Overview of Renewables in the ERCOT System

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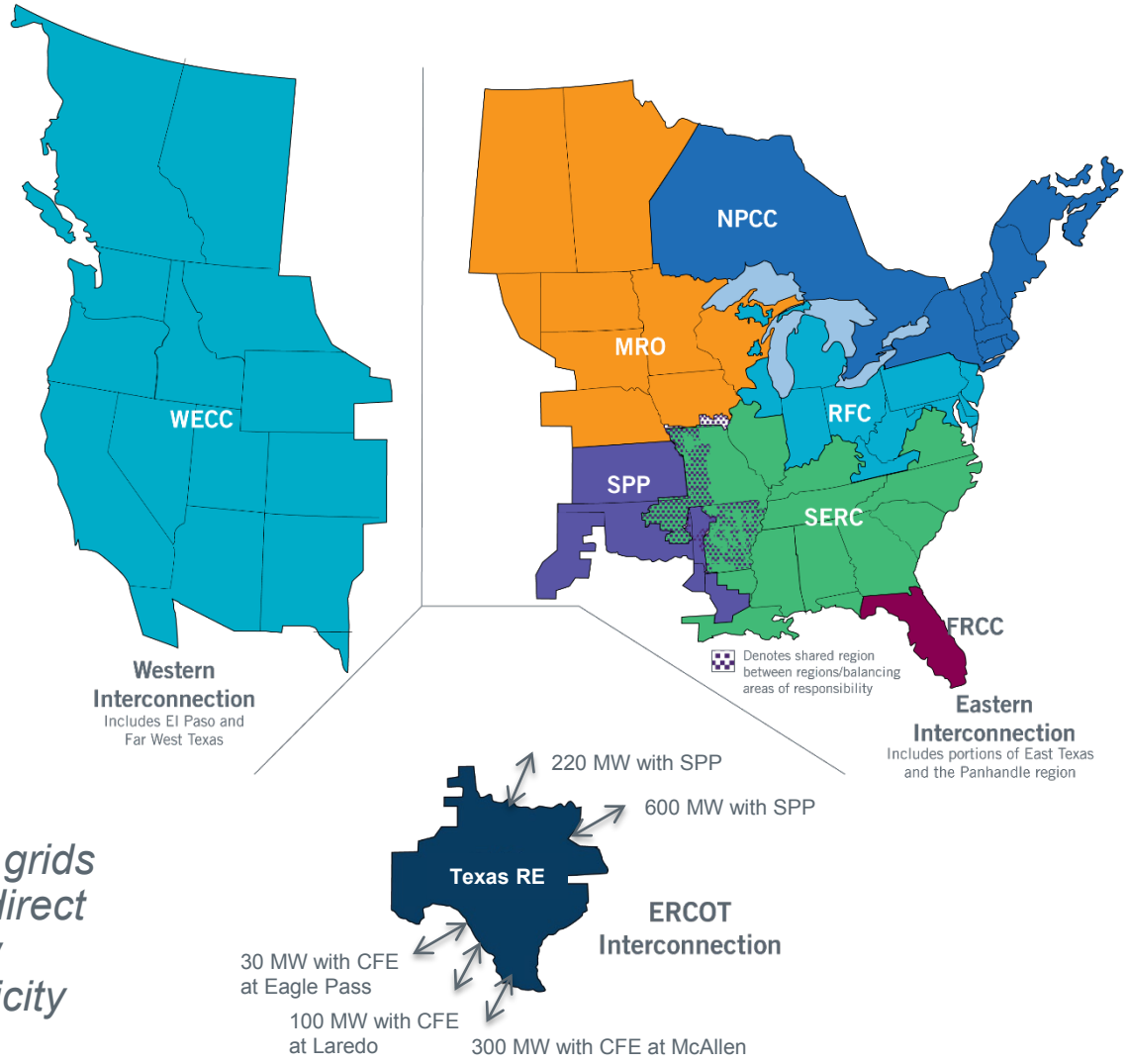
What is ERCOT

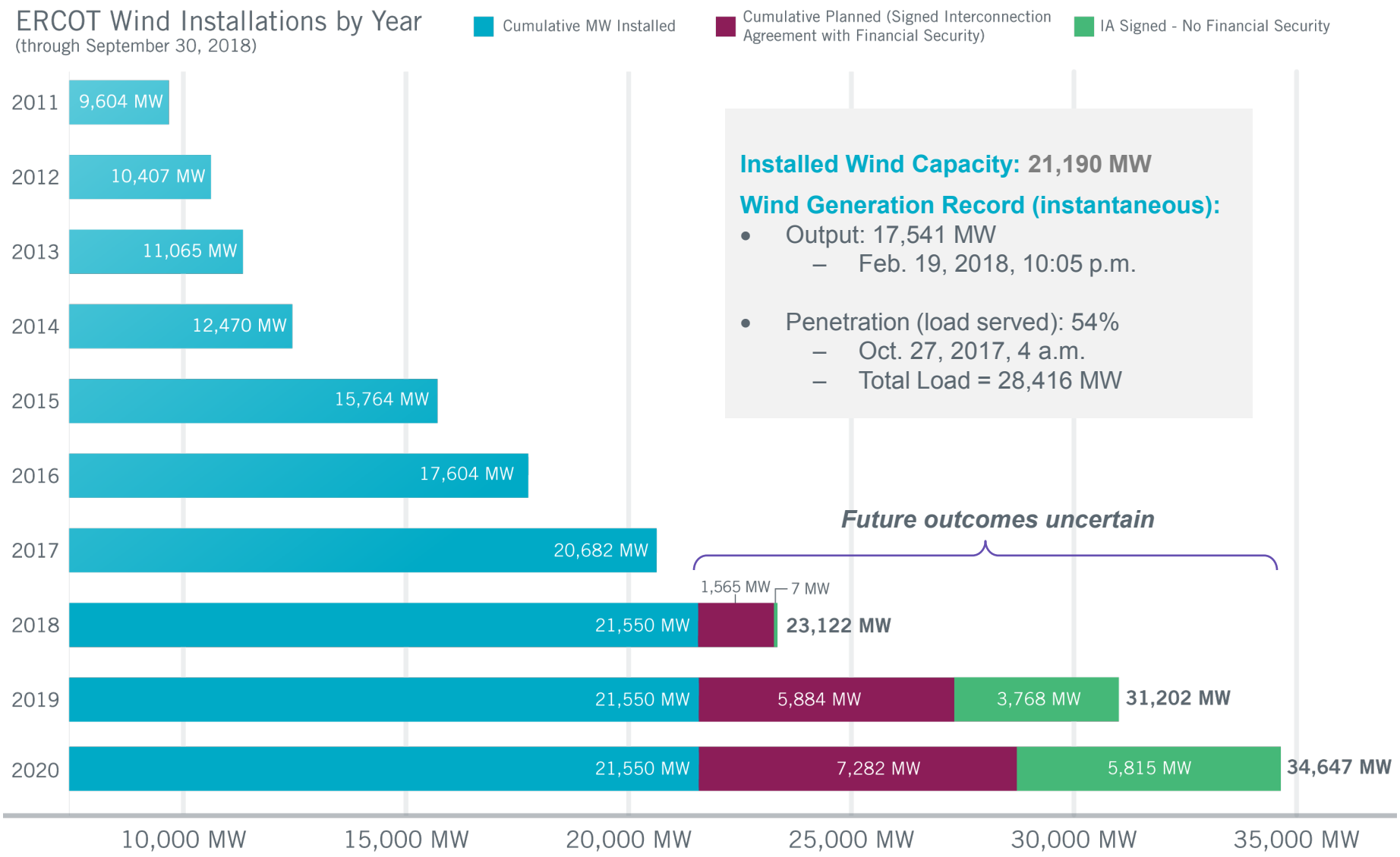
The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 73,308 MW peak demand, July 19, 2018
- 570+ generation units

ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over the flow of electricity



Wind Generation Capacity – September 2018

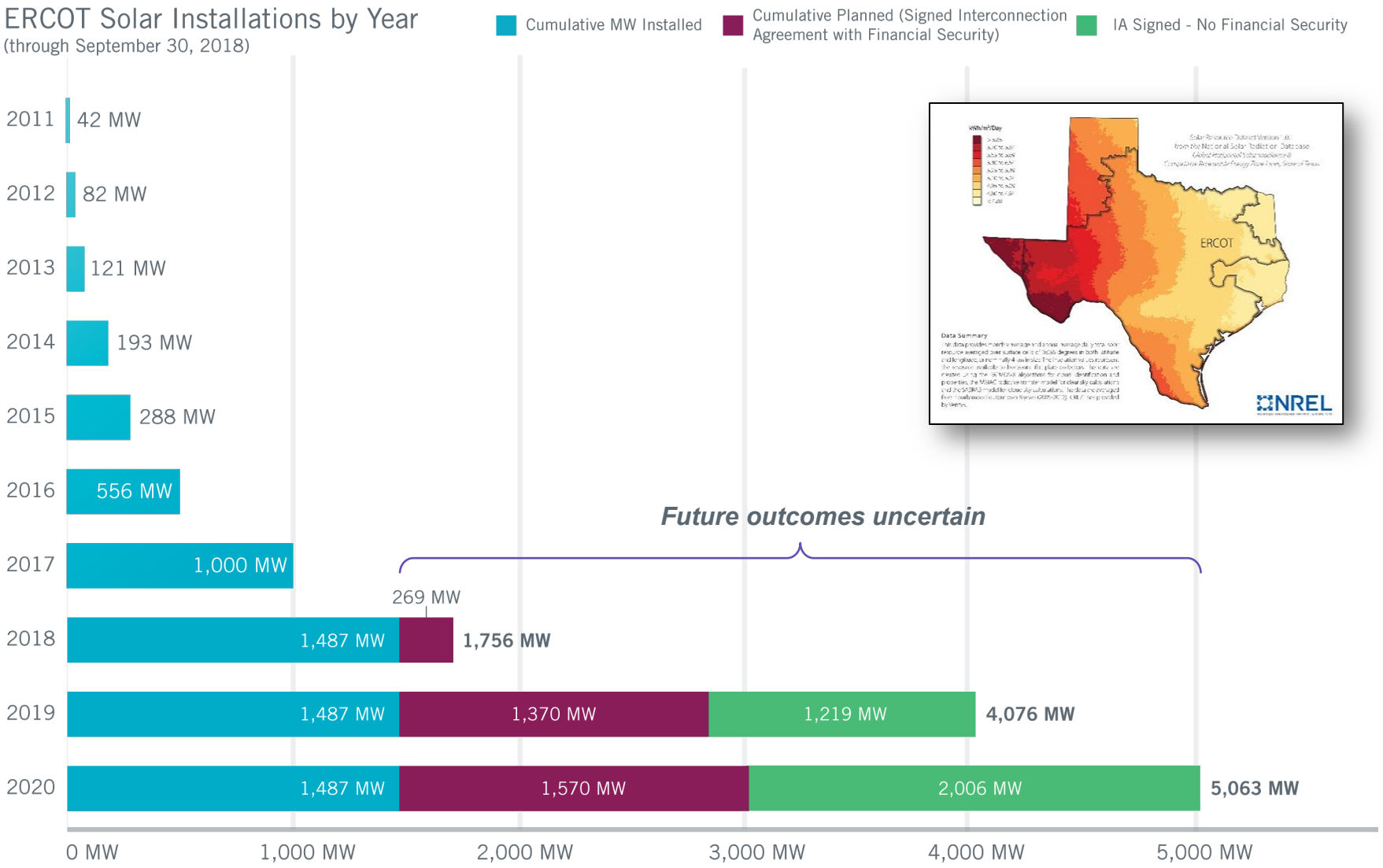


Installed Wind Capacity: 21,190 MW

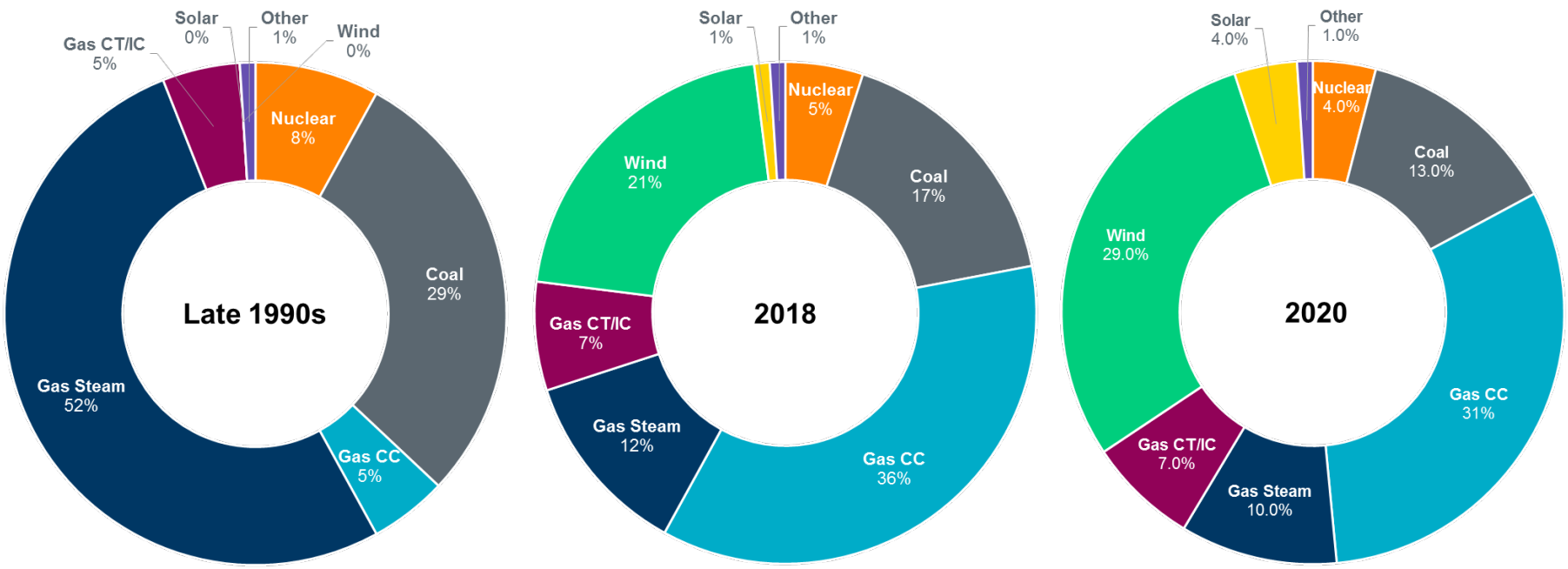
Wind Generation Record (instantaneous):

- Output: 17,541 MW
  - Feb. 19, 2018, 10:05 p.m.
- Penetration (load served): 54%
  - Oct. 27, 2017, 4 a.m.
  - Total Load = 28,416 MW

Utility Scale Solar Generation Capacity – September 2018



Changing Resource Capacity Mix: Variability + Flexibility



Note: 2020 capacity numbers include planned projects with commercial operation date through 2020, as well as account for confirmed retirements and mothballs

Before it all started…

Advantages:

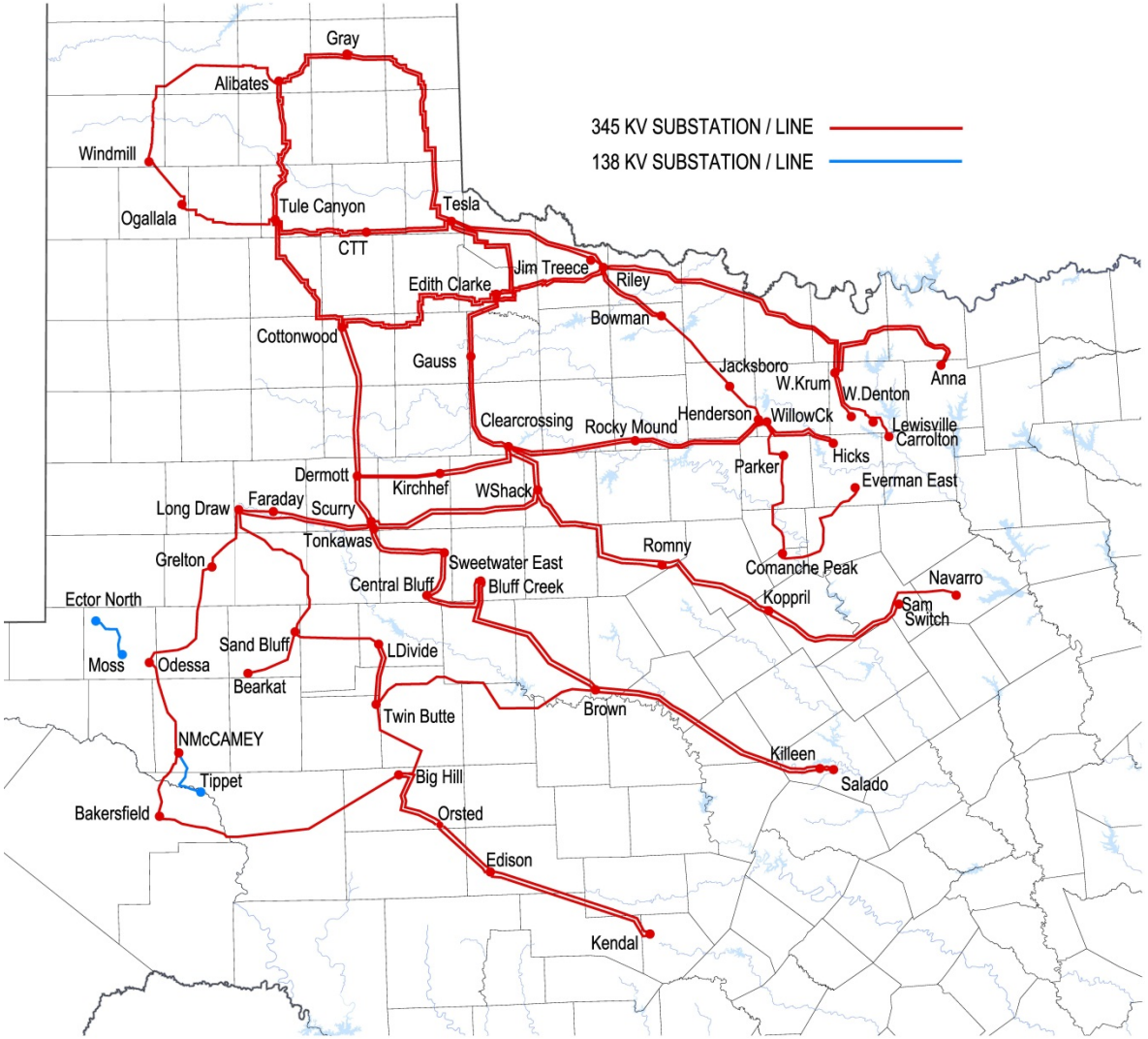
- Great wind & solar resources in the West and Panhandle regions
- Load Resources with underfrequency relays provided a portion of frequency containment reserve (at 59.7 Hz, full resp. in 0.5 second)
- All generators were required to provide governor response (5% droop, 36 mHz deadband)
- All generators were dispatchable on the market

Challenges:

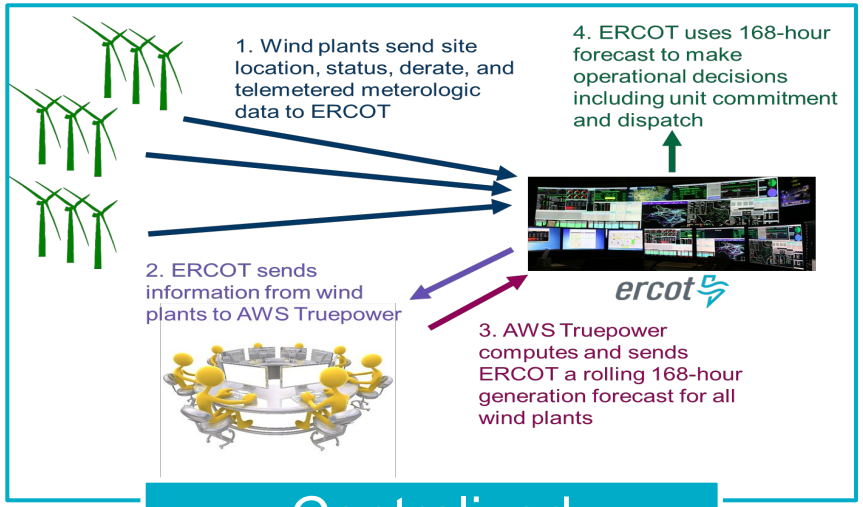
- Scarce or no transmission to renewable-rich areas
- Largest contingency to protect against is high compared to system size
- 15-minute, zonal market
- No experience with renewable forecasting and operation
- Uncertainty over essential reliability services.

Competitive Renewable Energy Zone Transmission 2005-2013

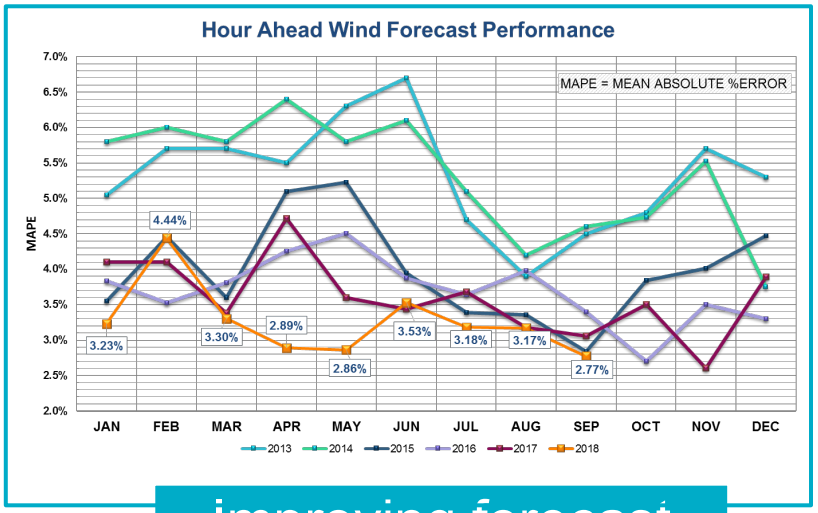
- Planning started in 2005
- Construction started in 2010
- Completed in January 2014
- Designed to serve 18.5 GW of wind resources
- ~3600 miles of 345 kV transmission
- Project cost: ~$6.9 billion
- Lines are open-access; use not limited to wind



Wind Forecasting, 2009 - Present



Centralized forecasting

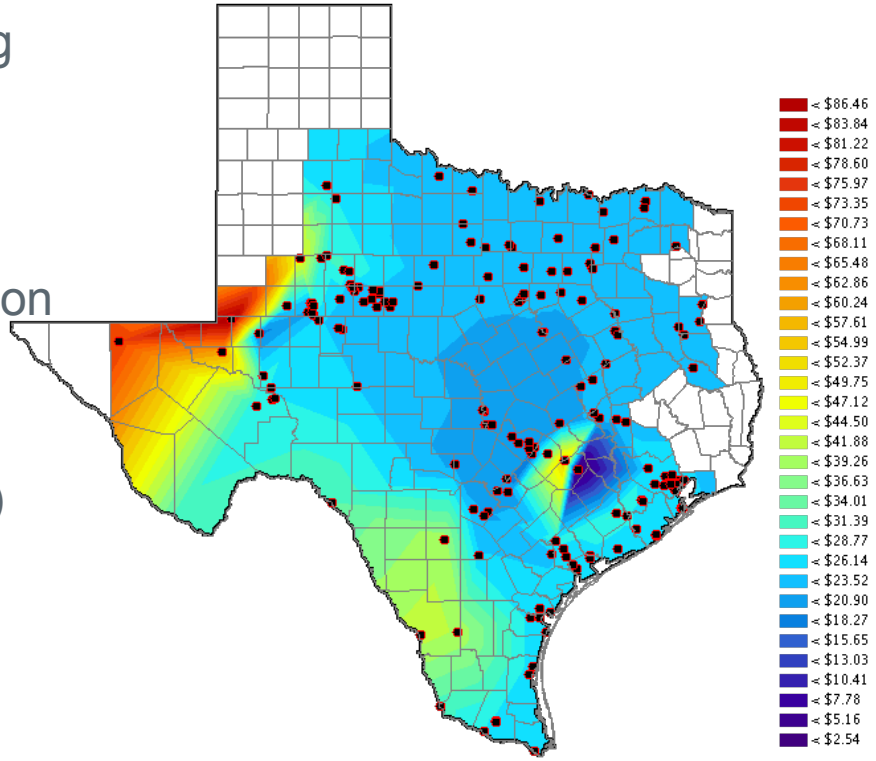


improving forecast accuracy

- Wind forecasting in use since 2009, initially 48-hour outlook
- Solar forecasting was introduced in 2015
- Currently, ERCOT uses a 168-hour rolling forecast with hourly resolution for all wind/solar resources.
- Average hour ahead wind forecast error is 3.35% in 2018

Nodal energy Market, 5-min Real Time Dispatch, 2010

- Voluntary Day-Ahead Market, where Ancillary Services are procured, co-optimized with energy;
- Generators self-commit; ERCOT makes residual reliability commitments;
- In Real-Time all generators (including renewables) submit offers for generation output
- Real-Time market clears every five minutes, using the cheapest generation to serve the load, subject to transmission constraints
- All generators (including renewables) receive output level instructions and locational marginal prices

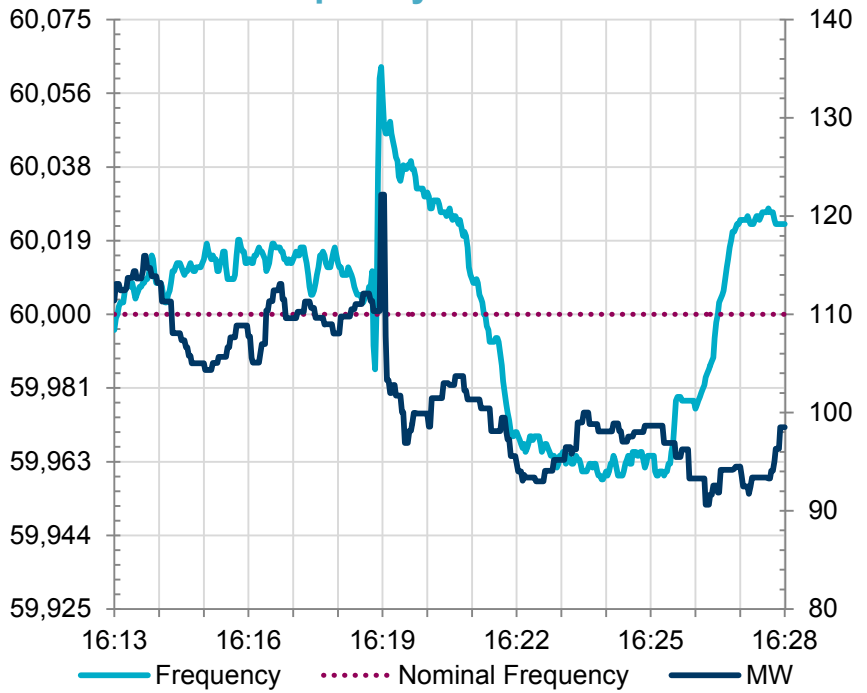


“Governor-like” response from Wind and Solar, 2012

- Requirement for all wind and solar resources with interconnection agreements after 2008 to provide a “governor-like” response;
- To date, about 2000 MW of older plants are exempt;
- In 2016 the deadband for **all** generation changed to from 36 to 17 mHz

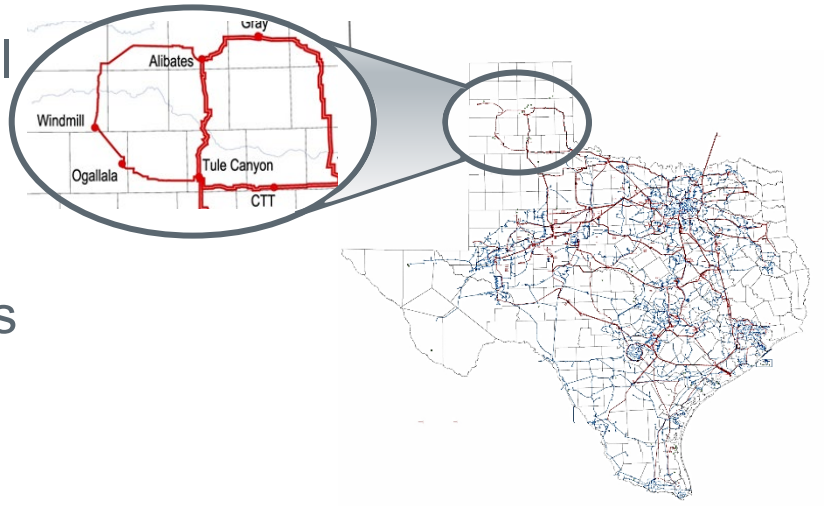
Wind Resource Response to Low Frequency 07/13/2016

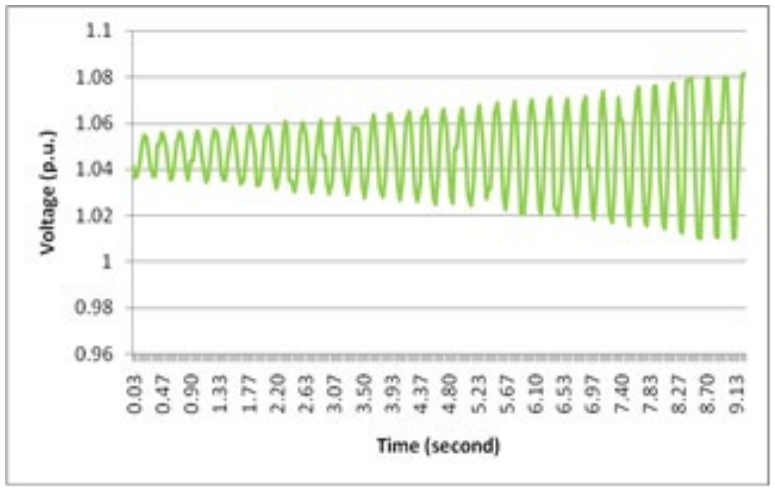
Wind Resource Response to High Frequency 08/25/2015

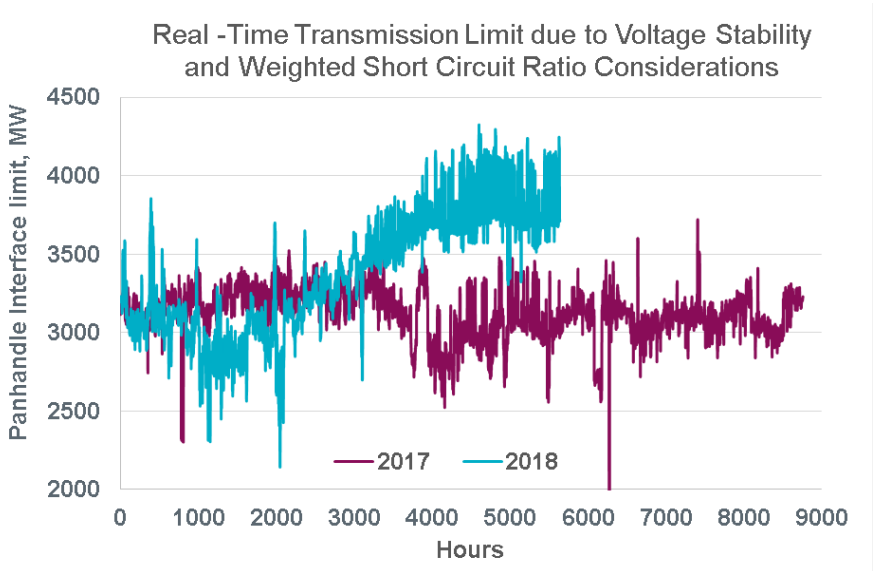


Weak Grid Issues in Panhandle, 2014 - present

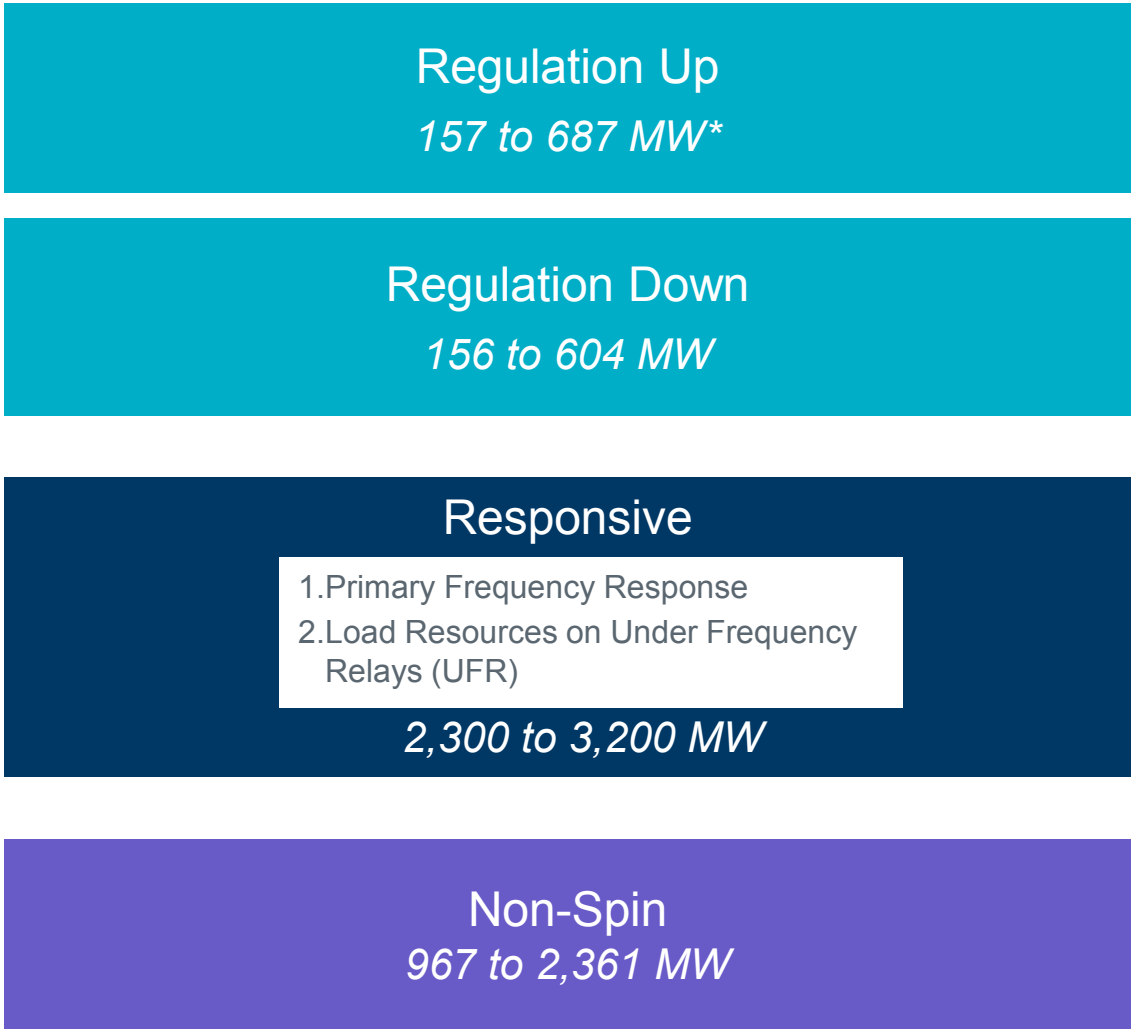
- ~ 5.5 GW planned, ~4 GW in service (all wind generation)
- ~2.8 GW planned in the nearby area
- No local load or synchronous generators
- Voltage support and system strength issues





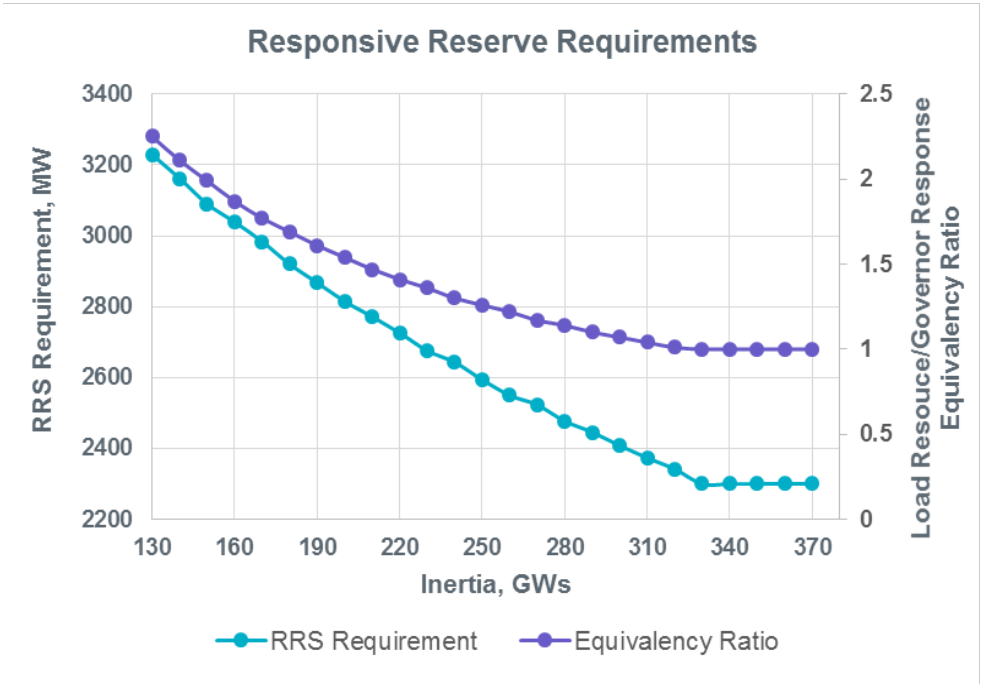


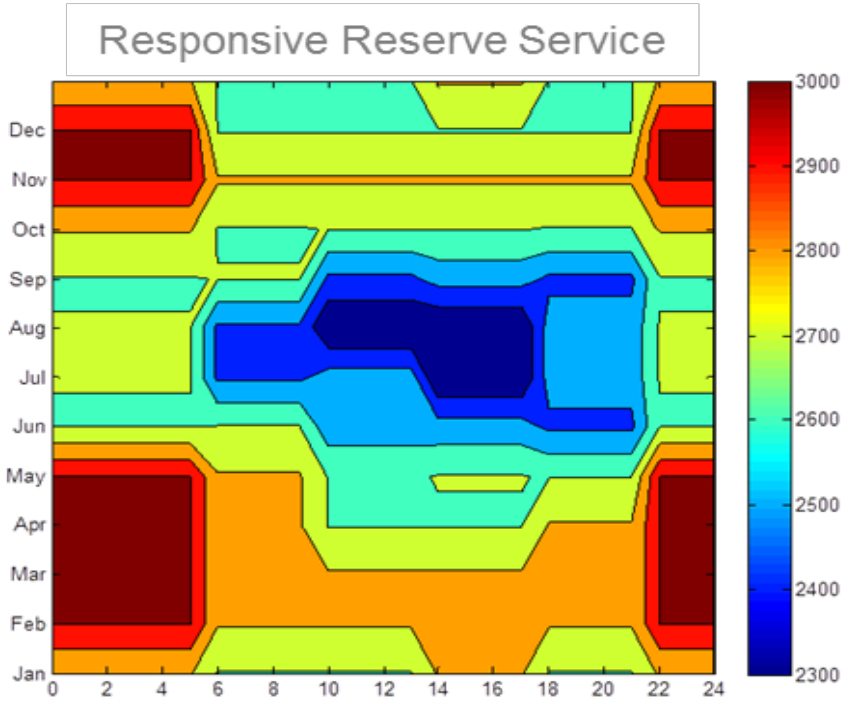
Ancillary Services



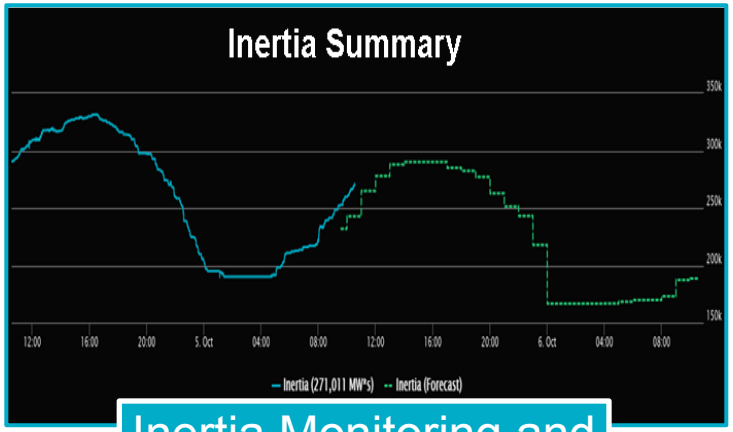
*The numbers are showing 2018 AS amounts

Frequency Containment Reserve Based on Inertia Conditions and Load Participation, 2015





Reliability Risk Desk, Situational Awareness, 2016

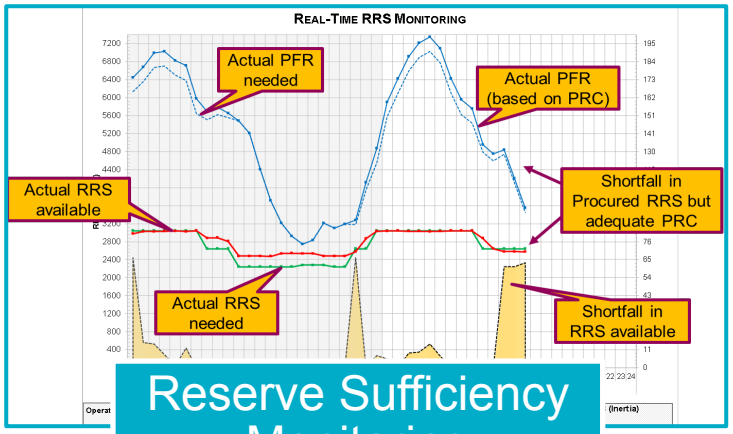


Inertia Monitoring and Forecasting

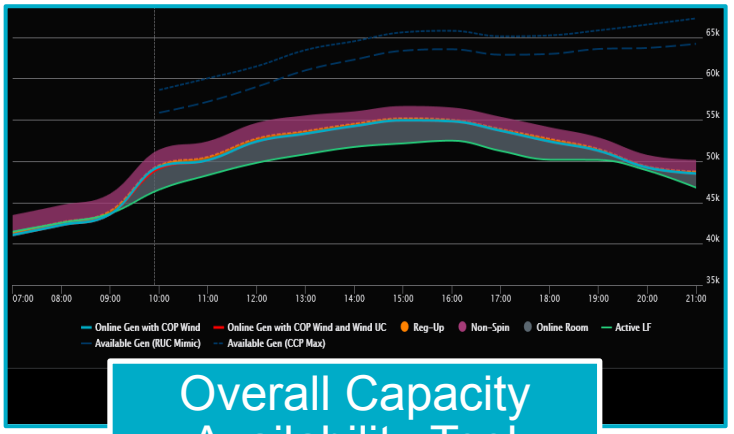
- 120 GW*s >= Inertia Normal
- 120 GW*s > Inertia >= 110 GW*s Yellow
- 110 GW*s > Inertia >= 100 GW*s Orange
- 100 GW*s < Inertia Red

Emergency BPs	Inactive
System Inertia	99,999 MW-s
SCED	00:04:00
RLC	00:00:06
STLF Forecast High	21.6
STLF Next 30 Mins	Normal
QSE ICCP	Normal

Critical Inertia alerts



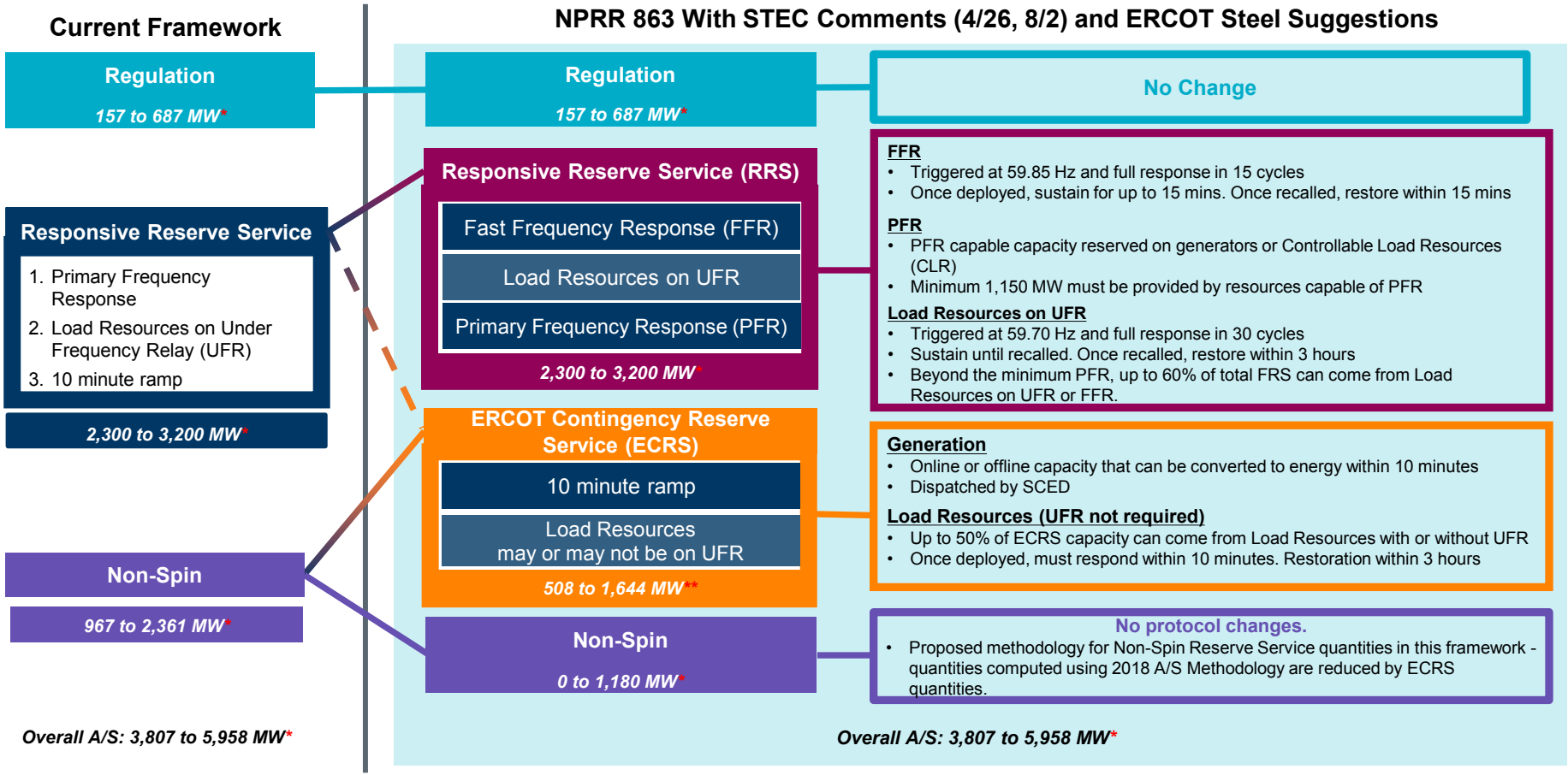
Reserve Sufficiency Monitoring



Overall Capacity Availability Tool

Proposed Ancillary Service Framework Changes, 2018

Last Edited on /16/2018



*Quantities computed/estimated using 2018 Ancillary Service Methodology. **Quantities estimated using this reference.
For Discussion Purposes Only. The intent of this slide is to represent NPRR 863 (with ERCOT comments from 7/6/2018). Protocol language prevails to the extent of any inconsistency with this one page summary.

Key Takeaways

- System operators in areas with growing amounts of renewables face challenges with system balancing (uncertainty, ramping, variability, voltage and frequency control);
- Granular real-time dispatch and accurate forecasting is key;
- Real-time awareness tools in the control room are essential for efficient and reliable operations with high levels of renewable resources;
- Ancillary Services can satisfy essential reliability needs for the system
  - Use market-based solutions as much as possible
- Some of the reliability requirements need to be implemented through grid codes. Modern renewable generation technology can provide grid support and AS.

Resolving integration issues increasingly requires ongoing coordination between grid/market operators, generation owner/operators and turbine/control manufacturers

Thank you! Questions?

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