Demonstration of PFR Improvement
September 2017

ERCOT
Operations Planning
Agenda

- Overview
- BAL-001-TRE-1 Standard
- Applicability to Alternative Resources
- Ancillary Service Products & Dispatch
- Improvements & Changes
  - Frequency Profile Comparison
- Lessons Learned
- Questions
Overview

• ERCOT has implemented NERC Regional Standard BAL-001-TRE-1
  – Effective April 1st, 2015
  – Implemented governor dead-band and droop setting requirements for Generation Resources (GRs)
  – Implemented enforcement mechanisms for evaluating quality of Primary Frequency Response (PFR) from GRs

• Fast Responding Regulation Service (FRRS) being provided from storage resources (i.e. batteries).

• Improvements made to Generation to be Dispatched (GTBD) (load balance equation) and Regulation Deployment (LFC).
• Requirements of Note
  – 1: Identify Frequency Events as Frequency Measurable Events (FMEs)
  – 2 & 3: Calculate Initial & Sustained PFR for each FME and include into a Rolling Average for each GR of each GO
  – 6: Generation Resource governor dead-band and droop setting requirements:

<table>
<thead>
<tr>
<th>Generator Type</th>
<th>Max. Deadband</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam and Hydro Turbines with Mechanical Governors</td>
<td>+/- 0.034 Hz</td>
</tr>
<tr>
<td>All Other Generating Units/Generating Facilities</td>
<td>+/- 0.017 Hz</td>
</tr>
</tbody>
</table>

Combined Cycle facilities get evaluated using a 5.78% droop setting to account for lack of PFR coming from Steam Turbine.
• Requirements of Note (cont’d.)
  – 7 & 8: Each GO must operate each GR with settings in R6 when it is online and available for dispatch, unless the GO has a valid reason not to. GO must inform ERCOT within 30mins if a governor is to be out of service.
  – 9 & 10: Each GO must maintain a 12-month rolling average PFR score of 0.75 (75%) or higher.
    • Opportunities for exemptions/re-evaluations
• Increases amount of governor action from GRs.
  – Improves frequency control performance (CPS1)
• Improves PFR during frequency events
  – Faster recovery times
  – Dampens initial excursion (governor dead-bands tighter)
  – Better Interconnection Combined Frequency Response Performance (R4 & R5)
• All GRs required to provide PFR with defined governor dead-band and droop settings.
  – Changed requirement from 36mHz to 17mHz on most GRs
  – Regardless if they are in Responsive Reserve (RRS) (contingency reserves) market
  – No current PFR market (no payment for providing PFR
Alternative Resources & PFR

• Storage Resources
  – Subject to BAL-001-TRE-1
  – Participate in FRRS market

• Wind & Solar Resources
  – Subject to BAL-001-TRE-1
  – Have required governor dead-band and droop settings.
    • Have had requirement since 2010. BAL-001-TRE-1 changed dead-band requirement from 36mHz to 17mHz.
  – All Resources only expected to provide PFR when they have enough headroom for low frequency events.
  – Wind & Solar typically dispatched to their Pmax (HSL), typically do not have headroom.
    • No headroom = not evaluated for PFR during FMEs.
  – PFR performance from Wind & Solar has thus far been satisfactory.
Alternative Resources & PFR

WIND RESOURCE RESPONSE TO LOW FREQUENCY 07/13/2016

WIND RESOURCE RESPONSE TO HIGH FREQUENCY 08/25/2015
Ancillary Service Products & Dispatch

- **Regulation (AGC)**
  - Annually/seasonally tune AGC parameters for regulation deployment.

- **FRRS**
  - Typically carried by storage resources (batteries.)
  - Deployed on a step scale based on frequency.
  - Maximum deployment time typically around 5-minutes.

- **Energy Dispatch**
  - Include ACE Integral in load balance equation
    - Dispatches energy to recent frequency trends
  - Include regulation deployment in load balance equation
    - Helps recover regulation deployment
Improvements & Changes
Frequency Profile Comparison, etc.

2008 - 2017
Comparing 2009 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2010 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2011 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2012 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2013 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2014 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2015 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2016 vs 2008 Frequency Profile in 5 mHz Bins
Comparing 2017 vs 2008 Frequency Profile in 5 mHz Bins
Rolling Average CPS1

Current 12-Month Rolling Average: 174.96%
Interconnection Minimum Frequency Response (IMFR) Performance

IMFR Rolling Average

IMFR Performance currently 793.85 MW/0.1 Hz
MW Loss vs. Frequency Recovery Time
Percent Beyond Dead-band – 17mHz

Significant improvement after March 2015

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
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<tbody>
<tr>
<td>Jan</td>
<td>41.051%</td>
<td>48.102%</td>
<td>42.429%</td>
<td>31.995%</td>
</tr>
<tr>
<td>Feb</td>
<td>44.427%</td>
<td>50.586%</td>
<td>44.148%</td>
<td>33.458%</td>
</tr>
<tr>
<td>Mar</td>
<td>45.921%</td>
<td>52.290%</td>
<td>36.276%</td>
<td>33.128%</td>
</tr>
<tr>
<td>Apr</td>
<td>43.779%</td>
<td>52.026%</td>
<td>33.607%</td>
<td>33.334%</td>
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<tr>
<td>May</td>
<td>41.289%</td>
<td>51.019%</td>
<td>33.985%</td>
<td>32.685%</td>
</tr>
<tr>
<td>Jun</td>
<td>45.053%</td>
<td>44.369%</td>
<td>32.814%</td>
<td>29.301%</td>
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<tr>
<td>Jul</td>
<td>41.170%</td>
<td>45.723%</td>
<td>28.677%</td>
<td>27.393%</td>
</tr>
<tr>
<td>Aug</td>
<td>40.682%</td>
<td>42.703%</td>
<td>29.639%</td>
<td>24.815%</td>
</tr>
<tr>
<td>Sep</td>
<td>43.564%</td>
<td>47.292%</td>
<td>29.652%</td>
<td>27.573%</td>
</tr>
<tr>
<td>Oct</td>
<td>47.753%</td>
<td>43.855%</td>
<td>31.120%</td>
<td>-</td>
</tr>
<tr>
<td>Nov</td>
<td>46.212%</td>
<td>42.698%</td>
<td>29.067%</td>
<td>-</td>
</tr>
<tr>
<td>Dec</td>
<td>41.306%</td>
<td>46.615%</td>
<td>29.385%</td>
<td>-</td>
</tr>
</tbody>
</table>

*Any interval outside deadband is counted.
17 mHz Below & Above Deadband Comparison

17 mHz Percent Beyond Deadband (negative)

17 mHz Percent Beyond Deadband (positive)

Most improvement made above 60 Hz
Percent Beyond Dead-band – 34mHz

Significant improvement after March 2015

*Any interval outside deadband is counted.
34 mHz Below & Above Deadband Comparison

34 mHz Percent Beyond Deadband (negative)

34 mHz Percent Beyond Deadband (positive)
Daily RMS1 of ERCOT Frequency by Year
Daily RMS1 of ERCOT Frequency by Month
Daily RMS1 of ERCOT Frequency by Month
Improvements & Changes

• Improved CPS1 scores
• Improved frequency response during frequency events
  – Better IMFR performance
• Increased governor action
  – Can be burdensome on certain Generation Resources
• Distribution of frequency leans towards 60.017
  – More resources able to respond to frequency deviations of +0.017Hz (wind, base loaded resources, etc.)
Lessons Learned

- Requires a lot of coordination with GOs
- Data quality from GRs is very important
- Evaluation of PFR scores per GR can be a strenuous process
Questions?

Thank you!!
Appendix
Total Energy

MWh

January February March April May June July August September October November December

Total Energy from Wind Generation
% Energy from Wind Generation
Daily Minimum System Inertia

- Outlier
- Mean