

2021 ASSESSMENT OF RELIABILITY PERFORMANCE



TEXASRE

Ensuring electric reliability for Texans

SUMMARY REPORT

MAY 2022

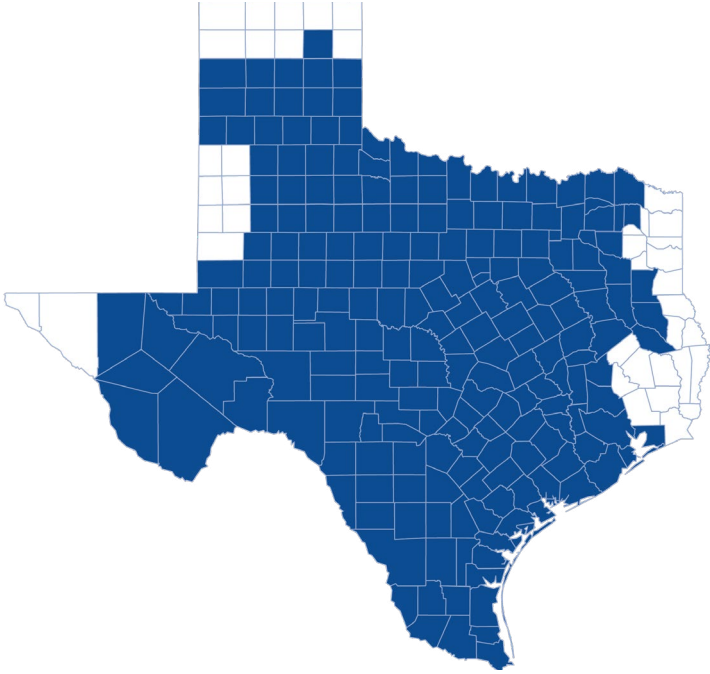


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INTRODUCTION



Texas RE periodically assesses and reports on the reliability and adequacy of the bulk power system (BPS) within the Texas Interconnection. The Assessment of Reliability Performance annually compiles analyses for the previous year and this document is the 2021 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 and create 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, this report 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 Electric Reliability Council of Texas (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-4,
& NERC Event Analysis
Process reports

Frequency Control
Performance and
Primary Frequency
Response (Source)

ERCOT ISO Data
and Reports

2021 IN REVIEW

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The ERCOT Region has shown that it has 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. 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. 2021 will be remembered for two major disturbances that tested the reliability of the ERCOT Region and are resulting in major changes.

WINTER STORM URI

Between February 8 and 20, 2021, Winter Storm Uri impacted the ERCOT region with extreme cold temperatures and freezing precipitation. As the coldest weather took hold



during the week of February 14, ERCOT, Southwest Power Pool (SPP), and Midcontinent Independent System Operator (MISO) simultaneously

faced emergency conditions as demand grew rapidly while generator unavailability increased. Generator outages between 7:00 a.m. Central February 15 and 1:00 p.m. February 17 in ERCOT averaged 34,000 MW of unavailable generation, nearly half of ERCOT's new all-time winter peak electric load of 69,871 MW. In response to these emergency conditions, and to avoid more damaging cascading outages and system-wide blackouts, ERCOT system operators issued firm load shed orders starting just after midnight on February 15. ERCOT load shed continued until late February 17, peaking at 20,000 MW; the combined 23,418 MW of manual firm load shed in ERCOT, SPP, and MISO was the largest controlled firm load shed event in U.S. history.

[The November 2021 FERC, NERC and Regional Entity Staff Report](#) notes over 4.5 million people in Texas lost power during the period while exposed to below-freezing temperatures for over six days, and at least 210 deaths were directly or indirectly attributed along with an estimated loss to just the Texas economy of between \$80 and \$130 billion.

The report identifies a confluence of two causes that led to sharp increases in generation unavailability and ultimately loss of firm load. First, generating units inadequately prepared for extreme cold weather conditions and failed in large numbers. Second, massive cold weather-induced natural gas production declines (and some declines in natural gas processing) were worsened by load shed that cut power to gas facilities. This meant that the natural gas fuel supply struggled to meet both residential heating load and generating unit demand for natural gas. The report also notes that the Region's increased reliance on the natural gas generation fleet exacerbated the impacts of reductions in natural gas supply relative to prior cold weather events in 2011, 2014, and 2018. The report identifies 28 recommendations aimed at improving electric and gas availability, including revisions to mandatory Reliability Standards. The ERO is currently implementing many of these recommendations, boosted by work at ERCOT and state regulatory agencies.

ODESSA DISTURBANCE

On May 9, 2021, the ERCOT Region experienced a widespread reduction of over 1,100 MW of solar photovoltaic (PV) resources due to a normally cleared fault on the BPS in the Odessa area. While the ERO has analyzed multiple similar events in California, this is the first such disturbance in the ERCOT Region. The event involved solar PV facilities across a large geographic area of up to 200 miles away from the location of the initiating event. Similar, smaller events have



occurred in the Region since this disturbance, while new solar interconnections are proceeding rapidly. The [September 2021 NERC, ERCOT, and](#)

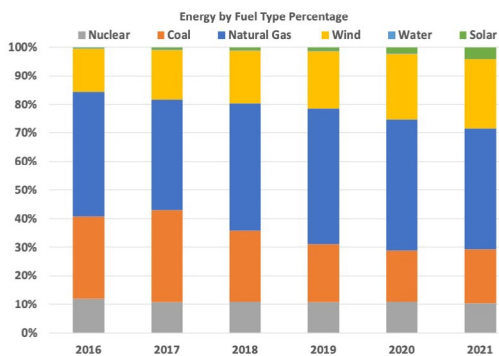
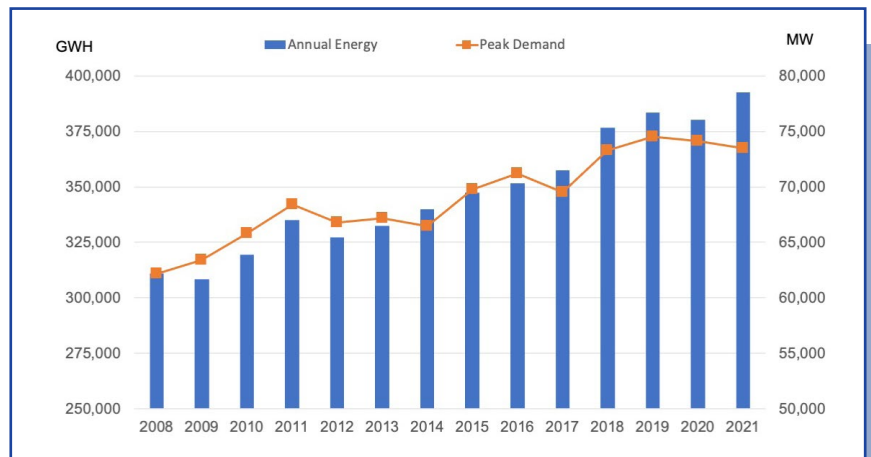
[Texas Reliability Entity Odessa Disturbance Report](#) identifies eight recommendations, including revisions to mandatory Reliability Standards. The ERO is currently implementing many of these recommendations.

DEMAND AND ENERGY

2021 AT A GLANCE

**SUMMER
PEAK DEMAND:**

73,476 MW
on 8/31/2021



**PEAK HOURLY
RENEWABLE
PENETRATION:**

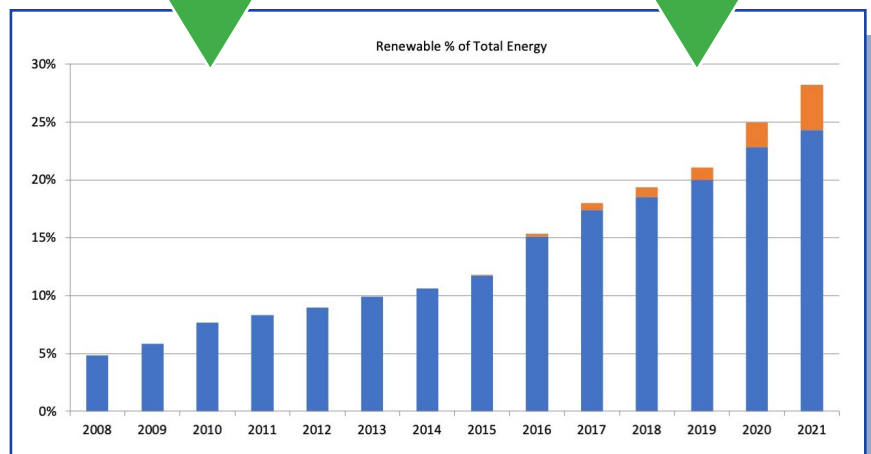
65.8% on
3/22/2021

**RENEWABLE ENERGY
SERVED:**

28.3% of total
energy in 2021

**PEAK HOURLY WIND
GENERATION:**

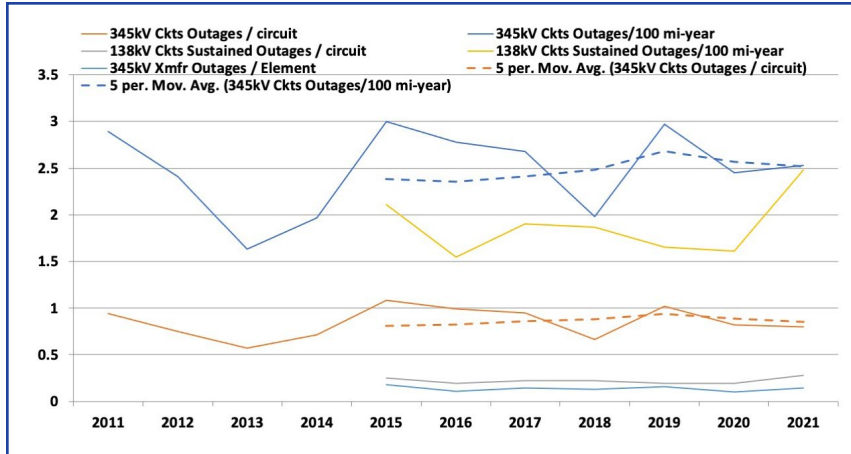
24,463 MW
on 12/23/2021





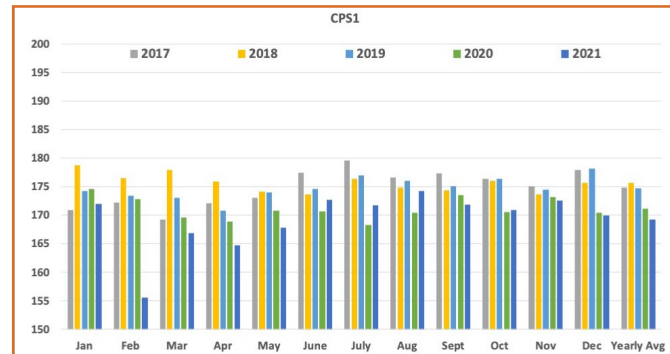
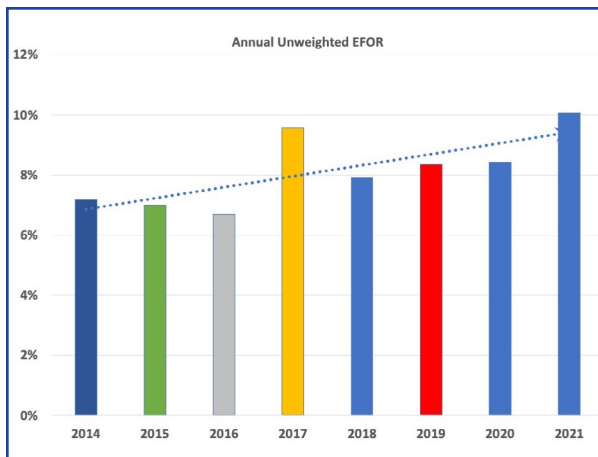
RELIABILITY

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PRIMARY FREQUENCY RESPONSE:

865 MW/0.1Hz for
for 2021 vs. NERC
Obligation of
471 MW/0.1Hz



CONTROL PERFORMANCE STANDARD 1 (CPS1)

TADS 345kV CIRCUIT AUTOMATIC OUTAGE RATE PER 100 MILES

PROTECTION SYSTEM MISOPERATION RATE

GADS EQUIVALENT FORCED OUTAGE RATE (EFOR) (MW WEIGHTED)

	2021	2020
CONTROL PERFORMANCE STANDARD 1 (CPS1)	169.3	171.2
TADS 345kV CIRCUIT AUTOMATIC OUTAGE RATE PER 100 MILES	2.52	2.45
PROTECTION SYSTEM MISOPERATION RATE	5.2%	5.8%
GADS EQUIVALENT FORCED OUTAGE RATE (EFOR) (MW WEIGHTED)	10.1%	8.4%



2021 FOCUS AREAS

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 2021 Assessment of Reliability Performance report provides a high-level overview of the data collected in the ERCOT Interconnection in 2021. It includes:

- Overview of 2021's numbers
- Associated historical data
- The current state of the Texas Interconnection
- Observations for the future of Texas RE's region

To gauge reliability of the ERCOT Interconnection and turn that data into actionable information, Texas RE assesses data and historical trends in these focus areas:



EVENT ANALYSIS

RESOURCE ADEQUACY AND PERFORMANCE

SYSTEM RESILIENCE

GRID TRANSFORMATION

HUMAN PERFORMANCE

BULK POWER SYSTEM PLANNING

LOSS OF SITUATIONAL AWARENESS

PROTECTION SYSTEM MISOPERATIONS

PHYSICAL AND CYBER SECURITY



PERFORMANCE METRICS TEXAS RE

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, target values, and an assessment of the current state of each.

Improving	Stable or No Change	Monitoring	Actionable
Key Performance Indicator with Description		2021 Performance & Trend Results	
Resource Adequacy Measures potential resource adequacy issues by analysis of planning reserve margin and energy emergency alerts.		Extreme event scenarios in reliability assessments	
Transmission Performance Measures transmission performance by analysis of transmission outage rates and IROL exceedances.		Resource weatherization	
Resource Performance Measures generation performance by analysis of generator outage rates, primary frequency response, and balancing contingency events.		345 kV & 138 kV transmission outage rates are stable	
Changing Resource Mix Measures potential issues related to the changing resource mix by analysis of system inertia and ramping.		IROL Exceedances	
Protection System Performance Measures protection system performance by analysis of protection system misoperations.		Resource outage rates during cold weather	
Human Performance Measures transmission outages, generation outages, and protection system misoperations caused by human error.		- Primary frequency response - No balancing contingency event failures	
Situational Awareness Measures situational awareness by analysis of state estimator convergence rates, event analysis, and telemetry performance.		- Solar ramp magnitudes continue to increase - Synchronous generator retirements	
		- Voltage ride through for inverter-based resources - Decrease in average system inertia levels	
		- Reduction in misoperations due to incorrect settings - Region misoperation rate reduced in 2021, remains less than overall NERC misoperation rate	
		Reduction in transmission and generation outage rates from human error	
		Repeated errors resulting in protection system misoperations	
		Six loss of situational awareness events	
		State estimator convergence rate is stable	

KEY FINDINGS

EVENT ANALYSIS

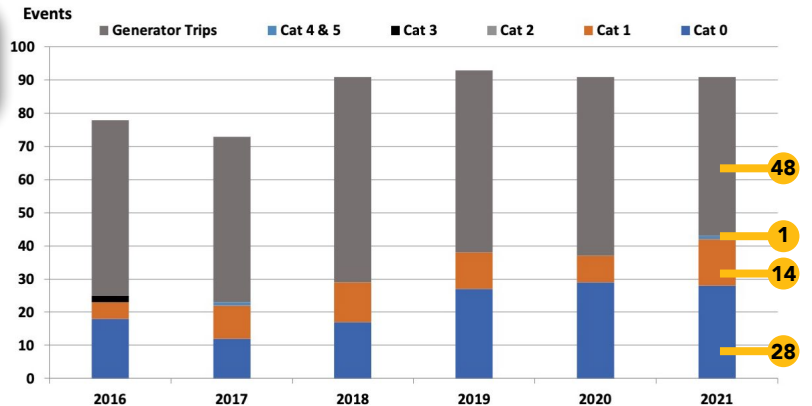


In 2021, Texas RE analyzed 89 BPS events (including Winter Storm Uri and the Odessa solar event), which is on par with the number of events reported per year during the preceding four years. In total, 439 events were reviewed between 2017 and 2021. Of the 411 root and contributing causes identified, the "Equipment/Material" category occurred most frequently with 36 percent of all identified causes. "Design/Engineering" was second with 11 percent, followed closely by "Management/ Organization" with 12 percent. The number of Category 1 events has been stable over the last five years.

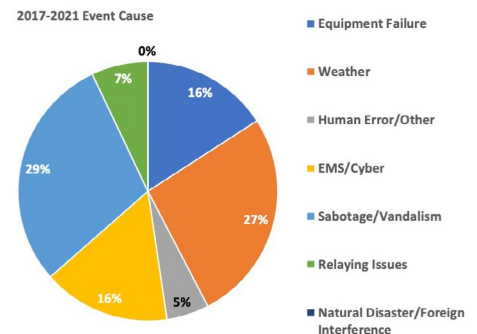
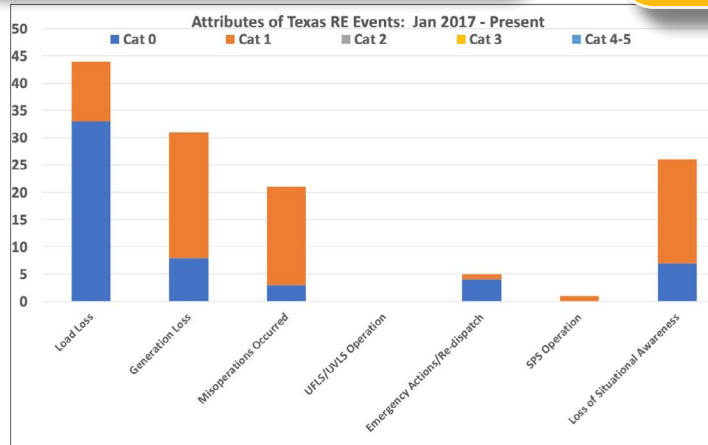
- 439 Events Analyzed
- Over 276 Event Reports

Qualified event attributes dominated by:

- Load loss
- Generation Loss
- Protection System Misoperations



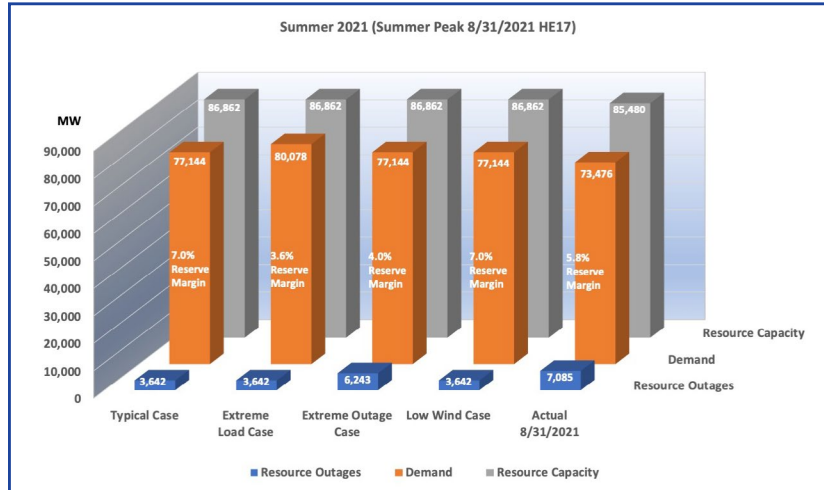
411 Root & Contributing Causes Identified



KEY FINDINGS

RESOURCE ADEQUACY

TEXAS RE

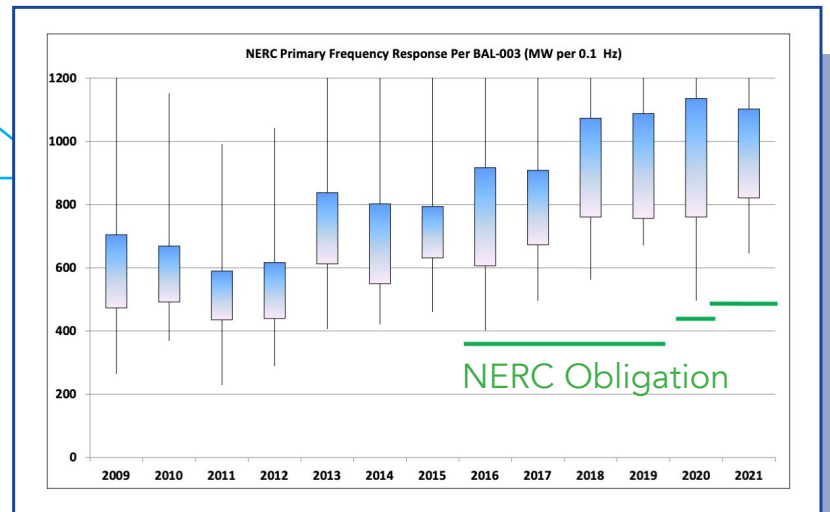


Projected Peak: 77,244 MW
Actual Peak: 73,476 MW

Renewable % at Peak: 13.7%
Max Hourly Wind: 24,463 MW
Max Hourly Solar: 6,988 MW
Max Hour Renewable%: 65.8%

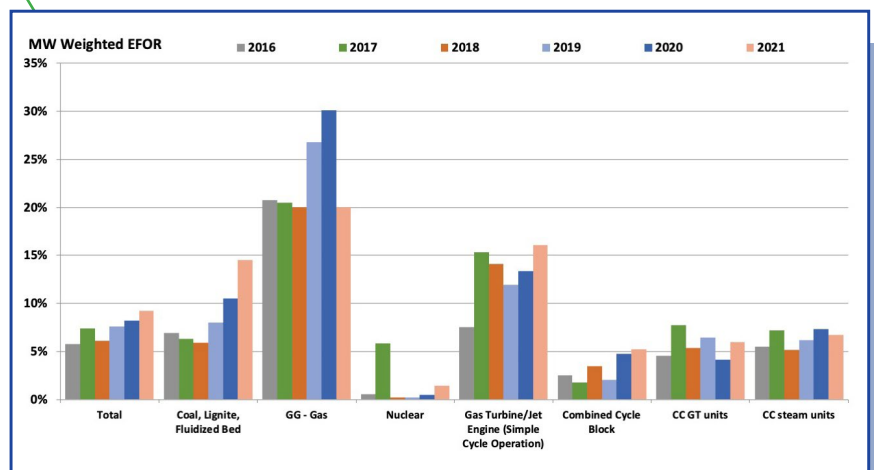
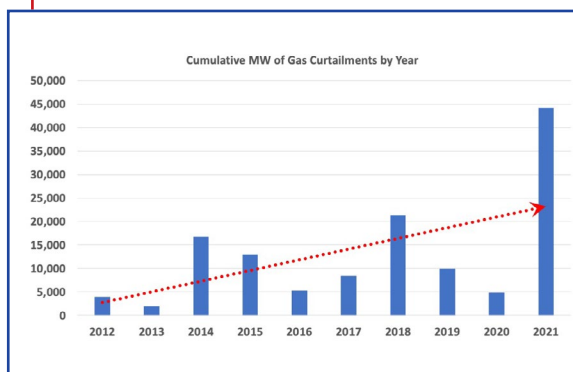
Advisories (PRC<3000): 7
Watches (PRC<2500): 2
EEA (PRC<2300): 1

Primary frequency response continues to far exceed NERC minimums



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

Gas curtailments increased dramatically in 2021 due to Winter Storm Uri



KEY FINDINGS

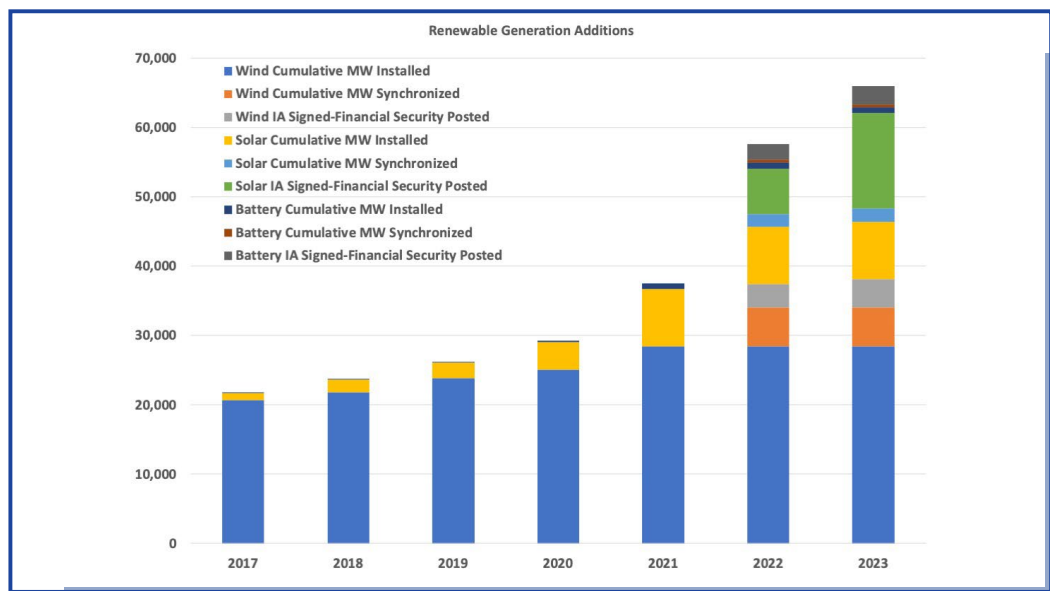
RESOURCE ADEQUACY

Generation outages during Winter Storm Uri affected all generation types (coal, nuclear, gas, combined cycle, wind, and solar) and resulted in insufficient operating reserves and firm load shed. Sufficient operating reserves were maintained during summer peak hours and other periods in 2021 despite periods in June with high thermal plant outages.

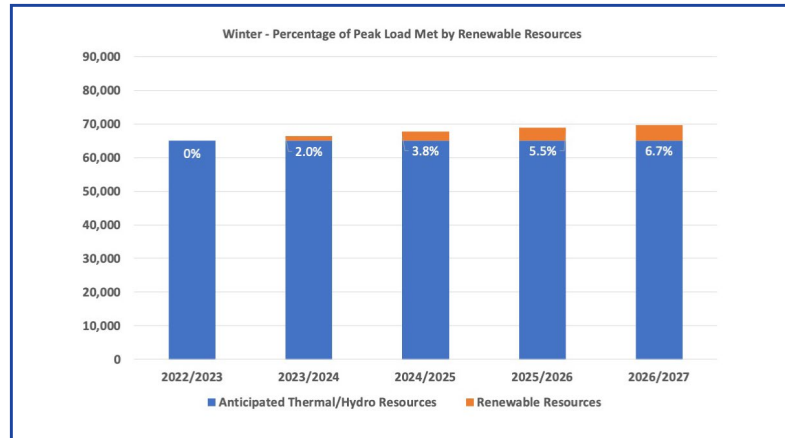
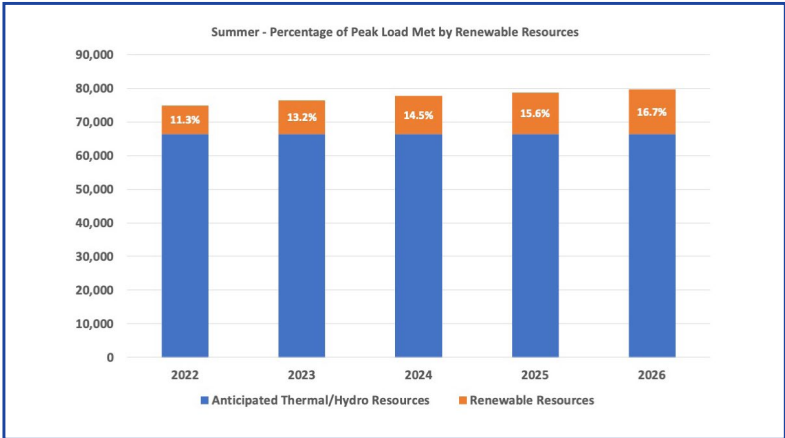
The cumulative generation capacity impacted by natural gas fuel curtailments increased dramatically in 2021 when compared to previous years due to the impact of Winter Storm Uri. This also points out a concern for fuel security given the dependence on pipelines for continuous supply of the gas generation fleet, including at present many blackstart units.

Approximately 20,000 MW of additional renewable resources are expected in 2022, plus another 8,300 MW by the end of 2023. These additions will continue to drive changes in how ERCOT manages and dispatches generation. Combined wind and solar generations curtailments exceeded 6,600 GWHrs in 2021.

There was a dramatic increase in Hourly Reliability Unit Commitments (HRUC) in 2021 compared to previous years due to ERCOT's decision to increase operating reserves in the summer. HRUC commitments totaled 88 units for 400 commitment hours. The primary reason for the commitments was capacity, which accounted for approximately 83 percent of all HRUC hours.



Finally, ERCOT no longer has sufficient thermal resources to meet its projected 50/50 peak and extreme peak loads. The balance of energy not provided by thermal resources must be provided by renewable resources, both at peak and throughout occasional periods of lengthy low renewable output in extreme conditions. The percentage of peak load provided by renewable resources will continue to increase. With increasing levels of variable renewable generation in the resource mix, there is a growing need to have resources available that can be reliably called upon (with minimal notice or for short periods on multiple days) to balance electricity supply and demand if shortfall conditions occur. Flexible resources that can include responsive generators with assured fuel and/or demand response are necessary during some periods to ensure resource adequacy and meet ramping needs. Battery and other energy storage may also play a role especially for shorter durations. Should solar and wind output fall below expectations during peak conditions, ERCOT will need to draw on such flexible resources to maintain balance between load and generation, given that imports from outside of the Interconnection are often fully utilized. Additionally, the high levels of solar resources cause the daily load shape to change such that greater amounts of flexible resources are needed to match steep ramping conditions during times when the change in wind or solar output changes rapidly.



KEY FINDINGS

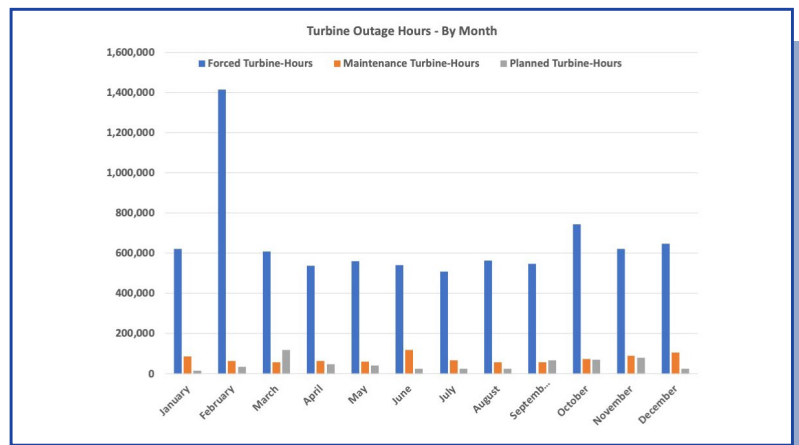
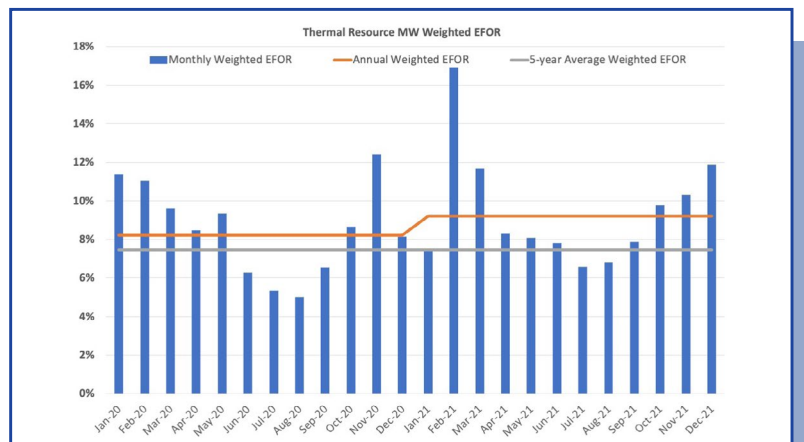
RESOURCE ADEQUACY

ADDITIONAL HIGHLIGHTS FOR 2021 INCLUDE:

- Primary Frequency Response achieved a median value of 865 MW/0.1 Hz versus the NERC obligation of 471 MW/0.1 Hz.
- No Reportable Balancing Contingency event recovery failures occurred in 2021.
- No Reportable Balancing Contingency events greater than the Most Severe Single Contingency (MSSC) occurred in 2021.

ADDITIONAL AREAS TO MONITOR INCLUDE:

- Following Winter Storm Uri, weatherization of resources will be a primary focus.
- GADS EFOR (Unweighted) for thermal resources was 10.1 percent for 2021 versus 8.4 percent for 2020. This increase was mostly attributable to Winter Storm Uri.
- GADS Wind Resource EFOR was 16.1 percent in 2021 versus 14.7 percent in 2020. This increase was also mostly attributable to Winter Storm Uri.
- Additional follow-up and potential requirement changes to improve voltage ride-through for inverter-based resources will also be a primary focus.
- Natural gas supply and delivery, and alternative fuel capability and availability for gas generation (including blackstart units) merit ongoing review.

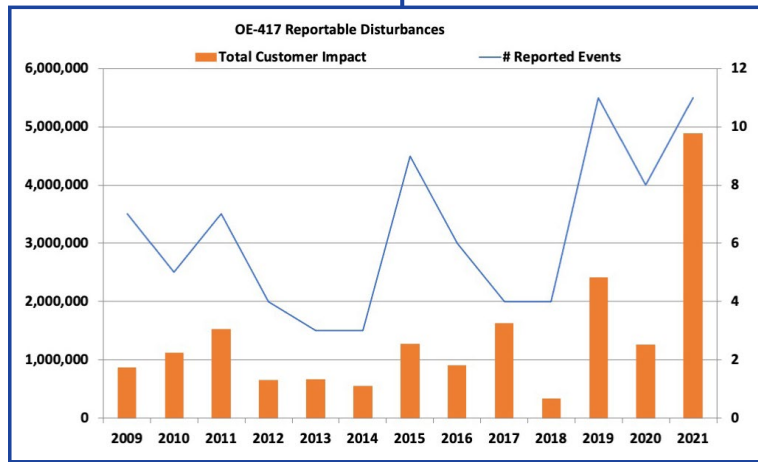
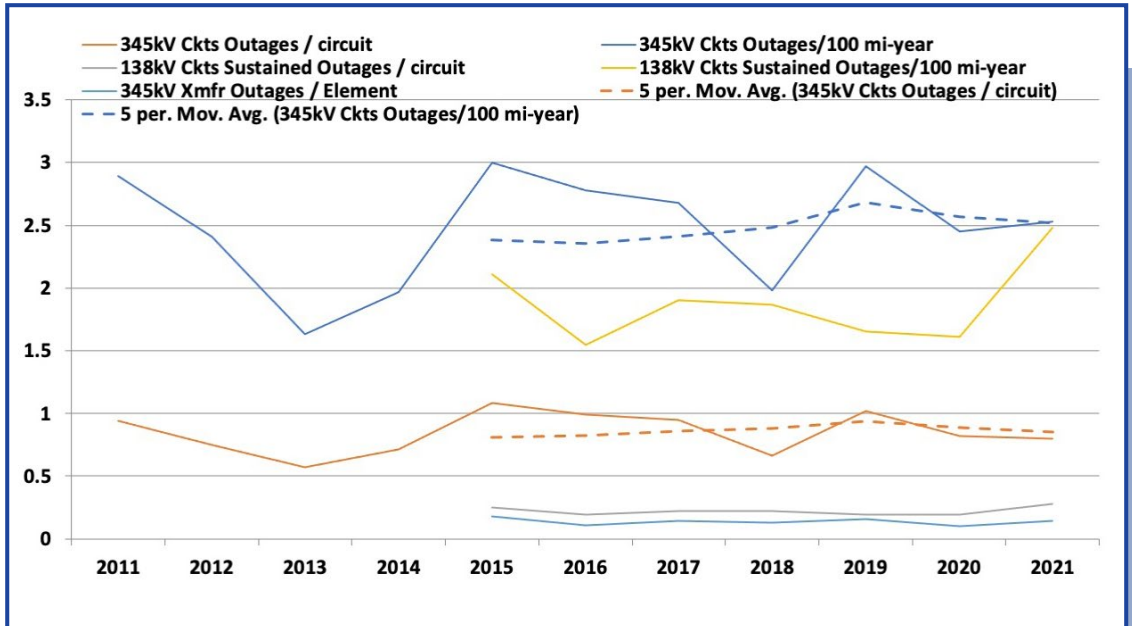


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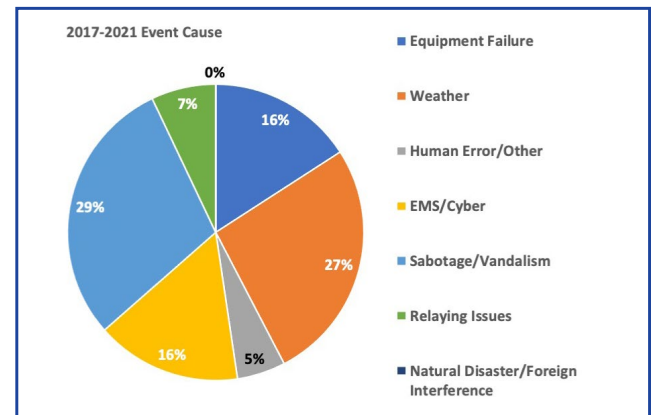
SYSTEM RESILIENCE

TEXAS RE

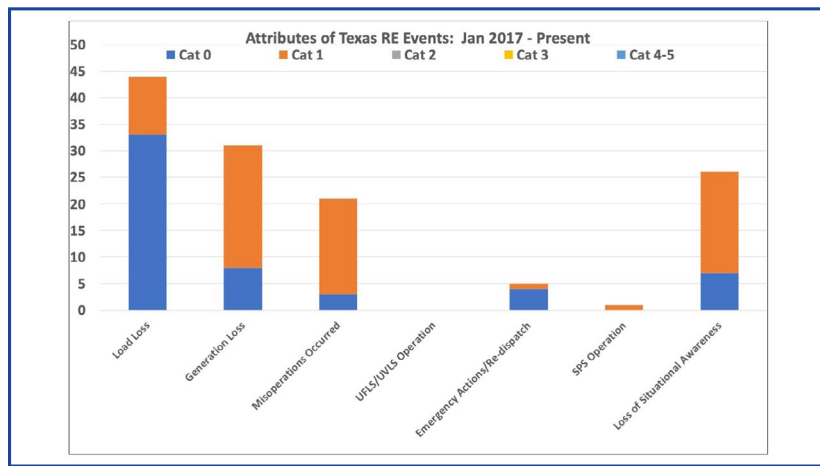
345 kV circuit automatic outage rates remained flat near the five-year moving average. 138 kV outage rate increased but remains near the five-year moving average. As in prior years, duration of sustained outages was primarily due to failed substation or circuit equipment. →



Customer outages from major storms increased significantly in 2021 due to Winter Storm Uri.



Equipment failure and weather continue to drive major events.

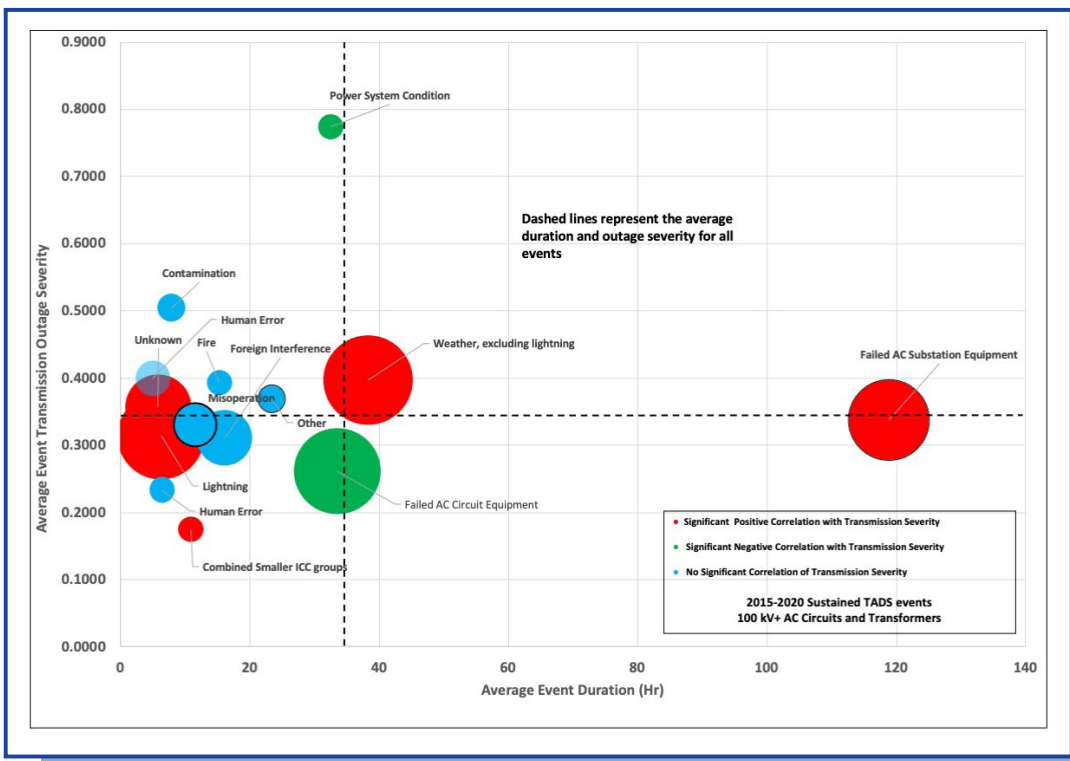


Uri and the Odessa solar disturbance were major events for 2021.

KEY FINDINGS

SYSTEM RESILIENCE

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, and Winter Storm Uri in February 2021. The ERCOT Region BPS has historically shown that it can withstand contingency events that are normally planned for and studied in the planning and operations horizons. Voltage ride-through issues with wind and solar units were highlighted in the Odessa disturbance in May 2021. 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 345kV and 138kV systems. Failed transmission circuit and substation equipment continued as the

dominant cause of sustained outages' duration, accounting for 73 percent of the 345 kV and 67 percent of the 138 kV sustained outages' duration, respectively.

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



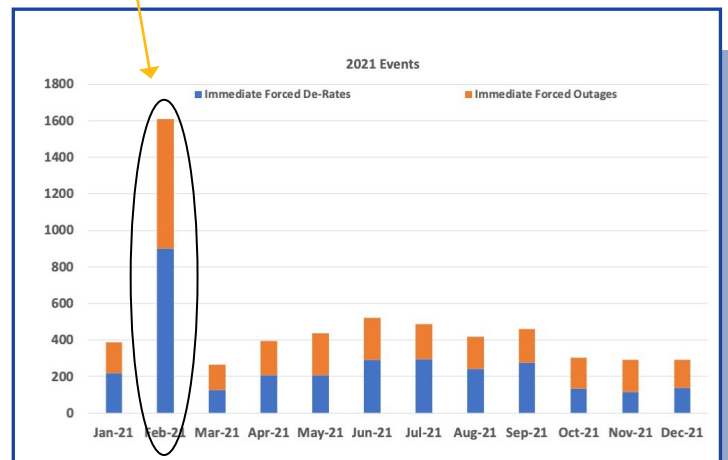
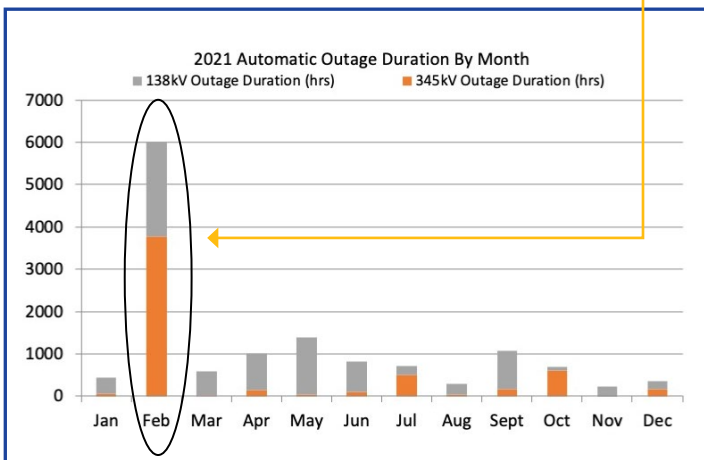
2021 HIGHLIGHTS FROM THE ANALYSIS OF RESILIENCE INCLUDE:

- 138 kV circuit outage rates per element remained stable in 2021 when compared to previous years and the five-year average rates.
- For the 345 kV circuit outages in 2021, 29 percent of sustained automatic outage events and 64 percent of sustained outage duration involved failed circuit equipment.
- For the 138 kV circuit outages in 2021, failed substation equipment and failed transmission circuit equipment dominated causes of sustained outages, accounting for 46 percent of the outage events and 67 percent of the outage duration.

AREAS TO MONITOR INCLUDE:

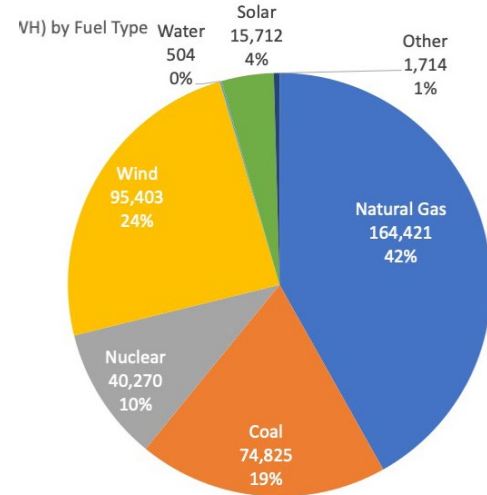
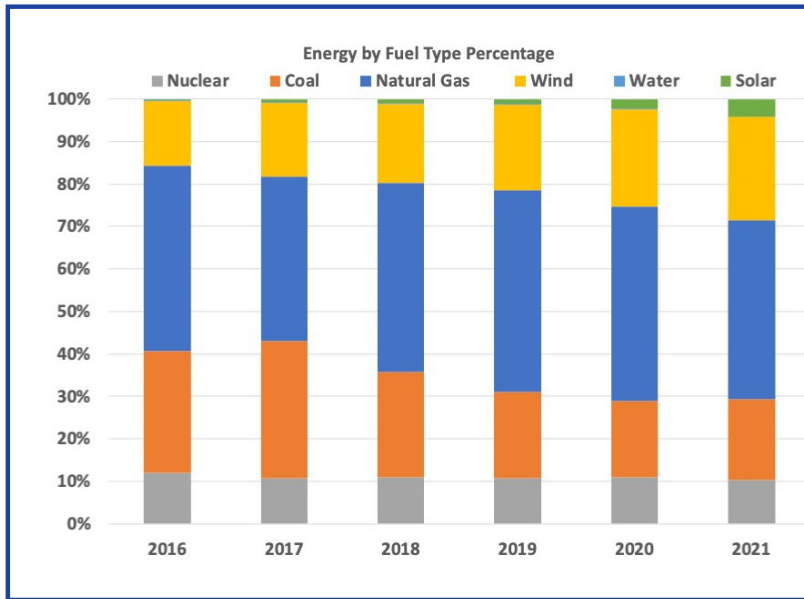
- Following Winter Storm Uri, weatherization of generation and transmission resources will be a primary focus.
- Additional follow-up and potential requirement changes to improve voltage ride-through for inverter-based resources will also be a primary focus.
- Transmission system performance on extreme days worsened in 2021 when compared to extreme days in 2017-2020 due to Winter Storm Uri.
- Generation system performance on extreme days also worsened in 2021 when compared to extreme days in 2017-2020 due to Winter Storm Uri.
- Protection System Misoperations continue to be an important causal factor in reported system events.

Impact from Winter Storm Uri, February 2021

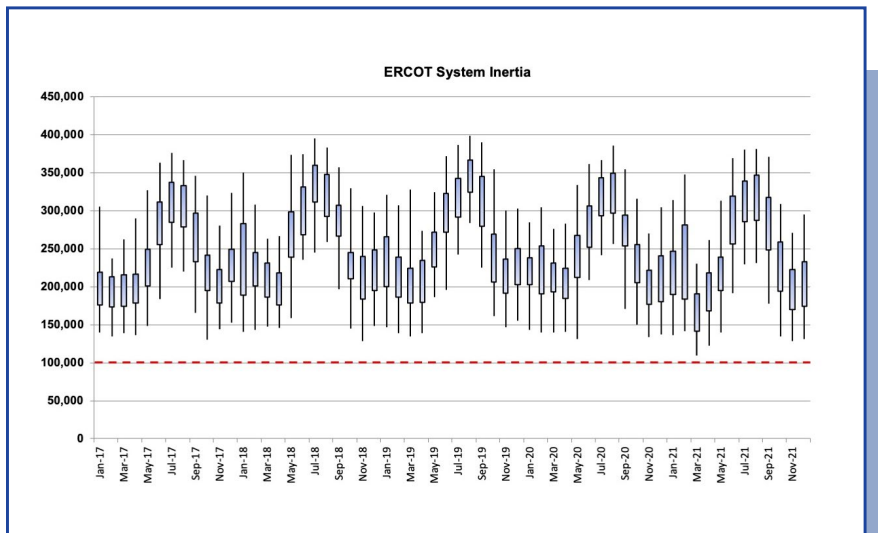


KEY FINDINGS

GRID TRANSFORMATION

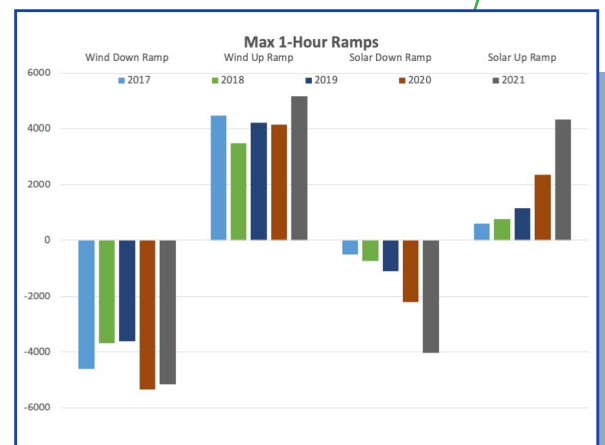


Since 2016, renewable generation has increased from 15% to 28% of energy while coal has decreased from 29% to 19%



In 2021, 569 MW of fossil generation was retired, mothballed, or announced an early 2022 shutdown. Simultaneously, over 9,300 MW of renewable generation was approved for commercial operation. Inertia levels during the highest penetration hours showed a large drop compared to previous years. The margin between minimum inertia conditions and critical inertia levels remains well within adequate safety margins.

Maximum up and down ramp magnitudes continue to increase as solar generation increases. ERCOT changes to include solar ramps in the Generation-to-be Dispatched (GTBD) formula used for generation dispatch in 2021.



KEY FINDINGS

GRID TRANSFORMATION

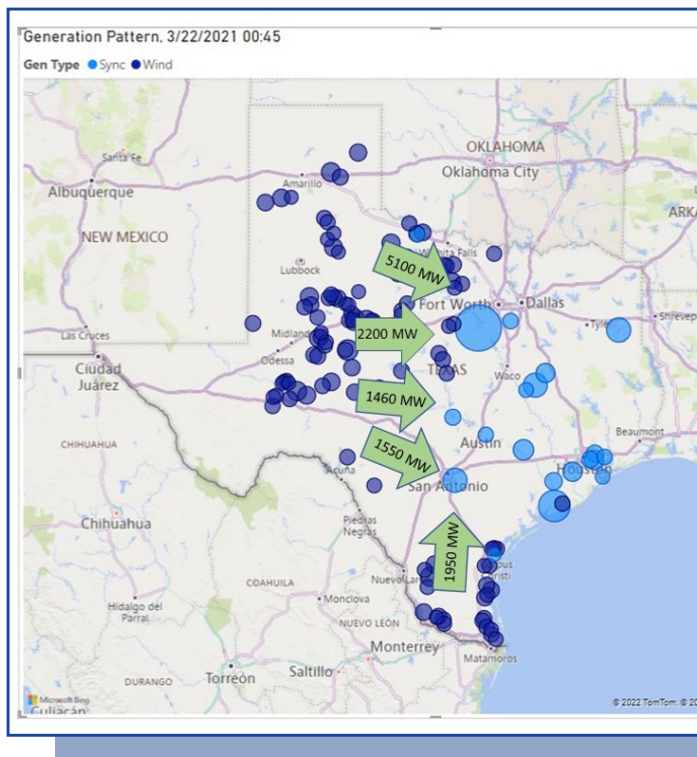
TEXASRE

Today's resource mix continues to evolve with the addition of inverter-based generation resources, energy storage, and government policies that encourage renewable generation. The Texas Panhandle area is continuing to experience significantly more interest from wind and solar generation developers than what was initially planned for the area. Stability conditions improved in the Panhandle with the integration of the City of Lubbock, 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.

ERCOT has implemented generic transmission constraints (GTCs) in West and South Texas to manage stability limits in operations. Processes to manage these GTCs may require increased curtailments of wind and solar

energy in order to maintain the power transfers within stability limits. Combined wind and solar generation curtailments exceeded 6,600 GWhrs in 2021. ERCOT classifies five of its GTCs as Interconnection Reliability Operating Limits (IROLs) as of late 2020, an indicator of the importance to grid reliability.

High wind-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.



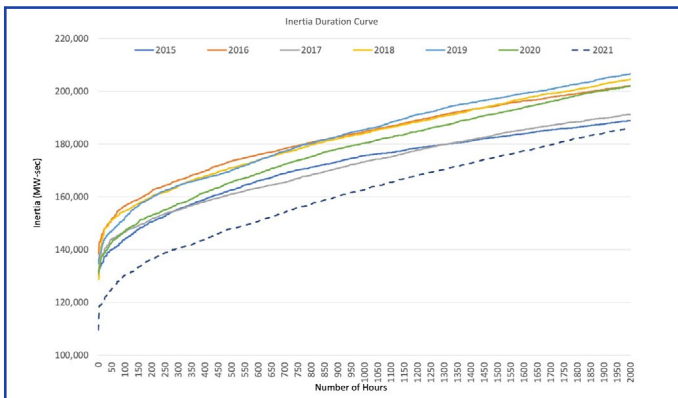
Snap shot of low inertia period: 3/22/2021 at 12:00 a.m.

- No synchronous generation online in West Texas, Panhandle, or lower Rio Grande Valley
- ERCOT load was 31,904 MW (net load of 10,905 MW)
- Inertia level was 109.6 GW-sec
- Wind generation was 20,998 MW
- Wind penetration was 65.8%
- Approx. 3,500 MW of wind was curtailed in West Texas and Panhandle

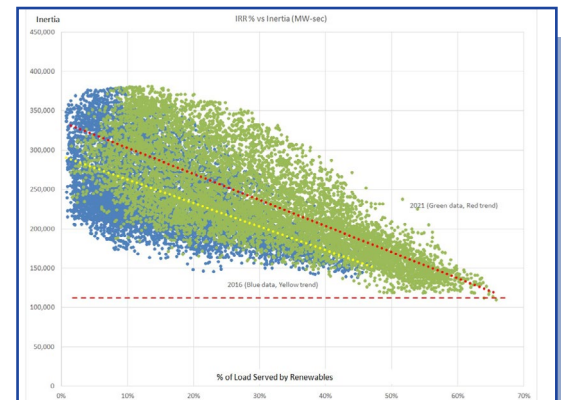
KEY FINDINGS

GRID TRANSFORMATION

Overall system inertia decreased in 2021 (dashed line on left-side graph below) compared to 2020. The minimum hourly inertia level in 2021 was 109.6 GW-s on March 22, 2021, at HE01 when the intermittent renewable resource (IRR) penetration level was 65.8 percent and system load was 31,904 MW (net load of 10,905 MW).



2021



HIGHLIGHTS FROM THE ANALYSIS OF GRID TRANSFORMATION INCLUDE:

- Primary frequency response continues to exceed NERC requirements.
- IROLs were exceeded six times in 2021, totaling 21 minutes in 2021. None were longer than 10 minutes.

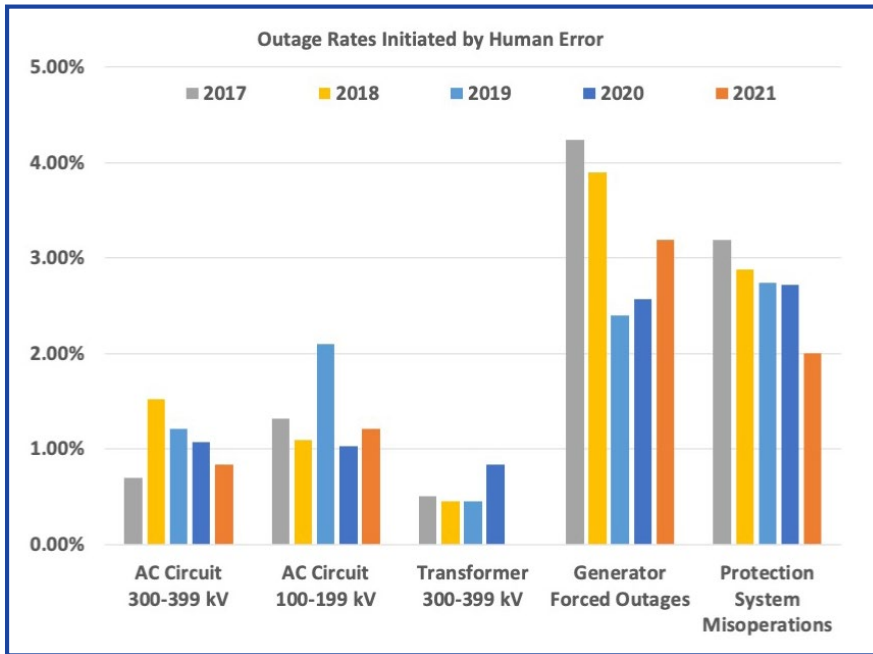
AREAS TO MONITOR INCLUDE:

- Ratio of dispatchable generation to renewable generation continues to change rapidly. Over 560 MW of coal and natural gas capacity was retired, mothballed, or announced an early 2022 shutdown in 2021. The system added over 8,050 nameplate MW renewable generation capacity and storage, plus 1,270 MW of gas and other fossil generation, including several units coming out of retirement status.
- Maximum one-hour ramp magnitudes for solar generation continue to increase. ERCOT has implemented changes to include solar ramp rates in the GTBD formula.
- Average synchronous inertia across most operating hours decreased in 2021 when compared to previous years.
- Low voltage ride-through issues for wind and solar inverters continue to occur during transient voltage disturbances on the transmission system.

KEY FINDINGS

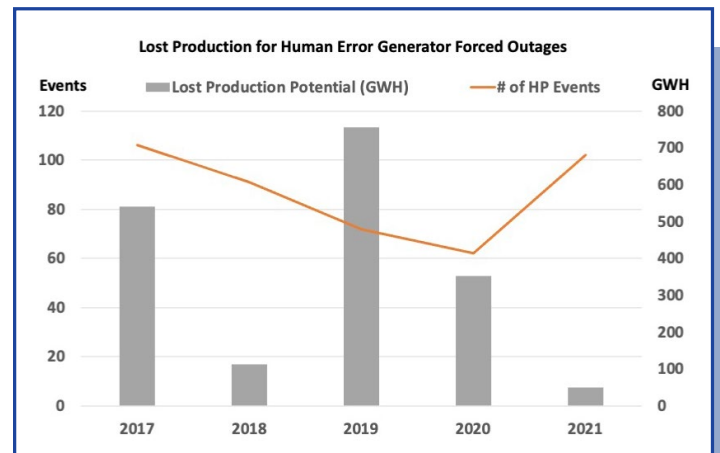
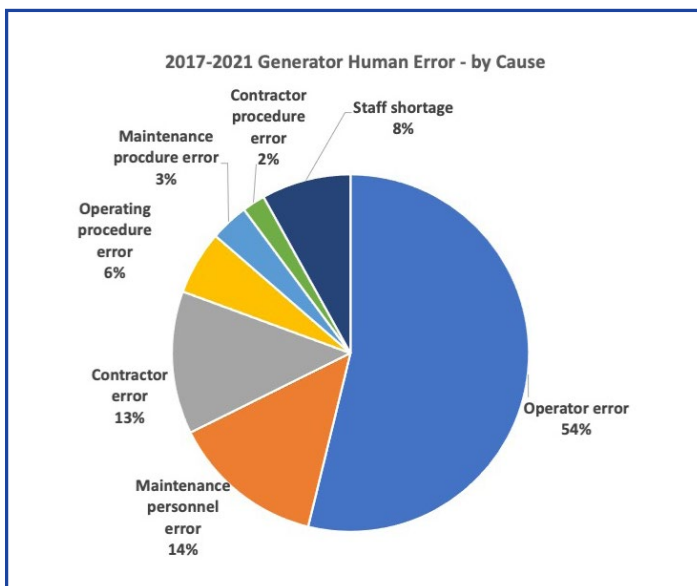
HUMAN PERFORMANCE

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2021 HIGHLIGHTS FROM THE ANALYSIS OF HUMAN PERFORMANCE INCLUDE:

- Outage rates in TADS and GADS data associated with Protection System Misoperations and caused by human error are continuing to show an improving, downward trend.
- Generator forced outage rates caused by human error increased in 2021 compared to previous years, but the impact to production from those outages decreased significantly compared to 2019 and 2020.



AREAS TO MONITOR INCLUDE:

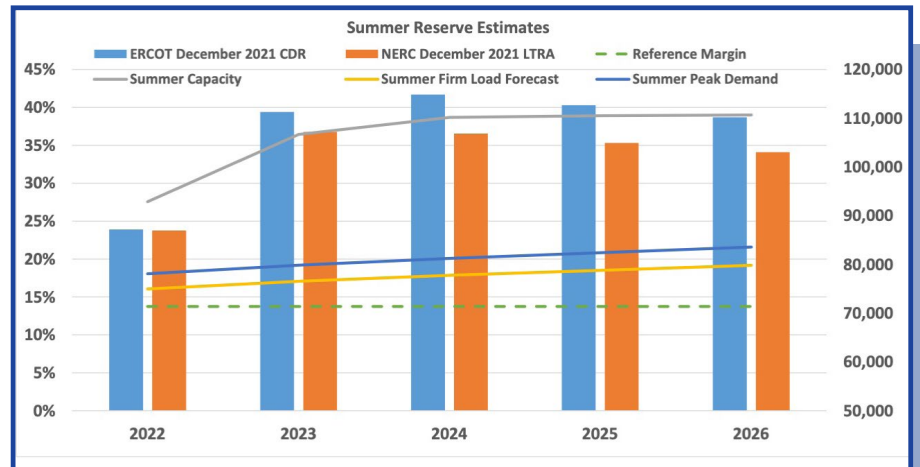
- Causal analysis of human errors in Protection System Misoperations continue to show repeated issues due to lack of adequate error-checking processes and procedures.
- Outage events for generation units due to human error increased sharply in 2021 and merits continued analysis and tracking.

KEY FINDINGS

BULK POWER SYSTEM PLANNING

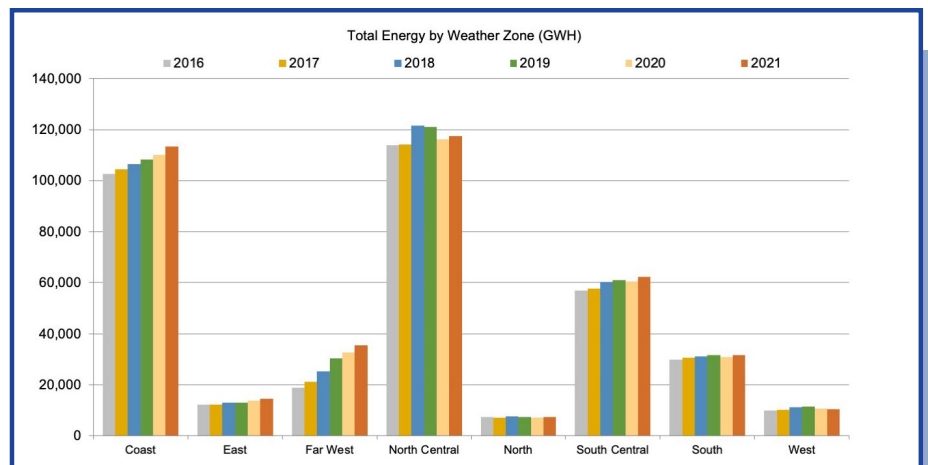
The [2021 NERC Long-Term Reliability Assessment \(LTRA\)](#) shows a planning reserve margin above the 13.75 percent target for the next five years in the Texas Interconnection. [ERCOT's December 2021 Capacity, Demand and Reserves \(CDR\)](#) report also shows a planning reserve margin above the 13.75 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 1,650 MW of non-modeled generation capacity and 1,331 MW of unregistered distributed generation resources (DGR) at the end of 2021.



2021 HIGHLIGHTS FROM THE ANALYSIS OF BULK POWER SYSTEM PLANNING INCLUDE:

- Summer Peak: Actual 73,476 MW versus projected 77,244 MW
- Winter Peak: Actual 69,216 MW versus projected 57,699 MW
- Renewable Percentage of Total Load at Summer Peak: 13.7 percent
- Peak hourly wind generation: 24,463 MW on December 23, 2021
- Peak hourly solar generation: 6,988 MW on October 16, 2021
- Peak hourly renewable penetration: 65.8 percent on March 22, 2021



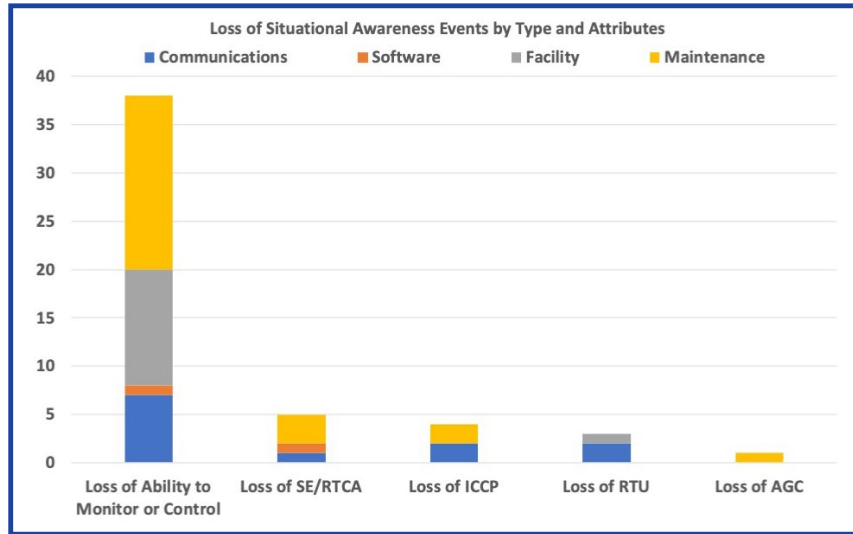
AREAS TO MONITOR INCLUDE:

- As of December 2021, ERCOT projections indicate utility-scale solar generation will increase 300 percent to over 24,000 MW and wind generation will increase 34 percent to more than 38,000 MW during the next two years (based on current signed generation interconnect agreements with financial security). During the same period, 1,500 MW of new gas unit capacity and over 3,000 MW of storage are projected.
- System inertia is expected to continue to decline as more renewables are commissioned and the operating hours of synchronous generators are reduced.

KEY FINDINGS



LOSS OF SITUATIONAL AWARENESS TEXAS RE

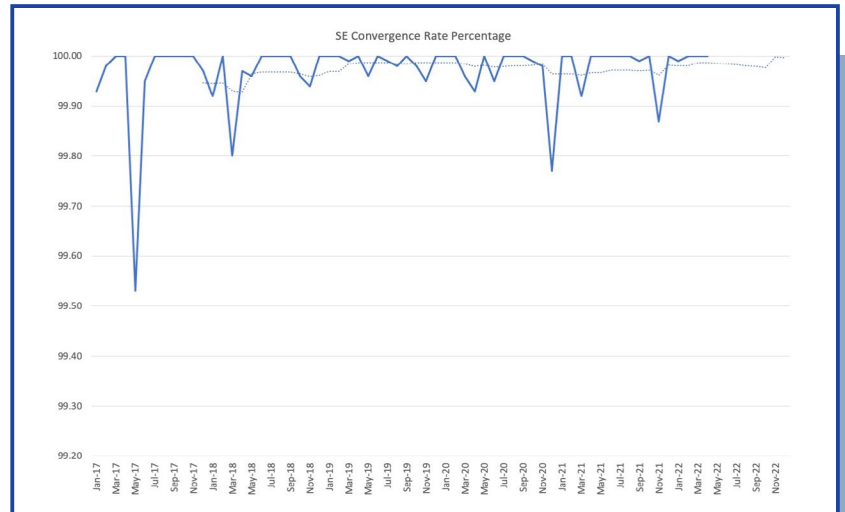


LOSS OF SITUATIONAL AWARENESS EVENTS ARE BROKEN DOWN INTO SEVERAL CATEGORIES BY THE CAUSE OF THE EVENT. THESE ARE:

- 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)

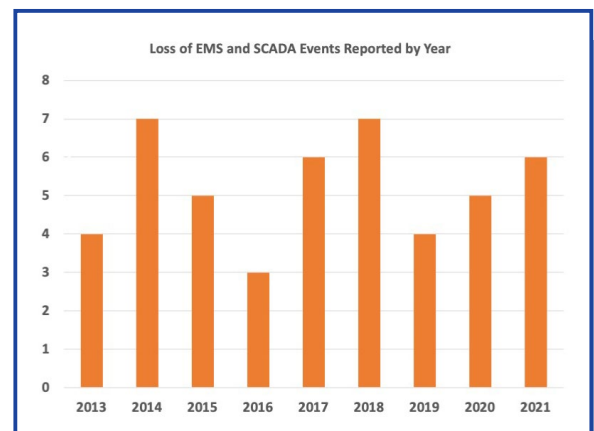
2021 HIGHLIGHTS FROM THE ANALYSIS OF LOSS OF SITUATIONAL AWARENESS INCLUDE:

- Convergence rates for ERCOT's State Estimator continue to surpass the goal of 97 percent, exceeding 99.98 percent in 2021.
- Telemetry availability rates remain stable at approximately 96.9 percent overall.



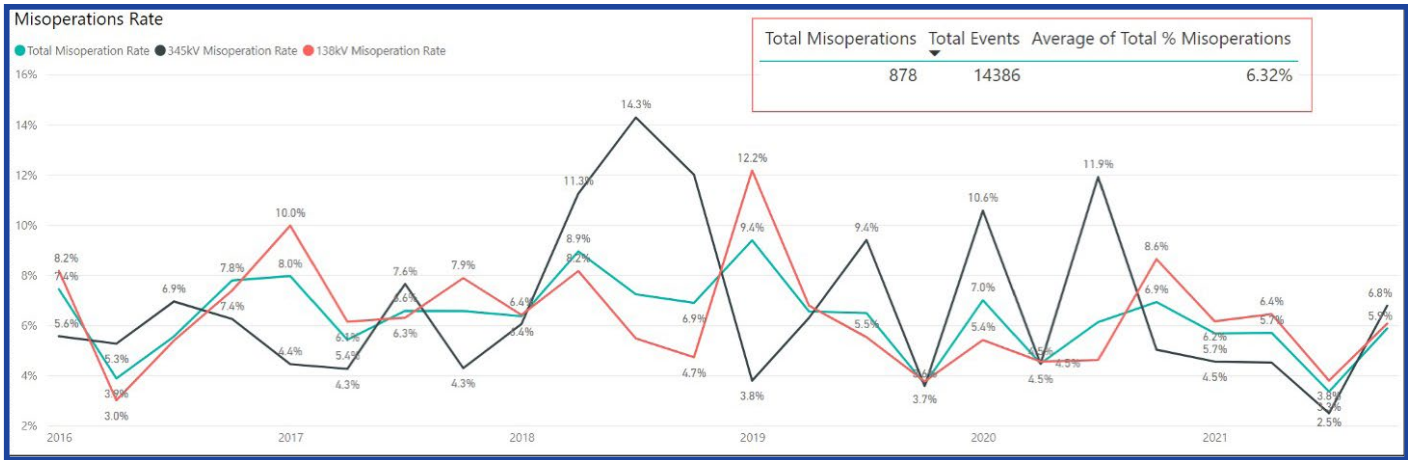
AREAS TO MONITOR INCLUDE:

- A total of six Category 1 loss of System Control and Data Acquisition (SCADA) or Energy Management System (EMS) events were reviewed in 2021 at Transmission Operators control facilities. Average duration was approximately 1.4 hours. Five of the six 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.



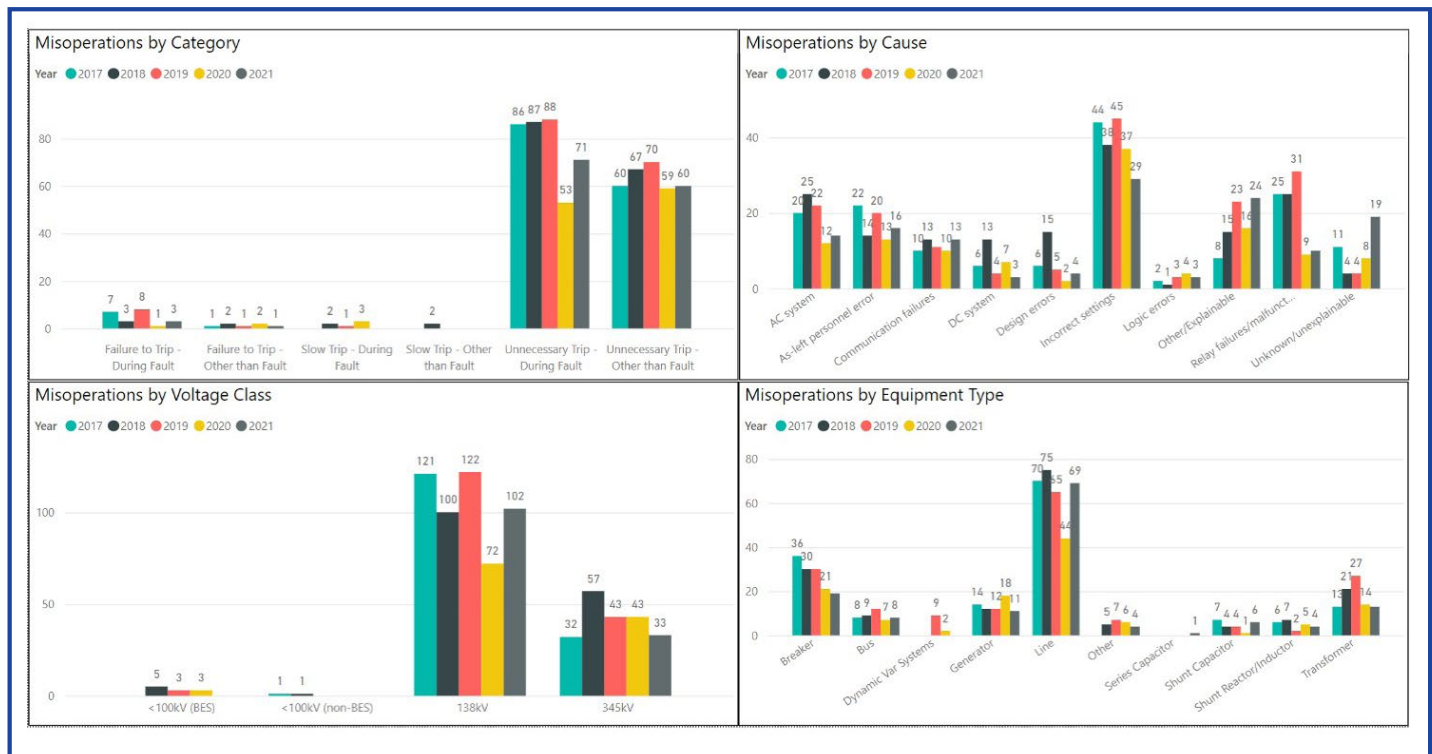
KEY FINDINGS

PROTECTION SYSTEM MISOPERATIONS



2021 HIGHLIGHTS FROM THE ANALYSIS OF REPORTED PROTECTION SYSTEM MISOPERATIONS INCLUDE:

- There is a continuing positive downward trend in the number of reported misoperations occurring each year due to incorrect settings and relay failures.
- The overall Protection System Misoperation rate decreased in 2021 to 5.2 percent from 5.8 percent for 2020.
- Corrective actions were completed or are in-progress on 84 percent of the misoperations that occurred in 2021.





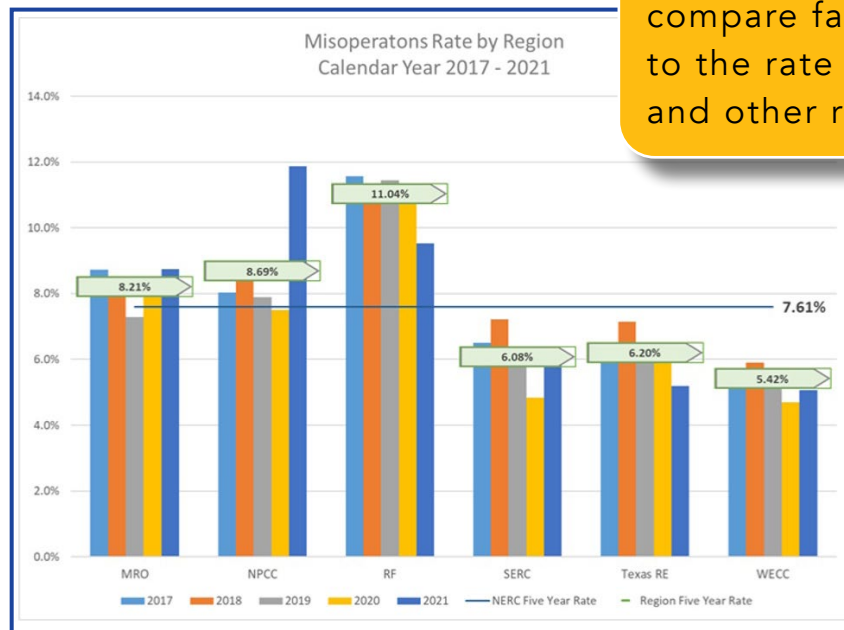
PROTECTION SYSTEM MISOPERATIONS

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AREAS TO MONITOR INCLUDE:

- Incorrect settings, logic, and design errors remained the largest cause of misoperations, accounting for 27 percent of misoperations in 2021.
- Unknown and Other misoperation causes increased significantly in 2021.
- Multiple system events occurred in 2021 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 NERC and other regions.



Despite an overall downward trend in the annual Misoperation rate, Protection System Misoperations were a contributing factor in several system events in 2021. 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 Misoperations of Protection Systems after faults on the following dates:

- February 1, 2021: A fault occurred on a 138 kV transmission line combined with protective relay misoperations, causing the loss of two 138 kV busses.
- August 2, 2021: A fault occurred on a 138 kV transmission line combined with protective relay misoperations due to incorrect breaker failure timer settings, causing the loss of three 138 kV lines and two power transformers.
- October 10, 2021: A fault occurred on a non-BES 12 kV transformer combined with protective relay misoperations due to incorrect settings, causing the loss of a 138 kV bus and multiple 138 kV lines.
- December 21, 2021: A fault occurred on a 138 kV transmission line combined with protective relay misoperations due to an incorrect setting and a failed trip coil, causing the loss of a 138 kV bus and multiple tapped substation loads.
- December 24, 2021: A fault occurred on a 345 kV autotransformer combined with protective relay misoperations due to a miswired relay, causing the loss of a 345 kV bus.

KEY FINDINGS

PHYSICAL AND CYBER SECURITY

2021 HIGHLIGHTS FROM THE ANALYSIS OF PHYSICAL AND CYBER SECURITY EVENTS INCLUDE:

- Ransomware and remote access: 2021 was the year of ransomware compromises (including remote access)
 - The Federal Bureau of Investigation (FBI), the Cybersecurity and Infrastructure Security Agency (CISA), and the National Security Agency (NSA) observed incidents involving ransomware against 14 of the 16 U.S. critical infrastructure sectors, including the Defense Industrial Base, Emergency Services, Food and Agriculture, Government Facilities, and Information Technology Sectors. [Joint Cybersecurity Advisory - AA22-040A: Trends Show Increased Globalized Threat of Ransomware \(cisa.gov\)](#)
 - Mitigating Log4Shell and Other Log4j-Related Vulnerabilities
 - Cyber threat actors are actively scanning networks to potentially exploit Log4Shell.
 - CISA Alert (AA21-356A) [Mitigating Log4Shell and Other Log4j-Related Vulnerabilities | CISA](#)
 - Hackers Breached Colonial Pipeline Using Compromised Password
 - Cyber threat actors gained entry into the networks of Colonial Pipeline Co. on April 29, 2021, through a virtual private network (VPN) account.
 - One week later, on May 7, 2021, in Colonial's control room there was a ransom note demanding cryptocurrency.
 - <https://www.energy.gov/ceser/colonial-pipeline-cyber-incident>
 - DarkSide Ransomware
 - CISA Alert (AA21-131A): [DarkSide](#)
- [Ransomware: Best Practices for Preventing Business Disruption from Ransomware Attacks | CISA](#)
- Compromise of U.S. Water Treatment Facility
 - CISA Alert (AA21-042A): [Compromise of U.S. Water Treatment Facility | CISA](#)
- Ongoing Cyber Threats to U.S. Water and Wastewater Systems
 - CISA Alert (AA21-287A): [Ongoing Cyber Threats to U.S. Water and Wastewater Systems | CISA](#)
- Miscellaneous
 - CISA (AA21-265A): [Conti Ransomware](#)
 - CISA (AA21-291A): [BlackMatter Ransomware](#)
- EXECUTIVE ORDER 14028, IMPROVING THE NATION'S CYBERSECURITY
 - The President's Executive Order (EO) on "Improving the Nation's Cybersecurity (14028)" issued on May 12, 2021, charges multiple agencies (including NIST) with enhancing cybersecurity through a variety of initiatives related to the security and integrity of the software supply chain.
 - [Executive Order 14028, Improving the Nation's Cybersecurity | NIST](#)
- Advanced persistent threats (such as the SolarWinds Orion incident, Log4J, and Russian state-sponsored threats) continued to present challenges in 2021
- Substation intrusions reported through ERCOT channels are low risk, with vandalism and copper theft being the most common.

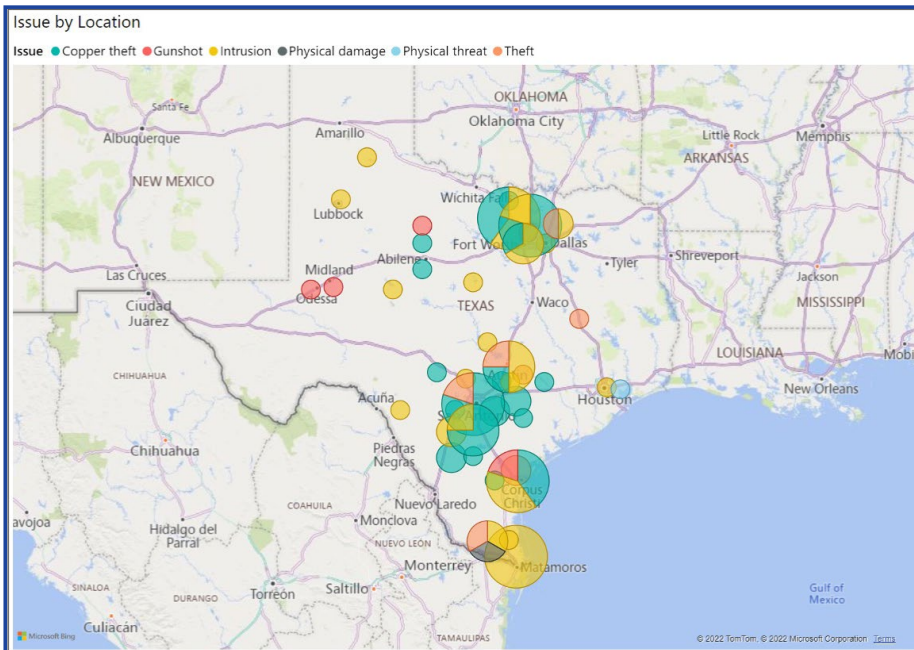
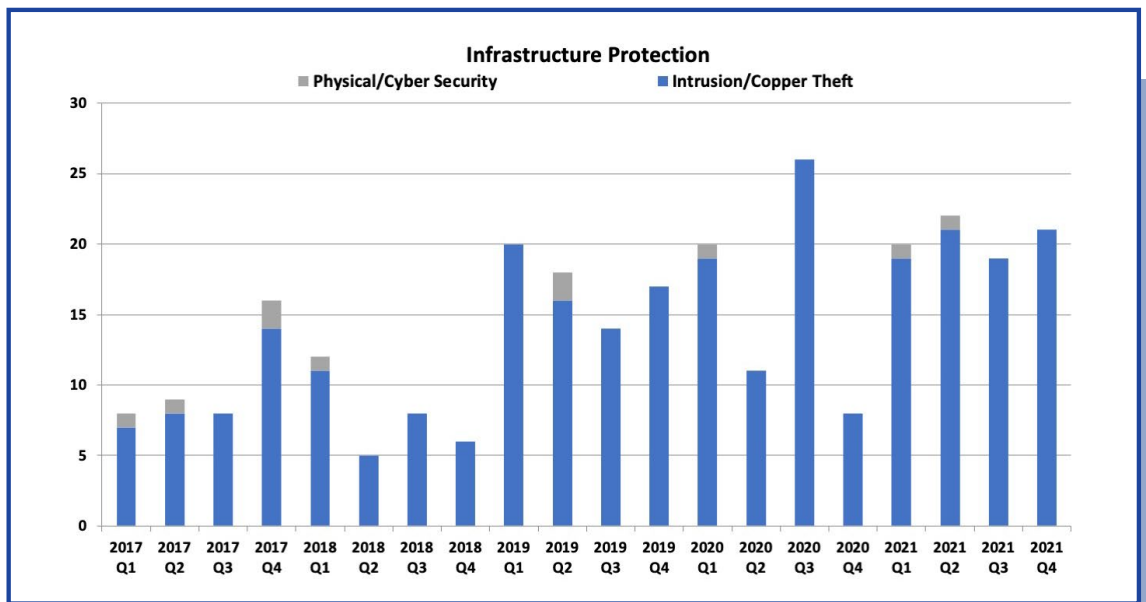
KEY FINDINGS



PHYSICAL AND CYBER SECURITY TEXAS RE

2021 PHYSICAL SECURITY EVENTS AFFECTING BES FACILITIES:

- Facility threatened by shooter
- Wind turbines damaged by gunshots
- Denial of service attacks against systems managed by a third-party internet provider
- Gunshot damage to fiber optic splice case on overhead transmission line
- Power transformer damaged by gunshots
- Multiple instances of intrusions and copper theft





FOCUS AREAS FOR 2022

CRITICAL INFRASTRUCTURE INTERDEPENDENCIES

- Critical industry relationships, especially between the electric industry and natural gas, but also electric-communication and electric-water
- Situational awareness of gas systems, including supply availability, pipeline status (i.e. gas compressor station locations and capability), and deliverability issues
- Identification of critical gas system loads

RESOURCE ADEQUACY

- Continuing impact of generation unit retirements and resource mix changes
- BES renewable resource impact on system ramping capability
- Distributed energy resource effects on demand, ramping, and voltage control

BULK POWER SYSTEM PLANNING

- Probabilistic planning for reserve margin issues across all operating hours
- Weak grid areas of the Interconnection

GRID TRANSFORMATION

- Increased use of stability-related generic transmission constraints
- Accurate dynamic and steady-state modeling of renewable generation
- Low voltage and low frequency characteristics of inverter-based resources
- Stability modeling challenges with inverter-based resources

RESILIENCE DURING MAJOR SYSTEM EVENTS

- Severe weather preparation including weatherization of facilities
- Extreme event forecasting and scenario development

CYBER AND PHYSICAL SECURITY

- Mitigation of advanced persistent threats
- Improved reporting and information sharing for cyber and physical security incidents

HUMAN PERFORMANCE

- Continued reduction of human performance errors in Protection System Misoperations
- Training for extreme condition operations including load shed and restoration



TEXASRE

Ensuring electric reliability for Texans

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