Summary of the CREZ Reactive Study

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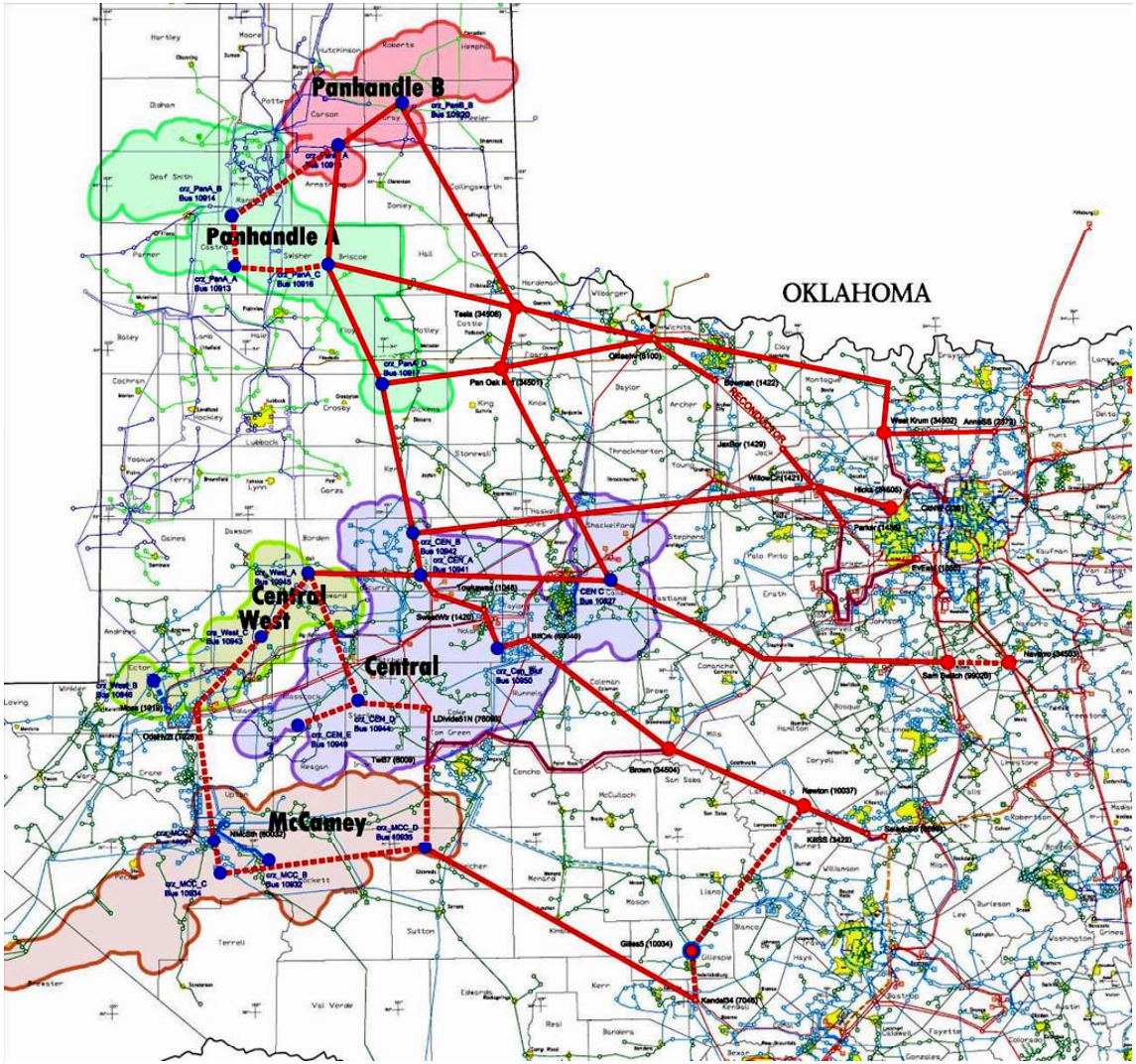
January 18, 2011

Project Background



S.B. No. 20 (79[1] - 2005) required the Public Utility Commission of Texas (PUCT) to designate Competitive Renewable Energy Zones (CREZ) in Texas, and to develop a plan to construct transmission to connect the CREZ with load centers.

PUCT designated 5 CREZ in 11/2007; selected the depicted transmission plan in October, 2008. Estimated cost: $4.93B

Project Purpose

Study is part of the CREZ transmission plan focusing on system reactive needs

Primary Goal: Development of a reactive plan to achieve the cost-effective and reliable implementation of the approved CREZ transmission infrastructure.

The CREZ Reactive Study had three major work areas:

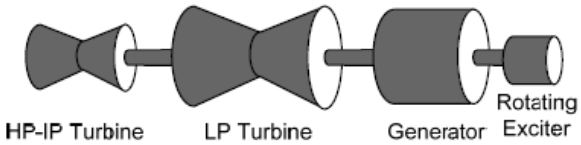
- Review and optimize design specifications of CREZ series compensation
- Review and optimize the location, size and response requirements of shunt compensation
- Evaluate potential impacts of sub-synchronous interactions

CREZ Reactive Study was conducted by a team of consultants from ABB, Inc. under the supervision of ERCOT and CREZ TSPs

The study report was filed with the PUCT and is posted at:
http://www.ercot.com/content/news/presentations/2011/CREZ%20Reactive%20Power%20Compensation%20Study.pdf

A Few Definitions

- **Reactive Device: a device which produces (capacitor) or consumes (reactor) reactive power. Reactive power is needed across the system to support the flow of real power.**
- **Shunt Reactive Device: a reactive device that is connected alongside (parallel to) the current flow in a transmission system**
- **Series Reactive Device: a device that is connected in line with (in series with) the current flow on the transmission system.**
- **Sub-synchronous frequencies: frequencies on the power grid that are lower than the fundamental frequency (60 Hz or cycles per second)**
- **Sub-synchronous resonance (SSR): when sub-synchronous frequencies interact with mechanical characteristics of generating plants to create potentially damaging stress along the turbine shafts**



- **Sub-synchronous Interactions (SSI): Potentially damaging interaction between power electronics devices (such as wind turbines) and sub-synchronous frequencies.**

Project Considerations

Reactive devices can be implemented in a timely, as-needed manner to meet system needs due to their relatively short lead times.

However, specific reactive equipment will be needed to maintain system reliability when circuits are initially energized (shunt reactors). Other equipment will be purchased to meet long-term needs (series capacitors), due to the cost of incremental upgrades.

Other reactive devices can be added to meet changing system needs (shunt capacitors, dynamic reactive devices).

Study Cases

- **The following system conditions were analyzed as part of this study:**
  - Minimum Exports (Low wind, low load)
    - Used to indicate the need for equipment to control circuit voltages under low-wind conditions and initial circuit energization
  - Peak Load
    - Used to indicate system reactive needs under high load conditions
  - Initial Build Case
    - Developed to reflect the reactive needs of the CREZ system while maintaining flexibility to adjust the reactive plan to meet evolving system needs
  - Maximum Exports (High wind, low load)
    - Used to indicate reactive needs under maximum loading of CREZ circuits
    - Results indicate a need for reactive devices to supplement localized system current strength (such as synchronous condensers)

	2008 CREZ Study (CTOS)	Minimum Exports	Initial Build	Maximum Exports
Wind Installed Capacity MW	18,455	21,958	17,517	21,958
Wind Dispatched Level MW	12,975	2,562	12,802	15,430

Sub-Synchronous Interaction Analysis

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

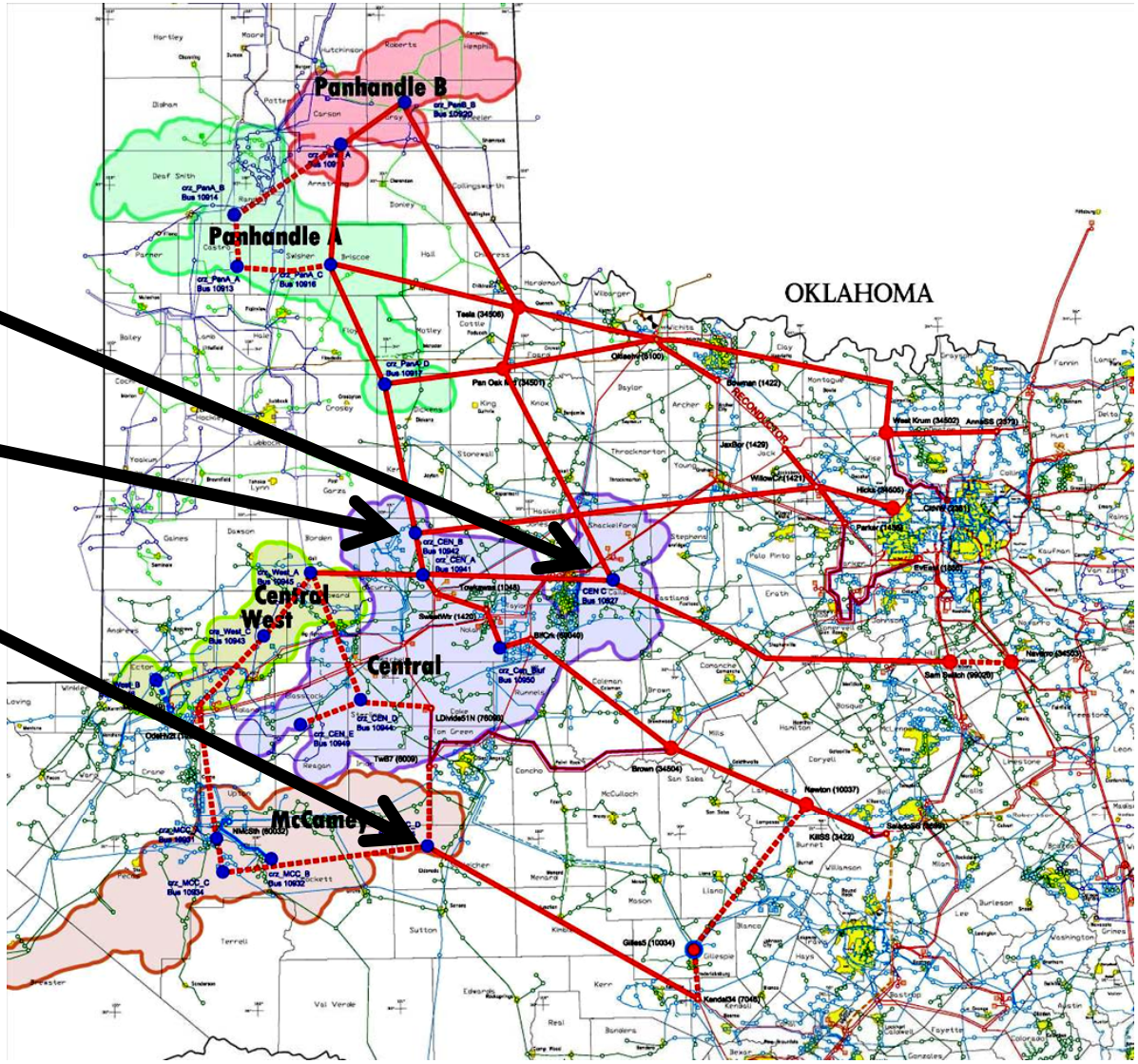
- Sub-synchronous Resonance (SSR) – primarily a concern for large synchronous generation units
  - Potential impacts to 6 existing generations units were evaluated (Comanche Peak, Tradinghouse, Willow Creek, Oklaunion, Hays, Odessa). ERCOT is working with CREZ TSPs and generators to evaluate these reports. Any impacts will be mitigated. No other existing synchronous generators are likely to be affected.
- Sub-synchronous Torsional Interactions (SSTI) – results from operation of power electronics devices near large synchronous generation units
  - Study results indicate this should not be a significant issue
- Sub-synchronous Interactions (SSI) – impacts to wind turbines were evaluated for a small set of turbines (few PSCAD turbine models were provided by vendors). Potential impacts noted at several locations on 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.



Conclusions

- The CREZ Reactive Study indicates the recommended location, size, and response characteristics of reactive devices through analysis of the Minimum Exports, Peak Load, and Initial Build cases
  - Will provide necessary reactive capability for system reliability upon initial energization of the CREZ transmission system and for significant subsequent build-out of wind generation
  - Will provide flexibility to add additional reactive devices, if needed, to reflect actual development of wind generation and other changes to the transmission grid
  - Analysis of maximum CREZ export conditions provides a potential build-out for the full CREZ system. However, any additional reactive capability needed to support the CREZ system (beyond current recommendations) can be planned and implemented in a timely manner.
- Further study to be done:
  - Work with CREZ TSPs to mitigate SSR (if needed), and to evaluate options to mitigate SSI
    - Develop modeling capability to analyze implications of SSI in future studies
    - Modifications to Generation Interconnection requirements/process
  - Identify new tool to determine cost-effectiveness of potential solutions to low system strength conditions for full CREZ build-out.

Reactive Device Recommendations

The following shunt capacitive devices are being recommended:

Station	Static Capacitors (MVAr)	Dynamic Reactive Devices (Static Var Compensator [SVC] - MVAr)
RILEY	316	
KRUM	50	
TESLA		+300 (-100)
EDITH CLARKE		
SILVERTON		
COTTON		
SCURRY	100	
WEST SHACKLEFORD		
GRELTON	50	
BROWN	200	2 x [+300 (-100)]
KILLEEN	100	
BIG HILL	144	
PARKER		+300 (-100)
HAMILTON		+200 (-50)

In addition, ~-4,000 MVArs of shunt static reactors will be required, at 30 substations, for voltage control under low wind conditions and for line maintenance and operations.

Estimated costs of these devices:

Shunt Capacitors: ~$25 M

Static Var Compensators: ~$150 M

Shunt Reactors: ~$220 M

Questions?