Lessons Learned in Wind Integration

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The ERCOT Region

The interconnected electrical system serving most of Texas, with limited external connections

- 75% of Texas land; 85% of Texas load
- 68,294 MW peak demand (set August 3, 2011)
- More than 40,000 miles of transmission lines
- 2 DC ties with SPP; 3 DC ties with Mexico; 1106 MW total
- 550+ generation units

Markets

- Fully unbundled Wholesale market
  - ERCOT operates a single Control Area with ancillary services markets
  - Generators are paid Locational Marginal Prices (LMPs) at their node
  - Load-serving entities pay averaged load-zone prices
- Full Retail competition except in municipal & co-op utility areas

Transmission Service

- All transmission costs are rolled-in to single postage-stamp rate paid by load
- All generators have, essentially, “network service”
ERCOT Inc.: A non-profit corporation designated the “Independent Organization” under state law and assigned these responsibilities [Texas Public Utility Regulatory Act (PURPA) 39.151]:

- Maintaining System Reliability
- Ensuring Open Access to Transmission
- Facilitating the Competitive Wholesale Market
- Facilitating the Competitive Retail Market

Regulatory Characteristics:

- ERCOT is regulated by the Texas Public Utility Commission with oversight by the Texas Legislature
- ERCOT is not a market participant and does not own generation or transmission/distribution wires
- ERCOT is the sole Reliability Coordinator, Balancing Authority, Planning Authority, Interchange Authority, and Transmission Service Provider for the ERCOT Region
Installed Wind Generation in ERCOT

ERCOT Wind Installations by Year (as of March 31, 2012)

The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years’ totals. Scheduling delays will also be reflected in the planned projects as that information is received.

This chart now reflects planned units in calendar year of installation rather than installation by peak of year shown.

Currently, 9,838 MW nameplate capacity installed

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Wind Output

- Peak wind generation output on 7,925MW on 4/13/12
  - 20.1% of Load at the time
- Maximum Percent of Load Served by Wind was 28.2% on 3/6/12
- 8.7% of Nameplate Capacity of wind counted towards reserve margin
Competitive Renewable Energy Zones (CREZ)

- Transmission Plan designed to serve approximately 18GW:
  - ~4600 circuit miles of 345 kV
  - $6.7 billion project cost
- All line certification cases completed
  - Construction underway
  - All lines expected to be complete by end of 2013
- Lines are open-access; use not limited to wind
Operational Challenges for Wind Integration

- Uncertainty
- Variability
- Interconnection
Wind power production forecast

- Hourly 50% probability of exceedance forecast for a rolling 48 hour period
- Provided for each wind farm and total for system

- Used to determine need for “residual” unit commitment
Wind Forecast Error

Average hour-ahead wind forecast error is significant (MAPE is ~7%)

MW errors may be high (>1000 MW; occasionally >2000 MW)
Predicting Large Ramps in Wind Power Output

- **ERCOT Large Ramp Alert System (ELRAS)**
  - Probabilistic forecast which alerts Operators of ramps during the next 6 hours
  - Provided on the system and regional level
Ancillary Services - Regulation

- ERCOT typically dispatches generation each five minutes.
- Regulation Service is used to balance the variation in load and generation between five-minute economic dispatch executions.
- Primary driver for determining required amount of regulation is historical deployments.
  - Adjusted for increase in installed wind capacity.
Ancillary Services – Non-Spin

- **Non-spin Reserve Service**
  - 30 minute product that can be provided by unloaded capacity, offline Generators, and Load Resources
  - Wind power forecast error is one of the inputs used for calculating the requirement for this service
• All generation in ERCOT is required to provide governor response with a 5% droop setting
• Wind farms were recently required to provide primary frequency response to frequency deviations from 60 Hz.
Interconnection-Related Requirements

- Inverter-connected resources may not fit with traditional technical requirements
- Need to address these issues to maintain system reliability:
  - Static and dynamic reactive capability
  - Voltage-ride through capability
  - Modeling
    - Collector system and support device modeling
    - Dynamic model and parameters
• There is a clear shift down in the duration curve of real-time prices for higher levels of wind power output

Duration Curve of Real-Time Cost of Energy for Various Levels of Aggregate WGR Output (12-1-10 thru 2-26-12)

- Less than 1 GW
- Between 1 and 2 GW
- Between 2 and 3 GW
- Between 3 and 4 GW
- Between 4 and 5 GW
- Between 5 and 6 GW
- Greater than 6 GW

System Lambda

Percent of Intervals

$70
$60
$50
$40
$30
$20
$10

0%
20%
40%
60%
80%
100%
Questions?