



Frequency Control and Grid Resiliency

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Discussion Outline

1. An Introduction to ERCOT
2. Primary Frequency Control and Grid Resiliency
3. Standards vs Guideline

ercot  4. Summary

The ERCOT Region

Peak Demand Record: 71,110 megawatts (MW)

- Aug. 11, 2016, 4-5 p.m.

Weekend Peak Demand Record: 68,368 MW

- Saturday, July 29, 2017, 4-5 p.m.

Winter Peak Demand Record: 65,915 MW

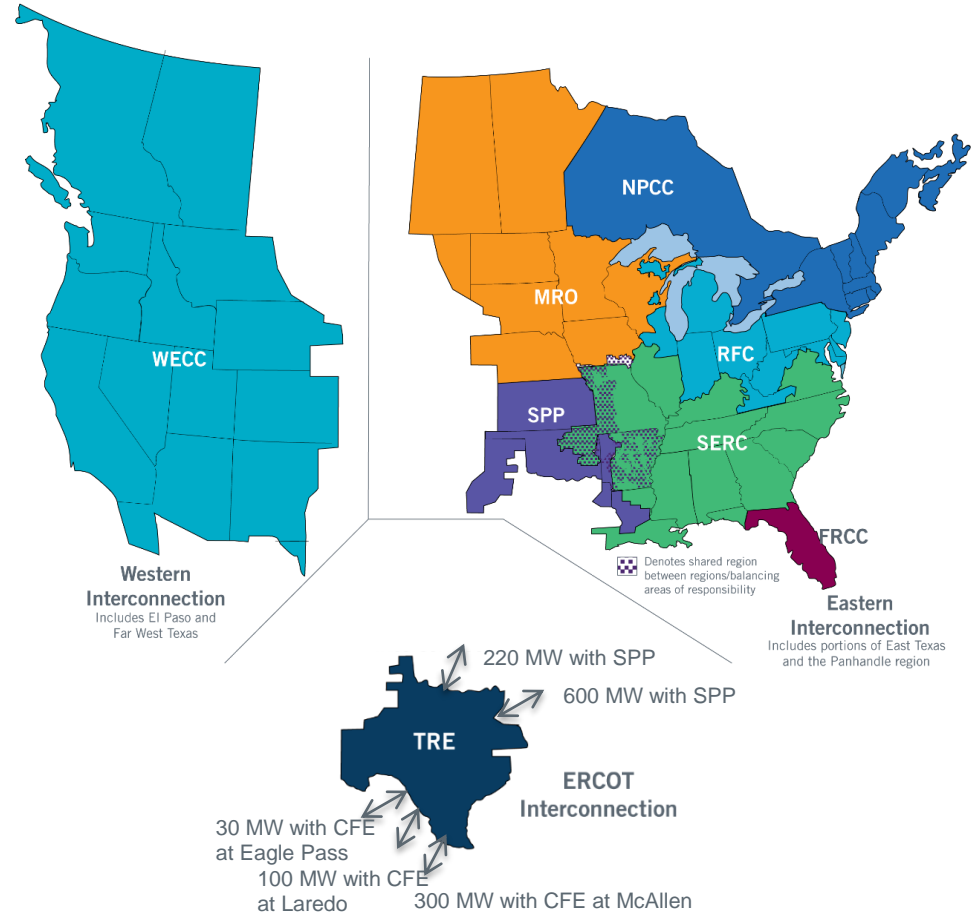
- Jan. 17, 2018, 7-8 a.m.

Minimum Demand Record: 22,355 MW (2011- date)

- April 17, 2011, 4-5 a.m.

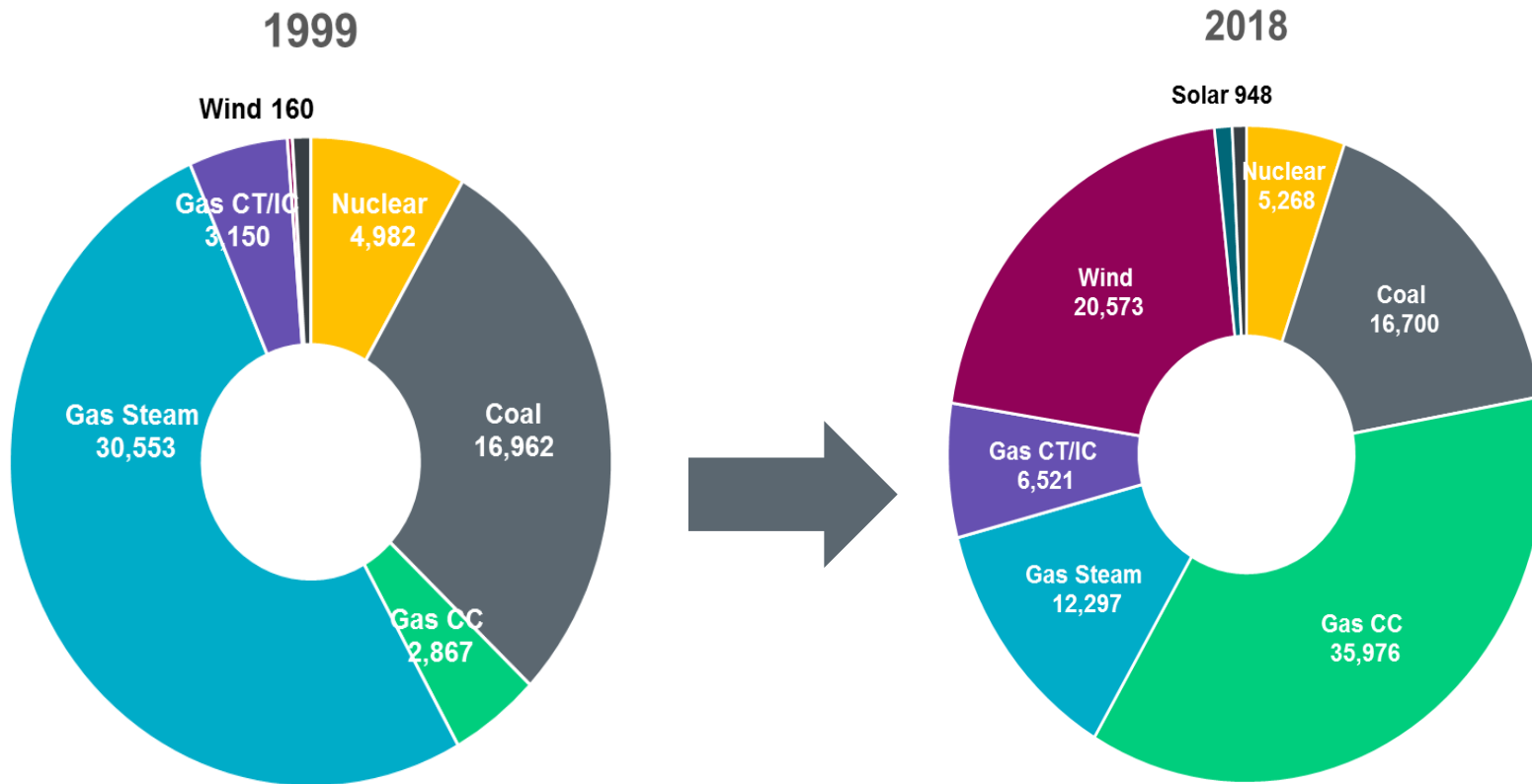
Wind Generation Records (instantaneous)

- 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



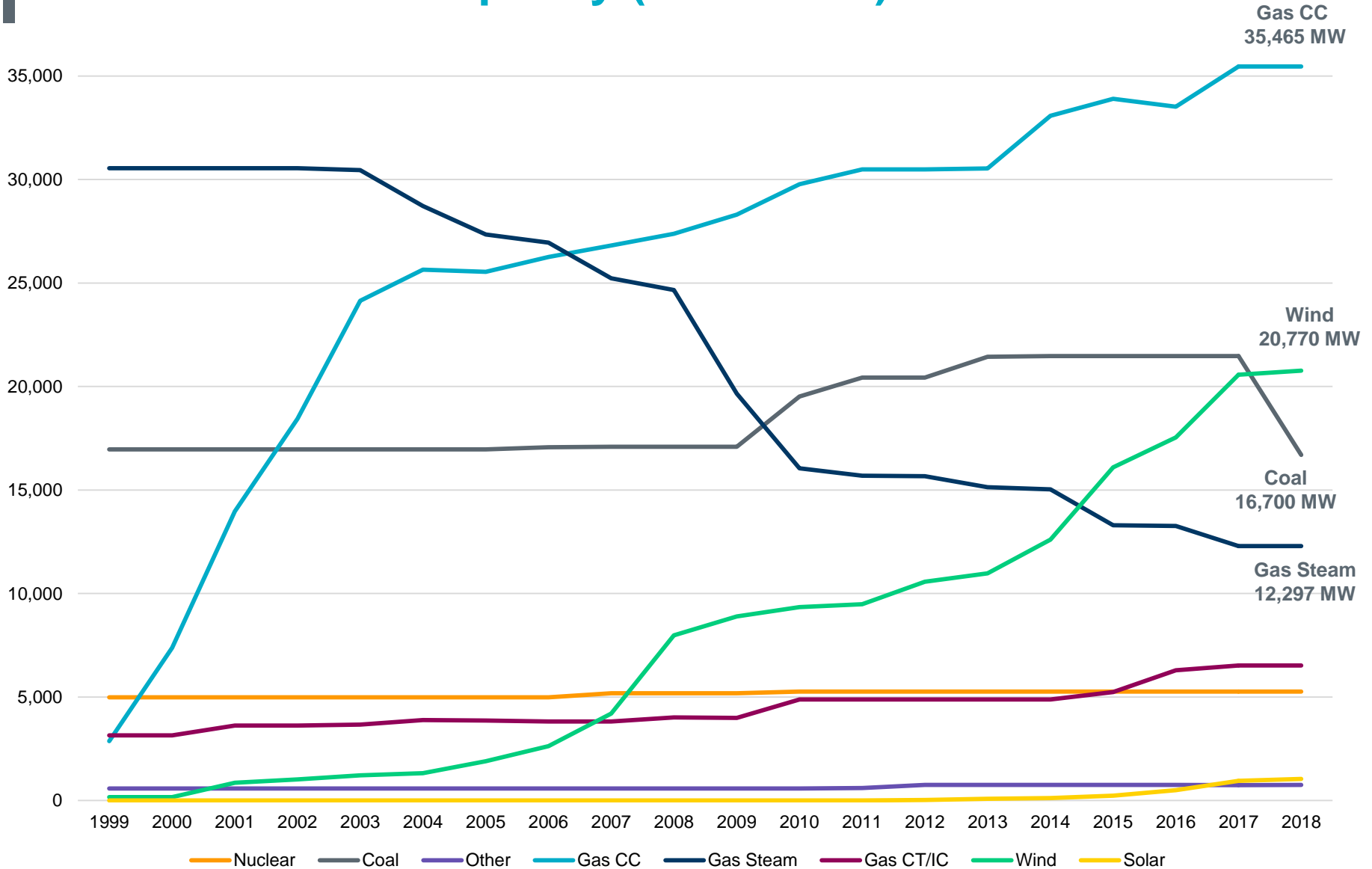
ERCOT connections to other grids are limited to ~1250 MW of direct current (DC) ties, which allow control over flow of electricity

Changing Resource Mix – Installed Capacity (MW)



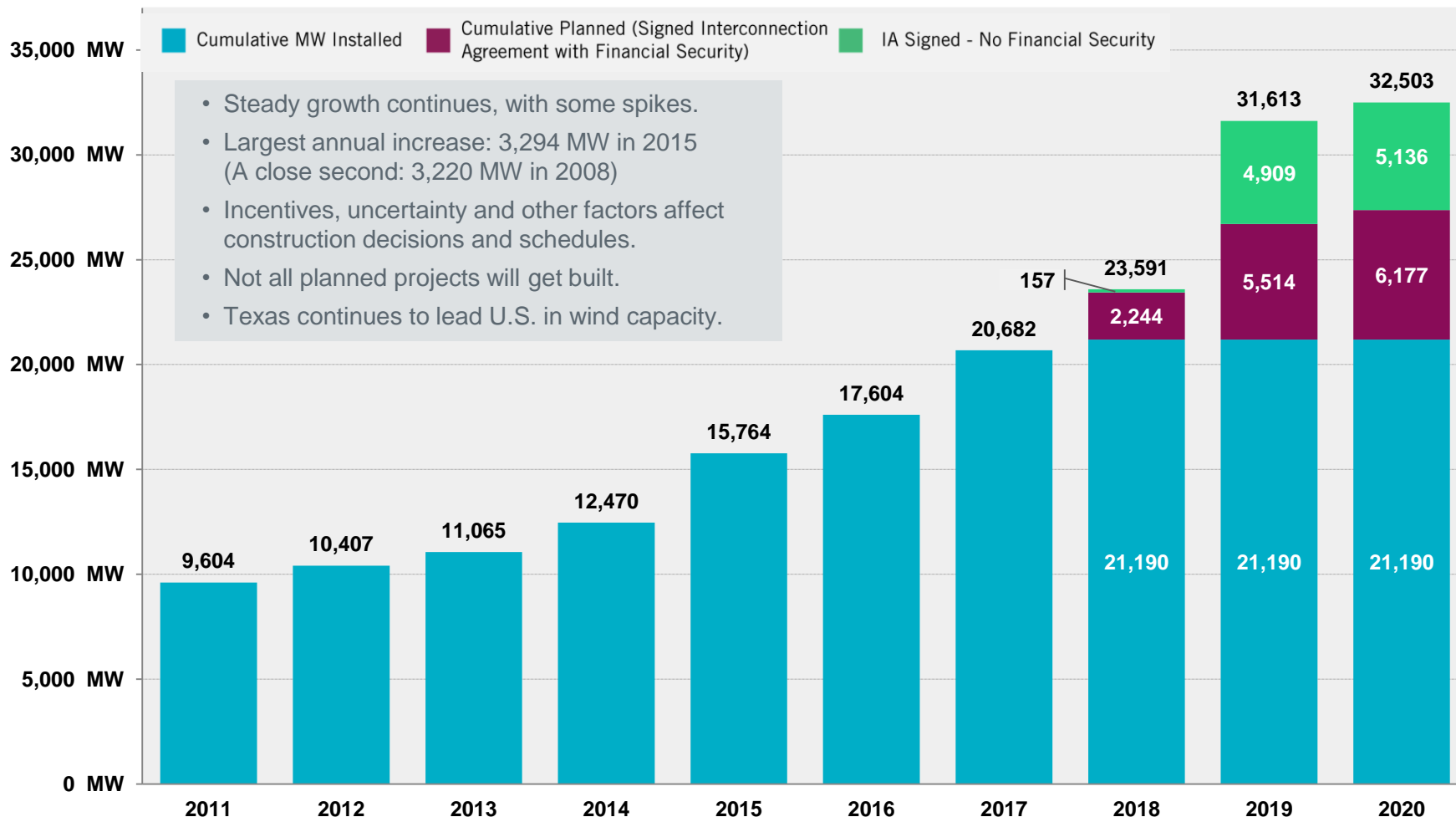
*as of Feb. 2018

ERCOT Installed Capacity (1999-2018)



Wind Generation Capacity – May 2018

Future outcomes uncertain



- Steady growth continues, with some spikes.
- Largest annual increase: 3,294 MW in 2015 (A close second: 3,220 MW in 2008)
- Incentives, uncertainty and other factors affect construction decisions and schedules.
- Not all planned projects will get built.
- Texas continues to lead U.S. in wind capacity.

The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information is received. This chart reflects planned units in the calendar year of submission rather than installations by peak of year shown.

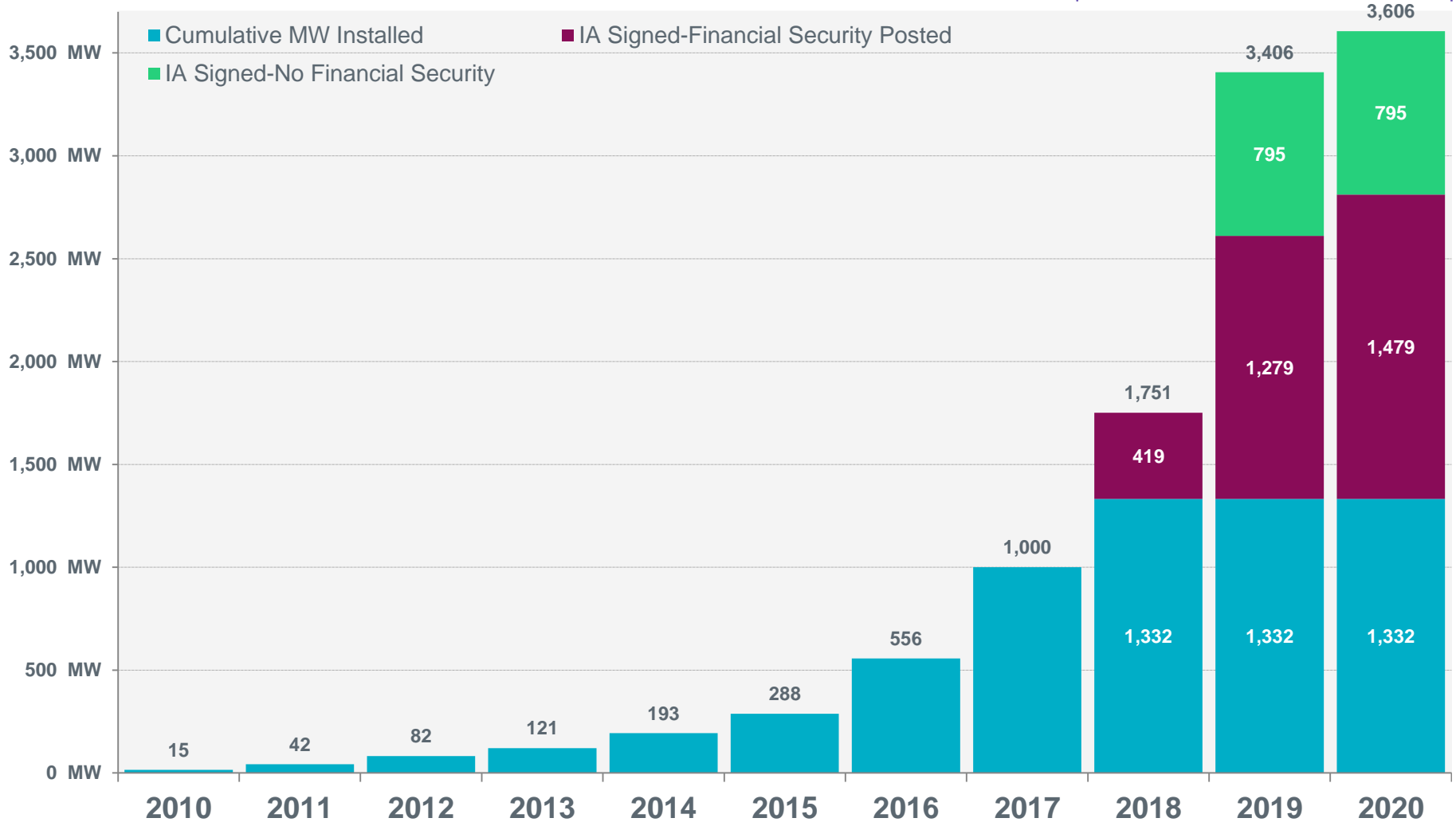
Financial security posted for funding interconnection facilities does not include CREZ security deposits, which are refunded to the Interconnecting Entity when an IA is signed.

As of May 31, 2018



Utility Scale Solar Generation Capacity – May 2018

Future outcomes uncertain



The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information is received. This chart reflects planned units in the calendar year of submission rather than installations by peak of year shown.

As of May 31, 2018



Primary Frequency Control & Resiliency

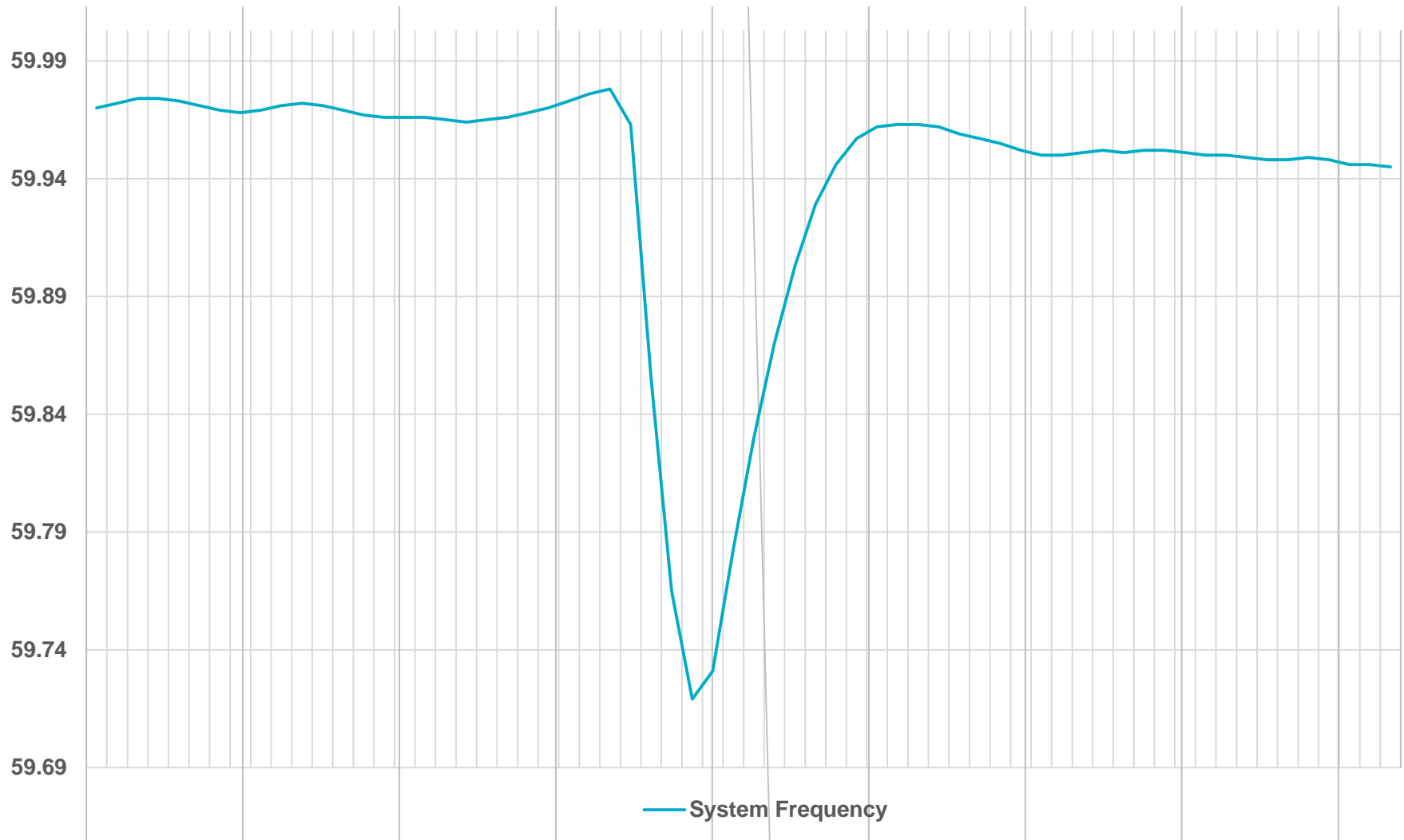
Resilience

*The ability to **withstand** and reduce the **magnitude and/or duration of disruptive events**, which includes the capability to anticipate, **absorb**, adapt to, and/or **rapidly recover from such an event**.*

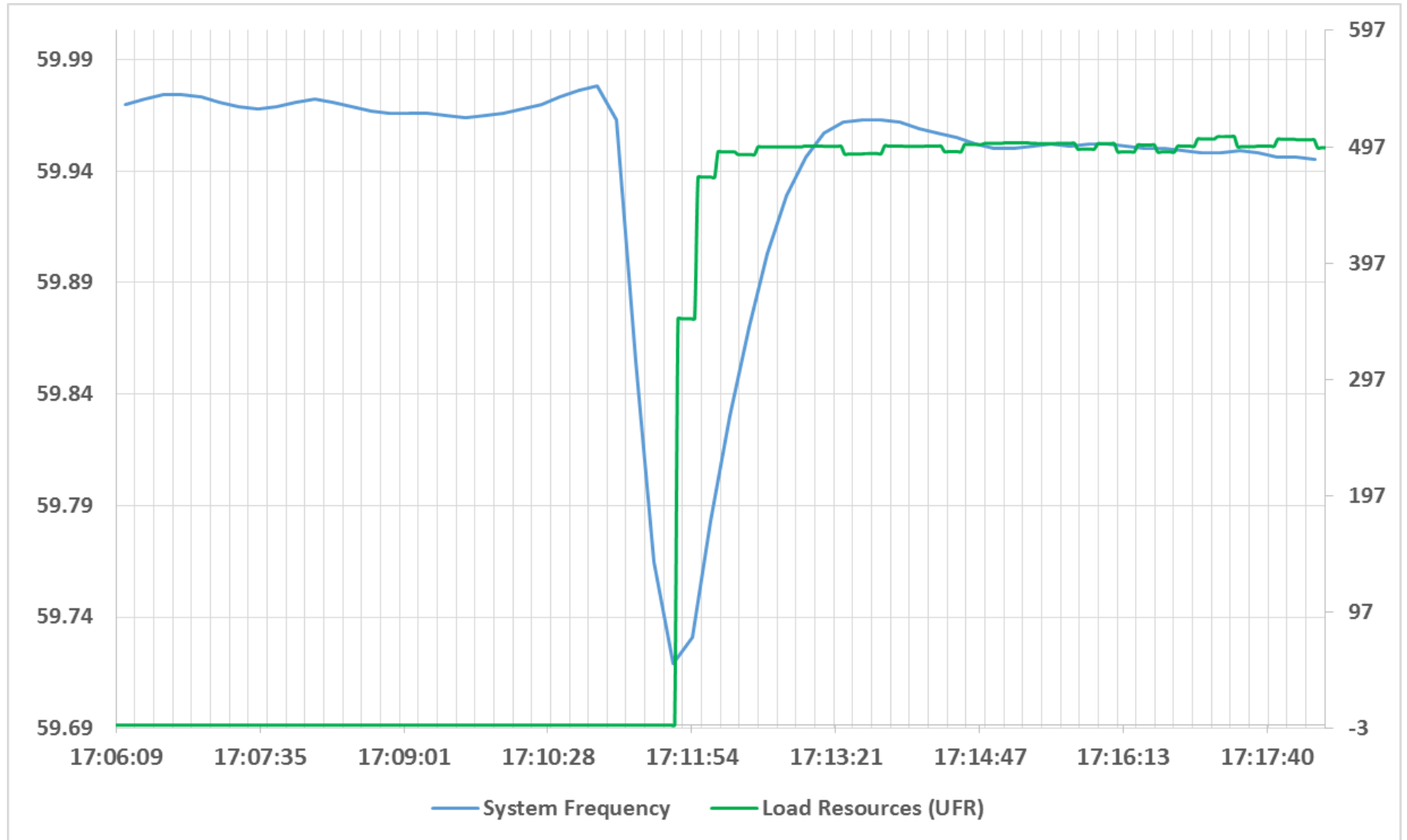
Primary Frequency Response (commonly referred to as Frequency Governor Response)

*The **immediate (without intentional delay) proportional increase or decrease in real power output provided by resources (generators, energy storage, load and others)**. This proportional response is in the direction that **stabilizes frequency**. Primary Frequency Control comes from **actions of local control systems**.*

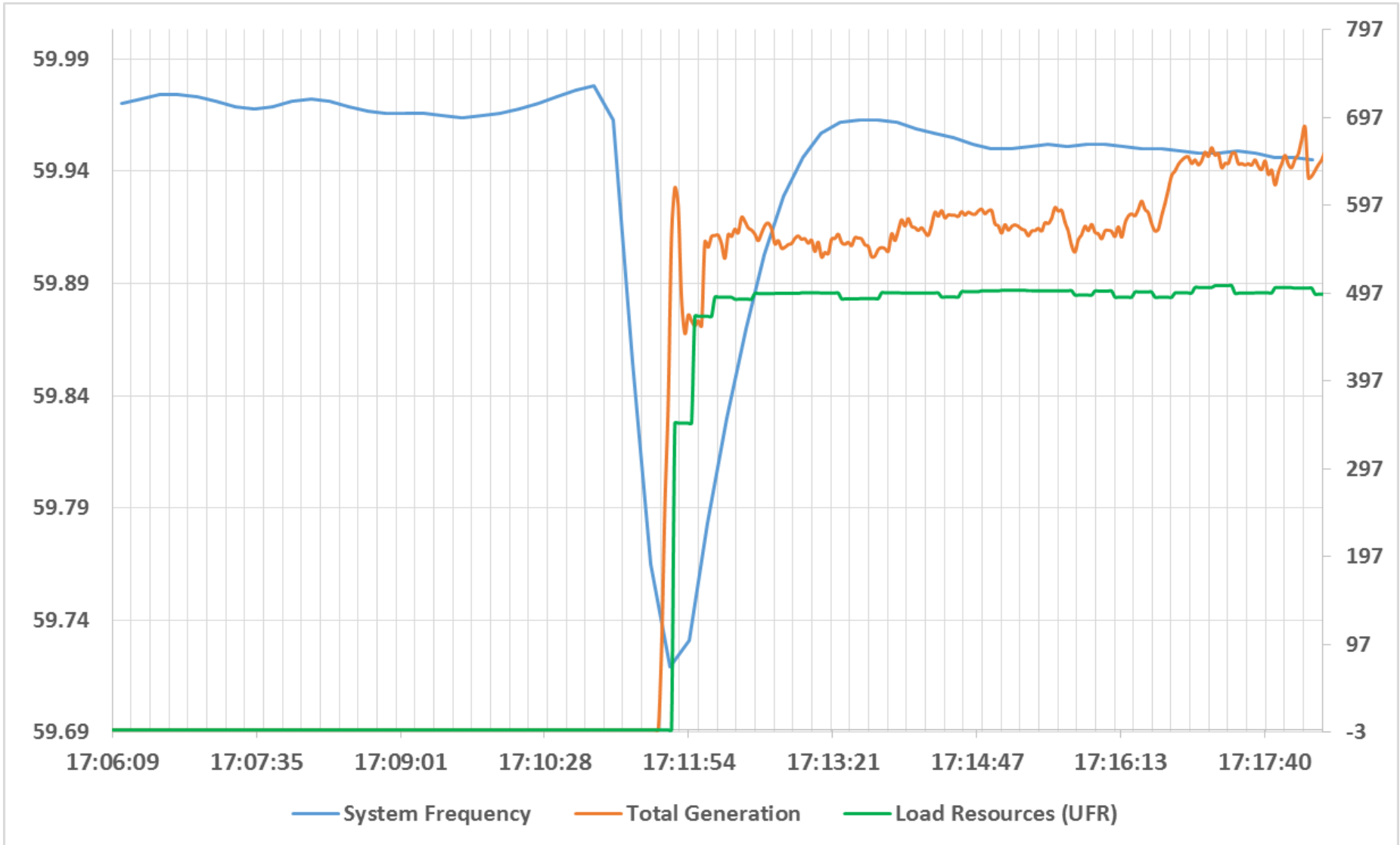
Frequency Event – Generator Forced Outage (1250 MW)



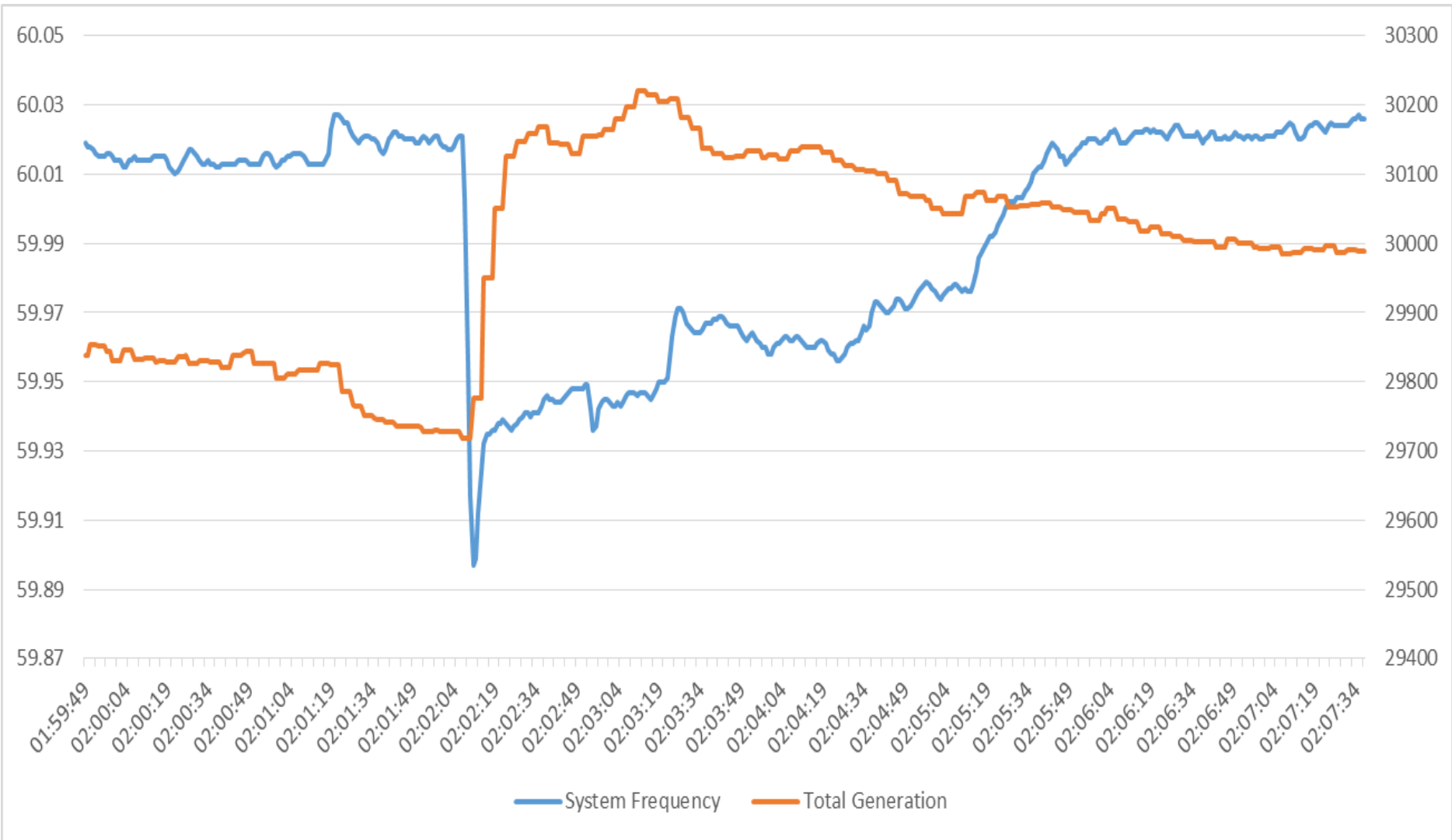
Frequency Event – Generator Forced Outage (1250 MW)



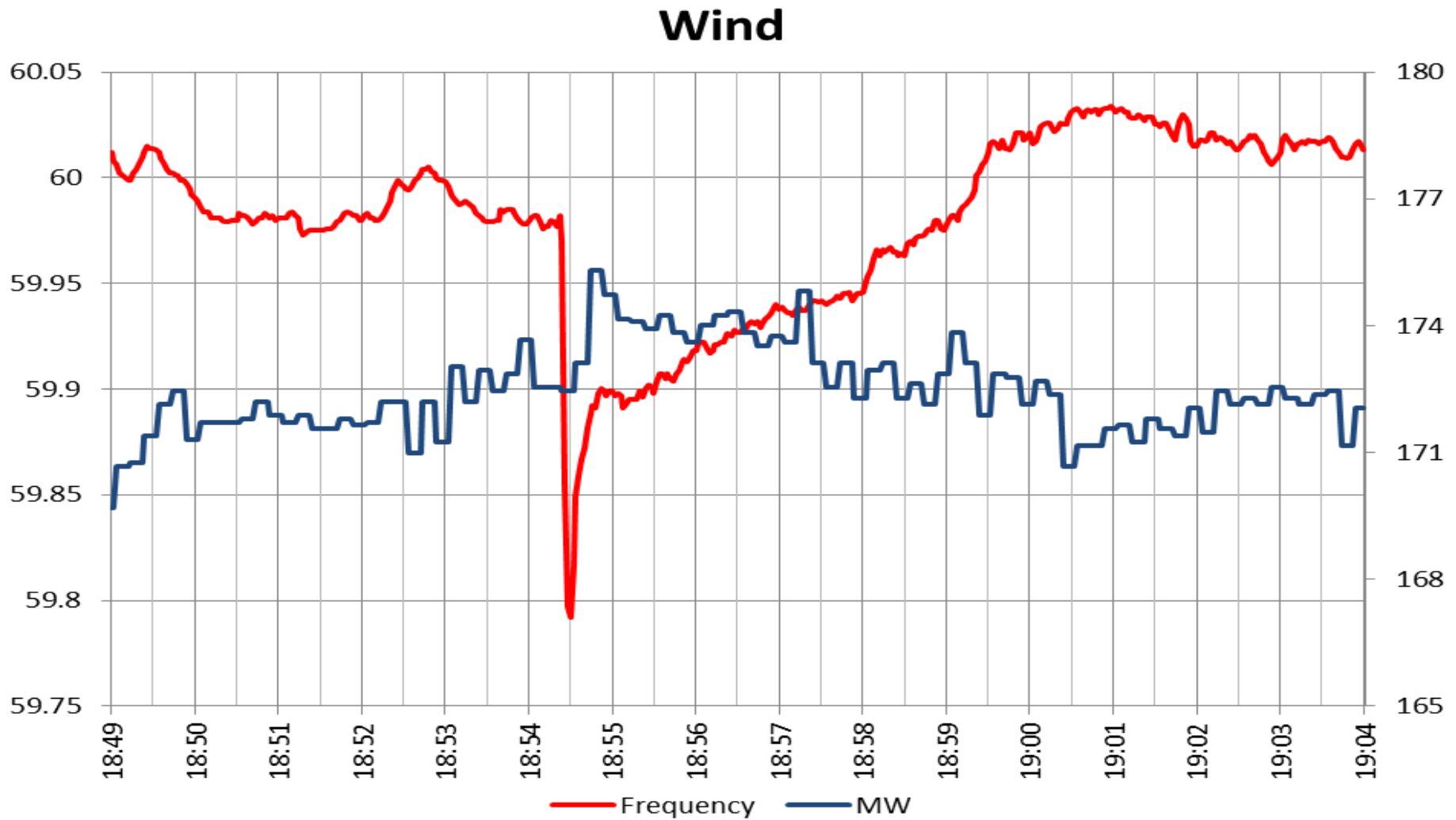
Frequency Event – Generator Forced Outage (1250 MW)



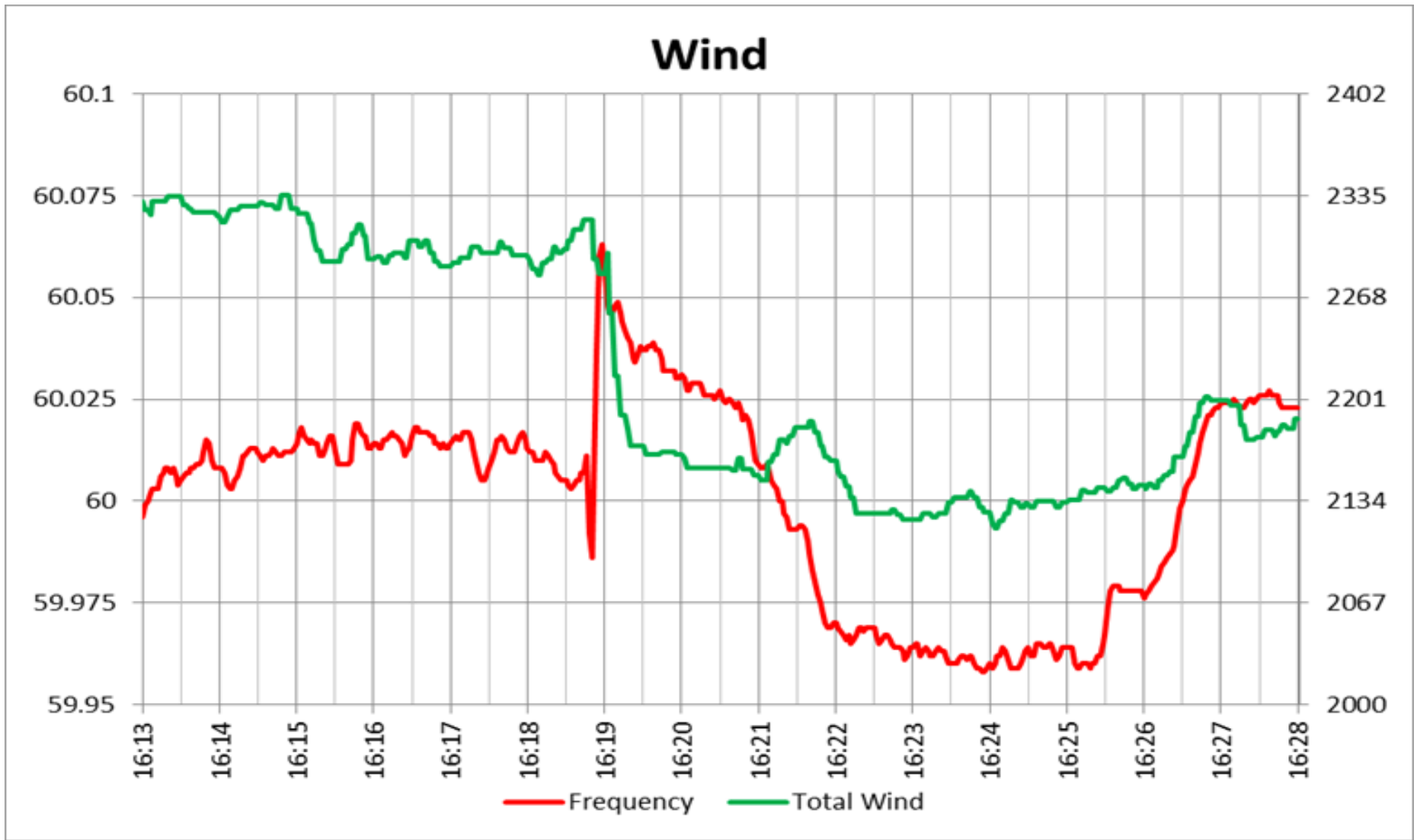
Frequency Event – Generator Forced Outage (438 MW)



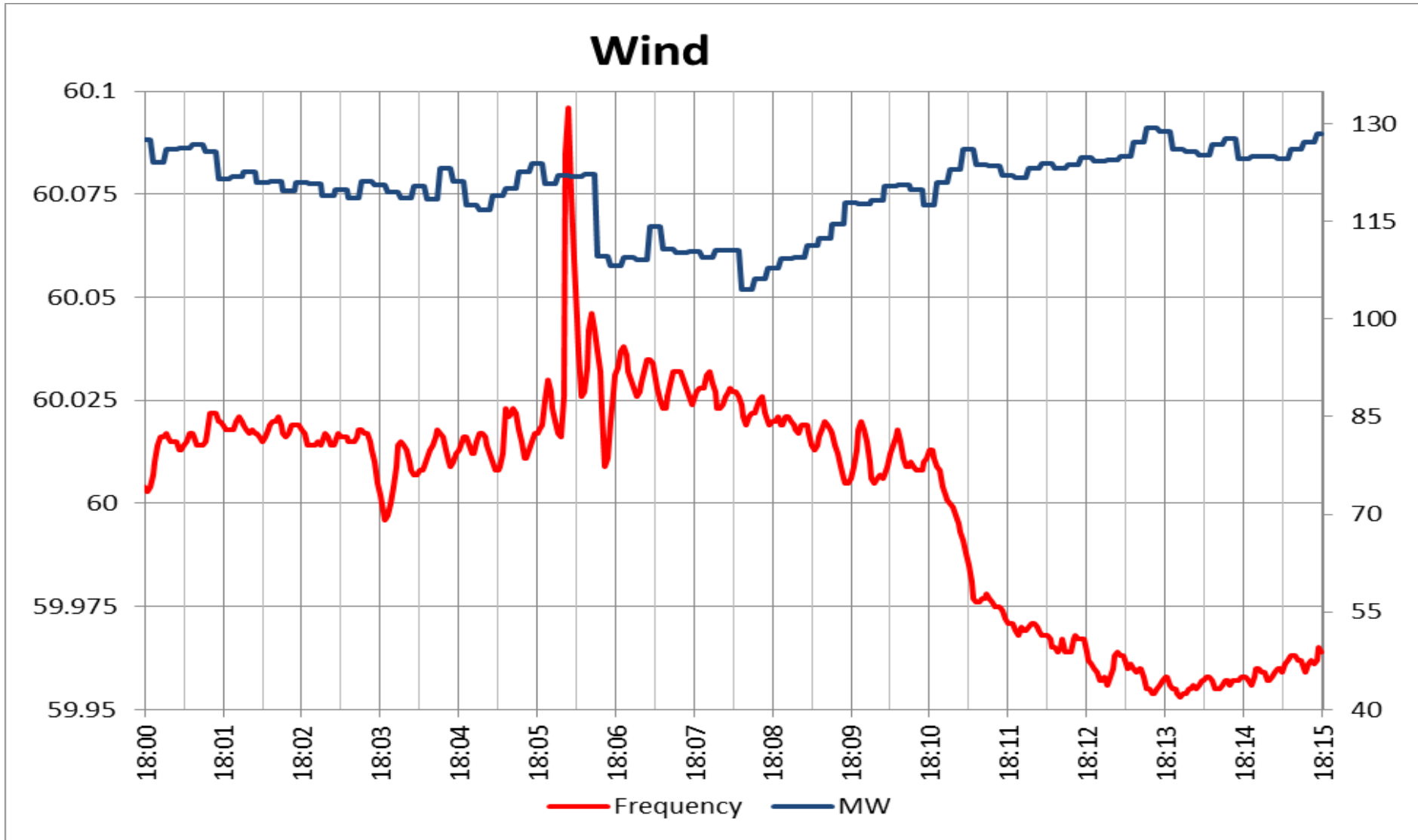
Wind Unit Response to Low Frequency



Wind Response to High Frequency



Wind Unit Response to High Frequency



BAL-001-TRE-1 Standard

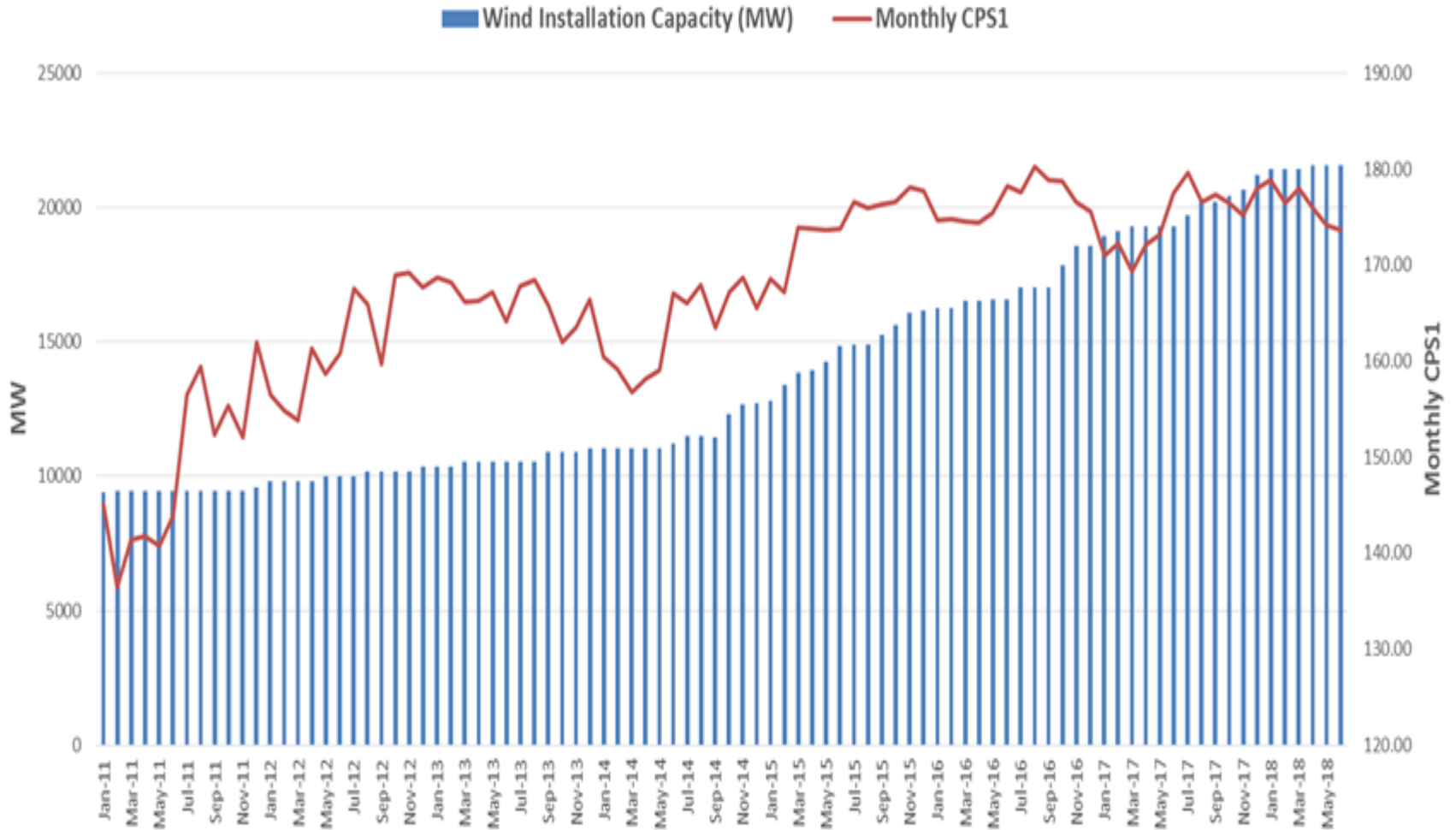
1. Purpose
 - To maintain Interconnection steady-state frequency within defined limits.

2. Requirements for Generation Owners:
 - Specifies Droop and Dead-band settings
 - Rolling 12-month performance requirements for generation resources

3. Requirements for the Balancing Authority/ERCOT:
 - Reporting transparency and changes to measuring Frequency Measurable Events
 - Calculations for Frequency Response measurements (PFR and IMFR)
 - Calculation of 12-month rolling performance averages for each Generator

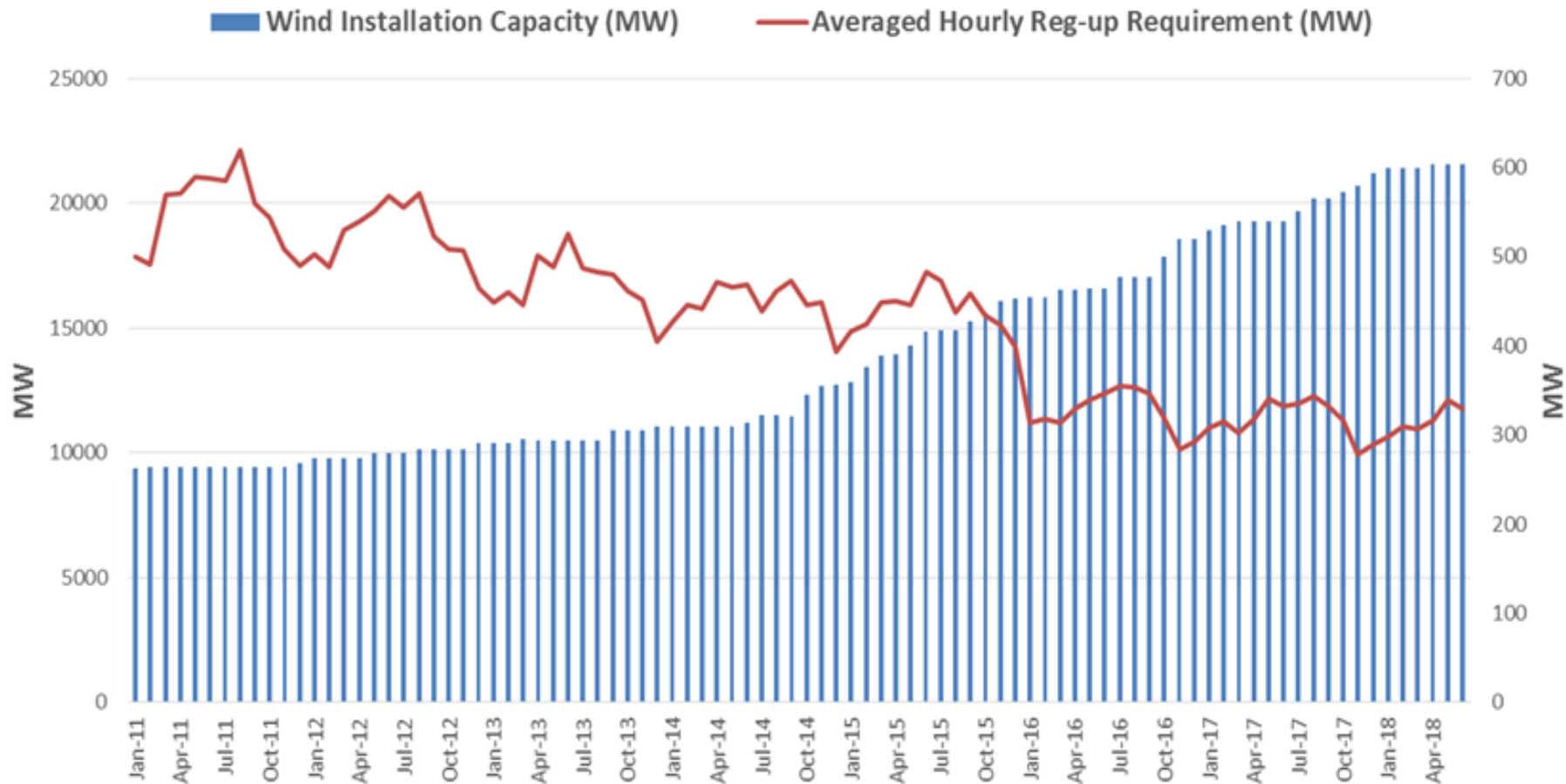
Installed Wind Capacity versus CPS1 (BAL-001)

Wind Installation Capacity (MW) v.s. Monthly CPS1



Wind Installed Capacity vs Reg-Up (MW)

Wind Installation Capacity (MW) v.s. Averaged Hourly Reg-up Requirement



Key Points

1. Inverter Based resources can provide Primary Frequency Response
 - Faster
 - Sustained
2. Frequency control from diverse set of resources makes grid more resilient
 - Generators providing continuous proportional response
 - Demand Resources providing Under-Frequency Relays triggered response in cycles
 - Energy Storage is suitable to provide faster response in cycles more often than demand response
3. Regional NERC Standard BAL-TRE-001 versus Guidelines
 - ERCOT saw big improvement in its primary frequency capability following implementation of BAL-TRE-001 Regional NERC Standard.
4. Frequency control must be coordinated
 - Primary Frequency Response must be coordinated with Secondary Frequency Controls
 - Generation dispatch must take wind and solar ramps into account in addition to load ramps.

QUESTIONS?