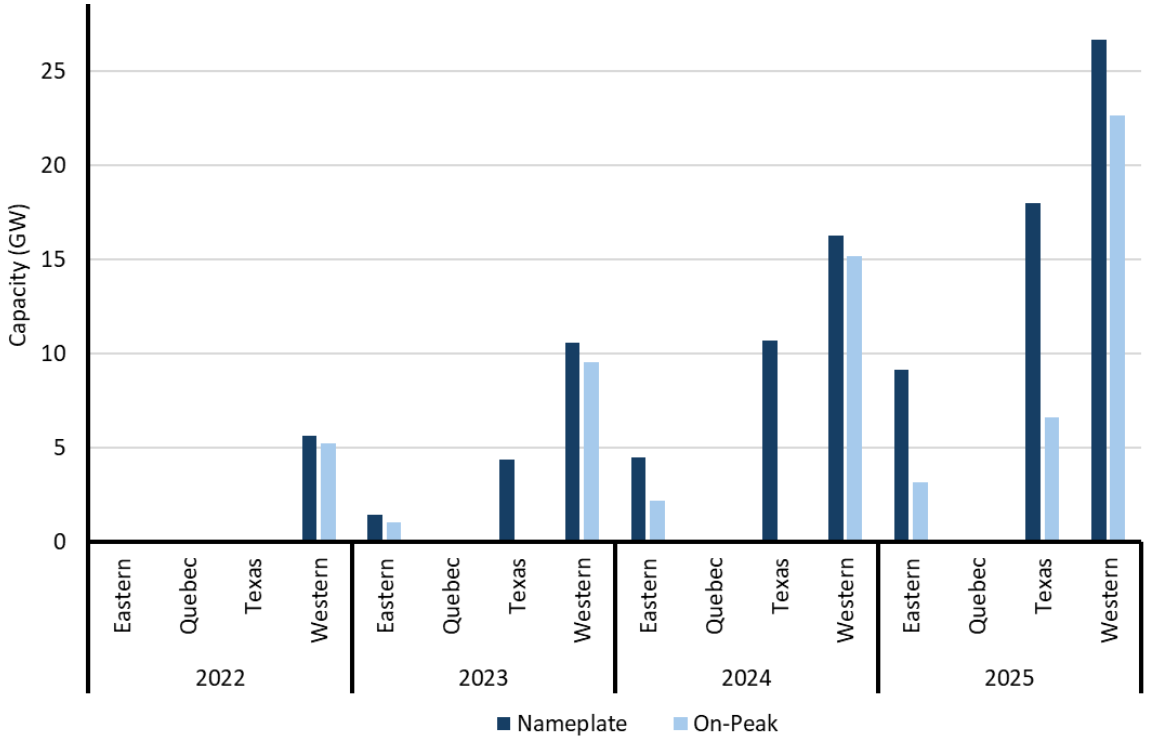


Figure 5: 2022–2025 Battery and Hybrid Capacity by Interconnection

Unique Failure Event

In January 2025, a 300 MW BESS facility experienced thermal runaway during routine testing that ultimately resulted in the functional destruction of a previous-generation warehouse-style facility.[34] While outages internal to the plant regularly occur with other generation resources of similar or greater capacities, the permanent, unplanned loss of a non-BESS facility is exceedingly rare. As such, this type of failure represents a risk consideration unique to BESS that needs to be taken into consideration as the resource continues to expand. Improvements to BESS reliability, thermal runaway mitigation, failure isolation, fire suppression, and updates to fire codes have all acted to significantly reduce the likelihood of these events occurring. NERC will continue to monitor these failure events, but they do not represent a significant concern to overall system reliability at this time.

Load Curve Smoothing

BESS is typically installed to take advantage of price differences between high-generation/low-load and low-generation/high-load conditions. As a result, it provides a smoothing effect that functionally reduces expected and unexpected variability from increasingly prevalent wind and solar generation (see **Figure 6**).

As a result, conventional generators have more time to come off-line and on-line during the most strenuous portions of the day in areas most impacted by as the period when solar resources are going off-line just before peak load conditions in the evening. Because many older, larger conventional generators were not designed to cycle on- and off-line daily, increasing the ramp period can reduce wear and tear, improving their reliability.

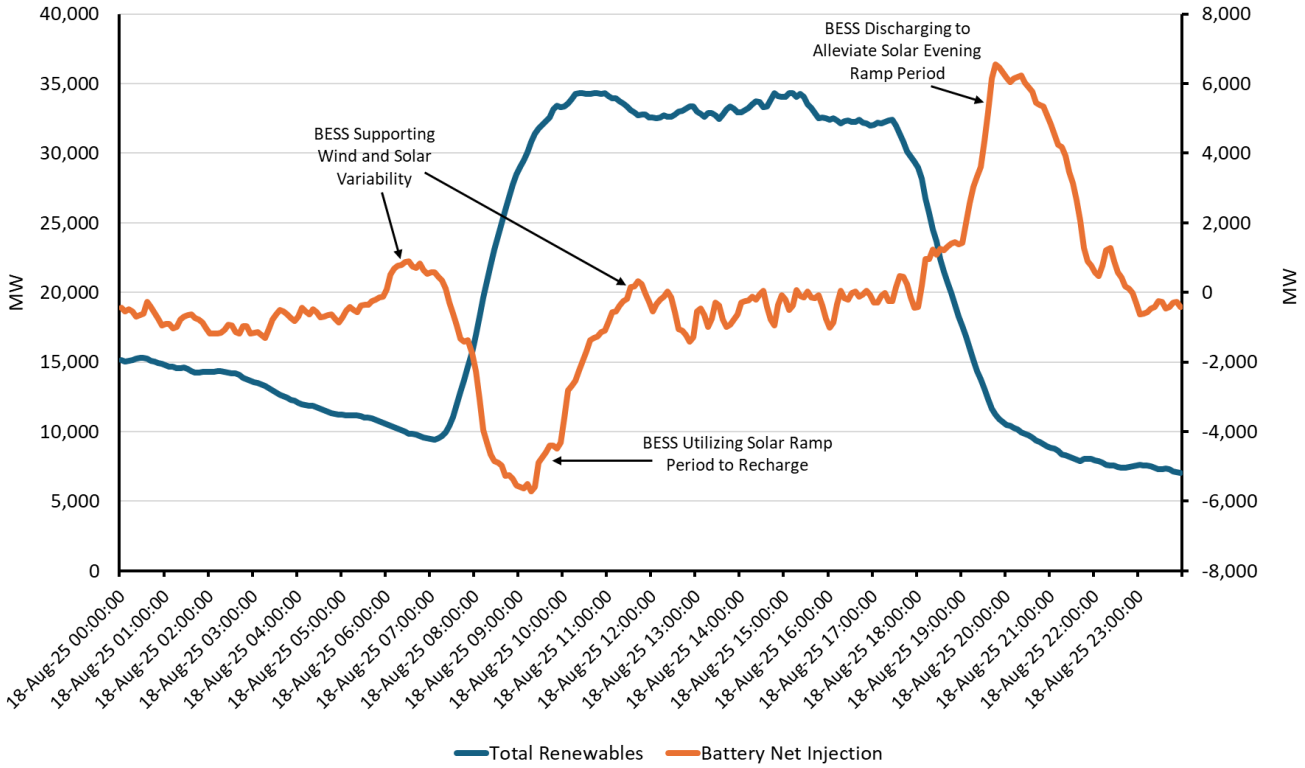


Figure 6: Total Renewables Plus Evening Solar Ramp[35]

[34] Moss Landing BESS Fire Report Final 12.22.25.pdf

[35] Secondary Y-axis has been shifted and scaled for visual clarity.

Frequency Response Impacts

As detailed earlier in the *2025 SOR Overview*,[36] BESS has demonstrated the capability to rapidly respond to frequency disturbances. In 2025, areas with sufficiently dense BESS installations and primary frequency response support initiatives continued to demonstrate the resource's ability to arrest frequency decline and restore frequency to deadband more quickly than conventional generators.

It should be noted that BESS are energy storage resources with limited capacity, typically intended to last a few hours. As a result, BESS's role in frequency disturbance events is ultimately to rapidly recover and maintain frequency until additional resources can come on-line for indefinite system support. This introduces a functional limitation during long-term widespread system degradation events, meaning that BESS is not a complete solution for events like major winter storms.

BESS-Related Actions

Recommendations

- BESS data collection and sharing value and viability are being evaluated by NERC's Performance Analysis team.
- NERC encourages BESS facilities to provide information on services that they are providing with relevant parties.
- NERC encourages policymakers to consider revisions to fire codes if they have not already.
- NERC will continue to monitor BESS performance and major events for risks.
- In November 2025, ERCOT stakeholders approved Nodal Operating Guide Revision Request 272 and Planning Guide Revision Request 121. These revisions require new BESS resources with a standard generation interconnection agreement (SGIA) date on or after April 1, 2026, to demonstrate the capability of providing advanced grid-support (grid-forming) functions as well as to provide appropriate models for these functions.

[36] 2025 NERC State of Reliability - Overview

Industry Mitigation Actions

Performance data reported to NERC enables a risk-based approach to reliability management across major emerging reliability issues prior to the creation of formal reliability indicators. Current areas of focus include severe weather, conventional generator performance, large loads, BESS, and IBRs (see **Table 3**). In response to these evolving risks, industry and the ERO Enterprise implemented a broad range of mitigation activities throughout 2025 detailed in the body of this report.

In addition to these top priorities, more cautionary mitigation activities included more conservative operating practices during stressed and cold-weather conditions, increased use of probabilistic and all-hours reliability assessments, improved model validation requirements, transmission planning resilience analysis for extreme weather events, and new planning and operational guidance associated with load-pocket reliability risks.

Table 3: Monitoring Emerging Trends and Mitigation Resolution

Monitored Reliability Challenge	Key Measures Tracked	2025 Trends	Mitigation Effectiveness Indicators	Indicators that Additional Attention is Required
Increasing Incidence of Severe Weather	Severity risk index (SRI), transmission outages, restoration duration, MVA-days lost, load loss	Worst SRI days remained within historically favorable ranges; overall weather conditions considered favorable	Reduced outage severity, faster restoration, lower cumulative SRI	Increasing high-SRI days, longer restoration times, larger correlated outages
Generator Forced Outage and Performance Trends	Annual/monthly WEFOR, fuel-specific outage rates, unavailable MWh, seasonal outage spikes	Overall WEFOR increased to 9.2%; coal 11.2% to 14.1% (39.8 TWh change), combined cycle 4.2% to 5.7% (19.1 TWh change)	Improved winter performance, reduced outage severity during extreme events	Elevated WEFOR, correlated winter outage spikes
Reliable Large Load Integration	Peak demand growth, frequency response, load forecast error, transmission constraints, CILR	Annual energy demand increased to ~4.95 million GWh; actual summer peak higher than forecast; two CILRs exceeding 1,000 MWs	Stable frequency performance, improved operational visibility	Rapid localized demand growth, frequency volatility, planning uncertainty
Reliable BESS Integration and Performance	Frequency arrest performance, recovery speed, BESS availability	BESS deployment approximately matched solar growth; improved fast frequency response performance observed when incentivized in high-BESS areas	Improved frequency recovery, successful grid-forming performance	Thermal runaway/fire events, duration limitations, unavailable BESS capacity
Reliable IBR Integration	Ride-through performance, rate-of-change-of-frequency (RoCoF), IBR trip events, model validation	Expanded IBR mitigation activities continued through 2025	Reduced disturbance-related tripping, improved model accuracy	Weak-grid instability, repeated tripping events, model-performance divergence