ERCOT Assessment of Synchronous Condensers to Strengthen the West Texas System

Version 1.0

Document Revisions

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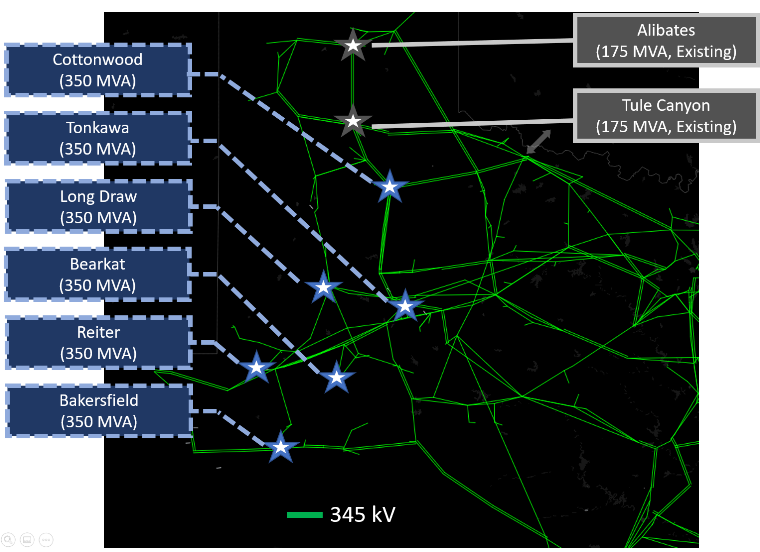
Executive Summary

Inverter-based resources (IBRs) in West Texas have experienced rapid and continued growth. The total capacity of IBRs in West Texas is projected to surpass approximately 42 GW[1] by the end of 2025. The performance of IBRs, such as solar, wind, and energy storage resources, heavily relies on power electronic controls and the strength of the system. The intricate controls of IBRs exhibit rapid responsiveness to even minor system perturbations, which can lead to adverse effects on the system, especially in weak system conditions. In regions like West Texas, the significant prevalence of IBRs coupled with the absence of conventional synchronous generation resources can weaken the system and increase the likelihood of potential instability issues.

In fact, the West Texas region experienced notable disturbances in 2021 and 2022, specifically the Odessa events, which unexpectedly led to a substantial reduction in power output from IBRs triggered by the widespread propagation of low voltages during single-line-to-ground (SLG) fault conditions. In addition, certain IBRs impacted by these events were located relatively far away from the SLG fault location. This observation raises concerns about the potential weakening of the West Texas system. As the penetration of these IBRs increases, the magnitude of the impact during such occurrences is likely to increase and pose a growing and significant reliability risk to the ERCOT system. Proactively addressing these concerns becomes essential to ensure a reliable and resilient system in West Texas.

In addition to various ongoing efforts (e.g., model review and updates based on the event analysis and the approved PGRR085, enhancing operating requirements and model review processes) to minimize such unexpected issues, ERCOT performed a study to strengthen the system in the West Texas region and to address the operational challenges. As a result of the study, ERCOT identified the installation of new synchronous condensers at the Cottonwood, Bearkat, Tonkawa, Long Draw, Reiter, and Bakersfield 345-kV substations. The study results indicated that the implementation of synchronous condensers would effectively bolster the reliability of the West Texas system, make the system more resilient to unexpected events, and address the challenges that may arise in real-time operations. The recommended locations of the synchronous condensers are shown in the map below.



Recommended Locations for Synchronous Condensers in West Texas

[1] West Texas IBRs in operation and meeting Planning Guide 6.9(1) by the end of 2025.

ERCOT recommends the following locations and engineering specifications for the new synchronous condensers:

- Six locations: Cottonwood, Bearkat, Tonkawa, Long Draw, Reiter, and Bakersfield 345-kV substations
- Approximately 350 MVAr capacity at each location
- Around 3,600 Ampere (A) of three-phase fault current contribution to the 345-kV point of interconnection (POI)[2]
- A combined total inertia of 2,000 MW-seconds (MW-s) or above at each location, incorporating synchronous condenser with flywheel
- Effective damping control to meet the ERCOT damping criteria in the Planning Guide Section 4.1.1.6.

ERCOT recommends that the affected TSPs consult with ERCOT if different specifications of the synchronous condensers are considered for implementation.

ERCOT plans to use this study report and TSP's Regional Planning Group (RPG) project submittal(s) in lieu of an ERCOT Independent Review Report. Cost estimate(s) and anticipated in-service date(s) of the recommended synchronous condensers with flywheels will be provided by the TSPs as part of the RPG project submittal(s).

[2] To estimate short circuit contribution from each location, the System Protection Working Group (SPWG) case outlined in Section 2.1.1 was employed. Saturated impedance was used based on ERCOT SPWG Short Circuit Case Building Procedure Manual.

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1. Introduction

Inverter-based resources (IBRs) in West Texas have experienced rapid and continued growth and are transforming the region's energy landscape, as shown below in Figure 1.1. The performance of IBRs, such as solar, wind, and energy storage resources, heavily relies on power electronics controls and the system strength. The controls associated with IBRs are very intricate and rapid, resulting in exceptionally sensitive responses. This sensitivity becomes particularly significant in weaker systems, such as the West Texas region, where IBRs are substantially present and conventional synchronous generation resources are lacking. As a consequence, the system becomes more vulnerable, posing a heightened risk of potential instability issues.

In fact, single-line-to-ground (SLG) fault events resulting in an unexpected significant power reduction of IBRs in the West Texas region were observed in the past two years, i.e., the 2021 and 2022 Odessa events. During these events, certain IBRs located at a considerable distance from the SLG fault location were impacted. ERCOT interprets this occurrence, along with the widespread propagation of low voltage, as a potential indication of the weakening of the West Texas system. As the penetration of IBRs continues to increase, the magnitude of their impact during such events is expected to escalate. Consequently, this poses a growing and significant reliability risk to the ERCOT system, and proactively addressing these concerns becomes essential to ensure a reliable and resilient system in West Texas.

In an effort to proactively address potential operational challenges, ERCOT conducted this study for adding potential synchronous condensers in the West Texas system. The primary objective of this study was to assess the benefit and feasibility of integrating synchronous condensers into the system and determine suitable locations and sizes for optimal effectiveness.

Figure 1.1 illustrates the trends of the cumulative operational and planned IBRs in the West Texas region up to the year 2025 based on the information obtained from the May 2023 GIS Report published in June 2023. Currently, there is approximately 4.9 GW of conventional synchronous generation in the West Texas region, some of the major conventional synchronous generators include Odessa Ector Combined Cycle (1,203 MW), Antelope Elk Energy Center (768 MW), and Graham Power Plant (624 MW). While there is no planned conventional synchronous generation that satisfied Planning Guide 6.9(1) as of June 2023, there has been a significant increase in IBRs in the West Texas region.

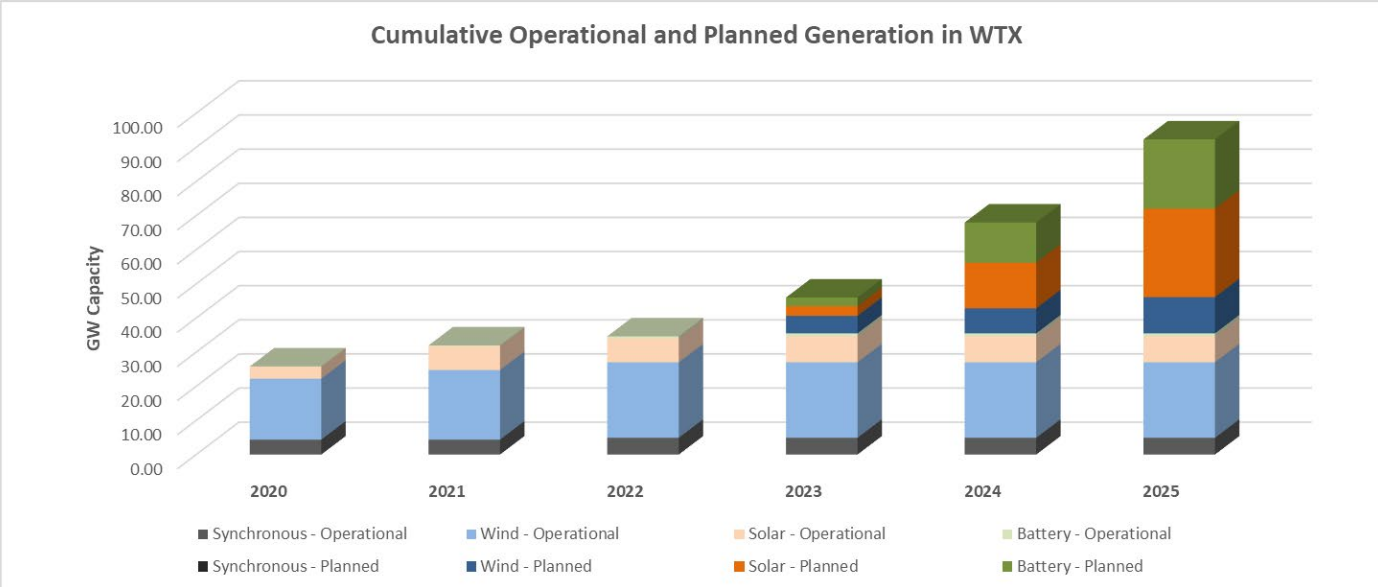


Figure 1.1 Cumulative Operational and Planned[3] Generation Resources in West Texas

In conjunction with this synchronous condenser study, ERCOT is actively engaged in multiple endeavors aimed at improving system stability and enhancing system resilience. One notable initiative is the Nodal Operation Guide Revision Request (NOGRR) 245 that is currently under the Stakeholder review process. NOGRR245 is expected to enhance the fault ride-through requirements associated with IBRs based on the IEEE2800-2022. Additionally, ERCOT and Stakeholders are making collaborative efforts to improve the model review process associated with IBRs, while conducting extensive model review of all existing generation resources based on the approved Planning Guide Revision Request (PGRR) 085. Furthermore, ERCOT is investigating the events that occurred in the Odessa area to implement measures to prevent similar incidents in the future. Through these concurrent efforts, ERCOT is proactively addressing key challenges and implementing measures to minimize such unexpected reliability issues.

[3] Planned Generation Resources includes all generation projects in West Texas under the generation interconnection process.

2. Study Assumptions and Methodology

This section provides an overview of the key assumptions and methodology that ERCOT employed to perform this assessment of the potential synchronous condensers.

2.1 Assumptions

The study region was defined as the ERCOT transmission system in the West Texas (WTX) region, as shown by the highlighted counties in Figure 2.1 below.

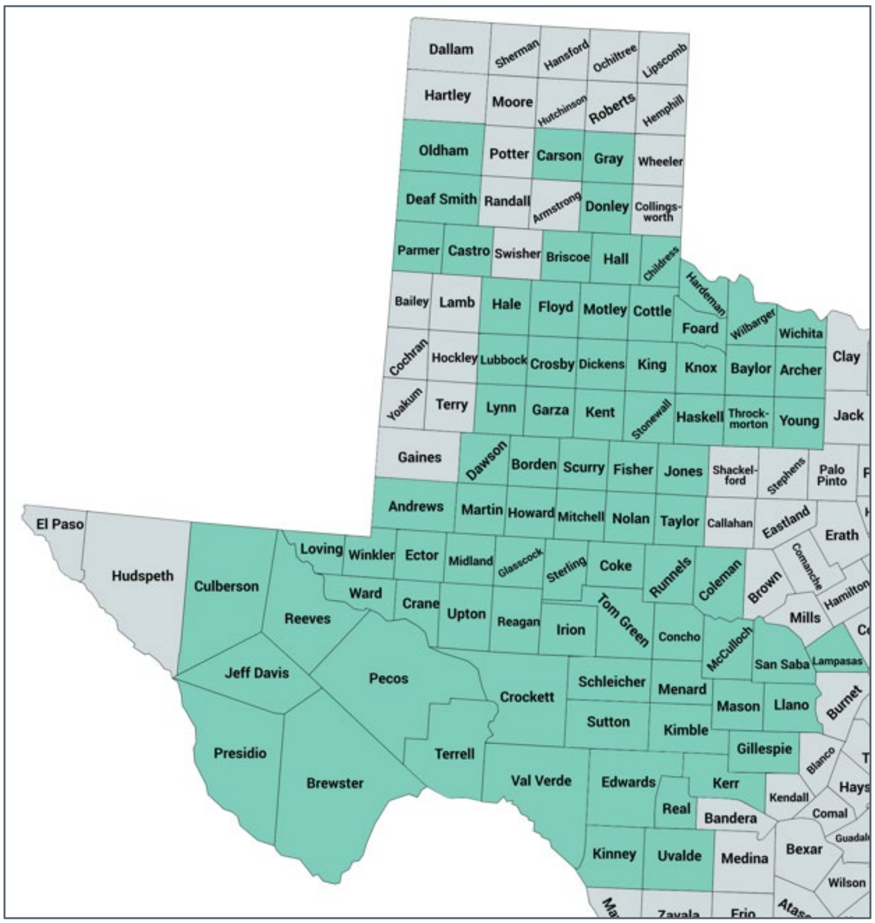


Figure 2.1 Study Region

2.1.1 Reliability Study Cases

The reliability study cases were developed based on the assumptions in the subsequent sections.

2.1.1.1. Base Case

- 2022 Dynamics Working Group (DWG) 2025 High Wind Low Load (HWLL) case
- 2022 System Protection Working Group (SPWG) 2025 Future Year (FY) case

2.1.1.2. Transmission Topology

Transmission system topology is consistent with the base case. In addition, the study region was further updated to incorporate major transmission upgrades identified in the 2022 ERCOT Regional Transmission Plan (RTP) that are scheduled for implementation in 2025 if they were not already modeled in the base case.

The placeholder reactive power support devices that were identified in the 2022 RTP were also modeled in the study case to address the potential steady-state voltage issues in the local areas of the Far West Texas (FWTX) region, as shown below in Table 2.1.1. The study case assumed a 350 MVAr synchronous condenser at the Reiter 345-kV substation to meet the common reactive power support need between the 2022 RTP and ERCOT Operations assessment. The selection of Reiter as the installation location was based on feedback received from Transmission Service Providers (TSPs), the identification of reactive power support devices in the 2022 RTP, and the proximity of Reiter to the Odessa location.

Table 2.1.1 Placeholder Reactive Power Support Upgrades Modeled in 2022 RTP

Weather Zone	MVAr
Far West	2,238

The Delaware Basin Stage 2 upgrade (i.e., the Bearkat – North McCamey – Sand Lake 345-kV transmission line addition) endorsed in 2022 by the ERCOT Board of Directors is expected to be in-service in 2026. Therefore, this major transmission upgrade was not modeled in the study case. A sensitivity of adding this project is discussed in section 6.2.

2.1.1.3. Generation

The list of generators in Table 2.1.2 that met Planning Guide Section 6.9(1) and (2) for inclusion in the planning models at the time of the study were added to the study region based on the January 2023 Generation Interconnection Status (GIS) report published in February 2023.

Table 2.1.2 List of New Generation Based on GIS Published in February 2023

GINR	Project Name	Fuel Type	Projected COD	Capacity (MW)
20INR0120	Vortex Wind	Wind	2/23/2023	350
20INR0249	Appaloosa Run Wind	Wind	4/29/2023	175
20INR0268	Pyron BESS II	Battery	3/15/2023	30
20INR0269	Texas Solar Nova 2	Solar	12/29/2023	201
21INR0401	Young Wind	Wind	4/1/2023	499
21INR0473	Vortex BESS	Battery	3/14/2023	122
22INR0326	Inertia Wind	Wind	4/28/2023	301
22INR0328	Inertia BESS	Battery	10/31/2023	13
22INR0360	Jade Solar	Solar	6/30/2023	327
22INR0363	Hayhurst Texas Solar	Solar	11/1/2023	25
22INR0372	BRP Hydra BESS	Battery	8/1/2023	202
22INR0384	BRP Pavo BESS	Battery	8/1/2023	177
22INR0412	Andromeda Solar	Solar	6/30/2023	327
22INR0485	House Mountain	Battery	5/31/2023	63
23INR0371	Rodeo Ranch Energy Storage	Battery	7/17/2023	307

Generation in the study region was dispatched according to Table 2.1.3. All conventional synchronous generation in the WTX region was turned offline to represent stressed system conditions, i.e., high penetration of IBRs and no online conventional synchronous generation resources in the WTX region. The dispatch level of IBRs in the WTX region was determined based on the following dynamic stability analysis:

- Uniformly increase the power output from IBRs in the WTX study region to stress the WTX interface (power transfer from WTX to the rest of the system) until the system goes unstable under critical NERC P1 or P7 events associated with the WTX Generic Transmission Constraint (GTC) interface.
- The critical dispatch level (maximum stable dispatch) was modeled as the initial IBR dispatch level in the study case, as shown in Table 2.1.3.

Table 2.1.3 WTX Study Region Generation Dispatch

Fuel Type	Dispatch
Solar	70%
Wind	70%
Energy Storage	70%
Conventional	Offline

2.1.1.4. Loads

Large loads in the WTX study region were updated to be consistent with the 2022 RTP. Load updates were needed for the various ERCOT regions that make up the WTX study region, as shown below in Table 2.1.4.

Table 2.1.4 Large Loads Modeled in the WTX Study Region

Weather Zone	Load (MW)
Far West	2,529
North	2,400
West	200

2.2 Methodology

ERCOT utilized the study cases developed based on the assumptions in Section 2.1. These study cases were then utilized to conduct a range of analyses, primarily focusing on reviewing operational challenges and assessing the benefits associated with the potential integration of synchronous condensers. The analyses encompassed system strength analysis, voltage dip analysis, and dynamic stability analysis. The subsequent sections provide a detailed description of the methodologies employed in these analyses.

2.2.1 System Strength Analysis

A system strength analysis was performed with the goal of confirming the locations of the synchronous condensers identified in the ERCOT Operations assessment. System strength is usually measured by short-circuit current (or MVA). ERCOT's weighted short-circuit MVA (WSCMVA) is proposed in this study:

$$WSCMVA = \frac{\sum_{k=1}^{n} SCMVA_k * P_{GK}}{\sum_{k=1}^{n} P_{GK}}$$

where:

$SCMVA_k$: short-circuit MVA at the POI of the k-th IBR in WTX

P_{GK}: the capacity (MW) of the k-th IBR in WTX

The locations of the synchronous condensers were adjusted, as needed. The general steps for performing the system strength analysis were to:

1. Apply a three-phase (3PH) fault and record system strength at all individual WTX 345-kV buses in the DWG study case using the WSCMVA.
2. Add a synchronous condenser at each bus on all major WTX 345-kV buses and record system strength. Repeat this step for all individual 345-kV buses in the WTX study region.
3. Confirm and adjust the locations of synchronous condensers identified in the ERCOT Operations assessment.

2.2.2 Voltage Dip Analysis

A voltage dip analysis was performed using the latest System Protection Working Group (SPWG) case built for the year 2025 with the objective to confirm or adjust the locations of the synchronous condensers identified in the system strength analysis. The SPWG study case was used to assess voltage dip via short circuit fault analysis. The DWG study case was also used to assess voltage dip via dynamic stability analysis by applying a fault near the Odessa area. All conventional synchronous generators were turned offline. The synchronous condensers identified in the system strength study were modeled to perform the impact analysis. All IBRs in the WTX study region are assumed to provide negligible short circuit contributions. The general steps for performing the voltage dip analysis were to:

1. Apply a SLG fault on all major WTX 345-kV buses with and without the synchronous condensers modeled.
2. Review 345-kV and 138-kV bus voltages in the WTX study region.
3. Check for any bus voltages less than 0.85 p.u., as this is the assumed voltage ride-through mode trigger threshold.
4. Identify if adding more synchronous condensers would provide a significant benefit.
5. Perform a dynamic stability analysis by testing critical 345-kV SLG events near the Odessa area with and without synchronous condensers to further assess the benefit.

The voltage dip analysis evaluated the impact of fault conditions on the voltage levels at major 345-kV WTX buses, and IBR generation terminals in the WTX study region.

2.2.3 Dynamic Stability Analysis

Dynamic stability simulations were conducted using the DWG study case to further assess the reliability benefits of the synchronous condensers. NERC Category P1 and P7 contingencies associated with the WTX interface and contingencies near the synchronous condenser locations were evaluated.

2.2.4 Study Tools

ERCOT utilized the following software tools to perform the study:

- PSSE versions 33 and 35
- PowerWorld Simulator version 22

3. Project Need

Over the past seven years, several system disturbances related to Inverter-Based Resources (IBRs) have been observed in the United States. Among these disturbances, three have occurred within ERCOT, as depicted in Figure 3.1. Notably, two of these events took place in the Odessa area, which falls within the WTX region. These events, known as the Odessa Disturbance events, occurred in May 2021 and June 2022 within ERCOT. They were characterized by SLG system faults that resulted in a substantial loss of generation from multiple solar farms located in the WTX region. Table 3.1 summarized the reductions of the power output associated with the IBRs during the two events. With the remarkable expansion of IBRs, particularly solar generation within ERCOT over the past few years, and the expectation of continued growth, there is a heightened potential for these events to amplify in magnitude, thereby posing significant reliability risks to the system.

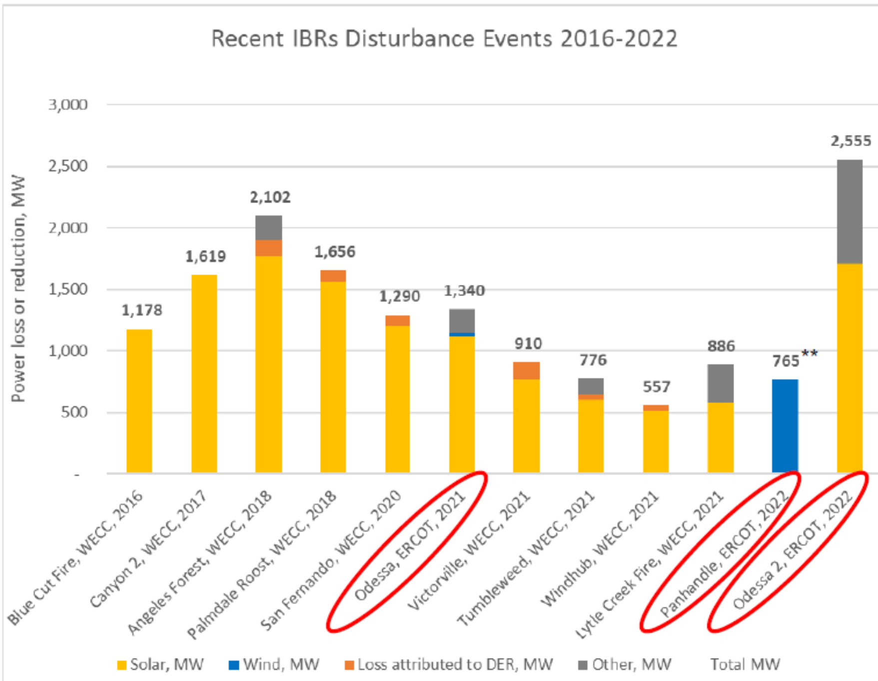


Figure 3.1. Historical IBR Disturbance Events (2016-2022)

Table 3.1 Reductions of MW Output by IBR Unit Type During the Odessa Events

Plant Type	MW Loss in 2021 Odessa Event	MW Loss in 2022 Odessa Event
Solar	1,112	1,711
Wind	36	-

Figure 3.2 depicts the generation interconnection projects by fuel type as of April 2023, showing a significant transition towards solar and energy storage resources (ESR). This shift highlights the evolving energy landscape in ERCOT, while also acknowledging the continued presence of wind projects in the generation interconnection pipeline.

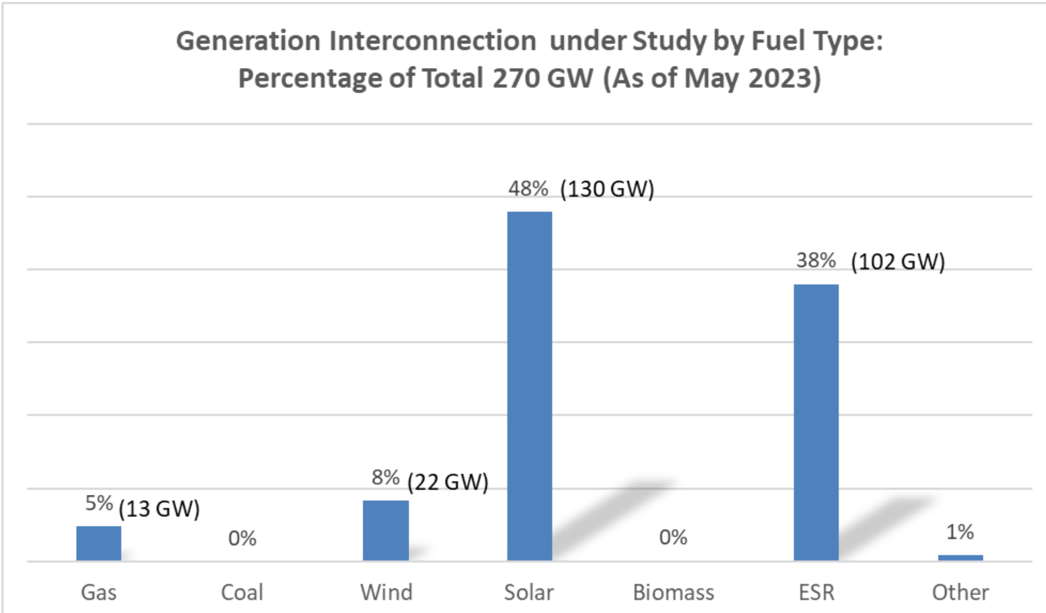


Figure 3.2. Generation Interconnection Projects by Fuel Type (Source: GIS_Report_May_2023)

The 2021 and 2022 Odessa events prompted NERC to issue a Level 2 alert on March 14, 2023, identifying them as systemic performance issues with the potential for unexpected losses of Bulk Power System (BPS)-connected generation. In light of these events, NERC recommended that any performance deficiencies in existing and future generation resources be promptly and effectively addressed to ensure the reliable operation of the power system in an efficient manner.

Following the 2021 Odessa event, ERCOT has also intensified its efforts to analyze the underlying causes of inverter tripping during such occurrences. The aim is to identify potential corrective measures that can enhance the ride-through performance of IBRs, strengthening the system's overall resilience. In February 2023, ERCOT Operations suggested integrating potential synchronous condensers at six locations in the WTX region to enhance system reliability and resilience. This initiative aimed to tackle operational challenges arising from unexpected generation or load loss during disturbances, while also strengthening the transmission system.

Based on the need drivers, ERCOT Planning conducted this study to assess operational challenges, evaluate the impact of synchronous condensers, and make recommendations to address these challenges effectively.

4. Project Option Evaluation

The high penetration of IBRs and the absence of conventional synchronous generation resources can weaken the system, increasing the risk of potential system instability and higher likelihood of triggering IBRs into ride-through mode during widespread voltage dips. The observed challenges during the Odessa events in the WTX region highlight the potential impact of system reliability and the need for mitigation.

Such system challenges in the WTX region can be improved through various options such as adding conventional synchronous generators, synchronous condensers, and other technologies (e.g., STATCOMs and grid-forming inverters). In this study, ERCOT considered adding synchronous condensers in the WTX region as the only transmission upgrade option because the installation of synchronous condensers can provide the necessary characteristics for supporting the reliable operation of a system with a high penetration of IBRs. The key characteristics of synchronous condensers include the following:

- Synchronous condensers' response to system disturbances is governed by the physical characteristics of the devices, which makes them more reliable and predictable than other device technologies that have a response based more on their control system programming. Inverter-based technology like grid-following inverters and STATCOMs are both based on power electronics control, which can be more susceptible to system conditions and unpredictable.
- Synchronous condensers are rotating machines, providing a strong system inertia which is important to keep the system frequency stable.
- Synchronous condensers provide dynamic reactive power support on the system by absorbing or generating reactive power as needed.
- Synchronous condensers improve system strength and increase fault current which is beneficial for the proper functioning of IBRs.
- Synchronous condensers are a mature technology with a long history of successful use.
- Synchronous condensers are being considered and implemented globally by the utility and system operators with a high penetration of IBRs. In addition, various countries in Europe (e.g., Germany, Latvia, Lithuania, UK, Ireland, Estonia, and Italy) are considering and have already implemented synchronous condensers augmented with flywheels in the last several years to improve the reliability of their systems.
- Flywheels, mechanically linked with synchronous condensers via couplings, provide additional inertia and are beneficial for frequency support. This addition is a valuable measure to prepare for uncertain system conditions that may arise in ERCOT.
- Two synchronous condensers were installed in 2018 in the ERCOT Panhandle region to provide the required voltage and system strength support. With the amount of existing and projected growth of IBRs, the need for the similar improvement has been identified for the broader WTX region.

4.1 Results of System Strength Analysis

ERCOT performed the system strength analysis based on the methodology outlined in Section 2.2.1 to evaluate the impact on the system strength by adding a synchronous condenser at each bus on all major WTX 345-kV buses. ERCOT repeated this step for all individual 345-kV buses in the WTX region and ranked those buses in terms of the WSCMVA.

According to the study results, there is an estimated average enhancement of 11% in the system strength within the WTX region. Based on the results of the system strength analysis, the 345-kV substations which ranked as the most suitable locations for the installation of new synchronous condensers were Cottonwood, Bearkat, Tonkawa, Long Draw, Reiter, and Bakersfield. These substations exhibited a higher average WSCMVA ranking compared to other substations in the WTX region.

4.2 Results of Voltage Dip Analysis

ERCOT performed a voltage dip analysis based on the methodology outlined in Section 2.2.2. A SLG fault was tested on all major WTX 345-kV buses with and without the synchronous condensers modeled to further assess the impact on the voltages at all WTX 345-kV buses and IBR terminals.

The results of the voltage dip analysis aligned with the findings of the system strength analysis, confirming the suitability of the 345-kV Cottonwood, Bearkat, Tonkawa, Long Draw, Reiter, and Bakersfield substations as effective locations for synchronous condensers. Synchronous condensers at these substations demonstrated their ability to mitigate voltage dips throughout the WTX region effectively, thereby minimizing the widespread voltage dips during fault events. This convergence of results from both analyses strengthens the case for selecting these substations as appropriate locations for synchronous condensers.

According to the study results, there is an estimated average reduction of 21% in the number of 345-kV and 138-kV buses and 22% in IBRs that encounter severe voltage dips (less than 0.85 p.u.) during major transmission faults in the WTX region. Figure 4.2.1 shows the voltage contour comparison illustrating a significant benefit of the synchronous condensers by mitigating the widespread voltage dip under a SLG fault in the Odessa area.

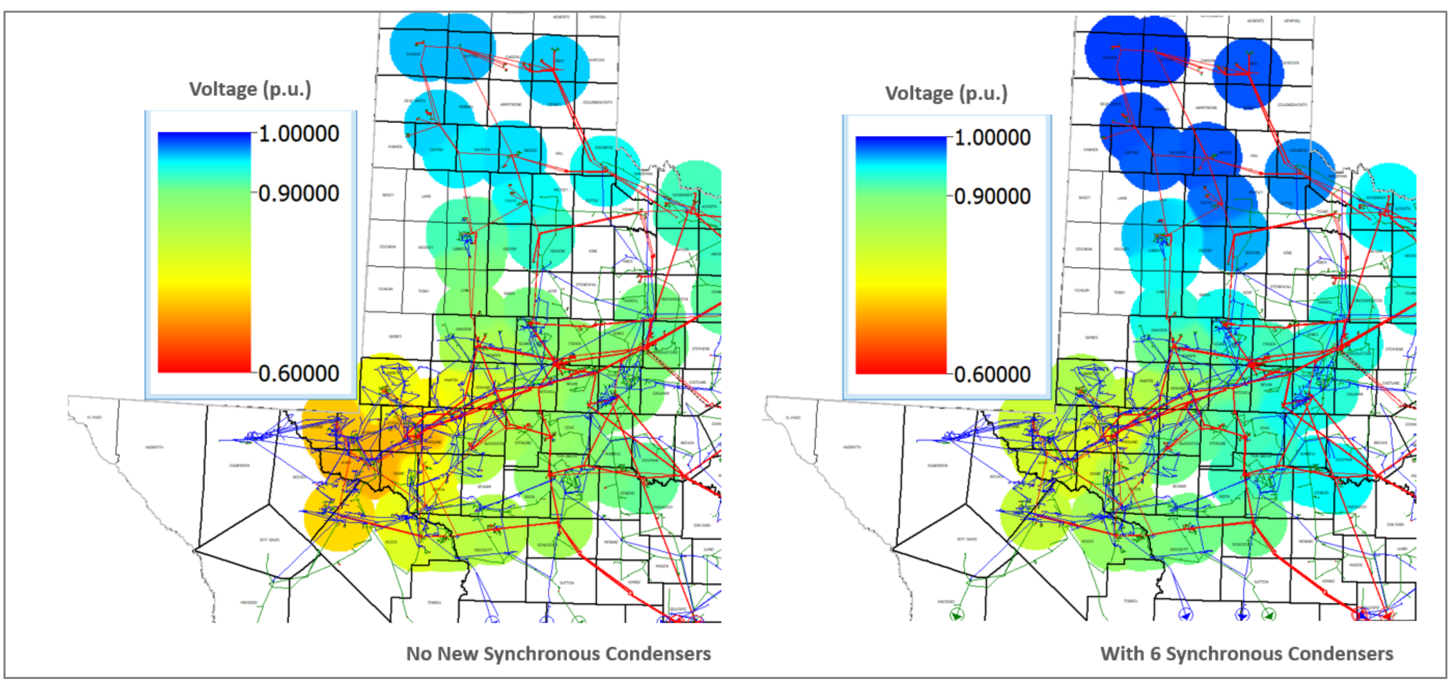


Figure 4.2.1 345-kV WTX Bus Voltage Profile Contour with a SLG Fault at Odessa-area 345-kV Bus

4.3 Results of Dynamic Stability Analysis

ERCOT tested SLG fault events at Odessa and other synchronous condenser locations with and without the potential synchronous condensers modeled in order to mimic the Odessa events and further assess any potential operational benefit. ERCOT also evaluated critical NERC P1 and P7 events with and without synchronous condensers to assess any potential reliability benefits.

The results of the stability analysis show no adverse impacts caused by the addition of the synchronous condensers and demonstrated improved stability, as depicted by the representative plots discussed below.

The plots in Figure 4.3.1 are representative of bus voltages for a critical NERC P1 contingency with a 3PH fault applied around a particular 345-kV substation in WTX. There is a notable reduction in voltage dip and voltage overshoot, and an improvement in voltage response during 3PH fault conditions, which can potentially lead to a reduction in unexpected generation tripping during critical events that occur under stressed system conditions.

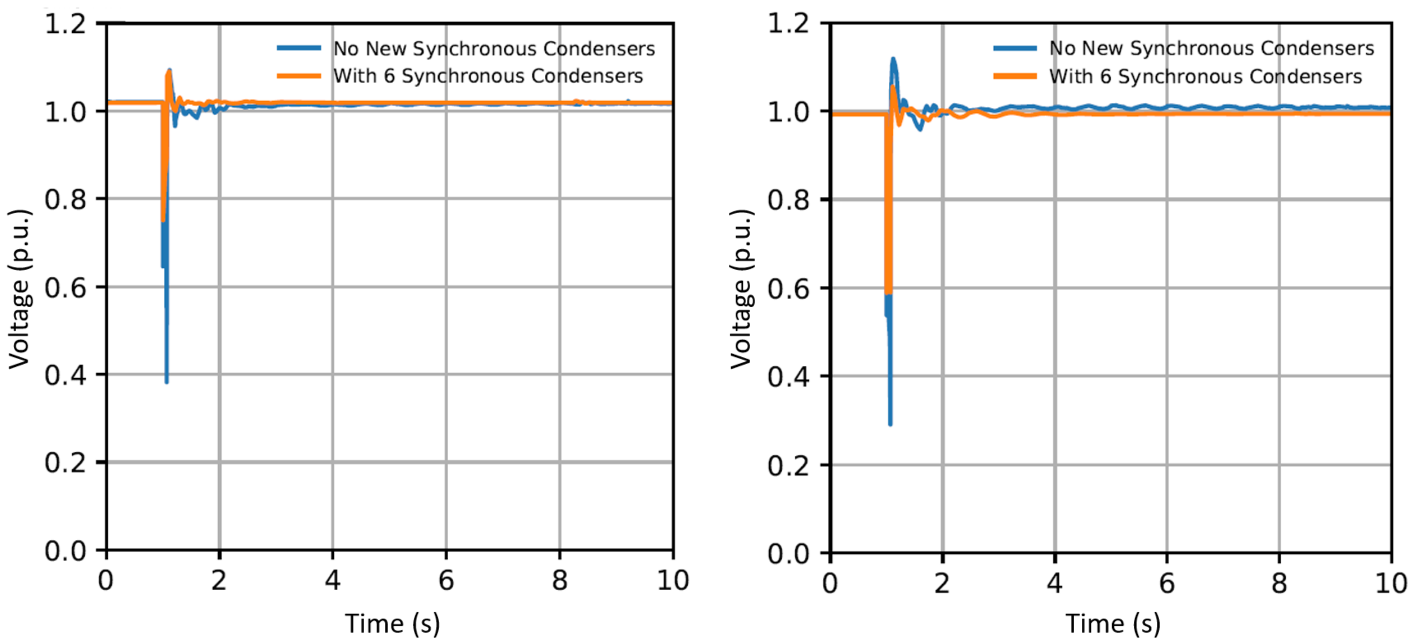


Figure 4.3.1 345-kV Bus Voltage Comparison for P1 (3PH) at the WTX Interface

The additional plots below are representative of bus voltages for a P7 contingency with a SLG fault applied around a particular 345-kV substation in WTX. Similarly, the results reveal a reduction in voltage dip and voltage overshoot during SLG fault conditions, as shown below in Figure 4.3.2.

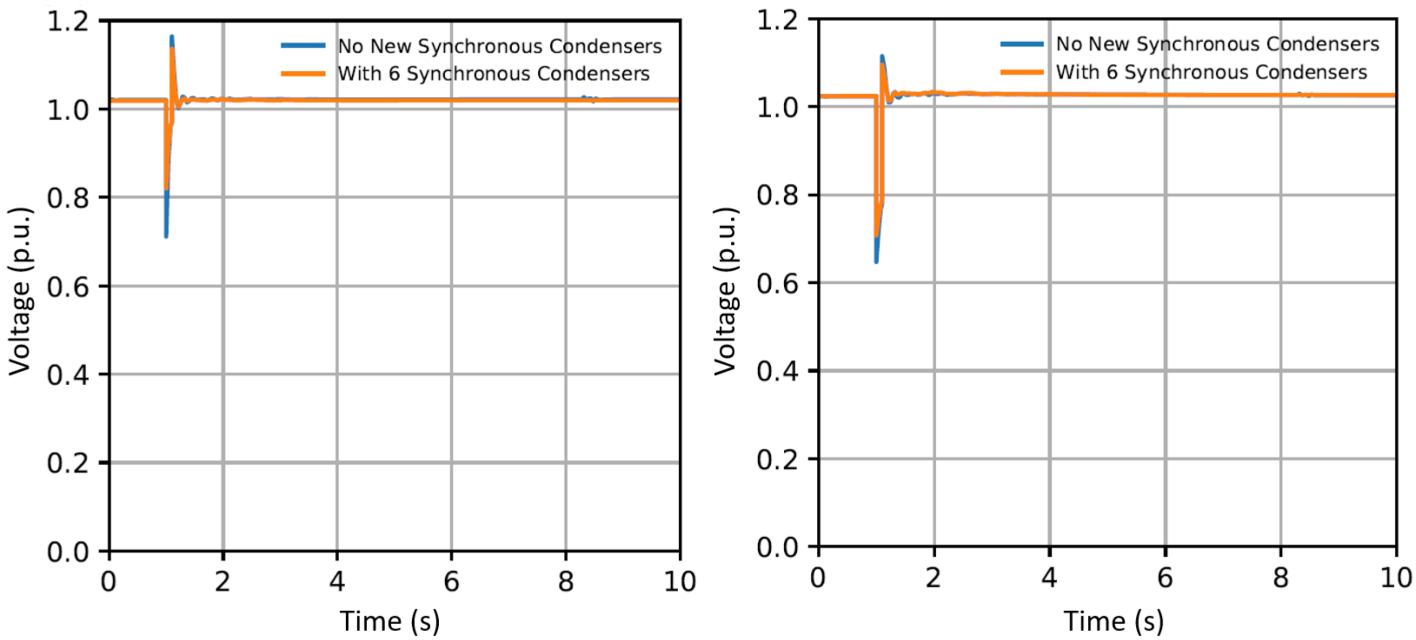


Figure 4.3.2 345-kV Bus Voltage Comparison for P7 (SLG) at the WTX Interface

5. Sub-Synchronous Oscillation (SSO) Assessment and Sensitivity Studies

For the potential synchronous condensers identified in this study, an SSO assessment was performed to identify any adverse impacts to the system in the study region. In addition, sensitivity studies were performed to identify the performance of the synchronous condensers under certain sensitivity scenarios.

5.1 SSO Assessment

Pursuant to Nodal Protocol Section 3.22.1.3, ERCOT conducted an SSO screening for the potential synchronous condensers. The results of the topology check indicated that all the synchronous condenser locations except at the Reiter 345-kV substation are considered to be potentially vulnerable to SSO. Therefore, a detailed SSO assessment is recommended, and the affected TSPs shall coordinate with ERCOT to perform and complete a detailed SSO assessment and provide any SSO Mitigation, if required, prior to energization of synchronous condensers.

5.2 Planning Guide Section 3.1.3(4) Sensitivity Studies

It is anticipated that the transmission upgrades (i.e., new synchronous condensers at six locations) is categorized as a Tier 1 project, pursuant to ERCOT Protocol 3.11.4.3. As required by Planning Guide Section 3.1.3 (4), ERCOT also performed generation and load sensitivity studies.

5.2.1 Generation Addition Sensitivity Analysis

Upon reviewing the May 2023 GIS Report published in June 2023, ERCOT concluded that conducting a generation sensitivity analysis is not required. This determination was made based on the fact that, apart from IBRs, there are no conventional synchronous generation resources that have a signed Standard Generation Interconnection Agreement (SGIA) that were excluded from the study cases.

5.2.2 Load Scaling Sensitivity Analysis

Planning Guide Section 3.1.3(4)(b) requires evaluation of the potential impact of load scaling on the criteria violations seen in this ERCOT independent review. ERCOT concluded that the load scaling would not have a material impact on the project need because of the following reason:

- The short circuit system strength and inertia primarily depend on the characteristics of the generation resources and the overall design of the power system. Load, on the other hand, is typically considered as a passive element in the system. While load plays a crucial role in determining the power flow and voltage levels within the system, it does not have a substantial influence on system strength and inertia.

6. Other Considerations

Further assessments were carried out to evaluate the potential effects of the new synchronous condensers on the existing GTCs and the conceptual long-term WTX improvement option[4]. ERCOT also conducted an analysis to evaluate the effectiveness of incorporating additional synchronous condensers or modifying their functional specifications. These analyses were undertaken to comprehensively understand the potential impacts and benefits of the new synchronous condensers.

6.1 West Texas and McCamey GTC Limit Impact Analysis

6.1.1 Impact on West Texas GTC

ERCOT performed dynamic stability studies utilizing the DWG study cases to assess the effect of the potential new synchronous condensers on the WTX GTC limit. The findings from the studies indicate that the WTX GTC limit was not significantly affected. Moving forward, the WTX GTC will undergo continuous review and updates in the future Quarterly Stability Assessments (QSAs) to ensure its accuracy and relevance.

6.1.2 Impact on McCamey GTC

ERCOT carried out dynamic stability studies using the most recent QSA case to analyze the influence of the potential new synchronous condensers on the existing McCamey GTC limit. The study findings indicate an anticipated average improvement of 15% in the McCamey GTC limit with the inclusion of the synchronous condensers. However, the extent of improvement may vary based on specific events and prior outage conditions. Moving forward, the McCamey GTC will undergo regular review and updates in future QSAs to ensure its accuracy and relevance.

6.2 Impact on the Delaware Basin Stage 2 Transmission Upgrades

ERCOT performed system strength and dynamic stability sensitivity analyses by modeling the Delaware Basin Stage 2 upgrade (i.e., the Bearkat – North McCamey – Sand Lake 345-kV Transmission Line Addition) in the DWG study case to evaluate the potential impacts on the locations of the new synchronous condensers. The Stage 2 upgrade was endorsed in 2022 by the ERCOT Board of Directors and is expected to be in-service in 2026.

The analysis revealed that none of the chosen locations were adversely affected by the transmission upgrades. However, it was observed that the 345-kV Bearkat location became even more advantageous due to the additional connections to the transmission system.

6.3 Impact on Long-Term West Texas Improvement Option

ERCOT utilized the previous 2030 HWLL study case from the ERCOT Long-term WTX Export study[4], specifically focusing on modeling the Option 1 (4AC upgrades), to evaluate the impact of the new synchronous condensers by testing select critical NERC P7+P7 contingencies. The results of this study found no adverse impacts on the potential long-term WTX export option and only showed similar system improvements to those observed in the previously conducted analysis. As shown in Figure 6.3.1, the inclusion of the new synchronous condensers in the 2030 HWLL study case showed the benefits of enhanced system performance under fault conditions.

[4] Long-Term West Texas Export Study Report: https://www.ercot.com/gridinfo/planning

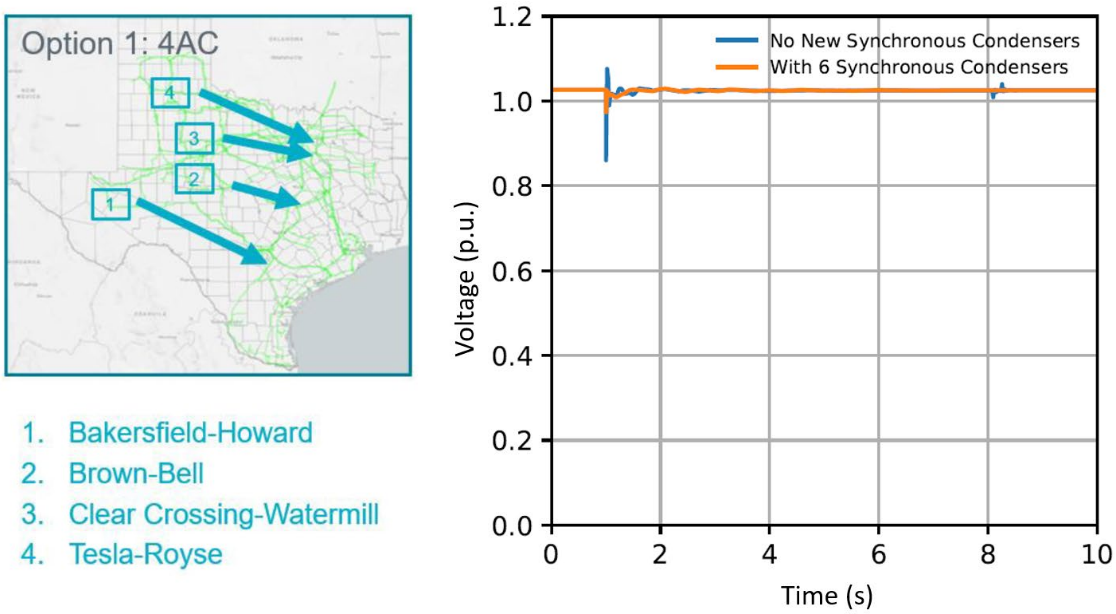


Figure 6.3.1 Long-Term WTX Export Improvement Option and Effects of Synchronous Condensers

6.4 Impact of Additional Synchronous Condensers

Based on the results of the system strength and voltage dip analyses, it has been determined that installing new synchronous condensers at the six locations is adequate and the potential benefit of adding more would likely diminish. By strategically placing new synchronous condensers in WTX, the system can effectively manage fault conditions and mitigate voltage dips. However, beyond this threshold, the benefits of additional synchronous condensers may diminish due to factors such as diminishing marginal gains in voltage dip improvement, as observed in the plots below.

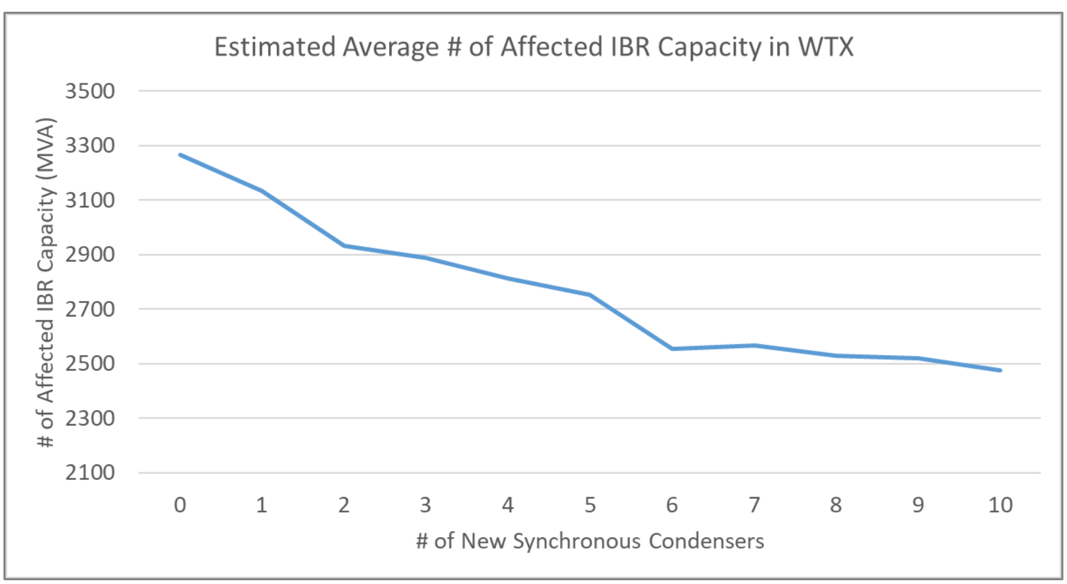


Figure 6.4.1 Diminishing # of Affected IBR Capacity with Additional Synchronous Condensers at Clear Crossing, Big Hill, Divide, and Dermott 345-kV substations

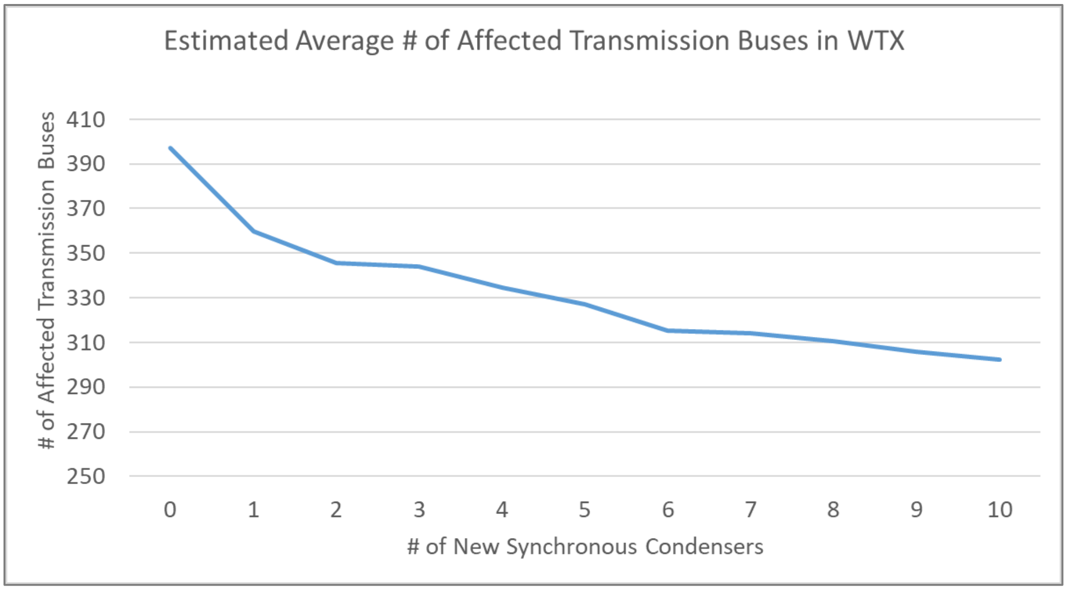


Figure 6.4.2 Diminishing # of Affected Transmission Buses with Additional Synchronous Condensers at Clear Crossing, Big Hill, Divide, and Dermott 345-kV substations

6.5 Impact of Synchronous Condenser Functional Specifications

The results of the system strength, voltage dip, and dynamic simulations support the selection of a 350 MVA size for the new synchronous condensers, favoring it over a smaller capacity of 175 MVA, as observed in the plots below. Considering these analyses, a synchronous condenser with a capacity of 350 MVA proves beneficial. Its larger capacity allows for enhanced system strength, voltage dip mitigation, and improved transient stability response. The higher capacity of the synchronous condensers provides a greater margin of reliability and flexibility, ensuing a robust and resilient system operation even under more stressed conditions.

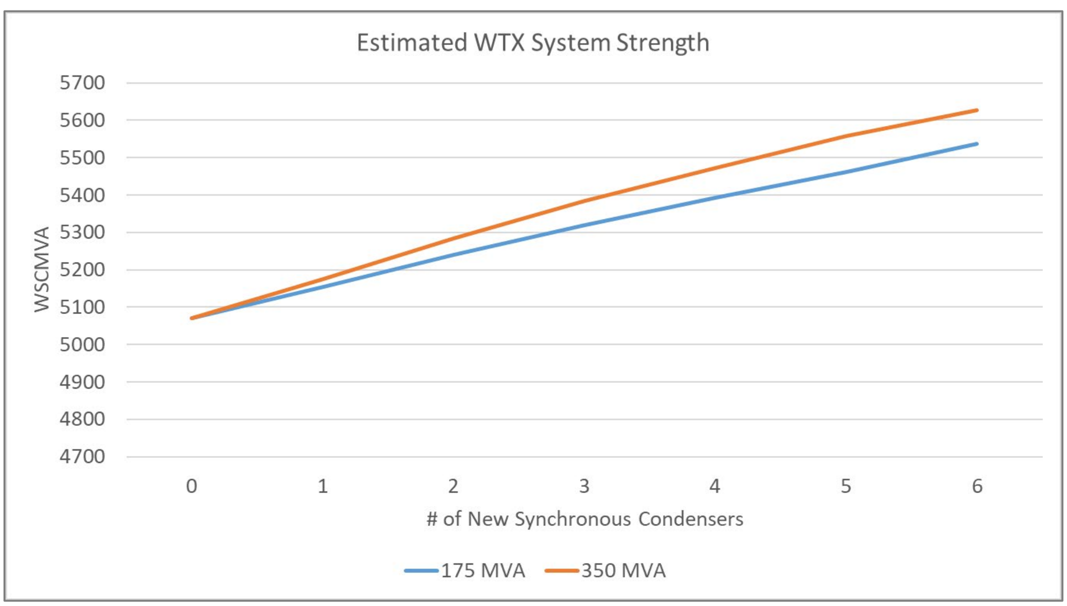


Figure 6.5.1 System Strength Results (175 MVA vs 350 MVA)

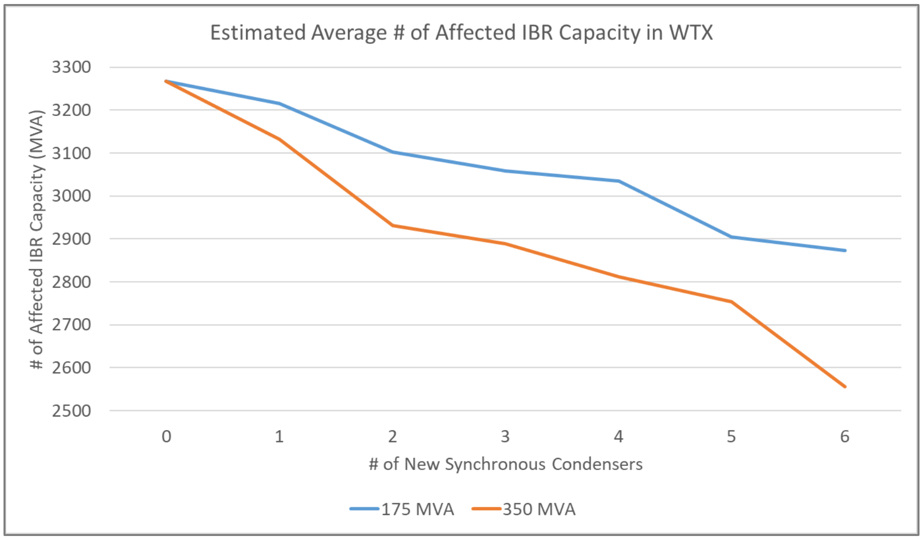


Figure 6.5.2 Voltage Dip Results Measured as IBR Capacity (175 MVA vs 350 MVA)

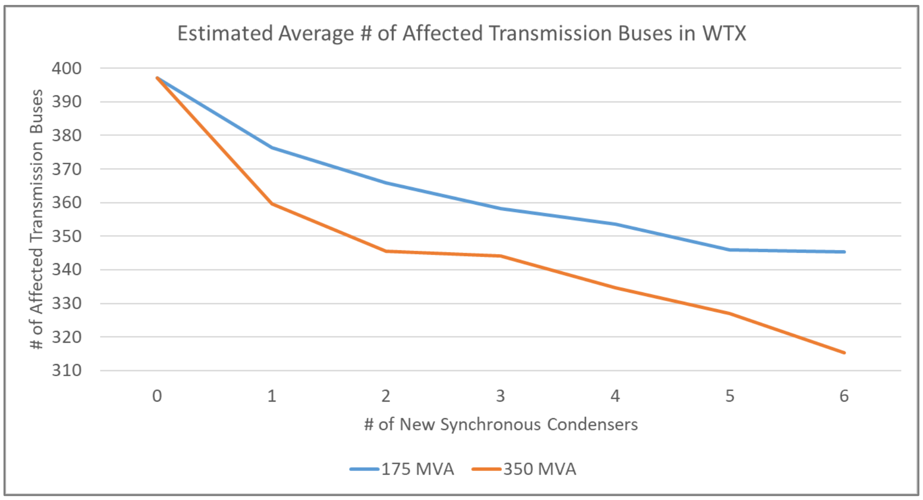


Figure 6.5.3 Voltage Dip Results Measured as Affected Transmission Buses (175 MVA vs 350 MVA)

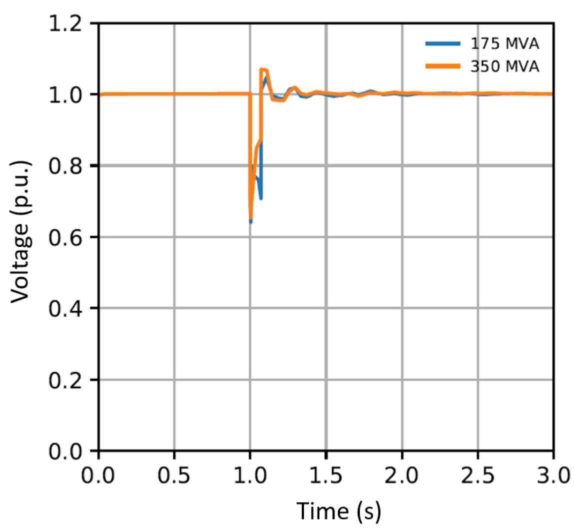


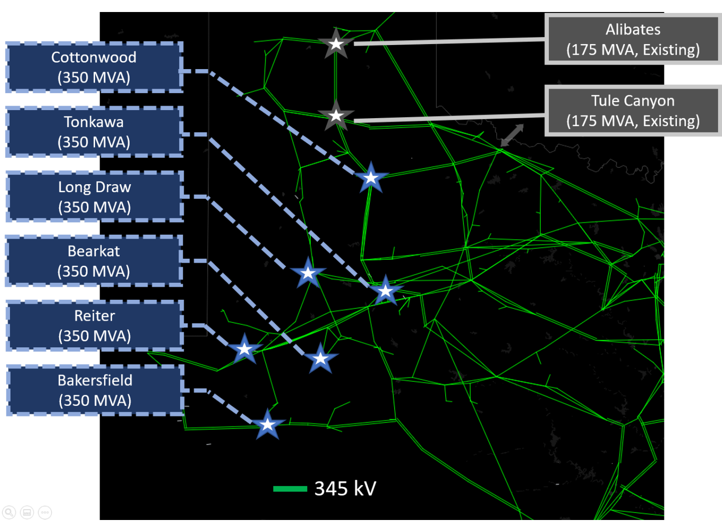
Figure 6.5.4 345-kV Bus Voltage Comparison for P1 (3PH) at the WTX Interface (175 MVA vs 350 MVA)

7. Conclusion and Recommendation

The findings of this study indicated that new synchronous condensers at the six locations with a total of 2,100 MVA will improve the reliability and resilience of the WTX system. The 345-kV substations at Cottonwood, Bearkat, Tonkawa, Long Draw, Reiter, and Bakersfield were identified as effective locations for the installation of a synchronous condenser. Firstly, the new synchronous condensers at these substations exhibited a high relative ranking compared to other locations in terms of average WSCMVA in the WTX region. Additionally, these locations are strategically spaced apart, avoiding proximity to existing synchronous condensers, which ensures optimal distribution of reactive power support across the WTX region. These locations provide support for a broad number of faults across the WTX region and provide a significant improvement in system responses for critical faults even under stressed system conditions, as demonstrated by the results of the voltage dip and stability simulations. Moreover, these substations have a significant number of major transmission connections, indicating their importance as key hubs within the system. Lastly, the feasibility of installing synchronous condensers at each substation was evaluated and determined to have adequate space by the affected TSP(s). Both these improvements on the transmission system and continued focus on improving IBRs' capability and performance are needed to maintain the reliable operation of the ERCOT system. Additional system improvements will be required to support the continued growth of IBRs in the ERCOT system.

ERCOT recommends the following locations and engineering specifications for the new synchronous condensers:

- Six locations: Cottonwood, Bearkat, Tonkawa, Long Draw, Reiter, and Bakersfield 345-kV substations
- Approximately 350 MVAr capacity at each location
- Around 3,600 Ampere (A) of three-phase fault current contribution to the 345-kV point of interconnection (POI)[2]
- A combined total inertia of 2,000 MW-seconds (MW-s) or above at each location, incorporating synchronous condenser with flywheel
- Effective damping control to meet the ERCOT damping criteria in the Planning Guide Section 4.1.1.6.



Recommended Locations for Synchronous Condensers in West Texas

ERCOT recommends that the affected TSPs consult with ERCOT if different specifications of the synchronous condensers are considered for implementation.

ERCOT plans to use this study report and TSP's RPG project submittal(s) in lieu of an ERCOT Independent Review Report. Cost estimate(s) and anticipated in-service date(s) of the recommended synchronous condensers with flywheels will be provided by the TSPs as part of the RPG project submittal(s).