West Texas Export Stability Assessment

Version 1.0

Document Revisions

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1. Executive Summary

Several recent studies[1] have indicated the potential for West Texas export constraints due to the addition of wind and solar generation in the region. Based on the Generation Interconnection Status report[2], the continued growth of wind and solar generation in West Texas is expected.

The purpose of this study was to analyze the stability of the ERCOT transmission system, with the year 2022 transmission topology, for high wind and solar generation dispatch conditions, including the existing and planned wind and solar generation projects which met Planning Guide 6.9 requirements at the time this study was conducted.

Since most of the wind and solar generation in ERCOT is located in the western part of the grid, this assessment focused on West Texas and on the power flows on the following selected sixteen 345 kV lines connecting western regions to the rest of ERCOT to represent the West Texas export in this assessment:

- Riley – West Krum double circuit
- Jacksboro – West Krum single circuit
- Jacksboro – Willow Creek double circuit
- Clear Crossing – Willow Creek double circuit
- Graham – Parker double circuit
- West Shackelford – Sam/Navarro double circuit
- Comanche Switch – Comanche Peak single circuit
- Brown – Killeen double circuit
- Big Hill – Kendall double circuit

Figure 1 shows the relative location of these lines within the 345 kV ERCOT transmission grid and the interface that was monitored to represent the West Texas export in this assessment.

To assess the system stability for stressed conditions, the synchronous generators in West Texas were turned off in the study case and the wind and solar generation was dispatched at approximately 83% of their maximum generation capacity across the

[1]2019 Regional Transmission Plan:
http://www.ercot.com/content/wcm/lists/172485/2019_RTP_Public_Version.zip
2018 Long-Term System Assessment for the ERCOT Region
http://www.ercot.com/content/wcm/lists/144927/2018_LTSA_Report.pdf
Dynamic Stability Assessment of High Penetration of Renewable Generation in the ERCOT Grid
http://www.ercot.com/content/wcm/lists/144927/Dynamic_Stability_Assessment_of_High_Penetration_of_Renewable_Generation_in_the_ERCOT_Grid.pdf
[2]GIS_Report_May_2020
https://mis.ercot.com/misdownload/servlets/mirDownload?mimic_duns=183529049&doclookupId=717314605

ERCOT system. The flow on the aforementioned sixteen 345 kV circuits in the developed study base case was close to 12.5 GW.

A summary of wind and solar generation capacity and output in the developed study case is provided in Table 1.

Table 1: Summary of Wind and Solar Generation in the Study Case

	Wind and Solar Capacity (MW)	Wind and Solar Output (MW)
ERCOT Total	31,214	25,781
West Texas	24,373	20,166

Both steady state voltage stability analysis and dynamic stability analysis, using fundamental frequency positive sequence models, were conducted to evaluate West Texas export levels and system dynamic response under tested major 345 kV outages, including NERC P1 (single circuit outage), P7 (double circuit outage), and P7-P7 (double circuit + double circuit outage). These outages were tested under both no-fault and three phase fault conditions.

Table 2 shows the assessment results, including voltage stability and dynamic stability limits for West Texas export based on maximum power flow on the monitored sixteen 345 kV lines where an acceptable stable response was observed.

Table 2: Identified West Texas Export for Acceptable Stability Response

Contingency Type	VSAT (GW)	Dynamics (GW)
P7-P7	10.9	10.1
P7	12.2	11.5

The highest historical West Texas export on the monitored sixteen lines has been observed as just above 10 GW. Continued growth of wind and solar generation in West Texas could further increase the export flow. Therefore, ERCOT will continue evaluating the system conditions in both Planning and in Operations to determine and to maintain acceptable power transfer limits from West Texas.

In addition, the identified West Texas export flows listed in Table 2 may be considered in ERCOT planning processes to evaluate future transmission system needs. In the meantime, this assessment can serve as a reference for ERCOT Operations to determine whether there is a need to consider additional stability constraints to properly manage the West Texas power transfer level in real time operations. It should be noted that the 345 kV circuits selected to represent the West Texas export in this stability assessment may require further review to determine adequacy in the operations horizon should such stability constraint consideration be necessary.

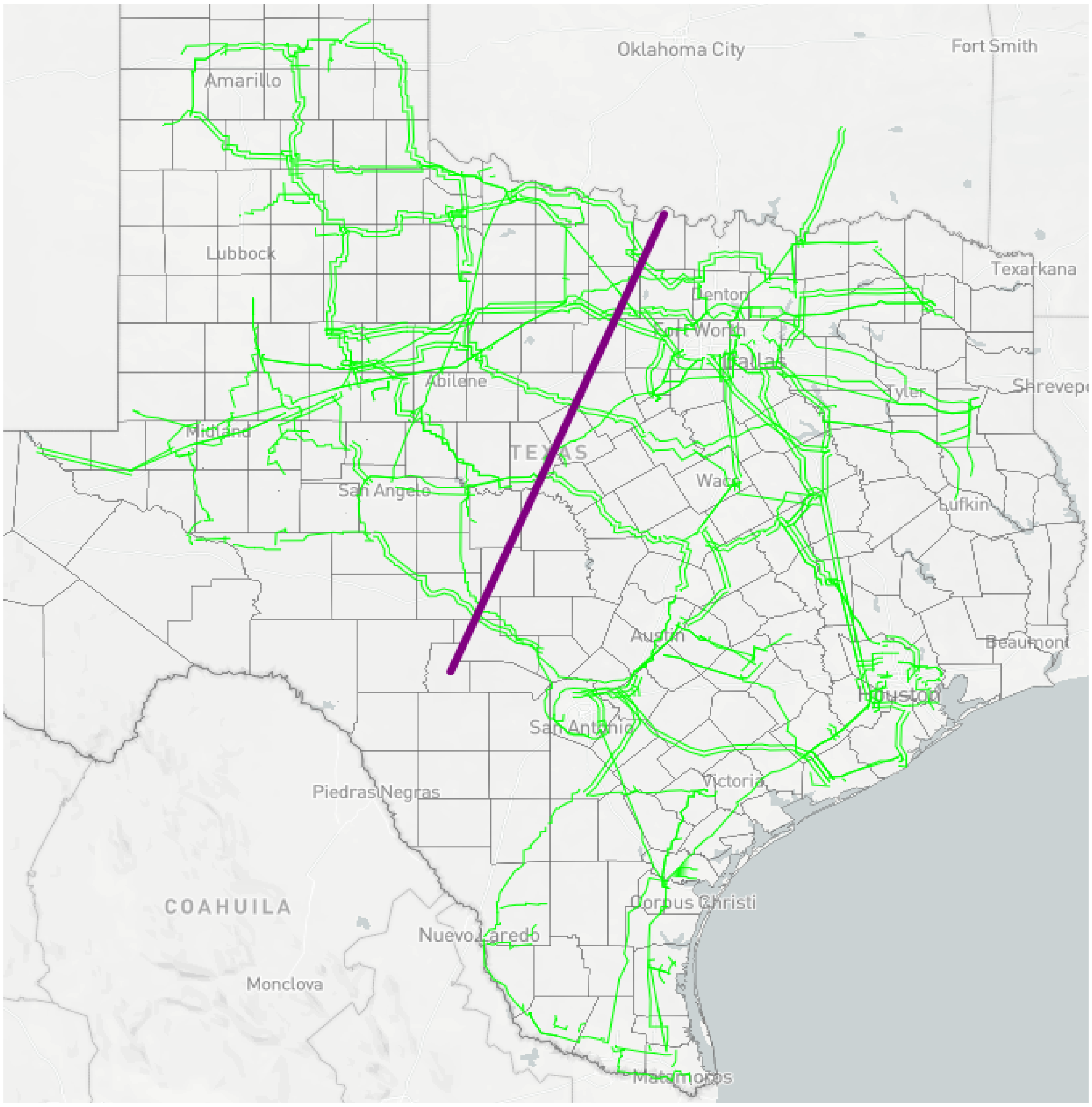

Figure 1: ERCOT 345 kV Transmission Grid and Approximate Location of Monitored Interface to Account for West Texas Export

2. Introduction

The ERCOT grid has experienced a high pace of wind and solar integration, mostly in West Texas. The increase in the wind and solar generation in West Texas results in increased flow from the western part of the ERCOT system to far-away load centers located in the eastern part of the state.

The purpose of this study was to analyze the stability of the ERCOT transmission system for high wind and solar generation dispatch conditions. Due to increasing wind and solar generation integration in West Texas, stability challenges associated with increasing export levels from the western region of the ERCOT grid were assessed.

To determine the West Texas export limits from a stability perspective, the following sixteen 345 kV lines connecting western regions to the rest of ERCOT were selected to represent the West Texas export flow:

- Riley – West Krum double circuit
- Jacksboro – West Krum single circuit
- Jacksboro – Willow Creek double circuit
- Clear Crossing – Willow Creek double circuit
- Graham – Parker double circuit
- West Shackelford – Sam/Navarro double circuit
- Comanche Switch – Comanche Peak single circuit
- Brown – Killeen double circuit
- Big Hill – Kendall double circuit

3. Study Scenario and Assumptions

3.1. Simulation Software and Study Case Development

The study was performed using the following power system analysis software:

- Powertech VSAT (version 18) for steady state voltage stability analysis
- Siemens PTI PSSE (version 33.12.1) for dynamic simulations

The DWG 2022 High Wind Low Load (HWLL) case was used to develop the study case. Generation meeting Planning Guide Section 6.9 requirements was added in the base case. Solar generation in the case was turned on and synchronous generation in the western part of ERCOT grid was turned off. Wind and solar generation were dispatched at approximately 83% of their full generation capacity across the ERCOT system. This dispatch level is consistent with wind output levels used in developing the ERCOT high wind cases. Additionally, operating scenarios where solar and wind output approached 80% of capacity simultaneously have been observed. Therefore, the wind and solar dispatch level of 83% was deemed to be a more credible stressed condition than evaluating a 100% dispatch level for this assessment. Because the 2022 transmission topology includes transmission reinforcements such as Lubbock integration upgrades and the Far West projects, the case conditions were expected to support higher dispatch levels from the Panhandle and McCamey areas when compared to current limits and known existing constraints in these areas were not enforced in the case dispatch[3]. A few planned generation projects were modeled as negative loads in dynamic simulations due to model unavailability or poor model quality. A summary of study case generation and load is provided in Tables 3 and 4.

Table 3: Summary of Wind and Solar Generation in the Study Case

	Wind and Solar Capacity (MW)	Wind and Solar Output (MW)
ERCOT Total	31,214	25,781
West Texas	24,373	20,166

Table 4: Summary Totals in the Study Case

	MW
Total Generation Output	48,312
Load (including PUN load)	45,542

The high wind and solar dispatch in the study case resulted in 12.5 GW total power flow on the monitored sixteen 345 kV export lines and the associated reactive losses significantly increased when compared to the DWG 2022 HWLL case to approximately 5.1 GVAr. As shown in Table 5, increasing real power transfer across the sixteen export lines by less than 30% (from 9.9 GW to 12.5 GW) caused reactive losses on those lines to more than double (from 2.3 GVAr to 5.1 GVAr). Under outage conditions, the reactive losses would be further increased. This indicates a fundamental challenge with high power transfers across the network.

Table 5: Comparison of Power Flows and Reactive Power Losses

Total for 16 Monitored 345 kV Lines	12.5 GW Transfer	9.9 GW Transfer
Reactive Losses (GVAr)	5.1	2.3

[3] The impact to the existing Generic Transmission Constraints (GTCs) will be assessed prior to the implementation of these transmission projects in Operations.

3.2. Test Contingencies

The focus of the analysis was primarily on the 345 kV transmission lines which transmit the power from the western part of the ERCOT grid to the rest of ERCOT. The following contingency types were studied:

- P1 (single element)
- P6 (single + single)
- P7 (double circuit)
- P1 + P7 (single + double)
- P7 + P7 (double + double)

It should be noted that no system adjustments were made prior to the second outage when analyzing multiple outage contingencies (P6, P1+P7, P7+P7). The voltage stability assessment considered 260 contingencies to determine the voltage stability transfer limit. A set of 40 of the most limiting contingencies based on the voltage stability assessment were then further assessed in dynamic simulation analysis. The dynamic contingency simulations were performed for both 3-phase fault with normal clearing and with no-fault conditions to identify the most limiting power transfer level values.

It was observed that simulating an outage under no-fault conditions sometimes resulted in more binding transfer limits than simulating the same event with a fault. Under fault conditions, many generators experience low voltages which result in the rapid injection of reactive power. This improves the overall voltage profile of the transmission network and helps maintain system stability. Additionally, the real power output is generally reduced as inverter-based resources (typically wind and solar) near the fault enter low voltage ride-through mode. Real power recovery occurs after the fault has been cleared and system voltages recover. This delay in the recovery of real power together with the rapid injection of reactive power during the fault and voltage recovery period helps with the post-contingency stability of the system. In the case of no-fault contingency conditions, the real power stays at higher levels which results in increased reactive loses due to the post-contingency state of the system. This can lead to a fast voltage collapse due to transmission of non-reduced bulk power over the higher impedance post-contingency transmission system.

4. Assessment Results and Observations

4.1. Assessment Results

VSAT analysis identified that the study case with approximately 12.5 GW power flow on the monitored sixteen 345 kV lines was insecure (could not reach a stable solution) for double circuit outages (P7). The outage of an element causes the system impedance to increase which results in the reduction of the amount power that can be securely transmitted. The transmission of real power is also dependent on the system voltages. The reactive losses resulting from the transmission of bulk power causes the voltages to sag which in turn could further reduce the ability to transfer power. Power transfers were reduced until a stable result was achieved in the VSAT analysis.

In the dynamic simulation analysis, further reductions in power transfer levels were required to achieve a stable result. This is an indication that although there are post-disturbance conditions that represent a potentially stable operating point, the system is not capable of maintaining stability throughout the time-domain dynamic event to get to that operating point. The dynamic simulation case for each tested transfer level was confirmed to show a stable response for a no-disturbance (flat-start) test run.

Figure 2 shows an example of an unstable dynamic simulation result leading to a simulation crash after loss of a 345 kV double circuit (no fault) at a transfer level of 11.8 GW. Figure 3 shows a stable response for the same contingency when the power transfer level was reduced to 11.5 GW. The system voltages became more sensitive at higher transfer levels as reactive losses increased at a greater rate, so relatively small changes in power transfer can have a significant impact on the system dynamic responses.

The decrease in the voltage (red and green traces in Figures 2 and 3) reflect the phenomenon of low voltages due to increased reactive losses for the buses located near the sending end of the power transmission path, whereas a voltage increase (black trace in Figures 2 and 3) occurred at the receiving end when the path consuming reactive power from the receiving end was tripped.

Table 6 shows the transfer limits identified using both VSAT and PSSE (dynamic simulation).

Table 6: Transfer Limits on Monitored Sixteen 345 kV Lines

Contingency Type	VSAT (GW)	Dynamic (GW)
P7-P7	10.9	10.1
P7	12.2	11.5

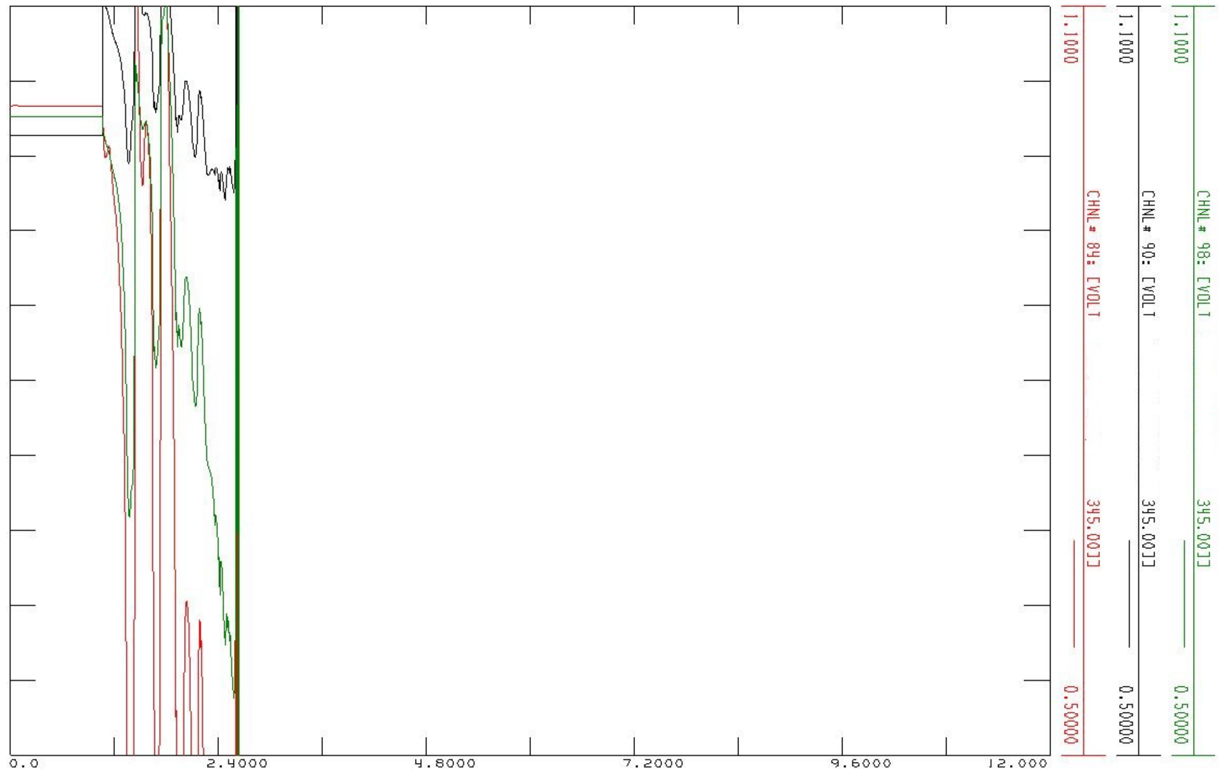

Figure 2: Selected 345-kV Bus Voltage (pu) - Unstable Result

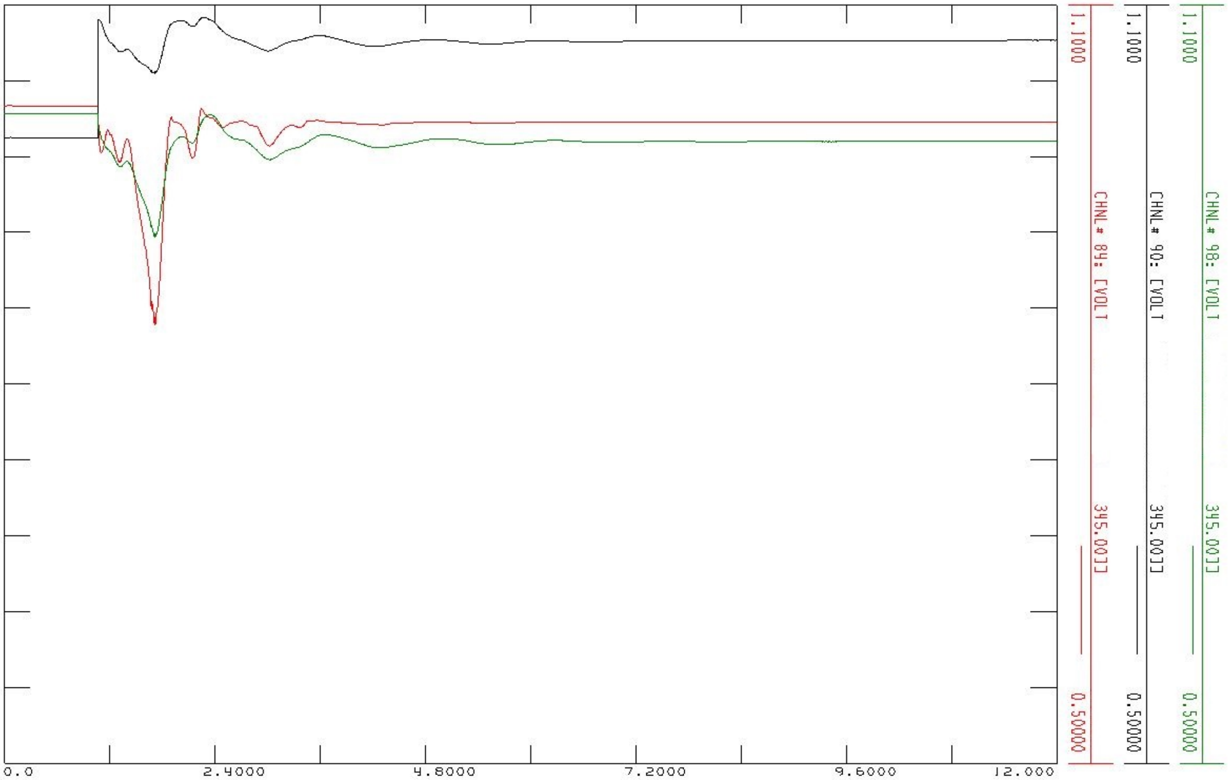

Figure 3: Selected 345 kV Bus Voltage (pu) – Stable Result

4.2. Observations

4.2.1 Stability Assessment

For this assessment, limits determined from dynamic simulation were more binding than limits determined from steady state voltage stability analysis. This highlights the importance of accurate dynamic models to properly assess West Texas export capability.

4.2.2 Interface Assessment

The transmission lines comprising the critical contingencies and the transmission lines exhibiting the largest increases in reactive losses that contributed to the observed voltage instability were along the interface path selected to be monitored. This indicates that this sixteen-line interface, or a subset of this interface, is appropriate for representing the stability limits in other planning analyses, such as production cost modeling for economic transmission planning. Future studies should examine whether all sixteen lines should be monitored or a subset of these lines.

4.2.3 Historical Transfer

Figure 4 below shows recent historical data depicting the flow on the monitored sixteen 345 kV lines. The diagram shows that the highest monthly power transfer had exceeded 10 GW in two previous months. It has not exceeded the 11.5 GW limit identified for P7 (double circuit) events. However, the data shows that the flow on the monitored lines is increasing and approaching the limits identified in this study.

The recently created West to Central Generic Transmission Constraint (GTC) is comprised of a subset of the sixteen 345 kV lines monitored in this analysis. Since the results and stability challenges are similar between the West to Central GTC study, performed for the operating horizon, and this study, performed for the planning horizon, these studies should be considered complimentary.

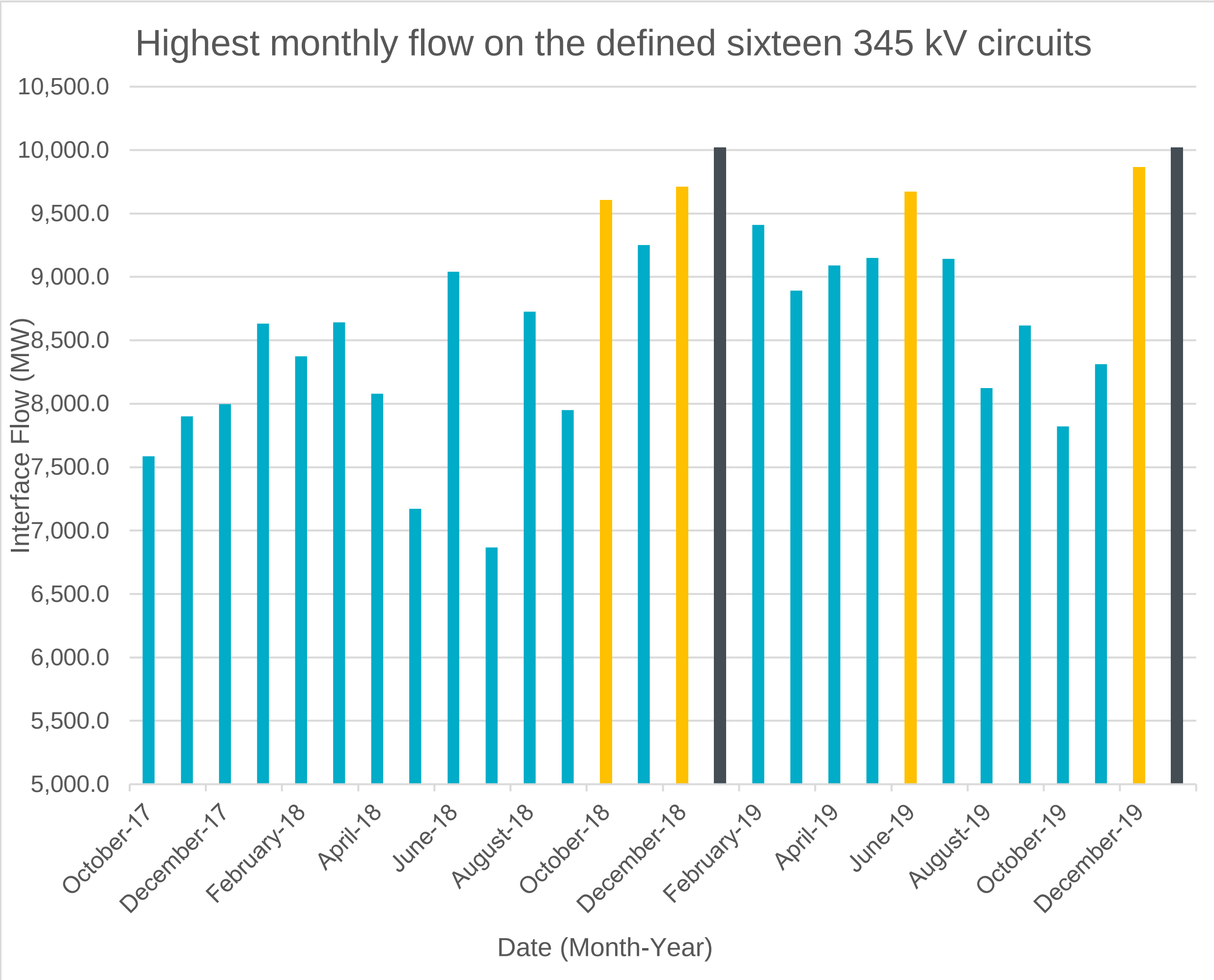

Figure 4: ERCOT Real-time monthly flow on the monitored sixteen 345 kV circuits