A Transmission Planning Case Study for Wind Integration – CREZ in ERCOT

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The ERCOT grid includes:
- 75% of Texas land
- 85% of Texas load
- 38,000 miles of transmission lines
- 550+ generation units
- 68,379 MW peak demand (set 8/3/2011)

Regional Import Capacity: 1,106 MW of Asynchronous Tie Capacity (820 MW with Eastern Interconnection)

The ERCOT region has a deregulated energy-only wholesale market and a deregulated retail market.
Construction of wind units in the McCamey area stopped after export limits were imposed (due to voltage constraints).
After the McCamey area became constrained, wind developers sought out locations where transmission capacity was available and wind resources were acceptable. By 2008, most of the wind in ERCOT was aggregated in three areas (red circles).
In 2005, the Texas Legislature passed SB 20, instructing the Public Utility Commission of Texas (PUCT) to designate transmission for Competitive Renewable Energy Zones (CREZs).

- The PUCT established contested-case docket 33672 in January, 2007
- Parties nominated CREZs and demonstrated financial commitment
- Transmission service providers proposed transmission solutions
- First Hearing held in June 2007
In Oct. 2007, the PUCT issued an Interim Order which designated 5 areas as CREZ and requested that ERCOT develop transmission plans for 4 levels of wind capacity.

<table>
<thead>
<tr>
<th>Wind Zone</th>
<th>Scen. 1</th>
<th>Scen. 2</th>
<th>Scen. 3</th>
<th>Scen. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panhandle A</td>
<td>1,422</td>
<td>3,191</td>
<td>4,960</td>
<td>6,660</td>
</tr>
<tr>
<td>Panhandle B</td>
<td>1,067</td>
<td>2,393</td>
<td>3,720</td>
<td>0</td>
</tr>
<tr>
<td>McCamey</td>
<td>829</td>
<td>1,859</td>
<td>2,890</td>
<td>3,190</td>
</tr>
<tr>
<td>Central</td>
<td>1,358</td>
<td>3,047</td>
<td>4,735</td>
<td>5,615</td>
</tr>
<tr>
<td>Central West</td>
<td>474</td>
<td>1,063</td>
<td>1,651</td>
<td>2,051</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12,053</strong></td>
<td><strong>18,456</strong></td>
<td><strong>24,859</strong></td>
<td><strong>24,419</strong></td>
</tr>
</tbody>
</table>

* Assumes 6,903 MW of existing wind capacity
ERCOT evaluated plans based on five different concepts:

1) Incremental 345-kV transmission system for wind in west Texas

2) Integrated 345-kV transmission system for wind in west Texas

3) Reduced number of right-of-ways using higher voltage circuits (500 kV or 765 kV)

4) Low impedance backbone or loop

5) HVDC circuit(s) to move power to load centers or between load centers, integrated with 345-kV upgrades
CREZ Ruling – 2,376 Miles of New ROW

Red lines are new 345-kV double circuit ROW
Dotted red lines are new 345-kV single circuit ROW

<table>
<thead>
<tr>
<th>Zone</th>
<th>New Wind Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panhandle A</td>
<td>3,200</td>
</tr>
<tr>
<td>Panhandle B</td>
<td>2,400</td>
</tr>
<tr>
<td>Central</td>
<td>3,000</td>
</tr>
<tr>
<td>Central West</td>
<td>1,100</td>
</tr>
<tr>
<td>McCamey</td>
<td>1,900</td>
</tr>
</tbody>
</table>
Initial Stability Results

Initial simulations indicated the presence of two sources of instability: large signal and small signal.

Graphical representation of oscillatory (small signal) behavior

These results are indicative of power system interactions due to low system strength.
Sub-Synchronous Interaction Analysis

Potential issues associated with use of power electronics on transmission systems:

- Sub-synchronous Resonance (SSR) – primarily a concern for large synchronous generation units
- Sub-synchronous Torsional Interactions (SSTI) – results from operation of power electronics devices near large synchronous generation units
- Sub-synchronous Interactions (SSI) – impacts to wind turbines. Potential impacts noted at several locations on the CREZ system. There are transmission system and turbine-specific mitigation options.
Geography of SSI

Locations most prone to have Sub-Synchronous Interaction (for Type 3 turbines):

1) West Shackelford – SSI with no contingencies
2) Dermott – SSI after 1 contingency
3) Big Hill – SSI after 1 contingency

Locations directly connected to a compensated line or potentially in a radial or semi-radial configuration following the outage of one or a few nearby circuits will be SSI prone.
The CREZ Plan Today

The project will be complete by end of 2013.

Latest Cost Estimate of CREZ Transmission Plan: $6.9 Billion

From legislative discussions to wire-in-the-air in just over 8 years.
Wind Generation Development in ERCOT

**Instantaneous wind generation record in ERCOT:** 9,674 MW on May 2, 2013 (28% of customer demand).

**ERCOT Wind Installations by Year** (as of June 30, 2013)

- 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.

- Instantaneous wind generation record in ERCOT: 9,674 MW on May 2, 2013 (28% of customer demand).
Questions?

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