Elements of Market Design that Support High Renewable Penetration

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ERCOT, Quick Facts, 2019

- Peak Demand Record: 74,820 MW (Aug. 12, 2019)

- Installed Wind Capacity 23,860 MW

- Installed Solar Capacity 2,2881 MW

- Wind Generation Record: (instantaneous)

  - Output: 20,066 MW Jan. 8, 2020
  - Penetration (load served): 57.88% Nov. 26, 2019
    Total MW served by wind = 18,084 MW

47% Natural Gas	20% Wind	20% Coal		

2019 Energy Use

11% Nuclear
2% Other*
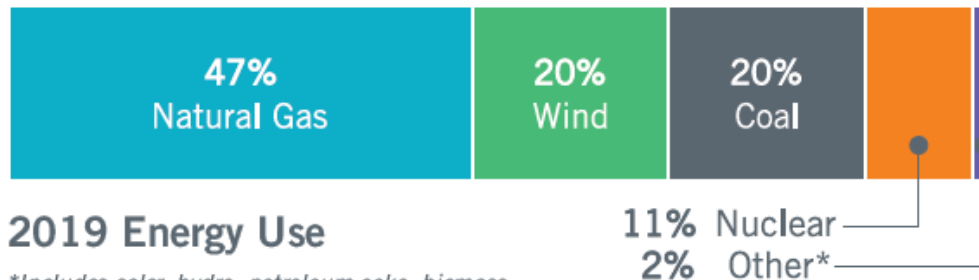
*Includes solar, hydro, petroleum coke, biomass, landfill gas, distillate fuel oil, net DC-tie and Block Load Transfer imports/exports and an adjustment for wholesale storage load

384 billion kilowatt-hours of energy were used in 2019, a 2 percent increase compared to 2018.
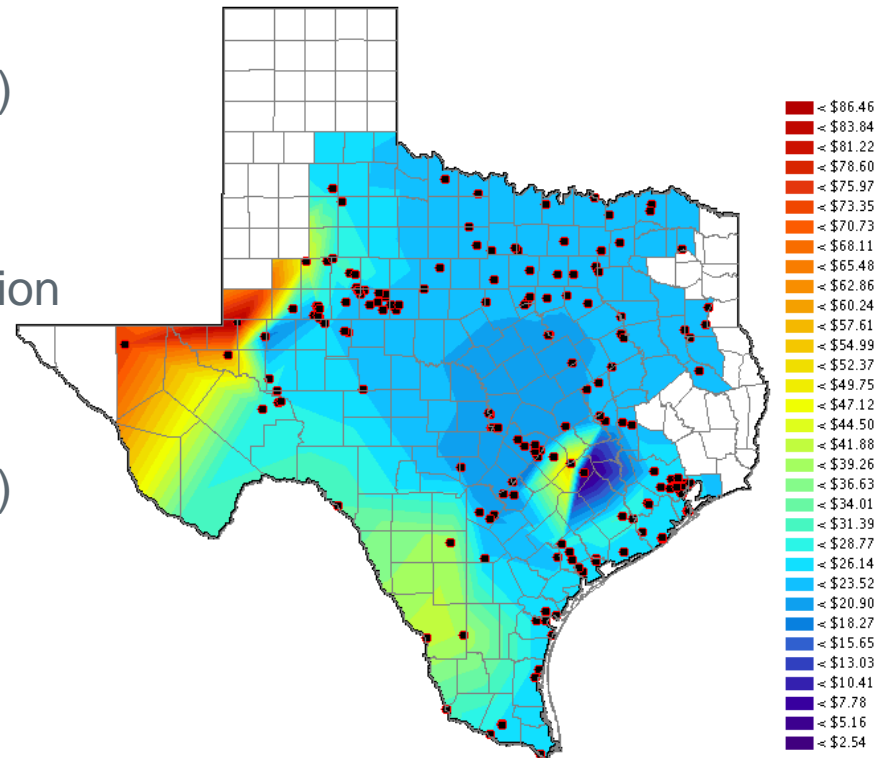
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Elements of Market Design that Supports High Renewable Penetration

- Reduced Uncertainty of Power Output

  - Granular Real-Time dispatch

  - Improved Forecasting

  - Dispatch of Wind and Solar Resources

- Scarcity Pricing and Power Balance Penalty Curve (incentivizes flexible generation)

- Changes to AS products and AS methodology

![ercot logo]

Nodal Energy Market, 5-min Real Time Dispatch

- Generator self-commitment; ERCOT makes residual reliability commitments

- Voluntary Day-Ahead Market (DAM); Ancillary Services are procured in DAM, co-optimized with energy

- <u>All</u> 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
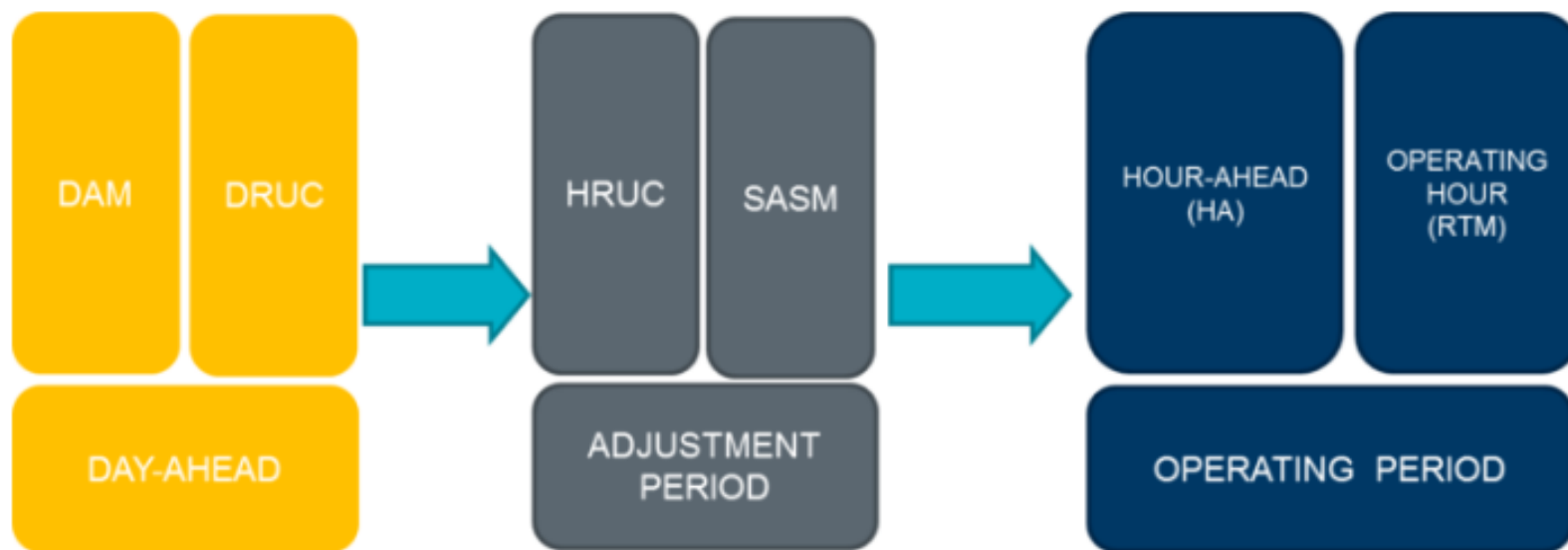
Use Wind and Solar Forecasting

1-HOUR AHEAD WIND FORECAST PERFORMANCE

MAPE = MEAN ABSOLUTE %ERROR
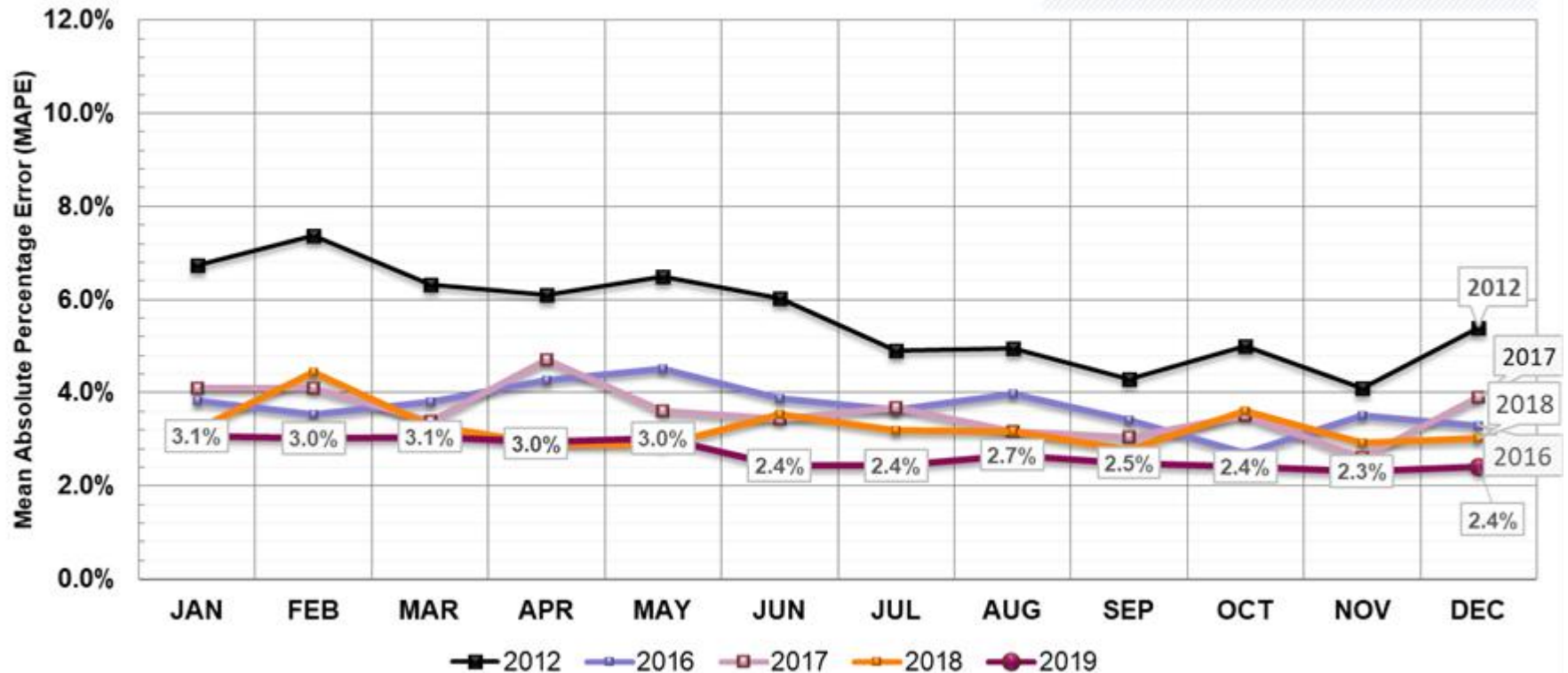
- Currently, ERCOT uses a 168-hour rolling forecast with hourly resolution for all wind/solar resources.

- Average hour ahead wind forecast error is 2.69% in 2019

Overview of ERCOT Market Processes

Dispatchability of Wind and Solar Resources

- Wind and Solar Resources are dispatched at their available production level, unless curtailment is needed due to transmission constraints or overproduction

- Deviation from the Dispatch Base Point only panelized during curtailment instructions, higher threshold is used than for thermal generation (10% vs 5%)
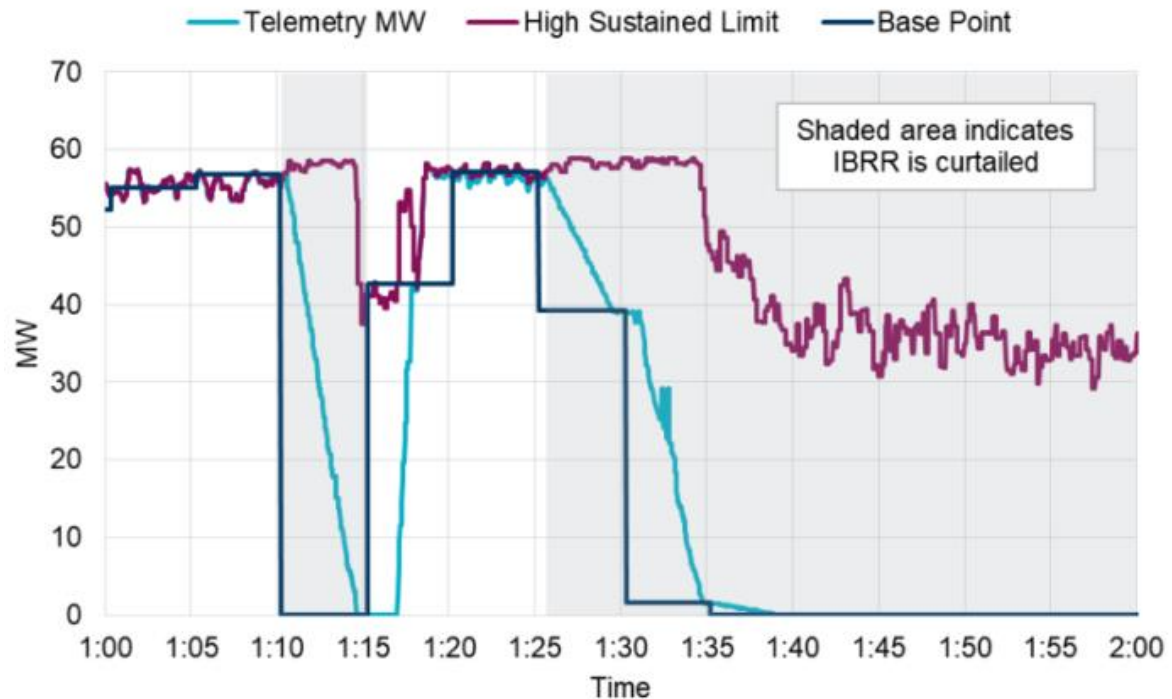
Power Balance Penalty Curve

- Power Balance Penalty Curve Creates a penalty price for excess/shortage of capacity and/or ramping capability in real time.

- The five-minute of up-ramping shortages or under generation in real-time are priced as high as $9,000/MWh and over-generation is priced as low as -$250/MWh.

SCED Under-generation Power Balance Penalty Curve

- Combination of scarcity pricing and PBPC creates opportunities for resources that can respond to real-time shortages of ramping flexibility and/or capacity by starting within five to 10 minutes.
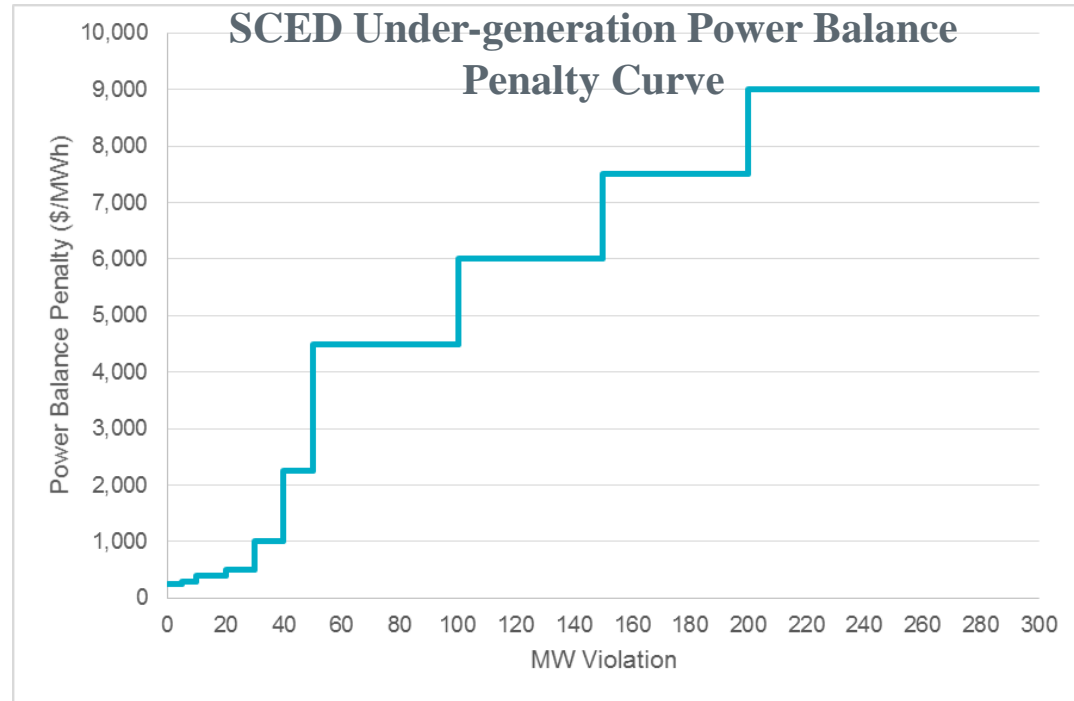
Installed Capacity of Fast Starting Gas Units
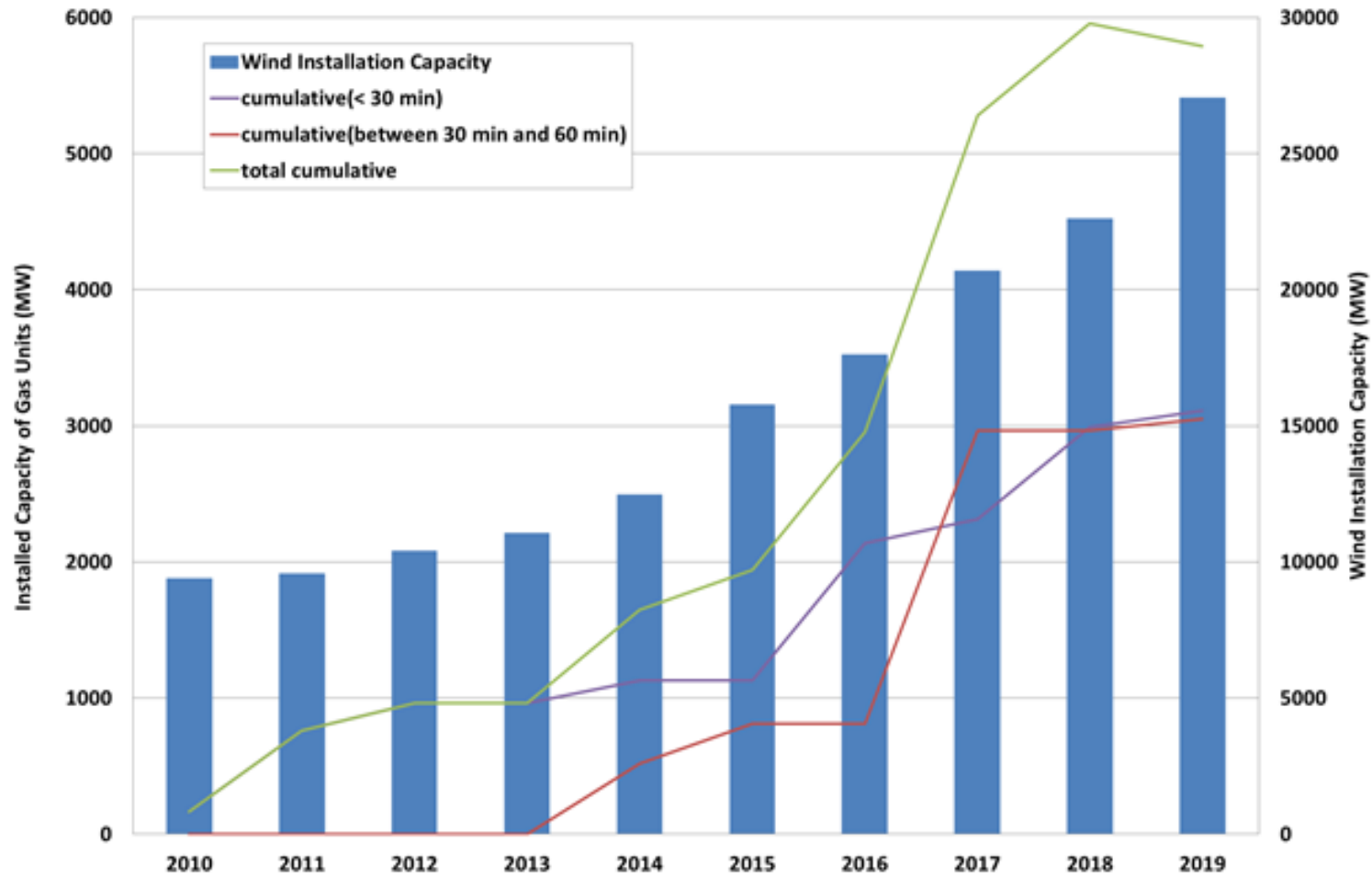
Revision to the AS Product Set
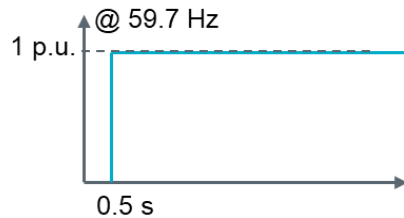
Previous AS Framework

Regulation
*157 to 687 MW**

Responsive Reserve Service

1. PFR
2. Load Resources on Under Frequency Relay (UFR)
3. 10 minute ramp

*2,300 to 3,200 MW**

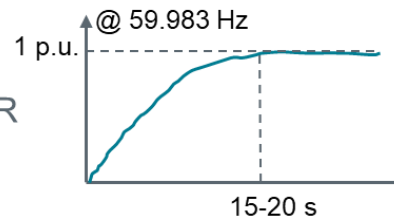@ 59.7 Hz

1 p.u.

0.5 s

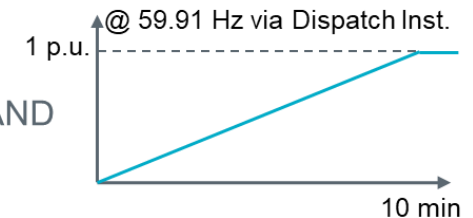Load Resources w. UFR

OR

@ 59.983 Hz

1 p.u.

15-20 s

PFR

AND

@ 59.91 Hz via Dispatch Inst.

1 p.u.

10 min

10-min ramp

Non-Spin (30 min)
*967 to 2,361 MW**

*Overall A/S: 3,807 to 5,958 MW**

Revision to the AS Product Set

New Framework, NPRR 863

Regulation
*157 to 687 MW**

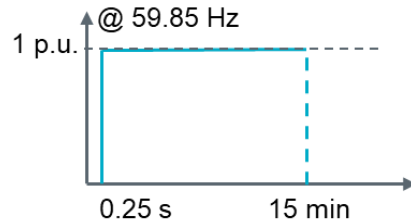| Responsive Reserve Service (RRS) |
|:---:|
| Fast Frequency Response (FFR) |
| Load Resources on UFR |
| Primary Frequency Response (PFR) |
| *2,300 to 3,200 MW** |

ERCOT Contingency Reserve Service (ECRS)
10 minute ramp
Load Resources may or may not be on UFR
*508 to 1,644 MW***

Non-Spin
*0 to 1,180 MW****

NEW

@ 59.85 Hz
1 p.u.
0.25 s   15 min
FFR

OR

Unchanged

@ 59.7 Hz
1 p.u.
0.5 s   1 hour
Load Resources w. UFR
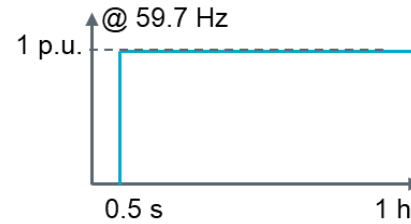
OR

Perf.-based award limits

@ 59.983 Hz
1 p.u.
15-20 s
PFR

NEW
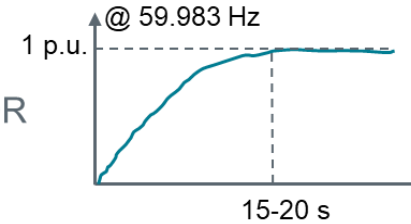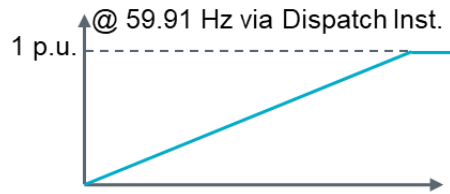
@ 59.91 Hz via Dispatch Inst.
1 p.u.
10 min
10-min ramp

*Overall A/S: 3,807 to 5,958 MW**

FFR implemented on 3/1/2020 and ECRS will be implemented in 01/2022

Summary of Elements of Market Design that Support High Renewable Penetration in ERCOT

- Re-dispatching every five minutes to reduce uncertainty associated with wind and solar

- SCED base points being effective immediately (reduces uncertainty),

- Using power balance penalty curve, incentivizes flexibility with high penalty price for lack of ramping capability.

- Continually assessing sufficiency of committed resources in meeting demand using forecasted output of wind and solar,

- Dispatching wind and solar in real-time while taking transmission security into account.

- Redesigning Ancillary Services to better fit changing system needs and allowing new technologies with needed capabilities to participate

- Additionally, ERCOT is currently working on enhancing its market design so that in real-time both energy and ancillary services can be co-optimized every five minutes using the ancillary service demand curves.

Thank you! Questions?

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Revision to the AS Product Set

FFR implemented in March 1, 2020

ECRS will be implemented in January 2022

Previous Framework

Regulation

*157 to 687 MW**

Responsive Reserve Service

1. PFR
2. Load Resources on Under Frequency Relay (UFR)
3. 10 minute ramp

*2,300 to 3,200 MW**

Non-Spin

*967 to 2,361 MW**

*Overall A/S: 3,807 to 5,958 MW**

New Framework, NPRR 863

Regulation

*157 to 687 MW**

No Change

Responsive Reserve Service (RRS)

Fast Frequency Response (FFR)

Load Resources on UFR

Primary Frequency Response (PFR)

*2,300 to 3,200 MW**

FFR
- Triggered at 59.85 Hz and full response in 15 cycles
- Once deployed, sustain for up to 15 mins. Once recalled, restore within 15 mins

PFR
- PFR capable capacity reserved on generators or Controllable Load Resources (CLR)
- Minimum 1,150 MW must be provided by resources capable of PFR

Load Resources on UFR
- Triggered at 59.70 Hz and full response in 30 cycles
- Sustain until recalled. Once recalled, restore within 3 hours
- Beyond the minimum PFR, up to 60% of total RRS can come from Load Resources on UFR or FFR.

ERCOT Contingency Reserve Service (ECRS)

10 minute ramp

Load Resources may or may not be on UFR

*508 to 1,644 MW***

Generation
- Online or offline capacity that can be converted to energy within 10 minutes
- Dispatched by SCED

Load Resources (UFR not required)
- Up to 50% of ECRS capacity can come from Load Resources with or without UFR
- Once deployed, must respond within 10 minutes. Restoration within 3 hours

Non-Spin

*0 to 1,180 MW****

No protocol changes.
- Proposed methodology for Non-Spin Reserve Service quantities in this framework - quantities computed using 2018 A/S Methodology are reduced by ECRS quantities.

*Overall A/S: 3,807 to 5,958 MW**

*Quantities computed/estimated using 2018 Ancillary Service Methodology. **Quantities estimated using this reference. ***Quantities estimated using this reference and method in box on far left.
For Discussion Purposes Only. The intent of this slide is to represent NPRR 863 (with STEC comments from 10/1/2018). Protocol language prevails to the extent of any inconsistency with this one page summary.

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