ERCOT Control Room Situational Awareness Tools

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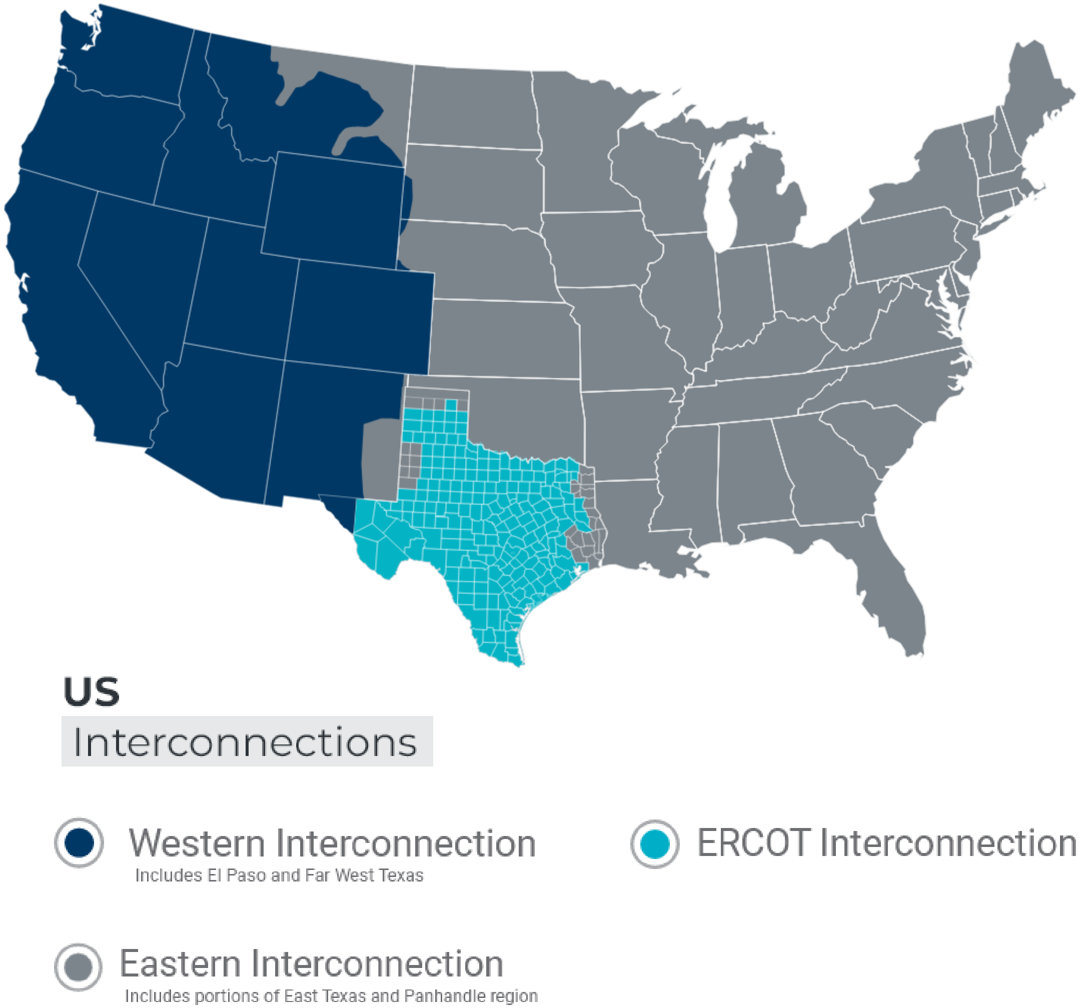
G-PST Future of Inertia

03/12/2024

The ERCOT Region

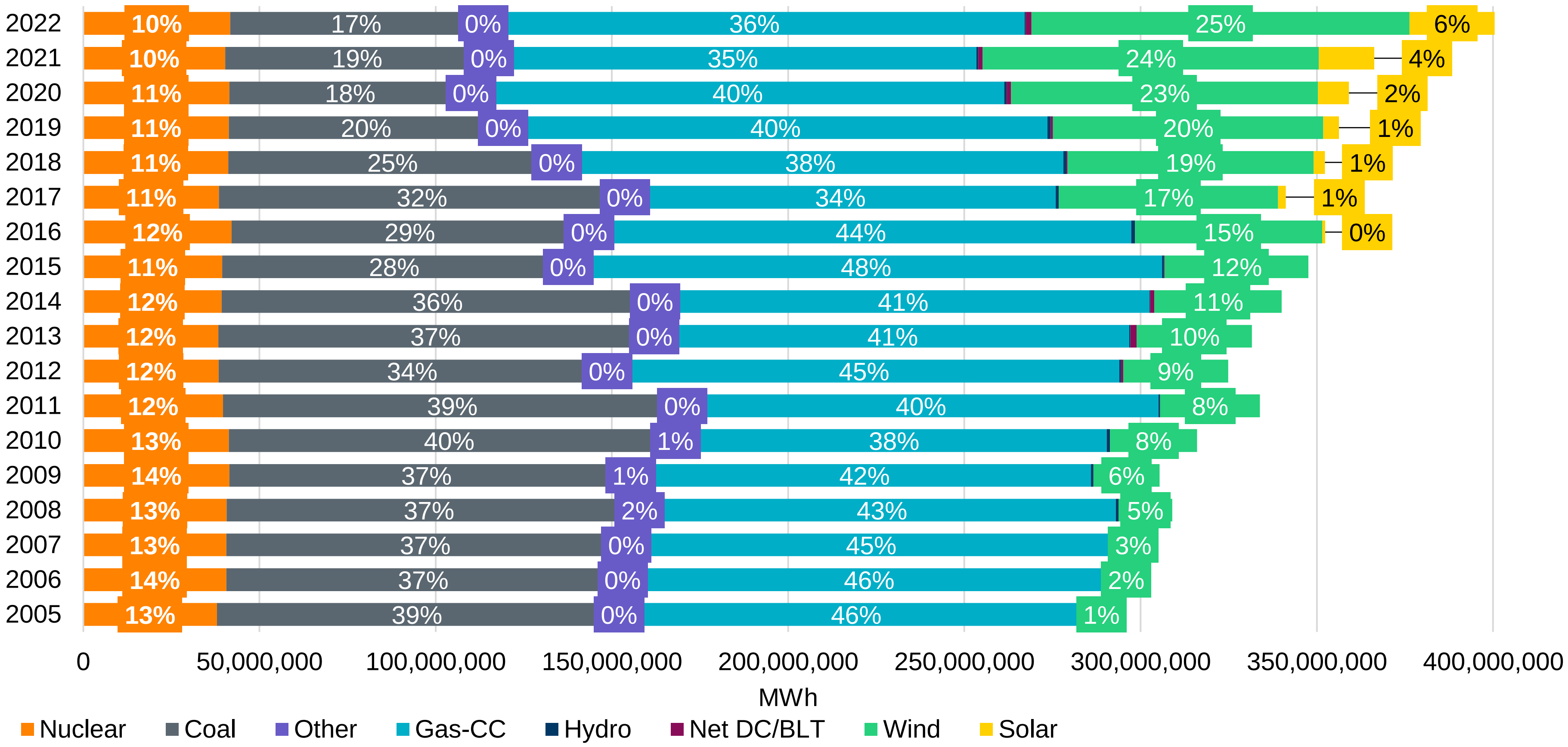


The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 85,508 MW peak, Aug. 10, 2023
- More than 54,100 miles of transmission lines
- 1,250+ generation units (including PUNs)

ERCOT connections to other grids are limited to ~1,220 MW of direct current (DC) ties, which allow control overflow of electricity

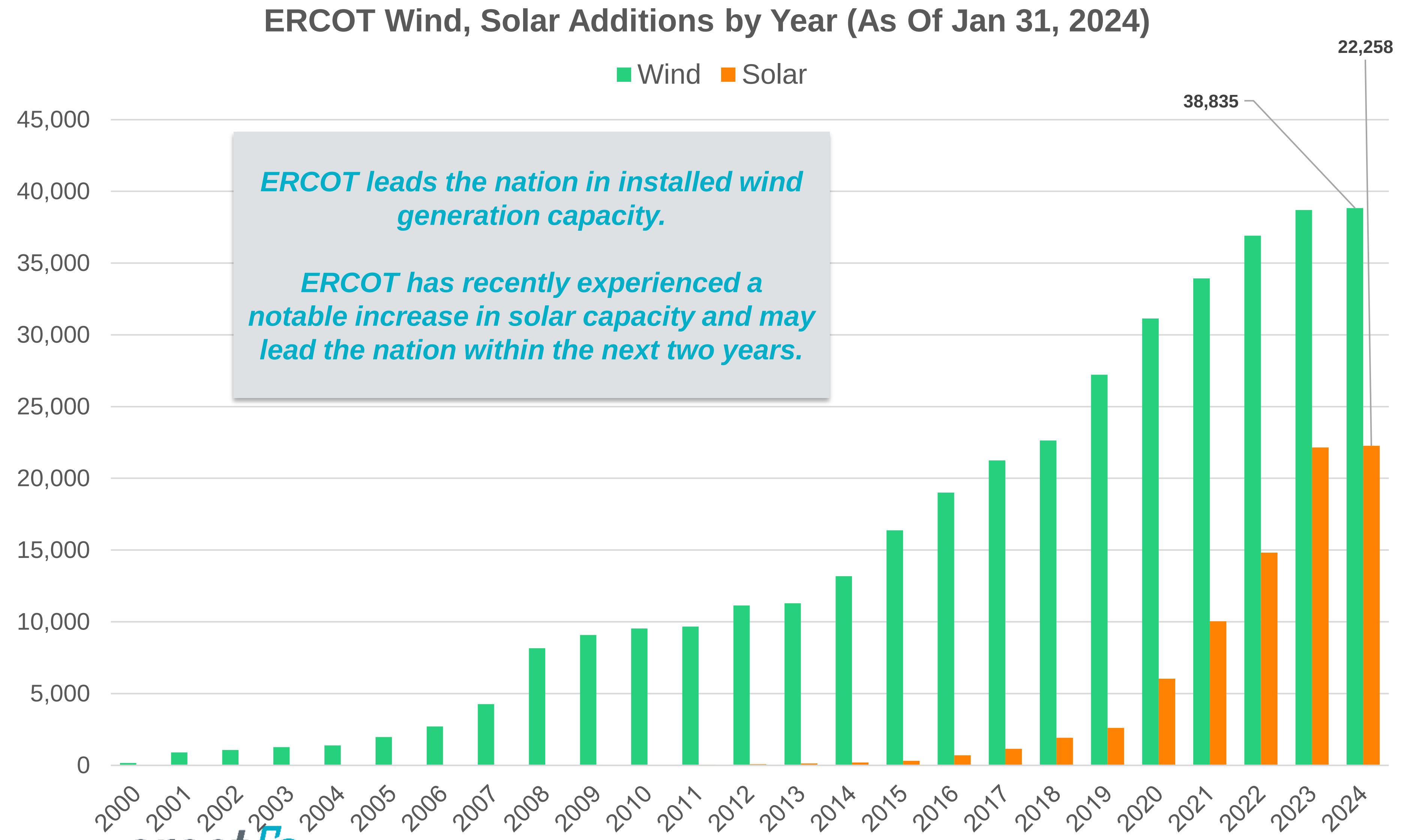
Energy Fuel Mix 2005-2022



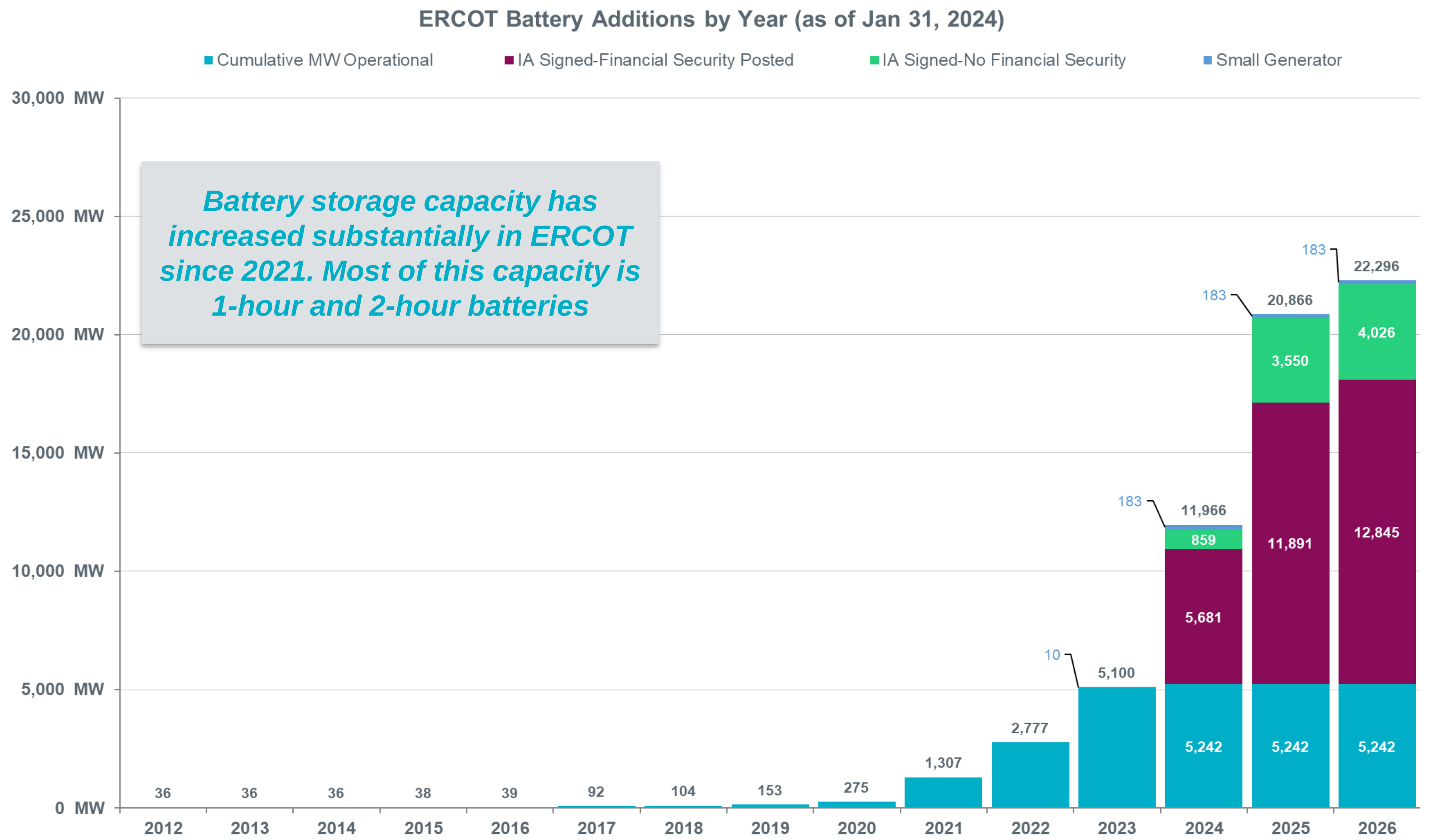
ERCOT has experienced steady load growth and a significant change in the resource mix, relying less on coal and gas and more on wind and solar.

*Source: Historical ERCOT Demand and Energy Reports

Wind, Solar Additions By Year (As Of Jan 31, 2024)



Energy Storage Resource Additions By Year (As Of Jan 31, 2024)



Current Records

Peak Demand Record: 85,508 megawatts (MW)

- August 10, 2023, 5-6 p.m.

Weekend Peak Demand Record: 85,116 MW*

- Sunday, August 20, 2023, 4-5 p.m.

Winter Peak Demand Record: 78,314 MW*

- January 16, 2024, 7-8 a.m.

Wind Generation Records (instantaneous)

- Output: 27,548 MW
  - January 7, 2024, 6:42 p.m.
- Penetration (load served): 69.15%
  - April 10, 2022, 1:43 a.m.
  - Wind power output at the time was 23,977 MW

Solar Generation Record (instantaneous)

- Output: 17,136 MW (35.11% of load)
  - February 18, 2024, 10:59 a.m.
- Penetration (load served): 39.94%
  - February 18, 2024, 3:05 p.m.

**New records are preliminary, subject to change in final settlement*

Recent Monthly Peak Demand Records

2024

- January: 78,314 MW* (Jan. 16, 7-8 a.m.)

2023

- November: 56,515 MW (Nov. 8, 3-4 p.m.)
- October: 71,181 MW (Oct. 4, 4-5 p.m.)
- September: 84,343 MW (Sept. 8, 5-6 p.m.)
- August: 85,464 MW (Aug. 10, 5-6 p.m.)
- July: 82,939 MW (July 31, 6-7 p.m.)
- June: 80,787 MW (June 23, 5-6 p.m.)

2022

- December: 74,525 MW (Dec. 23, 7-8 p.m.)
- October: 66,153 MW (Oct. 12, 4-5 p.m.)
- August: 78,505 MW (Aug. 8, 4-5 p.m.)
- July: 80,148 MW (July 20, 4-5 p.m.)
- June: 76,718 MW (June 23, 4-5 p.m.)
- May: 71,645 MW (May 31, 4-5 p.m.)
- April: 58,419 MW (April 5, 5-6 p.m.)

2021

- September: 72,370 MW (Sept. 1, 4-5 p.m.)
- February: 69,812 MW (Feb. 14, 6-7 p.m.)

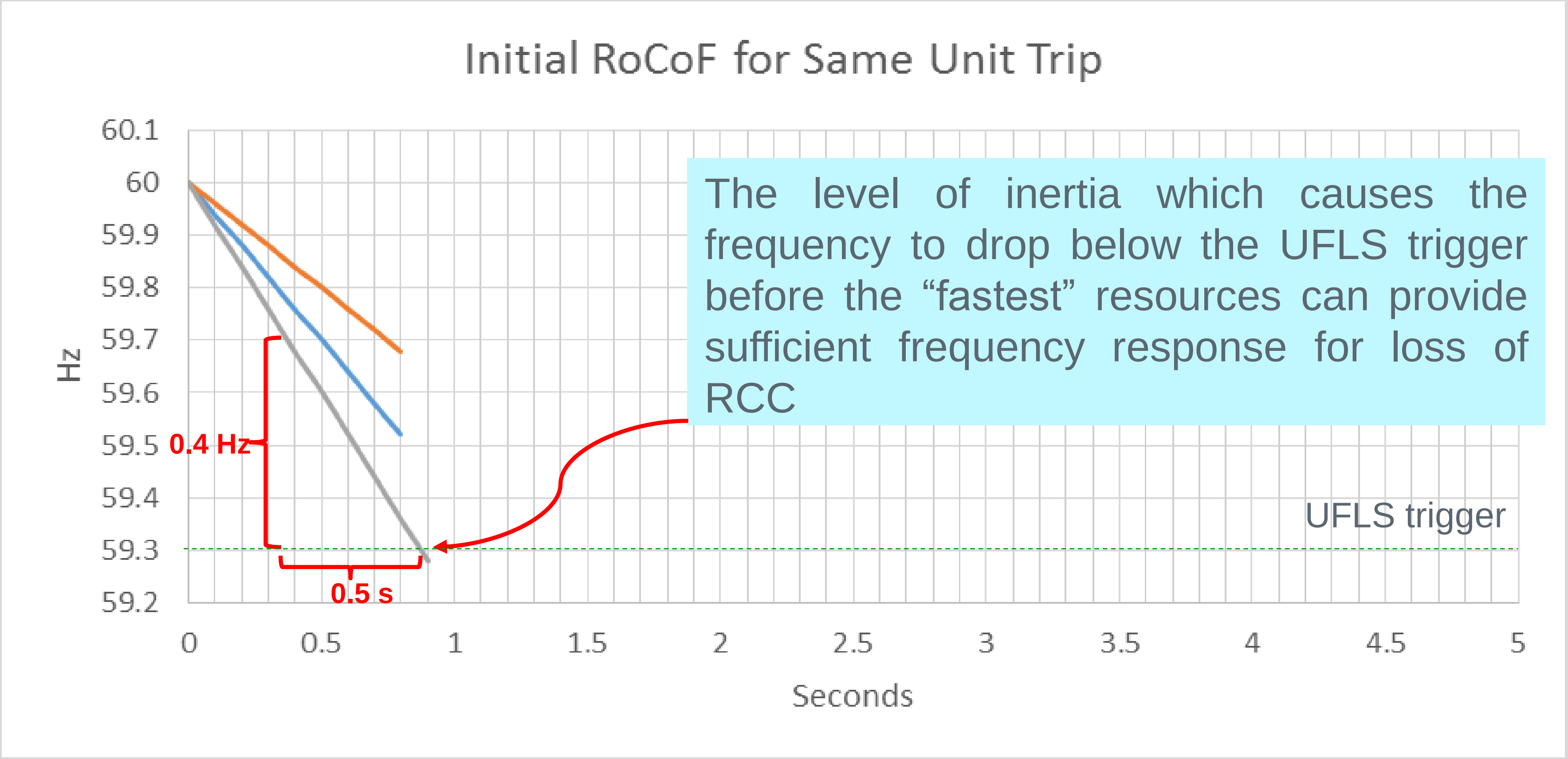
2020

- July: 74,344 MW (July 13, 4-5 p.m.)

Real-Time Inertia Estimation

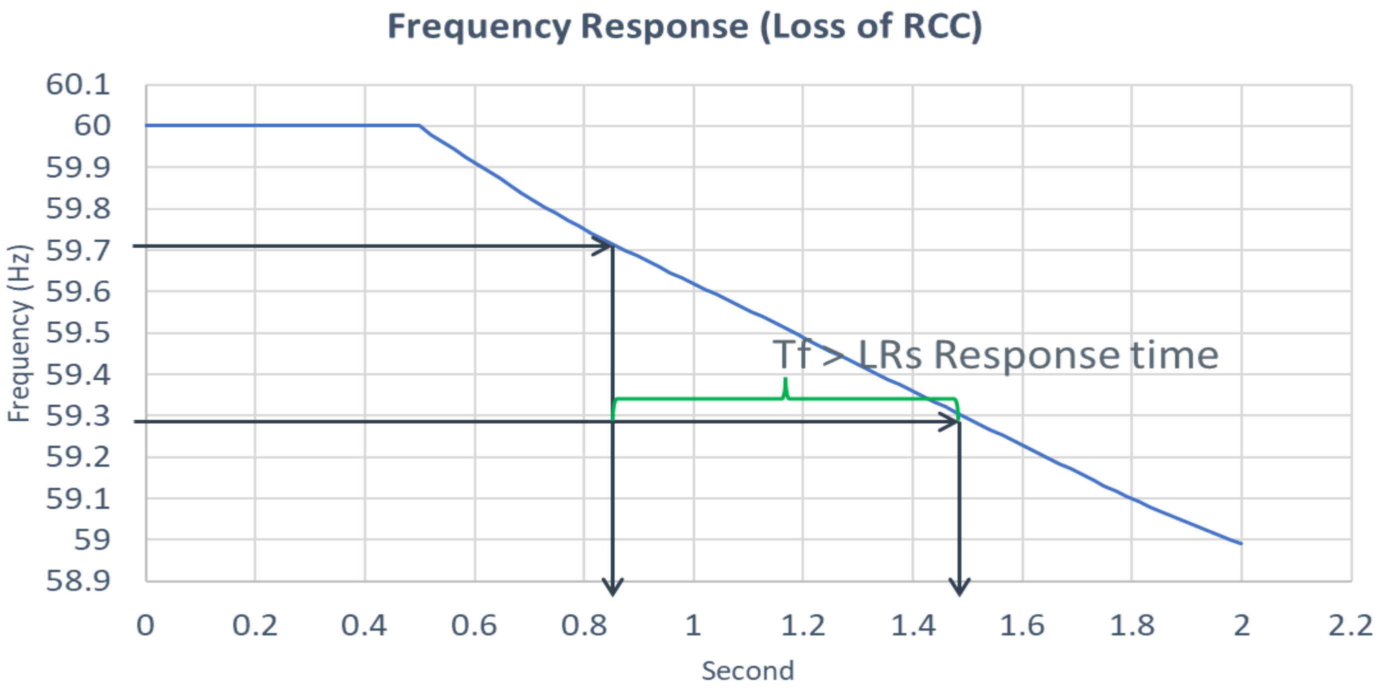
Critical Inertia

- With increasing integration of inverter-based generation, there could be periods when total inertia of the system could be low.



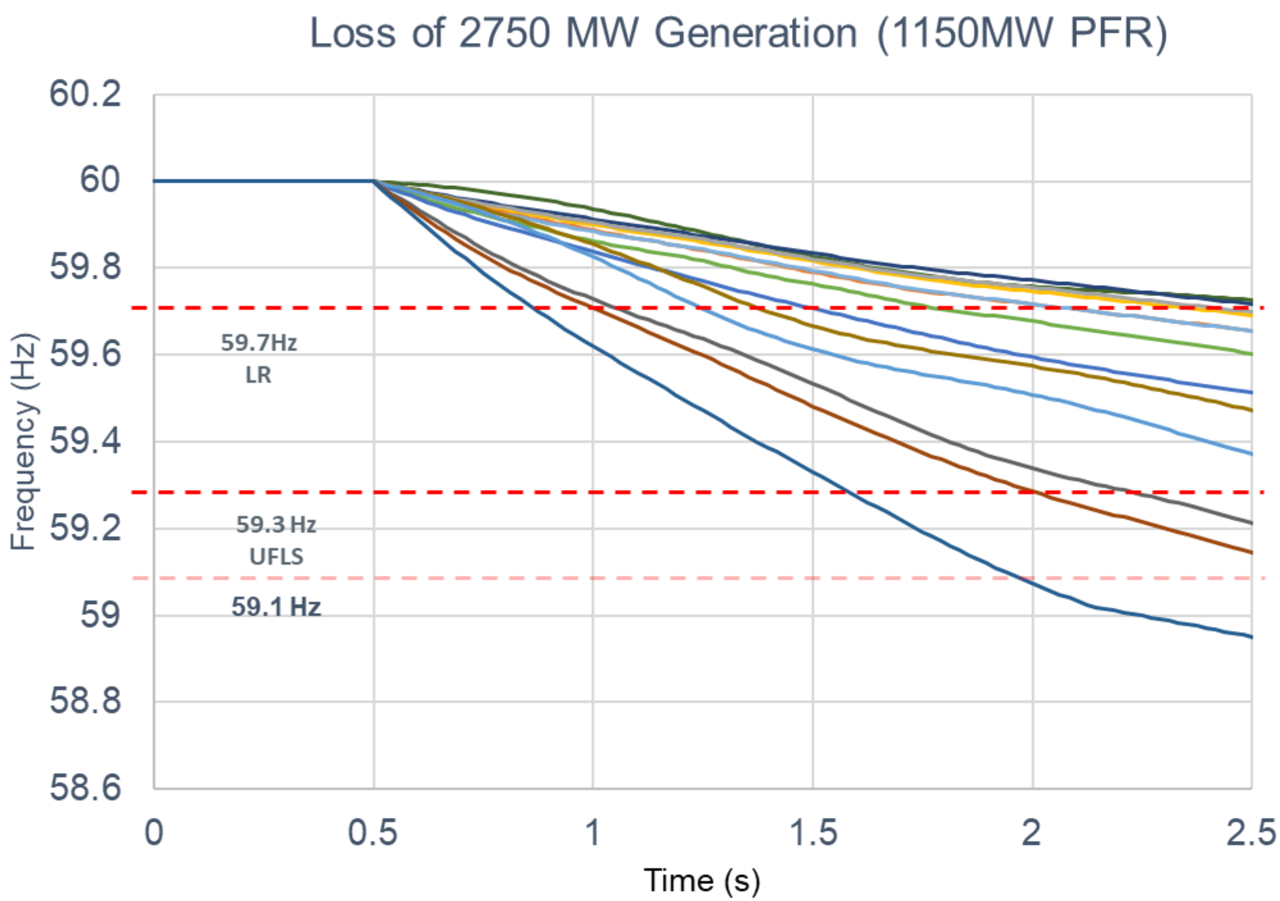
Critical Inertia Definition

- Minimum level of system inertia should ensure Load Resources (LRs) to be triggered before 59.3Hz (UFLS threshold)



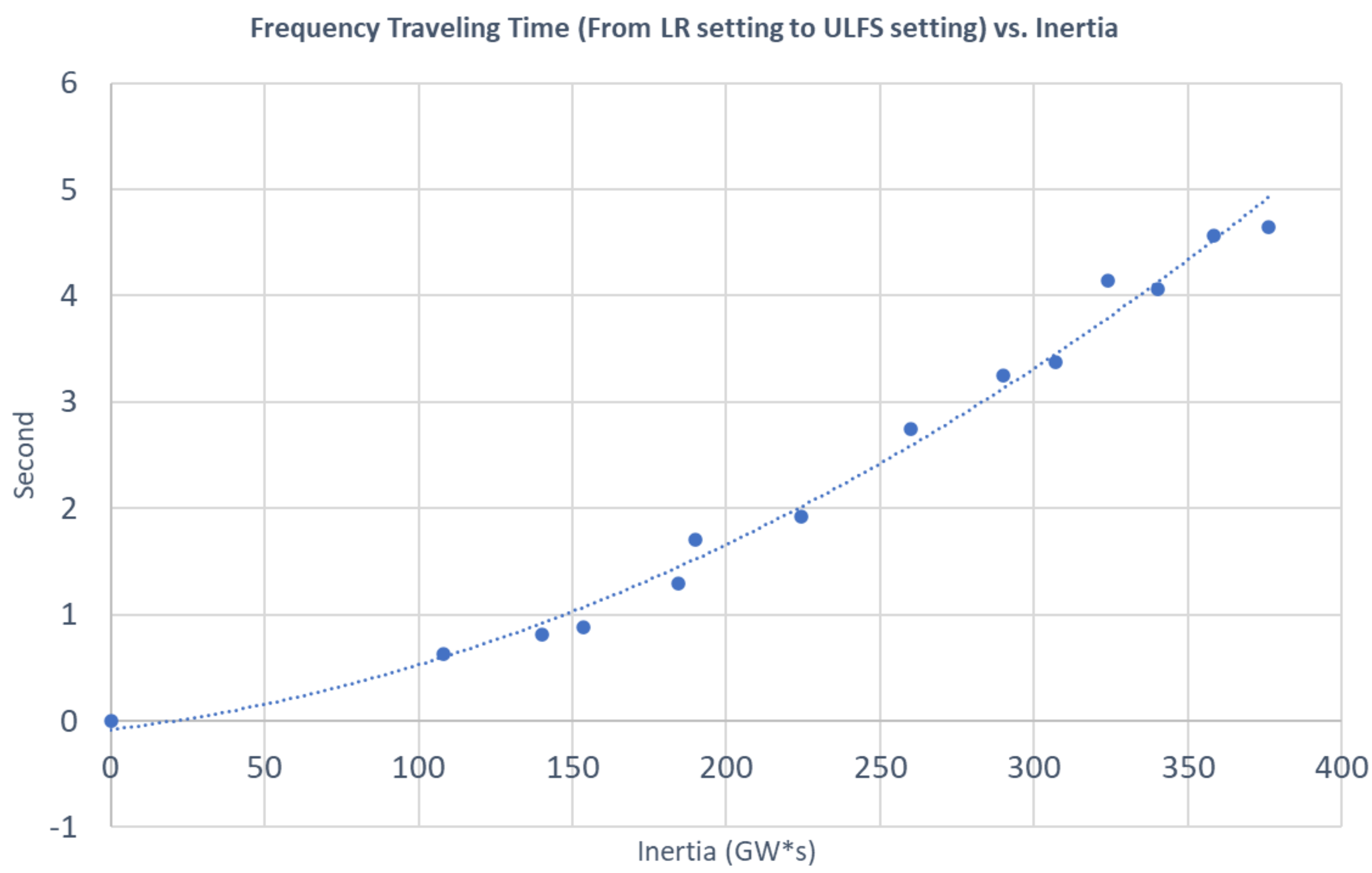
Load Resources (LRs) deploy on relay at 59.70 Hz within 30 cycles

Frequency Response (Initial Stage)

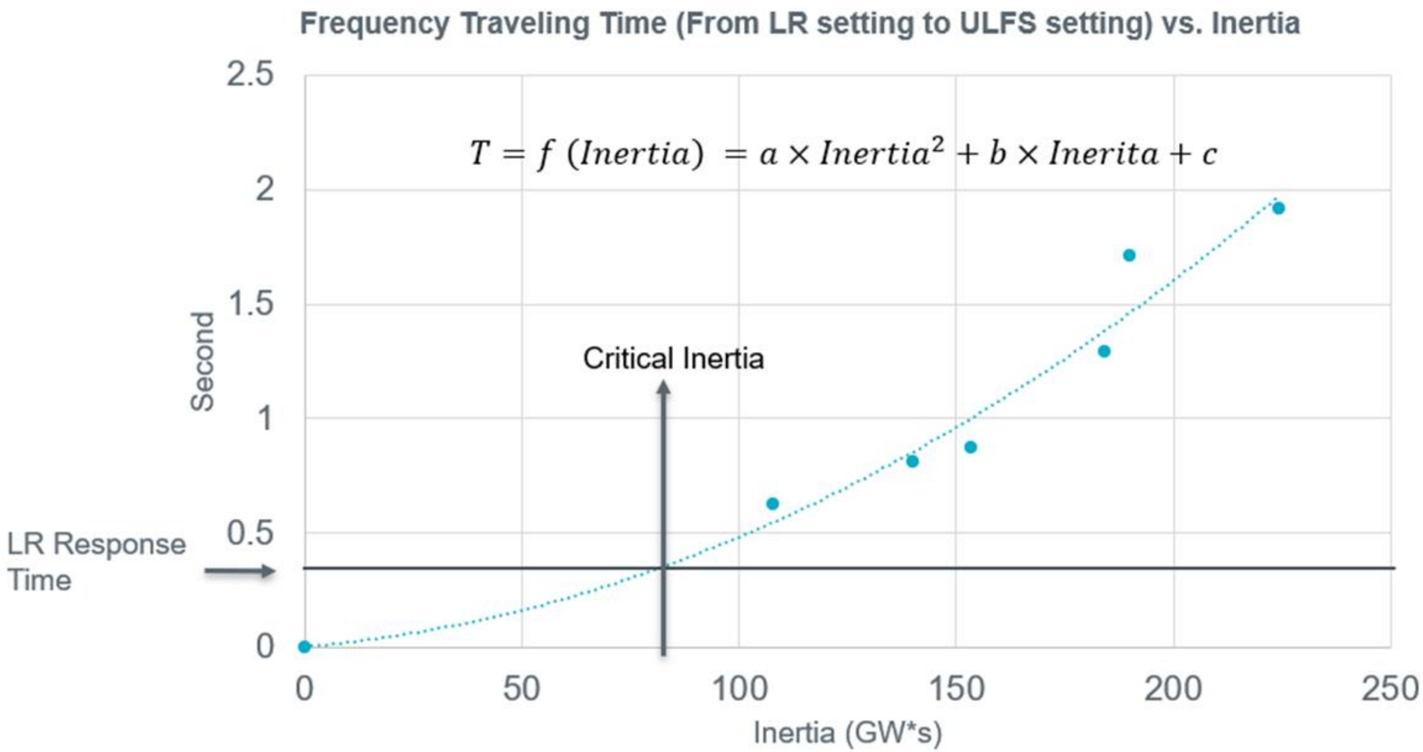


Case	Inertia (GW.s)
case13	376
case12	358.5
case11	340
case10	324
case9	307
case8	290
case7	260
case6	224.3
case5	190
case4	184.3
case3	153.6
case2	140
case1	108

Critical Inertia Quantification Methodology



Critical Inertia Quantification Methodology



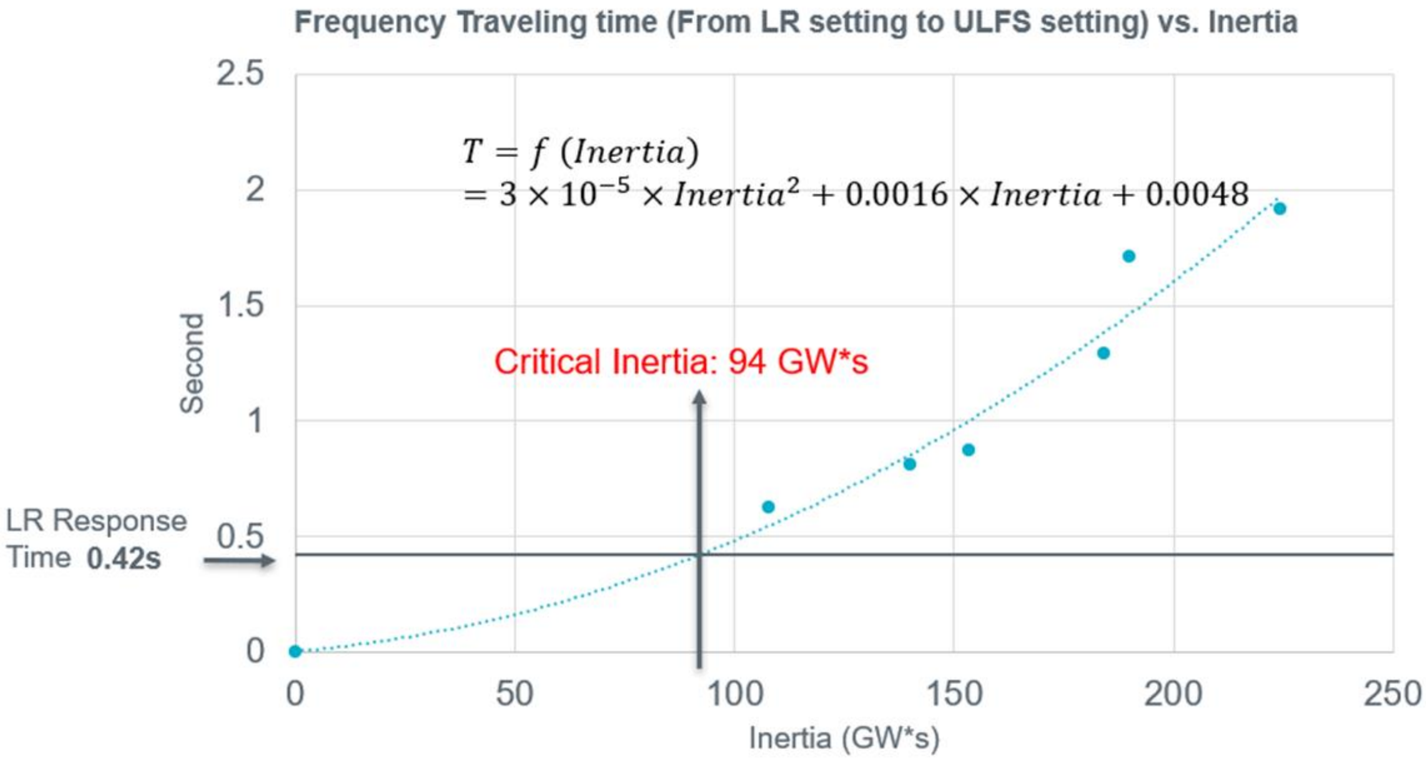
At Critical Inertia Level:

$$f\ (Inertia) \geq LRs\ Response\ Time$$

$$Inertia \geq f^{-1}\ (LRs\ Response\ Time)$$

Critical Inertia $= f^{-1}\ (LRs\ Response\ Time)$

Current Critical Inertia for ERCOT



At Critical Inertia Level:

$$3 \times 10^{-5} \times Inertia^2 + 0.0016 \times Inertia + 0.0048 \geq 0.42$$

$$Inertia \geq 94 GW{\cdot}s$$

Critical Inertia =94 $GW{\cdot}s$

Critical Inertia

- Currently, the Critical Inertia Level for ERCOT appears to be around 100 GW-s (based on current operations and response characteristics of current resources)
  - Simulation results have shown that below this level RoCoF is high enough that frequency would drop below 59.3 (UFLS threshold) Hz for the loss of RCC.

Inertia Monitoring in Real Time

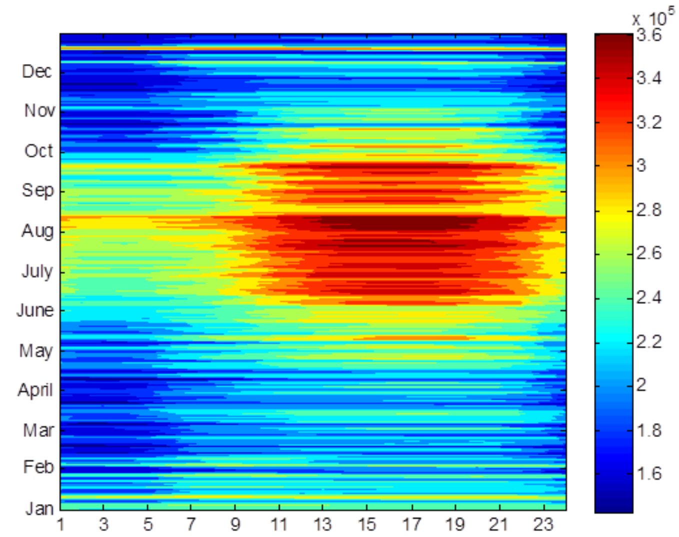
The system inertia is calculated as:

$$M_{sys} = \sum_{i \in I} H_i \cdot MVA_i$$

where *I* is the set of online synchronous generators or condensers,

MVA_i is MVA rating of on-line synchronous generator or synchronous condenser *i*, and H_i is inertia constant for on-line generator or synchronous condenser *i* in a system (in seconds on machine MVA_i)

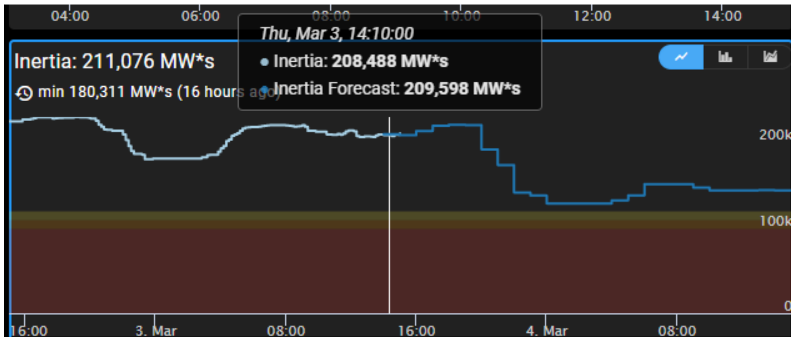
H_i is reviewed annually through our Dynamic Working Group Cases. Any updates are processed through the network model to be used by other systems.

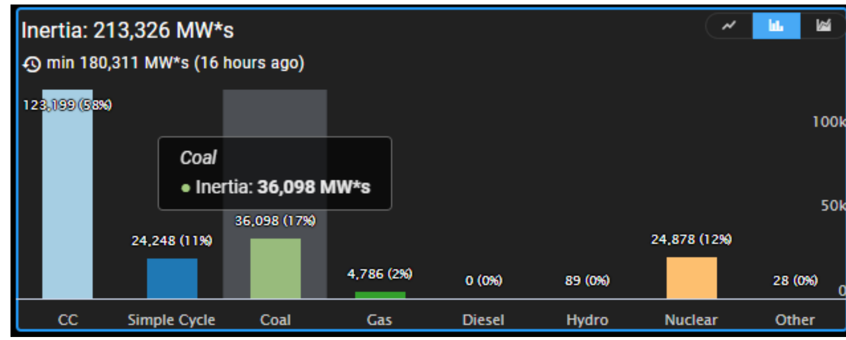


System Inertia 2016

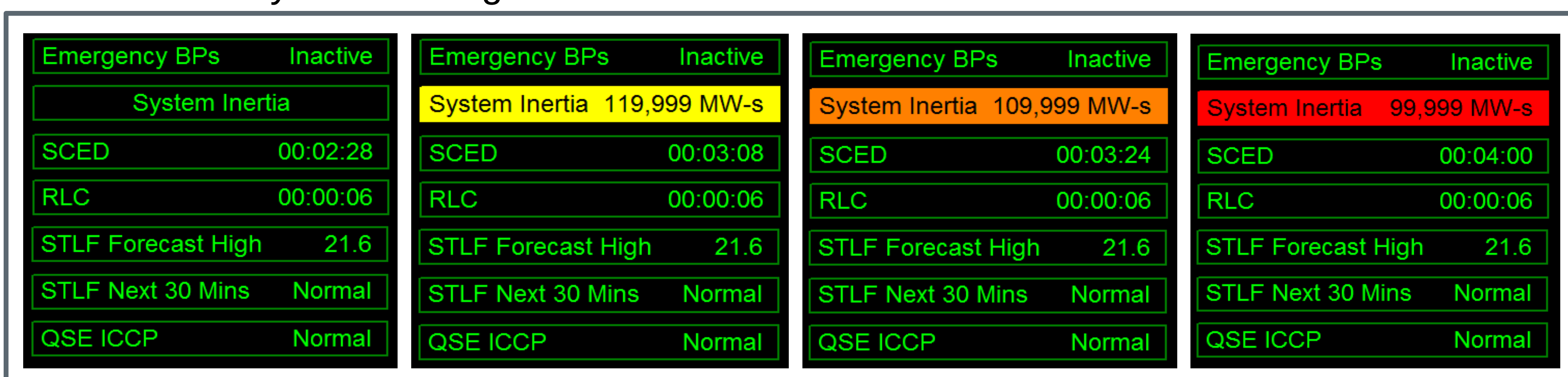
Inertia Monitoring in Real-Time

- In 2016, inertia monitoring was implemented in the control room. Visual alarms are raised alarms when inertia gets close to critical levels.





- As inertia approaches critical levels, ERCOT System Operators may take actions to bring additional synchronous generation resources with sufficient inertia online.

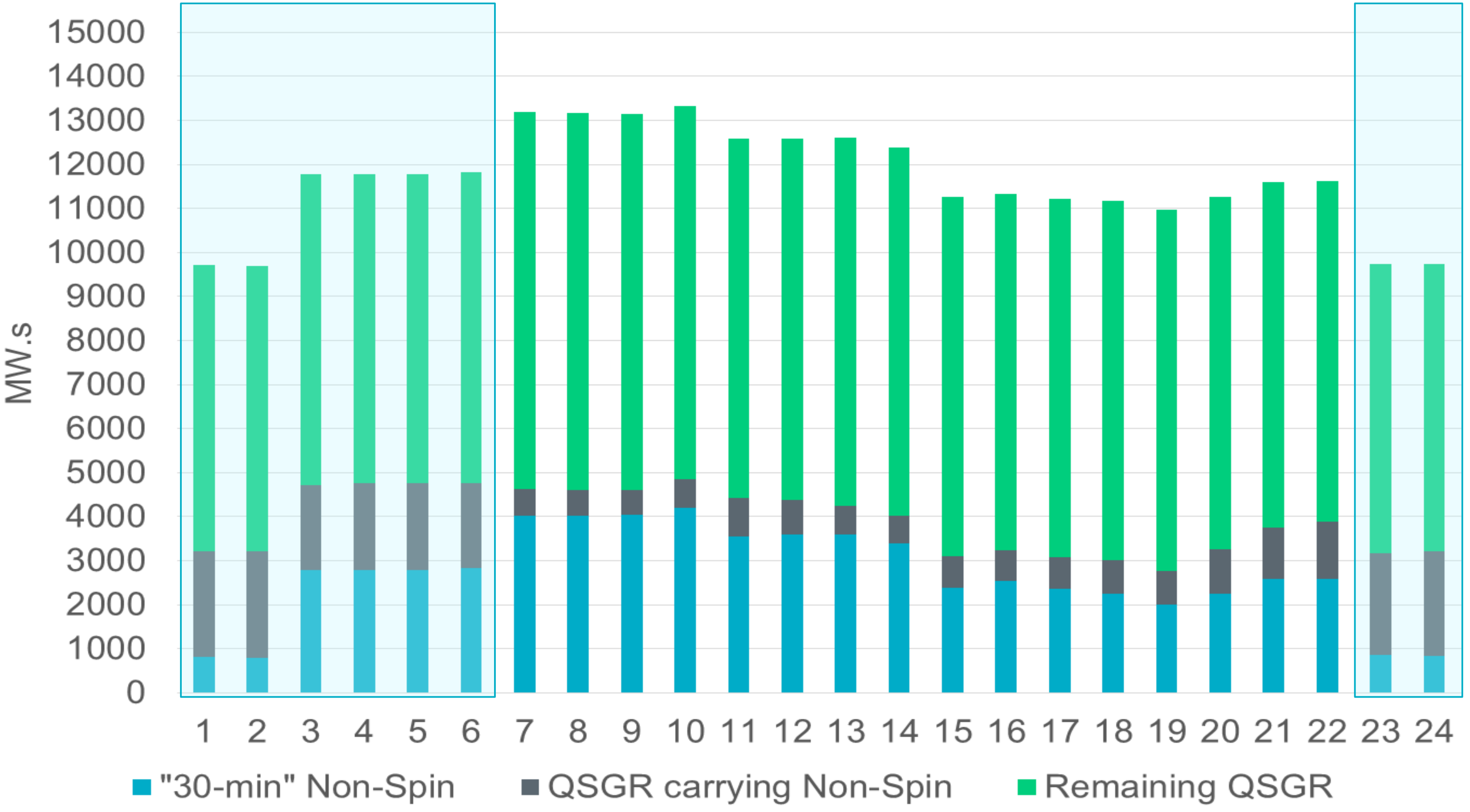


120 GW*s >= Inertia Normal
120 GW*s > Inertia >= 110 GW*s Yellow
110 GW*s > Inertia >= 100 GW*s Orange
100 GW*s < Inertia Red

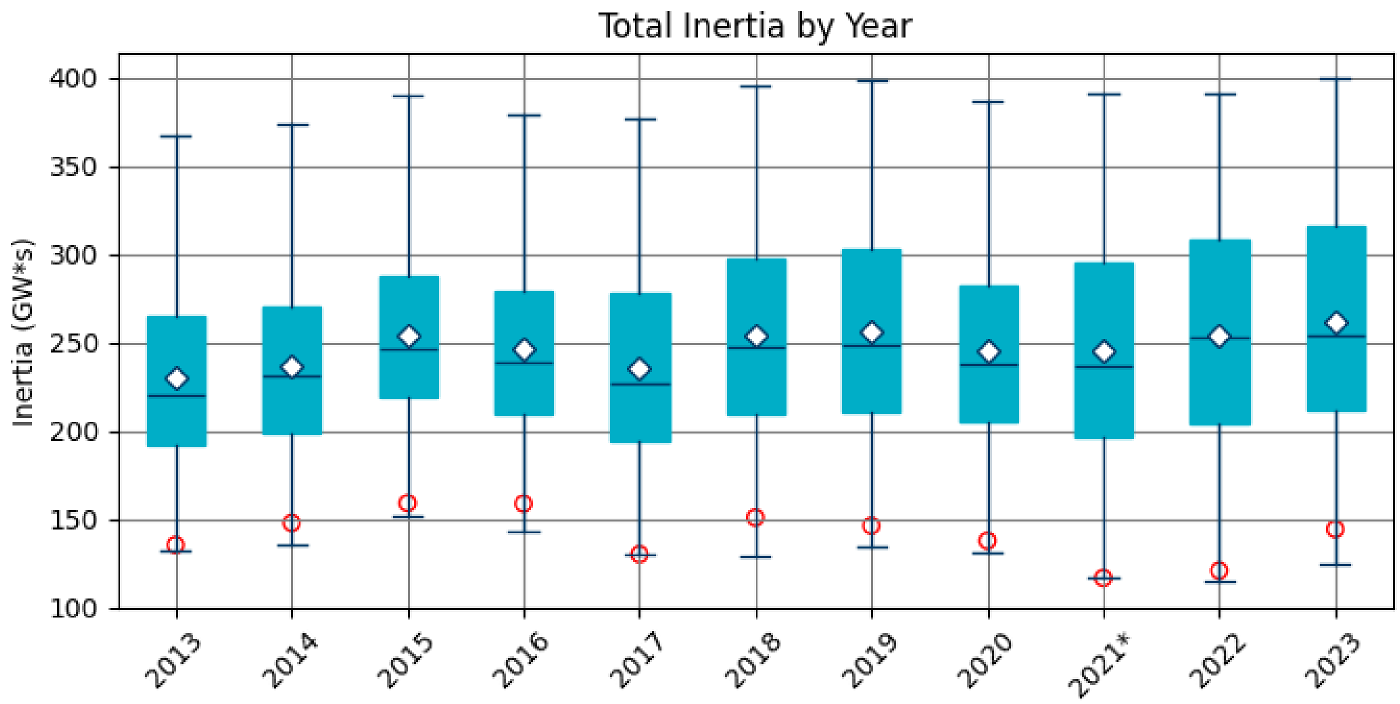
Approach for Maintaining Critical Inertia

- Monitor grid conditions closely when system inertia < 120 GW*s
- Take Actions when system inertia < 105 GW*s
  - Target increasing system inertia >= 105 GW*s
  - Possible Actions
    - Deploy Non-Spin from Offline Generation Resources (including Quick Start Generation Resource (QSGRs) that carry Non Spin)
    - Deploy remaining Quick Starts (not carrying Non-Spin)
    - RUC Generation Resource that can be turned on within one hour

Summer – Potential Inertia Contributions



ERCOT Inertia 2013-2023



Date and Time	2013 3/10 3:00 AM	2014 3/30 3:00 AM	2015 11/25 2:00 AM	2016 4/10 2:00 AM	2017 10/27 4:00 AM	2018 11/03 3:30 AM	2019 3/27 1:00 AM	2020 05/01 2:00 AM	2021* 03/22 1:00 AM	2022 03/21 2:00 AM	2023 04/18 3:00 AM
Min synch. Inertia (GW*s)	132	135	152	143	130	128.8	134.5	131.1	116.6*	115.0	124.3
System load at minimum synch. Inertia (MW)	24,726	24,540	27,190	27,831	28,425	28,397	29,883	30,679	31,767	33,784	35,578
Non-synch. Gen. in % of System Load	31	34	42	47	54	53	50	57	66	65	61

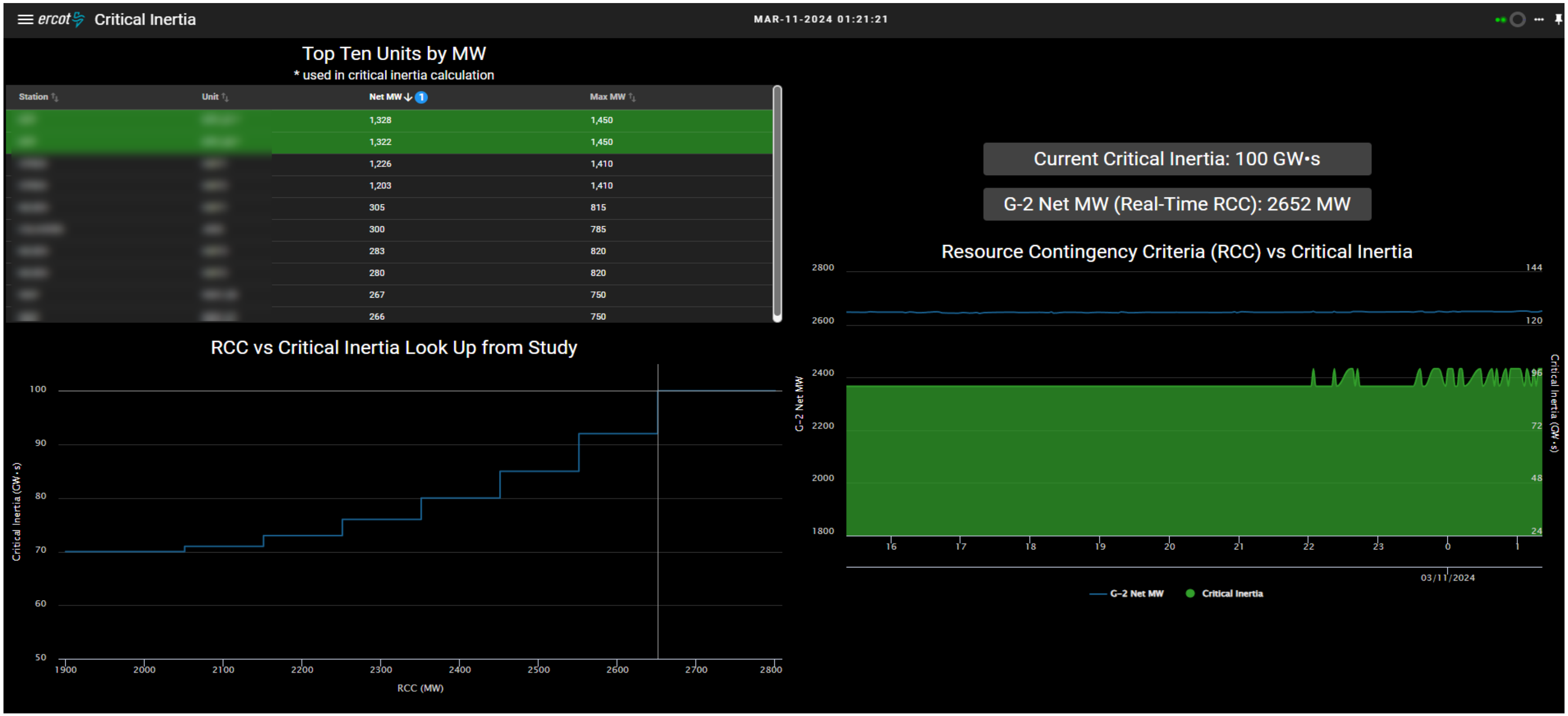
* Measured at 109.6 GW*s, re-calculated using corrected inertia constants

Ongoing Analysis

1. Faster and/or Earlier Response e.g.
   - Faster Response from Load Resources
   - Fast Frequency Response (FFR) from Energy Storage Resources (ESRs)
     - Response within 15 cycles
2. Critical Contingencies
   - Currently to meet BAL-003, ERCOT must plan not to activate UFLS for loss of RCC
   - RCC equates to the loss of two nuclear units
   - Maintenance outages on these units is typically during shoulder months, which are typically periods with low system inertia.
3. UFLS settings
   - Study potential changes in UFLS to 59.1 Hz, 59.4 Hz

Real-Time Critical Inertia based Assessment

1. Account for outages to determine RT RCC
2. Future Change - Account for FFR available



Questions?

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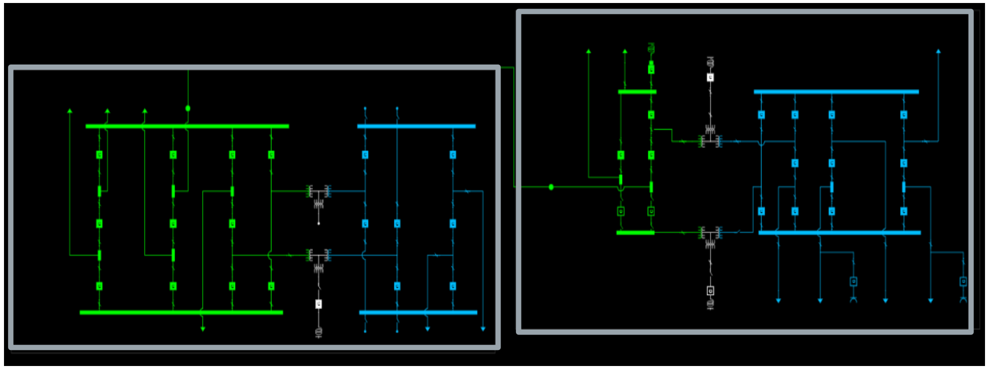
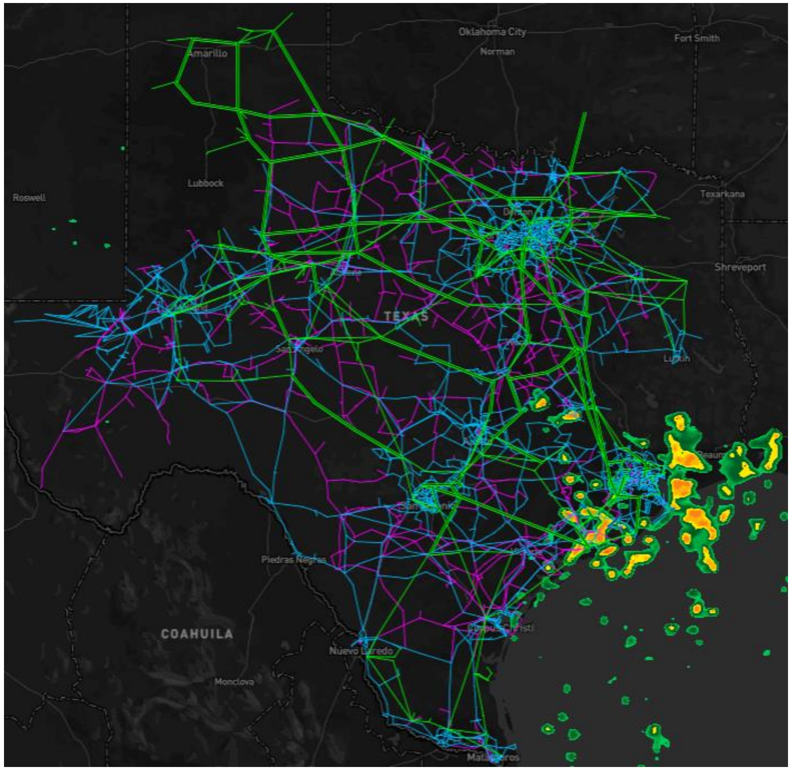
Appendix

Top-Down Approach: ERCOT's GridGeo Application

- ERCOT-developed, browser-based platform allowing for improved situational awareness.
- Targeted to control room operators, control room support staff, and operations training.
- Provides a combined view of the network operations model, real-time and historical information from reliability systems.
- Overlays current and future weather from external vendors

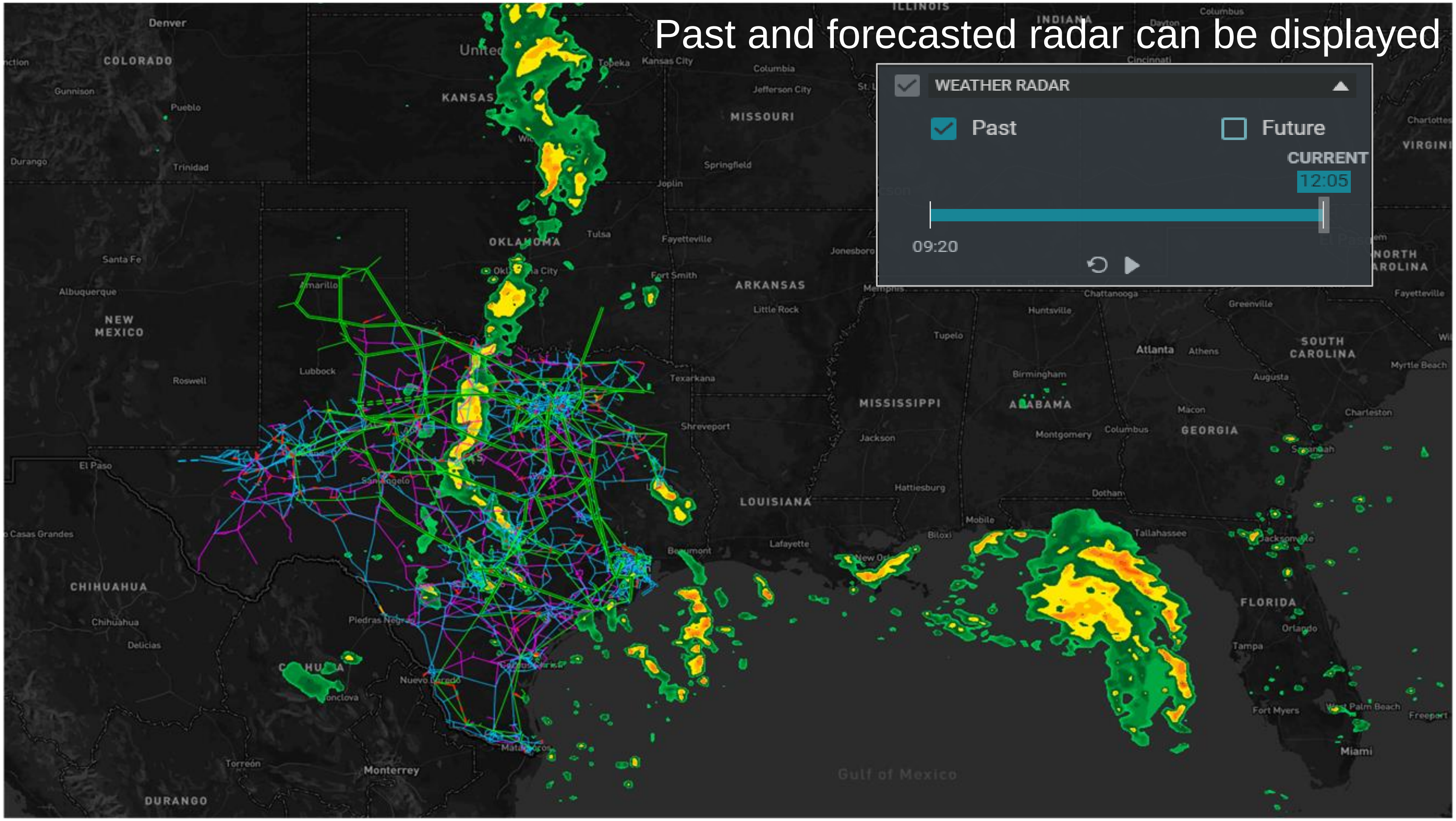


One-Lines and Multi-Station One-Lines

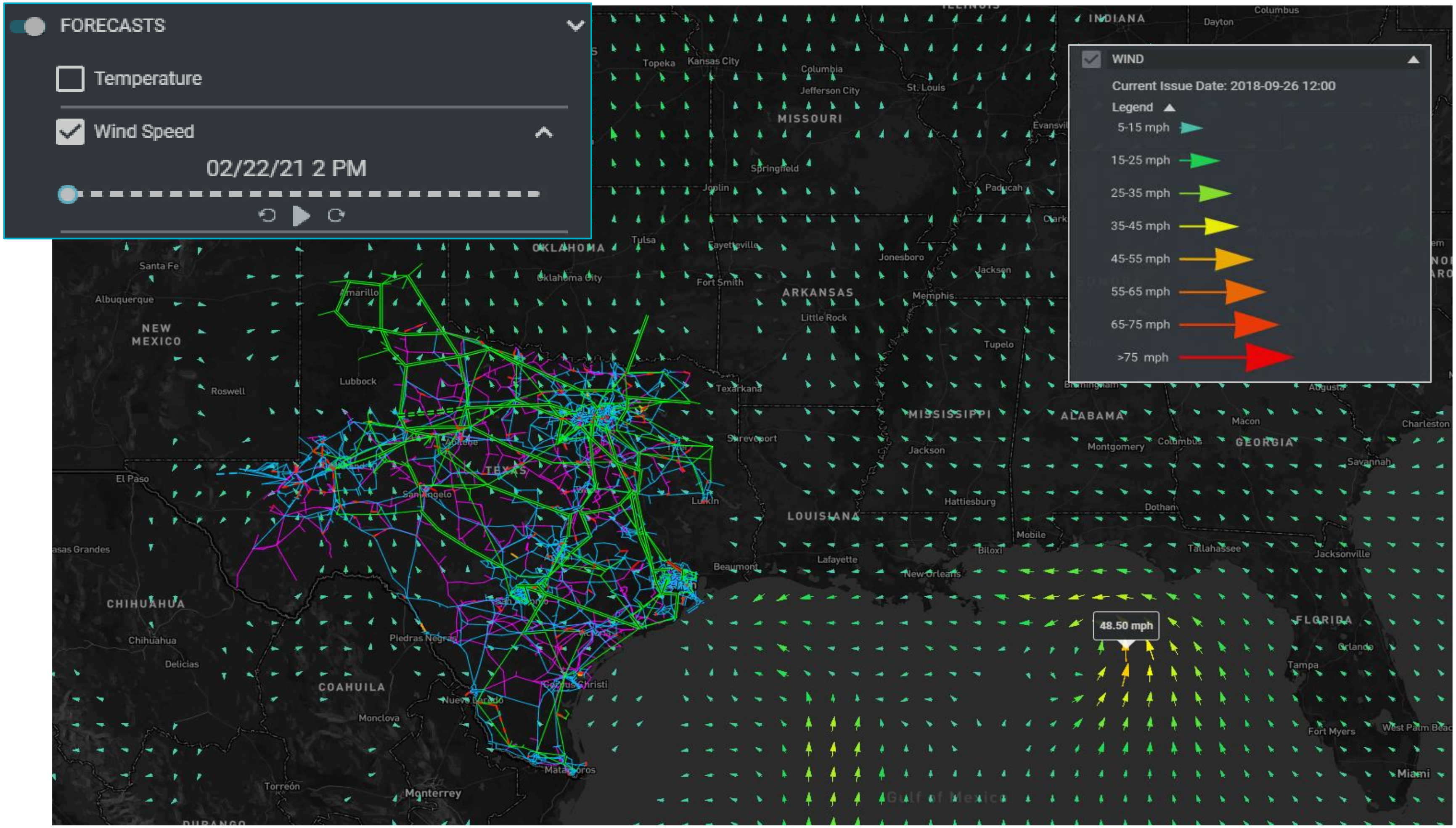


Texas Grid Map

Texas Grid Map – Radar Layer



Texas Grid Map – Wind Layer



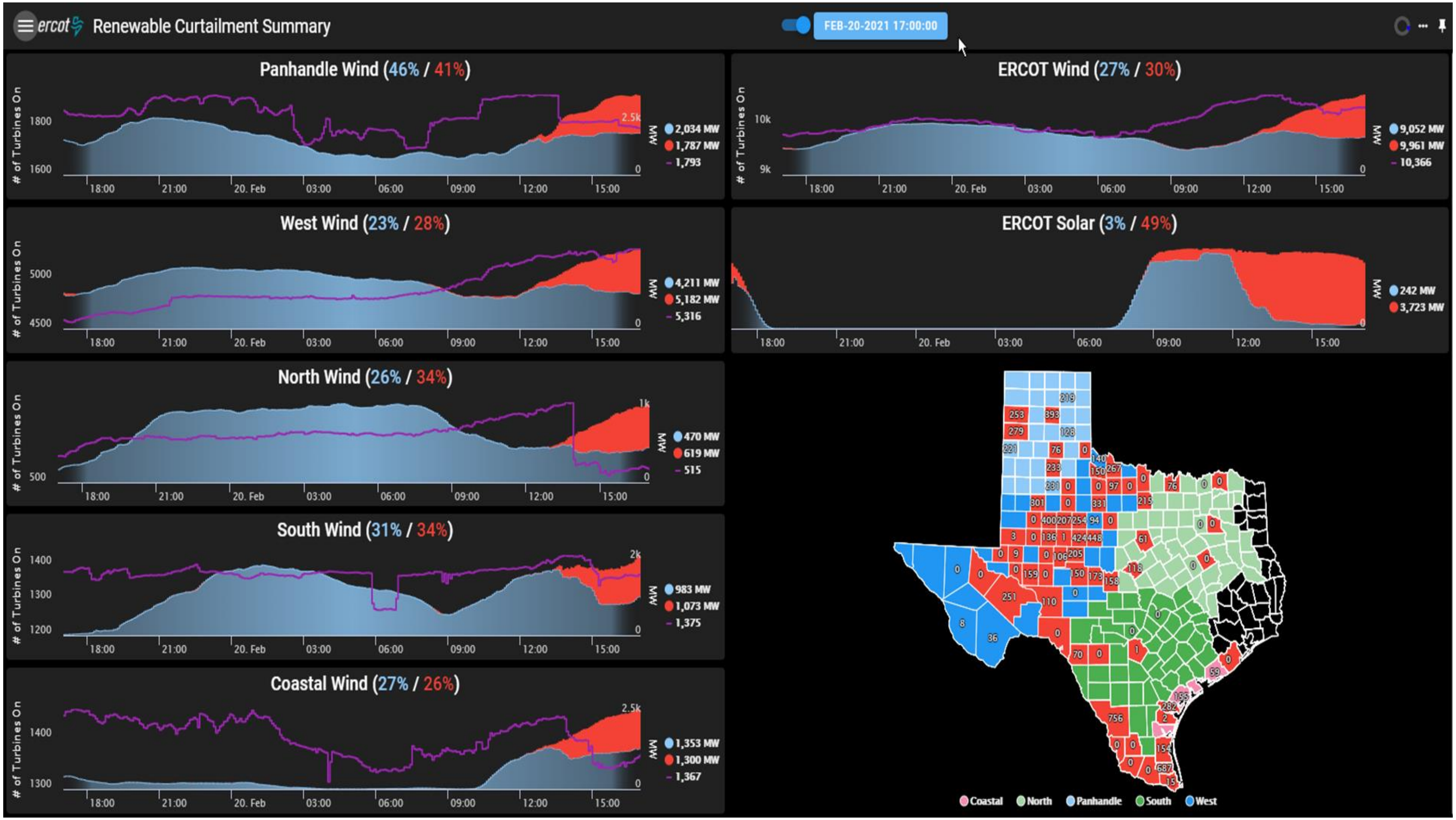
IBR Tabular Displays

Bottom-Up Approach: Browser-Based Tabular Displays

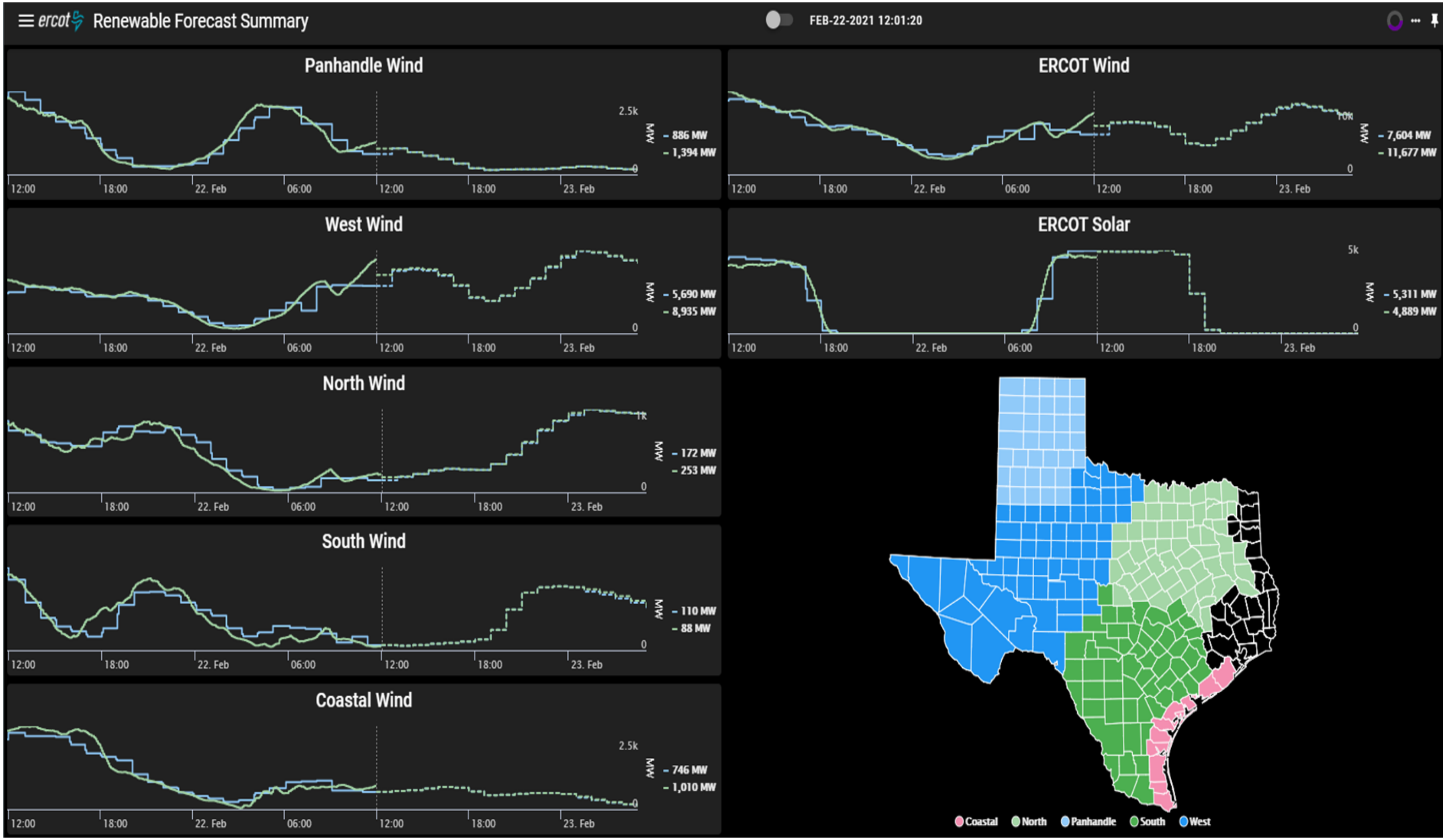
- Initially developed for the new Reliability Risk Desk
- Utilizes OSIsoft's Asset Framework model and WebAPI
- Available in the business and secure networks

Historical and Forecast Information is Available

Bottom Up: IRR Production and Curtailment



Bottom-Up: Forecast Displays



Bottom-Up: Energy Storage Resource Display