GEN-2015-014

Impact Restudy for Generator Modification (Turbine Change)

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By SPP Generator Interconnections Dept.

REVISION HISTORY

DATE OR VERSION NUMBER	AUTHOR	CHANGE DESCRIPTION
10/10/2018	SPP	Initial report issued.

CONTENTS

SUMMARY

The GEN-2015-014 Interconnection Customer has requested a modification to its Interconnection Request. This system impact restudy was performed to determine the effects of changing wind turbine generators from the previously studied seventy-five (75) Vestas V11 2.0 MW wind turbine generators to six (6) GE 1.715 MW, two (2) GE 2.0 MW and fifty-nine (59) GE 2.3 MW wind turbine generators. The total nameplate changes from 150 MW to 149.99 MW. The point of interconnection (POI) is on the Southwestern Public Service (SPS) Lehman to Cochran 115 kV line.

Specifically, the study was performed to determine whether the request for modification is considered Material. Study models that included Interconnection Requests through DISIS-2016-001 were used that analyzed the timeframes of 2016 winter, 2017 summer, and 2025 summer models.

The restudy showed that the stability analysis has determined with all previously assigned Network Upgrades in service, generators in the monitored areas remained stable and within the pre-contingency, voltage recovery and post fault voltage recovery criterion of 0.7pu to 1.2pu for the entire modeled disturbances with the exception of a prior outage on the GEN-2015-014 POI to Cochran 115 kV line followed by a three phase fault on the Plains to Yoakum 115 kV line. In this scenario, GEN-2015-014 may become unstable; to prevent an unstable response, GEN-2015-014 may be curtailed to an output of 90 MW. Additionally, the project wind farm was found to stay connected during the contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A. The requested modification is not considered Material.

A power factor analysis was previously performed and remains valid. The facility will be required to maintain a 95% lagging (providing VARs) and 95% leading (absorbing VARs) power factor at the POI. A low-wind/no-wind condition analysis was performed identifying a need for 8.4 MVAr of reactive compensation. This is necessary to offset the capacitive effect on the transmission network caused by the project's transmission line and collector system during low-wind/no-wind conditions. Reactive compensation can be provided either by discrete reactive devices or by the generator itself if it possesses that capability.

With the assumptions outlined in this report and with all the required network upgrades from the DISIS 2016-001-1 in place, GEN-2015-014 with the six (6) GE 1.715 MW, two (2) GE 2.0 MW and fifty-nine (59) GE 2.3 MW wind turbine generators should be able to interconnect reliably to the SPP transmission grid.

It should be noted that this study analyzed the requested modification to change generator technology, manufacturer, and layout. This study analyzed many of the most probable contingencies, but it is not an all-inclusive list and cannot account for every operational situation. It is likely that the customer may be required to reduce its generation output to 0 MW, also known as curtailment, under certain system conditions to allow system operators to maintain the reliability of the transmission network.

Nothing in this study should be construed as a guarantee of transmission service or delivery rights. If the customer wishes to obtain deliverability to final customers, a separate request for transmission service must be requested on Southwest Power Pool's OASIS by the customer.

A: CONSULTANT'S MATERIAL MODIFICATION STUDY REPORT

See next page for the Consultant's Material Modification Study report.

Submitted to

Southwest Power Pool

Report On

GEN-2015-014
Modification Request Impact Study

Revision R2

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Executive Summary

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2015-014, an active generation interconnection request with point of interconnection (POI) on the Lehman to Cochran 115 kV line.

The GEN-2015-014 project has proposed to interconnect in the Southwestern Public Service Company (SPS) control area with a capacity of 150 MW including 75 x Vestas V11 2.0MW wind turbines as shown in Table ES-1 below. This Study has been requested to evaluate the modification of GEN-2015-014 to change the turbine configuration to a combination of 6 x GE 1.715 MW, 2 x GE 2.0 MW, and 59 x GE 2.3 MW turbine generators for a total capacity of 149.99 MW. The new configuration also has 2 x 9 MVAr capacitor banks at the 34.5 kV bus of the collector substation. In addition, the modification request included changes to the generation interconnection line and the main substation transformer. The modification request changes are shown in Table ES-2 below.

Table ES-1: Existing GEN-2015-014 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-014	150	75 x Vestas V11 2.0 MW	Tap on Lehman (526352) to Cochran (526361) 115 kV Line

Table ES-2: GEN-2015-014 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Lehman to Cochran 115 kV line (560030)	Lehman to Cochran 115 kV line (560030)
Configuration/Capacity	75 x Vestas V11 2.0 MW = 150 MW	6 x GE 1.715 MW, 2 x GE 2.0 MW, and 59 x GE 2.3 MW (149.99 MW)
Generation Interconnection Line	Length = 9.5 miles R = 0.005490 pu X = 0.049990 pu B = 0.007740 pu	Length = 9.71 miles R = 0.004640 pu X = 0.048320 pu B = 0.008440 pu
Main Substation Transformer	Z = 10%, Rating 180 MVA	Z = 8%, Rating 170 MVA
Equivalent Collector Line	R = 0.005050pu X = 0.005820 pu B = 0.062610 pu	R = 0.004740 pu X = 0.007730 pu B = 0.077600 pu

GEN-2015-014 was last studied as part of Group 6 in the DISIS-2015-001 ReStudy #3 published on September 2017. Aneden performed reactive power analysis, short circuit analysis and dynamic stability analysis using the modification request data based on the DISIS-2016-001 ReStudy #1 Group 6 study models:

1. 2016 Winter Peak (2016WP),
2. 2017 Summer Peak (2017SP),
3. 2020 Summer Peak (2020SP),
4. 2020 Winter Peak (2020WP), and
5. 2025 Summer Peak (2025SP).

A power factor analysis was not performed as there was no change in the point of interconnection for GEN-2015-014.

The results of the reactive power analysis, also known as the low-wind/no-wind condition analysis, performed using all five models showed that the GEN-2015-014 project may require a 8.4 MVAr shunt reactor on the 115 kV bus of the project substation. The shunt reactor is needed to reduce the reactive power transfer at the POI to approximately zero during low/no wind conditions while the generation interconnection project remains connected to the grid.

The results from short circuit analysis showed that the maximum change in the fault currents in the immediate systems at or near GEN-2015-014 was 35.1%. All three-phase current levels with the GEN-2015-014 generator online was below 24 kA in both the 2017SP and 2025SP models.

The dynamic stability analysis was performed using the five loading scenarios 2016 Winter Peak, 2017 Summer Peak, 2020 Summer Peak, 2020 Winter Peak and 2025 Summer Peak simulating up to 35 contingencies that included three-phase faults, three phase faults on prior outage cases, and single-line-to-ground faults with stuck breakers faults.

The results of the dynamic stability analysis showed that with the prior outage on the GEN-2015-014 POI to Cochran 115 kV line followed by the three phase fault on the Plains to Yoakum 115 kV line, GEN-2015-014 may become unstable. To prevent the GEN-2015-014 unstable response during this prior outage condition, GEN-2015-014 may have to be curtailed to about 90 MW output after the loss of either line to prepare for the next event.

There were no other machine rotor angle damping or transient voltage recovery violations observed in the simulated fault events associated with GEN-2015-014. Additionally, the project wind farm was found to stay connected during the remaining contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A.

The results of this Study show that the GEN-2015-014 Modification Request does not constitute a material modification.

1.0 Introduction

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2015-014, an active generation interconnection request with point of interconnection (POI) on the Lehman to Cochran 115 kV line.

The GEN-2015-014 project has proposed to interconnect in the Southwestern Public Service Company (SPS) with a capacity of 150 MW including 75 x Vestas V11 2.0MW wind turbines as shown in Table 1-1 below. Details of the modification request as provided in Section 2.0 below.

Table 1-3: Existing GEN-2015-014 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-014	150	75 x Vestas V11 2.0 MW	Tap on Lehman (526352) to Cochran (526361) 115 kV Line

Scope

The Study included short circuit, power factor, reactive power and dynamic stabilities. The methodology, assumptions and results of the analyses are presented in the following six main sections:

1. Project and Modification Request
2. Power Factor Requirement
3. Reactive Power Analysis
4. Short Circuit Analysis
5. Dynamic Stability Analysis
6. Conclusions

Aneden performed a reactive power analysis, short circuit analysis and dynamic stability analysis using a set of modified study models developed using the modification request data and the three DISIS-2016-001 ReStudy #1 Group 6 study models:

1. 2016 Winter Peak (2016WP),
2. 2017 Summer Peak (2017SP),
3. 2020 Summer Peak (2020SP),
4. 2020 Winter Peak (2020WP), and
5. 2025 Summer Peak (2025SP).

All analyses were performed using the PTI PSS/E version 32 software. The results of each analysis are presented in the following sections.

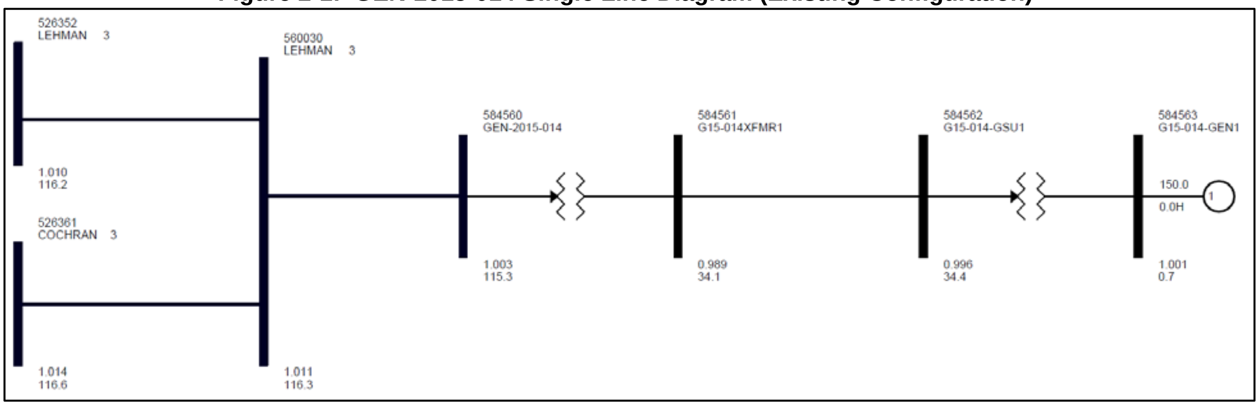
Study Limitations

The assessments and conclusions provided in this report are based on assumptions and information provided to Aneden by others. While the assumptions and information provided may be appropriate for the purposes of this report, Aneden does not guarantee that those conditions assumed will occur. In addition, Aneden did not independently verify the accuracy or completeness of the information provided. As such, the conclusions and results presented in this report may vary depending on the extent to which actual future conditions differ from the assumptions made or information used herein.

2.0 Project and Modification Request

Figure 2-1 shows the power flow model single line diagram for the existing GEN-2015-014 configuration. GEN-2015-014 was last studied as part of Group 6 in the DISIS-2015-001 ReStudy #3 (ReStudy #3) published on September 2017.

Figure 2-1: GEN-2015-014 Single Line Diagram (Existing Configuration)



The GEN-2015-014 Modification Request included a turbine change to 6 x GE 1.715 MW, 2 x GE 2.0 MW, and 59 x GE 2.3 MW wind turbines for a total capacity of 149.99 MW. In addition, the modification request also included changes to the generation interconnection line, the collection system and the main substation transformer. The new configuration also has 2 x 9 MVAr capacitor banks at the 34.5 kV bus of the collector substation. The major modification request changes are shown in Figure 2-2 and Table 2-1 below.

Figure 2-2: GEN-2015-014 Single Line Diagram (New Configuration)

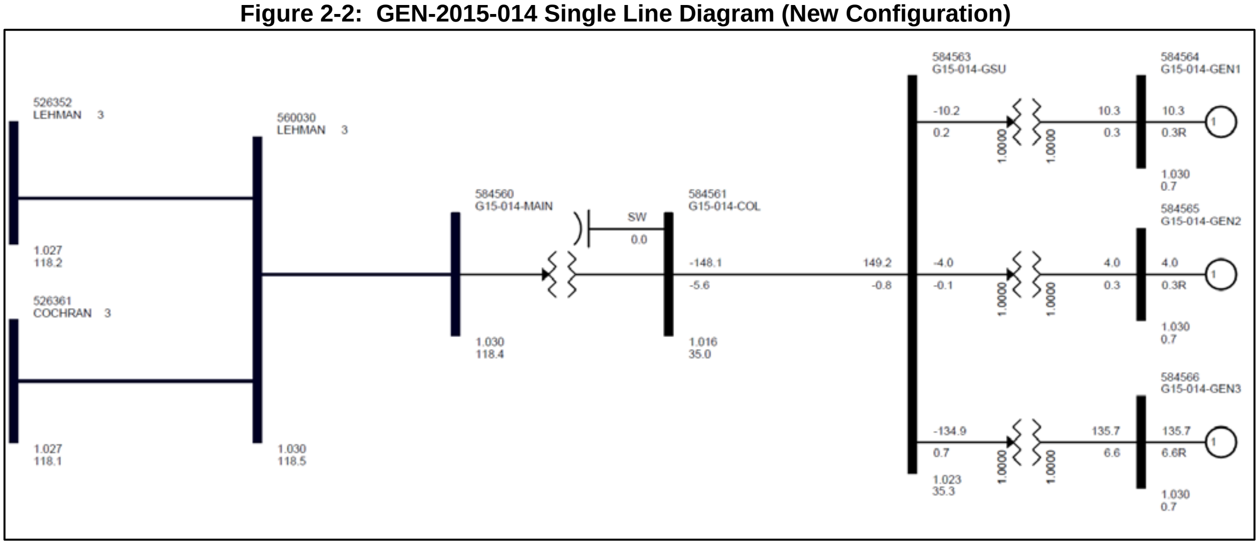


Table 2-4: GEN-2015-014 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Lehman to Cochran 115 kV line (560030)	Lehman to Cochran 115 kV line (560030)
Configuration/Capacity	75 x Vestas V11 2.0 MW = 150 MW	6 x GE 1.715 MW, 2 x GE 2.0 MW, and 59 x GE 2.3 MW (149.99 MW)
Generation Interconnection Line	Length = 9.5 miles R = 0.005490 pu X = 0.049990 pu B = 0.007740 pu	Length = 9.71 miles R = 0.004640 pu X = 0.048320 pu B = 0.008440 pu
Main Substation Transformer	Z = 10%, Rating 180 MVA	Z = 8%, Rating 170 MVA
Equivalent Collector Line	R = 0.005050pu X = 0.005820 pu B = 0.062610 pu	R = 0.004740 pu X = 0.007730 pu B = 0.077600 pu

3.0 Power Factor Requirement

The power factor analysis was not performed since the GEN-2015-014 modification request did not include a change in the point of interconnection.

4.0 Reactive Power Analysis

The reactive power analysis, also known as the low-wind/no-wind condition analysis, was performed for GEN-2015-014 to determine the reactive power contribution from the project's interconnection line and collector transformer and cables during low/no wind conditions while the project is still connected to the grid and to size shunt reactors that would reduce the project reactive power contribution to the POI to approximately zero.

Methodology and Criteria

For the GEN-2015-014 project, the generator was switched out of service while other collector system elements remained in-service. A shunt reactor was tested at the study project substation high side bus to bring the MVAr flow into the POI down to approximately zero.

Results

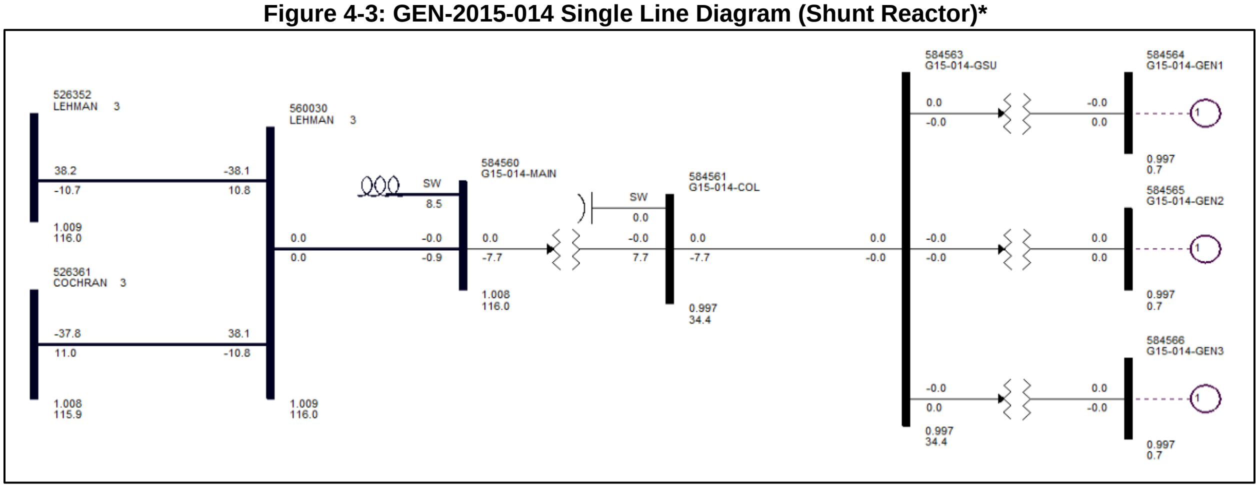
The results from the reactive power analysis showed that the GEN-2015-014 project required approximately 8.4 MVAr shunt reactance at the high side of the project substation to reduce the POI MVAr to zero. This represents the contributions from the project collector systems. Figure 4-1 illustrates the shunt reactor size required to reduce the POI voltage to approximately zero. Reactive compensation can be provided either by discrete reactive devices or by the generator itself if it possesses that capability.

Table 4-5: Shunt Reactor Size for Low Wind Study*

Machine	POI Bus Number	POI Bus Name	Reactor Size (MVAr)				
			16WP	17SP	20SP	20WP	25SP
GEN-2015-014	560030	LEHMAN 3	8.4	8.4	8.4	8.4	8.4

*Note that the 34.5 kV Collection System Capacitor Bank was Offline

Figure 4-3: GEN-2015-014 Single Line Diagram (Shunt Reactor)*



*The reactor MVAr contribution shown above depends on the bus voltage. It has a 8.4 MVAr capacity.

The shunt reactor identified in the previous DISIS-2015-001 ReStudy #3 was a 7.0 MVAr shunt reactor. The difference in the results can be attributed to the changes to the generation interconnection line and the collector system impedances.

5.0 Short Circuit Analysis

A short-circuit study was performed on the power flow models for the 2017SP and 2025SP models for GEN-2015-014 using the modified Cluster Scenario models. The detail results of the short-circuit analysis are provided in Appendix A.

Methodology

The short-circuit analysis included applying a 3-phase fault on buses up to 5 levels away from the Lehman 115 kV POI bus. The PSS/E "Automatic Sequence Fault Calculation (ASCC)" fault analysis module was used to calculate the fault current levels with and without the project online.

Results

The results of the short circuit analysis are summarized in Table 5-1 and Table 5-2 for the 2017SP and 2025SP models, respectively. The maximum increase in fault current was about 35.1%, 1.756 kA. The maximum fault current calculated within 5 buses with GEN-2015-014 was less than 24 kA and 24 kA in the 2017SP and 2025SP models respectively.

Table 5-6: 2017SP Short Circuit Results

Bus Distance	Max. Change (kA)	Max %Change
0	1.734	34.5%
1	1.353	27.4%
2	0.704	8.1%
3	0.659	6.3%
4	0.564	5.7%
5	0.427	4.6%

Table 5-7: 2025SP Short Circuit Results

Bus Distance	Max. Change (kA)	Max %Change
0	1.756	35.1%
1	1.369	27.9%
2	0.728	8.5%
3	0.685	6.6%
4	0.588	5.9%
5	0.448	4.8%

6.0 Dynamic Stability Analysis

Aneden performed a dynamic stability analysis to identify the impact of the turbine change and other modifications to the GEN-2015-014 project. The analysis was performed according to SPP's Disturbance Performance Requirements shown in Appendix B. The modification details are described in Section 2.0 above and the dynamic modeling data is provided in Appendix C. The simulation plots can be found in Appendix D.

Methodology and Criteria

The dynamic stability analysis was performed using models developed with the requested 6 x GE 1.715 MW, 2 x GE 2.0 MW, and 59 x GE 2.3 MW turbine for the GEN-2015-014 generating facility. This stability analysis was performed using PTI's PSS/E version 32 software.

The stability models were developed using the models from the DISIS-2016-001 ReStudy #1 (DISIS-2016-001-1) for Group 6. The modifications requested to project GEN-2015-014 were used to create modified stability models for this impact study.

The modified power flow models and associated dynamics database were initialized (no-fault test) to confirm that there were no errors in the initial conditions of the system and the dynamic data. The modified dynamics model data for the DISIS-2016-001-1 (Group 8) request and GEN-2015-014 is provided in Appendix C.

During the fault simulations, the active power (PELEC), reactive power (QELEC) and terminal voltage (ETERM) were monitored for GEN-2015-014 and other equally and prior queued projects in Group 6. In addition, voltages of five (5) buses away from the POI of GEN-2015-014 were monitored and plotted. The machine rotor angle for synchronous machines and speed for asynchronous machines within this study area including 520 (AEPW), 524 (OKGE), 525 (WFEC), 526 (SPS), 531 (MIDW), 534 (SUNC), 536 (WERE) were monitored. In addition, the voltages of all 100 kV and above buses within the study area were monitored.

Fault Definitions

Aneden selected the fault events simulated specifically for GEN-2015-014 in the DISIS-2015-001 Group 6 ReStudy #3 and included additional faults based on the location of the new point of interconnection. The new set of faults were simulated using the modified study models. The fault events include three phase faults with reclosing, stuck breaker, and prior outage events. Single-line-to-ground (SLG) fault impedance values were determined by applying a fault on the base case large enough to produce a 0.6 pu voltage value on the faulted bus. This SLG value was then used for the SLG faults.

The simulated faults are listed and described in Table 6-1 below. These contingencies were applied to the modified 2016 Winter Peak, 2017 Summer Peak, 2020 Summer Peak, 2020 Winter Peak and 2025 Summer Peak models.

Table 6-8: Fault Definitions

Fault ID	Fault Descriptions
FLT68-3PH	3 phase fault on the Lehman (560030) to Lehman (526352) 115 kV line circuit 1, near Lehman. a. Apply fault at the Lehman (560030) 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT69-3PH	3 phase fault on the Lehman (560030) to Cochran (526361) 115 kV line circuit 1, near Lehman. a. Apply fault at the Lehman 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT70-PH	3 phase fault on the Lehman (526352) to LG Plains (526944) 115 kV line circuit 1, near Lehman. a. Apply fault at the Lehman 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT71-3PH	3 phase fault on the Plains Int (526928) to Yoakum (526934) 115 kV line circuit 1, near Plains Int. a. Apply fault at the Plains Int 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT72-3PH	3 phase fault on the Plains Int (526928) to LG Plains (526944) 115 kV line circuit 1, near Plains Int. a. Apply fault at the Plains Int 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT73-3PH	3 phase fault on the Plains Int (526928) 115 kV/(528626) 69 kV transformer, near Plains Int 115 kV. a. Apply fault at the Plains Int 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT74-3PH	3 phase fault on the Cochran (526361) to Pacific (526424) 115 kV line circuit 1, near Cochran. a. Apply fault at the Cochran 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT75-3PH	3 phase fault on the Cochran (526361) 115 kV/(526360) 69 kV /(526358) 13.2kV transformer, near Cochran 115 kV. a. Apply fault at the Cochran 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT76-3PH	3 phase fault on the Sundown (526434) to LC-OPDYKE (526036) 115 kV line circuit 1, near Sundown. a. Apply fault at the Sundown 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT77-3PH	3 phase fault on the Sundown (526434) to Amoco Tap (526445) 115 kV line circuit 1, near Sundown. a. Apply fault at the Sundown 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table 6-1 continued

Fault ID	Fault Descriptions
FLT78-3PH	3 phase fault on the Sundown (526434) 115 kV/(526435) 230 kV /(526432) 13.2 kV transformer, near Sundown 115 kV. a. Apply fault at the Sundown 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT79-3PH	3 phase fault on the Sundown (526435) to Plant X (525481) 230 kV line circuit 1, near Sundown. a. Apply fault at the Sundown 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT80-3PH	3 phase fault on the Sundown (526435) to Amoco (526460) 230 kV line circuit 1, near Sundown. a. Apply fault at the Sundown 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT81-3PH	3 phase fault on the Yoakum (526934) to Prentice (526792) 115 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT82-3PH	3 phase fault on the Yoakum (526934) to Arco Tap (527041) 115 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT83-3PH	3 phase fault on the Yoakum (526934) to LG-PLSHILL (527194) 115 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT104-3PH	3 phase fault on the Wolfforth (526525) to Sundown (526435) 230 kV line circuit 1, near Wolfforth. a. Apply fault at the Wolfforth 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT110-3PH	3 phase fault on the Tolk Tap (525543) 230 kV/(525549) 345 kV /(525537) 13.2kV transformer, near Tolk Tap 230kV. a. Apply fault at the Tolk Tap 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT111-3PH	3 phase fault on the Tolk West (525531) to G13-027-TAP (562480) 230 kV line circuit 1, near Tolk West. a. Apply fault at the Tolk West 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT112-3PH	3 phase fault on the G13-027-TAP (562480) to Yoakum (526935) 230 kV line circuit 1, near G13-027-TAP. a. Apply fault at the G13-027-TAP 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table 6-1 continued

Fault ID	Fault Descriptions
FLT113-SB	Stuck Breaker on Yoakum – G13-027-TAP 230 kV line a. Apply single-phase fault at Yoakum 230 kV (526935) b. After 20 cycles, trip the Yoakum (526935) to G13-027-TAP (562480) 230 kV line c. Trip the Yoakum (526935) 230 kV/(526934) 115 kV /(526931) 13.2 kV XMFR, and remove the fault
FLT114-3PH	3 phase fault on the Yoakum (526935) to Amoco (526460) 230 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT115-3PH	3 phase fault on the Yoakum (526935) to OXYBRU Tap (527010) 230 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT116-3PH	3 phase fault on the Yoakum (526935) to Mustang (527149) 230 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT117-3PH	3 phase fault on the Yoakum (526935) to G1579&G1580T (560059) 230 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT118-3PH	3 phase fault on the Yoakum (526935) 230 kV /(526934) 115 kV /(526931) 13.2 kV transformer, near Yoakum 230 kV. a. Apply fault at the Yoakum 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT120-SB	Stuck Breaker on Yoakum – Amoco 230 kV line a. Apply single-phase fault at Yoakum 230 kV (526935) b. After 20 cycles, trip the Yoakum (526935) to Amoco (526460) 230 kV line c. Trip the Yoakum (526935) 230 kV bus, and remove the fault
FLT9001-SB	Stuck Breaker on Cochran (526361) to Pacific (526424) 115 kV line circuit 1 a. Apply single-phase fault at Cochran (526361) 115kV b. After 20 cycles, trip the Cochran (526361) to Pacific (526424) 115 kV line circuit 1 c. Trip the Cochran (526361) 115kV bus, and remove the fault
FLT9002-SB	Stuck Breaker on Plains Int (526928) to Yoakum (526934) 115 kV line circuit 1 a. Apply single-phase fault at Plains Int (526928) 115kV b. After 20 cycles, trip the Plains Int (526928) to Yoakum (526934) 115 kV line circuit 1 c. Trip the Plains Int (526928) 115kV bus, and remove the fault
FLT9003-3PH	3 phase fault on the Yoakum (526935) to G13-027-TAP (562480) 230 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum (526935) 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Table 6-1 continued

Fault ID	Fault Descriptions
FLT9004-3PH	3 phase fault on the Yoakum (526935) 230 kV /(526934) 115 kV /(526931) 13.2 kV transformer, near Yoakum 115 kV. a. Apply fault at the Yoakum 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9005-3PH	3 phase fault on the Yoakum (526934) to Plains Int (526928) 115 kV line circuit 1, near Yoakum. a. Apply fault at the Yoakum (526934) 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT71-PO1	Prior outage on the Lehman (560030) to Cochran (526361) 115 kV line circuit 1 3 phase fault on the Plains Int (526928) to Yoakum (526934) 115 kV line circuit 1, near Plains Int. a. Apply fault at the Plains Int 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT74-PO2	Prior outage on the Lehman (560030) to Lehman (526352) 115 kV line circuit 1 3 phase fault on the Cochran (526361) to Pacific (526424) 115 kV line circuit 1, near Cochran. a. Apply fault at the Cochran 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT75-PO2	Prior outage on the Lehman (560030) to Lehman (526352) 115 kV line circuit 1 3 phase fault on the Cochran (526361) 115 kV/(526360) 69 kV /(526358) 13.2kV transformer, near Cochran 115 kV. a. Apply fault at the Cochran 115 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT118-PO3	Prior outage on the Yoakum (526935) to Amoco (526460) 230 kV line circuit 1; 3 phase fault on the Yoakum (526935) 230 kV/(526934) 115 kV/(526931) 13.2 kV line circuit 1, near Yoakum 230 kV. a. Apply fault at the Yoakum 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.

Results

There were no damping or voltage recovery violations observed during the simulations and the system returned to stable conditions except for three fault conditions described below:

1. FLT73-3PH, 3-phase fault on the Plains 115/69 kV transformer, resulted in low voltages on the 69 kV system in the 17SP, 20SP and 25SP scenarios. These low voltages did not meet the voltage recovery criteria. These voltage violation was observed before and after the GEN-2015-014 modifications and also persisted when GEN-2015-014 was removed from the models. Therefore GEN-2015-014 has no impact on these 69 kV violations.
2. FLT9002-SB, the stuck breaker fault on the Plains to Yoakum 115 kV line causing the Plains 115 kV bus to be tripped, resulted in similar low voltage issues observed in #1 above. These voltage violation was observed before and after the GEN-2015-014 modifications and also persisted when GEN-2015-014 was removed from the models. Therefore GEN-2015-014 has no impact on these 69 kV violations.
3. FLT71-PO1, prior outage on the GEN-2015-014 POI to Cochran 115 kV line followed by the three phase fault on the Plains to Yoakum 115 kV line, caused GEN-2015-014 to

become unstable as it was isolated from the rest of the bulk system (100kV+ system) and connected only to the 69 kV system fed from the Plains 115/69 kV substation. The low voltages observed on the system connected to the Plains 69 kV substation did not meet the voltage recovery criteria. These violations were observed before and after the GEN-2015-014 modifications. To prevend this issue, GEN-2015-014 may have to be curtailed to 90 MW after the loss of either the GEN-2015-014 POI to Cochran 115 kV line or the Plains to Yoakum 115 kV line.

Table 6-2 shows the curtailment requires for FLT71-PO1 described above. GEN-2015-014 output may have to be limited to the amounts listed in Table 6-2.

Table 6-9: GEN-2015-014 Output Limits for FLT71-PO1 (MW)

Fault	2016WP	2017SP	2020SP	2020WP	2025SP
FLT71-PO1	90	90	100	95	100

Table 6-3 shows the results of the fault events simulated for each of the models.

Table 6-10: GEN-2015-014 Dynamic Stability Results

Fault ID	2016WP	2017SP	2020SP	2020WP	2025SP
FLT68-3PH	Stable	Stable	Stable	Stable	Stable
FLT69-3PH	Stable	Stable	Stable	Stable	Stable
FLT70-3PH	Stable	Stable	Stable	Stable	Stable
FLT71-3PH	Stable	Stable	Stable	Stable	Stable
FLT72-3PH	Stable	Stable	Stable	Stable	Stable
FLT73-3PH	Stable	Stable 69 kV System Voltage Recovery Violation. Also observed in PowerFlow and Baseline Models	Stable 69 kV System Voltage Recovery Violation. Also observed in PowerFlow and Baseline Models	Stable	Stable 69 kV System Voltage Recovery Violation. Also observed in PowerFlow and Baseline Models
FLT74-3PH	Stable	Stable	Stable	Stable	Stable
FLT75-3PH	Stable	Stable	Stable	Stable	Stable
FLT76-3PH	Stable	Stable	Stable	Stable	Stable
FLT77-3PH	Stable	Stable	Stable	Stable	Stable
FLT78-3PH	Stable	Stable	Stable	Stable	Stable
FLT79-3PH	Stable	Stable	Stable	Stable	Stable
FLT80-3PH	Stable	Stable	Stable	Stable	Stable
FLT81-3PH	Stable	Stable	Stable	Stable	Stable
FLT82-3PH	Stable	Stable	Stable	Stable	Stable
FLT83-3PH	Stable	Stable	Stable	Stable	Stable
FLT104-3PH	Stable	Stable	Stable	Stable	Stable
FLT110-3PH	Stable	Stable	Stable	Stable	Stable
FLT111-3PH	Stable	Stable	Stable	Stable	Stable
FLT112-3PH	Stable	Stable	Stable	Stable	Stable
FLT113-SB	Stable	Stable	Stable	Stable	Stable
FLT114-3PH	Stable	Stable	Stable	Stable	Stable
FLT115-3PH	Stable	Stable	Stable	Stable	Stable
FLT116-3PH	Stable	Stable	Stable	Stable	Stable
FLT117-3PH	Stable	Stable	Stable	Stable	Stable
FLT118-3PH	Stable	Stable	Stable	Stable	Stable
FLT120-SB	Stable	Stable	Stable	Stable	Stable
FLT9001-SB	Stable	Stable	Stable	Stable	Stable

Table 6-3 continued

Fault ID	2016WP	2017SP	2020SP	2020WP	2025SP
FLT9002-SB	Stable	Stable 69 kV System Voltage Recovery Violation. Also observed in Power Flow and Baseline Models	Stable 69 kV System Voltage Recovery Violation. Also observed in Power Flow and Baseline Models	Stable	Stable 69 kV System Voltage Recovery Violation. Also observed in Power Flow and Baseline Models
FLT9003-3PH	Stable	Stable	Stable	Stable	Stable
FLT9004-3PH	Stable	Stable	Stable	Stable	Stable
FLT71-PO1	**Unstable** Isolation from the 115kV system results in voltage collapse on the 69kV system which is mitigated by GEN-2015-014 curtailing generation output to 90MW	**Unstable** Isolation from the 115kV system results in voltage collapse on the 69kV system which is mitigated by GEN-2015-014 curtailing generation output to 90MW	**Unstable** Isolation from the 115kV system results in voltage collapse on the 69kV system which is mitigated by GEN-2015-014 curtailing generation output to 90MW	**Unstable** Isolation from the 115kV system results in voltage collapse on the 69kV system which is mitigated by GEN-2015-014 curtailing generation output to 90MW	**Unstable** Isolation from the 115kV system results in voltage collapse on the 69kV system which is mitigated by GEN-2015-014 curtailing generation output to 90MW
FLT74-PO2	Stable	Stable	Stable	Stable	Stable
FLT75-PO2	Stable	Stable	Stable	Stable	Stable
FLT118-PO3	Stable	Stable	Stable	Stable	Stable

The associated stability plots are provided in Appendix D. Additionally, the project wind farm was found to stay connected during the contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A.

7.0 Conclusions

The Interconnection Customer for GEN-2015-014 requested a Modification Request Impact Study to assess the impact of the turbine and facility changes presented in Table 7-1 below.

Table 7-11: Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Lehman to Cochran 115 kV line (560030)	Lehman to Cochran 115 kV line (560030)
Configuration/Capacity	75 x Vestas V11 2.0 MW = 150 MW	6 x GE 1.715 MW, 2 x GE 2.0 MW, and 59 x GE 2.3 MW (149.99 MW)
Generation Interconnection Line	Length = 9.5 miles R = 0.005490 pu X = 0.049990 pu B = 0.007740 pu	Length = 9.71 miles R = 0.004640 pu X = 0.048320 pu B = 0.008440 pu
Main Substation Transformer	Z = 10%, Rating 180 MVA	Z = 8%, Rating 170 MVA
Equivalent Collector Line	R = 0.005050pu X = 0.005820 pu B = 0.062610 pu	R = 0.004740 pu X = 0.007730 pu B = 0.077600 pu

A power factor analysis was not performed as there was no change in the point of interconnection for GEN-2015-014.

The reactive power analysis, low-wind/no-wind condition analysis, performed to determine the size of a reactor required at the GEN-2015-014 main substation during low wind conditions showed that an 8.4 MVAr reactor would be needed to maintain the project's reactive power contribution to the POI at zero. The ReStudy #3 showed a need for a 7 MVAr shunt reactor. The difference in the results can be attributed to the changes to the generation interconnection line and the collector system impedances.

The short circuit analysis showed that the maximum increase in fault current caused by GEN-2015-014 did not exceed 35.1%. The largest fault current calculated was below 24 kA for both the 2017SP and 2025SP models.

The results of the dynamic stability analysis showed that with the prior outage on the GEN-2015-014 POI to Cochran 115 kV line followed by the three phase fault on the Plains to Yoakum 115 kV line, GEN-2015-014 may become unstable. To prevent the GEN-2015-014 unstable response during this prior outage condition, GEN-2015-014 may have to be curtailed to about 90 MW output after the loss of either line to prepare for the next event.

In addition, there were some existing voltage violations on the 69 kV system before and after the GEN-2015-014 modification during three fault conditions and also persisted with GEN-2015-014 switched offline. Therefore GEN-2015-014 does not affect those 69 kV voltage violations.
There were no other machine rotor angle damping or transient voltage recovery violations observed in the simulated fault events associated with GEN-2015-014 and the system achieved stable operation after each fault event. Additionally, the project wind farm was found to stay

connected during the remaining contingencies that were studied and will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A.

In conclusion, the results of this Study showed that the Modification Request shown in Table 7-1 do not constitute a material modification.