Wind Integration in ERCOT

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Thoughts on ERCOT’s Wind Generation Experience

• More wind, more wind, more wind
• Better reliability metrics
• Reduced ancillary services requirements
Geography

Mexico

Panhandle

D

SA

H

Coast

Mexico
More wind producing more
2017 Unit Specific Wind Generation Capacity Factor

- Coastal
- Panhandle
- All Other Wind

Capacity Factor

InService Year

Improved Reliability Metrics

Current 12-Month Rolling Average: 176.90%
Declining Requirements for Ancillary Services
Key Enablers

• Common carrier model for Transmission
• Centralized forecasting of wind output
  – for every wind generator
  – ramp events
• Real-time output variations accommodated
ERCOT Transmission

- All loads pay for all transmission
- Generators are not required to make any transmission investment past their step-up transformer
- Public policy choice to build out transmission system in advance of need
  - CREZ investment - $7B
Transmission Costs

Average 4CP Load (GW)

Annual TCOS ($Billion)

Rate ($ per kW-year)

Indicative – Not Actual

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12
Transmission and Energy costs

Indicative Transmission Costs
Not Actual

$ per MWh


$ per MBtu

RT Load weighted Avg price  Average transmission cost  Gas
ERCOT Wind Forecasts

• Hourly forecast of wind production potential for each Wind-powered Generation Resource (WGR) updated hourly, for next 168 hours. (STWPF)

• Determine probability distribution of the hourly production potential from all wind-power in ERCOT for each of the next 168 hours. (TEWPF)

• WGR provide turbine availability via outage scheduler
ERCOT Wind Forecasts - WGR requirements

- Install and telemeter to ERCOT site-specific meteorological information necessary to produce the STWPF and TEWPF forecasts.
- ERCOT requires the following data be provided from each WGR every five minutes:

<table>
<thead>
<tr>
<th>MW Average</th>
<th>HSL Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Speed</td>
<td>Num of Turbines On</td>
</tr>
<tr>
<td>Wind Direction</td>
<td>Num of Turbines Off</td>
</tr>
<tr>
<td>Temperature</td>
<td>Num of Turbines Unknown</td>
</tr>
<tr>
<td>Barometric Pressure</td>
<td>Curtailment Flag</td>
</tr>
</tbody>
</table>
Accommodating variable output

• ERCOT dispatch executes every 5 minutes
• WGR High Sustained Limit (HSL), when not curtailed, to be telemetered as equal to the WGR’s current meter reading
• When curtailed, WGR’s receive a curtailment flag from ERCOT along with their Base Point (dispatch level)
• When WGR is curtailed, the HSL to be telemetered is the expected output, but for the curtailment
• WGR ramping when curtailed limited to 20% per minute, unless installed before 2009 and have a good excuse
Negative prices

![Chart showing negative prices from 2011 to 2017]

- **WEST Only**
- **ERCOT Wide**
- **Other**

Hours

- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
- 2017
In Summary

• ERCOT’s experience
  – More wind, more wind, more wind
  – Better reliability metrics
  – Reduced ancillary services requirements

• Enablers
  – Common carrier model for Transmission
  – Centralized forecasting of wind output
  – Real-time output variations accommodated