ERCOT Experience with Synchronous Condenser Applications

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Resource Adequacy
ERCOT Transmission Planning

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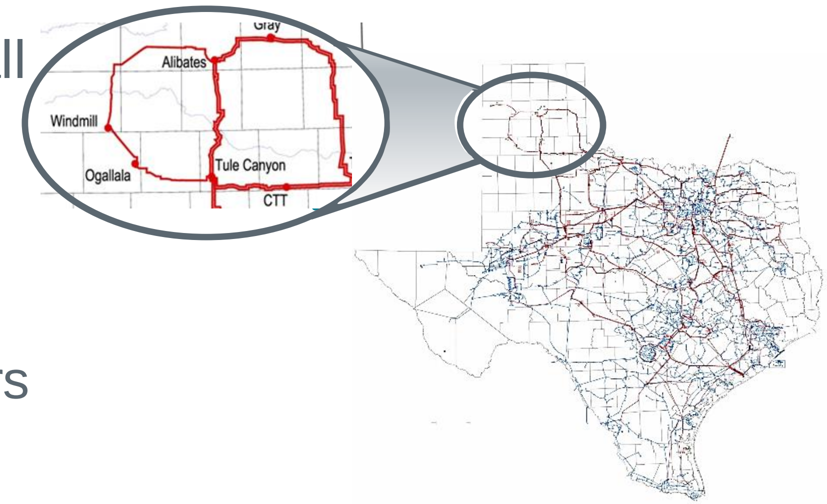
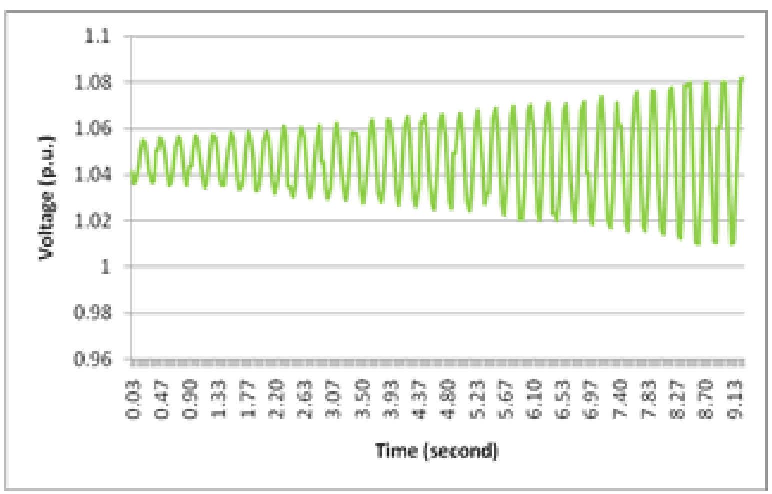
ERCOT Facts

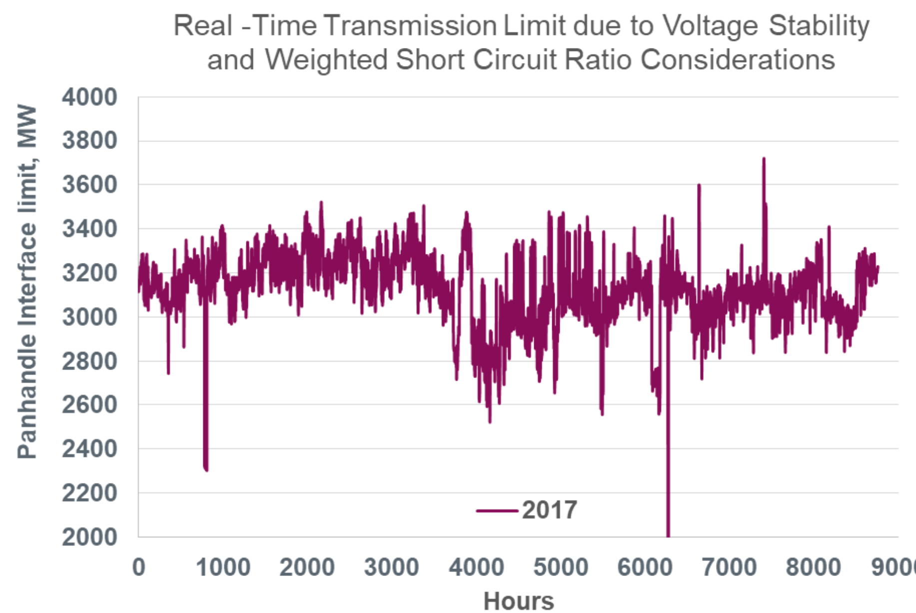
- Electrical Island
  - Limited asynchronous tie capacity to EI & Mexico (~1.2 GW)
- Peak Demand: 74.7 GW (August 12, 2019)
- Wind Capacity: 22.4 GW
- Maximum Wind Output: 19.7 GW (January 21, 2019)
- Maximum Wind Penetration: 56% (January 19, 2019)
- Energy Use: 18.6% Supplied By Wind in 2018
- Utility-Scale Solar Capacity Exceeds 1.8 GW
- Planned Wind and Solar Capacity over 16 GW by 2022

Weak Grid Issues in Panhandle

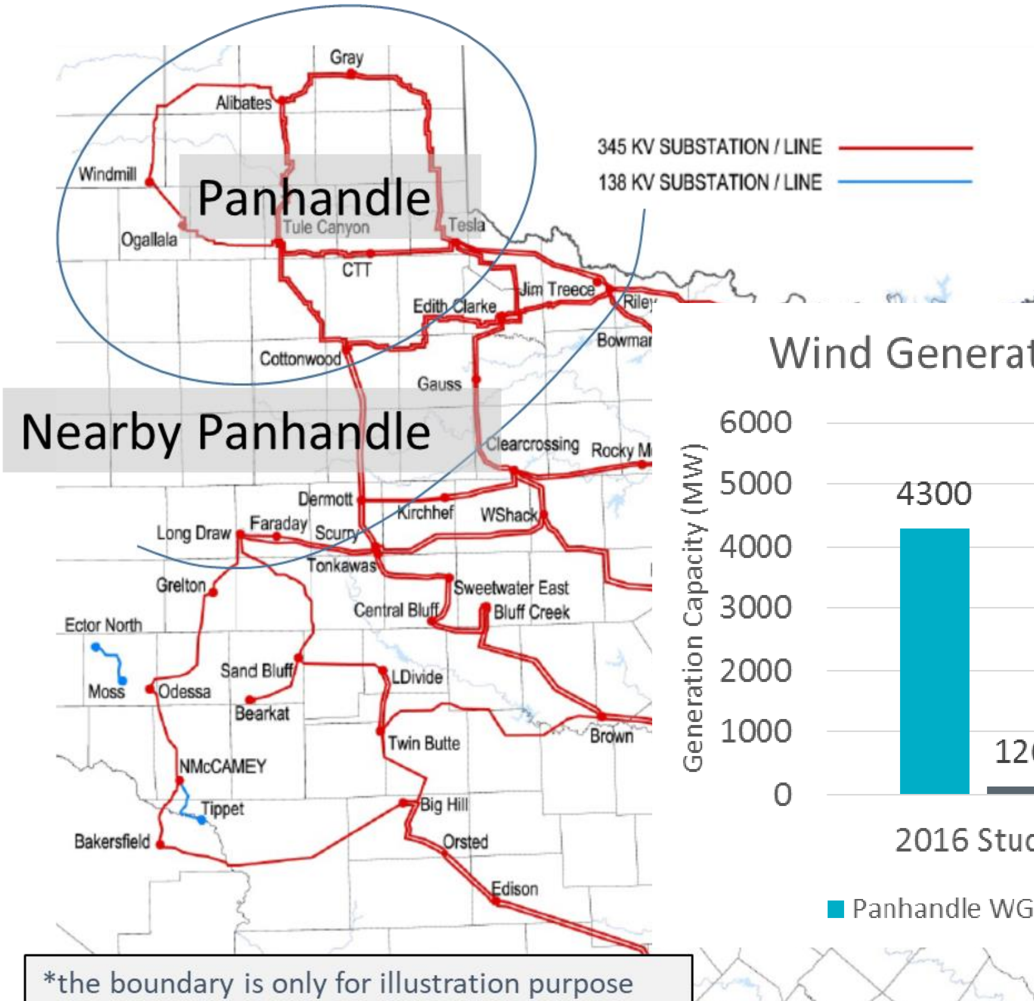
- ~ 4 GW in service, ~1.6 GW planned (all wind generation)
- ~2.3 GW in service, 1.9 GW planned in the nearby area
- No local load or synchronous generators
- Voltage support and system strength issues

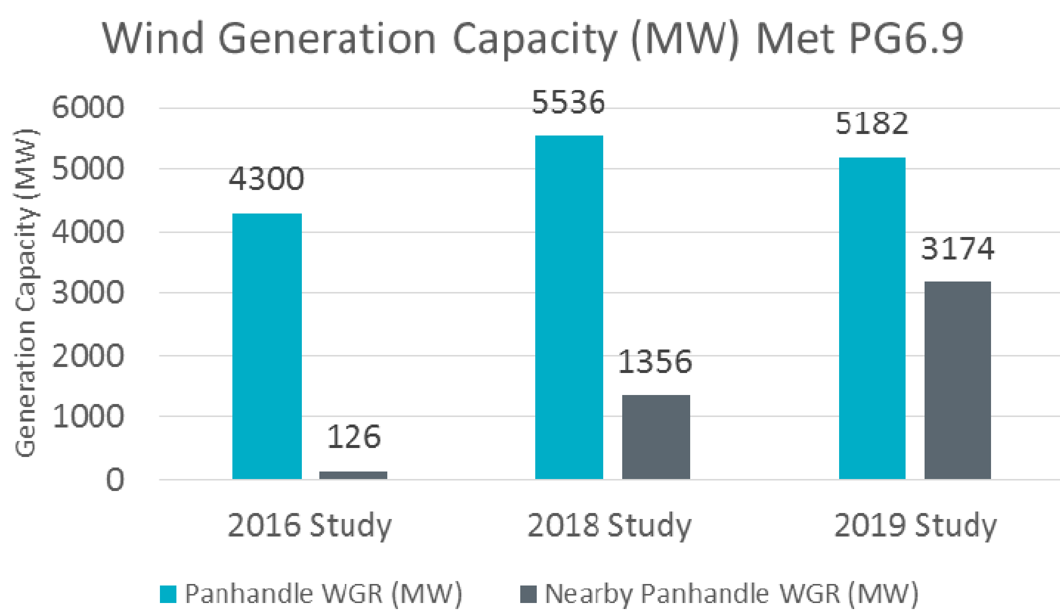






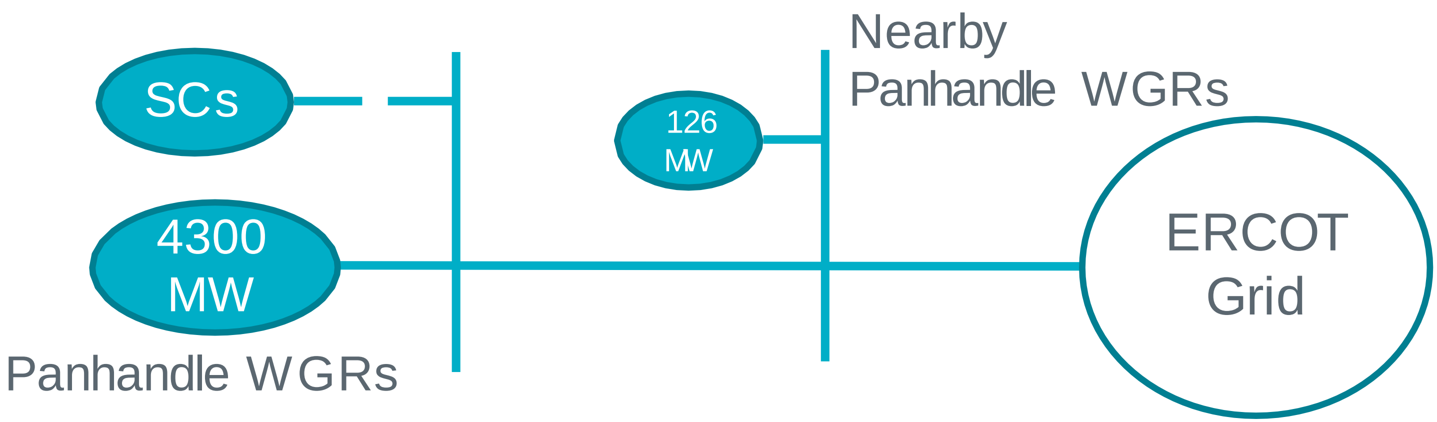
Overview of the Panhandle Region





*the boundary is only for illustration purpose

2016 Panhandle Study

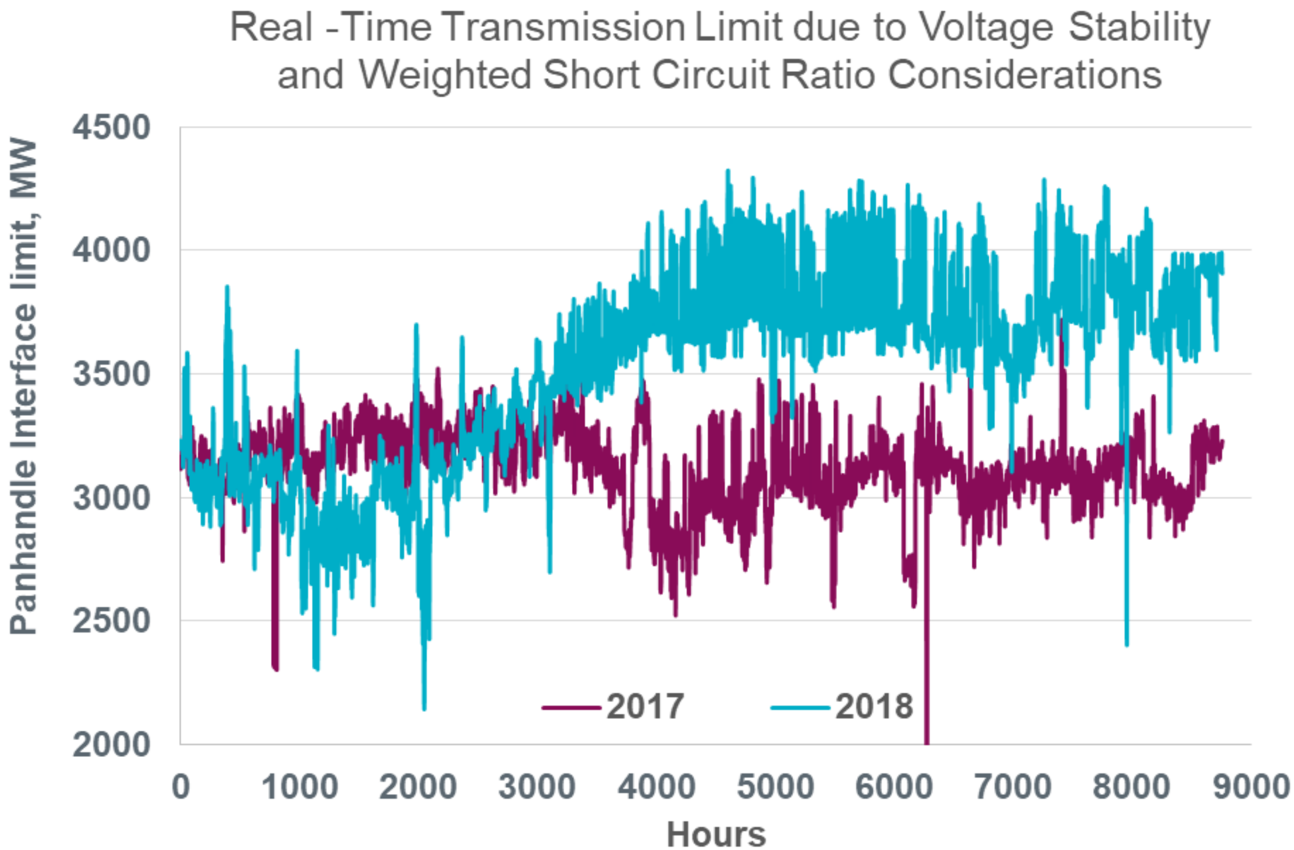


- Identified stability limitations in Panhandle
  - System strength in normal operation (no planned outages)
  - Voltage stability under planned outage condition
- Key takeaways:
  - Two synchronous condensers were proposed to provide system strength and voltage support in Panhandle to allow higher wind output
  - Enforce system strength operating limit (WSCR)

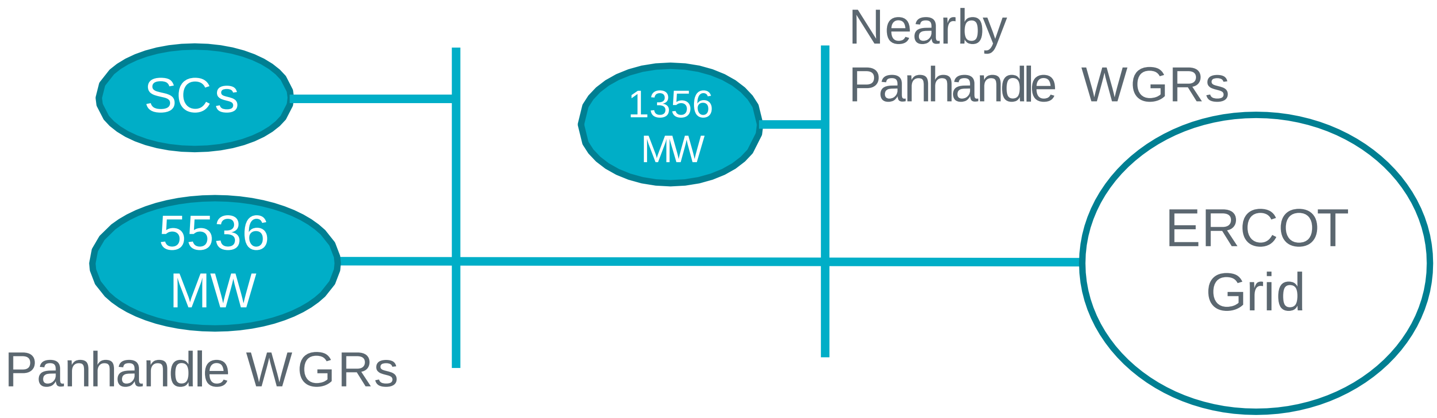
Syncon characteristics

- Two SynCons were installed in Panhandle in 1Q, 2018
- ~175/-125 MVAR, for +/- 10% voltage variation range
- ~1600 Amps short circuit capability
- Placed in locations that provide increase in WSCR but simultaneously also improve voltage support and transient response
- High availability design is required since SynCon outage directly translates into reduction of the maximum power export
- To achieve this adequate redundancy in cooling system auxiliary supply, control and protection systems was introduced
- The wide range of the machine operating voltage allows a design without a need of an on-load tap changer on the step-up transformer, increases reliability and reduces operating complexity
- Brushless excitation system to reduce maintenance time
- The introduction of synchronous condenser has enabled ERCOT to increase generation in the Panhandle by ~470 MW

Impact of Synchronous Condensers on Panhandle Transfer Limit

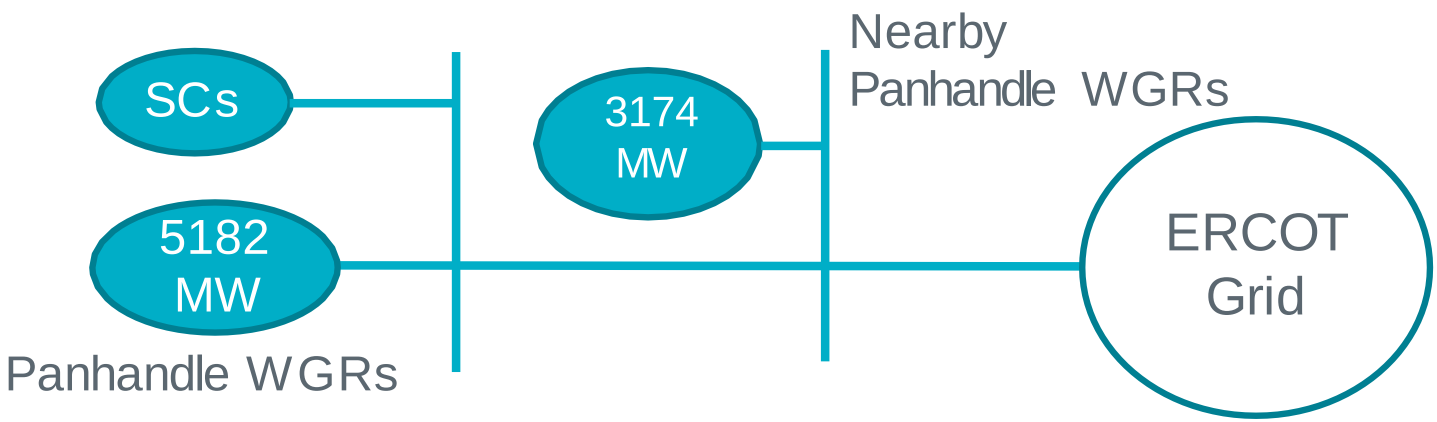


2018 Panhandle Study



- Identified stability limitations in Panhandle
  - System strength in normal operation (no planned outages)
  - Voltage stability under planned outage condition
- Key takeaways:
  - Confirmed adequacy of system strength operating limit
  - EMT modeling improvements (e.g. PPC representation) may help

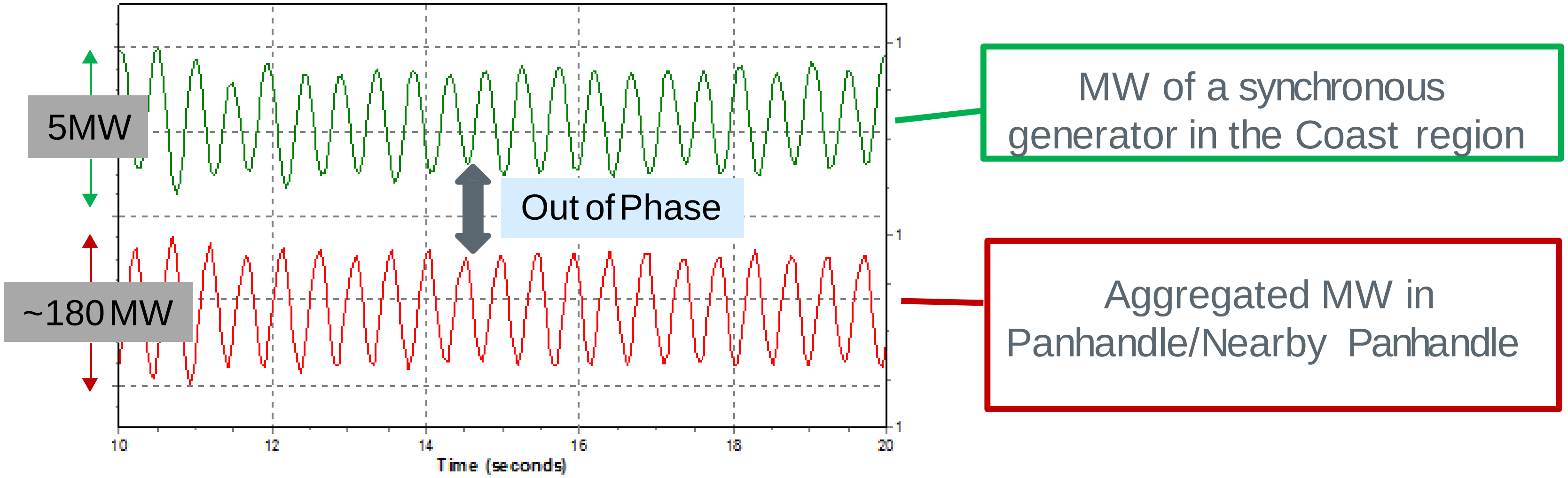
2019 Panhandle Study



- Identified stability limitations in Panhandle
  - Oscillatory/angular stability in normal operation (no planned outages)
  - Voltage stability under planned outage condition (modified thresholds)
- Key takeaways:
  - Nearby WGRs provide voltage support along transfer path
  - Nearby WGRs drive larger angles in Panhandle

Observed Oscillation

- Oscillatory responses are observed during high power transfer
- Synchronous condensers identified as primary participant

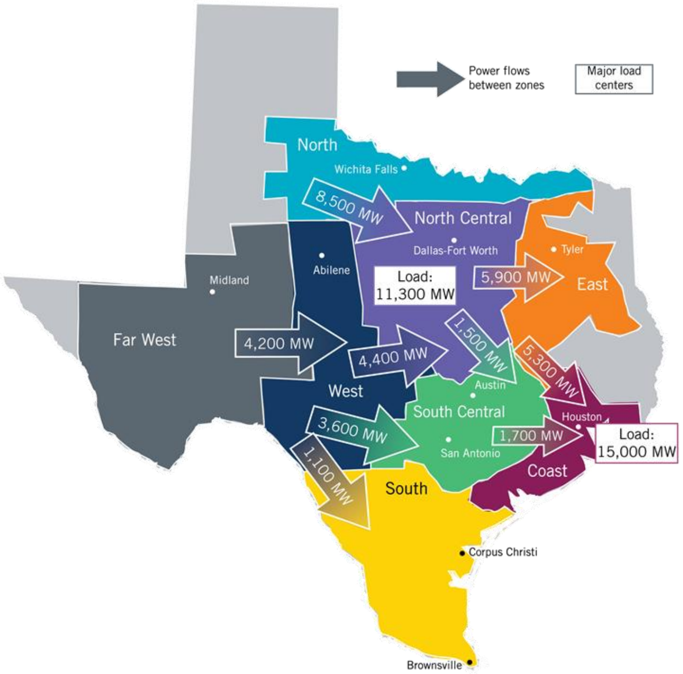


Mitigation Options

- Panhandle wind curtailment
  - Existing Panhandle interface is adequate and effective to maintain reliable transfer under all identified stability constraints
  - Test results indicate that to increase limit on the existing Panhandle interface by 1 MW, the nearby Panhandle WGRs need to be reduced by 3~6 MW
- Improved voltage support and control
- Areas for further consideration/investigation
  - Application of PSS to synchronous condensers
  - Incorporation of PSS-like functions to IBR and/or dynamic reactive device controllers to provide positive damping

ERCOT High Penetration Study

- ~70% Penetration of Inverter-Based Wind and Solar Resources
- Less Synchronous Generators
- Reduced System Strength
- Significant active and reactive power losses
- IBR controls require sufficient system strength for reliable operation or more robust inverter control capability is required, grid forming (?)
- Synchronous condensers are subject to synchronous machine instabilities (inter & intra area oscillations & angular instability)



Load:	42.2 GW (includes PUNs)
Solar output:	17 GW (90% dispatch)
Wind output:	11 GW (48% dispatch)
West Texas Exports:	15.5 GW (major 345 kV circuits)
Losses (MW):	6%

http://www.ercot.com/content/wcm/lists/144927/Dynamic_Stability_Assessment_of_High_Penertration_of_Renewable_Generatio....pdf

Discussion Points

- Synchronous condensers are not a “silver bullet” solution for system strength challenges
  - May introduce additional stability challenges
- System strength challenges
  - Increasing short circuit levels is not the only way to improve system strength
  - Independent instability phenomenon or simply an operating condition where traditional stability challenges are more prevalent
    - Voltage controller instability
    - Voltage instability
    - Angular/oscillatory instability

Thank you! Questions?

References:

- A. Dissanayaka, A. Isaacs "System Strength Assessment of the Panhandle System PSCAD Study", 2016 http://www.ercot.com/content/news/presentations/2016/Panhandle%20System%20Strength%20Study%20Feb%2023%202016%20(Public).pdf
- A. Dissanayaka, J. Wiebe, A. Isaacs, "Panhandle and South Texas Stability and System Strength Assessment", 2018 http://www.ercot.com/content/wcm/lists/144927/Panhandle_and_South_Texas_Stability_and_System_Strength_Assessment_March....pdf
- E. Rehman, M. Miller, J. Schmall, S.-H. Huang, "Dynamic Stability Assessment of High Penetration of Renewable Generation", 2018 http://www.ercot.com/content/wcm/lists/144927/Dynamic_Stability_Assessment_of_High_Penertration_of_Renewable_Generatio....pdf
- J. Conn, S.-H. Huang, J. Schmall, A. Atallah, S. Kynev, "Synchronous Condenser for Integration of Wind Generation in Texas Panhandle Area", CIGRE US NC, 2019 Grid of the Future Symposium
- J. Schmall, "ERCOT Experience with Synchronous Condensers for System Strength Improvement", IEEE PES General Meeting, 2019

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