GEN-2015-090

Impact Restudy for Generator Modification (Turbine Change)

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By SPP Generator Interconnections Dept.

REVISION HISTORY

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SUMMARY

The GEN-2015-090 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 one hundred ten (110) GE 2.0 MW wind turbine generators to eighty-eight (88) Siemens 2.3 MW, six (6) GE 2.3 MW and one (1) GE 2.2 MW (derated from GE 2.3 MW) wind turbine generators. The total nameplate changes from 220 MW to 218.4 MW. The point of interconnection (POI) is at the Westar (WERE) Buffalo Flats 345kV substation.

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. 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 19.3 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-2015-090 with the eighty-eight (88) Siemens 2.3 MW, six (6) GE 2.3 MW and one (1) GE 2.2 MW (derated from 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

SPP Southwest Power Pool

Report On

GEN-2015-090 Modification Request Impact Study

Revision R1

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anedenconsulting.com

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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-2015-090, an active generation interconnection request with point of interconnection (POI) on Thistle to Wichita 345 kV double circuit lines sometimes referred to as the Buffalo Flats 345kV substation.

The GEN-2015-090 project has proposed to interconnect in the Westar Energy (WERE) control area with a capacity of 220 MW including 110 x GE 2.0 MW wind turbines as shown in Table ES-1 below. This Study has been requested to evaluate the modification of GEN-2015-090 to change turbine configuration change to 88 x Siemens 2.3 MW and 6 x GE 2.3 MW and 1 x GE 2.2 MW (derated from GE 2.3 MW) turbines for a total capacity of 218.4 MW. In addition, the modification request included changes to the generation interconnection line, collection system and the main substation transformer. The modification request changes are shown in Table ES-2 below.

Table ES-1: Existing GEN-2015-090 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-090	220	110 x GE 2.0 MW	Thistle to Wichita 345 kV double circuit lines (560033)

Table ES-2: GEN-2015-090 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Thistle to Wichita 345 kV double circuit lines (560033)	Thistle to Wichita 345 kV double circuit lines (560033)
Configuration/Capacity	110 x GE 2.0 MW = 220 MW	88 x Siemens 2.3 MW, 6 x GE 2.3 MW, 1 x GE 2.2 MW turbines (218.4 MW)
Generation Interconnection Line(s)	Length = 44 + 15 + 8 = 67 miles R = 0.002305 pu X = 0.031285 pu B = 0.634458 pu	Length = 44 + 15 + 8 = 67 miles R = 0.002305 pu X = 0.031285 pu B = 0.634458 pu
Main Substation Transformer	Z = 8.5%, Rating 245 MVA	Z = 8.5%, Rating 245 MVA
Equivalent Collector Line	R = 0.00264 pu X = 0.00242 pu B = 0.03136 pu	R = 0.005275 pu X = 0.008806 pu B = 0.12115 pu

GEN-2015-090 was last studied as part of Group 8 in the DISIS-2015-002 ReStudy #4 published on November 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 8 study models:

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

All analyses were performed using the PTI PSS/E version 32 software and the results are summarized below.

A power factor analysis was not performed as there was no change in the point of interconnection for GEN-2015-090.

The results of the reactive power analysis, also known as the low-wind/no-wind condition analysis, performed using all three models showed that the GEN-2015-090 project may require a 19.3 MVAr shunt reactor on the 345 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 ReStudy #4 showed a need for a 71.4 MVAr shunt reactor. The difference in the results may be attributed to the changes to the configuration of the immediate system, generation interconnections in the vicinity of point of interconnection and the collector system impedances.

The results from short circuit analysis showed that the maximum change in the fault currents in the immediate systems at or near GEN-2015-090 was 0.38 kA. All three-phase current levels with the GEN-2015-090 generator online was below 38 kA and 44 kA in the 2017SP and 2025SP models respectively.

The dynamic stability analysis was performed using the three loading scenarios 2016 Winter Peak, 2017 Summer Peak and 2025 Summer Peak simulating up to 42 contingencies that included three-phase faults, three phase faults on prior outage cases, and single-line-to-ground faults stuck breakers faults. There were no machine rotor angle damping or transient voltage recovery violations observed in the simulated fault events. 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 results of this Study show that the GEN-2015-090 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-2015-090, an active generation interconnection request with point of interconnection (POI) on Thistle to Wichita 345 kV double circuit lines sometimes referred to as the Buffalo Flats 345kV substation.

The GEN-2015-090 project has proposed to interconnect in the Westar Energy (WERE) control area with a capacity of 220 MW including 110 x GE 2.0 MW wind turbines as shown in Table 1-1 below. Details of the modification request as provided in Section 2.0 below.

Table 1-1: Existing GEN-2015-090 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-090	220	110 x GE 2.0 MW	Thistle to Wichita 345 kV double circuit lines (560033)

1.1 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 study models:

1. 2016 Winter Peak (2016WP),
2. 2017 Summer Peak (2017SP), and
3. 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.

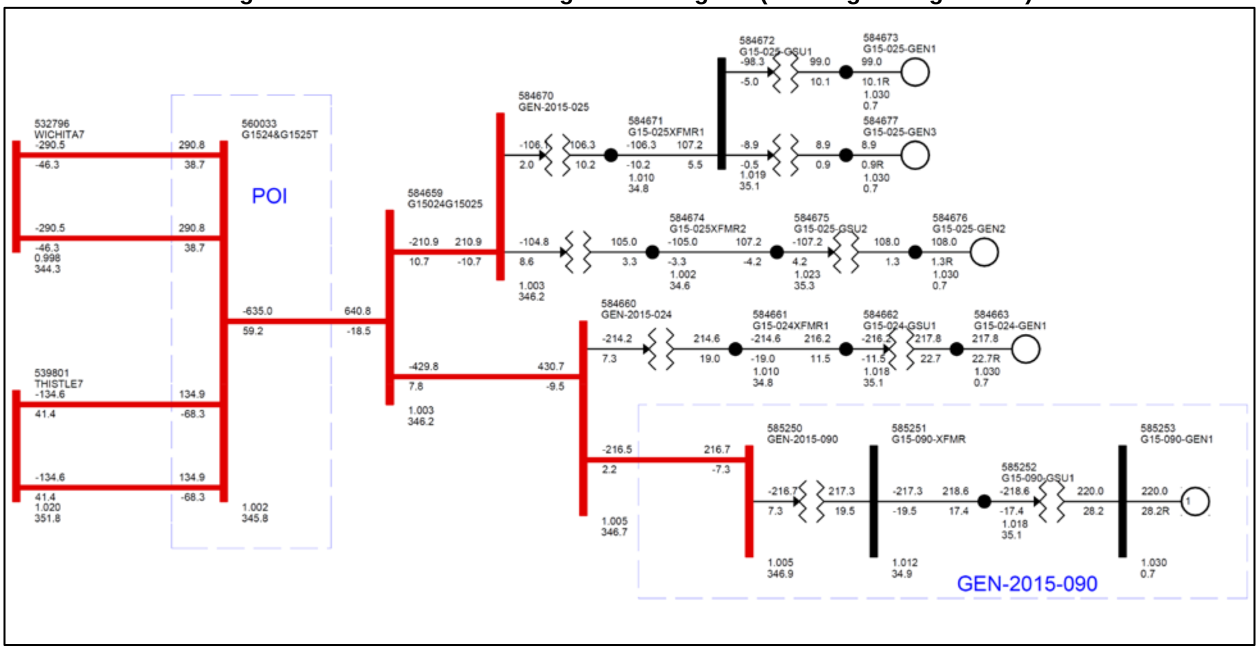
1.2 Study Limitations

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-2015-090 configuration. GEN-2015-090 was last studied as part of Group 8 in the DISIS-2015-002 ReStudy #4 (ReStudy #4) published on November 2017.

Figure 2-1: GEN-2015-090 Single Line Diagram (Existing Configuration)

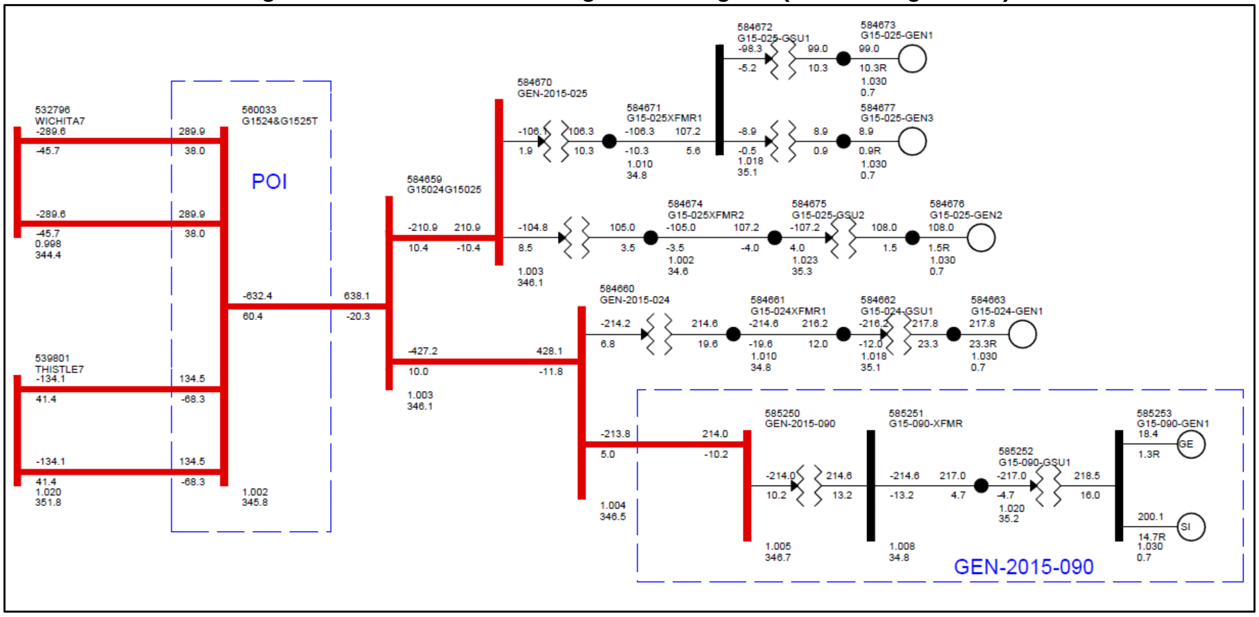


The GEN-2015-090 Modification Request included a turbine change to 88 x Siemens 2.3 MW, 6 x GE 2.3 MW, 1 x GE 2.2 MW (derated from GE 2.3 MW) turbines for a total capacity of 218.4 MW. In addition, the modification request also included changes to the collection system, the main substation transformer and the generation interconnection line. The major modification request changes are shown in Figure 2-2 and Table 2-1 below.

Table 2-1: GEN-2015-090 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Thistle to Wichita 345 kV double circuit lines (560033)	Thistle to Wichita 345 kV double circuit lines (560033)
Configuration/Capacity	110 x GE 2.0 MW = 220 MW	88 x Siemens 2.3 MW, 6 x GE 2.3 MW, 1 x GE 2.2 MW turbines (218.4 MW)
Generation Interconnection Line(s)	Length = 44 + 15 + 8 = 67 miles R = 0.002305 pu X = 0.031285 pu B = 0.634458 pu	Length = 44 + 15 + 8 = 67 miles R = 0.002305 pu X = 0.031285 pu B = 0.634458 pu
Main Substation Transformer	Z = 8.5%, Rating 245 MVA	Z = 8.5%, Rating 245 MVA
Equivalent Collector Line	R = 0.00264 pu X = 0.00242 pu B = 0.03136 pu	R = 0.005275 pu X = 0.008806 pu B = 0.12115 pu

Figure 2-2: GEN-2015-090 Single Line Diagram (New Configuration)



3.0 Power Factor Requirement

The power factor analysis was not performed since the GEN-2015-090 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-2015-090 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.

4.1 Methodology and Criteria

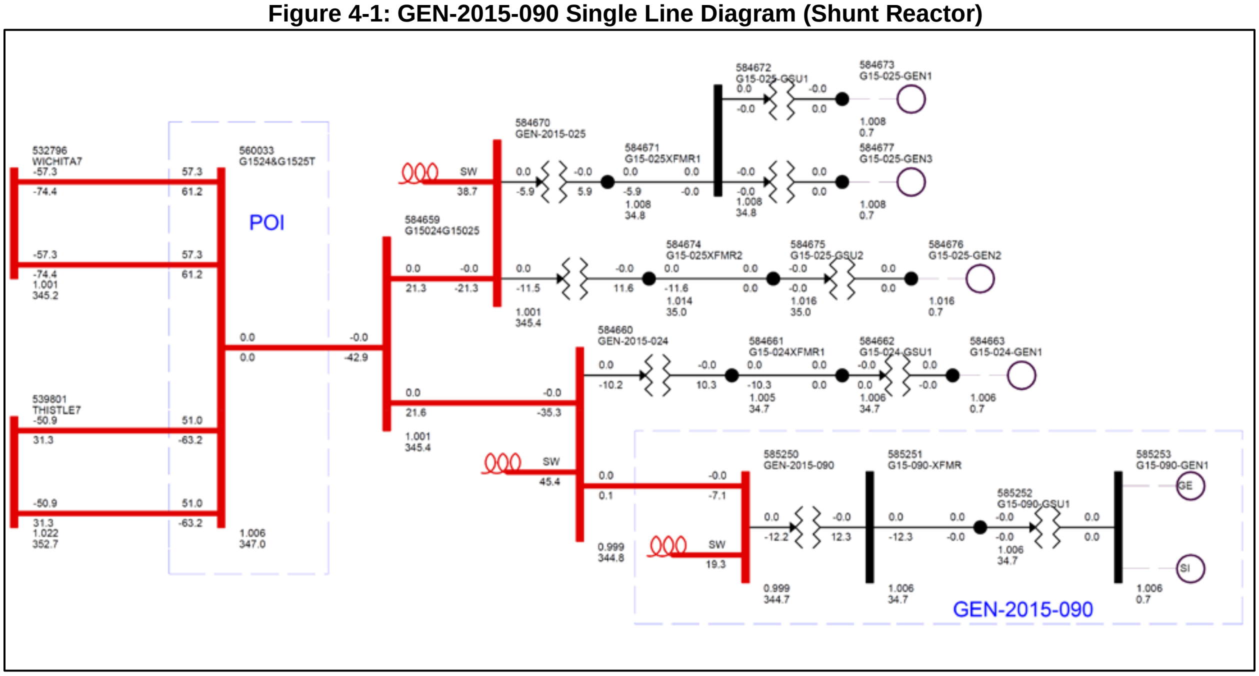
For the GEN-2015-090 project, the generator was switched out of service while other collector system elements remained in-service. A shunt reactor was tested at the study project substation high side bus to bring the MVAr flow into the POI down to approximately zero.

In the study models, there were two additional projects connected to the same POI GEN-2015-090 is proposed to connected, GEN-2015-024 and GEN-2015-025. The reactive requirements for those two higher-queued projects were first determined, without the transmission and collection system only associated with GEN-2015-090 out of service. Once those shunt reactor sizes for those two projects were determined, GEN-2015-090's shunt reactor requirements were then calculated.

4.2 Results

The results from the reactive power analysis showed that the GEN-2015-090 project required approximately 19.3 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.

Figure 4-1: GEN-2015-090 Single Line Diagram (Shunt Reactor)



Per the methodology described above, sizing for the reactors needed at the GEN-2015-025 and GEN-2015-024 was completed first. The two shunt reactors sizes were found to be 38.6 MVAR and 45.5 MVAR respectively for GEN-2015-025 and GEN-2015-024 respectively.

Table 4-1 shows the shunt reactor size determined for the three study models used in the assessment.

Table 4-1: Shunt Reactor Size for Low Wind Study

Machine	POI Bus Number	POI Bus Name	Reactor Size (MVAr)		
			16WP	17SP	25SP
GEN-2015-090	560033	G1524&G1525T	19.3	19.3	19.3

5.0 Short Circuit Analysis

A short-circuit study was performed on the power flow models for the 2017SP and 2025SP models for GEN-2015-090 using the modified Cluster Scenario models. The detail results of the short-circuit analysis are provided in Appendix A.

5.1 Methodology

The short-circuit analysis included applying a 3-phase fault on buses up to 5 levels away from the G1524&G1525T 345 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.

5.2 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 0.455 kA. The maximum fault current calculated within 5 buses with GEN-2015-090 was less than 38 kA and 44 kA for the 2017SP and 2025SP models respectively.

Table 5-1: 2017SP Short Circuit Results

Bus Distance	Max. Change (kA)	Max %Change
0	0.303	1.5%
1	0.422	6.5%
2	0.456	8.6%
3	0.051	0.2%
4	0.031	0.1%
5	0.025	0.1%

Table 5-2: 2025SP Short Circuit Results

Bus Distance	Max. Change (kA)	Max %Change
0	0.302	1.4%
1	0.422	6.4%
2	0.455	8.5%
3	0.055	0.2%
4	0.029	0.1%
5	0.025	0.1%

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-2015-090 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.

6.1 Methodology and Criteria

The dynamic stability analysis was performed using models developed with the requested 88 x Siemens 2.3 MW and 6 x GE 2.3 MW and 1 x GE 2.2 MW (derated from GE 2.3 MW) turbines turbine configuration for the GEN-2015-090 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 8 including network upgrades identified in that restudy. The modifications requested to project GEN-2015-090 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, GEN-2015-090 is provided in Appendix C.

During the fault simulations, the active power (PELEC), reactive power (QELEC) and terminal voltage (ETERM) were monitored for GEN-2015-090 and other equally and prior queued projects in Group 8. In addition, voltages of five (5) buses away from the POI of GEN-2015-090 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), 540 (GMO) and 541 (KCPL) were monitored. In addition, the voltages of all 100 kV and above buses within the study area were monitored.

6.2 Fault Definitions

Aneden selected the fault events simulated specifically for GEN-2015-090 in the DISIS-2015-002 Group 8 study and included additional faults based on the location of the 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, and the 2025 Summer Peak models.

Table 6-1: Fault Definitions

Fault Name	Description
FLT8-3PH	3 phase fault on the G1524&G1525T (560033) to THISTLE7 (539801) 345 kV line circuit 1, near G1524&G1525T
	a. Apply fault at the G1524&G1525T (560033) 345 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.
FLT9-3PH	3 phase fault on the G1524&G1525T (560033) to WICHITA7 (532796) 345 kV line circuit 1, near G1524&G1525T
	a. Apply fault at the G1524&G1525T (560033) 345 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.
FLT10-3PH	3 phase fault on the THISTLE7 (539801) to G16-005-TAP (560072) 345 kV line circuit 1, near THISTLE7.
	a. Apply fault at the THISTLE7 (539801) 345 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.
FLT11-3PH	3 phase fault on the THISTLE7 (539801) to WWRDEHV7 (515375) 345 kV line circuit 1, near THISTLE7.
	a. Apply fault at the THISTLE7 (539801) 345 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.
FLT12-3PH	3 phase fault on the THISTLE7 (539801) 345 kV / (539804) 138 kV / (539802) 13.8 kV transformer, near THISTLE7 345 kV.
	a. Apply fault at the THISTLE7 (539801) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT13-3PH	3 phase fault on the WICHITA7 (532796) to VIOLA 7 (532798) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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.
FLT14-3PH	3 phase fault on the WICHITA7 (532796) to RENO 7 (532771) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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.
FLT15-3PH	3 phase fault on the WICHITA7 (532796) to BENTON 7 (532791) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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.
FLT16-3PH	3 phase fault on the WICHITA7 (532796) to G14-001-TAP (562476) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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 Name	Description
FLT17-3PH	3 phase fault on the WICHITA7 (532796) 345 kV / (533040) 138 kV / (532830) 13.8 kV transformer, near WICHITA7 345 kV.
	a. Apply fault at the WICHITA7 (532796) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT99-SB	Stuck breaker on WICHITA7 (532796) - G1524&G1525T (560033) 345 kV circuit 2 line.
	a. Apply single-phase fault at WICHITA7 (532796) on the 345 kV bus.
	b. after 16 cycles trip the WICHITA7 (532796) 345 kV / (533040) 138 kV / (532829) 13.8 kV transformer
	c. Trip the WICHITA7 (532796) - G1524&G1525t (560033) 345 kV circuit 2 line, and remove the fault
FLT100-SB	Stuck breaker on WICHITA7 (532796) - G1524&G1525T (560033) 345 kV circuit 1 line.
	a. Apply single-phase fault at WICHITA7 (532796) on the 345 kV bus.
	b. After 16 cycles trip the WICHITA7 (532796) - VIOLA 7 (532798) 345 kV line circuit 1
	c. Trip the WICHITA7 (532796) - G1524&G1525t (560033) 345 kV circuit 1 line, and remove the fault
FLT101-SB	Stuck breaker on WICHITA7 (532796) - G14-001 Tap (562476) 345 kV circuit 1 line.
	a. Apply single-phase fault at WICHITA7 (532796) on the 345 kV bus.
	b. after 16 cycles trip the WICHITA7 (532796) 345 kV / (533040) 138 kV / (532829) 13.8 kV transformer
	c. Trip the WICHITA 7 (532796) - G14-001 Tap (562476) 345 kV line, and remove the fault
FLT102-SB	Stuck breaker on WICHITA7 (532796) - RENO 7 (532771) 345 kV circuit 1line
	a. Apply single-phase fault at WICHITA7 (532796) on the 345 kV bus.
	b. After 16 cycles trip the WICHITA7 (532796) - BENTON (532791) 345 kV line circuit 1
	c. Trip the WICHITA7 (532796) - RENO 7 (532771) 345 kV circuit 1 line, and remove the fault
FLT124-SB	Stuck breaker on G1524&G1525T (560033) - WICHITA7 (532796) 345 kV line circuit 1
	a. Apply single-phase fault at G1524&G1525T (560033) on the 345 kV bus.
	b. After 16 cycles trip the G1524&G1525T (560033) - THISTLE 7 (539801) 345 kV line circuit 1
	c. Trip the G1524&G1525T (560033) - WICHITA7 (532796) 345 kV circuit 1 line, and remove the fault
FLT79-PO1	Prior outage on the G1524&G1525T (560033) - WICHITA7 (532796) 345 kV line circuit 1
	3 phase fault on the G1524&G1525T (560033) to WICHITA7 (532796) 345 kV line circuit 2, near G1524&G1525T
	a. Apply fault at the G1524&G1525T (560033) 345 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-PO1	Prior outage on the G1524&G1525T (560033) - WICHITA7 (532796) 345 kV line circuit 1
	3 phase fault on the G1524&G1525T (560033) to THISTLE7 (539801) 345 kV line circuit 2, near G1524&G1525T
	a. Apply fault at the G1524&G1525T (560033) 345 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.
FLT79-PO2	Prior outage on the G1524&G1525T (560033) - THISTLE7 (539801) 345 kV line circuit 1
	3 phase fault on the G1524&G1525T (560033) to WICHITA7 (532796) 345 kV line circuit 2, near G1524&G1525T
	a. Apply fault at the G1524&G1525T (560033) 345 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-PO2	Prior outage on the G1524&G1525T (560033) - THISTLE7 (539801) 345 kV line circuit 1
	3 phase fault on the G1524&G1525T (560033) to THISTLE7 (539801) 345 kV line circuit 2, near G1524&G1525T
	a. Apply fault at the G1524&G1525T (560033) 345 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 Name	Description
FLT9001-3PH	3 phase fault on the WWRDEHV7 (515375) to BORDER 7 (515458) 345 kV line circuit 1, near WWRDEHV7
	a. Apply fault at the WWRDEHV7 (515375) 345 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.
FLT9003-3PH	3 phase fault on the WWRDEHV7 (515375) to TATONGA7 (515407) 345 kV line circuit 1, near WWRDEHV7
	a. Apply fault at the WWRDEHV7 (515375) 345 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.
FLT9004-3PH	3 phase fault on the WWRDEHV7 (515375) to G16-003-TAP (560071) 345 kV line circuit 1, near WWRDEHV7
	a. Apply fault at the WWRDEHV7 (515375) 345 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.
FLT9005-3PH	3 phase fault on the WWRDEHV7 (515375) 345 kV / (515376) 138 kV / (515799) 13.8 kV transformer, near WWRDEHV7 345 kV.
	a. Apply fault at the WWRDEHV7 (515375) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9006-3PH	3 phase fault on the G16-005-TAP (560072) to CLARKCOUNTY7 (539800) 345 kV line circuit 1, near G16-005-TAP
	a. Apply fault at the G16-005-TAP (560072) 345 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.
FLT9007-3PH	3 phase fault on the BENTON 7 (532791) to WOLFCRK7 (532797) 345 kV line circuit 1, near BENTON 7
	a. Apply fault at the BENTON 7 (532791) 345 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.
FLT9008-3PH	3 phase fault on the BENTON 7 (532791) 345 kV / (532986) 138 kV / (532821) 13.8 kV transformer, near BENTON 7 345 kV.
	a. Apply fault at the BENTON 7 (532791) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9009-3PH	3 phase fault on the BENTON 7 (532791) to ROSEHIL7 (532794) 345 kV line circuit 1, near BENTON 7
	a. Apply fault at the BENTON 7 (532791) 345 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.
FLT9010-3PH	3 phase fault on the G14-001-TAP (562476) to EMPEC 7 (532768) 345 kV line circuit 1, near G14-001-TAP
	a. Apply fault at the G14-001-TAP (562476) 345 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.
FLT9011-3PH	3 phase fault on the VIOLA 7 (532798) to RENFROW7 (515543) 345 kV line circuit 1, near VIOLA 7
	a. Apply fault at the VIOLA 7 (532798) 345 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 Name	Description
FLT9013-3PH	3 phase fault on the RENO 7 (532771) to SUMMIT 7 (532773) 345 kV line circuit 1, near RENO 7
	a. Apply fault at the RENO 7 (532771) 345 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.
FLT9014-3PH	3 phase fault on the RENO 7 (532771) 345 kV / (533416) 115 kV / (532810) 13.8 kV transformer, near RENO 7 345 kV.
	a. Apply fault at the RENO 7 (532771) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9015-3PH_25SP	3 phase fault on the VIOLA 7 (532798) 345 kV / (533075) 138 kV / (532832) 13.8 kV transformer, near VIOLA 7 345 kV.
	a. Apply fault at the VIOLA 7 (532798) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT10-PO1	Prior outage on the G1524&G1525T (560033) - WICHITA7 (532796) 345 kV line circuit 1
	3 phase fault on the THISTLE7 (539801) to G16-005-TAP (560072) 345 kV line circuit 1, near THISTLE7.
	a. Apply fault at the THISTLE7 (539801) 345 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.
FLT11-PO1	Prior outage on the G1524&G1525T (560033) - WICHITA7 (532796) 345 kV line circuit 1
	3 phase fault on the THISTLE7 (539801) to WWRDEHV7 (515375) 345 kV line circuit 1, near THISTLE7.
	a. Apply fault at the THISTLE7 (539801) 345 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.
FLT12-PO1	Prior outage on the G1524&G1525T (560033) - WICHITA7 (532796) 345 kV line circuit 1
	3 phase fault on the THISTLE7 (539801) 345 kV / (539804) 138 kV / (539802) 13.8 kV transformer, near THISTLE7 345 kV.
	a. Apply fault at the THISTLE7 (539801) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT13-PO2	Prior outage on the G1524&G1525T (560033) - THISTLE7 (539801) 345 kV line circuit 1
	3 phase fault on the WICHITA7 (532796) to VIOLA 7 (532798) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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.
FLT14-PO2	Prior outage on the G1524&G1525T (560033) - THISTLE7 (539801) 345 kV line circuit 1
	3 phase fault on the WICHITA7 (532796) to RENO 7 (532771) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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.
FLT15-PO2	Prior outage on the G1524&G1525T (560033) - THISTLE7 (539801) 345 kV line circuit 1
	3 phase fault on the WICHITA7 (532796) to BENTON 7 (532791) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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 Name	Description
FLT16-PO2	Prior outage on the G1524&G1525T (560033) - THISTLE7 (539801) 345 kV line circuit 1
	3 phase fault on the WICHITA7 (532796) to G14-001-TAP (562476) 345 kV line circuit 1, near WICHITA7.
	a. Apply fault at the WICHITA7 (532796) 345 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.
FLT17-PO2	Prior outage on the G1524&G1525T (560033) - THISTLE7 (539801) 345 kV line circuit 1
	3 phase fault on the WICHITA7 (532796) 345 kV / (533040) 138 kV / (532830) 13.8 kV transformer, near WICHITA7 345 kV.
	a. Apply fault at the WICHITA7 (532796) 345 kV bus.
	b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9100-SB	Stuck breaker on THISTLE (539801) - G1524&G1525T (560033) 345 kV circuit 1 line.
	a. Apply single-phase fault at THISTLE (539801) 345 kV bus.
	b. after 16 cycles trip the THISTLE (539801) - G1524&G1525T (560033) 345 kV circuit 1 line.
	c. Trip the THISTLE (539801) - G16-005-TAP (560072) 345 kV circuit 2 line. and remove the fault
FLT9200-SB	Stuck breaker on THISTLE (539801) - G1524&G1525T (560033) 345 kV circuit 2 line.
	a. Apply single-phase fault at THISTLE (539801) 345 kV bus.
	b. after 16 cycles trip the THISTLE (539801) - G1524&G1525T (560033) 345 kV circuit 2 line.
	c. Trip the THISTLE7 (539801) 345 kV / (539804) 138 kV / (539802) 13.8 kV transformer. and remove the fault

6.3 Results

Table 6-2 shows the results of the fault events simulated for each of the models. There were no damping or voltage recovery violations observed during the simulations and the system returned to stable conditions following each of the fault events. 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.

Table 6-2: GEN-2015-090 Dynamic Stability Results

Fault ID	2016WP	2017SP	2025SP
FLT8-3PH	Stable	Stable	Stable
FLT9-3PH	Stable	Stable	Stable
FLT10-3PH	Stable	Stable	Stable
FLT11-3PH	Stable	Stable	Stable
FLT12-3PH	Stable	Stable	Stable
FLT13-3PH	Stable	Stable	Stable
FLT14-3PH	Stable	Stable	Stable
FLT15-3PH	Stable	Stable	Stable
FLT16-3PH	Stable	Stable	Stable
FLT17-3PH	Stable	Stable	Stable
FLT99-SB	Stable	Stable	Stable
FLT100-SB	Stable	Stable	Stable
FLT101-SB	Stable	Stable	Stable

Table 6-2 continued

Fault ID	2016WP	2017SP	2025SP
FLT102-SB	Stable	Stable	Stable
FLT124-SB	Stable	Stable	Stable
FLT9001-3PH	Stable	Stable	Stable
FLT9002-3PH	Stable	Stable	Stable
FLT9003-3PH	Stable	Stable	Stable
FLT9004-3PH	Stable	Stable	Stable
FLT9005-3PH	Stable	Stable	Stable
FLT9006-3PH	Stable	Stable	Stable
FLT9007-3PH	Stable	Stable	Stable
FLT9008-3PH	Stable	Stable	Stable
FLT9009-3PH	Stable	Stable	Stable
FLT9010-3PH	Stable	Stable	Stable
FLT9011-3PH	Stable	Stable	Stable
FLT9013-3PH	Stable	Stable	Stable
FLT9014-3PH	Stable	Stable	Stable
FLT9015-3PH_25SP	N/A	N/A	Stable
FLT79-PO1	Stable	Stable	Stable
FLT80-PO1	Stable	Stable	Stable
FLT10-PO1	Stable	Stable	Stable
FLT11-PO1	Stable	Stable	Stable
FLT12-PO1	Stable	Stable	Stable
FLT79-PO2	Stable	Stable	Stable
FLT80-PO2	Stable	Stable	Stable
FLT13-PO2	Stable	Stable	Stable
FLT14-PO2	Stable	Stable	Stable
FLT15-PO2	Stable	Stable	Stable
FLT16-PO2	Stable	Stable	Stable
FLT17-PO2	Stable	Stable	Stable
FLT9100-SB	Stable	Stable	Stable
FLT9200-SB	Stable	Stable	Stable

7.0 Conclusions

The Interconnection Customer for GEN-2015-090 requested a Modification Request Impact Study to assess the impact of the turbine and facility changes presented in Table 7-1 below.

Table 7-1: Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Thistle to Wichita 345 kV double circuit lines (560033)	Thistle to Wichita 345 kV double circuit lines (560033)
Configuration/Capacity	110 x GE 2.0 MW = 220 MW	88 x Siemens 2.3 MW, 6 x GE 2.3 MW, 1 x GE 2.2 MW turbines (218.4 MW)
Generation Interconnection Line(s)	Length = 44 + 15 + 8 = 67 miles R = 0.002305 pu X = 0.031285 pu B = 0.634458 pu	Length = 44 + 15 + 8 = 67 miles R = 0.002305 pu X = 0.031285 pu B = 0.634458 pu
Main Substation Transformer	Z = 8.5%, Rating 245 MVA	Z = 8.5%, Rating 245 MVA
Equivalent Collector Line	R = 0.00264 pu X = 0.00242 pu B = 0.03136 pu	R = 0.005275 pu X = 0.008806 pu B = 0.12115 pu

A power factor analysis was not performed as there was no change in the point of interconnection for GEN-2015-090.

The results of the reactive power analysis, also known as the low-wind/no-wind condition analysis, performed using all three models showed that the GEN-2015-090 project may require a 19.3 MVAr shunt reactor on the 345 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 short circuit analysis showed the maximum increase in fault current caused by GEN-2015-090 did not exceed 0.455 kA. The largest fault current calculated was below 38 kA and 44 kA for the 2017SP and 2025SP models respectively.

The results of the dynamic stability analysis showed that there were no machine rotor angle damping or transient voltage recovery violations observed in the simulated fault events and the system achieved stable operation after each fault event. 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.

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