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Reliability Performance and Regional Risk Assessment

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Director, Reliability Services

June 16, 2025

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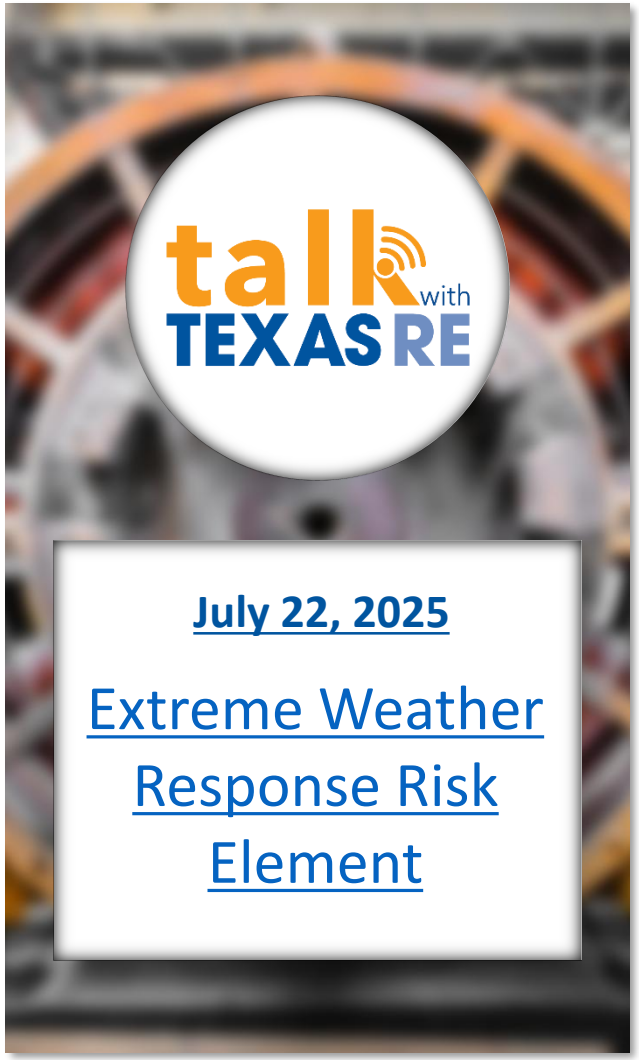
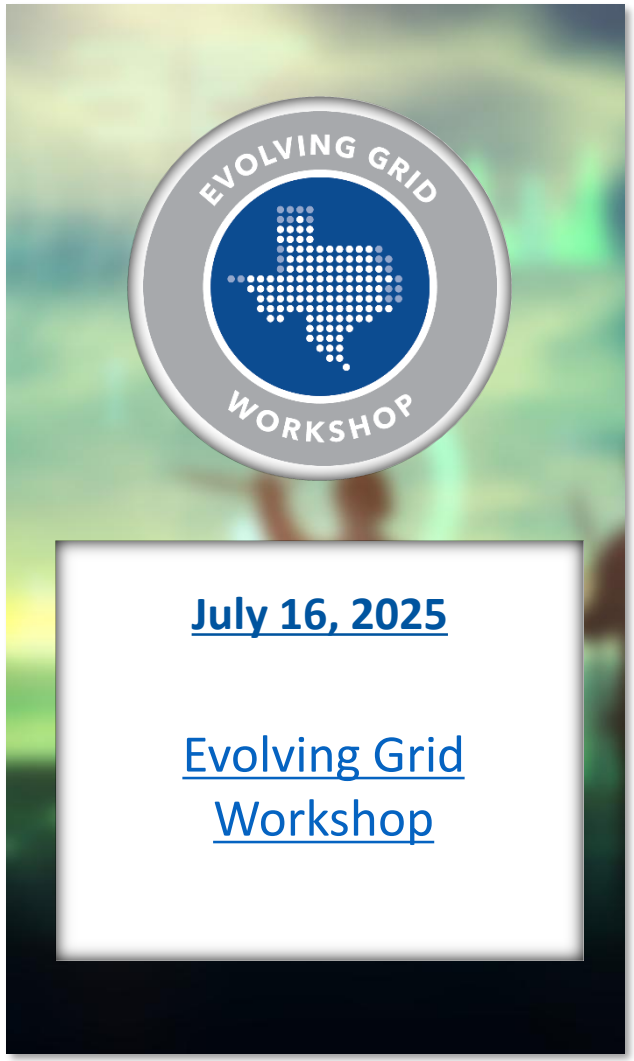
Upcoming Texas RE Events



Upcoming Texas RE Events



July 16, 2025

Evolving Grid Workshop

September 17, 2025

Q3 MRC, AGR&F, and Board Meetings

October 1, 2025

Winter Weatherization Workshop

Upcoming ERO Enterprise Events

Date	Event
June 16	Technical Talk with RF (RF)
June 19	Reliability & Security Monthly Update (WECC)
July 17	Reliability & Security Monthly Update (WECC)
July 21	Technical Talk with RF (RF)

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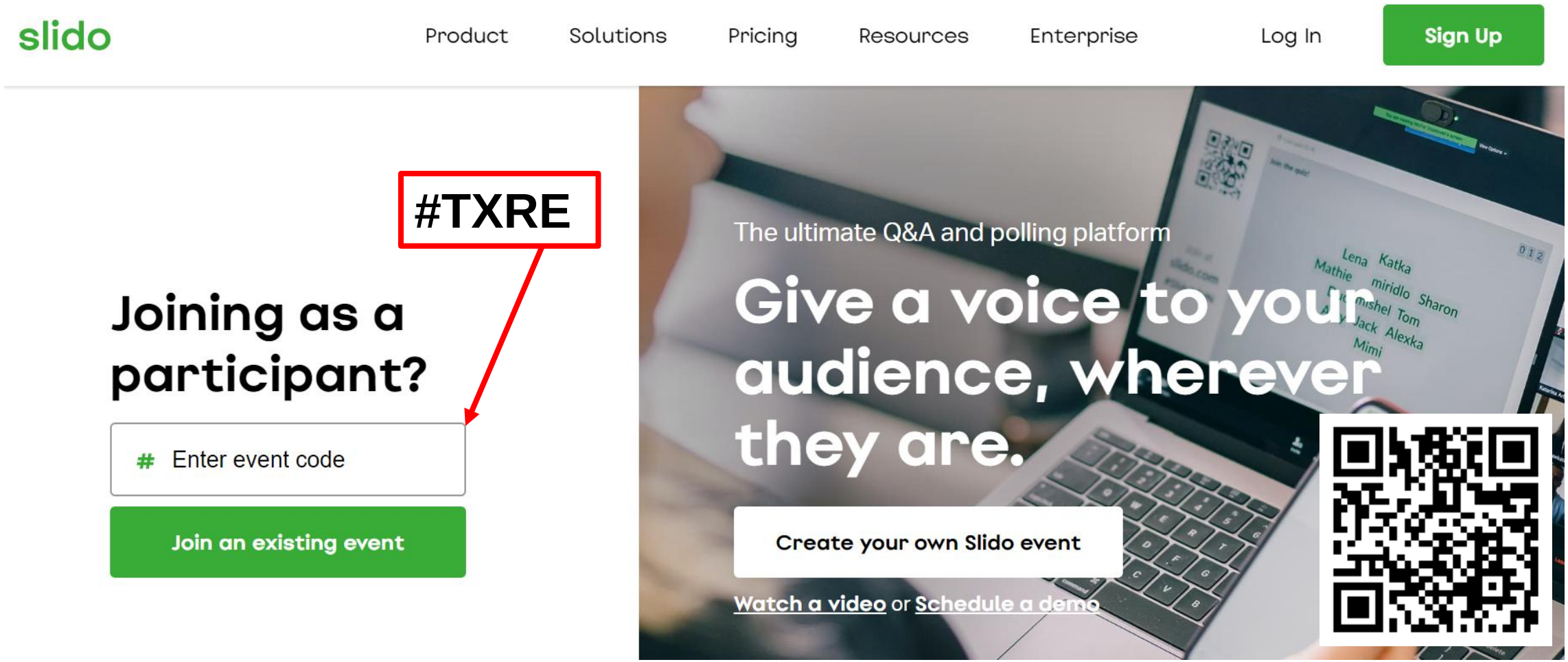
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Key Findings

- Efforts to reduce inverter-based resource risks continue
- Increased risk due to large load integration
- Large load impact on future reserve margins
- Reduced impact from cold weather on generators
- Artificial intelligence presents new challenges

Reliability Performance and Regional Risk Assessment

Performance Analysis and Key Risk Areas

- Grid Transformation
  - Resource Adequacy and Performance
  - Bulk Power System Planning
  - Protection and Control Systems
  - Situational Awareness Challenges
  - Human Performance
  - Changing Resource Mix
- Resilience to Extreme Events
- Cyber and Physical Security
- Critical Infrastructure Interdependencies

Reliability Performance Metrics

Improving	Stable or No Change	Monitoring	Actionable
(Improving trend compared to previous 4 years or improved event performance of observed conditions)	(Minimal or no change compared to previous 4 years)	(Declining trend compared to previous 4 years or specific negative event performance issues)	(Declining trend for two or more consecutive years or significant negative event performance)

Key Performance Indicator with Description	2024 Performance & Trend Results
Resource Adequacy Measures potential resource adequacy issues by analysis of planning reserve margin and energy emergency alerts	Reserve margins show resource deficiencies due to integration of large loads
	Resource weatherization resulted in sustained performance during cold weather events
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
	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 EFOR decreased in 2024, long term rate increase
	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 Voltage ride through for IBRs and large loads
	Inertia levels are stabilizing Synchronous generator retirements slowed
Protection System Performance Measures Protection System performance by analysis of Protection System Misoperations	Misoperations due to incorrect settings continued to decrease in 2024
	Misoperation rate decreased in 2024, 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	Eight loss of situational awareness events (up from four)
	State Estimator convergence rate remained stable

Performance Metrics

- Resource deficiencies and negative reserve margins forecasted in future years due to integration of large loads
- Improvements noted in resource weatherization and cold weather resiliency
- Improvements noted in frequency response due to integration of battery energy storage
- Solar down-ramp magnitude continues to increase
- Inverter-based resource ride-through continues to be a point of emphasis
- Voltage ride-through issues with large loads
- Misoperation rates improving but human performance continues to be primary causal factor in both misoperations and system events
- Increased number of loss of situational awareness events

2025 Risk Focus Areas

CONSEQUENCE/ IMPACT		LIKELIHOOD (L)				
		L1	L2	L3	L4	L5
		VERY LIKELY	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
C5	SEVERE					
C4	MAJOR			Supply Chain	Disorganized Integration of Large Loads	
				Energy Availability		
			Extreme Weather & Resource Weatherization	Gas Supply Restrictions During Cold Weather	IBR Ride-Through	
C3	MODERATE		Provision of Essential Reliability Services from a Changing Resource Mix	Remote Access		
			Facility Ratings	Inaccurate Resource Modeling		
			Artificial Intelligence		Physical Security	
C2	MINOR					
C1	NEGLIGIBLE					

RISK LEVEL			
LOW	MODERATE	HIGH	VERY HIGH

Risk Focus Areas for 2025

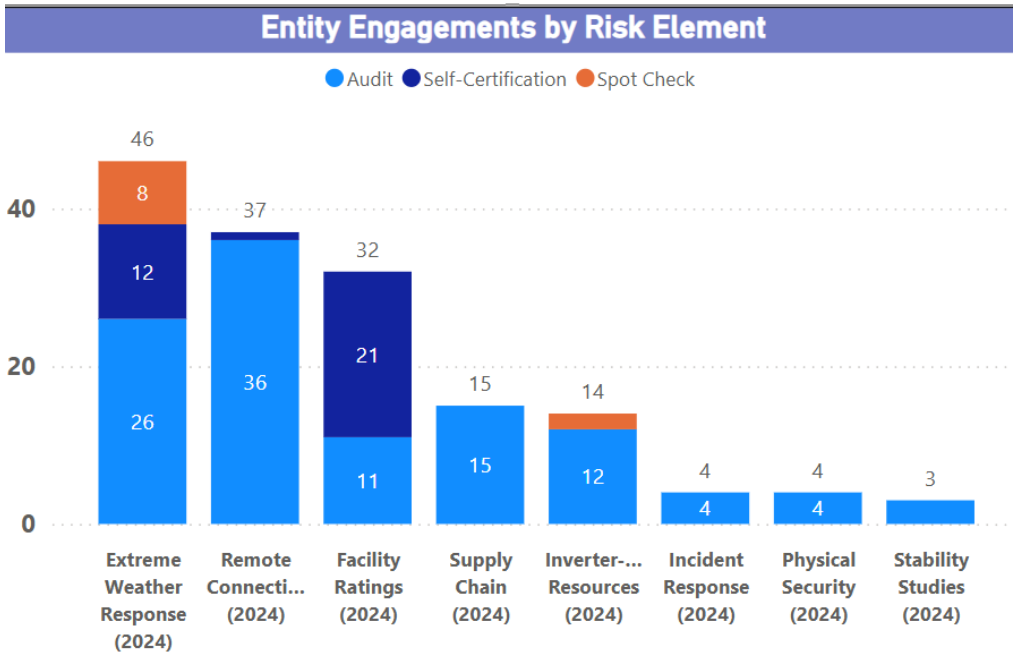
- Continuous Evaluation of Emerging Risks
- Priorities Based on Likelihood and Impact
- Major Areas
  - IBR Ride-Through
  - Physical Security
  - Remote Access Threats and Vulnerabilities
  - Gas-Electric Interdependencies
  - Supply Chain
  - Resource Modeling
- New for 2025: Artificial Intelligence

Risk Focus Area Follow-up and Outreach

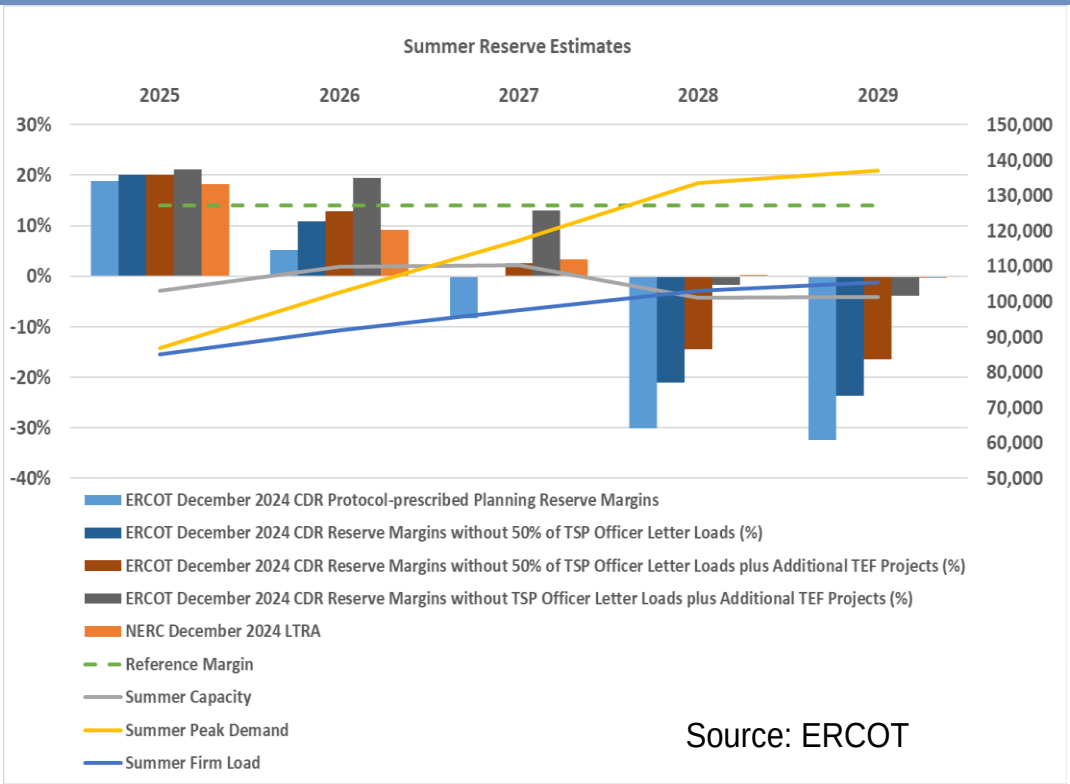
2024 Risk and CMEP IP Focus Areas

Inverter-Based Resource Ride Through
Provision of Essential Reliability Services from a Changing Resource Mix
Energy Reliability Planning
Inaccurate Resource Modeling
Remote Access
Supply Chain
Physical Security
Extreme Weather & Resource Weatherization
Facility Ratings
Gas Supply Chain Restrictions during Cold Weather
Integration of Large Loads
Incident Response
Stability Studies

- Eighteen Talk with Texas RE webinars on risk focus area topics
- Winter Weatherization Workshop
- Cyber and Physical Security Workshop
- NERC Alert issued on IBR model quality
- Multiple entity engagements



Resource and Energy Adequacy



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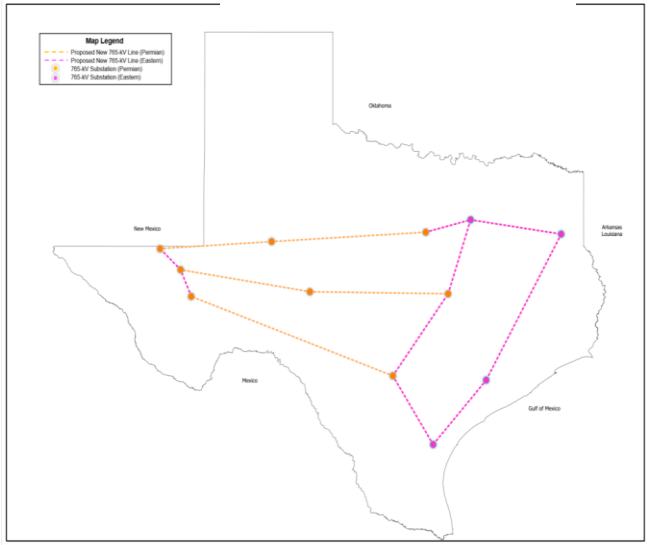
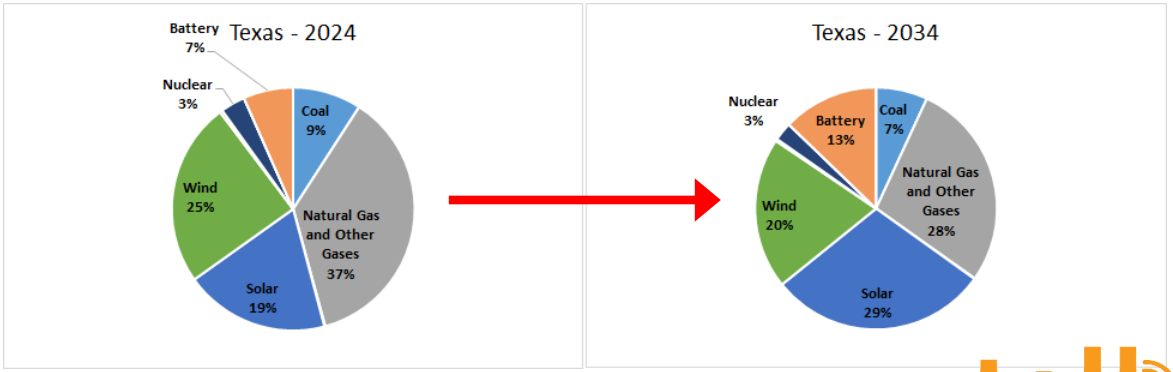
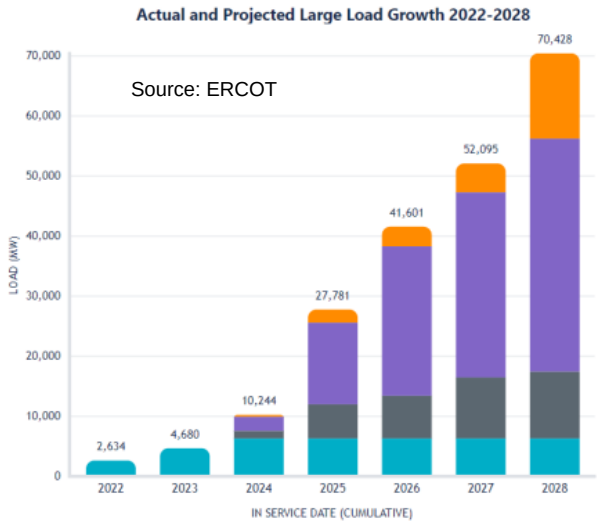


- PUCT Reliability Standard
- Texas Energy Fund Projects
- 765kV Transmission Projects
- Energy Assessment pilot study kick off May 2025
- NERC Interregional Transfer Capability Study
  - Energy deficiencies identified in multiple weather years studied

Metric	2026 Summer	2026 Winter	2028 Summer	2028 Winter
LOLE (days/year)	0.38	0.51	0.05	0.04
LOLH (hours/year)	1.41	1.57	0.18	0.16
EUE (MWh)	10,985	11,090	857	781
Max Hourly EUE (MWh)	29,124	29,266	17,762	16,851
Max EUE Duration (Hr)	15	16	12	11



Large Load Integration



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Incident Review

Considering Simultaneous Voltage-Sensitive Load Reductions

Primary Takeaways

Operators and planners of the Bulk Electric System (BES) should be aware of the risks and challenges associated with voltage-sensitive large loads that are rapidly being connected to the power system. Specifically, when considering data centers and cryptocurrency mining facilities, entities should be aware of the potential for large amounts of voltage-sensitive load loss during normally cleared faults on the BES. Voltage-sensitive data center-type loads have increased on the system and are predicted to continue growing rapidly. The 2024 NERC *Long-Term Reliability Assessment* (LTRA) documents and discusses this potential growth of data center-type loads. This vignette highlights this load-loss potential based on analysis of a recent event in the Eastern Interconnection and offers some considerations for BES operators, planners, and regulators concerning identifying and mitigating the potential reliability effects and risks presented by these large voltage-sensitive load losses for future operations.

Summary of Incident

A 230 kV transmission line fault led to customer-initiated simultaneous loss of approximately 1,500 MW of voltage-sensitive load that was not anticipated by the BES operators. The electric grid has not historically experienced simultaneous load losses of this magnitude in response to a fault on the system, which has historically been planned for large generation losses but not for such significant simultaneous load losses. Simultaneous large load losses have two effects on the electric system: First, frequency rises on the system as a result of the imbalance between load and generation; second, voltage rises rapidly because less power is flowing through the system. In this incident, the frequency did not rise to a level high enough to cause concern. The voltage also did not rise to levels that posed a reliability risk, but operators did have to take action to reduce the voltage to within normal operating levels. However, as the potential for this type of load loss increases, the risk for frequency and voltage issues also increases. Operators and planners should be aware of this reliability risk and ensure that these load losses do not reach intolerable levels.

Incident Details

At approximately 7:00 p.m. Eastern on July 10, 2024, a lightning arrestor failed on a 230 kV transmission line in the Eastern Interconnection, resulting in a permanent fault that eventually "locked out" the transmission line. The auto-reclosing control on the transmission line was configured for three auto-reclose attempts staggered at each end of the line. This configuration resulted in 6 successive system faults in an 82-second period. The protection system detected these faults and cleared them properly. The shortest fault duration was the initial fault at 42 milliseconds, and the longest fault duration was 66 milliseconds. The voltage magnitudes during the fault ranged from .25 to .40 per unit in the load-loss area.

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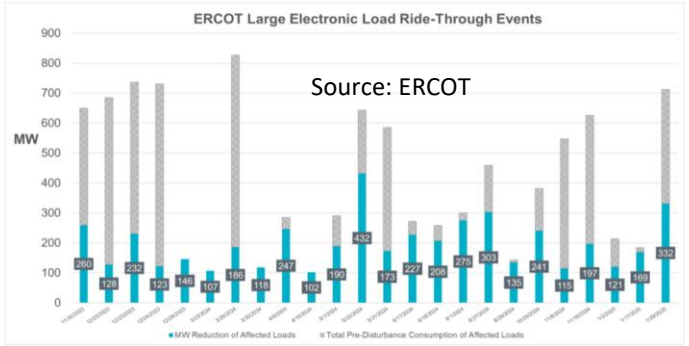
Large Loads Task Force (LLTF)

Work Plan

Website: LLTF	**Chair:** Matthew Vieth, AEP	**NERC Leads:** Jack Gibfried and Evan Mickelson
Hierarchy: Reports to RSTC	**Vice-chair:** Agee Springer, ERCOT	**Scope Approved:** August 2024

#	Task Description	Target Completion	Status
1	**White Paper: Characteristics and Risks of Emerging Large Loads** White Paper on the unique characteristics and risks associated with emerging large loads. This paper will leverage the NERC Framework to address known and emerging reliability and security risks to identify, validate, and prioritize potential reliability risks related to the integration of emerging large loads	Q2 – 2025	In Progress
2	**White Paper: Assessment of gaps in existing practices, requirements, and Reliability Standards for Emerging Large Loads** White Paper assessing whether existing engineering practices, requirements, and Reliability Standards can adequately capture and mitigate reliability impact(s) of large loads interconnected to the BPS. The paper will also highlight gaps in load modeling practices that LMWG can leverage to take further action to improve load modeling.	Q4 – 2025	In Progress
3	**Reliability Guideline: Risk Mitigation for Emerging Large Loads** Reliability Guideline identifying risk mitigation including improvements to existing planning, and operation processes and interconnection requirements for large loads. Guidance may include recommended improvements to modeling practices, analyses, coordination and data collection efforts, real time monitoring and event analysis.	Q2 – 2026	Not Started

Large Power Electronic Load Ride-Through Events November 2023 - Present



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- NERC Large Load Task Force activities
- Issues with future reserve margins due to anticipated large load growth
- Multiple voltage-sensitive load reduction events
- Price-responsive load swings
- Regulation exhaustion during large load swings
- No defined registration criteria

Inverter-Based Resource Risks

185 FERC ¶ 61,042
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part 40

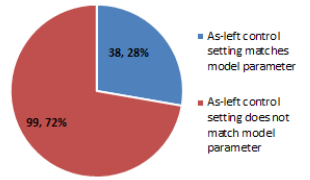
[Docket No. RM22-12-000; Order No. 901]

Reliability Standards to Address Inverter-Based Resources

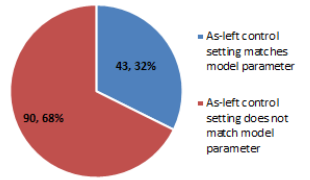
(Issued October 19, 2023)

- Increased reliance on IBRs to meet load
- NOGRR245 and 255 approval
- FERC Order 901 projects
- Smaller disturbances still occurring in ERCOT
- Four large IBR disturbances in WECC
- NERC Alert on IBR model quality
- Need for Grid-Forming battery capabilities

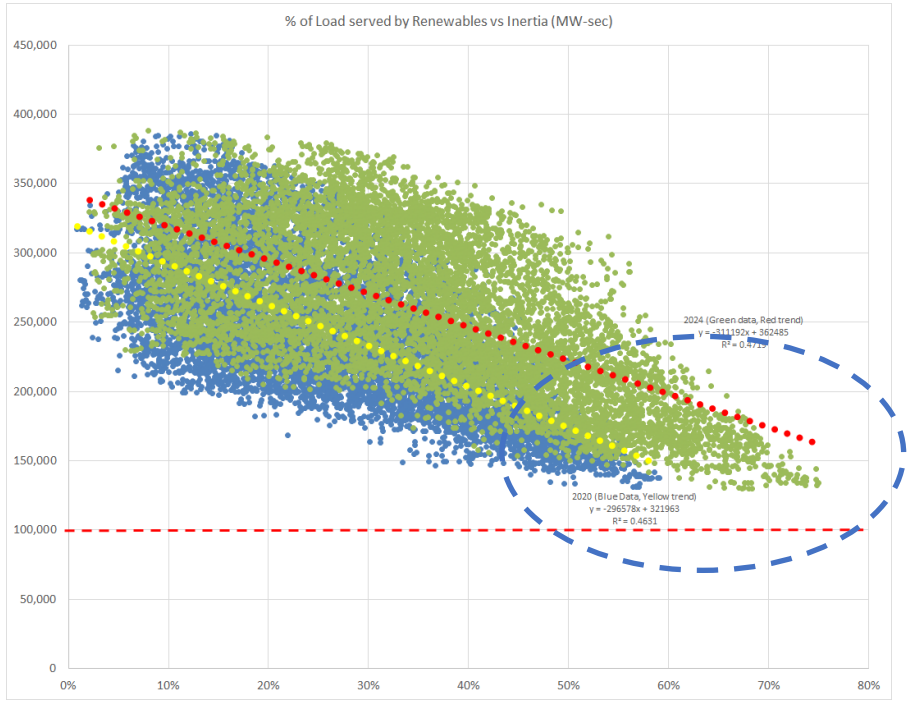
High Voltage Threshold Settings Model vs Reported	# of Facilities	%
As-left control setting matches model parameter	38	28%
As-left control setting does not match model parameter	99	72%
Total	137	100%

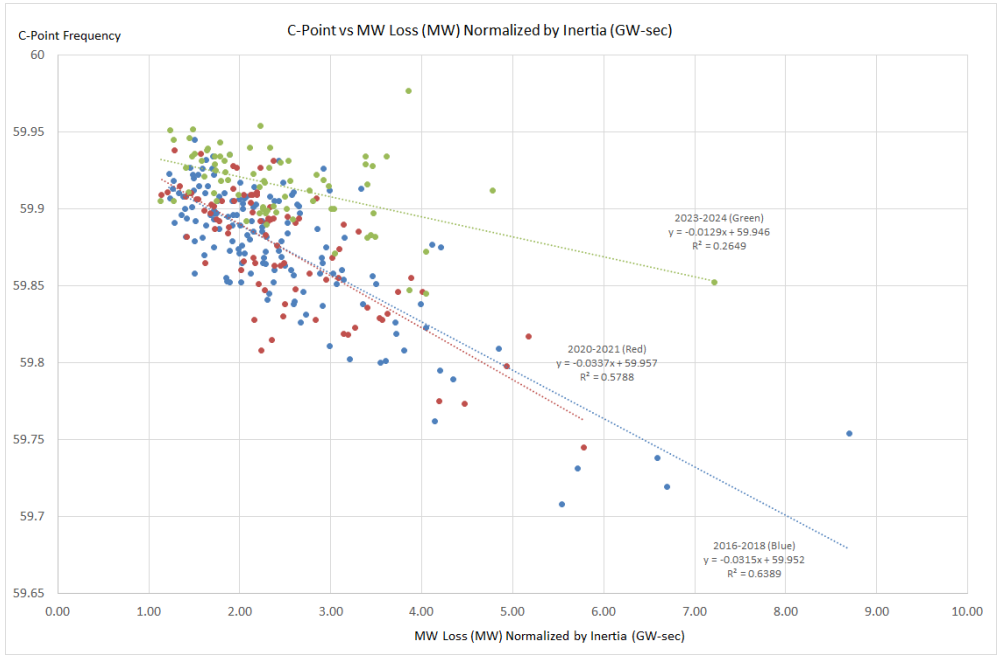


Low Voltage Threshold Settings Model vs Reported	# of Facilities	%
As-left control setting matches model parameter	43	32%
As-left control setting does not match model parameter	90	68%
Total	133	100%

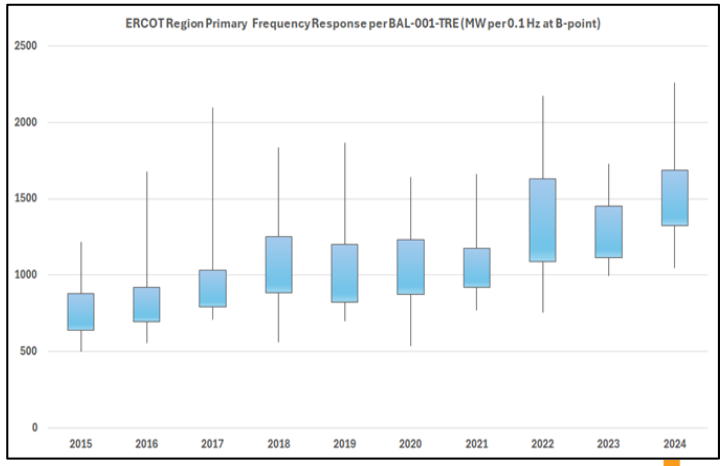


Inertia and Frequency Response

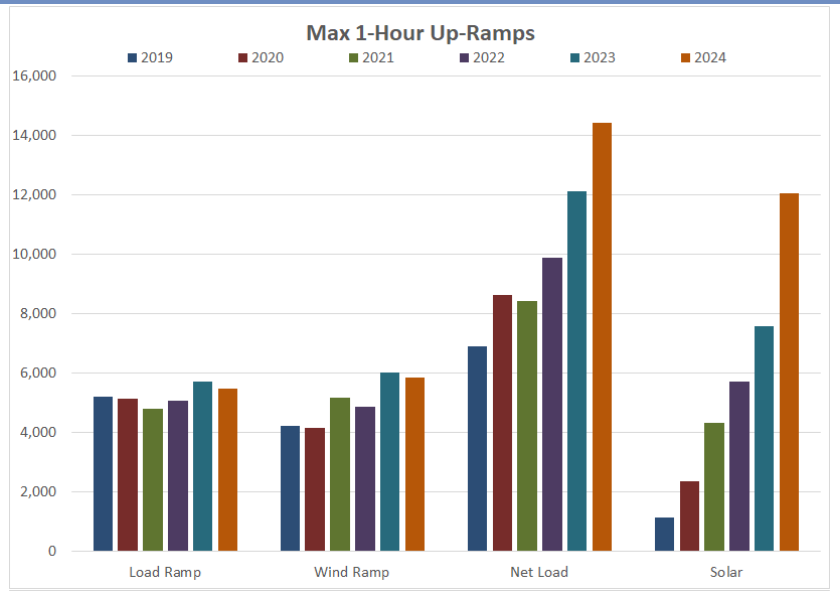


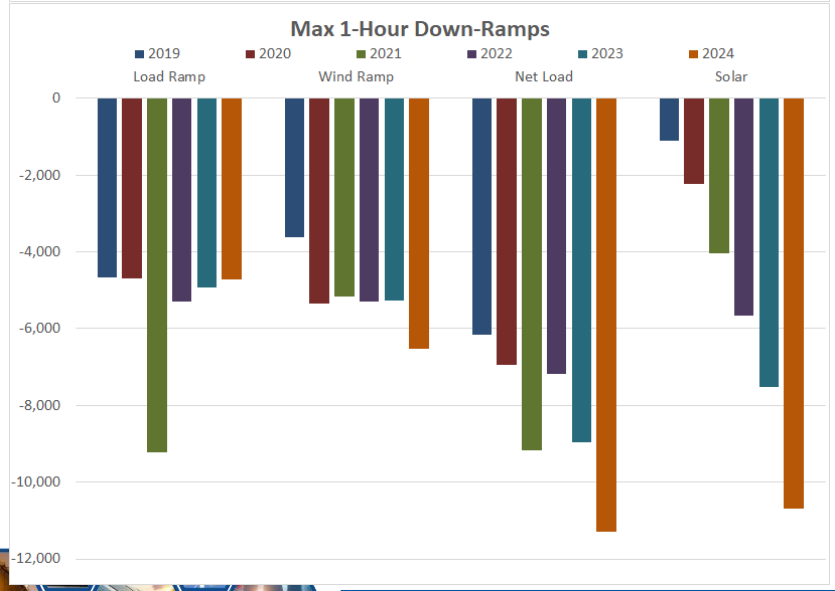


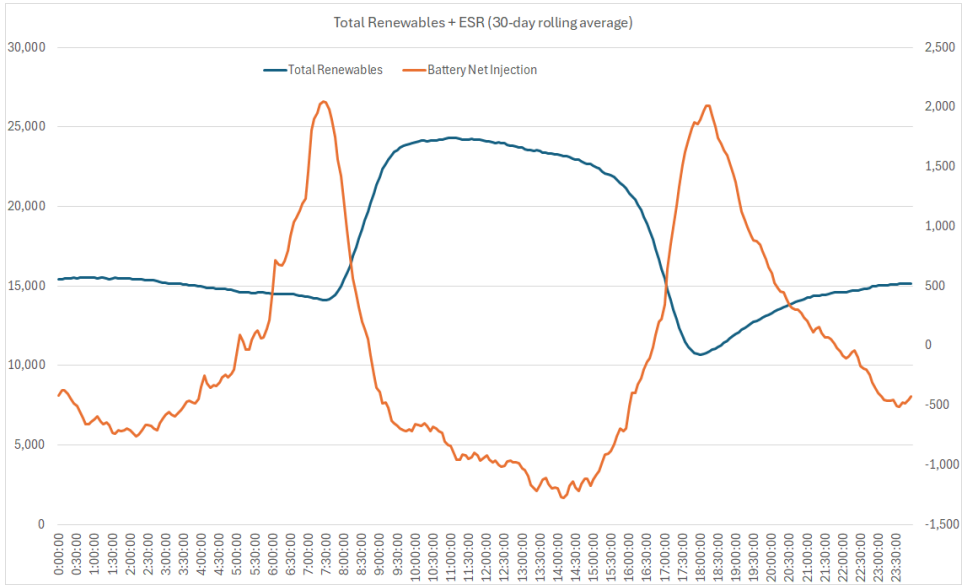
- Continued shift in inertia levels as resource mix changes
- Lowest hourly inertia level of 129.9 GW-sec in 2024
- Frequency response improvements noted due to higher levels of PFR capacity from integration of batteries



Solar and Net Load Ramping



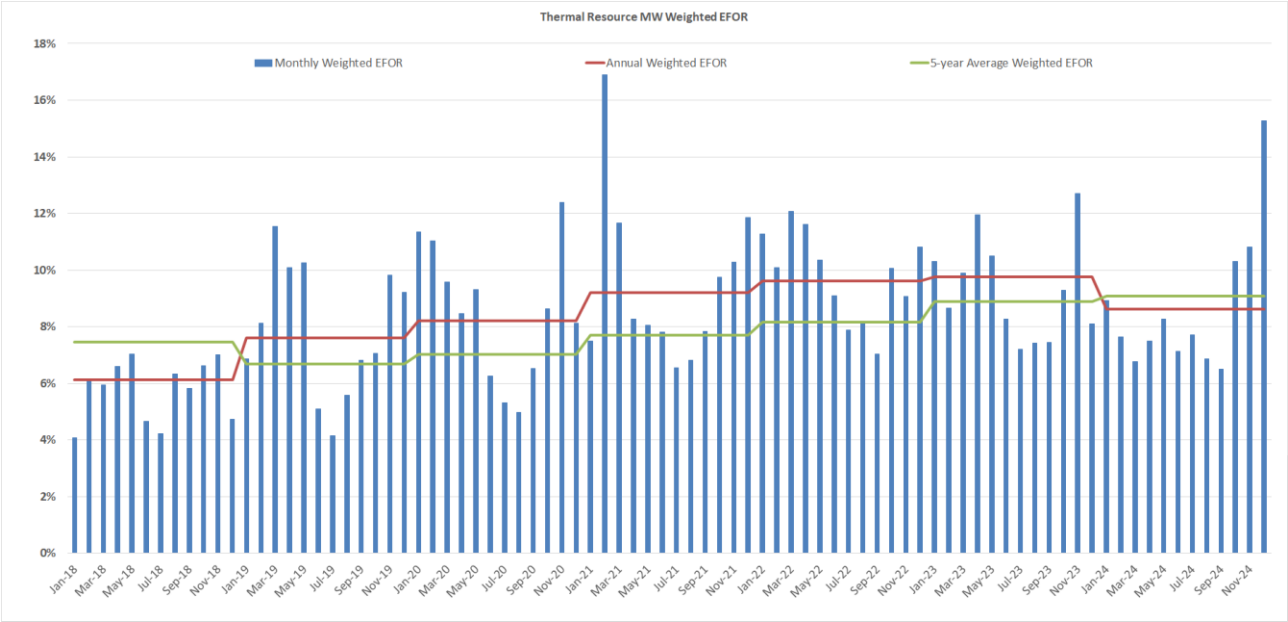


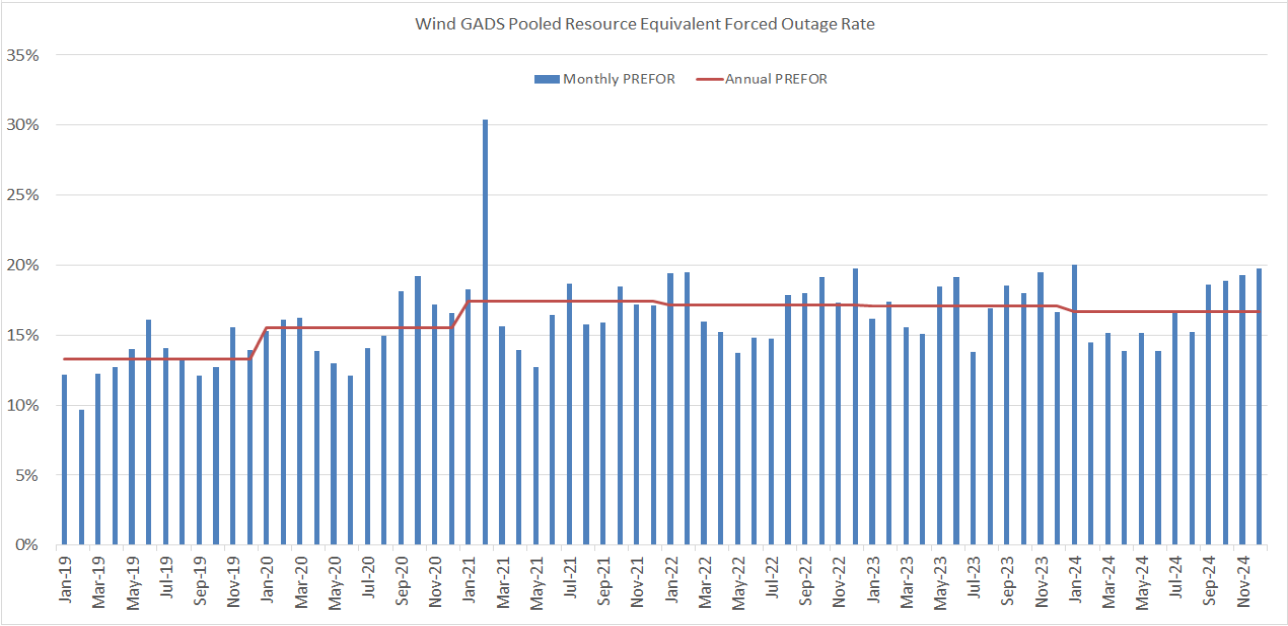


- Solar and net load ramp rates continue to increase
- Non-spin and ECRS deployments occasionally used during steep ramp hours
- Battery resources continue to provide valuable capability during ramp hours

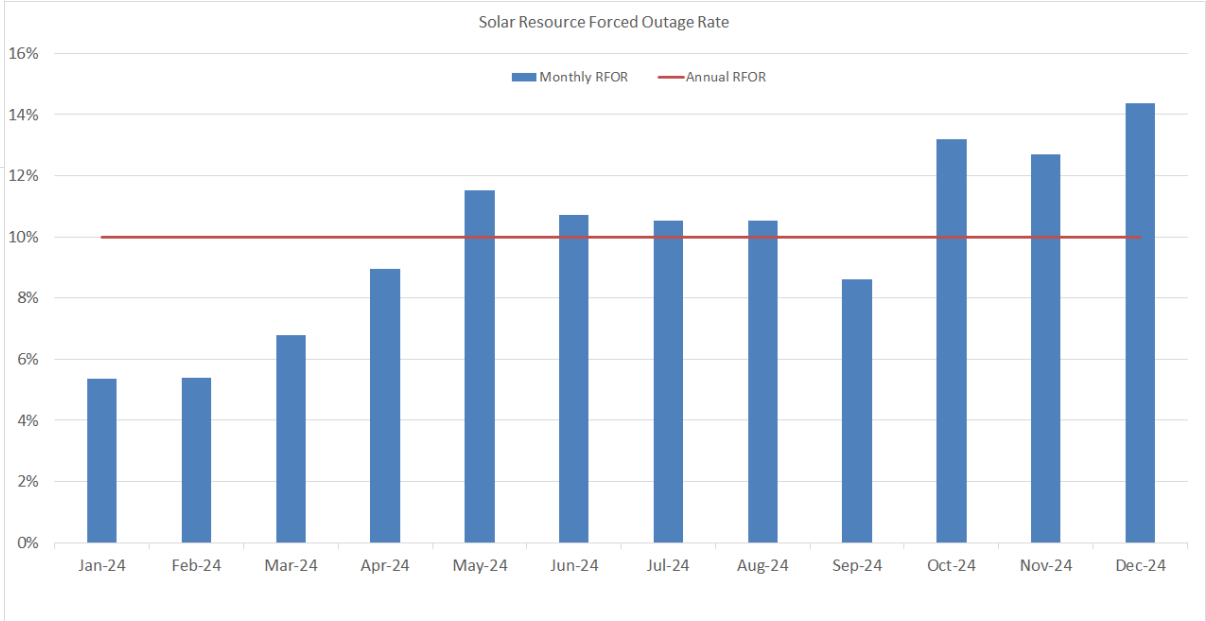
Ramping Variability 2024	Load	Wind Gen	Solar Gen	Net Load
Maximum One-Hour Increase	5,487 MW	5,868 MW	12,053 MW	14,432 MW
Maximum One-Hour Decrease	-4,730 MW	-6,521 MW	-10,697 MW	-11,301 MW

Generator Outage Rates



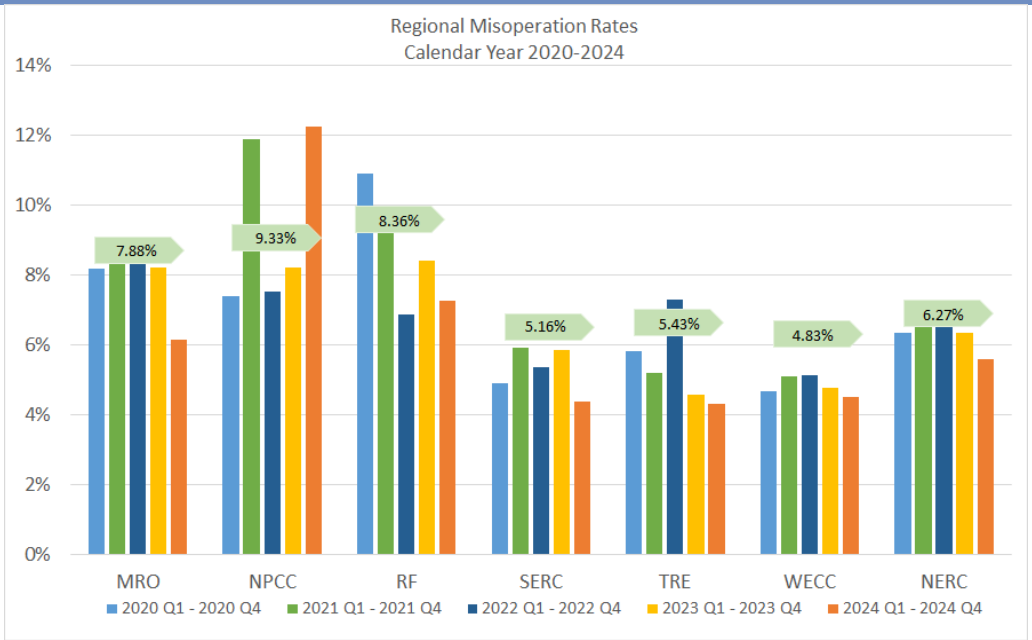


- Decrease in thermal EFOR rates in 2024, but long-term trend is still increasing
- Wind resource EFOR rates remained flat in 2024
- Initial year of collecting solar resource EFOR rates

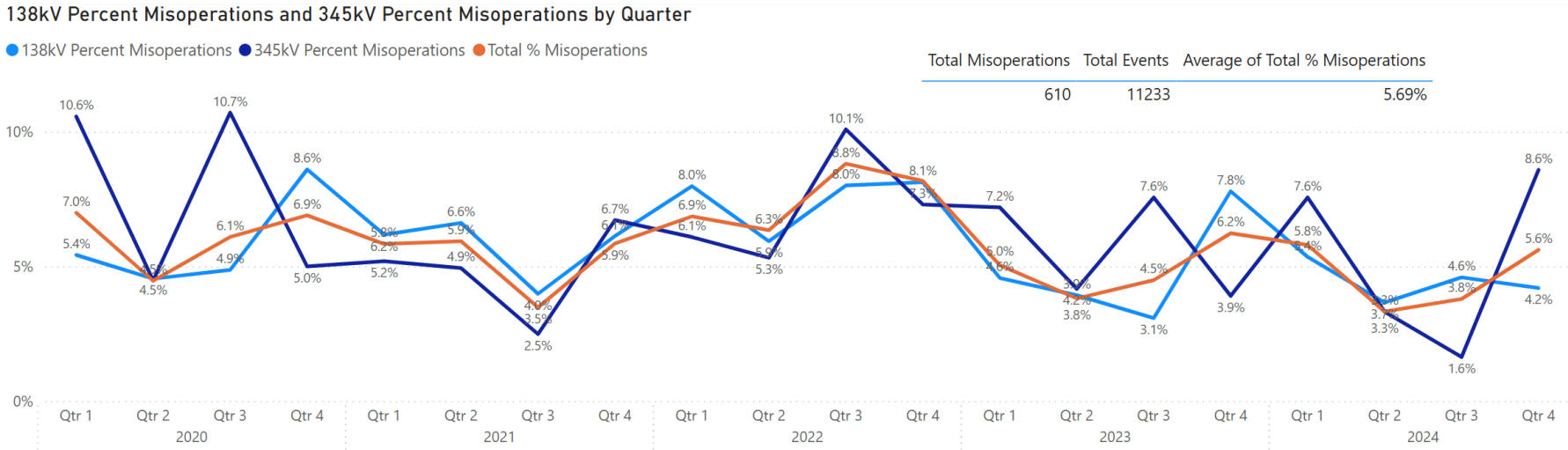


talk with TEXAS RE

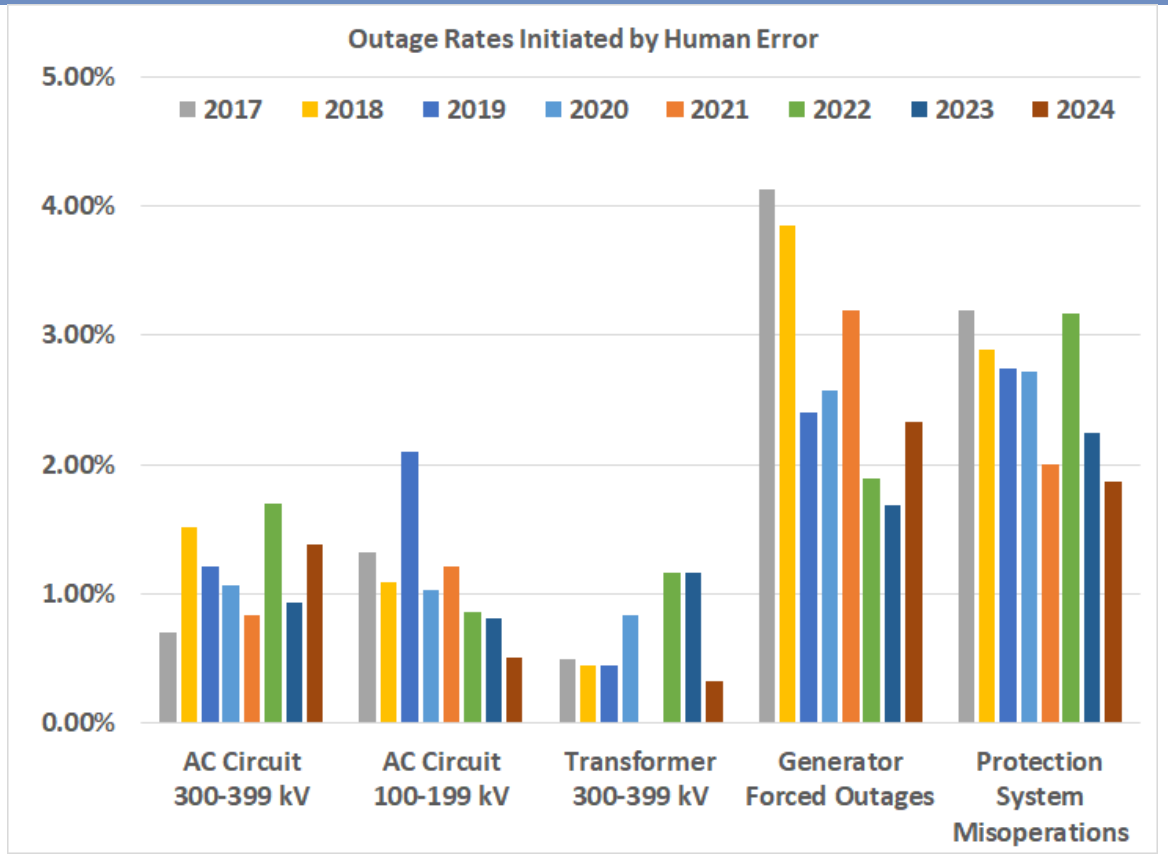
Protection System Misoperations



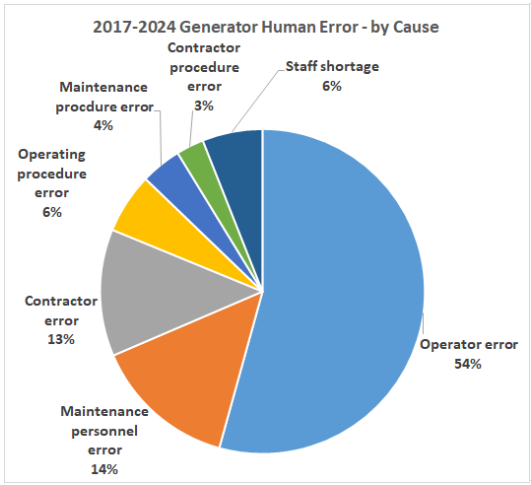
- Overall Misoperation rate trending lower, from 6.0% in 2020 to 4.3% in 2024
- Incorrect settings, logic, and design errors remain the largest cause
- Region compares favorably with NERC overall and other regions

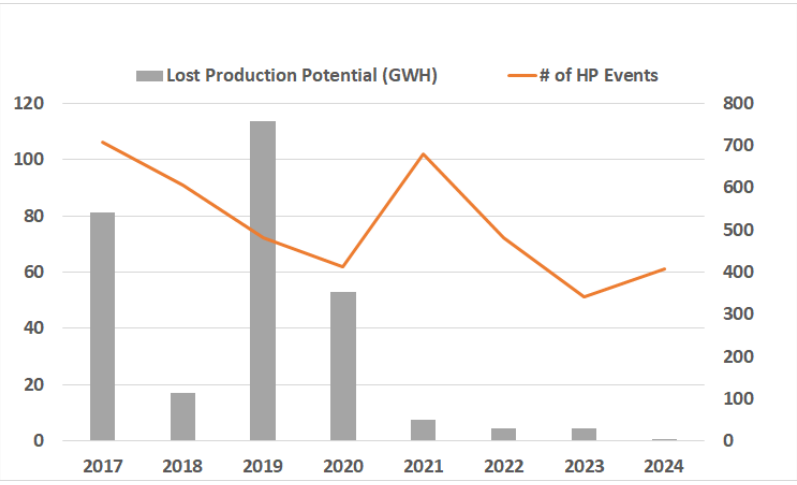


Human Performance

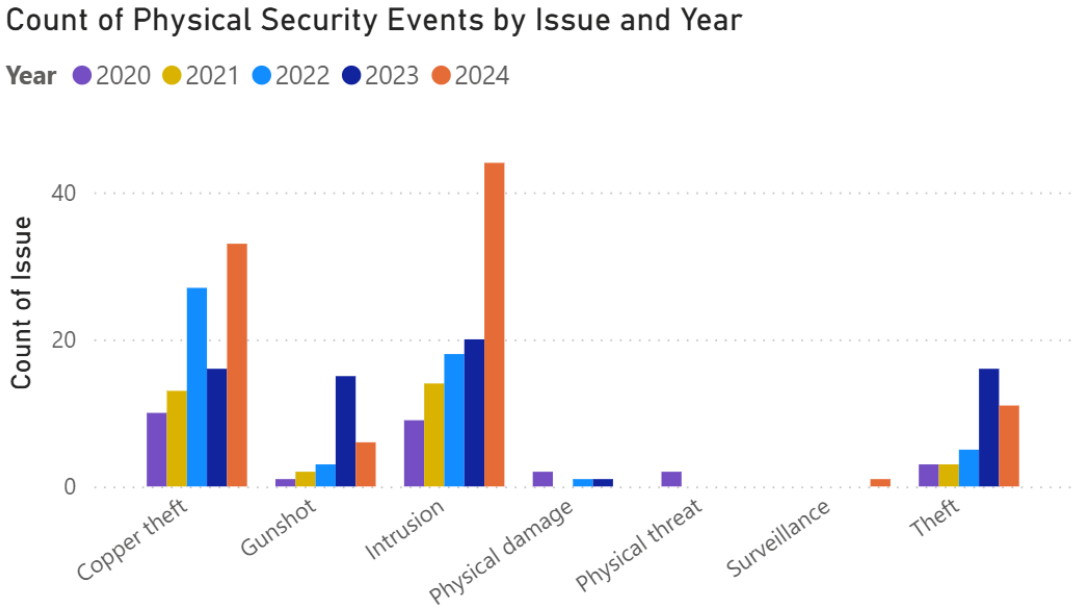


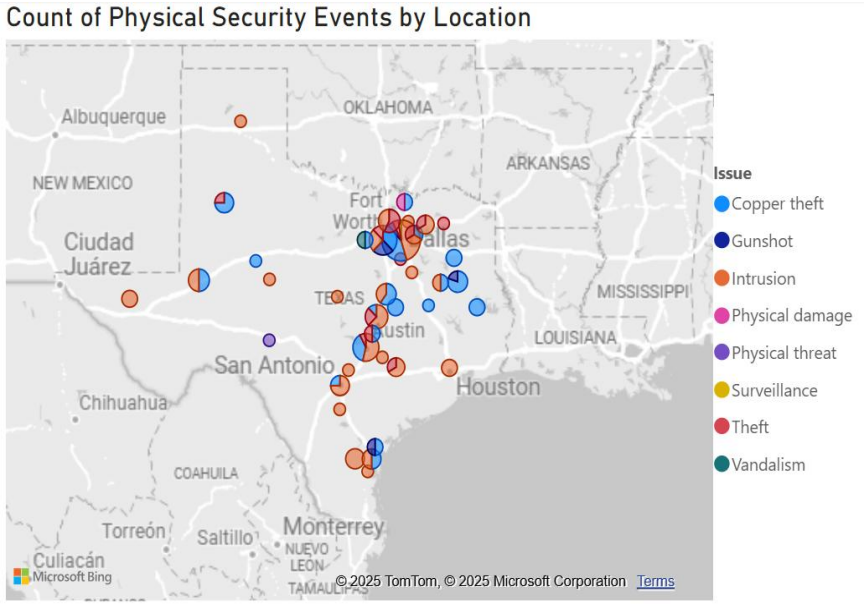
- Human performance remains primary causal in Protection System Misoperations
- Outage rates caused by human error for 138 kV circuit outages and transformers showed a decrease in 2024 compared to prior years.
- Outage rates caused by human error for generators and 345 kV circuit outages increased in 2024 but remained within the long-term trend averages.
- 54% of event root and contributing causes related to human or organizational performance





Physical Security





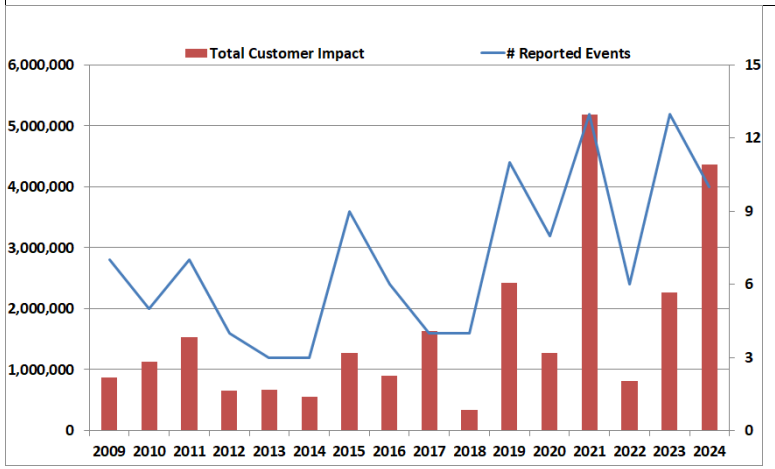
Significant events

- Transformer outage when control cables were cut and stolen from a cable tray
- Multiple transmission lines damaged due to gunfire
- Transformer radiator damage and oil leak due to gunfire
- Primary protective relaying and communications affected due to cut fiber optic cable
- Individuals drove through the gate at a coal power plant after being instructed by security to turn around
- Multiple wind turbines damaged by gunfire

Resilience and Extreme Day Analysis

Generation and Transmission outage severity and duration continues to be driven by weather and failed equipment

Generation Extreme Day Analysis	Number of Generation Outage Events on Extreme Day	Leading Causes for Extreme Day	Cumulative Outage Duration on Extreme Day	Cumulative MW Impact on Extreme Day	Cumulative GWh Impact on Extreme Day
8/27/2017	41	Weather	22,798 hours	10,107 MW	2,917.5 GWH
1/16/2018	84	Balance of Plant/Fuel	2,891 hours	11,893 MW	517.8 GWh
5/11/2019	36	Turbine Generator	1,626 hours	6,449 MW	282.5 GWh
7/1/2020	44	Auxiliary systems	3,352 hours	8,251 MW	247.9 GWh
2/15/2021	187	Weather	6,937 hours	35,241 MW	1,204.1 GWh
12/23/2022	164	Weather	2,180 hours	23,163 MW	321.8 GWh
1/30/2023	65	Turbine Generator/Fuel	2,745 hours	9,327 MW	332.4 GWH
1/15/2024	81	Fuel, Weather	885 hours	9,292 MW	86.3 GWH



2024 was the second highest level of customer outages in the last fifteen years

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Ensuring electric reliability for Texans