Stability Impact of Providing Frequency Response from IBRs in Lower Inertia Regions

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Oct 26, 2022
ESIG

(1) ERCOT (2) GE Power (3) HickoryLedge LLC

Discussion Outline

- Overview
  - Records and Recent Trends
  - Evolution of ERCOT's Resource Mix
- Current Practices to Use Responsive Reserve to Meet BAL-003 Requirement
- New Trend of Energy Storage Resources (ESRs) Providing Responsive Reserve
- New Study Commissioned to Investigate Reliability Impacts of ESRs Providing Responsive Reserve

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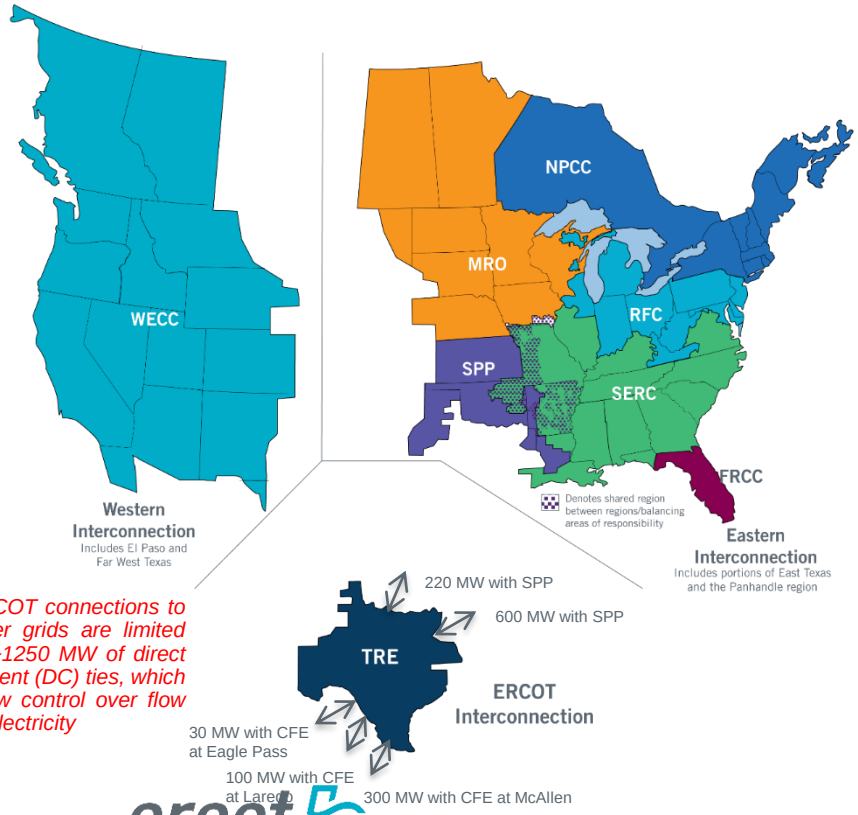
Introduction to ERCOT Region & Company

ERCOT Region

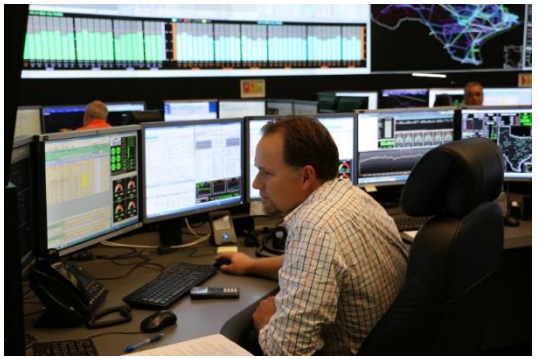
- The interconnected electrical system serving most of Texas, with limited external connections
  - 90% of Texas electric load; 75% of Texas land
  - 79,928 MW peak, July 20, 2022
  - More than 46,500 miles of transmission lines
  - 570+ generation units



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

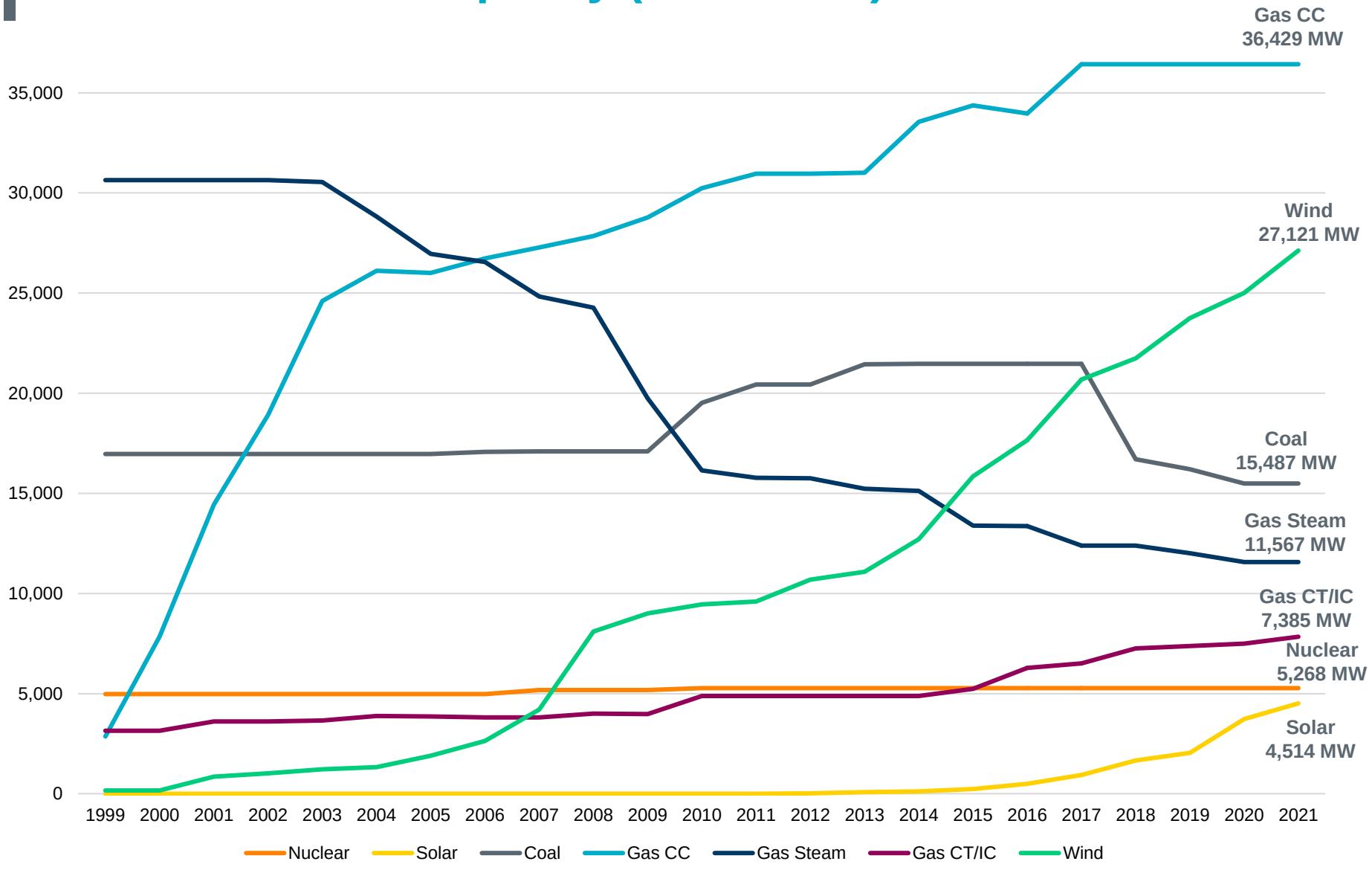
ERCOT Inc.

- The Texas Legislature restructured the Texas electric market in 1999 and assigned ERCOT four primary responsibilities:
  - Maintain system reliability
  - Facilitate competitive wholesale market
  - Ensure open access to transmission
  - Facilitate competitive retail market
- ERCOT is regulated by the Texas Public Utility Commission (PUC) with oversight by the Texas Legislature.

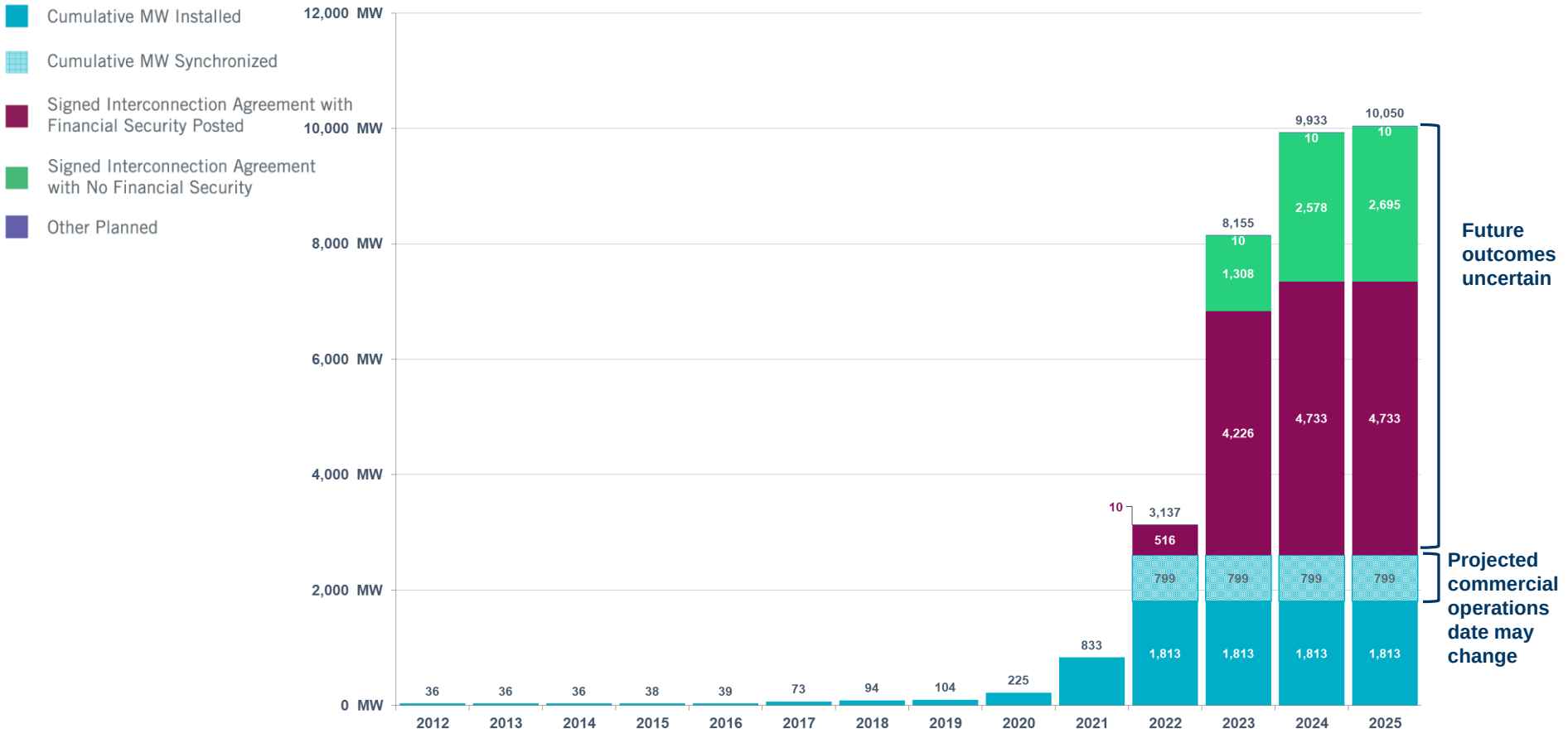


ERCOT is not a market participant and does not own generation or transmission/distribution wires.

ERCOT Installed Capacity (2001-2021)

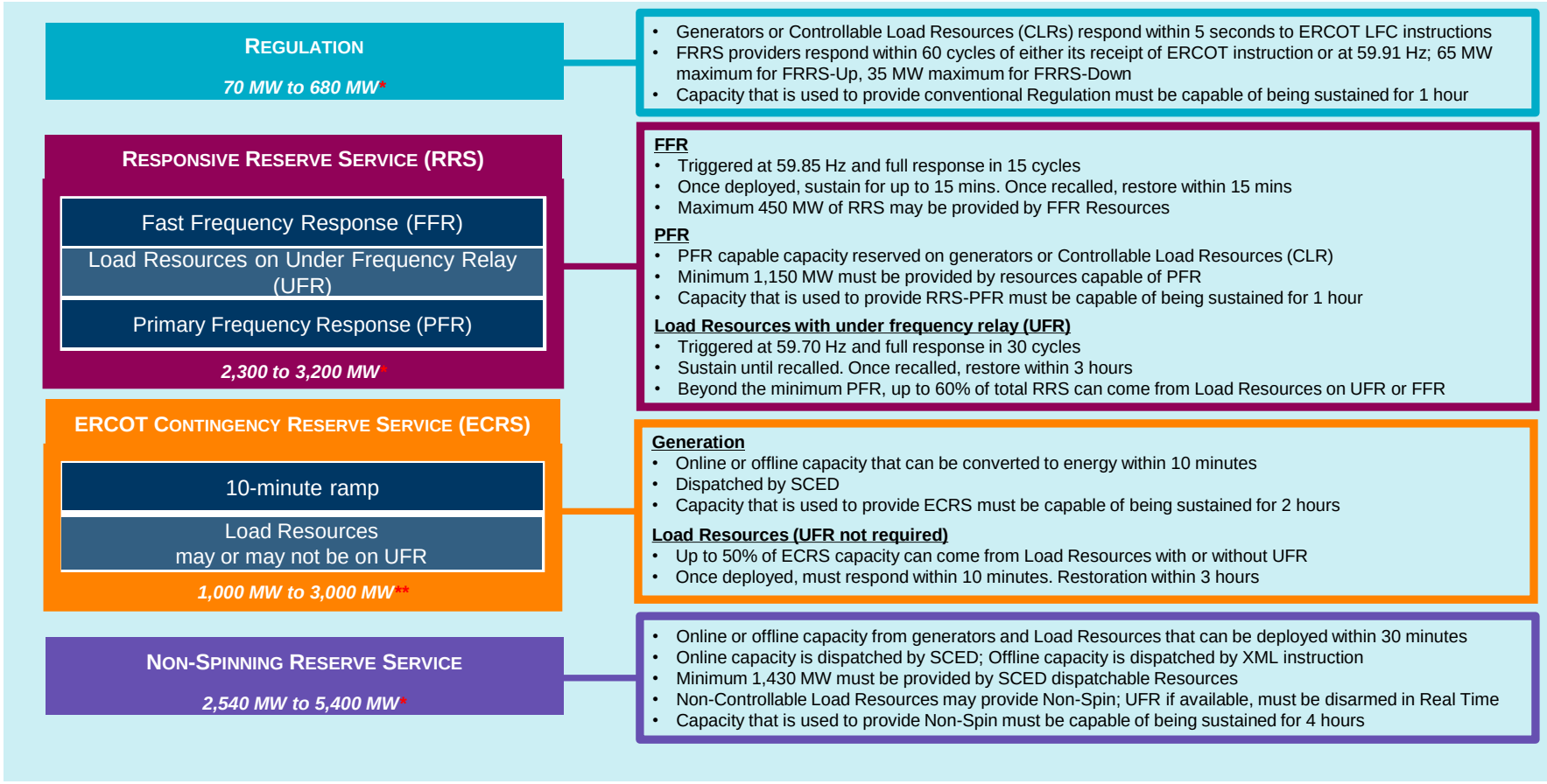


Battery Storage Capacity



- Cumulative MW Synchronized pertains to projects that ERCOT has approved to generate energy for the grid but have not passed all qualification testing necessary to be approved for participation in ERCOT market operations.
- Other Planned capacity reflects registered projects under 10 MW in size that are not included in the Resource Integration and Ongoing Operations Interconnection Services (RIOO-IS) System.

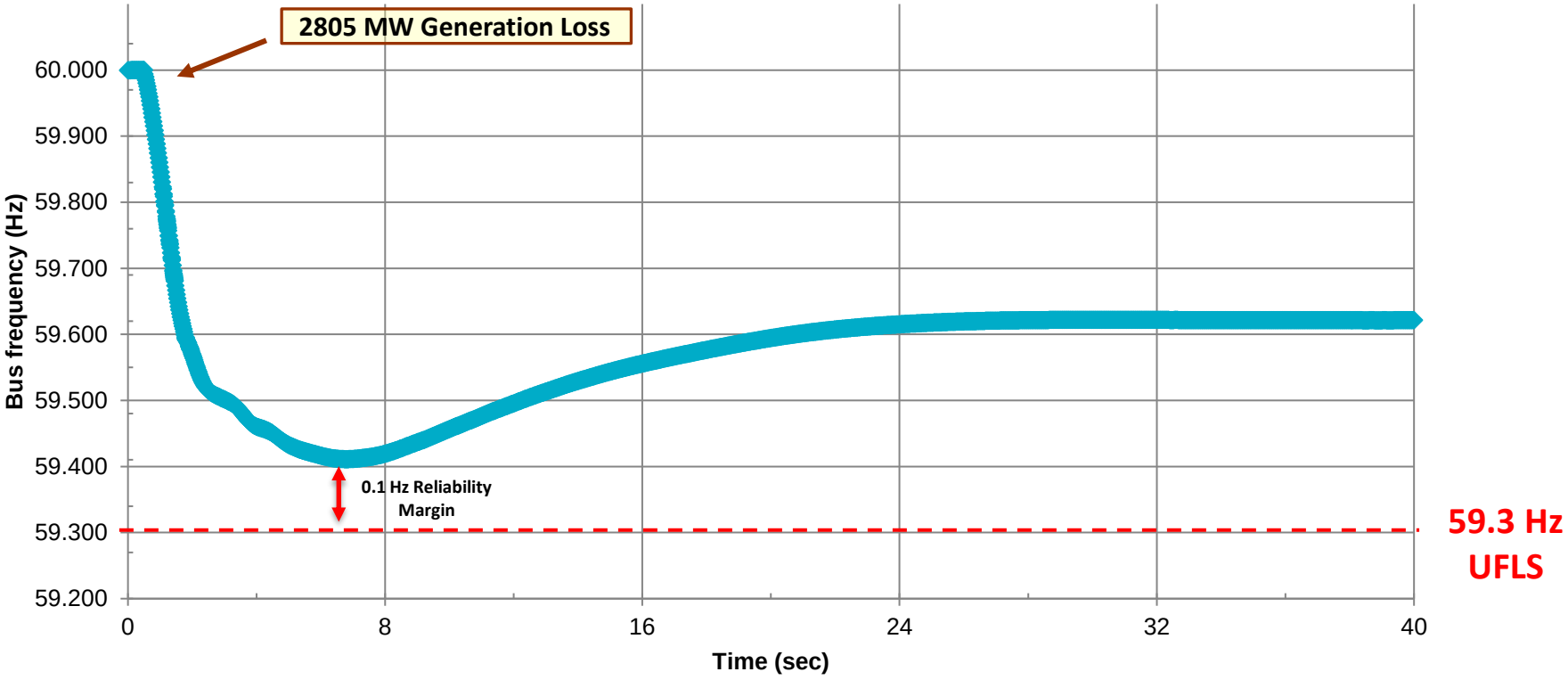
Ancillary Service (AS) Framework in 2023



*Quantities for 2022 computed/estimated using 2022 Ancillary Service Methodology. **Preliminary 2023 quantities estimated using proposed approach that will be discussed at Aug 2022 WMWG meeting.
For Discussion Purposes Only. The intent of this slide is to represent Ancillary Service (AS) Framework after ECRS is implemented around mid 2023. Protocol language prevails to the extent of any inconsistency with this one-page summary.

Responsive Reserve Service (RRS) Study Criteria

- To protect against Interconnection Resource Loss Protection Criteria (RLPC) (2805 MW for ERCOT)
- Avoid Under Frequency Load Shedding (UFLS) – First stage @59.3 Hz
- Minimum amount of RRS should prevent frequency from dropping below 59.4 Hz



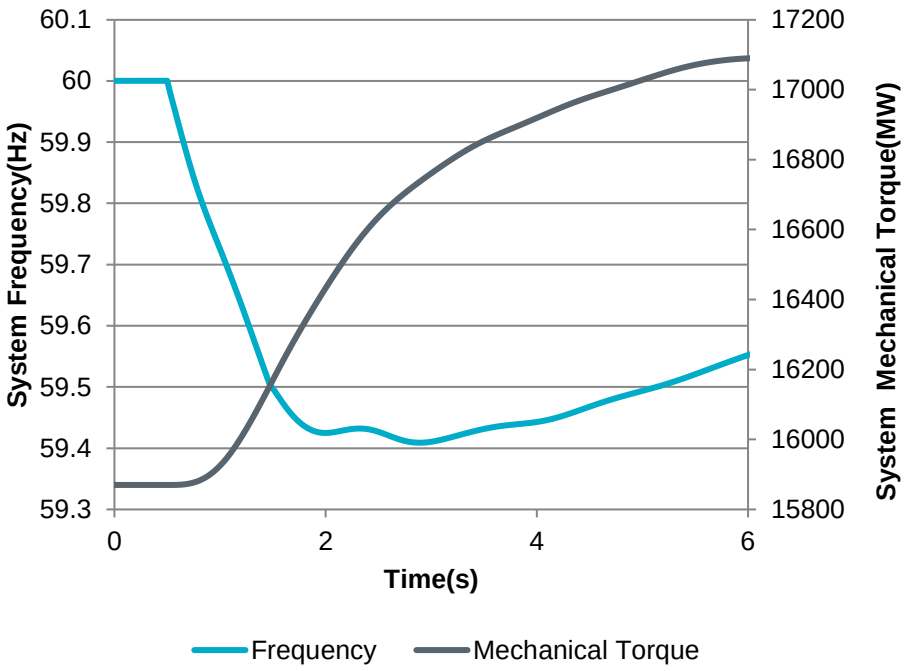
RRS Response Type

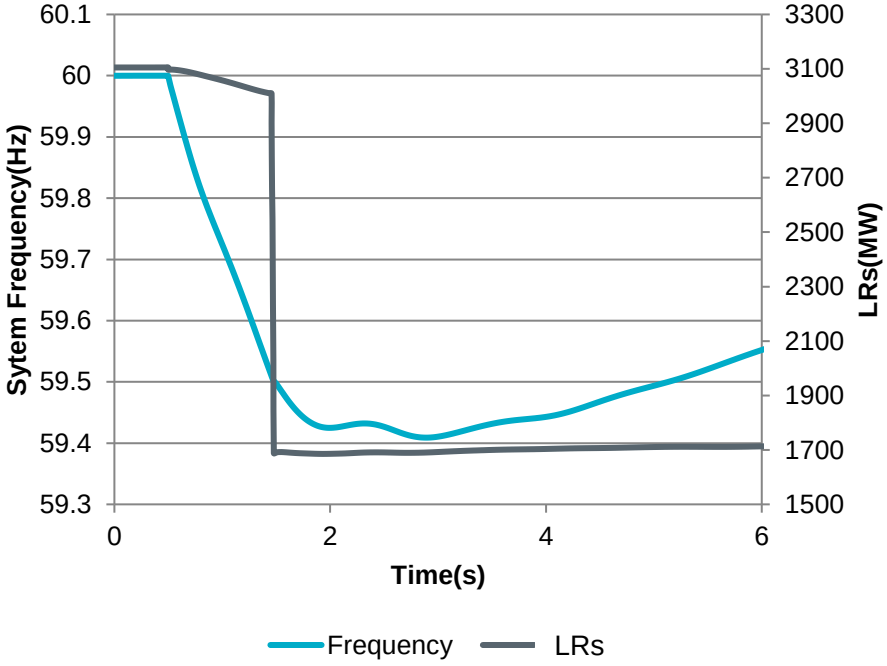
From Generators, ESRs and CLRs (PFR):

- Delivered within 12 to 16 seconds
- From governor response

From Load/ other resources (UFR, FFR):

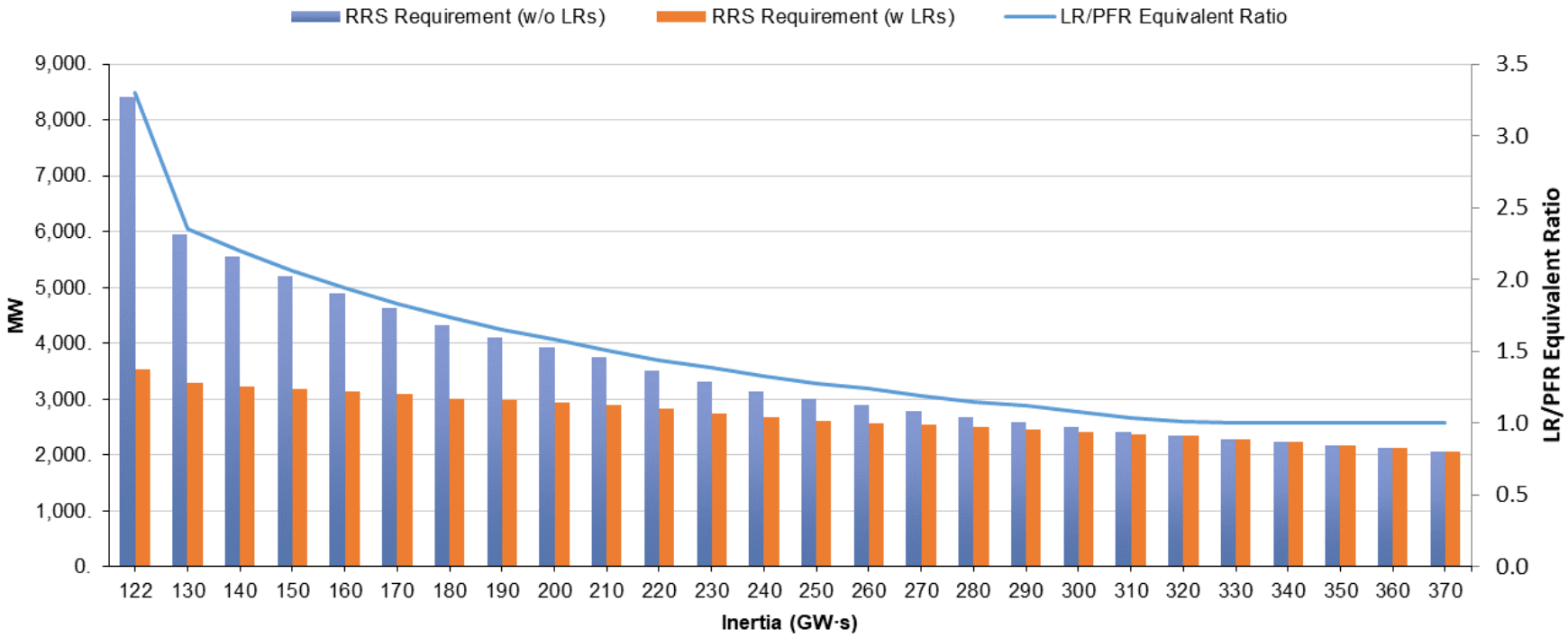
- Delivered within 30 cycles (0.5 seconds)
- Triggered by under frequency relay (59.7Hz)
- * Fast Frequency Response (FFR @59.85 Hz within 15 cycles)





UFR: Under Frequency Relay, **CLR**: Controllable Load Resources,
PFR: Primary Frequency Response, **FFR**: Fast-Frequency Response,
LR: Load Resource

RRS Need vs. Inertia



Low Load; High Wind — System Conditions — **High Load; Low Wind**

Low Inertia — **High Inertia**

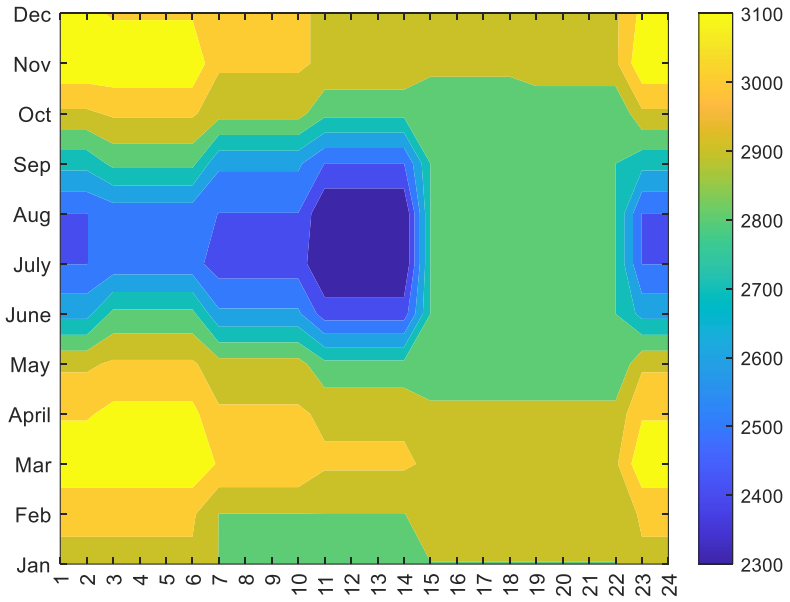
Reference: Li, Weifeng, Pengwei Du, and Ning Lu. "Design of a new primary frequency control market for hosting frequency response reserve offers from both generators and loads." *IEEE Transactions on Smart Grid* 9, no. 5 (2017): 4883-4892.

RRS Requirement (w LRs) assumes a minimum of 1390 MW of RRS-PFR (governor type response)

Responsive Reserve Service (RRS)

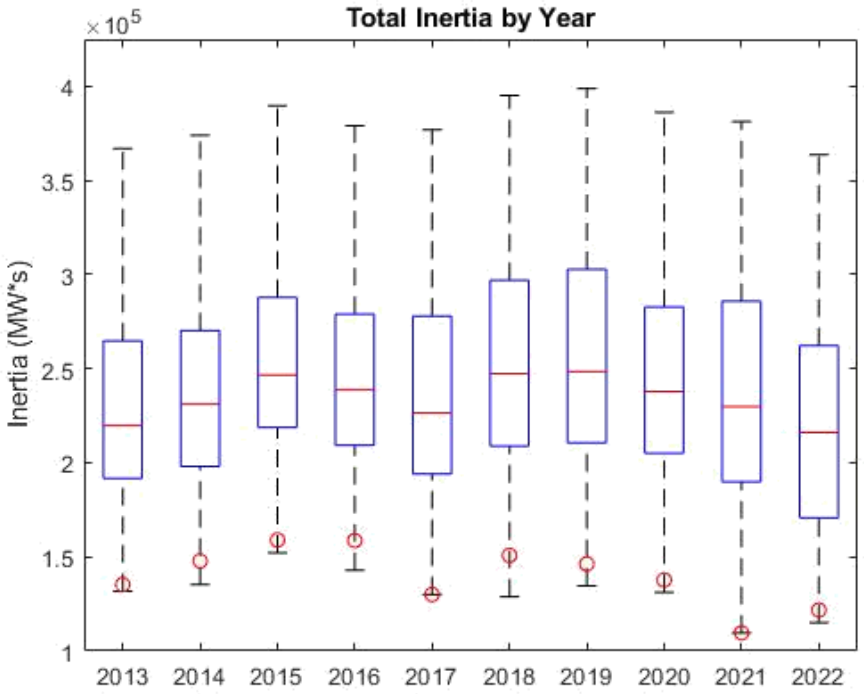
- Responsive Reserves are procured to ensure sufficient capacity is available to respond to frequency excursions during unit trips.
  - This reserve is designed such that under frequency load shed (UFLS) is not triggered for a generation trip that is equal to ERCOT's Resource Contingency Criteria (~2,805 MW) (as established by BAL-003).
  - This is calculated based on 30th percentile of historical inertia conditions from past 2 years.

- Hourly average quantities: 2864 MW for RRS in 2022



RRS Requirement in 2022

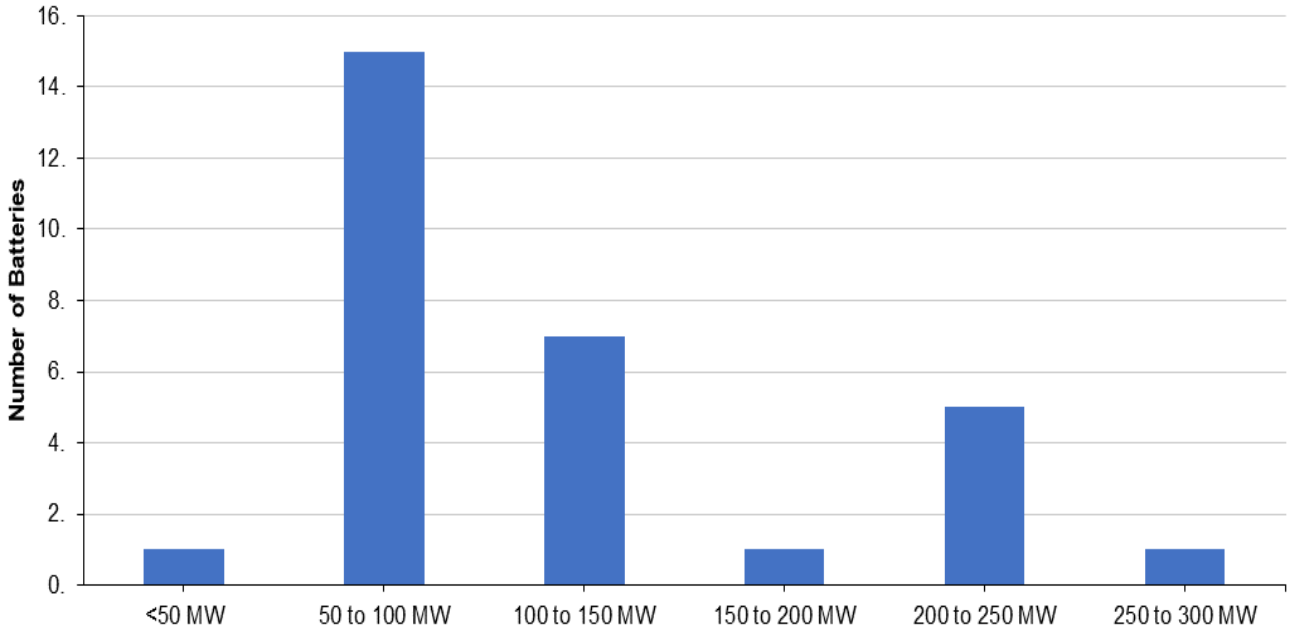
ERCOT Inertia 2013-2022*



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
Min synch. Inertia (GW*s)	132	135	152	143	130	128.8	134.5	131.1	116.6	115.0
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
Non-synch. Gen. in % of System Load	31	34	42	47	54	53	50	57	66	65

ERCOT ESR OVERVIEW

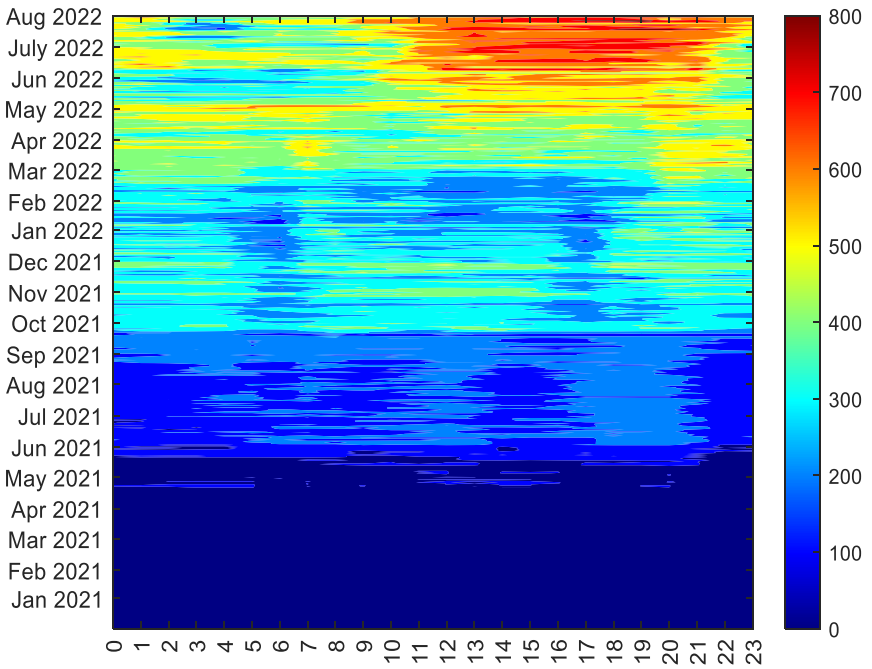
- ERCOT is modifying its systems to help address the grid's changing resource mix, including energy storage technologies.
  - The changes will allow these emerging technologies to expand their participation in ERCOT's wholesale electricity markets.
- Most of ESRs have an energy duration less than 2 hours and the size of ESRs can be over 200 MW.



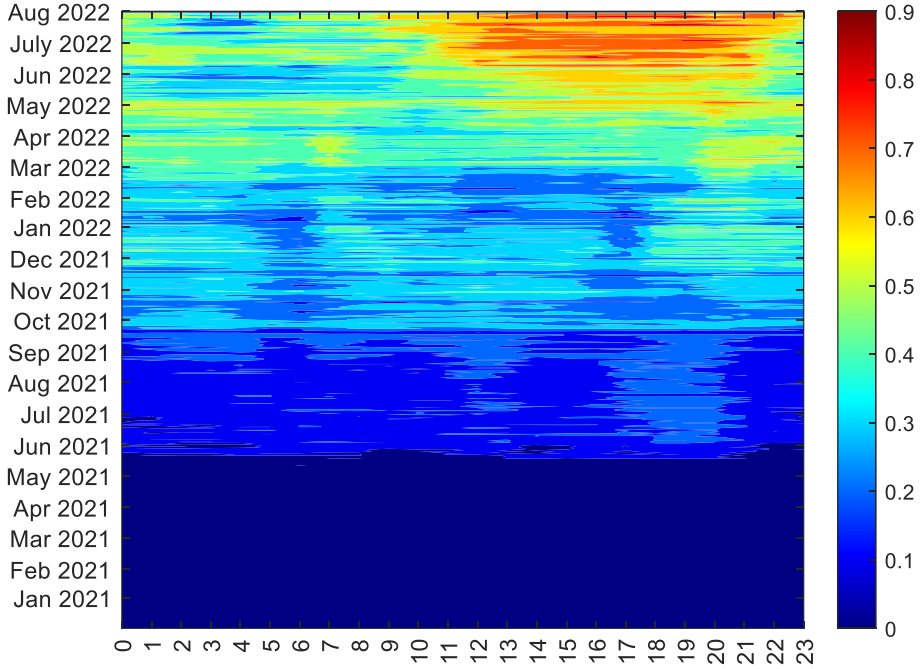
Size of New Batteries

RRS-PFR from Energy Storage Resources (ESRs)

- ESRs are providing larger volumes of RRS-PFR in 2022 as their volume continues to increase.
  - ERCOT has modified its tools that measure performance of ESRs during Frequency Measurable Events (FMEs) beginning April 2022. Since then, ERCOT has been closely working with Resources that have not met the performance criteria.



MW
Max: 878 MW
Avg: 269 MW

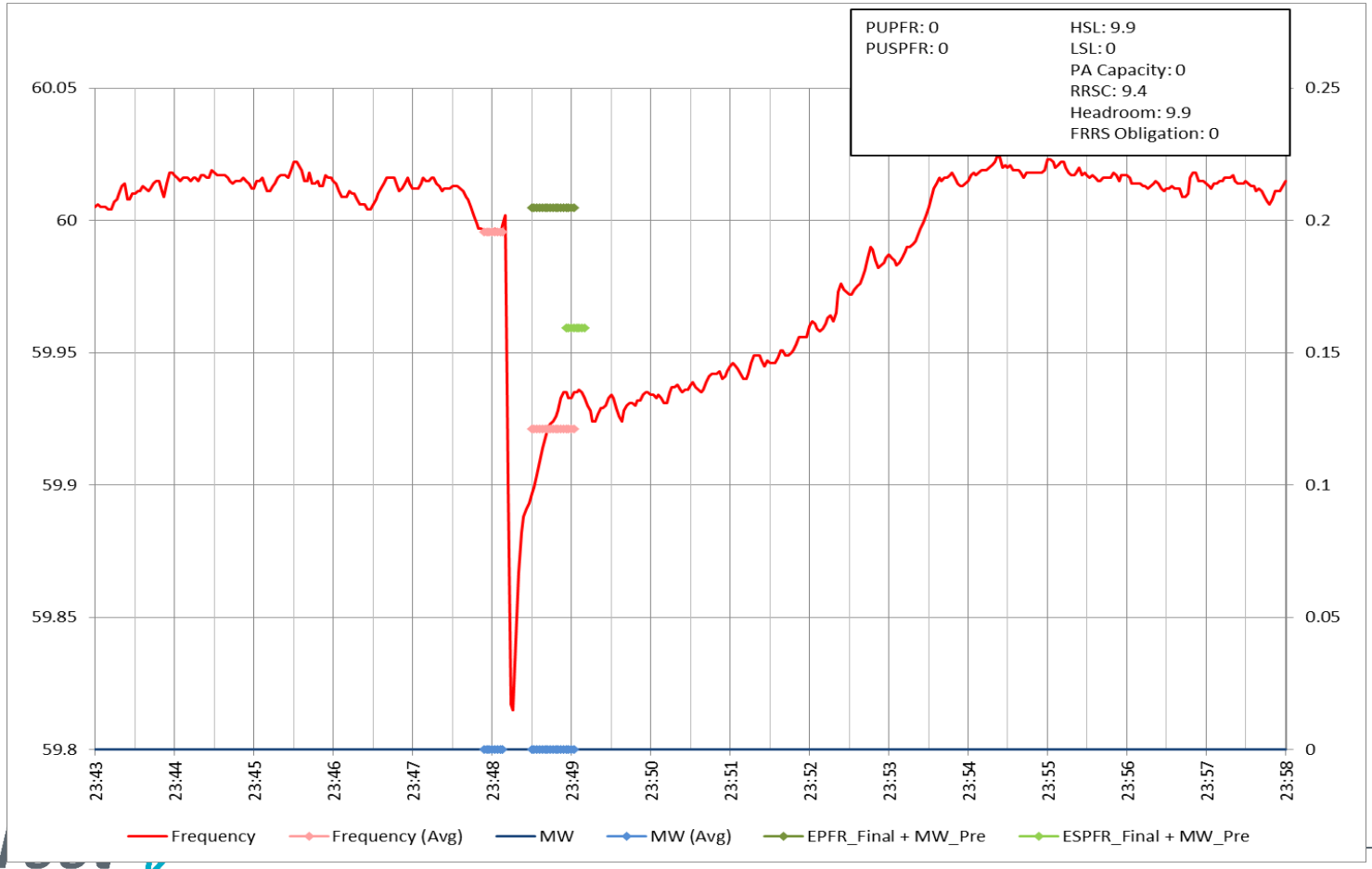


Percentage*
Max: 92%
Avg: 26%

*RRS-PFR from ESRs as a percentage of total RRS-PFR from CLRs, Gas, Coal and ESRs.

Failure of Response

Various reasons have contributed to the failure of ESRs in delivering RRS response when needed: incorrect logic implementation, insufficient headroom for RRS responsibility, wrong telemetry data.



Recent Trend in Type of Resources Providing RRS

- ERCOT rules allow non-thermal resources like ESRs (which may have a 1% or lower governor droop setting) to provide up to 100% of their capability as RRS-PFR.
- Some of ESRs have failed to deliver the required RRS response when needed as observed from their field performance.
- As more ESRs are in operations, ESRs provide a large amount of RRS-PFR responsibility.
- **As installed capacities of these types of resources grow, there is a concern that the inherent diversity in the fleet of resources providing RRS-PFR may diminish and potentially too much RRS-PFR may be carried by a single resource/facility.**

Objectives of Work and Progress

- Objectives: Investigate whether there is a reliability reason to establish one or more types of limits on Resources providing RRS-PFR limit per Resource, group, and/or at system level for different technologies or the limit on the number of Resources providing RRS-PFR

- Timeline
  - The project was kicked off on Dec. 14, 2021 and planned to be completed later this year
  - The GE project team presented the proposed work at Feb 2022 PDCWG and provided the responses to the comments received.

- The end results are to determine whether there is a reliability reason to establish one or more types of limits on resource providing RRS-PFR
  - whether such limits will be established per Resource, resource group, or at system level
  - whether such limits will be tied to specific technologies or fuel types
  - whether such limits will be related to specific operation conditions

ERCOT BESS PFR evaluation methodology

INPUTS

SYSTEM CONSIDERATIONS

- Resource response: PFR, FFR, UFR
- PFR participation: SMs, BESS, no RE
- $PFR_{total} = PFR_{mkt} + PFR_{non\text{-}mkt}$

COMPLIANCE RISK

1. **Frequency compliance:** FRO met, nadir>UFLS

RELIABILITY RISKS

2. **Voltage:** collapse
3. **Freq stability:** settling, overshoot, backlash
4. **Small signal:** locational or regional oscillations
5. **Controls** instability: interactions, dysfunction
6. **Transient** instability
7. **Common mode** failure

iterate

EVALUATIONS

BESS EVALUATIONS

1. **Scenarios:** locations , rating of BESS
2. **Disturbances**: faults, trips, size, location
3. **Sensitivity tests:** droop, SM governor on/off, …
4. **Risk assessment:** FR compliance; unintended consequences

RECOMMENDATIONS

CONSTRAINTS

- Location
- Amount
- Mix (SM, BESS)
- Size
- Count
- Rating
- Controls
- Headroom
- Inertia

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Baseline case – No BESS

Case: No BESS, Disturbance triggers UFR (NERC Event – 2.8GW generation trip

FR = Δ P / Δ F = 1519 MW / 0.27 Hz = **569 MW/ 0.1Hz > FRO**

Δ F = 60Hz – $F_{settling}$ = 60 – 59.73 = **267 mHz < MDF**

Δ P = Δ $P_{SM, Mech}$ = **1519 MW**

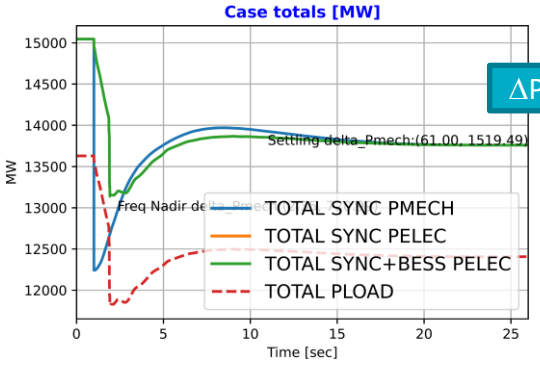
Δ $P_{SM, Mech}$ = $P_{SM, mech, settling}$ - $P_{SM, mech, min}$ = **1519 MW**

Frequency vs time

1150MW UFR triggered at 59.7Hz

ERCOT practice of maintaining 100mHz margin above UFLS threshold of 59.3Hz

SM Power vs time

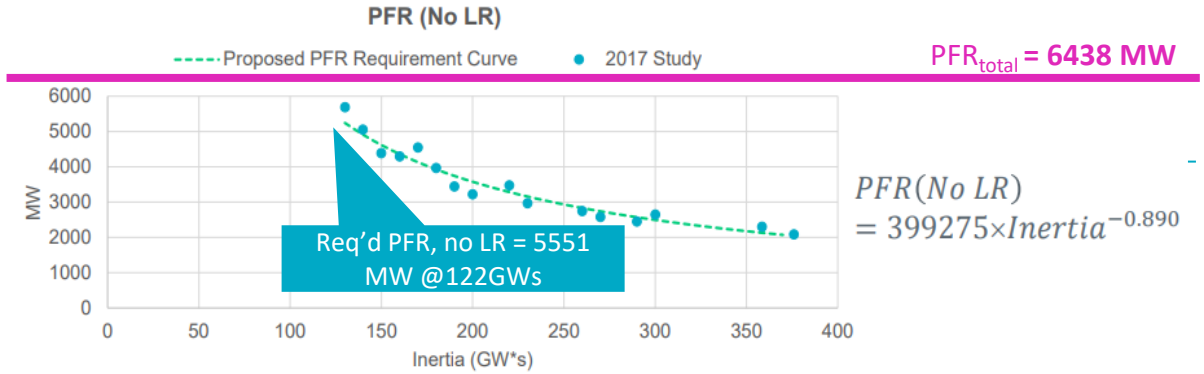


$\Delta P_{SM,Mech}$=1519MW

How much PFR_{BESS} reliably displaces PFR_{SM} + LR?

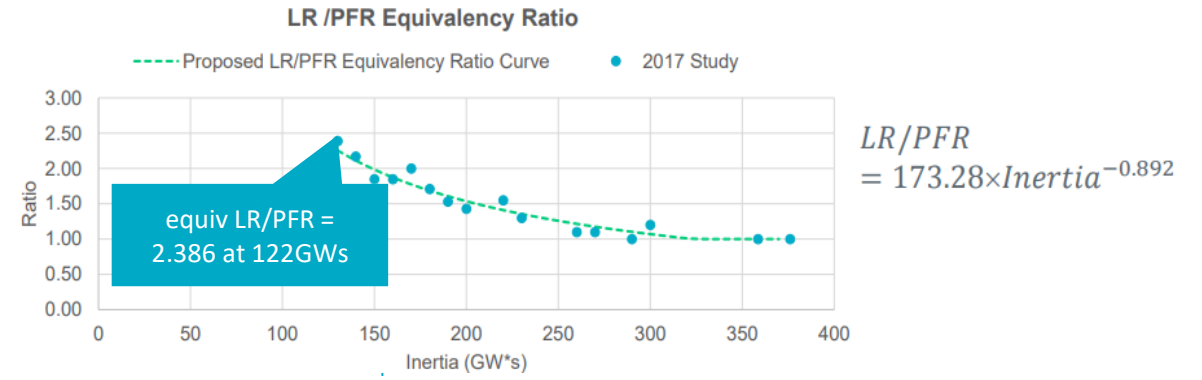
*Displacement cases in context of RRS req'ts (w/ 122 GW*s inertia)*

RRS Requirements and Equivalency Ratio



PFR_{total} = **6438 MW**

$$PFR(No\ LR) = 399275 \times Inertia^{-0.890}$$



$$LR/PFR = 173.28 \times Inertia^{-0.892}$$

NO BESS (BASE CASE)

1150MW LR => **LR equiv PFR = 2744 MW**
+ 3695 MW PFR_{SM}
= **total of 6438 MW** equiv PFR.

The base case is a good representation of ERCOT practice and **well suited as a starting point** for our investigation

ALL DISPLACEMENT SCENARIOS

PFR_{BESS} displaces PFR_{SM} 1:1 by turning off governors in our model

	LR equiv	+ BESS rating	+ Available PFR_{SM}	= Available PFR_{total}
0	2744 MW	0 MW	3695 MW	6438 MW
1	2744	700	2995	6438
2	2744	1400	2295	6438
3	2744	2800	891	6435

Govs turned off

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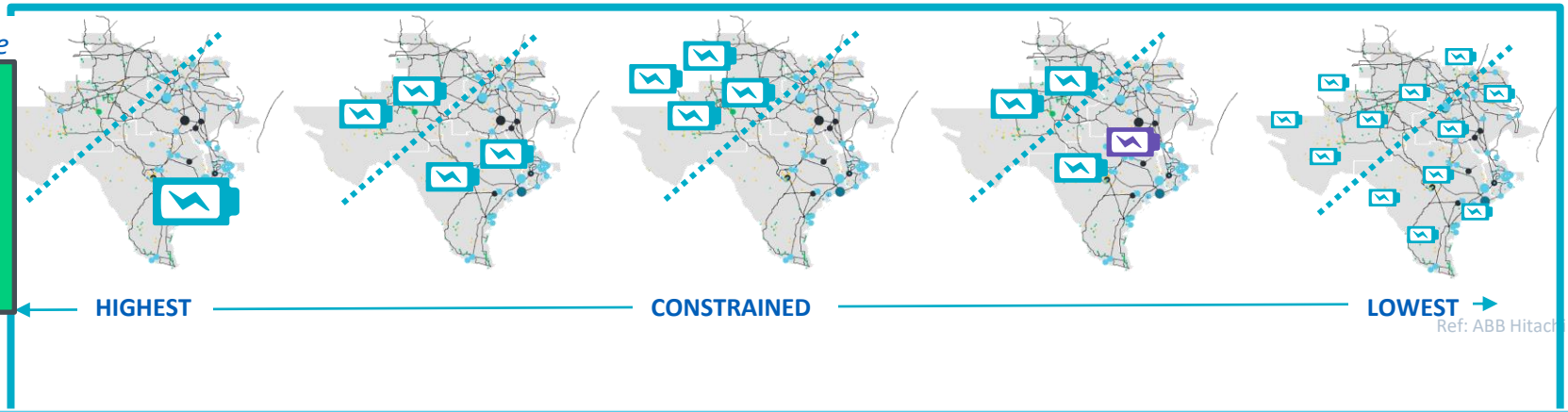
- Before summer 2015, ERCOT used to procure 2,800 MW of RRS for every hour of the year.
- Criteria: At each inertia level, RRS amount should be sufficient to avoid UFLS after 2,750 MW generation trip.

Scenarios: Methodology to assess BESS PFR risks

FOCUS is on the ***systemic behavior***. Looking for insights on overall frequency performance as BESS displaces PFR from "conventional" synchronous machines.

Prioritize

- Rating
- BESS Headroom
- Droop
- PFR displacement



Ref: ABB Hitachi

RISK	5 SCENARIOS (LOAD FLOWS)				
	1: One big BESS	**2: Dumbbell** *4 BESS: 2 Odessa, 2 coast*	**3: West BESS** *4 BESS close proximity … weakest zone*	**4: Granularity test** *2x+1x – 25%FO*	**5: Distributed BESS** *Use queue distribution*
1. Freq **compliance**	**X**	**X**	**X**	**X**	**X**
2. Voltage collapse	X	X	**X**	X	X
3. Freq instability	X	**X**	X	X	X
4. **Interactions**		**X**	**X**		**X**
5. **Dysfunction**		X	X	**X**	X
6. **Transient** stability	X	X	**X**		X
7. **Common mode**	X	X		**X**	**X**

Key Takeaways

- ERCOT is an islanded electrical grid in North America with a high penetration of utility scale wind and solar resources.
  - ERCOT's system inertia is trending downward.
  - As the volume of ESRs increases, ESRs have provided a large share of RRS-PFR responsibility.
  - ESRs, if set at a 1% or lower governor droop setting, can provide up to 100% of their capability as RRS-PFR. This leads to a concern that the inherent diversity in the fleet of resources providing RRS-PFR may diminish and potentially too much RRS-PFR may be carried by a single resource/facility.
  - ERCOT is working with GE team to investigate whether there is a reliability reason to establish one or more types of limits on Resources providing RRS-PFR limit per Resource, group, and/or at system level for different technologies or the limit on the number of Resources providing RRS-PFR.

Questions?

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