2023 State of Reliability Overview

June 2023

Assessment Overview of 2022 Bulk Power System Performance

2023 SOR Technical Assessment | 2023 SOR Video | 2023 SOR Infographic

Table of Contents

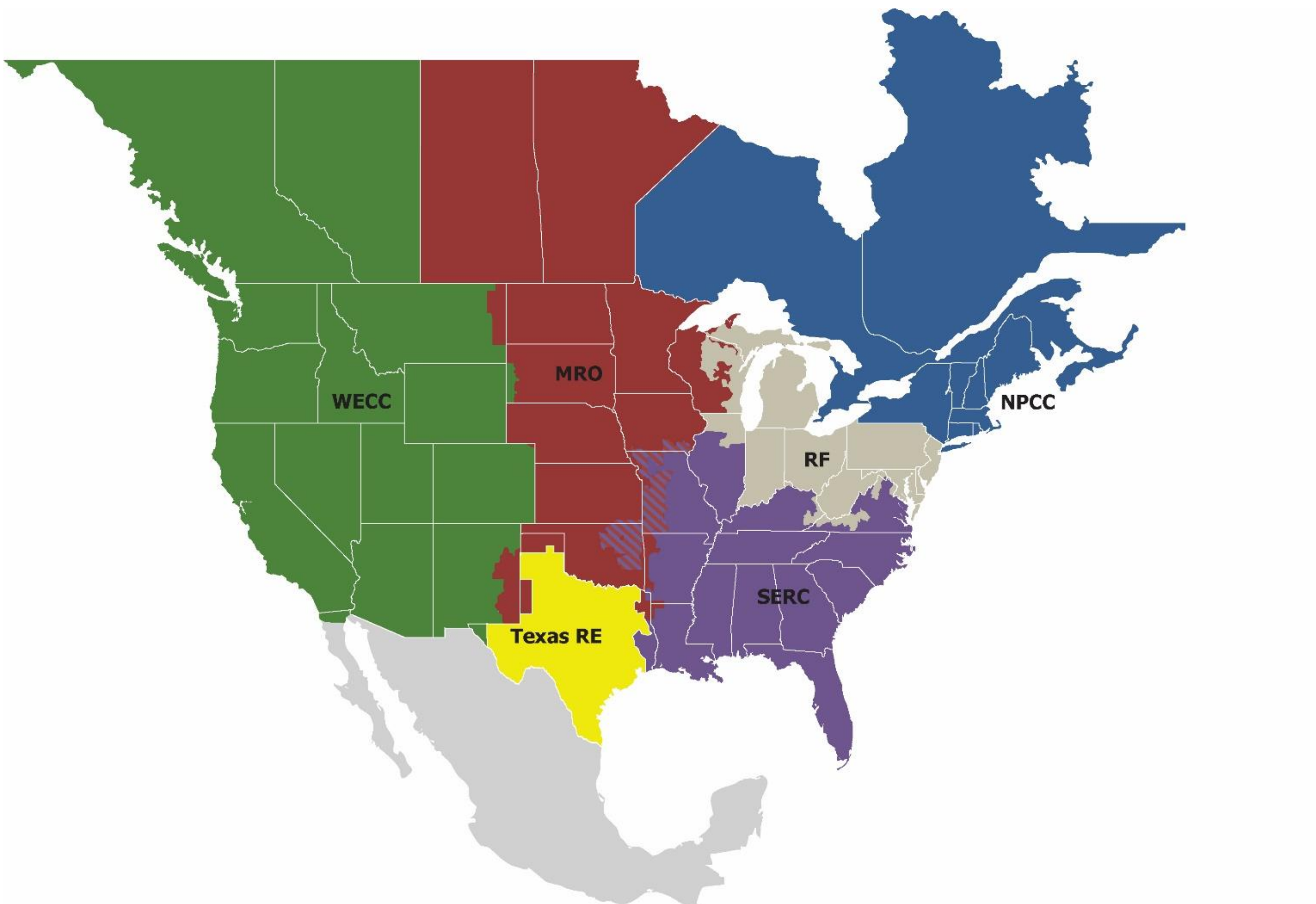
Preface

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) is comprised of two publications: this *2023 State of Reliability Overview,* which is a high-level summary of the important findings, and the *2023 State of Reliability Technical Assessment,*[1] which provides NERC's detailed comprehensive, annual analytical review of Bulk Power System (BPS) reliability for the 2022 operating (or calendar) year. The purpose of this overview is to inform regulators, policymakers, and industry leaders on the most significant reliability risks facing the BPS and to describe the actions that NERC has taken and will take to address them.

Development Process

ERO staff, supported by the Performance Analysis Subcommittee, developed this overview and the corresponding *2023 State of Reliability Technical Assessment* based on 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), and NERC's annual *Long-Term Reliability Assessment* (LTRA). In addition, voluntary information reported by industry to the Event Analysis Management System (TEAMS), the Electricity Information Sharing and Analysis Center (E-ISAC), and the Institute of Electrical and Electronics Engineers (IEEE) Distribution Reliability Working Group is also included.

Considerations

- Data in this overview represents the performance for the January–December 2022 operating year unless otherwise noted.
- Information used in this overview is based on data available Spring 2023. All dates and times shown are in Coordinated Universal Time (UTC).
- This overview 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 for confidentiality unless specific analysis for the Québec Interconnection is shown.

[1] https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2023_Technical_Assessment.pdf

2022 Highlights

Based on data and information collected for this *SOR Overview* of BPS reliability performance in 2022, NERC identified the following findings:

- **Key Finding 1: Conventional Generation Reliability**
- **Key Finding 2: Solar PV Inverter Performance during Transmission Faults**
- **Key Finding 3: Security Threats**
- **Key Finding 4: Transmission System Reliability**
- **Misoperations**
- **Expanding Role of Data in Assessing BES Performance**

Overall, the BPS was reliable[2] throughout 2022. However, extreme weather events continue to pose the greatest risk to reliability due to the increase in frequency, footprint, duration, and severity. In 2022, the National Oceanic and Atmospheric Administration identified 18 separate billion-dollar weather-related disasters in the United States, see **Figure 1**. Additionally, one such disaster occurred in Canada.[3] Thirteen of these events affected the performance observed on the days with the most significant reliability impacts on generation, transmission, and loss of customer load (as measured by the severity risk index[4]).

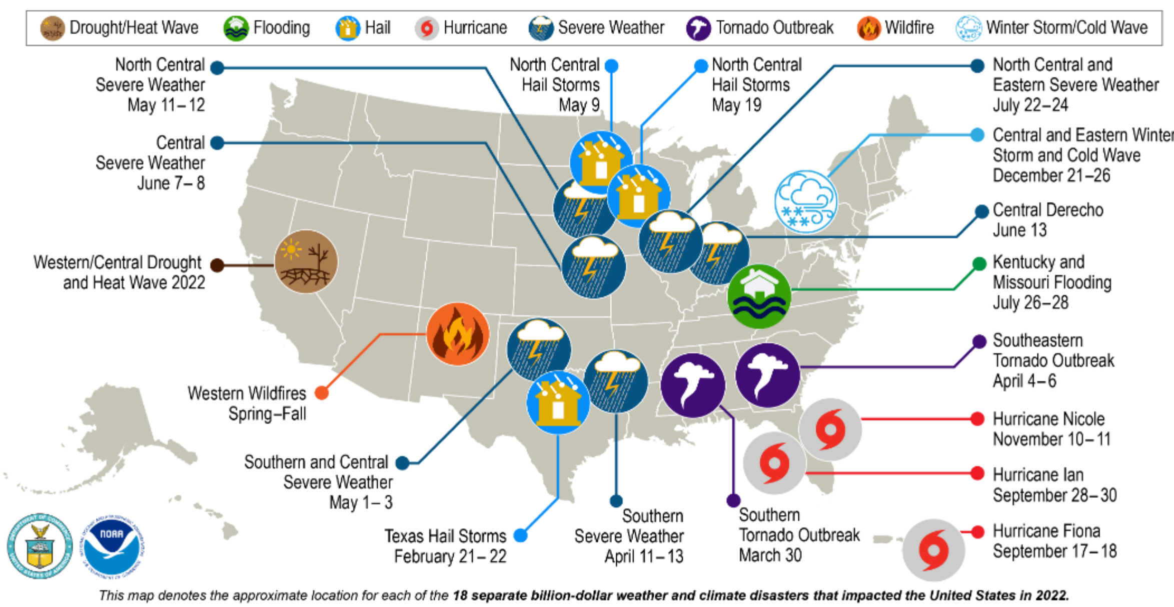


Figure 1: 2022 U.S. Billion Dollar Weather Related Disasters[5]

Notably, the most significant reliability event of the year was Winter Storm Elliot, which swept over the majority of the Central and Eastern United States in December 2022. The severity of this event led the Federal Energy Regulatory Commission (FERC) and NERC to form a joint inquiry with Regional Entities that is currently underway. Accordingly,

[2] Learn About NERC provides background information about NERC, the definition of reliability, and understanding the grid.
[3] Severe weather in Canada caused $3.1 billion in insured damages in 2022.
[4] The Severity Risk Index is a daily metric where transmission, generation, and load loss events aggregate into a single value that indicates the performance of the BES: https://www.nerc.com/comm/PC/Performance%20Analysis%20Subcommittee%20PAS%202013/SRI_Enhancements_October_2020.pdf
[5] *National Oceanic and Atmospheric Administration National Centers for Environmental Information U.S. Billion-Dollar Weather and Climate Disasters* (2023): https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73

this overview does not discuss the actions resulting from this event that will be incorporated in the inquiry findings later this year.

Figure 2 highlights a few key numbers and facts about the North American BPS.

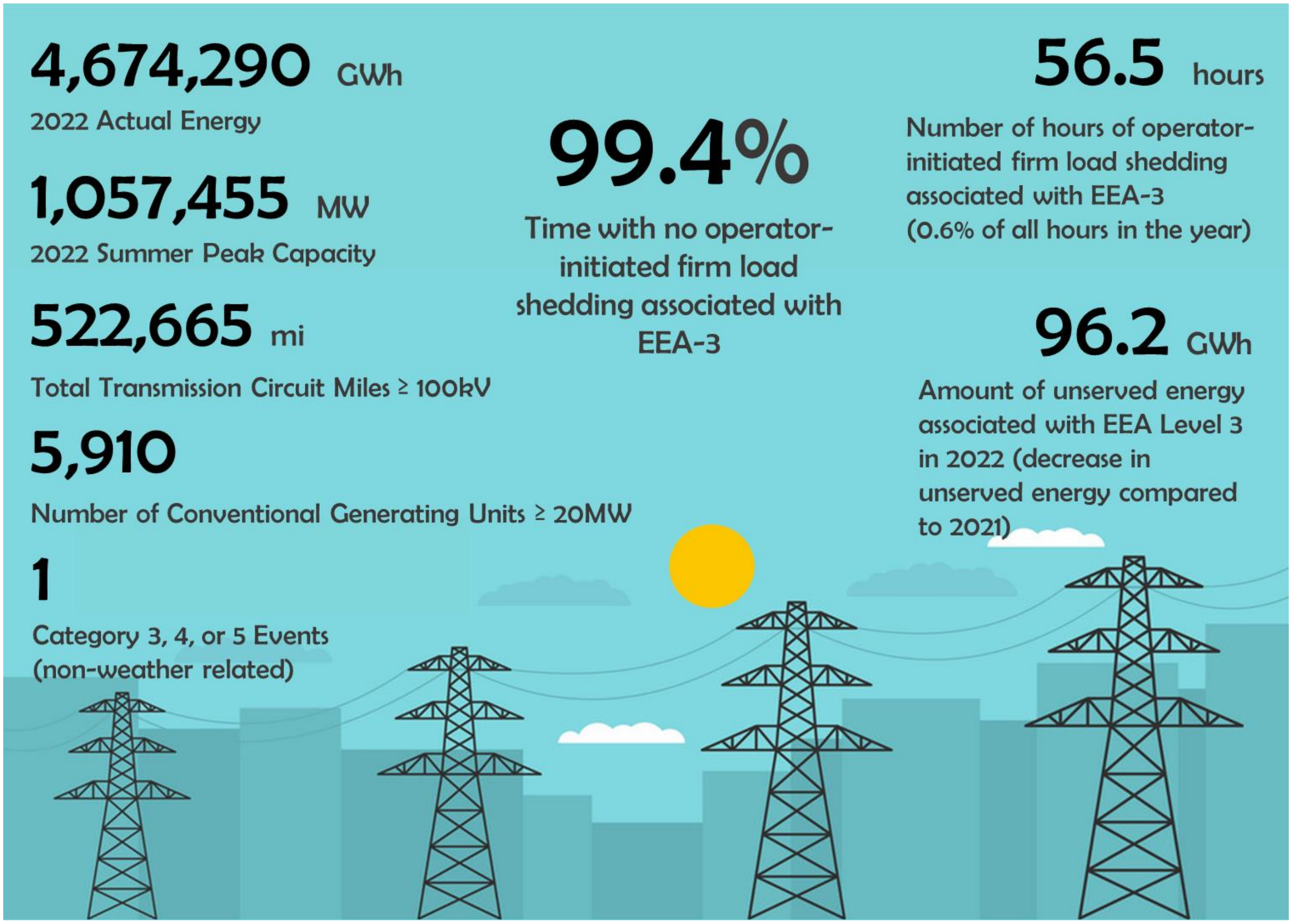


Figure 2: 2022 BPS Inventory and Performance Statistics

Key Finding 1: Conventional Generation Reliability

The reliability of conventional generation is significantly challenged by more frequent extreme weather, high-demand conditions, and a changing resource mix, resulting in higher overall outage rates and surpassing transmission in their contribution to major load loss events.

In 2022, conventional generation experienced its highest level of unavailability (8.5%) overall since NERC began gathering GADS data in 2013 as measured by the weighted equivalent forced outage rate (WEFOR). **Figure 3** shows consistently increasing outage rates for coal over the observed five years, correlating with higher numbers of startups and maintenance outages. **Figure 3** also shows that the unavailability of the gas-fired generation fleet in recent years has been consistently higher during the winter months. These are the two primary factors to conventional generation surpassing transmission in contributing to major load loss events. There are no apparent trends in the unavailability of the other forms of generation.

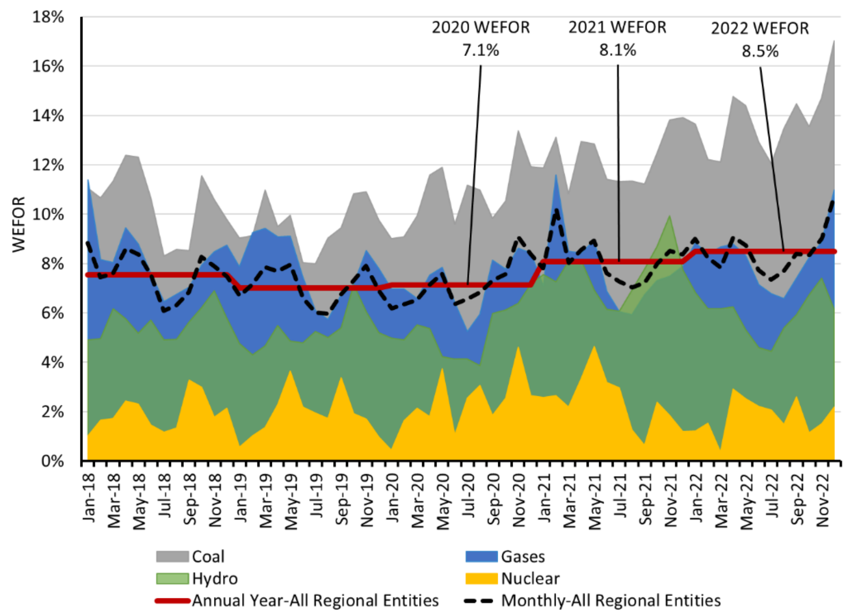


Figure 3: 2022 Monthly Weighted Equivalent Forced Outage Rate by Fuel Type

Inverter-based resource (IBR) capacity has increased while conventional generation capacity has decreased in both the Texas and Western Interconnections (as seen in **Figure 4**). The Texas Interconnection can no longer meet peak demands with only conventional generation. The variability in IBRs also places increased operational demands on the now smaller fleet of conventional generation.

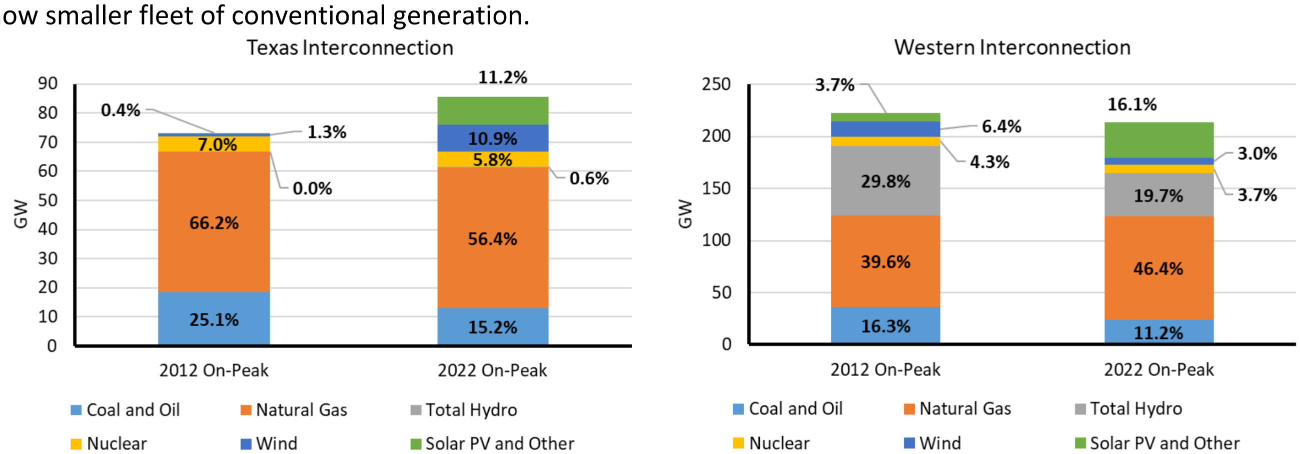


Figure 4: Texas Interconnection and Western Interconnection 2012 and 2022 On-Peak Capacity Resource Mix

For the second year in a row, high temperatures have created reliability challenges, including a notable near-miss event. In mid-June, sustained high temperatures across North America caused a large number of generator outages and a large amount of load loss. In the Western Interconnection, the multi-year drought reduced water levels in the Hoover and Glen Canyon dam reservoirs, which represent a combined capacity of more than 3,300 MW, to the lowest levels since first filled. Continued drought conditions would lead to an inability of these (and other) dams to produce power, introducing major operational challenges during high demand periods. In September, an Interconnection-wide heat wave set record high temperatures in more than 1,000 cities, leading to a record peak demand of 167,530 MW for the Western Interconnection. Seven Level 3[6] energy emergency alerts (EEA), energy conservation, demand-side management, and other measures enabled Western Interconnection Balancing Authorities to operate through the period without having to shed firm load.

Resultant Actions

- NERC issued a Level 3 essential action alert[7] in May 2023: *Essential Actions to Industry - Cold Weather Preparations for Extreme Weather Events*.[8]
- Three standards were revised as a result of the 2019 cold weather event that became effective April 1, 2022;[9] additional standards revisions resulting from the 2021 cold weather event are ongoing.[10]
- NERC published three lessons learned[11] documents.
- *FERC - NERC - Regional Entity Staff Report: The February 2021 Cold Weather Outages in Texas and the South Central United States.*[12]
- FERC, NERC, and Regional Entity joint report on the 2022 Winter Storm Elliott is expected in late 2023.
- NERC hosted its annual Preparation for Severe Cold Weather webinar.
- Reliability assessment data requests were expanded to further measure preparedness during cold weather events.
- The WECC Reliability Risk Committee is identifying specific risk areas under “Extreme Natural Events” that pose unique risks to the Western Interconnection and how industry can best address them.
- NERC GADS Section 1600 data request revisions,[13] which include reporting of specific environmental contributing factors for outages and event performance for wind and solar photovoltaic (PV) plants, become effective January 1, 2024.

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6 https://www.nerc.com/pa/Stand/Reliability%20Standards/EOP-011-1.pdf
7 https://www.nerc.com/pa/rrm/bpsa/Pages/About-Alerts.aspx
8 https://www.nerc.com/news/Pages/NERC-Releases-Essential-Action-Alert-Focused-on-Cold-Weather-Preparations.aspx
9 https://www.nerc.com/pa/Stand/Pages/Project%202019-06%20Cold%20Weather.aspx
10 https://www.nerc.com/pa/Stand/Pages/Project-2021-07-ExtremeColdWeather.aspx
11 LL20220301 “Managing UFLS Obligations and Service to Critical Loads during an Energy Emergency
LL20221201 “Air Breaker Cold Weather Operations
LL20230401 “Combustion Turbine Anti-Icing Control Strategy
12 FERC - NERC - Regional Entity Staff Report: The February 2021 Cold Weather Outages in Texas and the South Central United States
13 https://www.nerc.com/pa/RAPA/PA/Pages/Section1600DataRequests.aspx

Key Finding 2: Solar PV Inverter Performance during Transmission Faults

To continue benefiting from the rapid expansion of inverter-based resources, their dynamic performance during system events must improve.

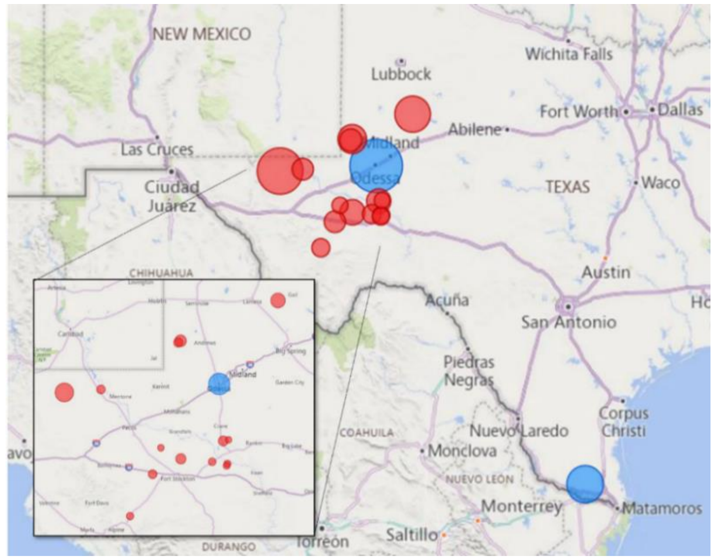

Figure 5: 2022 Impact of Odessa Disturbance

On June 4, 2022, a failed surge arrestor caused the loss of 333 MW of synchronous generation, leading to an erroneous loss of an additional 511 MW of synchronous generation and an unexpected loss of 1,700 MW of solar PV generation in the Texas Interconnection titled the Odessa Disturbance.[14] **Figure 5** shows the locations of the solar PV plants (**red**), the MW (by bubble size), and the conventional generation lost (**blue**). The total generation lost exceeded the most severe single contingency and nearly exceeded the Texas Interconnection resource loss protection criteria, the design threshold that is used to establish the requirements for frequency recovery in the Texas Interconnection.

Notably, the event was nearly identical to one that took place at the same location just over a year ago.[15] It is consistent with recent Western Interconnection events that have also shown that newly built solar PV and battery storage resources continue to be commissioned with known performance issues; these issues have long been highlighted in disturbance reports and NERC alerts dating back to 2016.[16]

Resultant Actions

- FERC Notice of Proposed Rulemaking issued November 17, 2022,[17] was released to address concerns regarding reliability impacts on IBRs.
- NERC Level 2 alert[18] was issued March 14, 2023, on IBR issues.[19]
- Reliability Standard[20] modifications are in progress for PRC-024, MOD-025, MOD-026, MOD-027, FAC-001, FAC-002, PRC-002, PRC-019, and EOP-004.
- NERC published multiple guidelines and resources.[21]
- Immediate industry action is necessary to implement published guidelines and ensure reliable operation of the BPS with the increasing penetration of IBRs.
- IBR modeling requirements need significant improvement to ensure that high-quality, accurate models are used during reliability studies so performance issues can be identified before they occur during real-time operations.

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[14] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_2022_Odessa_Disturbance_Report%20(1).pdf
[15] https://www.nerc.com/pa/rrm/ea/Pages/May-June-2021-Odessa-Disturbance.aspx
[16] https://www.nerc.com/pa/rrm/ea/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_Interruption_Final.pdf
[17] https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20221117-3114&optimized=false
[18] https://www.nerc.com/pa/rrm/bpsa/Pages/About-Alerts.aspx
[19] https://www.nerc.com/pa/rrm/bpsa/Alerts DL/NERC Alert R-2023-03-14-01 Level 2 - Inverter-Based Resource Performance Issues.pdf
[20] https://www.nerc.com/pa/Stand/Pages/ReliabilityStandards.aspx
[21] https://www.nerc.com/pa/Documents/IBR_Quick_Reference_Guide.pdf

Key Finding 3: Security Threats

Physical and cyber security attacks are increasing, reinforcing the need for further development and adaptation of standards and guidelines.

Physical and cyber security are essential to BPS reliability, and security is becoming increasingly important in the ongoing grid transformation. The growing attack surfaces that result from the increasing penetration of distributed energy resources call for ongoing development and adaptation of cyber and physical security standards and guidelines to keep up with the ever-changing threat landscape. Furthermore, cyber-informed planning should include designs and be considered when planning and integrating the technologies into the grid to strengthen the cyber robustness.[22]

Hostile nation-states persist in targeting North American critical infrastructure and are constantly evolving their methods to compromise the grid's reliability, resilience, and security. Domestic extremists have demonstrated the intent to attack the electricity infrastructure and take violent action against grid assets. **Figure 6** provides the breakdown of Level 2 and 3 incident types.[23]

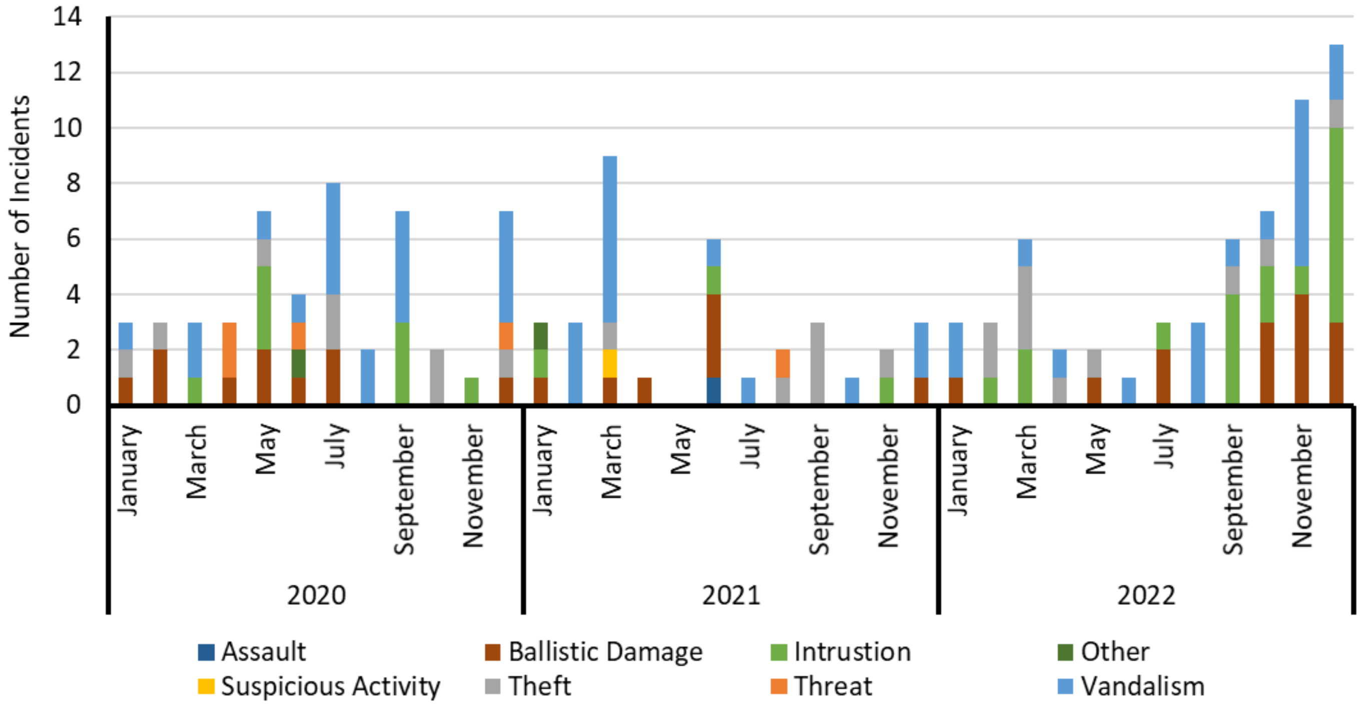

Figure 6: Level 2 and 3 Physical Incidents by Type for 2020–2022

Resultant Actions

- The E-ISAC continuously gathers and distributes industry threat intelligence and works with government and industry partners to mitigate risks and provide guidance as threats arise.
- Through coordination and collaboration with the ERO Enterprise and industry stakeholders, NERC will provide insightful white paper guidance, implement robust security strategies, and continue to refine and adapt critical standards about cyber-informed engineering design to ensure a reliable and secure BPS. These efforts will enable industry to be better positioned against physical and cyber threats now and in the future.

[22] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/ERO_Enterprise_Whitepaper_Cyber_Planning_2023.pdf

[23] Incident types: Level 1: Criminal activity with no impact to the grid. Level 2: Physical security incident with any impact to the grid. Level 3: Physical security incident with direct and significant impact to the grid.

Key Finding 4: Transmission System Reliability

The Bulk Electric System (BES) transmission system continues to demonstrate significantly improved reliability for the fifth year in a row.

Figure 7 shows that the reliability of the transmission system, as measured by overall transmission outage severity (TOS), has improved continuously over the past five years. Figure 8 shows that the unavailability of ac transmission circuits in 2022 was lower than the average over the prior four years. Hard to predict high-wind and lightning systems continue to be the most regular notable challenges to the system.

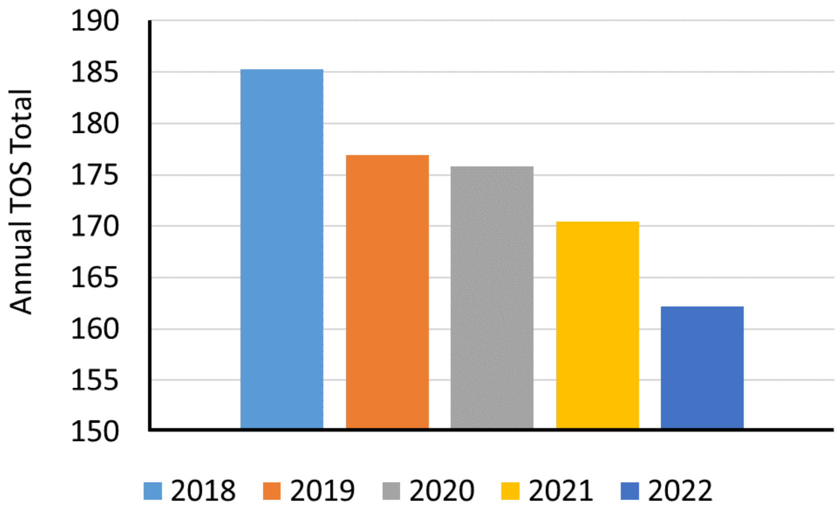

Figure 7: TOS Annual Comparison

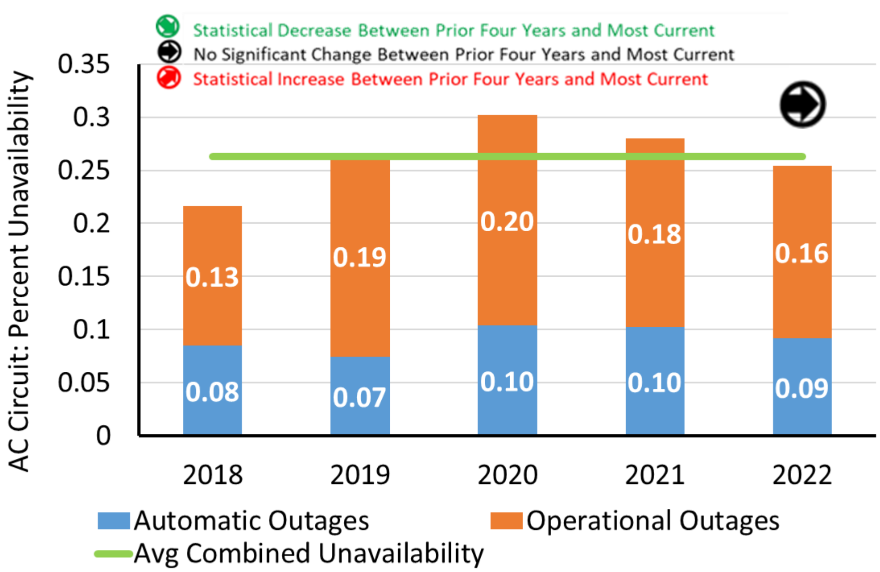

Figure 8: AC Circuit Unavailability

Transmission System Response to Hurricane Ian

Hurricane Ian began as a Category 5 hurricane that crossed Central Florida then made a secondary landfall on the East Coast of the United States two days later. **Figure 9** shows a timeline of the transmission outages and restorations during the event. The Outages Curve (**orange**) depicts the cumulative number of elements out at any given time during the event, while the Restores Curve (**green**) depicts the cumulative number of elements restored. The Simultaneous Elements Out Curve (**blue**) combines the degradation and recovery phases of the event, depicting the number of elements out simultaneously at any given time. The effective restoration (95%) was completed within 3.8 days compared to an average hurricane restoration time of 8.6 days from 2017–2022.

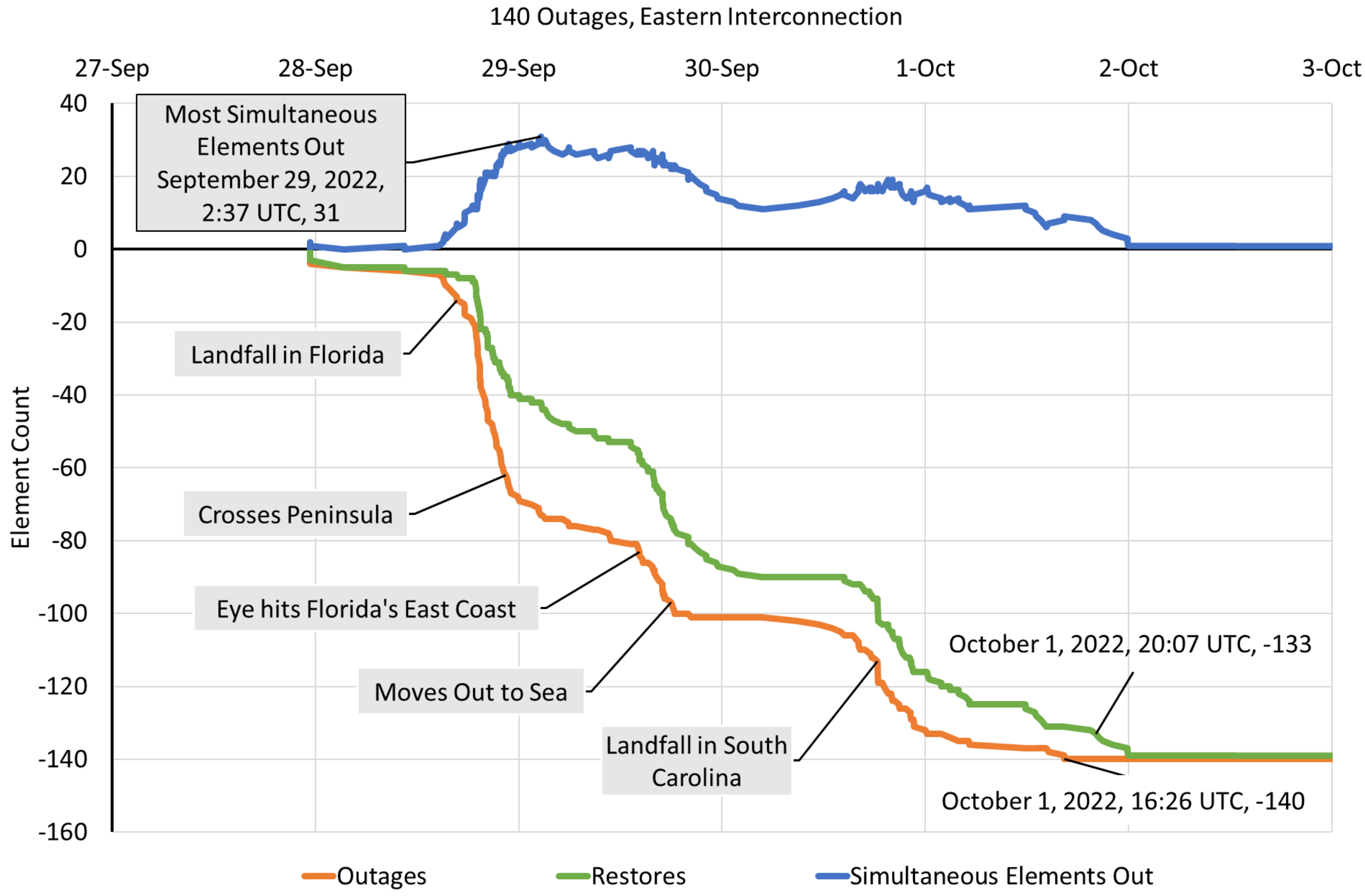

Figure 9: Hurricane Ian Restoration Curves

Misoperations

Protection system misoperations continue to improve with a downward trend in counts, rates, and impact metrics.

Analysis of misoperations indicates a continuing downward trend in misoperation counts, rates, and impact metrics. When comparing 2022 to the prior four years, the misoperations rate statistically significantly decreased in the ReliabilityFirst footprint and overall (see **Figure 10**) but increased in Texas RE. Analysis indicates that this misoperations rate increase is due to a decrease in protection system operations that is not reflected in the misoperations count; this is also supported by a slight increase in misoperations caused by incorrect settings, and relay and communication failures. This aligns with the overall trend that protection system operations counts have only decreased by 10% since 2018 while misoperations have decreased from 1,536 in 2018 to 1,170 in 2022. New analysis, which is detailed in the *2023 SOR Technical Assessment*, approximates the impact of misoperations on the BES and indicates no increase in overall severity. The ERO is continuing to develop analyses to provide comprehensive measures of protection systems while keeping industry informed through a variety of outreach opportunities.

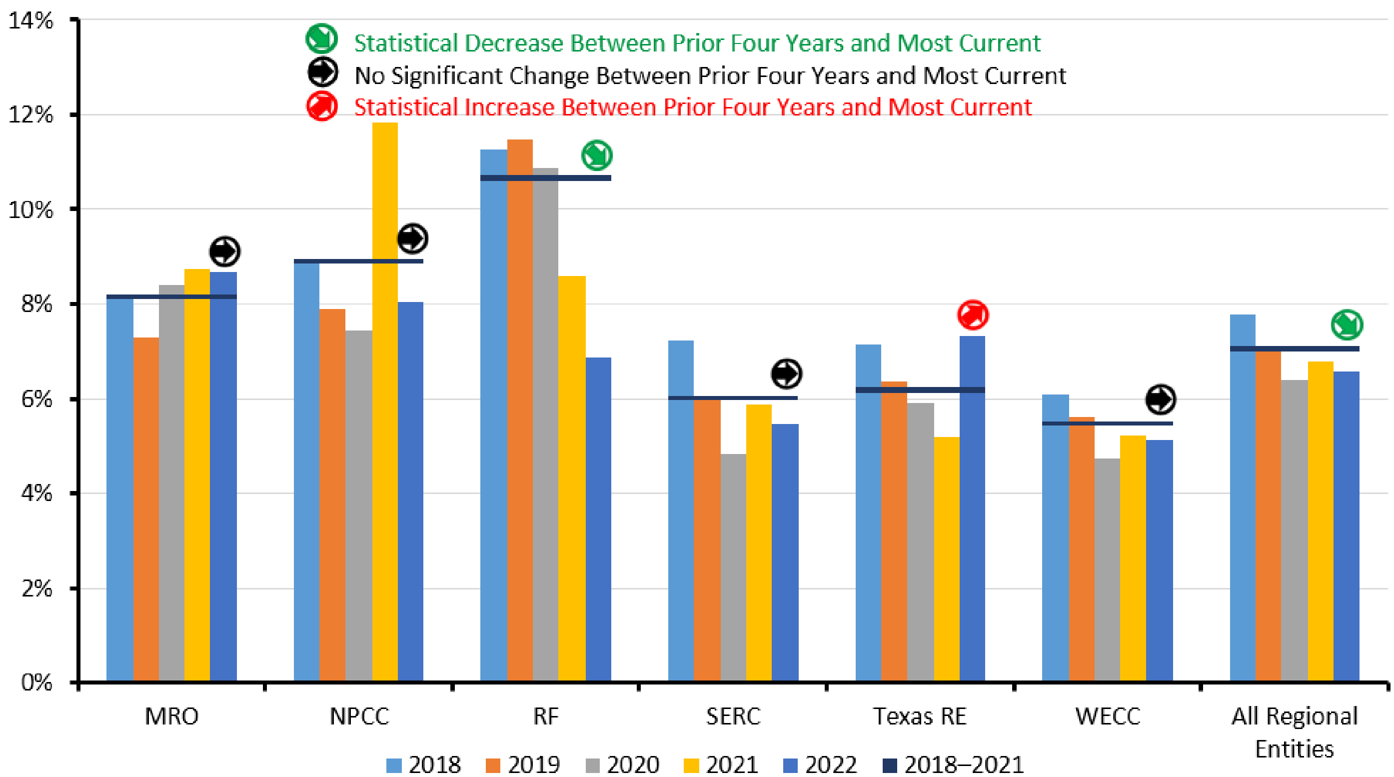

Figure 10: Changes and Trends in the Annual Misoperations Rate by Regional Entity

Expanding Role of Data in Assessing BES Performance

In recent years, the limited access to data necessary to conduct deeper analysis of current BES challenges, such as extreme weather, have become increasingly evident.

Alignment of data sources, clarity of data granularity, timeliness, modeling capabilities, precision with definitions, and the ability to correlate data across and within datasets has become increasingly critical. Revisions to GADS Section 1600 that become effective in 2024 include additional wind and solar PV data as well as information to clearly indicate whether external operating conditions have contributed to a reported outage. NERC is also reviewing Section 1600 data requests currently in effect to align them with current and future analytical needs. Areas under consideration include BES load loss information, IBR modeling capabilities, modeling data accuracy, transmission information to identify relation to weather events, daily peak generation capacity or demand information, and more quantifiable information regarding the severity of transmission outages and protection system misoperations.

Acknowledgements

NERC would like to express its appreciation to all the people across the industry who work tirelessly to keep the lights on each and every day in addition to the many individuals who provided technical support and identified areas for improvement in this report.

NERC Industry Group Acknowledgements	
Group	**Officers**
Reliability and Security Technical Committee	Chair: Greg Ford, Georgia System Operations Corporation Vice Chair: Rich Hydzik, Avista
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
Event Analysis Subcommittee	Chair: Chris Moran, PJM Vice Chair: James Hanson, WECC
Generation Availability Data System User Group	Chair: Leeth DePriest, Southern Company Vice Chair: Danny Small, City Utilities
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 & NPCC: Bill Henson, ISO-NE
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