2022 ASSESSMENT OF RELIABILITY PERFORMANCE

TEXAS RE

Ensuring electric reliability for Texans

SUMMARY REPORT

MAY 2023

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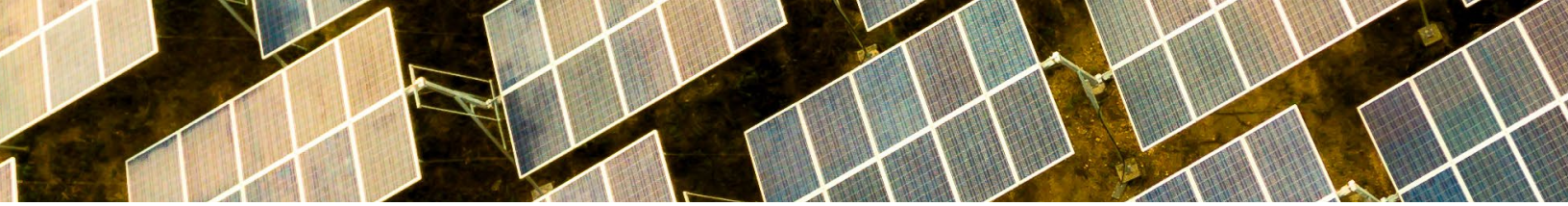
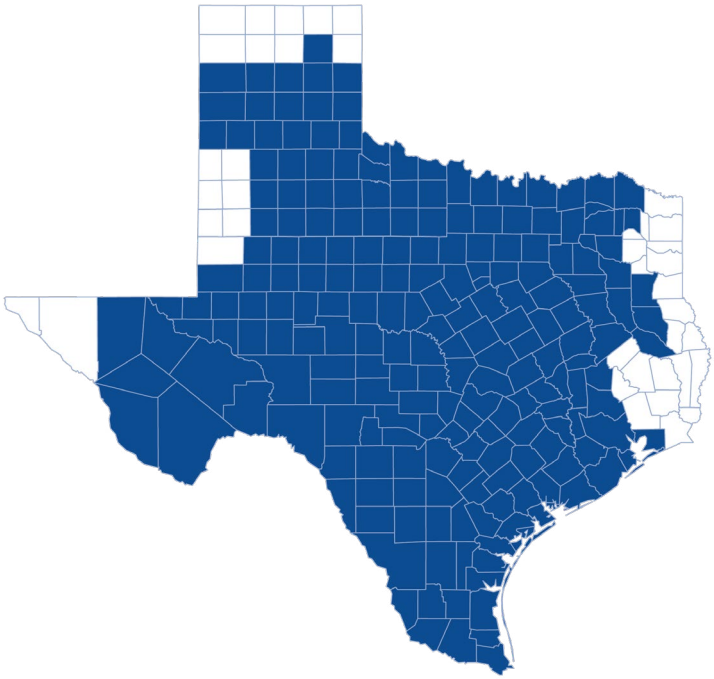


INTRODUCTION

Texas Reliability Entity, Inc. (Texas RE) periodically assesses and reports on the reliability and adequacy of the bulk power system (BPS) within the Texas Interconnection (also known as the Electric Reliability Council of Texas [ERCOT] Interconnection). The Assessment of Reliability Performance annually compiles analyses for the previous year and this document is the 2022 report of that analysis.



The goals of this report are to paint the overall BPS reliability picture with historical context, identify current and future risk areas, and prioritize them to promote actionable results for reliability improvement.

This report provides insight into areas where reliability goals can be more effectively achieved by addressing key measurable components of BPS reliability. Additionally, it aligns data and facts reported from multiple sources with full information transparency. The key findings and observations can serve as inputs to process improvements, event analyses, reliability assessments, and critical infrastructure protection.

TEXAS RE'S MISSION

To assure efficient and effective reduction of risks to the reliability and security of the bulk power system within the ERCOT Interconnection.

DATA SOURCES

TADS
Transmission Availability Data System

GADS
Generation Availability Data System

DADS
Demand Response Availability Data System

MIDAS
Misoperation Information Data Analysis System

EVENT REPORTS
OE-417,
NERC EOP-004,
& NERC Events Analysis

Frequency Control Performance and Primary Frequency Response

ERCOT ISO Data and Reports

2022 IN REVIEW

The Texas RE/ERCOT Region (hereafter "Region") demonstrated adequate reliability for normal operating conditions and when subjected to contingencies within planned parameters. As in recent years, the Region's resources handled extended high summer peak periods, helped by new solar generation and milder weather in 2022. Annual energy production has grown along with renewable generation output and peak renewable penetration levels to meet projected summer peak loads. However, multiple extreme events in the last five years have tested the grid's ability to maintain the reliability and adequacy levels expected by Texans. 2022 was no exception.

ODESSA DISTURBANCE

The June 2022 Odessa Disturbance (Joint NERC Texas RE Staff Report released December 2022) involved over 1,700 MW of reduced output from solar photovoltaic (PV) facilities up to several hundred miles away from the location of the initiating event—a single-line-to-ground fault at a 345 kV substation near Odessa, Texas. The event was categorized as a Category 3a event in the North American Electric Reliability Corporation (NERC) Event Analysis Process.

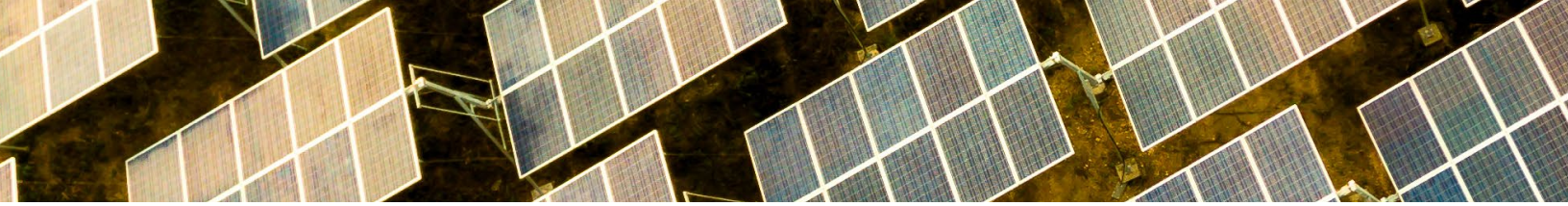
The size of this disturbance nearly exceeded the Region's Interconnection Resource Loss Protection Criteria defined in NERC BAL-003 that is used to establish the largest credible contingency for frequency stability in an Interconnection. Furthermore, this disturbance involved the abnormal performance of multiple solar PV facilities and synchronous generating facilities. These types of concurrent and unexpected losses in generation pose a significant risk to BPS reliability when many of the underlying causes of abnormal performance are systemic in nature, should be captured in system planning assessments or interconnection studies, and are not mitigated in a timely manner. As the penetration of solar PV (and all inverter-based resources (IBRs)) continues to grow rapidly in the ERCOT footprint, it is paramount that these performance issues are immediately addressed. ERCOT should be commended for the proactive approach it has taken to address these performance issues, including multiple outreach opportunities with plants and manufacturers, as well as drafting new performance requirements in the Operating Guides and Protocols.

Like the previous Odessa disturbances in May and June 2021, the June 2022 event in Texas was mainly attributed to abnormal performance of the inverter controls, plant controls, and protections within the facilities. This event continues to highlight the criticality of ensuring a reliable resource mix that can support the BPS by providing essential reliability services especially during contingency-related events.

WINTER STORM ELLIOTT

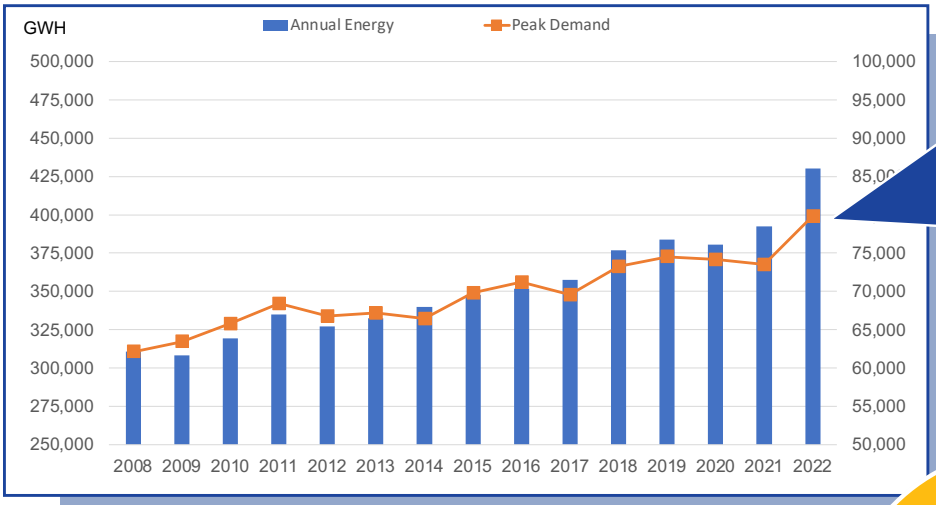
Between December 22 and December 25, much of the United States (including most of Texas) was impacted by Winter Storm Elliott's extreme cold temperatures. As with previous cold weather events, outages due to freeze-related issues and natural gas curtailments affected the generation fleet. ERCOT did not have any capacity conditions that necessitated an energy emergency declaration, even as it set a new all-time winter peak record of 73,976 MW on December 23, 2022. Winter Storm Elliott was very different from February 2021's Winter Storm Uri, however. Winter Storm Elliott did not contain the freezing precipitation and ice that so drastically impacted the wind and solar generation in 2021. With the lack of precipitation, wind generation provided over 20 GW of generation during the peak periods and allowed ERCOT to pass through the event with no issues.

During Winter Storm Elliott, areas of the Eastern Interconnection had energy emergency load shed events due to generation capacity issues. A Federal Energy Regulatory Commission (FERC) inquiry team is currently investigating these issues and is expected to issue a report later in 2023.



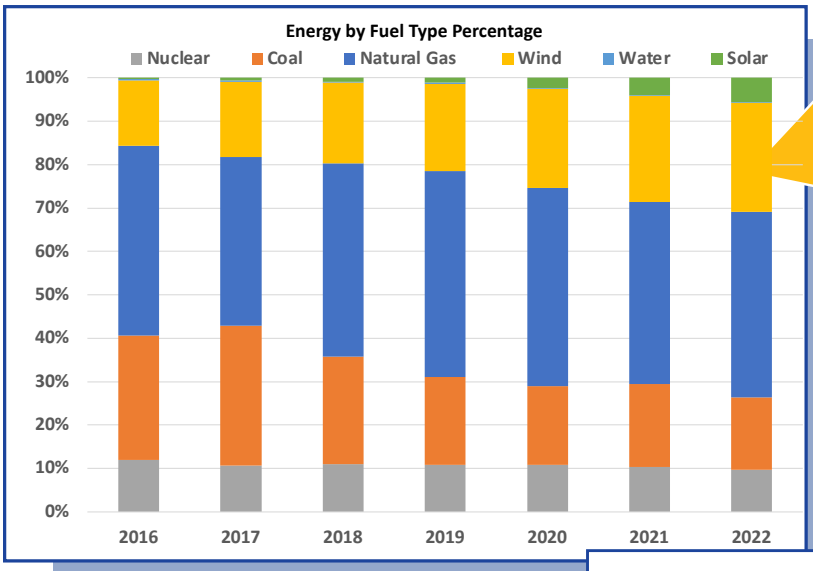
DEMAND AND ENERGY

2022 AT A GLANCE



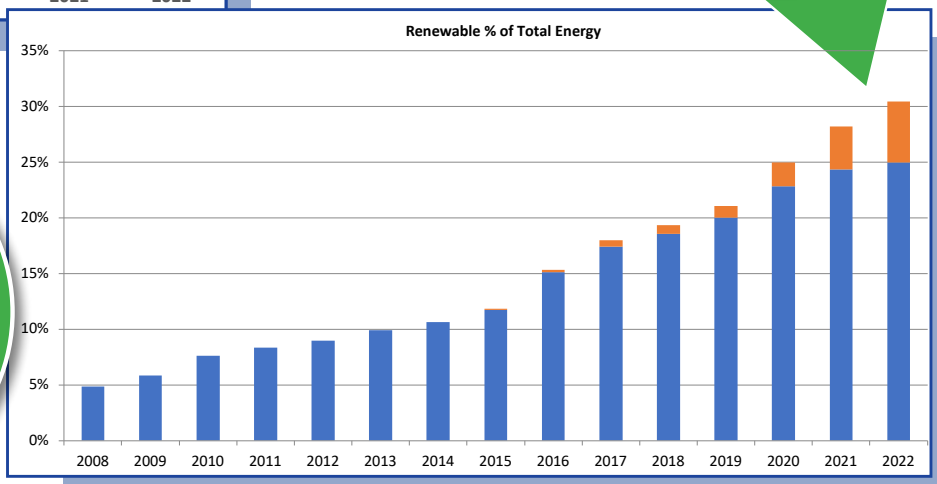
ALL-TIME SUMMER PEAK DEMAND RECORD:
79,830 MW
on 7/20/2022

ALL-TIME WINTER PEAK DEMAND RECORD:
73,976 MW
on 12/23/2022



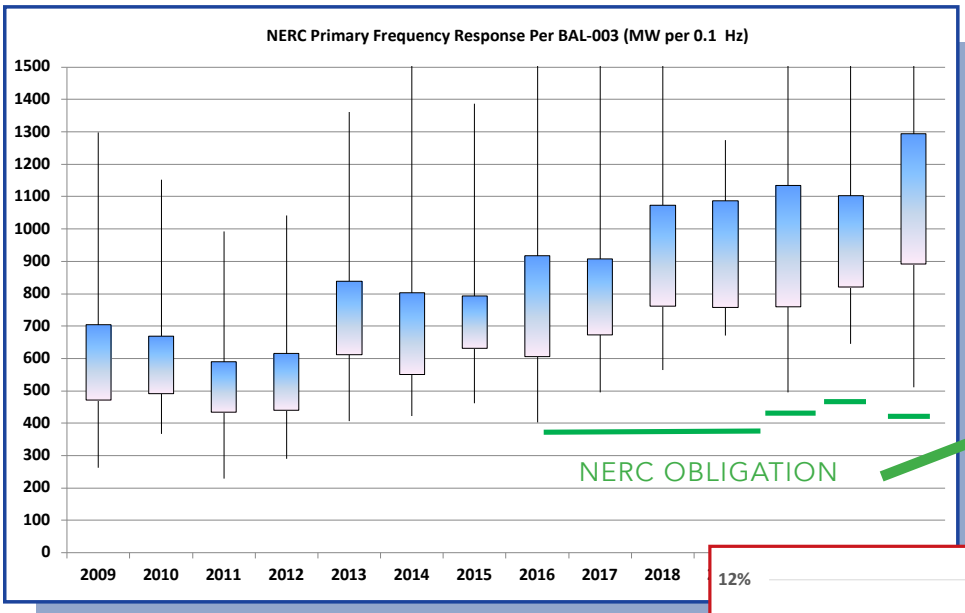
PEAK HOURLY WIND GENERATION:
26,871 MW
on 05/29/2022

RENEWABLE ENERGY SERVED:
31.0% of total energy in 2022

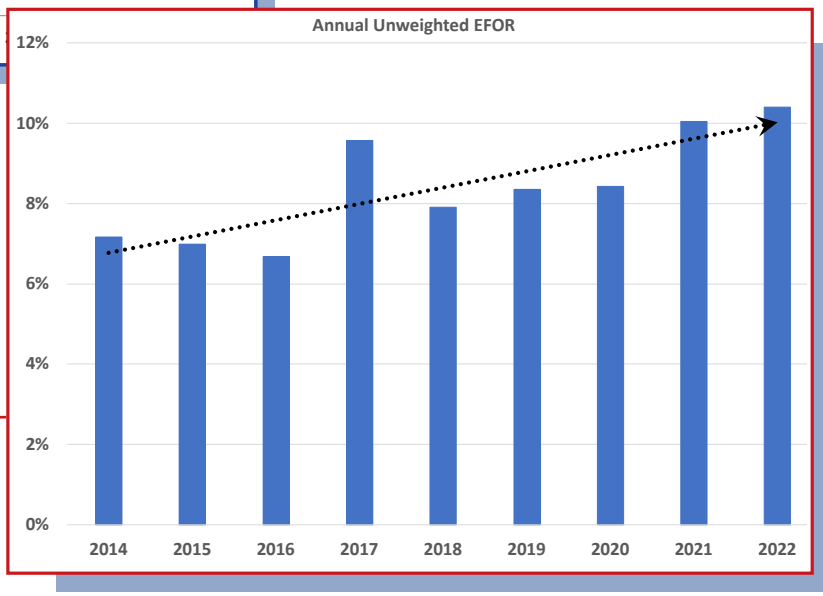


RECORD PEAK HOURLY RENEWABLE PENETRATION:
70.5% on
04/10/2022

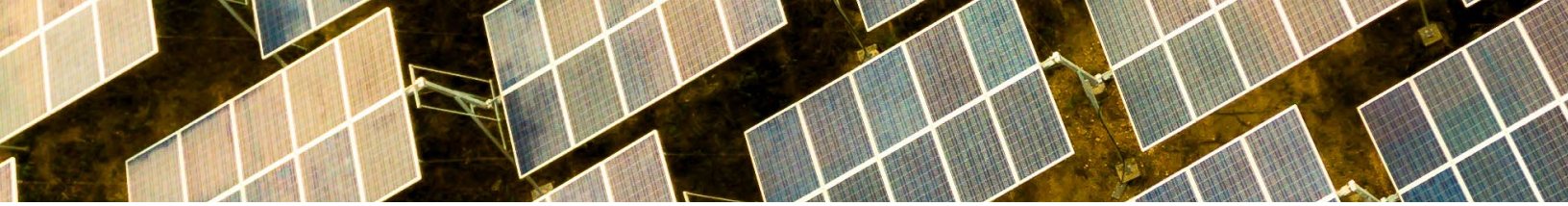
RELIABILITY



PRIMARY FREQUENCY RESPONSE:
1082 MW/0.1Hz for for 2022 vs. NERC Obligation of 412 MW/0.1Hz



	2022	2021
CONTROL PERFORMANCE STANDARD 1 (CPS1)	173.4	169.3
TADS 345kV CIRCUIT AUTOMATIC OUTAGE RATE PER 100 MILES	2.04	2.52
PROTECTION SYSTEM MISOPERATION RATE	7.3%	5.2%
GADS EQUIVALENT FORCED OUTAGE RATE (EFOR) (MW WEIGHTED)	10.4%	10.1%



2022 PERFORMANCE METRICS

Texas RE utilizes key performance indicators to evaluate how effectively the region is meeting targeted electric reliability objectives. The table below describes these indicators, how they are measured, the target values, and an assessment of the current state of each.

Improving	Stable or No Change	Monitoring	Actionable

Key Performance Indicator with Description	2022 Performance & Trend Results
Resource Adequacy Measures potential resource adequacy issues by analysis of planning reserve margin and energy emergency alerts.	• Reserve margins show sufficient resource capacity • Extreme event scenarios highlight risk areas • Resource weatherization
Transmission Performance Measures transmission performance by analysis of transmission outage rates and Interconnection Reliability Operating Limits (IROL) exceedances.	• 345 kV & 138 kV transmission outage rates are stable • IROL Exceedances
Resource Performance Measures generation performance by analysis of generator outage rates, primary frequency response, and balancing contingency events.	• Resource outages/gas restrictions during cold weather • Year-over-year continued increase in EFOR rates • Primary frequency response • No balancing contingency event failures
Grid Transformation Measures potential issues related to grid transformation by analysis of system inertia and ramping.	• Solar ramp magnitudes continue to increase • Synchronous generator retirements • Voltage ride through for inverter-based resources • Decrease in average system inertia levels
Protection System Performance Measures Protection System Performance by analysis of Protection System Misoperations.	• Misoperations due to incorrect settings increased in 2022 • Misoperation rate increased in 2022, remains less than overall NERC Misoperation rate
Human Performance Measures transmission outages, generation outages, and Protection System Misoperations caused by human error.	• Reduction in transmission and generation outage rates from human error • Human error primary causal factor in Misoperations and events
Situational Awareness Measures situational awareness by analysis of state estimator convergence rates, event analysis, and telemetry performance.	• Four loss of situational awareness events • State estimator convergence rate is stable

2022 KEY FINDINGS

Texas RE continually evaluates risks to grid reliability in its Region through long-term and seasonal reliability assessments, event analyses, situational awareness, tracking reliability indicators, real-time performance monitoring, and planning observations. The 2022 Assessment of Reliability Performance report provides a high-level overview of the data collected in 2022. It includes:

- Overview of 2022's numbers
- Associated historical data
- The current state of the Interconnection
- Observations for the future of Texas RE's Region

To gauge reliability of the Region and turn that data into actionable information, Texas RE assessed data and historical trends in these areas:

EVENT ANALYSIS

RESOURCE ADEQUACY

SYSTEM RESILIENCE

GRID TRANSFORMATION

HUMAN PERFORMANCE

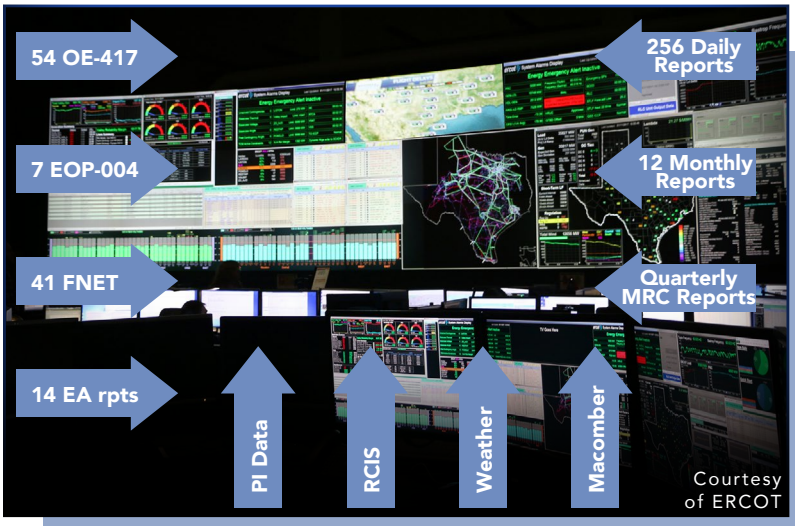
BULK POWER SYSTEM PLANNING

LOSS OF SITUATIONAL AWARENESS

PROTECTION SYSTEM MISOPERATIONS

PHYSICAL AND CYBER SECURITY

EVENT ANALYSIS

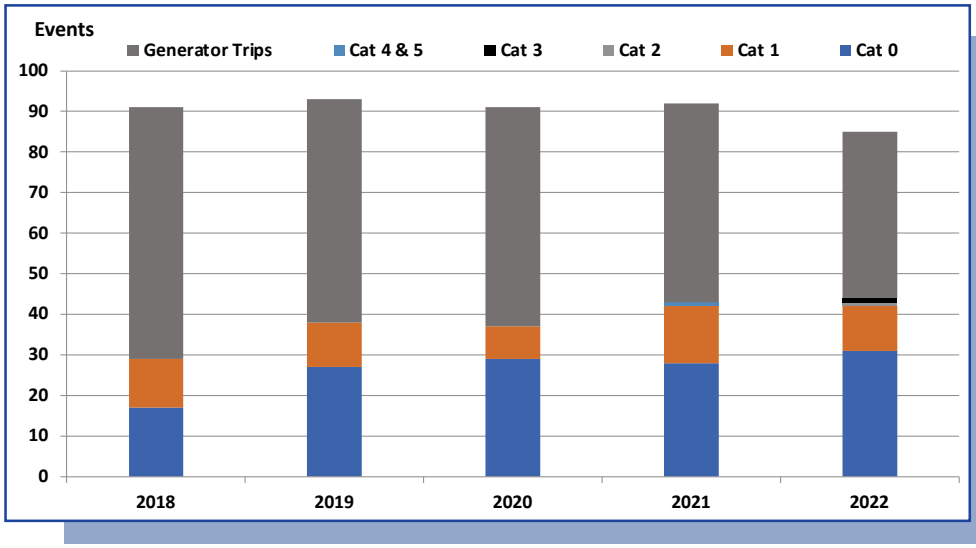


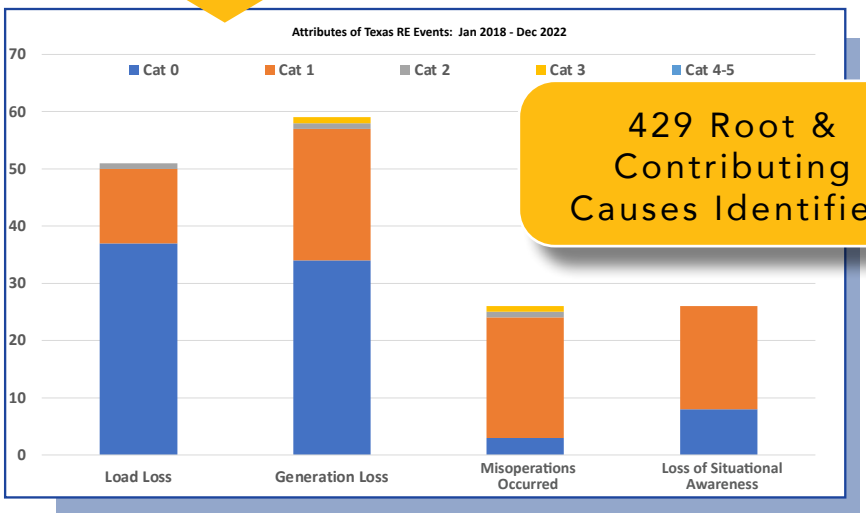
In 2022, Texas RE analyzed 83 BPS events, including the Odessa disturbance, which is on par with the number of events reported per year during the preceding four years. In total, 452 events were reviewed between 2018 and 2022. Of the 429 root and contributing causes identified, the "Equipment/Material" category occurred most frequently with 37 percent of all identified causes. "Design/Engineering" was second with 13 percent, followed closely by "Management/ Organization" with 11 percent. The number of Category 1 events has been stable over the last five years.

- 452 Events Analyzed 2018-2022

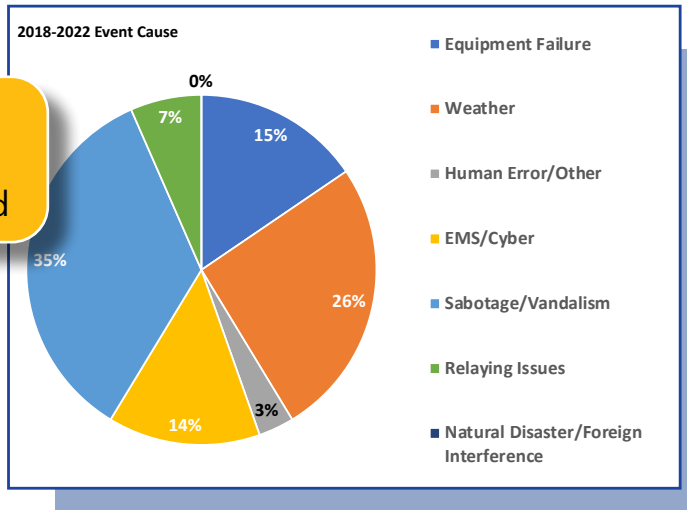
Qualified event attributes dominated by:

- Load Loss
- Generation Loss
- Protection System Misoperations
- Loss of Situational Awareness

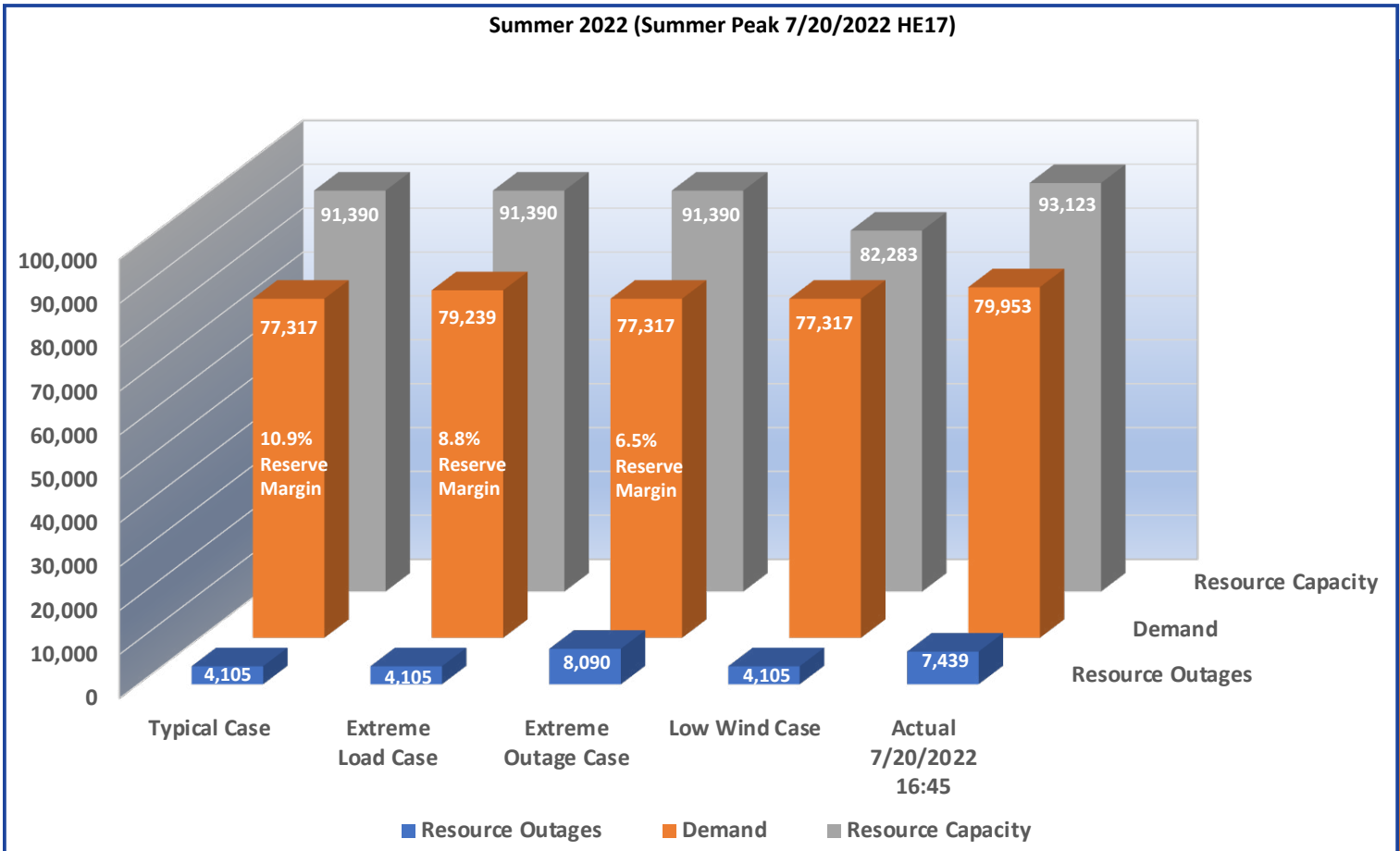




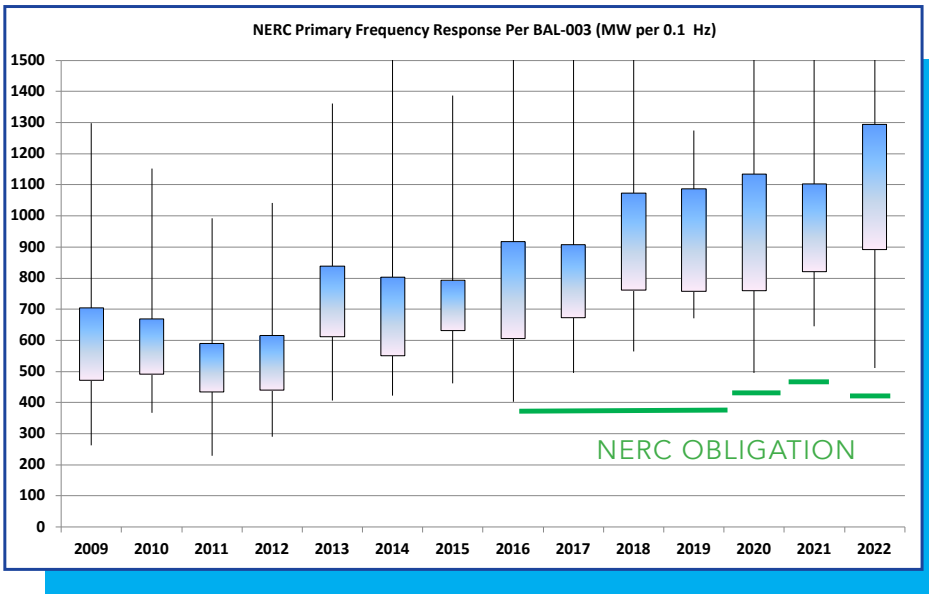
429 Root & Contributing Causes Identified



RESOURCE ADEQUACY



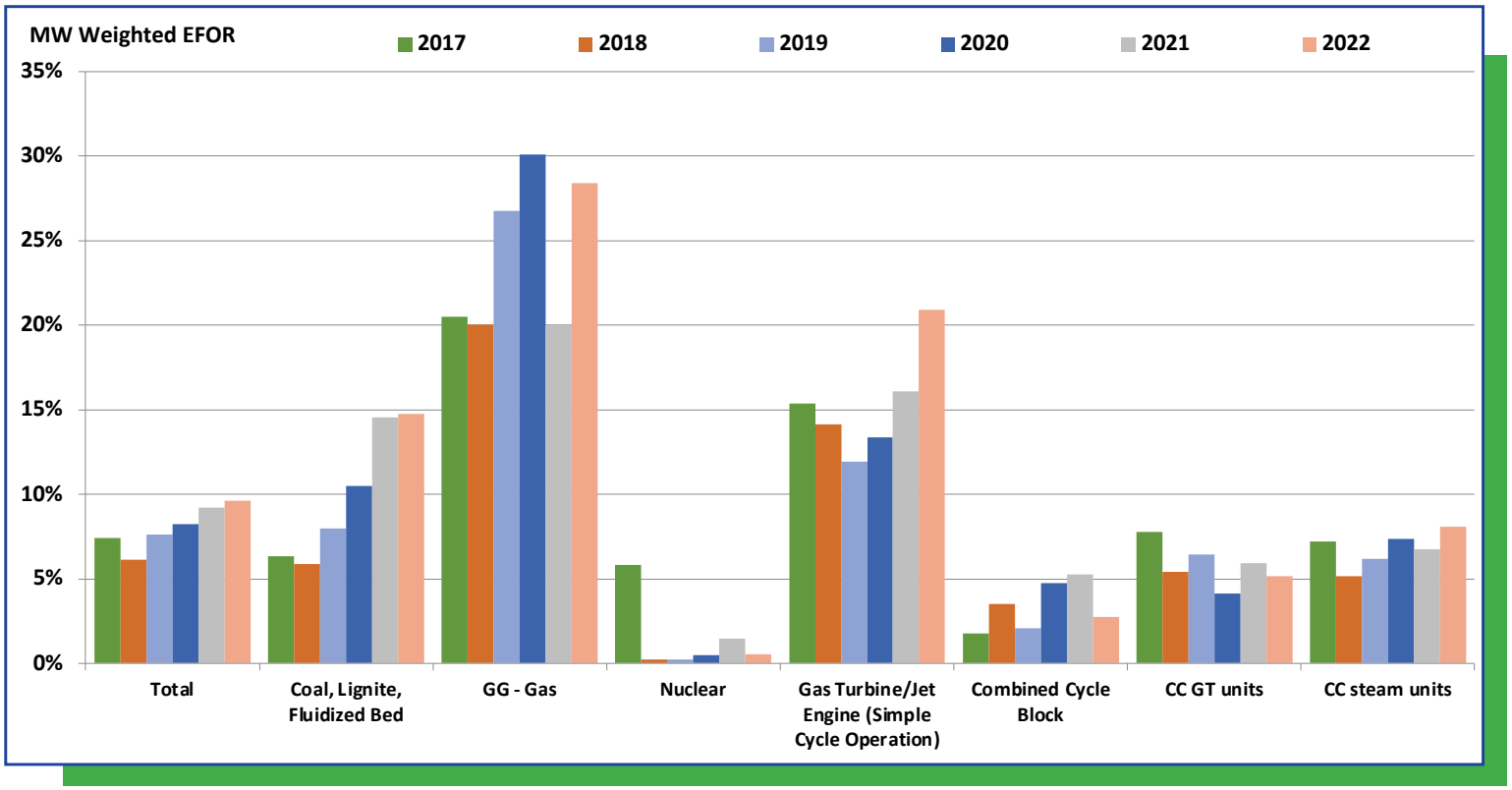
Projected Peak:	77,317 MW
Actual Peak:	79,830 MW
Renewable % at Peak:	19.4%
Max Hourly Wind:	26,871 MW
Max Hourly Solar:	10,039 MW
Max Hour Renewable%:	70.5%
Advisories (PRC<3000):	1
Watches (PRC<2500):	0
EEA (PRC<2300):	0



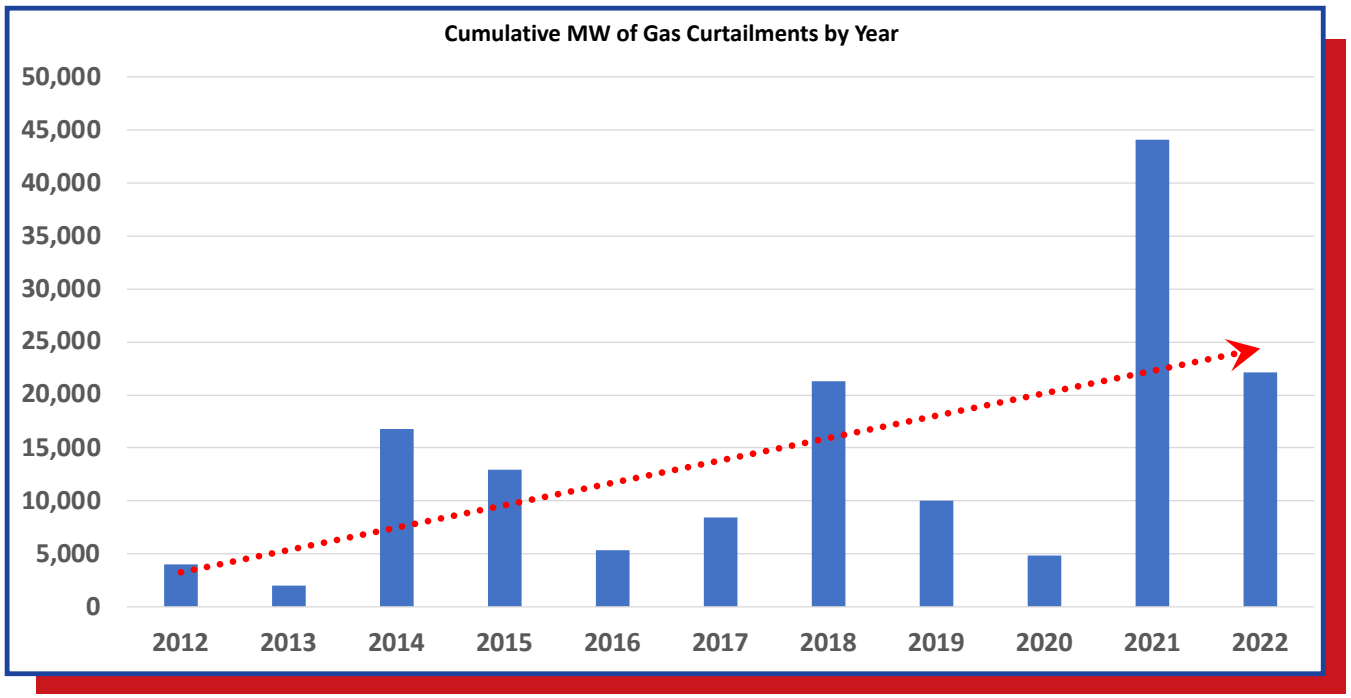
Primary frequency response continues to far exceed NERC minimums

RESOURCE ADEQUACY

EFOR (forced outage) rates for coal and combined cycle fleet continue to increase

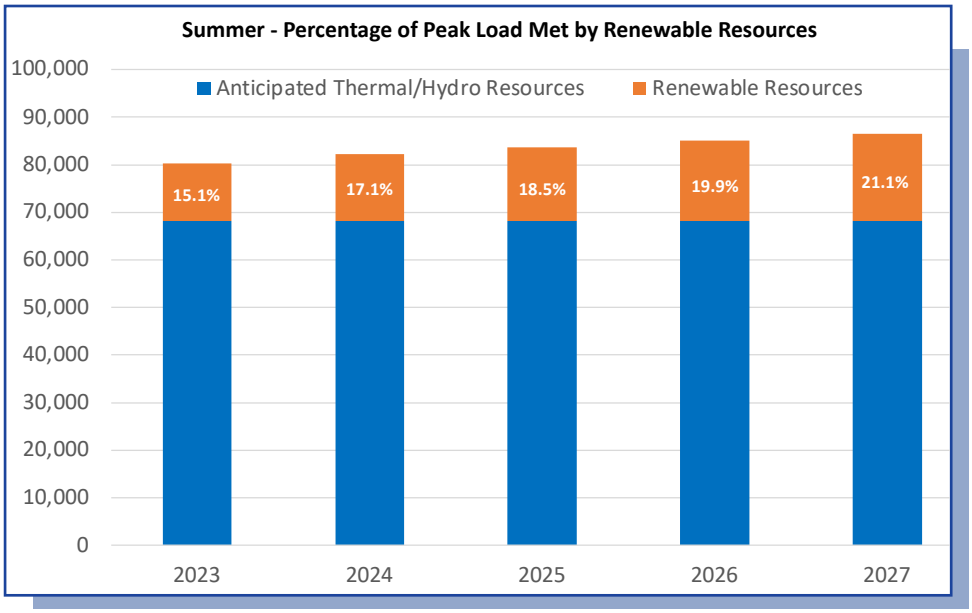


Gas curtailments reduced in 2022 and were comparable to 2014 and 2018 that also had notable cold weather periods.

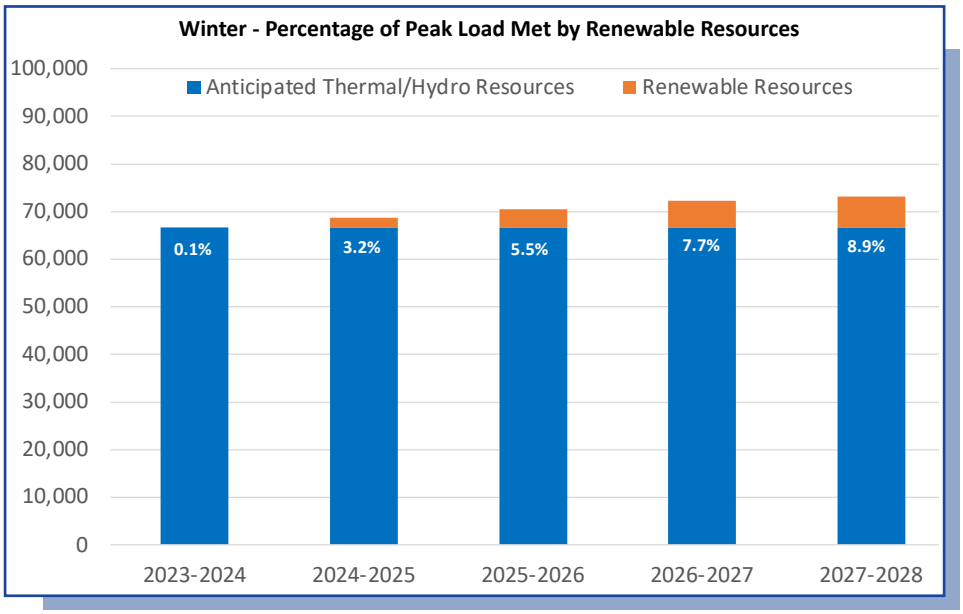


RESOURCE ADEQUACY

ERCOT no longer has sufficient dispatchable resources to meet its projected 50/50 peak and extreme peak loads. The balance of energy not provided by dispatchable thermal resources must be provided by renewable resources, both at peak and during other periods with limited thermal resource availability. The percentage of peak load provided by renewable resources has shown an increase over the last few years, a trend that is expected to continue. The increased level of variable renewable generation results in a growing need to have flexible resources and demand response available that can be reliably called upon—at times with minimal notice or for short periods across multiple days to balance electricity supply and demand as conditions occur. Flexible resources and demand response are necessary during some periods to ensure resource adequacy and meet ramping needs. Batteries and other energy storage options may play a key role, especially for shorter duration needs. Should solar and wind output fall below expectations during peak conditions, ERCOT will need to draw on such flexible resources and/or demand response to maintain balance between load and generation. Imports from outside of the Interconnection are often fully utilized and not expected to grow in magnitude soon. Additionally, the high levels of solar resources generate a need for more flexible resources to match steep ramping conditions during times when the change in wind or solar output changes rapidly.



Sufficient operating reserves were maintained during the all-time summer peak day in July 2022 and again during Winter Storm Elliott in December 2022.



Gas curtailments decreased in 2022 and were comparable to 2014 and 2018, winters that also had notable cold weather periods. Natural gas supply and delivery, and alternative fuel capability and availability for gas generation (including blackstart units) will be the focus of follow-up recommendations from Winter Storm Uri in 2023.

Approximately 28,000 MW of additional renewable and storage resources are expected by the end of 2025. These additions will continue to drive changes in how ERCOT manages and dispatches generation. Combined wind and solar generations curtailments exceeded 7,600 gigawatt-hours (GWh) in 2022.

The dramatic increase in Hourly Reliability Unit Commitments (HRUC) in 2021 continued and increased in 2022. HRUC commitments totaled 115 units for 8,336 commitment hours. The primary reason for the commitments was capacity accounting for approximately 80 percent of all HRUC hours.

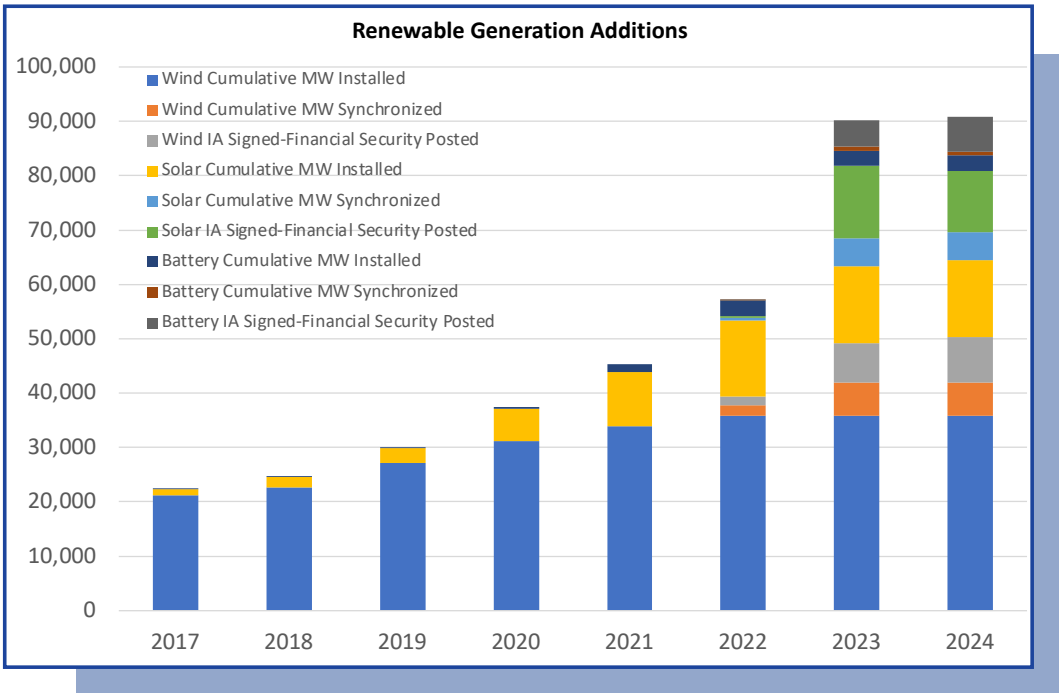
RESOURCE ADEQUACY

ADDITIONAL HIGHLIGHTS FOR 2022 INCLUDE:

- Primary Frequency Response achieved a median value of 1,199 MW/0.1 Hz versus the NERC obligation of 412 MW/0.1 Hz.
- No Reportable Balancing Contingency Event Recovery Period failures occurred in 2022.
- One Reportable Balancing Contingency Event greater than the Most Severe Single Contingency (MSSC) occurred in 2022.

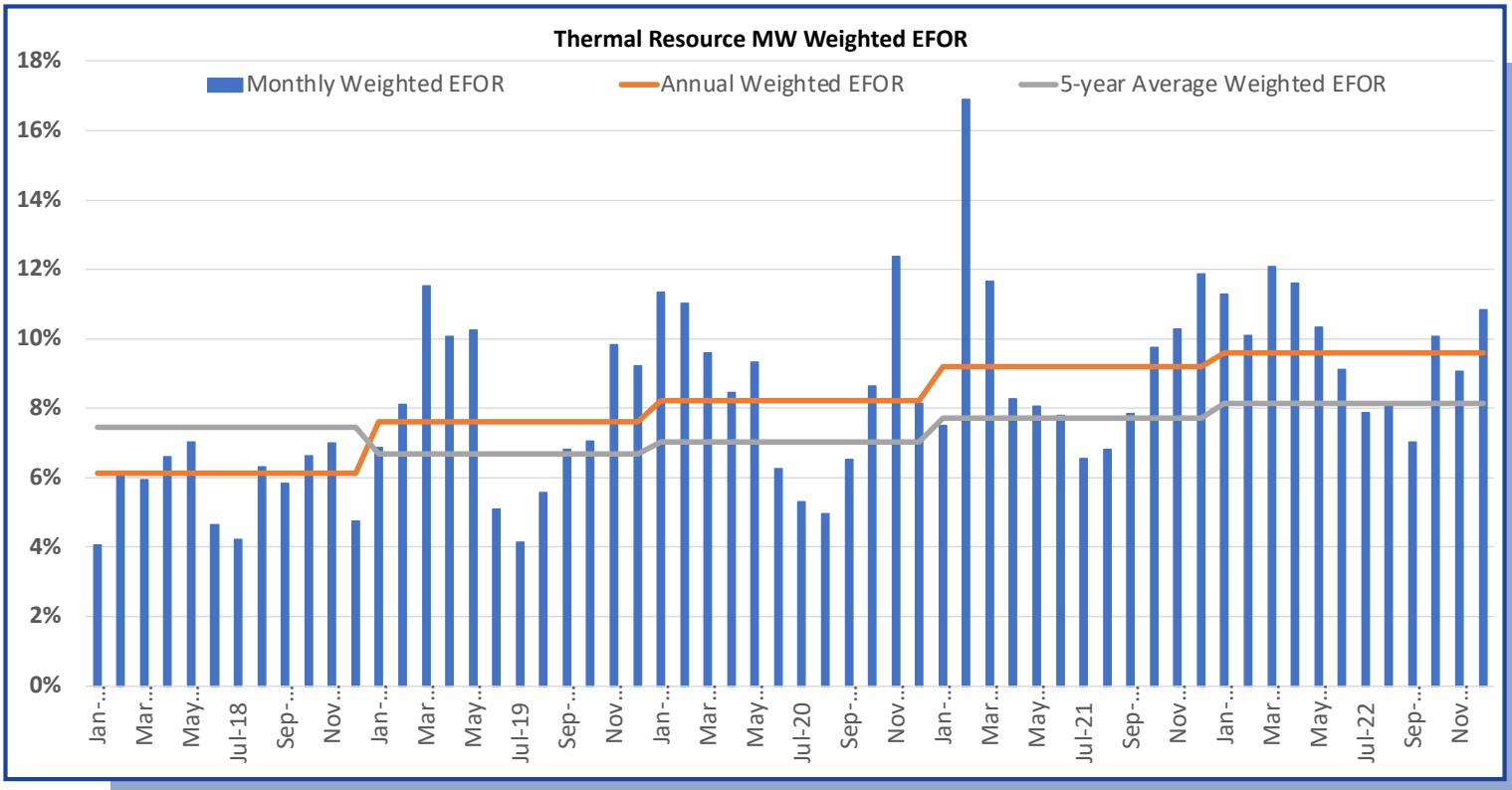
AREAS TO MONITOR INCLUDE:

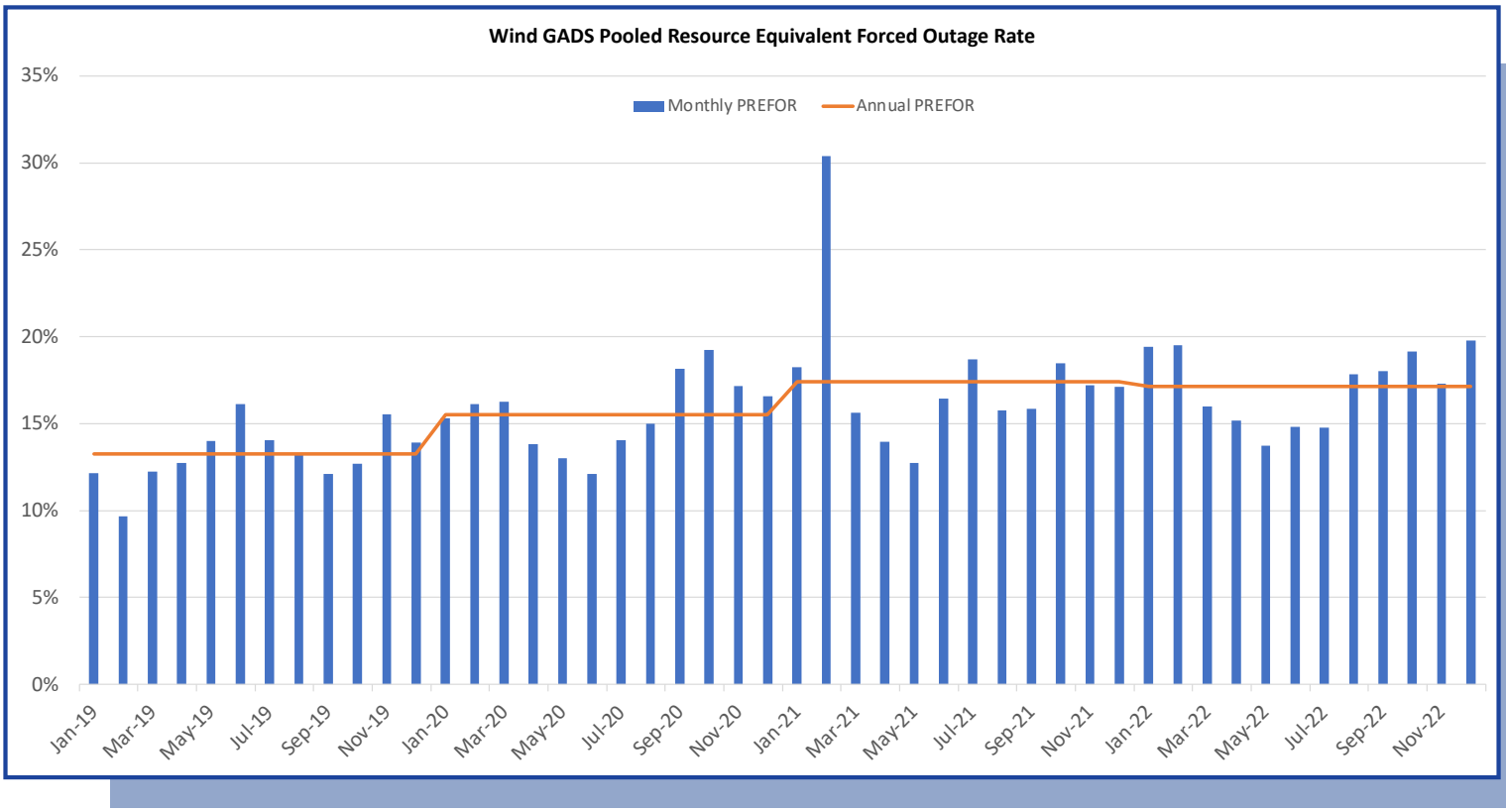
- Weatherization of generation resources will continue to be a primary focus for the foreseeable future.
- Additional follow-up and potential requirement changes to improve voltage ride-through for IBRs will be a primary focus after the Odessa disturbance in June 2022.



- GADS EFOR (unweighted) for thermal resources was 10.4 percent for 2022 and long-term trends show an increasing rate.
- GADS Wind Resource EFOR increased to 17.1 percent in 2022 versus 16.1 percent in 2021.
- Natural gas supply and delivery, and alternative fuel capability and availability for gas generation (including blackstart units) will be the focus of follow-up recommendations from Winter Storm Uri in 2023.

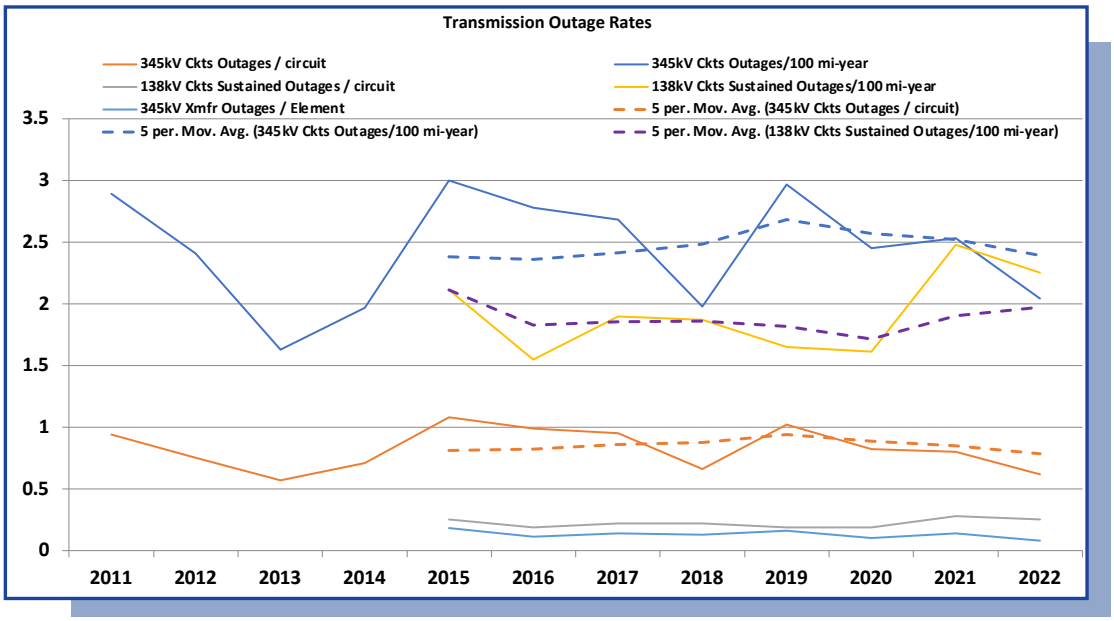
RESOURCE ADEQUACY

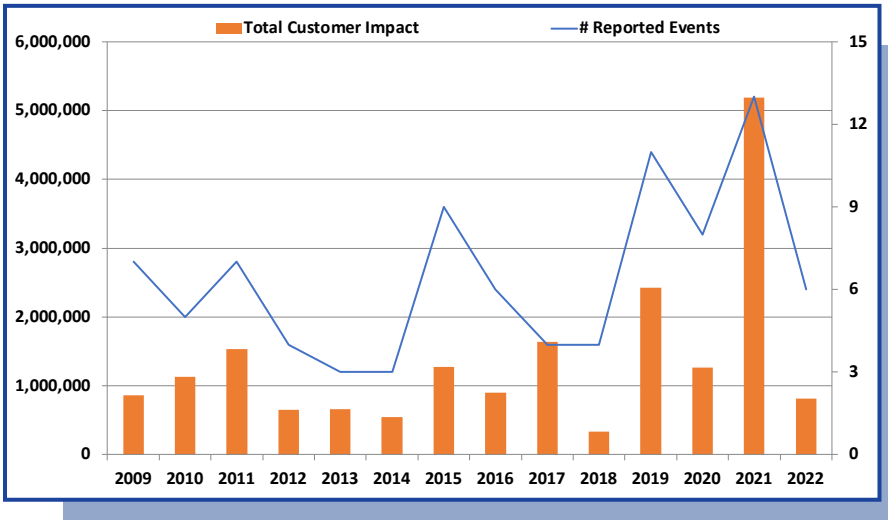




SYSTEM RESILIENCE

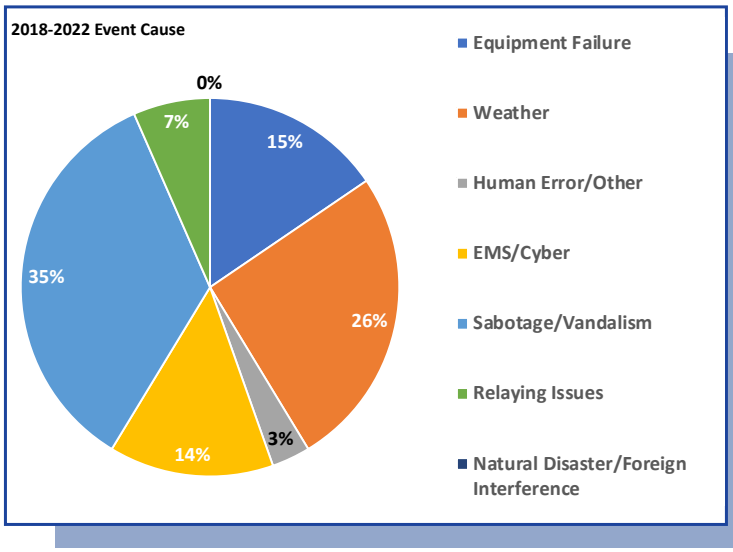
345 kV circuit automatic outage rates remained flat near the five-year moving average. 138 kV outage rates were also flat near the five-year moving average. As in prior years, duration of sustained outages was primarily due to failed substation or circuit equipment.





2022 customer outages were within historical norms.

Equipment failure and weather continue to drive major events. Physical intrusions and damage reports have increased significantly.



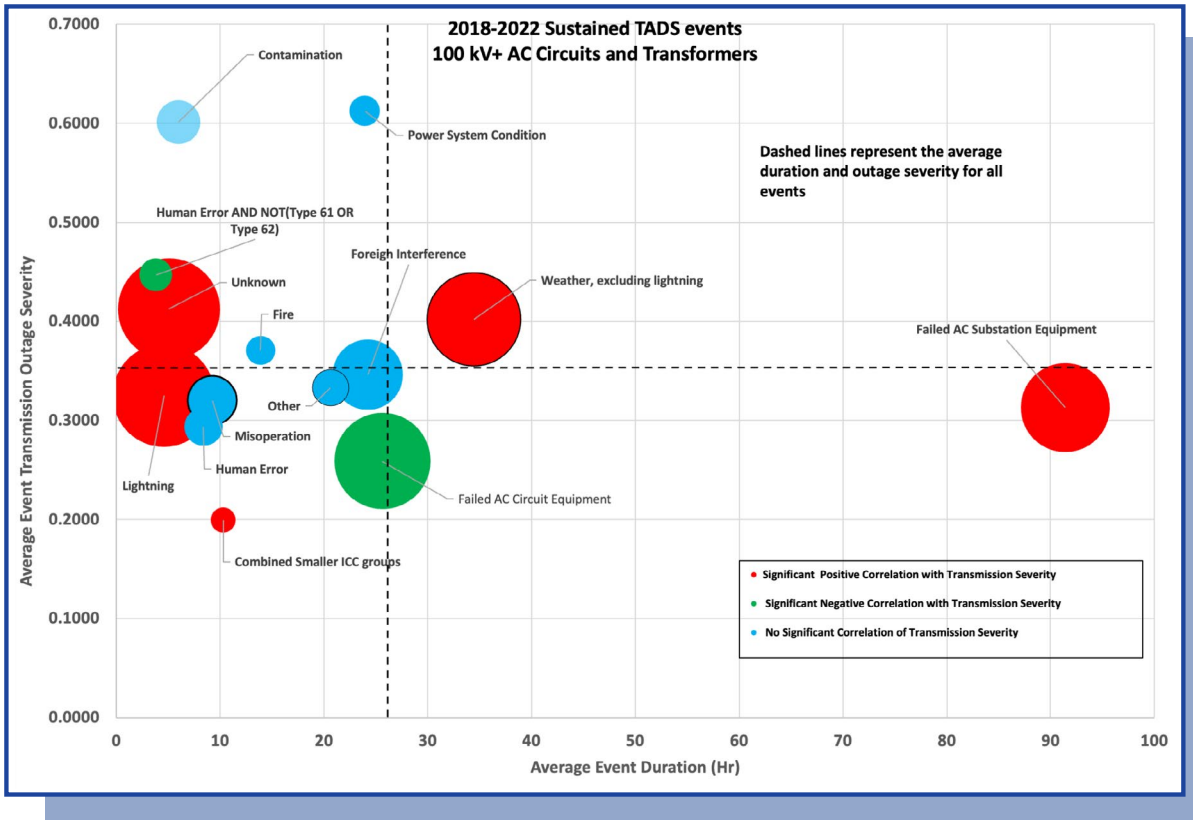
The Odessa disturbance, Texas City outage, Winter Storm Elliott, and Panhandle wind event were the major events for 2022.

SYSTEM RESILIENCE

The Region's BPS has historically shown that it can withstand contingency events that are normally prepared for and studied in the planning and operations horizons. Multiple extreme events in the last five years have tested the transmission grid's ability to maintain the reliability levels expected by Texans. These include Hurricane Harvey in August 2017, the cold weather event of January 2018, the Panhandle ice storm of October 2020, Winter Storm Uri in February 2021, and Winter Storm Elliott in December 2022. Generation system outage performance on extreme days continues to be related to cold weather events. The extreme day for 2022 generation outages was during Winter Storm Elliott. The Odessa disturbances in May 2021 and June 2022, and the Panhandle wind disturbance in March 2022, all highlighted voltage ride-through issues with wind and solar units. Protection System Misoperations also magnified the impact of several system events, causing the loss of additional transmission elements.

Despite the higher number of affected circuits and equipment associated with major events, examination of reported transmission outage data over time shows that rates trend in a consistent range and the relative order of causes have not changed significantly for both 345 kV and 138 kV systems. Failed transmission circuit and substation equipment continued to be the dominant cause of sustained outages' duration, accounting for 81 percent of the 345 kV and 69 percent of the 138 kV sustained outages' duration, respectively, from 2018 through 2022.

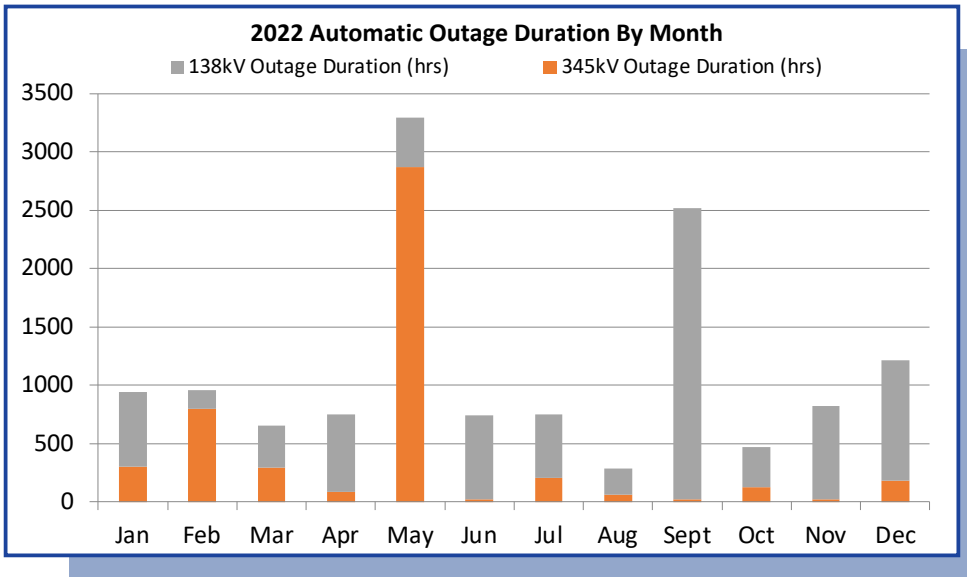
Transmission outage severity, as measured by the cumulative unavailable ratings of the circuit(s) outaged (expressed in megavolt-amperes (MVA)) and duration of the outage, is one measure of transmission system resilience. Outage severity can be further broken down by the causes of the sustained outages.



SYSTEM RESILIENCE

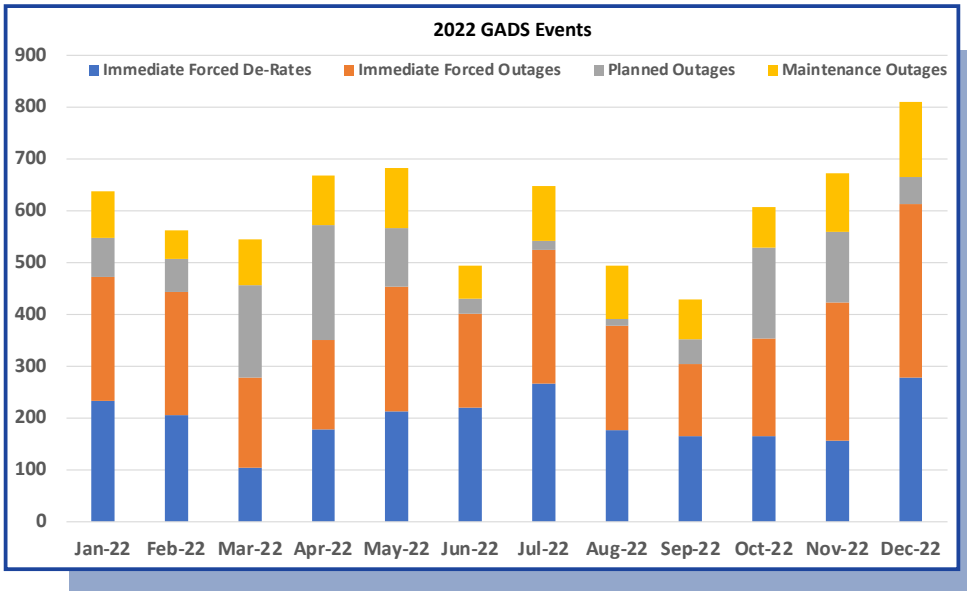
2022 HIGHLIGHTS FROM THE ANALYSIS OF RESILIENCE INCLUDE:

- Long-term trends are indicating stable trends in outage rates per circuit and per 100 miles of line for the 345 kV and 138 kV systems.
- For 345 kV transmission circuits, the predominant causes for sustained outages in 2022 were weather (excluding lightning), unknown, and foreign interference, representing 45 percent of the total sustained outages. Failed transmission circuit equipment accounted for 61 percent of the outage duration.
- For 138 kV transmission circuits, the predominant causes for sustained outages in 2022 were foreign interference, unknown, failed circuit equipment, and failed substation equipment, representing 61 percent of the total sustained outages. Failed transmission circuit equipment and foreign interference accounted for 60 percent of the outage duration.



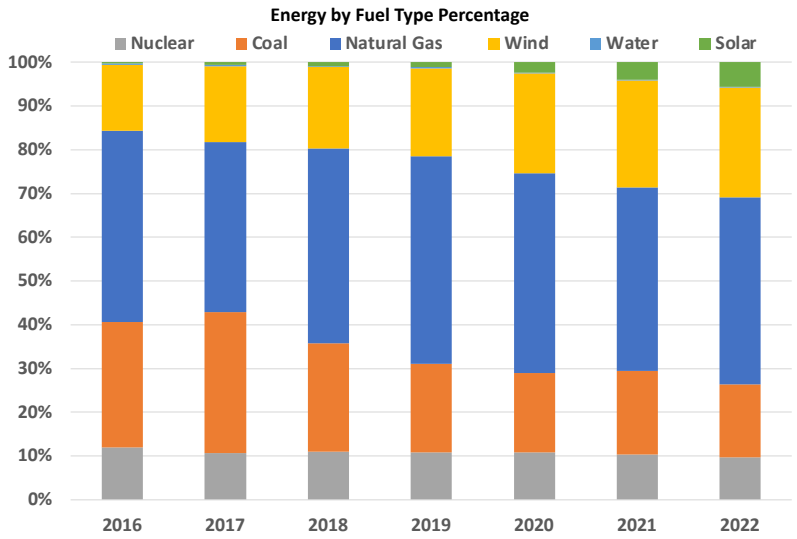
AREAS TO MONITOR:

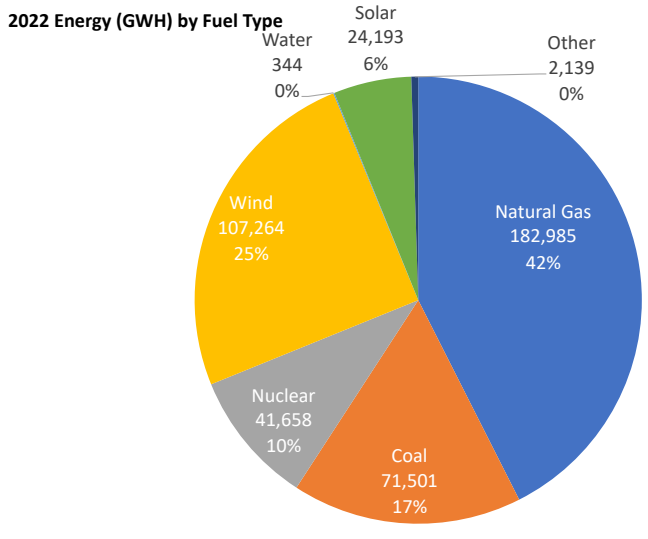
- Weatherization of generation and transmission resources will continue to be a primary focus for the foreseeable future.
- Additional follow-up and potential requirement changes to improve voltage ride-through for IBRs will also be a primary focus.
- Generation system performance on extreme days during cold weather events. Extreme day generation outages for 2022 occurred during Winter Storm Elliott.

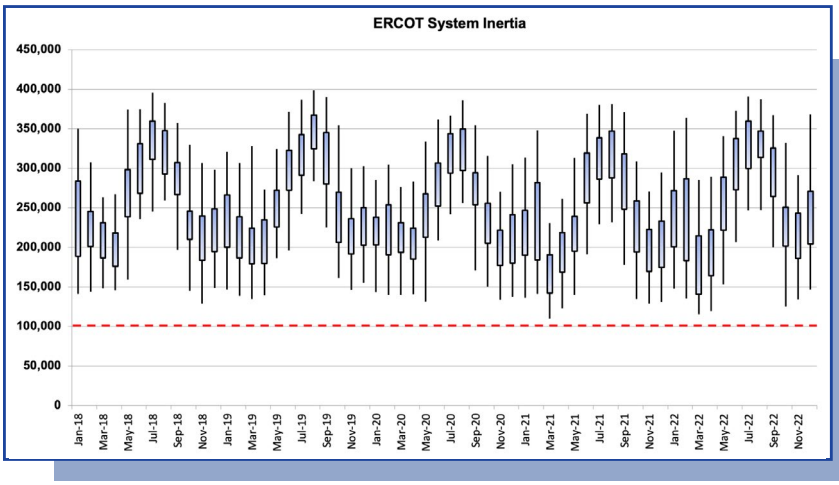


- Protection System Misoperations continue to be an important causal factor in reported system events.

GRID TRANSFORMATION



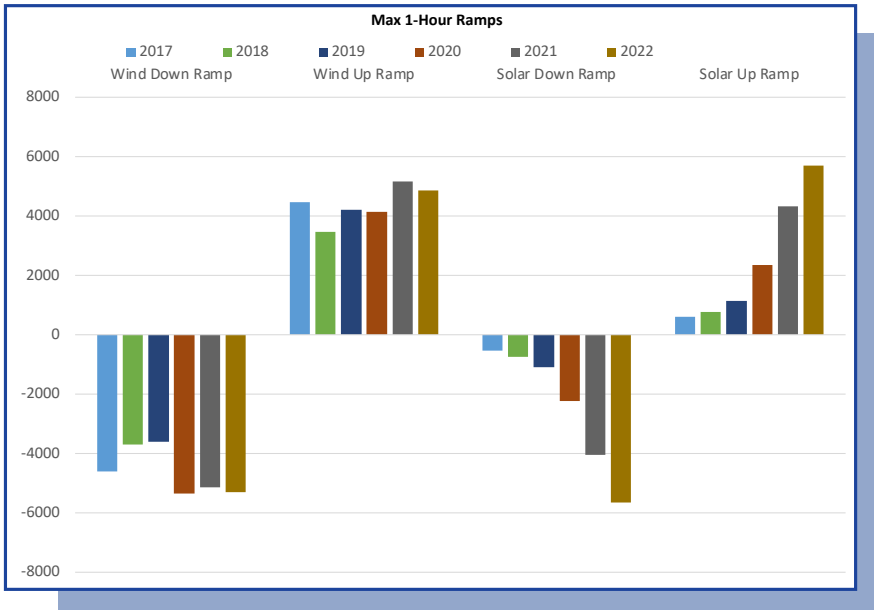




In 2022, 499 MW of fossil generation was retired or mothballed and 987 MW of gas generation was added. Simultaneously, over 5,301 MW of renewable generation was approved for commercial operation. Inertia levels during the highest penetration hours were comparable to 2021. The margin between minimum inertia conditions and critical inertia levels remains well within adequate safety margins.

Since 2016, renewable generation has increased from 17% to 31% of energy while coal has decreased from 29% to 17%.

Maximum up and down ramp magnitudes continue to increase as solar generation increases. Maximum solar up and down ramps exceeded 5,500 MW per hour. ERCOT's incorporation of these ramps into the Generation-to-be-Dispatched (GTBD) formula have helped mitigate these issues.



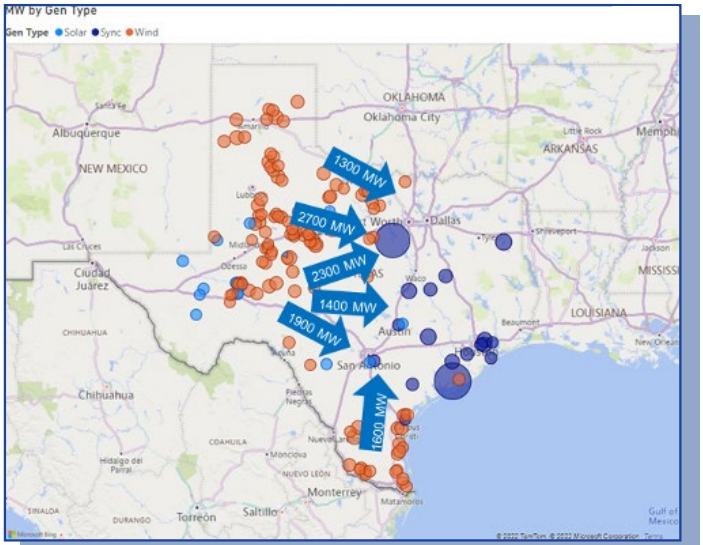
GRID TRANSFORMATION

Today's resource mix continues to evolve with the addition of inverter-based generation resources, energy storage, and government policies that encourage renewable generation. While the growth in wind resources has slowed, there have been exponential increases in both solar and storage resources added to the grid. The integration of the City of Lubbock load in West Texas in 2022 have improved stability conditions to a certain extent, however, stability challenges and weak system strength are expected to continue to be significant constraints. West Texas and the Lower Rio Grande Valley are also continuing to experience rapid growth in wind and solar development. Voltage and dynamic stability constraints associated with large-scale power transfers from West Texas to the east are expected to continue. Management of stability constraints through generic transmission constraints (GTCs) in West and South Texas has resulted in increased curtailments of wind and solar energy in order to maintain the power transfers within stability limits. Combined wind and solar generation curtailments increased by 15 percent in 2022, from 6,600 GWh in 2021 to 7,600 GWh in 2022.

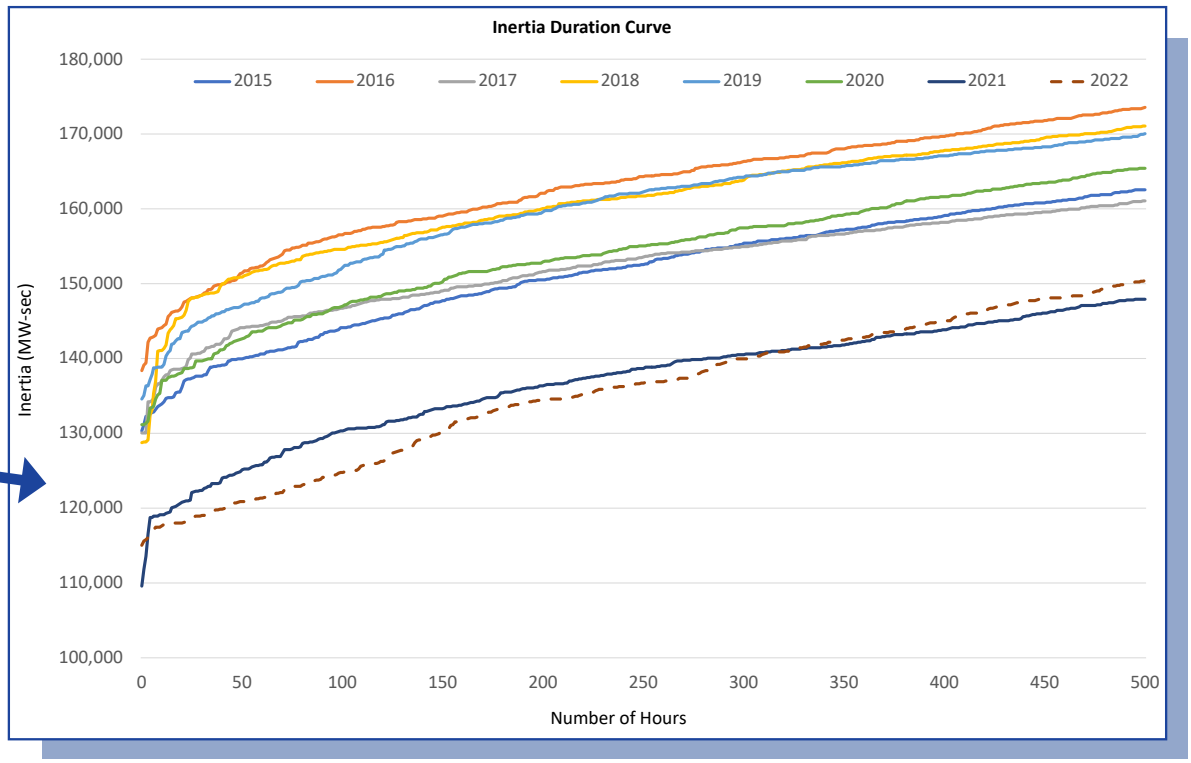
Snapshot of highest renewable penetration period: 4/10/2022 HE09:

- No synchronous generation online in West Texas, Panhandle, or Lower Rio Grande Valley
- ERCOT load: 35,867 MW (net load of 10,565 MW)
- Inertia level: 120.8 GW-sec
- Wind gen: 23,008 MW
- Solar gen: 2,294 MW
- Renewable penetration: 70.5%
- Approx. 2,300 MW of wind and solar curtailments

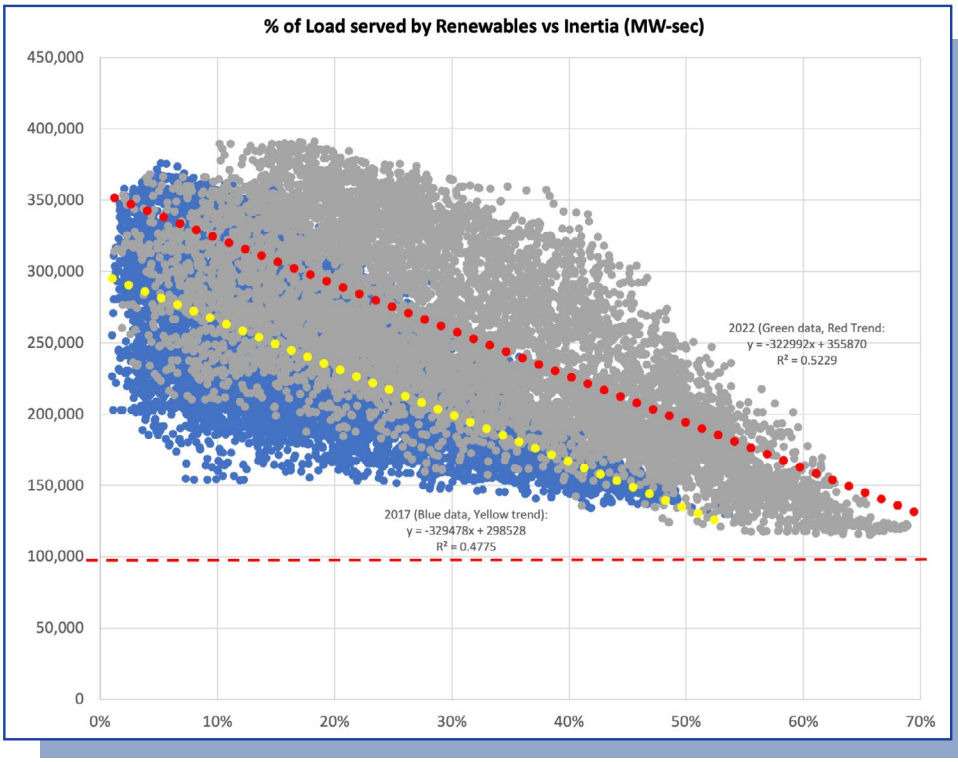
High wind with low load periods (i.e., low inertia) occurred within the year when little or no synchronous generation was on-line in large areas of the Texas Interconnection. Large power transfers from west-to-east and south-to-north can occur under these high wind conditions. This creates risk conditions for voltage stability and low short-circuit current ratios, in addition to issues caused by low inertia levels. These risks are monitored and managed through GTCs, several of which are also IROLs.



GRID TRANSFORMATION



Overall system inertia decreased slightly in 2022 (dashed line) compared to 2021. The minimum hourly inertia level in 2022 was 115.0 GW-s on March 22, 2021, at HE02 when the intermittent renewable resource (i.e. solar and wind generation) (IRR) penetration level was 65.7 percent and system load was 33,365 MW (net load of 11,445 MW). The chart above shows a comparison of inertia levels during the lowest inertia hours. 2021 and 2022 both indicate the decline in inertia levels during these hours.



The chart to the left shows the relationship between the percentage of load served by renewables and system inertia levels. The chart compares 2017 versus 2022. Notice how 2022 has shifted significantly to the right as the renewable penetration levels have increased.

GRID TRANSFORMATION

2022 HIGHLIGHTS FROM THE ANALYSIS OF GRID TRANSFORMATION INCLUDE:

- Primary frequency response continues to surpass NERC requirements.
- An IROL was exceeded one time (totaling six minutes) in 2022.

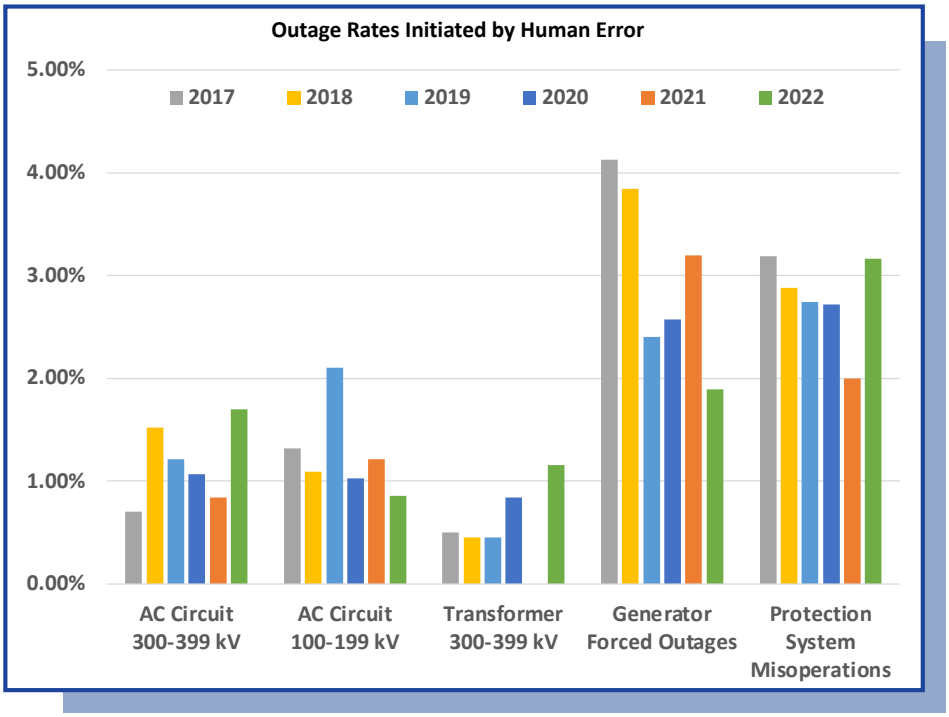
AREAS TO MONITOR INCLUDE:

- Ratio of dispatchable generation to renewable generation continues to change rapidly. In 2022, 499 MW of coal and natural gas capacity was retired or mothballed. The system added 5,301 nameplate MW renewable generation capacity and storage, plus 987 MW of gas generation.
- Maximum one-hour ramp magnitudes for solar generation continue to increase. The changes that ERCOT has implemented to include solar ramp rates in the GTBD formula have managed frequency variations during these ramp periods, however increased solar penetration will continue to stress the system and may require more flexible resource capability.
- Average synchronous inertia across most operating hours was comparable to 2021, which was a significant decrease from 2020.
- Low voltage ride-through issues for wind and solar inverters continue to occur during transient voltage disturbances on the transmission system.

HUMAN PERFORMANCE

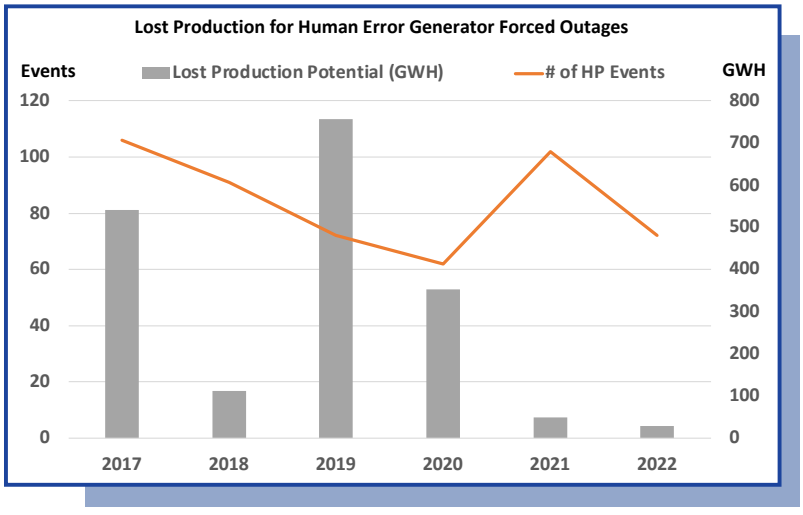
2022 HIGHLIGHTS FROM THE ANALYSIS OF HUMAN PERFORMANCE INCLUDE:

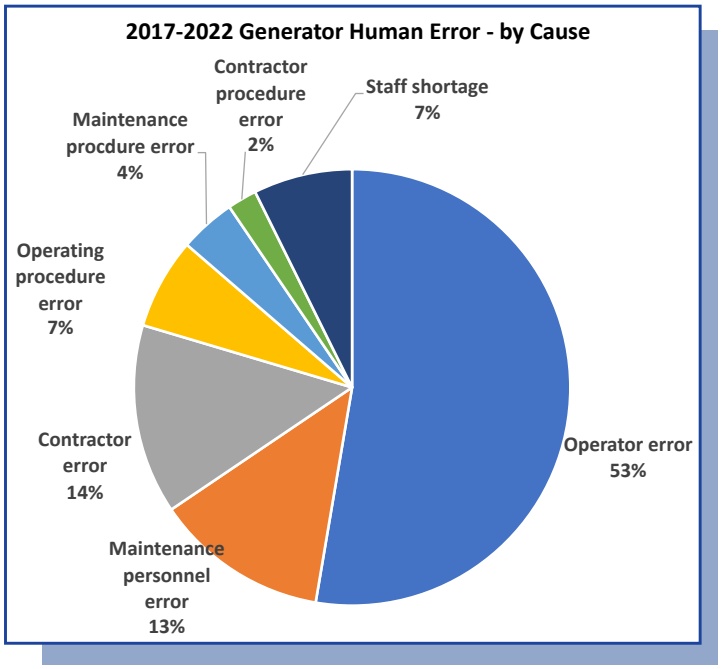
- Outage rates in GADS data caused by human error are continuing to show an improving, downward trend.
- TADS human error outage rates for 138 kV circuits decreased in 2022 compared to prior years.
- TADS human error outage rates for 345 kV circuits, transformers, and misoperations increased in 2022 compared to prior years.



AREAS TO MONITOR INCLUDE:

- Causal analysis of human errors in Protection System Misoperations continue to show repeated issues due to lack of adequate error-checking processes and procedures.

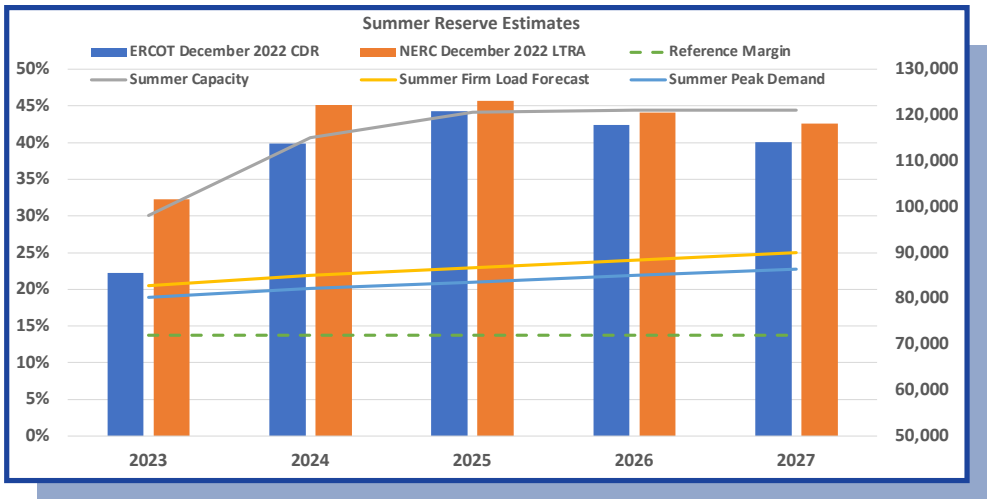




BULK POWER SYSTEM PLANNING

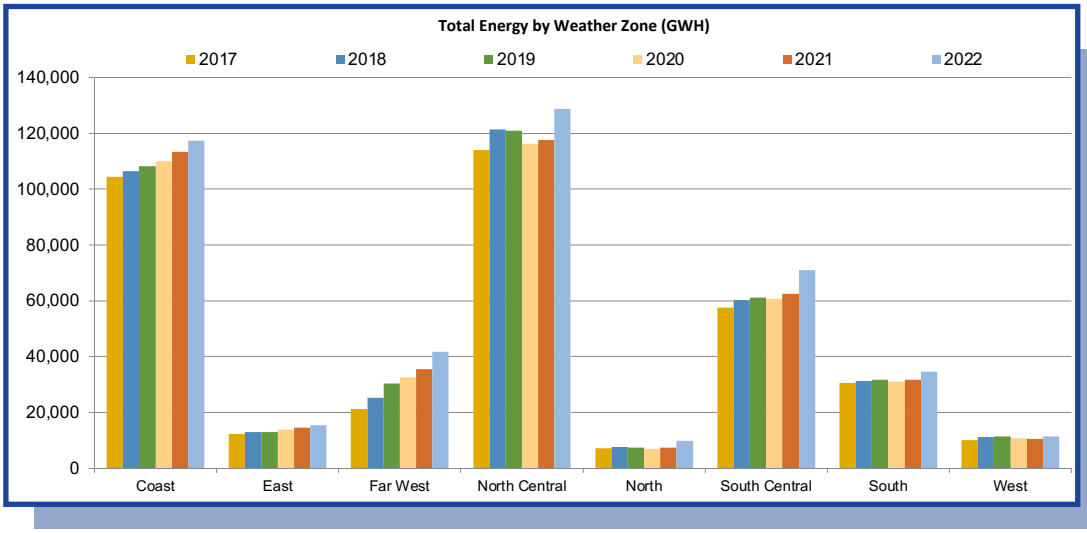
The 2022 NERC Long-Term Reliability Assessment (LTRA) shows a planning reserve margin above the 13.75 percent target for the next five years in the Region. ERCOT's 2023-2032 Capacity, Demand and Reserves (CDR) report also shows a planning reserve margin above the 13.75 percent target for the next five years. While both of these reports are focused on the long-term planning reserve margins, the results will differ due to multiple factors such as data collection dates and forecasting of load.

ERCOT had 1,688 MW of non-modeled generation capacity and 1,972 MW of unregistered distributed generation resources (DGR) at the end of 2022.



2022 HIGHLIGHTS FROM THE ANALYSIS OF BULK POWER SYSTEM PLANNING INCLUDE:

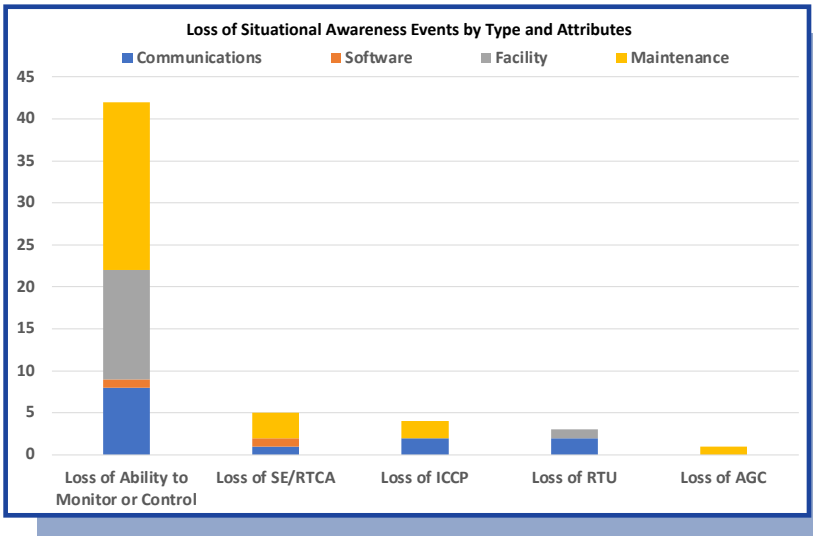
- Summer Peak: Actual 79,830 MW versus projected 77,884 MW
- Winter Peak: Actual 73,976 MW versus projected 67,423 MW
- Renewable Percentage of Total Load at Summer Peak: 19.4 percent
- Peak hourly wind generation: 26,871 MW on May 29, 2022
- Peak hourly solar generation: 10,039 MW on October 1, 2022
- Peak hourly renewable penetration: 70.5 percent on April 10, 2022



AREAS TO MONITOR INCLUDE:

- As of December 2022, ERCOT projections indicate utility-scale solar generation will increase 230 percent to over 34,000 MW, wind generation will increase seven percent to more than 39,600 MW, and storage generation will increase 300 percent to over 8,500 MW during the next two years (based on current signed generation interconnect agreements with financial security).
- Load growth rates in the Coastal, South Central, and Far West Weather zones continue to drive the overall ERCOT demand.

LOSS OF SITUATIONAL AWARENESS

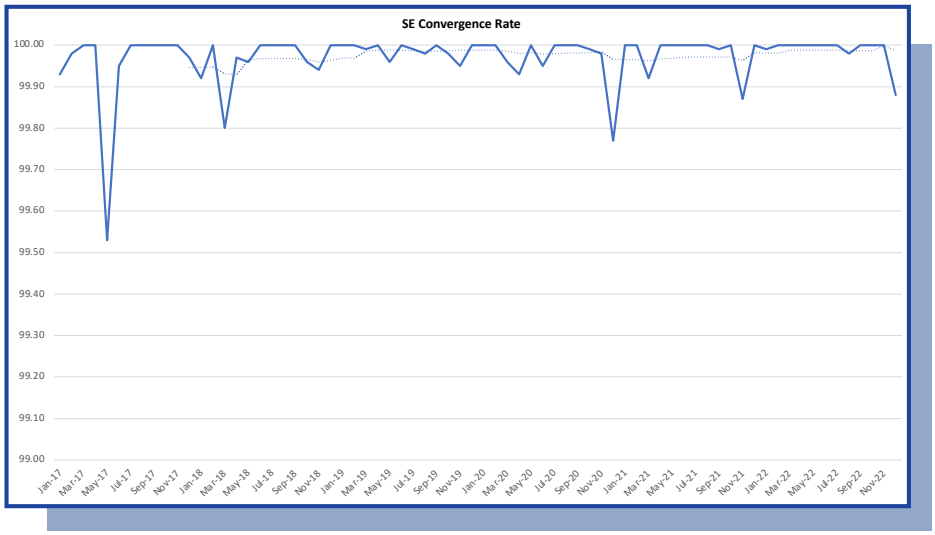


LOSS OF SITUATIONAL AWARENESS EVENTS ARE BROKEN DOWN INTO SEVERAL CATEGORIES BY THE CAUSE OF THE EVENT. THESE ARE:

- Loss of ability to monitor or control
- Loss of State Estimator (SE) or Real-time Contingency Analysis (RTCA)
- Loss of Inter-Control Center Communication Protocol (ICCP) links
- Loss of remote terminal units (RTUs)
- Loss of Automatic Generation Control (AGC)

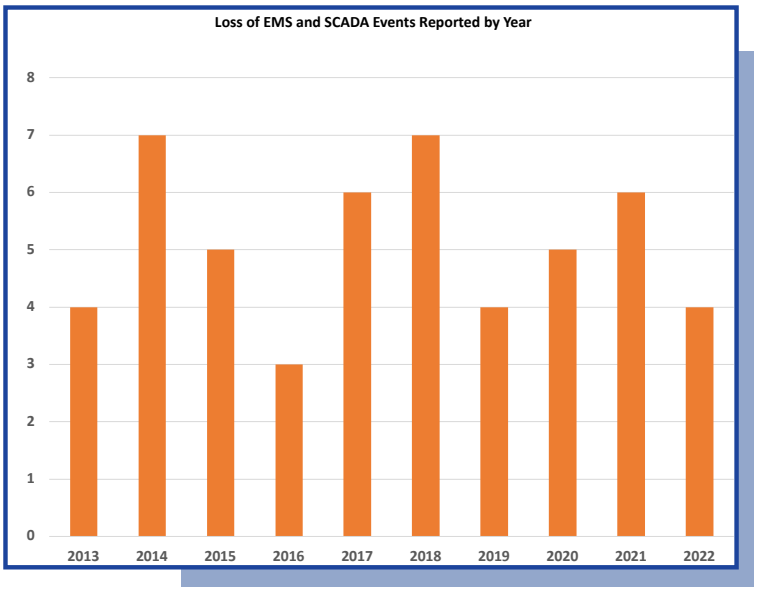
2022 HIGHLIGHTS FROM THE ANALYSIS OF LOSS OF SITUATIONAL AWARENESS INCLUDE:

- Convergence rates for ERCOT's state estimator continue to surpass the goal of 97 percent, exceeding 99.99 percent in 2022.
- Telemetry availability rates remain stable at approximately 97 percent overall.

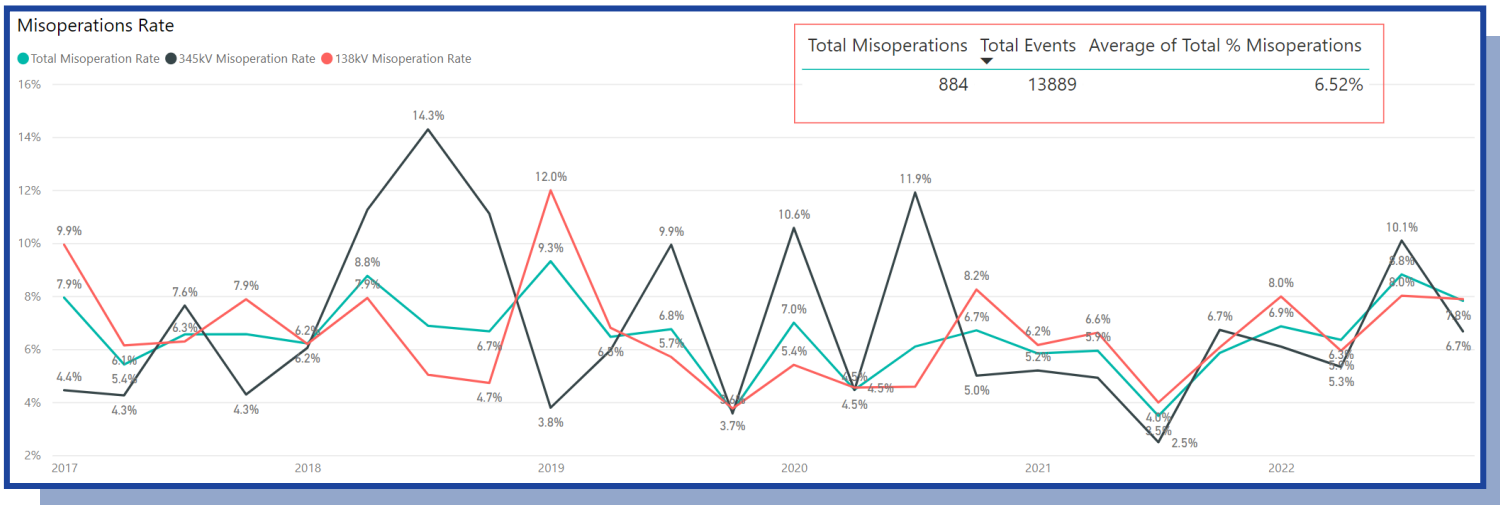


AREAS TO MONITOR INCLUDE:

- A total of four Category 1 loss of System Control and Data Acquisition (SCADA) or Energy Management System (EMS) events were reviewed in 2022 at Transmission Operators' control facilities. Average duration was approximately 68 minutes. Two events were caused by maintenance activities on the system (i.e., data base uploads or other system modifications). These types of activities are historically responsible for approximately 50 percent of loss of SCADA or EMS events.

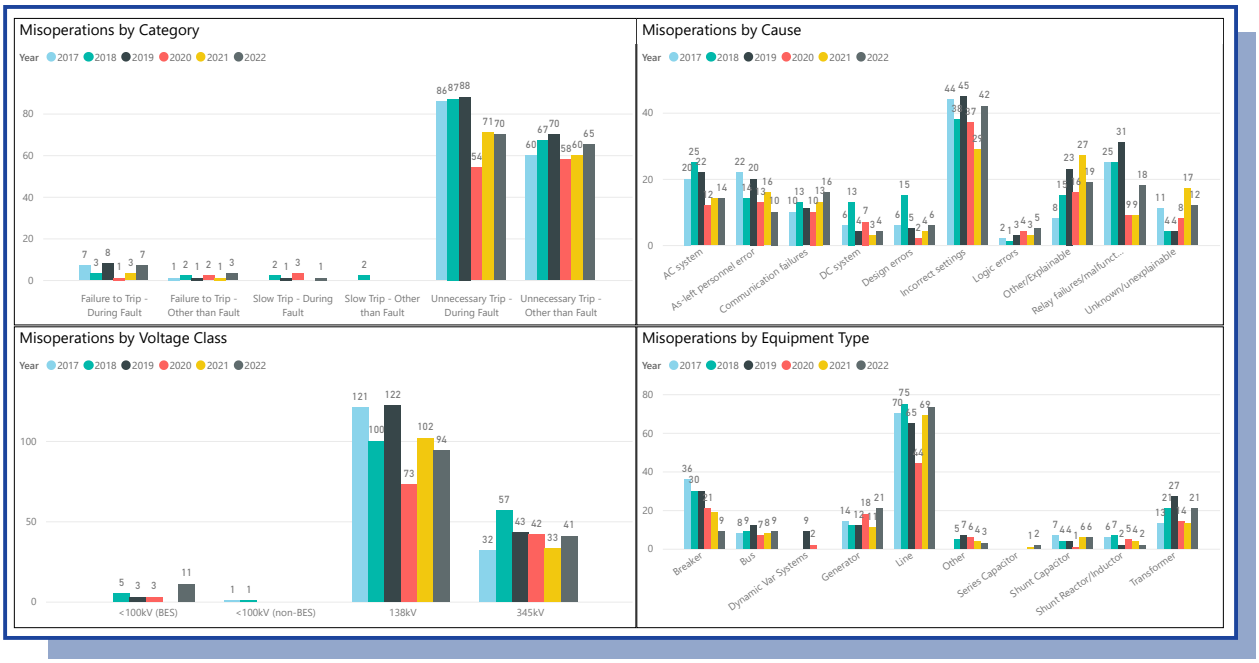


PROTECTION SYSTEM MISOPERATIONS



2022 HIGHLIGHTS FROM THE ANALYSIS OF REPORTED PROTECTION SYSTEM MISOPERATIONS INCLUDE:

- Since January 2018, the overall transmission system Protection System Misoperation rate has been essentially flat, at 7.2 percent in 2018 to 7.3 percent in 2022. The five-year misoperation rate from 2018-2022 was 6.3 percent.
- In 2022, three main categories account for 58 percent of the total Misoperations: incorrect settings/ logic/design (36 percent), relay failures (12 percent), and other (13 percent).
- Misoperations due to incorrect settings, communication failures, and relay failures increased in 2022 compared to 2021.
- Misoperations due to AC systems and as-left personnel error are showing a positive downward trend. However, unknown errors and other/explainable errors continue to show negative upward trends.
- Corrective actions were completed or are in progress on approximately 90 percent of Misoperations that occurred in 2022.

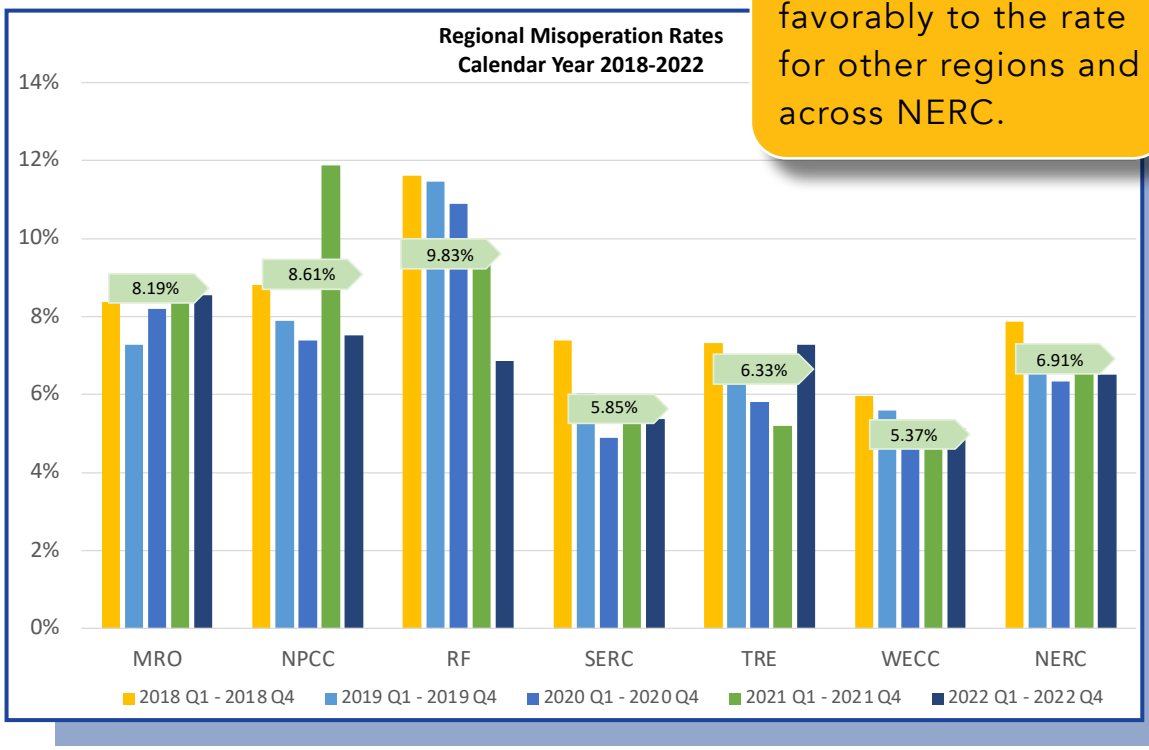


PROTECTION SYSTEM MISOPERATIONS

AREAS TO MONITOR INCLUDE:

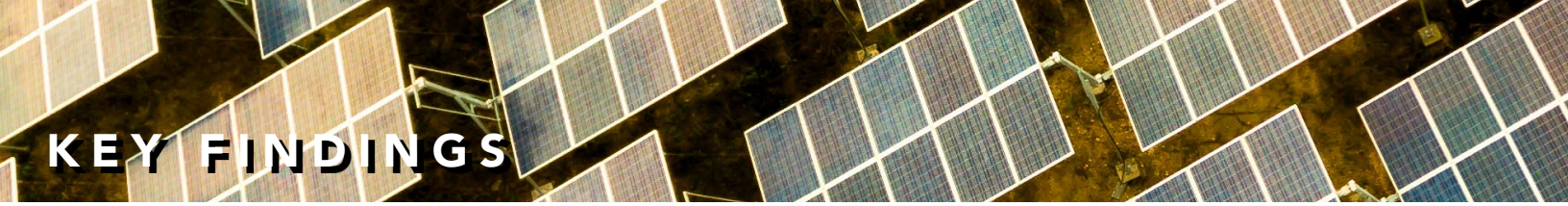
- Incorrect settings, logic, and design errors remained the largest cause of Misoperations, accounting for 35 percent of Misoperations in 2022.
- Misoperations due to incorrect settings, communication failures, and relay failures increased in 2022 compared to 2021.
- Multiple system events continue to occur where Protection System Misoperations expanded the magnitude of the transmission elements outaged or caused loss of generation or load.

The Texas RE Region Protection System Misoperation rate continues to compare favorably to the rate for other regions and across NERC.



Despite an overall downward trend in the annual Misoperation rate, Protection System Misoperations were a contributing factor in several system events in 2022. In all of these events, the Misoperations expanded the magnitude of the transmission elements outaged or caused loss of generation or load. Loss of multiple elements resulted from Protection System Misoperations after faults on the following dates:

- February 4, 2022: A fault occurred on a 138 kV disconnect switch, which when combined with protective relay Misoperations caused the loss of multiple 138 kV lines and over 1,200 MW of generation.
- June 27, 2022: A fault occurred on a 138 kV bus, which when combined with protective relay Misoperations caused the loss of two 138 kV lines, two generating units comprising 372 MW of generation, and two auto transformers.
- October 31, 2022: A fault occurred on a 345 kV transformer along with a slow trip of the Protection System, which caused the loss of four 138 kV lines and 680 MW of generation.
- December 7, 2022: A fault occurred at a 138 kV substation due to a failed potential transformer, causing the loss of multiple 138 kV lines and over 1,600 MW of non-consequential voltage-sensitive load reduction.



PHYSICAL AND CYBER SECURITY

Critical infrastructure protection continues to demand vigilance for the reliability and security of the electric grid. For 2022, the Region experienced minimal impact from physical and cyber security events affecting BPS facilities. Additionally, there were numerous notable risks and events that occurred outside the electric industry and the Region that merit further consideration. Remote code execution vulnerabilities such as Log4Shell, PrintNightmare, and VMware vSphere continued to be known exploited vulnerabilities. Foreign state-sponsored (Russia, China, North Korea, etc.) advanced persistent threats that continued to present challenges in 2022, such as the malware PIPEDREAM affecting industrial control systems.

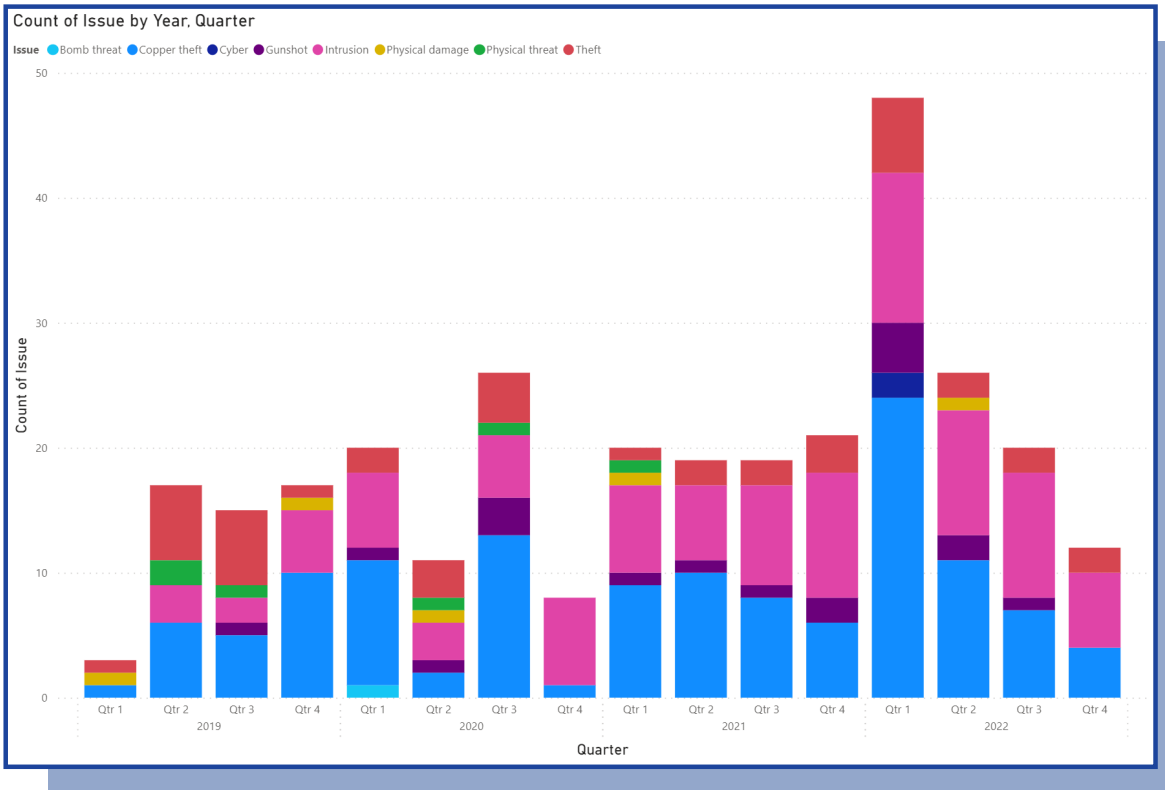
2022 HIGHLIGHTS FROM THE ANALYSIS OF PHYSICAL AND CYBER SECURITY EVENTS INCLUDE:

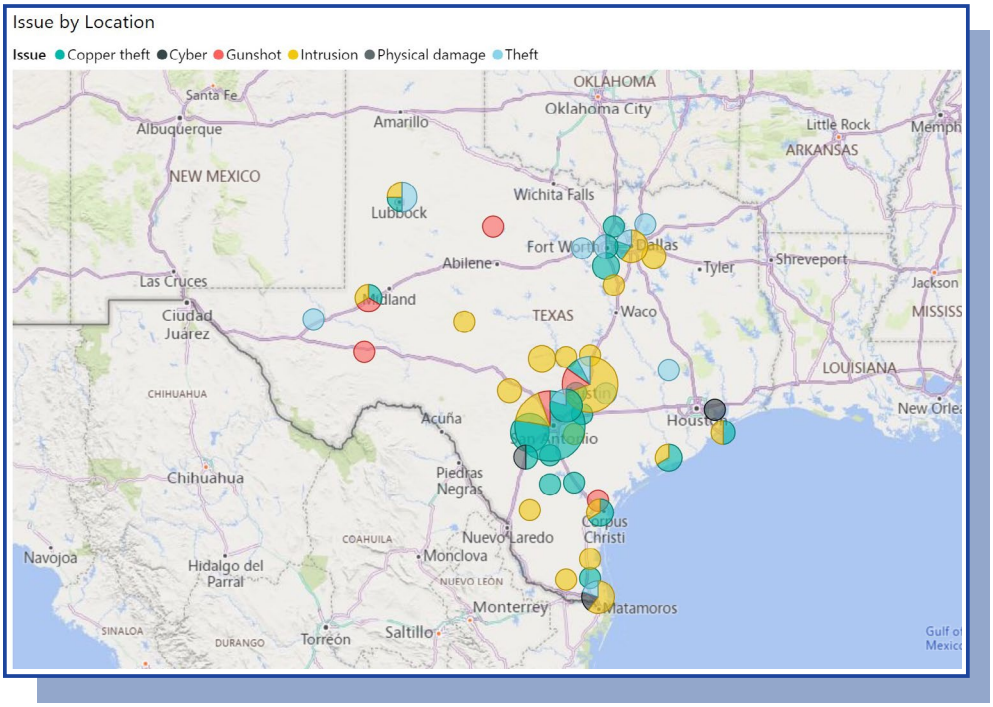
- January 2022 – President Joe Biden signed the Memorandum (NSM-8) on "Improving the Cybersecurity of National Security, Department of Defense, and Intelligence Community Systems."
- February 2022 – The Office of the Director of National Intelligence released the Annual Threat Assessment of the U.S. Intelligence Community highlighting cyber concerns from numerous threat actors including Russia and China.
- February 2022 – The Department of Homeland Security (DHS) Cybersecurity and Infrastructure Agency (CISA) issued a "SHIELDS UP" advisory regarding Russian cyber threats.
- The Department of Energy (DOE), along with CISA, the National Security Agency (NSA), and the Federal Bureau of Investigation (FBI), issued numerous joint cybersecurity advisories including:
- Joint Cybersecurity Advisory - AA22-047: Russian State-Sponsored Cyber Actors Target Cleared Defense Contractor Networks to Obtain Sensitive U.S. Defense Information and Technology
- Joint Cybersecurity Advisory - AA22-074A: Russian State-Sponsored Cyber Actors Gain Network Access by Exploiting Default Multifactor Authentication Protocols and "PrintNightmare" Vulnerability
    - Joint Cybersecurity Advisory - AA22-083A: Tactics, Techniques, and Procedures of Indicted State-Sponsored Russian Cyber Actors Targeting the Energy Sector
    - Joint Cybersecurity Advisory - AA22-103A: APT Cyber Tools Targeting ICS/SCADA Devices
    - Joint Cybersecurity Advisory - AA22-110A: Understanding and Mitigating Russian State-Sponsored Cyber Threats to U.S. Critical Infrastructure
- December 2022 - FERC directed NERC to study the effectiveness of the existing Reliability Standard for physical security of the BPS (CIP-014), and determine if improvements are needed as a response to physical attacks on substations in North Carolina, Washington, and Oregon.

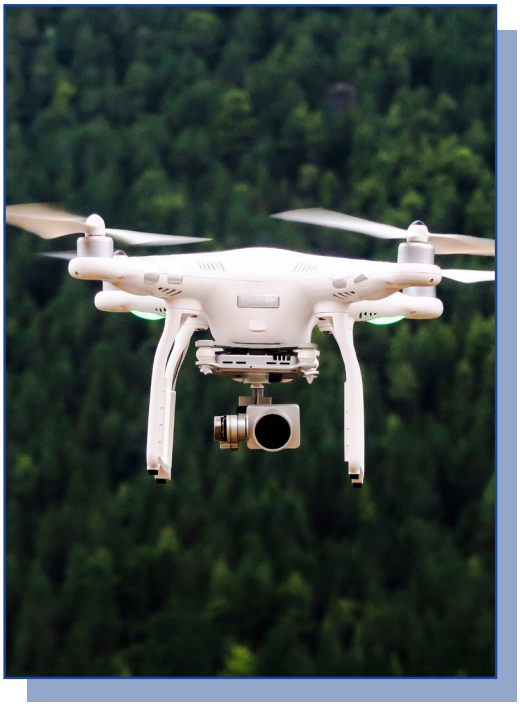
PHYSICAL AND CYBER SECURITY

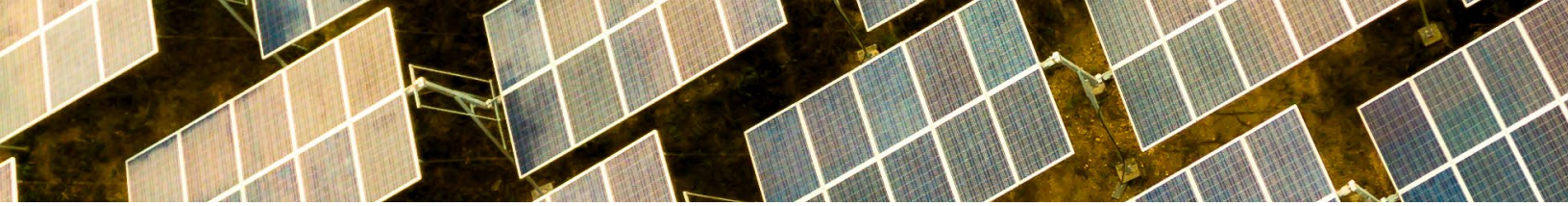
2022 PHYSICAL SECURITY EVENTS AFFECTING BPS FACILITIES:

- Bullet holes found on transformer conservator tank
- Multiple reports of gunshot damage to transmission line conductors and insulators
- Intruder entered control house and operated multiple 138 kV breakers
- Multiple reports of drones flying over substations and power plants
- Suspicious letters received at power plants
- Threats of violence made against power plant employees









FOCUS AREAS FOR 2023

Texas RE continuously evaluates existing and emerging risks to the interconnection as a key input to developing risk-based programs across all areas of our work. The risk priorities and focus areas for 2023 are summarized by likelihood and impact in the risk matrix and discussion below.

CONSEQUENCE/ IMPACT		LIKELIHOOD				
		VERY LIKELY	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
C5	SEVERE					
C4	MAJOR			Extreme Weather & Resource Weatherization		
				Supply Chain		
				Energy Adequacy Planning		
				Gas Supply Restrictions during Cold Weather		
C3	MODERATE		Provision of Essential Reliability Services from a Changing Resource Mix	Malware	IBR Ride-Through	
				Remote Access		
				Inaccurate Resource Modeling		
				Physical Security		
C2	MINOR		Equipment Failures/ Misoperations			
			Loss of Situational Awareness			
C1	NEGLIGIBLE					

RISK LEVEL			
LOW	MODERATE	HIGH	VERY HIGH

EXTREME WEATHER & RESOURCE ADEQUACY

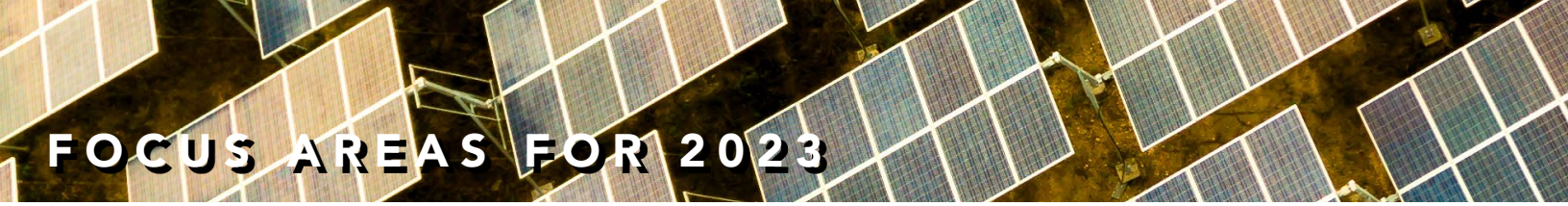
In February 2021, Winter Storm Uri impacted the entire South-Central United States, including Texas. Since February 2021, Texas regulators, ERCOT, and Generator Owners have implemented a range of winter preparedness measures, along with other reforms, aimed at improving generator performance during extreme weather events and ensuring effective coordination and information sharing with planners and operators. In addition, NERC Reliability Standards addressing cold weather preparedness, winterization plans, and information sharing became effective in April 2023, with additional requirements in progress.

2022's Winter Storm Elliott undcerscored the importance of these ongoing measures and the need for continued vigilance in connection with extreme weather preparedness and planning. The storm also impacted Texas with extreme cold temperatures and resulted in outages due to freeze-related issues and natural gas curtailments. However, ERCOT did not experience any capacity conditions that necessitated an energy emergency declaration, even as it set a new all-time winter peak record of 73,976 MW. Parts of the Eastern Interconnection, though, had energy emergency load shed events due to generation capacity issues. A FERC inquiry team is currently investigating these issues and is expected to issue a report later in 2023.

Winterization of generation and transmission resources, as well as preparation for extreme weather generally, is expected to continue to be a primary focus area for the foreseeable future.

INVERTER-BASED RESOURCE RIDE-THROUGH

Failures of IBRs have contributed to a steady stream of system events in recent years. These events have occurred primarily in California and Texas and have grown in scope and severity as renewable generation has increased penetration. For example, the 2022 Odessa Disturbance involved over 1,700 MW of reduced output from solar PV facilities up to several hundred miles away from the location of the initiating event, a single-line-to-ground fault at a 345 kV substation near Odessa, Texas.



FOCUS AREAS FOR 2023

As noted in the 2022 Odessa Disturbance Report, inverter performance issues continue to be a systemic risk to BPS reliability. In particular, the inability of IBRs to reliably ride through faults and support the BPS with essential reliability services poses a reliability concern. ERCOT is working with Generator Owners (GOs) to mitigate any abnormal performance issues identified in previous disturbances and has taken a proactive approach to address performance issues. In addition, NERC staff have submitted a Standards Authorization Request (SAR) to enhance the current Reliability Standards through the development of a comprehensive ride-through standard. While these mitigation measures are being developed, the increasing penetration of IBRs requires focus on addressing IBR performance issues and ensuring a reliable resource mix that can effectively support the BPS during contingency events.

MALWARE

Advanced persistent threats leveraging malware tools (such as ransomware directed toward numerous types of critical infrastructure) continue to steadily increase. The high-profile ransomware attack on the Colonial Pipeline and recent concerns regarding the PIPEDREAM malware targeting industrial control systems highlight the utmost importance of implementing effective malware protection. Deployment of malware tools across multiple environment layers (IT, OT, network, etc.) to deter, detect, and prevent malicious code and communications is critical to mitigating this threat.

REMOTE ACCESS

Remote access interactions between employees, vendors, and other actors continue to expand to leverage technologies and services. As Cyber Assets associated with critical infrastructure become more remote and increasingly inter-connected, the risk of remote access threats and vulnerabilities correspondingly increases as well. Effective implementation of identity and access management, multi-factor authentication, encryption, malware protection, and monitoring and alerting controls are key to protecting from remote access risks such as exploitation of remote code execution vulnerabilities.

SUPPLY CHAIN

The SolarWinds and Microsoft Azure cloud services compromises, along with supply chain shortages stemming from the coronavirus pandemic, have highlighted the need for vigilance in the supply chain realm. A 2021 Presidential Executive Order further emphasized the importance of resilient, diverse, and secure supply chains. Identification, assessment, and mitigation of supply chain risks associated with vendor products and services is critical to enhancing controls relevant to software integrity and authenticity, vendor remote access, as well as incident notification and coordination. Lastly, FERC's recent approval of CIP-003-9 further extends supply chain vendor remote access controls for low impact BES Cyber Systems.

PROVISION OF ESSENTIAL RELIABILITY SERVICES FROM A CHANGING RESOURCE MIX

The changing composition of the Region's resource mix from dispatchable to variable generation resources requires attention to the procurement of sufficient essential reliability services to maintain reliable grid operations. As the penetration of variable resources increases, merely having available generation capacity does not equate to having the necessary reliability services such as ramping capability to balance generation and load.

Texas RE continues to monitor key indicators such as primary frequency response, ramping capabilities, and system inertia. In 2022, primary frequency response continued to exceed NERC's requirements. Regarding ramping capabilities, the maximum hourly ramp rate for solar resources continued to increase in 2022. ERCOT has implemented enhancements to better manage frequency variations during these ramp periods. Lastly, average synchronous inertia in 2022 was

comparable to 2021, but remained well below 2020 levels.

ENERGY RELIABILITY PLANNING

ERCOT no longer has sufficient dispatchable resources to meet its projected 50/50 peak and extreme peak loads. Increasingly, variable resources such as wind and solar must be counted on to provide necessary energy to meet demand and the percentage of peak load provided by variable resources is expected to further increase in the coming years. As of December 2022, ERCOT projections indicate utility-scale solar generation will increase 230 percent to over 34,000 MW and wind generation will increase seven percent to more than 39,600 MW (based on current signed generation interconnect agreements with financial security). As the penetration of wind and solar resources grows, the risk of tight operating reserves during hours other than the daily peak load will also rise.

The traditional question of whether enough resources will be available at system peak has therefore become more complex. The assessment of resource adequacy requires considering all times of day and all times of the year—not simply peak hours. ERCOT is continuing to update processes, tools, and techniques to better model the contribution of variable resources to meet demand. Further, flexible resources such as batteries and demand response are being modeled and incorporated into the planning process to balance demand and load. Additionally, the Public Utility Commission of Texas (PUCT) is currently in the process of establishing reliability metrics to reflect these more complex operational dynamics. Similar issues are also being explored at the NERC Energy Reliability Assessment Task Force, ensuring this will remain a key focus area in the coming years.

GAS SUPPLY CHAIN RESTRICTIONS DURING COLD WEATHER

Natural gas represents the largest fuel source in the Region and serves as an essential fuel to meet demand and balance variable resources on the system. Given this critical role, vulnerabilities associated with natural gas delivery to generators can result in generator outages. This is particularly true during cold weather conditions. During Winter Storm Uri, natural gas fuel supply issues accounted for 87 percent of all fuel-related outages and derates, resulting in over a quarter of all generation outages observed during the event. Natural gas fuel supply issues included declines in natural gas production, unplanned outages of natural gas wellheads due to freeze-related issues, loss of power supply to natural gas infrastructure, facility shut-ins to prevent freezing, and unplanned outages of gathering and processing facilities.

Texas regulators have implemented a range of measures to address gas supply and gas-electric coordination issues, including developing critical

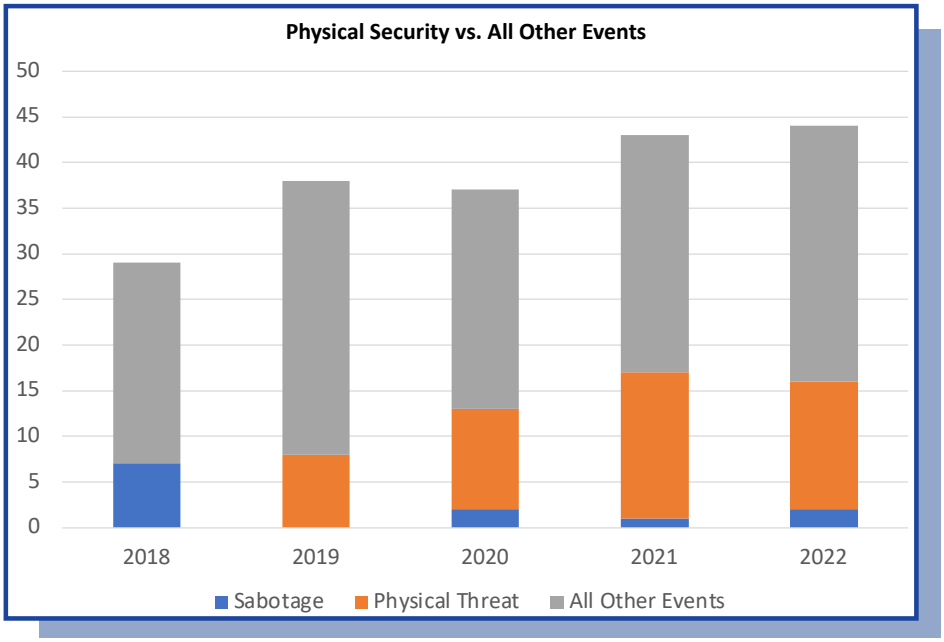
infrastructure mapping to prevent reduction in power to critical gas infrastructure during manual load shedding, winterization requirements for certain natural gas facilities, and flexible fuel market products. Gas curtailments were reduced in 2022 and were comparable to 2014 and 2018 that also had notable cold weather periods. However, generation resources during Winter Storm Elliott still experienced outages or derates because of natural gas curtailments. Natural gas supply and delivery, and alternative fuel capability and availability for gas generation (including blackstart units) will be the focus of follow-up recommendations from Winter Storm Uri in 2023, as well as part of the ongoing Winter Storm Elliott inquiry.

INACCURATE RESOURCE MODELING

As previously noted, the 2022 Odessa Disturbance involved the abnormal performance of multiple solar PV and synchronous generating facilities. These types of concurrent and unexpected losses in generation pose a significant risk to BPS reliability because many of the underlying causes of abnormal performance are systemic in nature. As discussed in the 2022 Odessa Disturbance report, system planning assessments need to accurately capture these types of systemic performance issues. As part of this process, a comprehensive review is needed to ensure that IBR models are accurate, have passed rigorous quality checks, and that sufficient documentation is in place for transmission planners to assess and verify model quality and fidelity. Improvements to the resource commissioning processes to ensure the "as built" plant condition matches what was studied during the interconnection process (with gaps or discrepancies clearly documented, understood, and corrected as needed) should occur. ERCOT is developing enhancements to its model review and verification process through work at the Inverter-Based Resource Task Force.

PHYSICAL SECURITY

There has been a gradual increase in physical security issues in recent years prior to several highly publicized events that occurred in 2022. FERC's recent directive to NERC to review possible enhancements to the physical security standard highlights the urgency of the recent uptick in physical attacks. While it is considered unlikely that a single attack could disrupt widespread areas of the grid in Texas, coordinated multiple attacks—or a single attack in a populated area—could result in significant localized disruption.



Copper theft, ballistic damage, and facility intrusions are the most common incidents and represent lower-level physical security vulnerabilities. Continued reporting and tracking of these event types is important to maintain awareness of the overall physical security environment. Ongoing vigilance, particularly with respect to more impactful assets, will be necessary to mitigate this risk further.

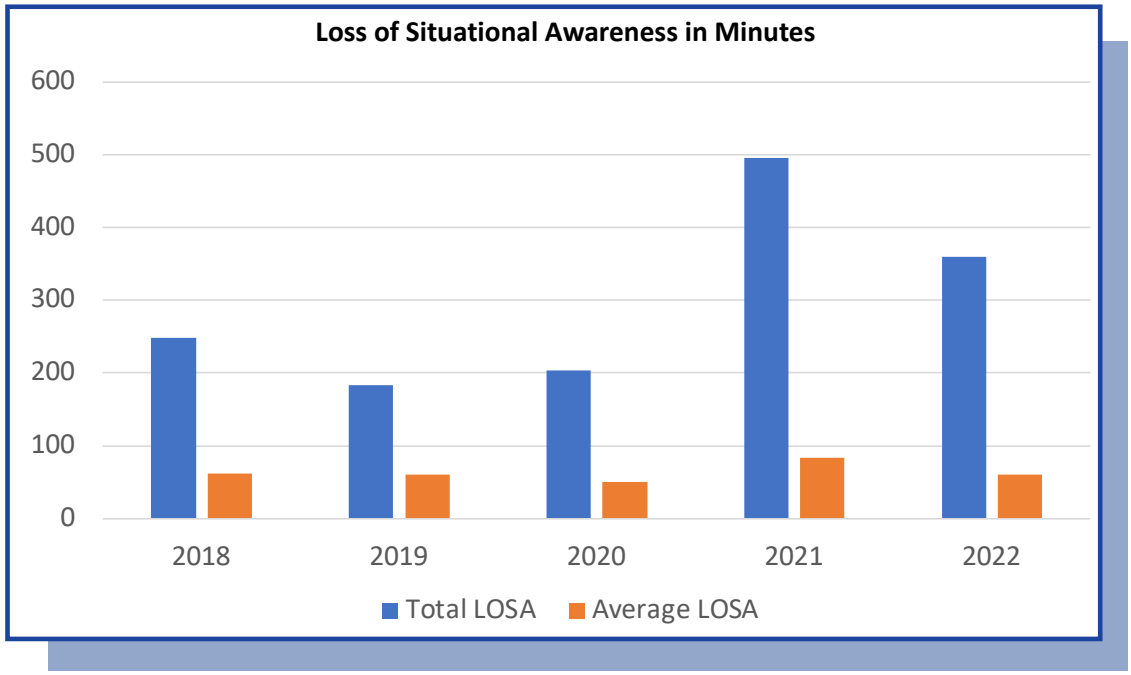
EQUIPMENT FAILURES/MISOPERATIONS

Equipment failures cause or contribute to a significant number of events in the Region. These failures include, but are not limited to, Protection System components. Other equipment, such as switches, lightning arrestors, and other components fail for numerous reasons, sometimes resulting in cascading effects. Protection System Misoperations often exacerbate the effects of the equipment failures. In 2022, 100 percent of non-SCADA events that were Category 1 and above were caused or aggravated by equipment failures.

While the overall Protection System Misoperation rate has remained essentially flat over the past five years, the misoperation rate increased from 2021 to 2022. Moreover, unknown errors and other/explainable errors continued to show negative, upward trends. Conversely, entities completed or are in the process of completing Corrective Action Plans (CAPs) addressing approximately 90 percent of 2022 misoperations. Improvement in this area will enhance reliability further by limiting the impacts of faults and various types of equipment failures. Vigorous review of all Protection System operations, plus the implementation of CAPs for misoperations, are vital to the continued reduction of risk due to misoperations.

LOSS OF SITUATIONAL AWARENESS

One-third of all events of Category 1 or higher in the Region in 2022 were EMS/SCADA failures. Additionally, a significant percentage of NERC lessons learned focused on EMS outages during the same period. These failures affected both large and small entities and lasted just over one hour on average. In 2022, the total time for losses of situational awareness (LOSA) declined from 2021, but still remains above the average outage times for 2018 through 2020.



The relative frequency at which these events have occurred, coupled with the potential for longer-duration losses of situational awareness, require continued monitoring for trends and common issues.

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