Overview of Renewables in the ERCOT System

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Outline

• ERCOT Overview

• Current Status of Wind, Solar and Storage

• Variable Renewable Energy Resources Integration Timeline

• Key Success Factors
The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 74,666 MW* peak, August 12, 2019
- More than 46,500 miles of transmission lines
- 650+ generation units (excluding PUNs)

*preliminary operating data

**ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over flow of electricity**
Inverter-Based Resources in ERCOT, as of September 2019

Wind Generation Records (instantaneous)
- Output: 19,672 MW
  - Jan. 21, 2019, 7:19 p.m.
- Penetration (load served): 56.16%
  - January 19, 2019, 3:10 a.m.
  - Total MW Served by Wind = 17,406 MW
VRE Integration Timeline

~1998: Load Resources, with UFR participating in RRS

All Generation Resources have PFR enabled

Transmission expansion to RE zones

Steady increase in CC and CT Capacity

5-min Real Time Market

VRE Forecasts

PFR from VRE

VRT

AS Changes

WSCR Limit

Inertia monitoring

Voltage Support
ERCOT Installed Capacity; Increasing Fleet Flexibility

Wind and solar values are based on nameplate capacity (not adjusted for peak capacity contribution)
• As of Jan. 30, 2014, the CREZ transmission projects were complete.
• The transmission plan is designed to serve approximately 18.5 GW:
  – ~3,600 right-of-way miles of 345-kV
  – $6.9 billion project cost
• Lines are open-access; use not limited to wind

**Far West Texas projects (non-CREZ)**
• Endorsed by ERCOT Board June 2017 and June 2018
• Reliability projects to serve growing oil field load
• Expected in-service date of 2020
Wind Forecasting, 2009 - Present

1. Wind plants send site location, status, derate, and telemetered meterologic data to ERCOT
2. ERCOT sends information from wind plants to AWS Truepower
3. AWS Truepower computes and sends ERCOT a rolling 168-hour generation forecast for all wind plants
4. ERCOT uses 168-hour forecast to make operational decisions including unit commitment and dispatch

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

- Generator self-commitment; ERCOT makes residual reliability commitments
- Voluntary Day-Ahead Market (DAM); Ancillary Services are procured in DAM, co-optimized with energy
- 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
Primary Frequency 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
Reliability Risk Desk, Situational Awareness

Inertia Summary

- 120 GWs >= Inertia: Normal
- 120 GWs > Inertia >= 110 GWs: Yellow
- 110 GWs > Inertia >= 100 GWs: Orange
- 100 GWs < Inertia: Red

Critical Inertia alerts

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

Inertia Monitoring and Forecasting

- Actual PFR needed
- Actual PFR (based on PRC)
- Shortfall in Procured RRS but adequate PRC
- Actual RRS available
- Actual RRS needed
- Shortfall in RRS available

Reserve Sufficiency Monitoring

Overall Capacity Availability Tool
ERCOT's Resource Contingency Criteria is 2750 MW;
Load Resources with underfrequency relays provide a portion of frequency containment reserve (at 59.7 Hz, full response in 0.5 s)

By 2018 over 300 LRs, ~4200 MW;
Participation rates are 1600-1700 MW of offers and about 1400 MW of awards in every hour

Single site loads (no aggregation), 100-250 MW:
- Chemical plants each site >150 MW
- Air separation plants that extract industrial gasses, each site ≤ 100 MW
- Natural gas compression sites, part of pipeline operation
- Oil field loads (from few kW to tens of MW),
- Industrial process loads (i.e. cement plants, manufacturing plants),
- Very few large commercial sites, mainly data centers.
Weak Grid Issues and WSCR/Voltage Satiability limit calculation in near Real-Time, 2016

Weak Grid Challenge:
- ~ 4 GW in service, ~1.6 GW planned
- No local load or synchronous generators
- System Strength/Voltage support issues

Real Time Limit Assessment (every 10-minutes)
- WSCR assessment based on actual grid and wind conditions
- Voltage Stability assessment
- Panhandle Transmission Interface Limit determined by the more conservative of the two assessments
Revision to the AS Product Set Approved

Current target for FFR implementation is March 1, 2020
ECRS will be implemented no earlier than January 2022

Current 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*

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
967 to 2,361 MW*

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

NPRR 863

Regulation
157 to 687 MW

Responsive Reserve Service (RRS)
- 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
- 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***

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.
Key Success Factors

- Granular real-time dispatch and accurate forecasting is key;
- Primary Frequency Response Capability enabled on all online resources provides valuable safety net for the system;
- Real-time awareness tools in the control room are essential for efficient and reliable operations with high levels of renewable resources;
- Real-time limit calculation based on actual system and resource conditions;
- Ancillary Services can satisfy essential reliability needs for the system
  - Use market-based solutions as much as possible
  - Design products to attract load participation along side generation
- Some of the reliability requirements need to be implemented through grid codes. Modern renewable generation technology can provide grid support.

*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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• Generation Resources greater than 20 MVA shall operate with AVR in voltage control mode to maintain voltage set point at the point of interconnection;

• Reactive power capability of 0.95 lead/lag (at $P_{\text{max}}$) is required at all MW output levels $\geq$10% of the Renewable Resource nameplate capacity;

• The requirement may be met through a combination of the Resource’s VAr capability and/or dynamic VAr capable devices.
Low and High Voltage Ride Through, 2014

- No Tripping, No Ceasing to Inject:
  - Remain interconnected to the grid
  - Provide support to recover the voltage

HVRT:
- Maintain active power
- Absorb reactive power

LVRT:
- May temporary reduce active power to increase reactive power support
- Recover active power shortly after fault is cleared