2019 Panhandle Regional Stability Study

Version 1.0

Document Revisions

Date	Version	Author(s)
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1. Executive Summary

This 2019 Panhandle stability study was conducted to evaluate the impact of increasing amounts of wind generation connecting just outside the existing Panhandle GTC interface while incorporating model updates and improvements recommended in previous studies. Scenarios considering existing operational conditions as well as planned future conditions both before and after Lubbock integration were studied. The study included both PSS/e and PSCAD analysis.

Study findings:

- The current WSCR threshold of 1.5 in real time Operations is adequate until Lubbock integration.
    - The application of WSCR in the Panhandle is becoming blurred and may no longer be adequate to identify Panhandle export limits after Lubbock integration.
- Adjustment of real time VSAT was necessary and made in May 2019 to ensure that post-disturbance voltage is maintained above the revised threshold in the Panhandle region so that identified VSAT limits reflect dynamic simulation results.
    - Similar adjustments to maintain post-disturbance voltage may be required to cover a broader area, including nearby Panhandle region, in the future.
- A need to maintain an off-line Panhandle export limit table for some planned or forced outage conditions is expected to ensure stability in operations.
- No system voltage collapse or stability issue was identified with Panhandle WGRs at full output under normal system conditions after Lubbock integration. However, WGR tripping (less than 750 MW) and power oscillations associated with specific models were observed in the PSCAD simulations and are currently being reviewed by the appropriate Resource Entities and manufacturers.

Future Work and Recommendations:

- Investigate the feasibility and benefits of damping support provided by dynamic reactive devices, inverter-based resources, and synchronous condensers.
- Continue to improve the PSCAD models in the Panhandle and nearby Panhandle.
- Work with Resource Entities and developers to confirm voltage regulation at the POI and ensure this is properly reflected in the dynamic models.
- Work with Resource Entities and manufacturers to investigate WGR tripping and oscillation in PSCAD simulation.
- Investigate the potential reactive power deficit along the transfer paths between West Texas and rest of ERCOT grid.

- Perform regular PSS/e and PSCAD studies given the fast changing generator additions in the Panhandle and nearby Panhandle regions.
- Explore various Panhandle interface considerations and alternative stability metrics to be utilized in operations to properly capture Panhandle export limits.

2. Introduction

The Panhandle generic transmission constraint (GTC) is a limit implemented in operations to maintain dynamic stability and reliable power transfer from the Panhandle region. The Panhandle GTC limits are currently determined in operations by the pre-contingency weighted short circuit ratio (WSCR) threshold of 1.5 and the PV voltage stability, which were recommended by previous Panhandle stability studies including Panhandle system strength studies in 2016[1] and 2018[2]. This 2019 Panhandle stability study was conducted to evaluate the impact of increasing amounts of wind generation connecting just outside the GTC interface boundary (in the nearby Panhandle region as shown in Figure 1) while incorporating model updates and improvements recommended in the previous studies. Scenarios considering existing operational conditions as well as planned future conditions both before and after Lubbock integration were studied. This report documents the 2019 Panhandle Stability Study performed by ERCOT System Planning.

1 http://www.ercot.com/content/news/presentations/2016/Panhandle%20System%20Strength%20Study%20Feb%2023%202016%20(Public).pdf

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

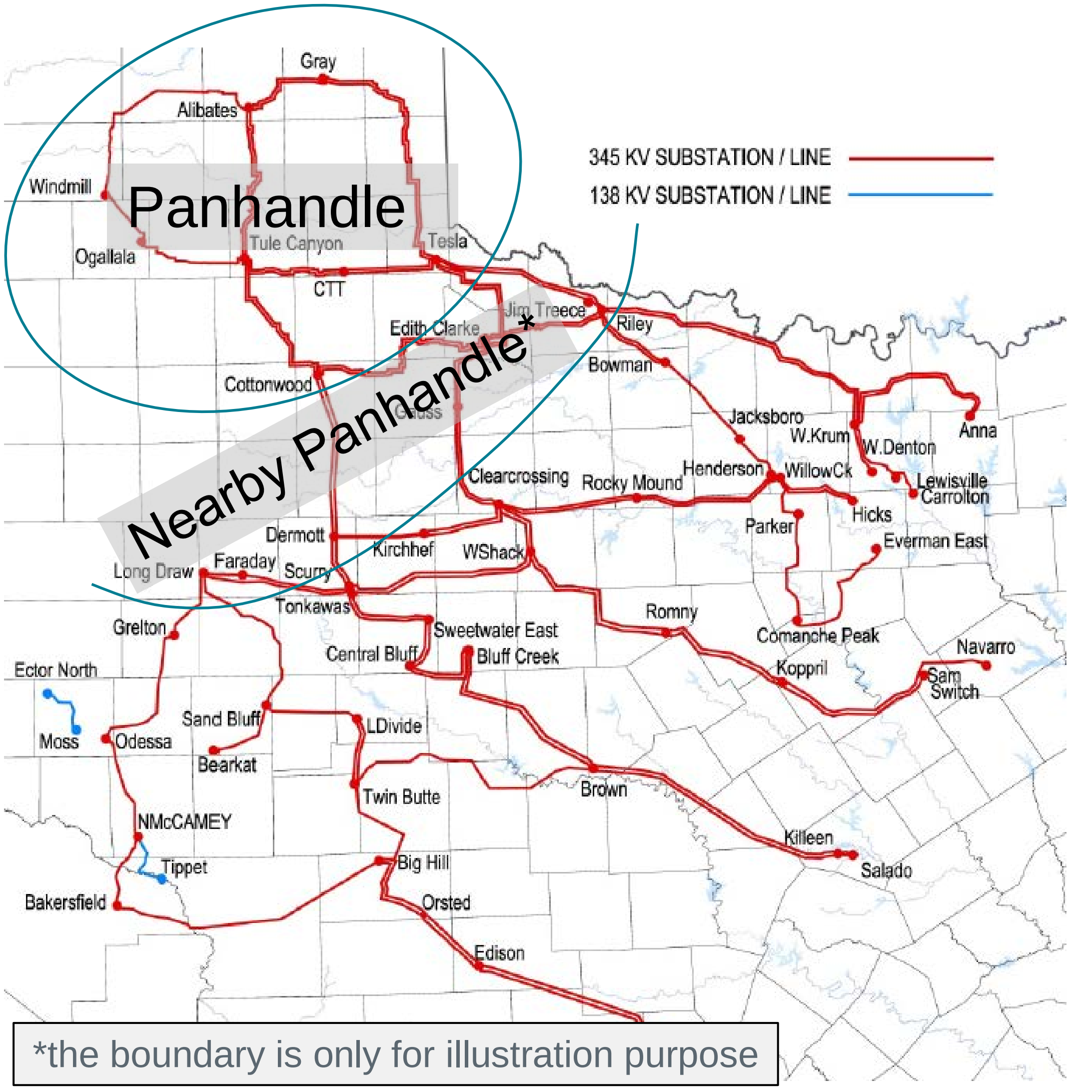

Figure 1: Panhandle and Nearby Panhandle

3. Study Scenarios and Assumptions

Three study scenarios were assessed in this study, as summarized in Table 1.

Table 1. Panhandle Stability Study Scenarios

Scenario	Panhandle WGR Capacity (MW)	Nearby Panhandle WGR Capacity (MW)	Lubbock Load (MW)
Existing/Operational (As of May 2019)	3,988	2,219	n/a
Existing + IA Signed-Financial Security Posted (without Lubbock Integration)	5,182	3,158	n/a
Existing + IA Signed-Financial Security Posted (with Lubbock Integration)	5,182	3,158	171 (Off Peak)

A summary of Panhandle and nearby Panhandle wind generation resources (WGRs) for existing and future planning scenarios is provided in the Appendix. The Panhandle and nearby Panhandle solar generation were assumed to be off-line in all the study scenarios. Increasing amounts of solar generation are expected to have impact on the Panhandle export limits and will be included in future Panhandle studies.

3.1. Study Approach and Cases

To evaluate the dynamic stability in the Panhandle region, both PSS/e and PSCAD studies were conducted for the identified low system strength condition in the Panhandle. PSS/e dynamic models for WGRs incorporate assumptions associated with inverter controls that may not be valid under low system strength conditions. PSCAD models allow a more detailed representation of power electronic controls that are necessary to properly represent the dynamic responses of WGRs under a low system strength scenario. Therefore, it is prudent to analyze and assess limits associated with low system strength and high penetrations of inverter-based resources with both PSCAD and PSS/e.

The DWG 2021 High Wind Low Load (HWLL) case was used as the starting base case for both PSS/e and PSCAD analysis with the following modeling assumptions:

- Conventional power plants in West Texas including in the Panhandle region were turned off in all the study cases.
- Two synchronous condensers in the Panhandle were in-service in all the study cases.
- The Lubbock system was added to the case to create the planning scenario after Lubbock integration.
- The ERCOT network outside the Panhandle and nearby Panhandle region was represented with a passive equivalent for PSCAD analysis.

All the detailed proprietary PSCAD models were provided by the manufacturers as black box modules to be incorporated in the PSCAD studies. Therefore, it is often challenging to troubleshoot model issues (which may involve interactions between multiple sites/manufacturers) and investigate certain abnormal simulation results. Based on the experience from previous PSCAD model requests, ERCOT developed a PSCAD model submittal guideline[3] for the Interconnecting Entities and Resource Entities that submit PSCAD models. In an effort to improve PSCAD model quality for this study, site-specific feedback was provided to the model provider for each site based on user experience with the model submitted for previous PSCAD studies with a request to submit an updated (improved) model where appropriate. The observations associated with the PSCAD model quality are summarized as below:

- The overall PSCAD model quality for 40 WGRs included in this study was improved compared to models used in the previous 2018 Panhandle system strength study.
- No model was received for two planned WGRs in the study region. They were modeled using other WGR models with the same turbine manufacturer and similar project size.
- No power plant control (PPC) model was received for five (5) WGRs in the study region.
- The remaining thirty-three (33) WGR models were considered as acceptable lacking only certain usability/efficiency features such as no “snapshot” feature or no flag to disable protection.
- The overall PSCAD model review and update activities took approximately 6 months and required coordination from Resource Entities/Interconnecting Entities and technical support from manufacturers. Despite these extensive efforts, there is still a need for further model improvements as noted above. PSCAD models are complex and the process for reviewing and updating models is time-consuming.

Due to the complexity and computational burden to perform regional PSCAD simulations involving a large number of detailed WGR models, a parallel processing approach utilizing the ETRAN+ software was adopted. The PSCAD study case was comprised of one master case to model 1) the Panhandle and nearby Panhandle transmission system, including the two synchronous condensers and other transmission-connected dynamic devices, such as SVCs, 2) the equivalent network of the rest ERCOT system, represented as several equivalent systems at the interface boundaries, and 3) the interfaces to communicate to thirty-two (32) slave cases modeling forty (40) WGRs in the study area. The PSCAD simulations for this study case were assigned to the parallel computation setup incorporating 24 CPUs (48 threads) and the simulation of a single contingency run took 1.5 ~ 2 hours to complete. In this Panhandle study, more than four scenarios with total of 110 PSCAD simulation runs were conducted creating more than 130 GB of simulation result files.

[3] http://www.ercot.com/content/wcm/lists/168307/PSCAD_Model_Guideline_Checksheet_2019.docx

4. Study Results

4.1. Existing/Operational Scenario

Based on the operational scenario listed in Table 1, both normal and outage conditions were tested in the PSS/e dynamic simulation to examine the Panhandle export limits while nearby Panhandle WGRs were fully dispatched. Both WSCR and voltage stability assessments were also conducted to assess Panhandle export limits. Based on the study results in this operational scenario, observations and findings are listed below.

- Under normal system condition without pre-outages, the Panhandle export limit was 3,750 MW (~94% dispatch of in-service Panhandle WGRs) determined by the existing WSCR threshold of 1.5.
- More new renewable generation connecting to the Panhandle and nearby Panhandle regions increase power transfer levels and could further stress voltage stability issues and low system strength conditions. Dynamic voltage stability analysis identified that post-disturbance transmission voltage in the Panhandle region would need to be above 0.93 pu in steady-state analysis to ensure stable operation. Therefore, an adjustment of the voltage threshold used in steady state operational analysis to 0.93 pu is needed to properly evaluate the existing system condition. As a result, an adjustment of real time VSAT was made in May 2019.
- The study results of the tested outage conditions indicated the Panhandle export limit can be identified using the existing real time WSCR and VSAT analysis except during the outage of Clear Crossing – Edith Clarke/Smoky Hill double circuit line. Since there is no dynamic stability tool implemented in operations, a pre-determined Panhandle GTC limit relying on off-line dynamic stability studies will need to be considered as an off-line table to manage the Panhandle export for this outage.

4.2. Planned (Prior to Lubbock Integration)

As recommended by the 2018 Panhandle system strength assessment, both PSS/e and PSCAD simulation were performed to re-evaluate Panhandle export limits including the planned WGRs meeting Planning Guide Section 6.9 requirements for inclusion in the models. Two dispatch cases were studied for the planning scenario without Lubbock integration:

- P80NP30: Panhandle WGRs dispatched at 80% (4,145 MW) and nearby Panhandle WGRs dispatched at 30% (947 MW)
- P80NP100: Panhandle WGRs dispatched at 80% (4,145 MW) and nearby Panhandle WGRs dispatched at 100% (3,158 MW)

The pre-contingency WSCR in the Panhandle for both cases was 1.35. The observations based on the simulation results of two tested dispatch cases are as follows:

- PSCAD and PSS/e simulation results were generally consistent for most of the simulated contingencies in both dispatch cases. An example is shown in Figure 2.
- No instability or unacceptable oscillation was observed for all the simulated contingencies in both dispatch cases in PSCAD simulation.
- No instability or unacceptable oscillation was observed for all the simulated contingencies in the P80NP30 dispatch case with PSS/e simulation.
- No instability or unacceptable oscillation was observed for simulated contingencies except for one double circuit contingency CTG#16 in the P80NP100 case. Simulation results of aggregated Panhandle and nearby Panhandle wind generation output under CTG#16 in both PSS/e and PSCAD simulations are shown in Figure 3. The undamped power oscillation in Figure 3 was observed only in PSS/e simulation; the oscillation frequency is around 2 Hz.

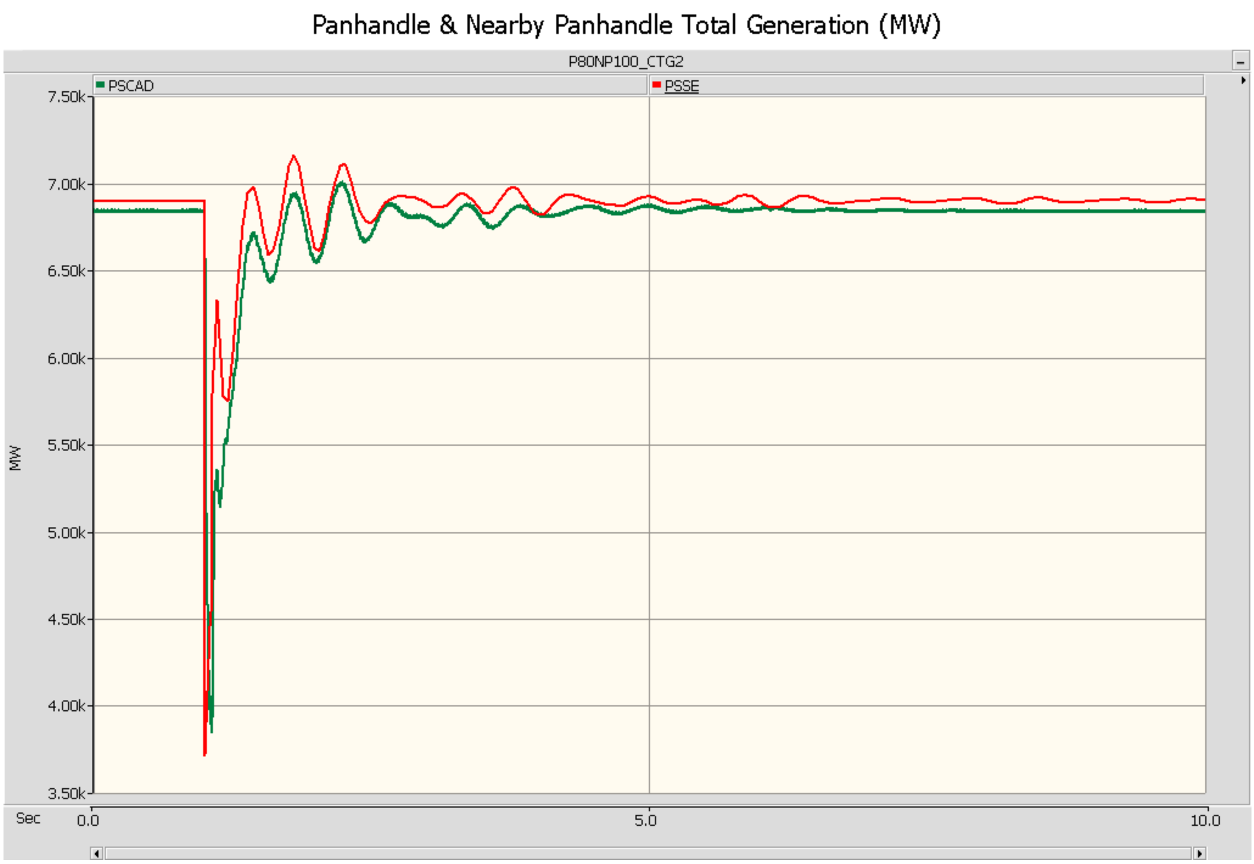

Figure 2: PSS/e and PSCAD Simulation Results Comparison (CTG #2)

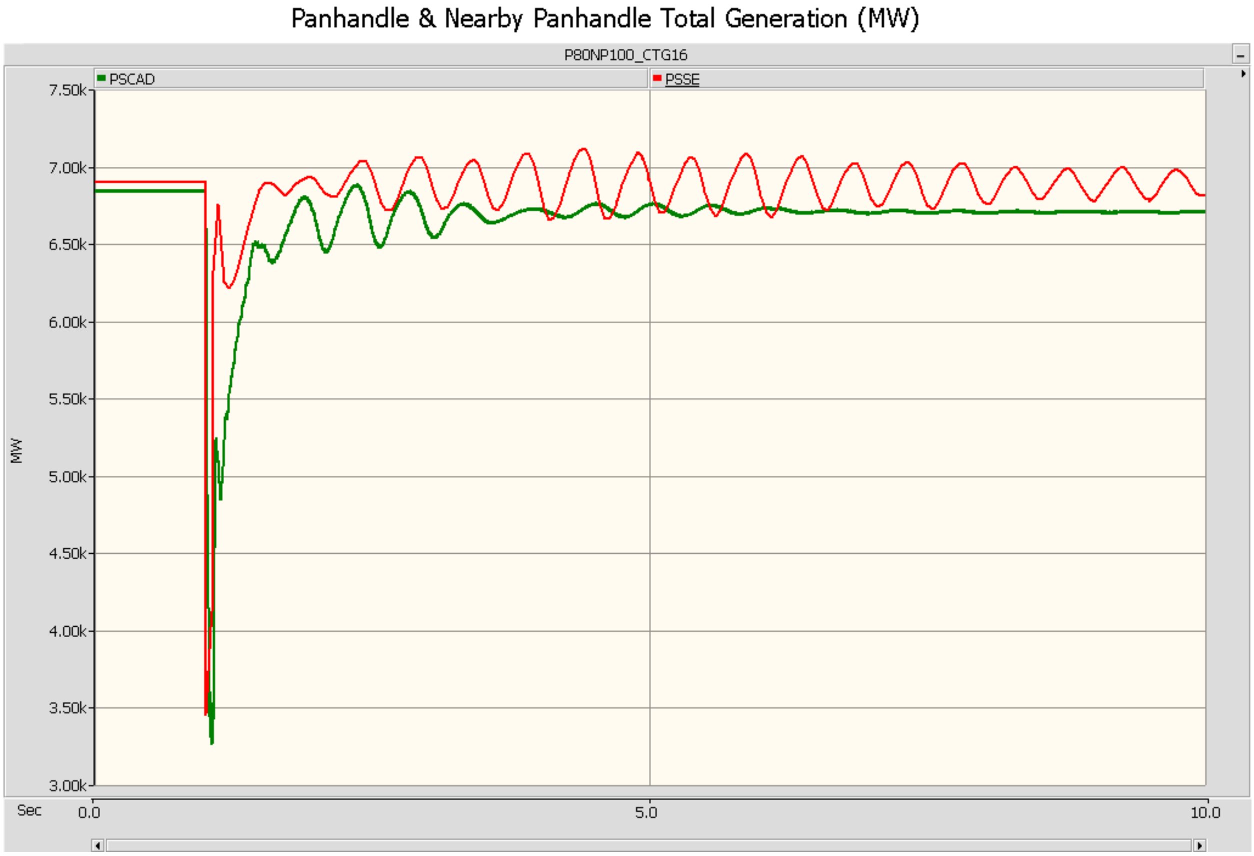

Figure 3: PSS/e and PSCAD Simulation Results Comparison (CTG #16)

The oscillation observed in the PSS/e simulation could be due to the interaction of synchronous condensers in the Panhandle with other synchronous generators far away from the Panhandle region under a high Panhandle and nearby Panhandle dispatch condition with large power transfers to electrically distant load centers. Further analysis was performed for the power oscillation observed in CTG#16 in the PSS/e simulation. Acceptable and well-damped results were observed by reducing the Panhandle WGR dispatch from 80% to 75% (3,888 MW).

It should be noted that most of the conventional generators in West Texas were assumed off-line under the studied high wind output condition. In addition, there is no specifically designed damping support provided or required from the existing wind generation, solar generation, synchronous condensers, or dynamic reactive devices like SVC and STATCOM, in the ERCOT system. As a result, there is limited damping capability in the ERCOT system to damp out the oscillation induced by the synchronous condensers and other synchronous machines. Several sensitivity tests were also conducted to identify potential mitigation options to resolve the oscillation issues.

- One sensitivity assumed the existing SVCs were capable of providing damping support through the power oscillation damping (POD) control function. Enabling the SVC model POD function did not provide a discernable benefit in the P80NP100 case (with Panhandle WGR dispatch at 80%), but slightly improved response was observed when the Panhandle WGR dispatch was at 77% (3,992 MW - corresponding to a WSCR of 1.4). This indicates a potential damping support deficit in the Panhandle and West Texas. Thus, it is recommended to further investigate the feasibility and effectiveness of damping support to be provided by transmission dynamic devices (SVC, STATCOM, and synchronous condenser) and inverter-based resources (wind, solar, and battery).
- Another sensitivity was performed by adding reactive support on the transfer paths in West Texas. In this case, the power oscillation was also damped out when the Panhandle WGRs dispatch was at 77% (3,992 MW). This indicates a potential reactive power deficit along the transfer paths from West Texas to the load centers in ERCOT.
- The dynamic models provided to ERCOT by several WGRs were set to regulate the voltage at the turbine terminal instead of the point of interconnection (POI) or high side of main transformer, as required by Protocol Section 3.15. A sensitivity was tested by revising the models to regulate the voltage at the POI and improved damping was observed in the PSS/e simulations. During the disturbance, the POI voltage would experience lower voltage than the turbine terminal. Therefore, wind turbine controls should respond to the more severe voltage dip and inject more reactive support to the system to assist the system recovery. ERCOT will work with the Resource Entities for those WGRs to ensure that the voltage control point is properly reflected in the dynamic models. In addition, ERCOT is conducting a survey to all of the existing wind and solar Resource Entities to understand their voltage control practices and will work with Resource Entities to improve the voltage controls if needed.

4.3. Planned (With Lubbock Integration)

Both PSS/e and PSCAD simulations were performed to assess Panhandle export limits, including the planned WGRs meeting Planning Guide Section 6.9 requirements for inclusion in the models, for the scenario with the Lubbock Power and Light system integrated into ERCOT. Two Panhandle WGR dispatch levels, 100% and 97.5% were studied in the PSCAD platform with Lubbock integration and nearby Panhandle WGRs fully dispatched in both scenarios. Observations and findings are listed below.

- Although there was no system-wide instability observed in all the tested contingencies in the PSCAD simulation, wind generation tripped and sustained power oscillations were identified under certain tested contingencies.

  - At 100% Panhandle dispatch level, a maximum of three WGRs tripped with total of 700 MW in the Panhandle tripped for four tested double circuit contingencies.
  - At 97.5% Panhandle dispatch level, the observed maximum wind generation tripped was reduced to 450MW for two WGRs.
  - Sustained power oscillation was observed for one WGR in Panhandle for most of the tested contingencies at both dispatch levels.
- While the WGR tripping and power oscillations are still under investigation by the manufacturer, further tests were conducted to assess the impact by assuming the wind trip and oscillations can be addressed by the manufacturer through control adjustments. A test was run assuming those tripped WGRs are able to remain connected during the disturbance. There was no system voltage instability issues identified in the tested PSCAD simulation at both 100% and 97.5% Panhandle dispatch level.
- There was no stability issue identified with Panhandle WGRs at full output under normal system conditions without transmission outages in the PSS/e simulation. No WGRs were tripped in the PSS/e simulation at 100% Panhandle dispatch level. In contrast, three WGRs were tripped in the PSCAD simulation under the same tested system condition. As identified in the previous Panhandle stability studies, the Panhandle is a low system strength area due to a large amount of inverter-based wind generation remote from the ERCOT main grid and synchronous generators. As a result, PSS/e dynamic models need to be used carefully and detailed PSCAD modeling and simulation should be used to benchmark the adequacy of the model and simulation results between PSS/e and PSCAD. As mentioned, ERCOT is working with the Resource Entities and manufacturers to investigate the cause of observed wind trips in the PSCAD simulation results. It should be noted that PSCAD model updates can take months due to model complexity and constraints on the ability of manufacturers to provide technical support to review and update the model.
- The Panhandle GTC is currently determined by real time WSCR calculations and VSAT analysis. The Lubbock integration project provides one additional 345-kV transfer path in the Panhandle region and significantly reduces the electrical distance between the Panhandle and main ERCOT grid as well as providing a load sink close to the Panhandle. In addition, the significant amount of nearby Panhandle renewable generation development further reduces the separation between Panhandle and main ERCOT grid. Based on the dynamic simulation results and the WSCR calculation methodology, the application of WSCR metric in the Panhandle is blurred and may no longer be appropriate to identify Panhandle export limits after the Lubbock integration.
- Based on the simulation results with Lubbock integration and additional new generation to be connected to the Panhandle and nearby Panhandle regions, post-disturbance voltage

thresholds for VSAT analysis may need to be maintained at 0.93 pu (or even higher) across a broader area to ensure consistency with dynamic stability limits.

- There was one outage (Long Draw – Grassland) for which the Panhandle export limit, based on dynamic simulation, could not be adequately captured by VSAT analysis. Since there is no real time dynamic stability tool implemented in the real time operation, a pre-determined Panhandle GTC limit relying on off-line dynamic stability studies will need to be considered as an off-line table to manage Panhandle export under the outage of (Long Draw – Grassland).
- The stability interface is generally defined to maintain an acceptable export power transfer level to avoid instability in the area behind the interface. Due to the improved transmission connectivity and increased renewable generation in the nearby Panhandle, stability challenges may become more complicated and affect both the Panhandle region and the nearby Panhandle region. In other words, one fixed stability interface may no longer be adequate to efficiently manage the stability constraints under various system conditions with the objective to minimize the generation curtailments. However, it may not be feasible to manage multiple interfaces with different interface limits under various system conditions in the operations. Therefore, it is recommended to review the existing operational tools for stability constraint management and identify alternatives to efficiently manage stability limits.

5. Appendix

Station	Panhandle WGR Capacity (MW)	
	Existing (As of May 2019)	Existing + IA Signed & Financial Security Posted (As of March 2019)
Gray 345-kV	463	463
Railhead 345-kV	410	658
Alibates 345-kV	562	562
Tule Canyon 345-kV	350	350
AJ Swope 345-kV	355	355
Windmill 345-kV	893	1046
Ogallala 345-kV	0	303
White River 345-kV	699	980
Cotton Wood 345-kV	257	257
CB_TAP 345-kV	0	210
Total	3989	5184