Southwest Power Pool

GEN-2015-064

Impact Restudy for Generator Modification

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By SPP Generator Interconnections Dept.

REVISION HISTORY

DATE OR VERSION NUMBER	AUTHOR	CHANGE DESCRIPTION
09/03/2019	SPP	Initial report issued.

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SUMMARY

The GEN-2015-064 Interconnection Customer has requested a modification to its 197.8 MW Interconnection Request. This system impact restudy was performed to determine the effects of changing wind turbine generators from 86 Siemens 2.3 MW wind turbine generators (for a total of 197.8 MW) to 72 GE 2.73 MW wind turbine generators (for a total of 196.56 MW). In addition, the modification request included changes to the generation interconnection line, collection system and the generator substation transformer. The point of interconnection (POI) for GEN-2015-064 remains at the Mingo 115 kV Substation.

This study was performed by Aneden Consulting to determine whether the request for modification is considered Material. A short circuit analysis, a low-wind/no-wind condition analysis, and stability analysis was performed for this modification request. The study report follows this executive summary.

The generating facility will be required to maintain a 95% lagging (providing VARs) and 95% leading (absorbing VArs) in accordance with FERC Order 827. Additionally, the project will be required to install approximately 9.2 MVArs of reactor shunts on its substation 115 kV bus or provide an alternate means of reactive power 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.

The results of the dynamic stability analysis showed that there was one existing system performance violation that was not associated with the GEN-2015-064 modification. Generation interconnecting at Mingo substation (GEN-2015-064, GEN-2015-065, & GEN-2016-067) may have to be curtailed following the outage of either Mingo to Red Willow 345 kV line or Mingo to Setab 345 kV line in order to maintain system reliability. The three projects may have to be curtailed by a combined amount of approximately 123 MW (with GEN-2016-067 switched off first). This combined curtailment includes complete curtailment of GEN-2016-067 to 0 MW and approximately 25 MW curtailment of GEN-2015-064 and Gen-2015-065 each. The need for curtailment was observed both with the existing and post-modification project configurations.

With curtailment requirement described above, there were no other 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 requested modification is not considered Material.

It should be noted that this study analyzed the requested modification to change generator technology and layout. Powerflow analysis was not performed. 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.

Submitted to

Southwest Power Pool

SPP Southwest Power Pool

Report On

GEN-2015-064
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-2015-064, an active generation interconnection request with point of interconnection (POI) on the Mingo 115kV substation.

The GEN-2015-064 project was proposed to interconnect in the Sunflower Electric Power Corporation (SUNC) control area with a capacity of 197.8 MW as shown in Table ES-1 below. This Study has been requested to evaluate the modification of GEN-2015-064 to change turbine configuration to a total of 72 x GE 2.73 MW wind turbines for a total capacity of 196.56 MW. In addition, the modification request included changes to the collection system and the generator substation transformer. The modification request changes are shown in Table ES-2 below.

Table ES-1: Existing GEN-2015-064 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-064	197.8	86 x Siemens 2.3 MW	Mingo 115 kV (531429)

Table ES-2: GEN-2015-064 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Mingo 115 kV Substation (531429)	Mingo 115 kV Substation (531429)
Configuration/Capacity	86 x Siemens 2.3 MW = 197.8 MW	72 x GE 2.73 MW = 196.56 MW
Generation Interconnection Line	Length = 3.54 miles	Length = 3.54 miles
	R = 0.002800 pu	R = 0.002800 pu
	X = 0.013500 pu	X = 0.013500 pu
	B = 0.003900 pu	B = 0.003900 pu
Main Substation Transformer	Z = 8%, Winding 135 MVA, Rating A 180 MVA, Rating B 225 MVA	Two Identical Transformers:
		Z = 9%, Winding 66 MVA, Rating 110 MVA
GSU Transformer	Equivalent Qty: 86:	Equivalent Qty: 72:
	Z = 6%, Rating 223.6 MVA	Z = 6.2%, Rating 225.9 MVA
Equivalent Collector Line	R = 0.005264 pu	R = 0.003195 pu
	X = 0.007185 pu	X = 0.004096 pu
	B = 0.042590 pu	B = 0.087760 pu

GEN-2015-064 was last studied as part of Group 4 in the DISIS-2015-002-7. Aneden performed reactive power analysis, short circuit analysis and dynamic stability analysis using the modification request data on the initial DISIS-2016-002 Group 4 study models.

All analyses were performed using the PTI PSS/E version 33.7 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-2015-064.

The results of the reactive power analysis, also known as the low-wind/no-wind condition analysis, performed using the three main models showed that the GEN-2015-064 project may require an 9.2

MVAr shunt reactor on the 115kV 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-2015-064 was approximately 2.42 kA for the 2018SP and 2.44kA for 2026SP. All three-phase fault current levels with the GEN-2015-064 generator online were below 24 kA for the 2018SP models and 2026SP models.

The dynamic stability analysis was performed using the three from DISIS-2016-002 models 2017 Winter Peak, 2018 Summer Peak, 2026 Summer Peak. Up to 80 contingencies were simulated, which 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, consistent with the previous DISIS-2015-002 & DISIS-2016-001 Group 4 studies, generation interconnecting at Mingo substation (GEN-2015-064, GEN-2015-065, & GEN-2016-067) may have to be curtailed following the prior outage of either the Mingo to Red Willow 345 kV line or the Mingo to Setab 345 kV line in order to maintain system reliability. The three projects may have to be curtailed by a combined amount of approximately 123 MW (with GEN-2016-067 switched off first). This combined curtailment includes complete curtailment of GEN-2016-067 to 0 MW and approximately 25 MW curtailment of GEN-2015-064 and Gen-2015-065 each. The need for curtailment was observed both with the existing and post-modification project configurations.

With curtailment requirement described above, there were no other machine rotor angle damping or transient voltage recovery violations observed in the remaining simulated fault events associated with this modification request study. Additionally, the project wind farm was found to stay connected during the other 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-2015-064 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-2015-064, an active generation interconnection request with point of interconnection (POI) at the Mingo 115kV substation.

The GEN-2015-064 project was proposed to interconnect in the Sunflower Electric Power Corporation (SUNC) control area with a combined capacity of 197.8 MW as shown in Table 1-1 below. Details of the modification request are provided in Section 2.0 below.

Table 1-1: Existing GEN-2015-064 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-064	197.8	86 x Siemens 2.3 MW	Mingo 115 kV (531429)

1.1 Scope

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

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

The analyses were performed using a set of modified study models developed using the modification request data and the three initial DISIS-2016-002 study models:

1. 2017 Winter Peak (2017WP),
2. 2018 Summer Peak (2018SP), and
3. 2026 Summer Peak (2026SP).

All analyses were performed using the PTI PSS/E version 33.7 software. The results of each analysis are presented in the following sections.

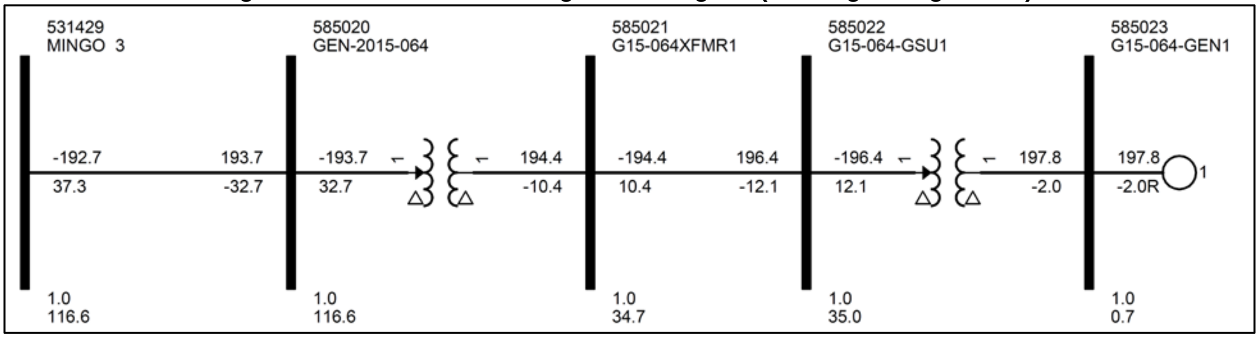
1.2 Study Limitations

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-2015-064 configuration. GEN-2015-064 was originally studied as part of Group 4 in the DISIS-2015-002 study.

Figure 2-1: GEN-2015-064 Single Line Diagram (Existing Configuration)



The GEN-2015-064 Modification Request included a turbine configuration change to a total of 72 x GE 2.73 MW wind turbines for a total capacity of 196.56 MW. In addition, the modification request also included changes to the collection system and the generator substation transformer. The major modification request changes are shown in Figure 2-2 and Table 2-1 below.

Figure 2-2: GEN-2015-064 Single Line Diagram (New Configuration)

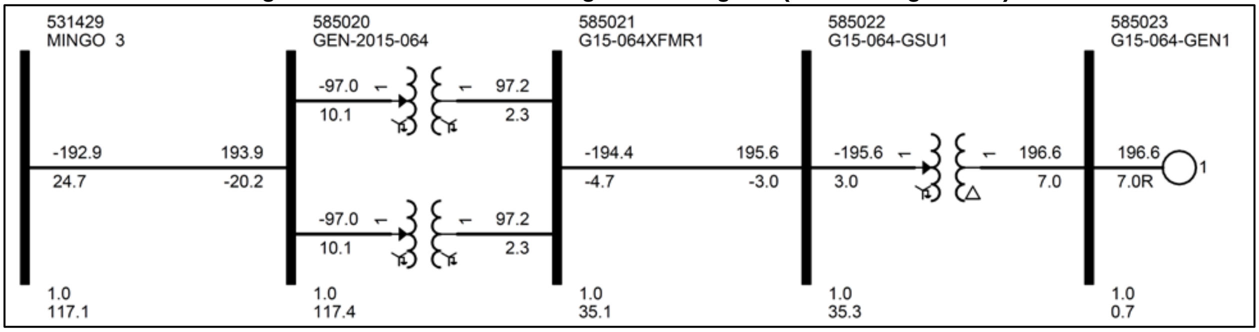


Table 2-1: GEN-2015-064 Modification Request

Facility	Existing	Modification Request
Point of Interconnection	Mingo 115 kV Substation (531429)	Mingo 115 kV Substation (531429)
Configuration/Capacity	86 x Siemens 2.3 MW = 197.8 MW	72 x GE 2.73 MW = 196.56 MW
Generation Interconnection Line	Length = 3.54 miles	Length = 3.54 miles
	R = 0.002800 pu	R = 0.002800 pu
	X = 0.013500 pu	X = 0.013500 pu
	B = 0.003900 pu	B = 0.003900 pu
Main Substation Transformer	Z = 8%, Winding 135 MVA, Rating A 180 MVA, Rating B 225 MVA	Two Identical Transformers:
		Z = 9%, Winding 66 MVA, Rating 110 MVA
GSU Transformer	Equivalent Qty: 86:	Equivalent Qty: 72:
	Z = 6%, Rating 223.6 MVA	Z = 6.2%, Rating 225.9 MVA
Equivalent Collector Line	R = 0.005264 pu	R = 0.003195 pu
	X = 0.007185 pu	X = 0.004096 pu
	B = 0.042590 pu	B = 0.087760 pu

3.0 Reactive Power Analysis

The reactive power analysis, also known as the low-wind/no-wind condition analysis, was performed for GEN-2015-064 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.

3.1 Methodology and Criteria

For the GEN-2015-064 project, the generator was switched out of service while other collector system elements remained in-service. A shunt reactor was tested at the collection substation 115 kV bus to set the MVAr flow into the POI to approximately zero.

3.2 Results

The results from the reactive power analysis showed that the GEN-2015-064 projects required approximately 9.2 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 collection system. Figure 3-1 illustrates the shunt reactor size required to reduce the POI MVAr to approximately zero. Reactive compensation can be provided either by discrete reactive devices or by the generator itself if it possesses that capability.

Figure 3-1: GEN-2015-064 Single Line Diagram (Shunt Reactor)

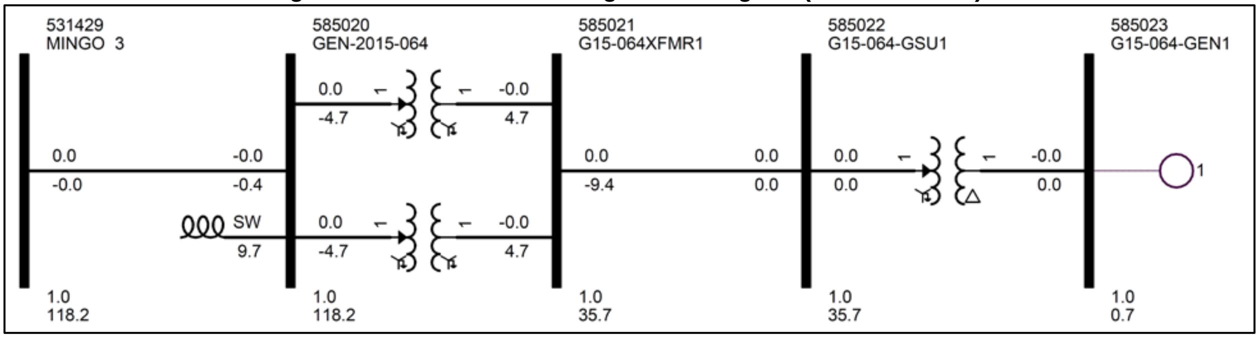


Table 3-1 shows the shunt reactor size determined for the three study models used in the assessment.

Table 3-1: Shunt Reactor Size for Low Wind Study

Machine	POI Bus Number	POI Bus Name	Reactor Size (MVAr)		
			17WP	18SP	26SP
GEN-2015-064	531429	Mingo Substation	9.2	9.2	9.2

4.0 Short Circuit Analysis

A short-circuit study was performed using the 2018SP and 2026SP models for GEN-2015-064. The detail results of the short-circuit analysis are provided in Appendix A.

4.1 Methodology

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

4.2 Results

The results of the short circuit analysis for the 2018SP and 2026SP models are summarized in Table 4-1 and Table 4-2 respectively. The maximum increase in fault current was about 21.1%, 2.44 kA. The maximum fault current calculated within 5 buses with GEN-2015-064 was less than 24 kA for the 2018SP and 2026SP models respectively.

Table 4-1: 2018SP Short Circuit Results

Voltage (kV)	Max. Current (kA)	Max kA Change	Max %Change
69	4.6	0.13	3.3%
115	22.3	2.44	21.1%
230	19.2	0.02	0.1%
345	16.0	0.62	10.3%
Max	**22.3**	**2.44**	**21.1%**

Table 4-2: 2026SP Short Circuit Results

Voltage (kV)	Max. Current (kA)	Max kA Change	Max %Change
69	4.8	0.06	1.4%
115	23.1	2.42	20.7%
230	19.8	0.02	0.1%
345	17.3	0.61	10.1%
Max	**23.1**	**2.42**	**20.7%**

5.0 Dynamic Stability Analysis

Aneden performed a dynamic stability analysis to identify the impact of the turbine configuration change and other modifications to the GEN-2015-064 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.

5.1 Methodology and Criteria

The dynamic stability analysis was performed using models developed with the requested 72 x GE 2.73 MW turbine configuration for the GEN-2015-064 generating facilities. This stability analysis was performed using PTI's PSS/E version 33.7 software.

The stability models were developed using the models from DISIS-2016-002 for Group 4 including network upgrades identified in Section 1.0. The modifications requested to project GEN-2015-064 were used to create modified stability models for this impact study.

The modified dynamics model data for the DISIS-2016-002 Group 4 request, GEN-2015-064 is provided in Appendix C. 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.

During the fault simulations, the active power (PELEC), reactive power (QELEC) and terminal voltage (ETERM) were monitored for GEN-2015-064 and other equally and prior queued projects in Group 4. In addition, voltages of five (5) buses away from the POI of GEN-2015-064 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), 640 (NPPD) were monitored. In addition, the voltages of all 100 kV and above buses within the study area were monitored.

5.2 Fault Definitions

Aneden selected a subset of the fault events simulated specifically for GEN-2015-064 in the DISIS-2015-002 Group 4 study as well as fault definitions from DISIS-2016-001 & DISIS-2016-002 Group 4 studies. The new set of faults were simulated using the modified study models. The fault events include three-phase faults, three phase faults on prior outage cases, and single-line-to-ground faults with stuck breakers. The simulated faults are listed and described in Table 5-1 below. These contingencies were applied to the modified 2017 Winter Peak, 2018 Summer Peak, and the 2026 Summer Peak models.

Table 5-1: Fault Definitions

Fault ID	Fault Descriptions
FLT17-3PH	3 phase fault on the Colby 115kV (530555) to Atwood 115kV (530554) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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.
FLT18-3PH	3 phase fault on the Colby 115kV (530555) to Seguin Tap 115kV (530682) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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.
FLT19-3PH	3 phase fault on the Colby 115kV (530555) to Mingo 115kV (531429) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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.
FLT20-3PH	3 phase fault on the Mingo 115kV (531429) to Pheasant Run 115kV (530559) CKT 1, near Mingo. a. Apply fault at the Mingo 115kV 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.
FLT21-3PH	3 phase fault on the Mingo 115kV (531429) to Brewster 115kV (531351) CKT 1, near Mingo. a. Apply fault at the Mingo 115kV 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.
FLT22-3PH	3 phase fault on the Mingo 115kV (531429) to Mingo 345kV (531451) to Mingo 13.8kV (531452) XFMR CKT 1, near Mingo 115kV. a. Apply fault at the Mingo 115kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT23-3PH	3 phase fault on the Mingo 345kV (531451) to Red Willow 345kV (640325) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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.
FLT25-3PH	3 phase fault on the Mingo 345kV (531451) to Setab 345kV (531465) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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.
FLT26-3PH	3 phase fault on the Setab 345kV (531465) to Holcomb 345kV (531449) CKT 1, near Setab. a. Apply fault at the Setab 345kV 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.
FLT27-3PH	3 phase fault on the Holcomb 345kV (531449) to Buckner 345kV (531501) CKT 1, near Holcomb. a. Apply fault at the Holcomb 345kV 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.
FLT28-3PH	3 phase fault on the Setab 345kV (531465) to Setab 115kV (531464) to Setab 13.8kV (531259) XFMR CKT 1, near Setab 345kV. a. Apply fault at the Setab 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.

Table 5-1 continued

Fault ID	Fault Descriptions
FLT29-3PH	3 phase fault on the Red Willow 345kV (640325) to Gentleman 345kV (640183) CKT 1, near Red Willow. a. Apply fault at the Red Willow 345kV 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.
FLT30-3PH	3 phase fault on the Red Willow 345kV (640325) to Red Willow 115kV (640326) to Red Willow 13.8kV (640327) XFMR CKT 1, near Red Willow. a. Apply fault at the Red Willow 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT31-3PH	3 phase fault on the Gentleman 345kV (640183) to Sweetwater 345kV (640374) CKT 1, near Gentleman. a. Apply fault at the Gentleman 345kV 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.
FLT32-3PH	3 phase fault on the Pheasant Run 115kV (530559) to Seguin 115kV (530683) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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.
FLT33-3PH	3 phase fault on the Pheasant Run 115kV (530559) to Grinnel 115kV (531412) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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.
FLT34-3PH	3 phase fault on the Gove 115kV (531411) to Arnold 115kV (531409) CKT 1, near Gove. a. Apply fault at the Gove 115kV 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.
FLT35-3PH	3 phase fault on the Arnold 115kV (531409) to Ransom 115kV (531414) CKT 1, near Arnold. a. Apply fault at the Arnold 115kV 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.
FLT36-3PH	3 phase fault on the Atwood 115kV (530554) to Atwood SW 115kV (531364) CKT 1, near Atwood. a. Apply fault at the Atwood 115kV 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.
FLT37-3PH	3 phase fault on the Atwood 115kV (530554) to Beaver Valley 115kV (531488) CKT 1, near Atwood. a. Apply fault at the Atwood 115kV 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.
FLT38-3PH	3 phase fault on the Holcomb 345kV (531449) to Finney 345kV (523853) CKT 1, near Holcomb. a. Apply fault at the Holcomb 345kV 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.
FLT39-3PH	3 phase fault on the Holcomb 345kV (531449) to Holcomb 115kV (531448) to Holcomb 13.8kV (531450) XFMR CKT 1, near Holcomb 345kV. a. Apply fault at the Holcomb 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.

Table 5-1 continued

Fault ID	Fault Descriptions
FLT40-3PH	3 phase fault on the Gentleman 345kV (640183) to Keystone 345kV (640252) CKT 1, near Gentleman. a. Apply fault at the Gentleman 345kV 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.
FLT20-PO1	Prior Outage of Mingo to Brewster 115kV. 3 phase fault on the Mingo Pheasant Run 115kV line. a. Prior outage Mingo (531429) 115kV to Brewster (531351) 115kV (solve network for steady state solution). b. 3 phase fault on the Mingo (531429) 115kV to Pheasant Run (530559) 115kV, near Mingo 115kV. c. Leave fault on for 5 cycles, then trip the faulted line in (b).
FLT25-PO2	Prior Outage of Mingo to Red Willow 345kV. 3 phase fault on the Mingo to Setab 345kV line. a. Prior outage Mingo (531451) 345kV to Red Willow (640325) 345kV (solve network for steady state solution). b. 3 phase fault on the Mingo (531451) 345kV to Setab (531465) 345kV, near Mingo 345kV. c. Leave fault on for 5 cycles, then trip the faulted line in (b).
FLT48-3PH	3 phase fault on the Mingo (531429) 115kV to Colby (530555) 115kV, near Mingo 115kV. a. Apply fault at the Mingo 115kV 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.
FLT48-PO3	Prior Outage of Setab to Mingo 345kV. 3 phase fault on the Mingo Colby 115kV line. a. Prior outage Setab (531465) 345kV to Mingo (531451) 345kV (solve network for steady state solution). b. 3 phase fault on the Mingo (531429) 115kV to Colby (530555) 115kV, near Mingo 115kV. c. Leave fault on for 5 cycles, then trip the faulted line in (b).
FLT49-SB	Mingo 115kV Stuck Breaker a. Apply single phase fault at the Mingo (531429)115kV bus on the Mingo Brewster (531351) 115kV line. b. Wait 16 cycles, and then trip Mingo (531429) to Brewster (531351) 115kV. c. Trip Mingo (531429) to Colby (530555) 115kV and remove the fault.
FLT50-SB	Mingo 345kV Stuck Breaker a. Apply single phase fault at the Mingo (531451) 345kV bus on the Mingo Red Willow (640325) 345kV line. b. Wait 16 cycles, and then trip Mingo (531451) to Red Willow (640325) 345kV. c. Trip Mingo (531451) 345kV to Mingo (531429) 115kV to Mingo (531452) 13.8kV transformer and remove the fault.
FLT51-SB	Holcomb 345kV Stuck Breaker a. Apply single phase fault at the Holcomb (531449) 345kV bus on the Holcomb Buckner (531501) 345kV line. b. Wait 16 cycles, and then trip Holcomb (531449) to Buckner (531501) 345kV. c. Trip Holcomb (531449) 345kV to Holcomb (531448) 115kV to Holcomb (531450) 13.8kV transformer and remove the fault.
FLT9001-3PH	3 phase fault on the Seguin 3 115kV (530683) to Segntp 115kV (530682) CKT 1, near Seguin. a. Apply fault at the Seguin 115kV 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.
FLT9002-3PH	3 phase fault on the Grinnel3 115kV (531412) to Gove 115kV (531411) CKT 1, near Grinnel3. a. Apply fault at the Grinnel3 115kV 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 Segntp 115kV (530682) to Hoxie 115kV (530556) CKT 1, near Segntp. a. Apply fault at the Segntp 115kV 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 5-1 continued

Fault ID	Fault Descriptions
FLT9004-3PH	3 phase fault on the Colby 115kV (530555) to Colby 69kV (530644) to Clryt1 13.8kV (530645) XFMR CKT 1, near Colby 115kV. a. Apply fault at the Colby 115kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9005-3PH	3 phase fault on the Brewstr3 115kV (531351) to Goodlnd 115kV (531353) CKT 1, near Brewstr3. a. Apply fault at the Brewstr3 115kV 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.
FLT9006-3PH	3 phase fault on the Goodlnd 115kV (531353) to Godlndt3 115 kV (531443) CKT 1, near Goodlnd. a. Apply fault at the Goodlnd 115kV 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 Mingo 345kV (531451) to GEN-2015-065 345kV (585030) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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 GEN-2015-065 345kV (585030) to GEN2016-067 (587450) CKT 1, near GEN-2015-065. a. Apply fault at the GEN-2015-065 345kV 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.
FLT9009-3PH	3 phase fault on the GEN-2015-065 345kV (585030) to G15-065XFMR1 34.5kV (585031) CKT 1, near GEN-2015-065. a. Apply fault at the GEN-2015-065 345kV 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 GENTLMN3 345kV (640183) to GEN2016-106 345kV (587850) CKT 1, near GENTLMN3. a. Apply fault at the GENTLMN3 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 GENTLMN3 345kV (640183) to GENTLMN3 230 kV (640184) to GENTLEMANT29 13.8kV (643066) XFMR CKT 1, near GENTLMN3 345kV. a. Apply fault at the GENTLMN3 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9012-3PH	3 phase fault on the Gentleman 345kV (640183) to Gentlm 24kV (640011) transformer CKT 1, near Gentleman. a. Apply fault at the Gentleman 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9013-3PH	3 phase fault on the Setab 115kV (531464) to Ctysert3 115kV (531416) CKT 1, near Setab. a. Apply fault at the Setab 115kV 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 Setab 115kV (531464) to Scotcty 115kV (531433) CKT 1, near Setab. a. Apply fault at the Setab 115kV 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 5-1 continued

Fault ID	Fault Descriptions
FLT9015-3PH	3 phase fault on the GENTLMN4 230kV (640184) to GENTLM 23kV (640010) transformer CKT 1, near GENTLMN4. a. Apply fault at the GENTLMN4 115kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT9016-3PH	3 phase fault on the GENTLMN4 230kV (640184) to Ogalala 230kV (640302) CKT 1, near GENTLMN4. a. Apply fault at the GENTLMN4 115kV 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.
FLT9017-3PH	3 phase fault on the GENTLMN4 230kV (640184) to N.Platt 230kV (640286) CKT 1, near GENTLMN4. a. Apply fault at the GENTLMN4 115kV 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.
FLT9018-3PH	3 phase fault on the Redwilo7 115kV (640326) to Beverly 115kV (640082) CKT 1, near Redwilo7. a. Apply fault at the Redwilo7 115kV 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.
FLT9019-3PH	3 phase fault on the Redwilo7 115kV (640326) to Stockvl7 115kV (640365) CKT 1, near Redwilo7. a. Apply fault at the Redwilo7 115kV 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.
FLT9020-3PH	3 phase fault on the Redwilo7 115kV (640326) to Mccook 115kV (640269) CKT 1, near Redwilo7. a. Apply fault at the Redwilo7 115kV 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.
FLT23-PO1	Prior Outage of Mingo 115 kV (531429) – Brewstr3 115 kV (531351); 3 phase fault on the Mingo 345kV (531451) to Red Willow 345kV (640325) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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.
FLT25-PO1	Prior Outage of Mingo 115 kV (531429) – Brewstr3 115 kV (531351); 3 phase fault on the Mingo 345kV (531451) to Setab 345kV (531465) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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-PO1	Prior Outage of Mingo 115 kV (531429) – Brewstr3 115 kV (531351); 3 phase fault on the Mingo 345kV (531451) to GEN-2015-065 345kV (585030) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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-PO1	3 phase fault on the Colby 115kV (530555) to Atwood 115kV (530554) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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 5-1 continued

Fault ID	Fault Descriptions
FLT18-PO1	Prior Outage of Mingo 115 kV (531429) – Brewstr3 115 kV (531351); 3 phase fault on the Colby 115kV (530555) to Seguin Tap 115kV (530682) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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-PO1	Prior Outage of Mingo 115 kV (531429) – Brewstr3 115 kV (531351); 3 phase fault on the Colby 115kV (530555) to Colby 69kV (530644) to Clryt1 13.8kV (530645) XFMR CKT 1, near Colby 115kV. a. Apply fault at the Colby 115kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT32-PO1	Prior Outage of Mingo 115 kV (531429) – Brewstr3 115 kV (531351); 3 phase fault on the Pheasant Run 115kV (530559) to Seguin 115kV (530683) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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.
FLT33-PO1	Prior Outage of Mingo 115 kV (531429) – Brewstr3 115 kV (531351); 3 phase fault on the Pheasant Run 115kV (530559) to Grinnel 115kV (531412) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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-PO4	Prior Outage of Mingo 115kV (531429) to Mingo 345kV (531451) to Mingo 13.8kV (531452) transformer; 3 phase fault on the Brewstr3 115kV (531351) to Goodlnd 115kV (531353) CKT 1, near Brewstr3. a. Apply fault at the Brewstr3 115kV 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-PO4	Prior Outage of Mingo 115kV (531429) to Mingo 345kV (531451) to Mingo 13.8kV (531452) transformer; 3 phase fault on the Colby 115kV (530555) to Atwood 115kV (530554) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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.
FLT18-PO4	Prior Outage of Mingo 115kV (531429) to Mingo 345kV (531451) to Mingo 13.8kV (531452) transformer; 3 phase fault on the Colby 115kV (530555) to Seguin Tap 115kV (530682) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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.
FLT32-PO4	Prior Outage of Mingo 115kV (531429) to Mingo 345kV (531451) to Mingo 13.8kV (531452) transformer; 3 phase fault on the Pheasant Run 115kV (530559) to Seguin 115kV (530683) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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.
FLT33-PO4	Prior Outage of Mingo 115kV (531429) to Mingo 345kV (531451) to Mingo 13.8kV (531452) transformer; 3 phase fault on the Pheasant Run 115kV (530559) to Grinnel 115kV (531412) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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 5-1 continued

Fault ID	Fault Descriptions
FLT9004-PO4	Prior Outage of Mingo 115kV (531429) to Mingo 345kV (531451) to Mingo 13.8kV (531452) transformer; 3 phase fault on the Colby 115kV (530555) to Colby 69kV (530644) to Clryt1 13.8kV (530645) XFMR CKT 1, near Colby 115kV. a. Apply fault at the Colby 115kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT23-PO5	Prior Outage of Mingo 115kV (531429) to Pheasant Run 115kV (530559); 3 phase fault on the Mingo 345kV (531451) to Red Willow 345kV (640325) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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.
FLT25-PO5	Prior Outage of Mingo 115kV (531429) to Pheasant Run 115kV (530559); 3 phase fault on the Mingo 345kV (531451) to Setab 345kV (531465) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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-PO5	Prior Outage of Mingo 115kV (531429) to Pheasant Run 115kV (530559); 3 phase fault on the Mingo 345kV (531451) to GEN-2015-065 345kV (585030) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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-PO5	Prior Outage of Mingo 115kV (531429) to Pheasant Run 115kV (530559); 3 phase fault on the Brewstr3 115kV (531351) to Goodlnd 115kV (531353) CKT 1, near Brewstr3. a. Apply fault at the Brewstr3 115kV 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-PO5	Prior Outage of Mingo 115kV (531429) to Pheasant Run 115kV (530559); 3 phase fault on the Colby 115kV (530555) to Atwood 115kV (530554) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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.
FLT18-PO5	Prior Outage of Mingo 115kV (531429) to Pheasant Run 115kV (530559); 3 phase fault on the Colby 115kV (530555) to Seguin Tap 115kV (530682) CKT 1, near Colby. a. Apply fault at the Colby 115kV 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-PO5	Prior Outage of Mingo 115kV (531429) to Pheasant Run 115kV (530559); 3 phase fault on the Colby 115kV (530555) to Colby 69kV (530644) to Clryt1 13.8kV (530645) XFMR CKT 1, near Colby 115kV. a. Apply fault at the Colby 115kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
FLT23-PO6	Prior Outage of Mingo (531429) 115kV to Colby (530555) 115kV; 3 phase fault on the Mingo 345kV (531451) to Red Willow 345kV (640325) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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.
FLT25-PO6	Prior Outage of Mingo (531429) 115kV to Colby (530555) 115kV; 3 phase fault on the Mingo 345kV (531451) to Setab 345kV (531465) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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-PO6	Prior Outage of Mingo (531429) 115kV to Colby (530555) 115kV; 3 phase fault on the Mingo 345kV (531451) to GEN-2015-065 345kV (585030) CKT 1, near Mingo. a. Apply fault at the Mingo 345kV 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 5-1 continued

Fault ID	Fault Descriptions
FLT9005-PO6	Prior Outage of Mingo (531429) 115kV to Colby (530555) 115kV; 3 phase fault on the Brewstr3 115kV (531351) to Goodlnd 115kV (531353) CKT 1, near Brewstr3. a. Apply fault at the Brewstr3 115kV 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.
FLT32-PO6	Prior Outage of Mingo (531429) 115kV to Colby (530555) 115kV; 3 phase fault on the Pheasant Run 115kV (530559) to Seguin 115kV (530683) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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.
FLT33-PO6	Prior Outage of Mingo (531429) 115kV to Colby (530555) 115kV; 3 phase fault on the Pheasant Run 115kV (530559) to Grinnel 115kV (531412) CKT 1, near Pheasant Run. a. Apply fault at the Pheasant Run 115kV 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.
FLT1001-SB	Stuck Breaker at PH RUN (530559) a. Apply single phase fault at PH RUN (530559) 115 kV bus. b. Clear fault after 16 cycles and trip the following elements c. PH RUN (530559) – Mingo (531429) 115 kV CKT 1 line d. PH RUN (530559) – Grinnel3 (531412) 115 kV CKT 1 line
FLT1002-SB	Stuck Breaker at Colby (530555) a. Apply single phase fault at Colby (530555) 115 kV bus. b. Clear fault after 16 cycles and trip the following elements c. Colby (530555) – Mingo (531429) 115 kV CKT 1 line d. Colby (530555) 115 kV to Colby (530644) 69kV to Clryt1 (530645) 13.8kV CKT 1 transformer
FLT1003-SB	Stuck Breaker at Brewstr3 (531351) a. Apply single phase fault at Brewstr3 (531351) 115 kV bus. b. Clear fault after 16 cycles and trip the following elements c. Brewstr3 (531351) – Mingo (531429) 115 kV CKT 1 line d. Brewstr3 (531351) – Goodlnd3 (531353) 115 kV CKT 1 line

5.3 Results

Table 5-2 shows the results of the fault events simulated for each of the models. The associated stability plots are provided in Appendix D. There was one existing base case issue FLT25-PO2, as shown in Table 5-2 and described in more detail below.

The results of the dynamic stability analysis, specifically FLT25-PO2, showed that generation interconnecting at Mingo substation (GEN-2015-064, GEN-2015-065, & GEN-2016-067) may have to be curtailed following, the outage of either Mingo to Red Willow 345 kV line or the Mingo to Setab 345 kV line in order to maintain system reliability. The need for curtailment was observed both with the existing project configuration and the project configuration post-modification.

Table 5-2: GEN-2015-064 Dynamic Stability Results

Fault ID	17W			18S			26S		
	Volt. Recovery	Volt. Violation	Stable	Volt. Recovery	Volt. Violation	Stable	Volt. Recovery	Volt. Violation	Stable
FLT17-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT18-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT19-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable

Table 5-2 continued

Fault ID	17W			18S			26S		
	Volt. Violation	Stable	Volt. Recovery	Volt. Violation	Stable	Volt. Recovery	Volt. Violation	Stable	Volt. Recovery
FLT20-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT21-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT22-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT23-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT25-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT26-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT27-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT28-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT29-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT30-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT31-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT32-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT33-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT34-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT35-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT36-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT37-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT38-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT39-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT40-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT48-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT49-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT50-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT51-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9001-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9002-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9003-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9004-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9005-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9006-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9007-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9008-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9009-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9010-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9011-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9012-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9013-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9014-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9015-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9016-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9017-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9018-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9019-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9020-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT1001-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable

Table 5-2 continued

Fault ID	17W			18S			26S		
	Volt. Violation	Stable	Volt. Recovery	Volt. Violation	Stable	Volt. Recovery	Volt. Violation	Stable	Volt. Recovery
FLT1002-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT1003-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT17-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT18-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT20-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT23-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT25-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT32-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT33-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9004-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9007-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT25-PO2	Fail	Fail	GEN Trip*	Fail	Fail	GEN Trip*	Fail	Fail	GEN Trip*
FLT48-PO3	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT17-PO4	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT18-PO4	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT32-PO4	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT33-PO4	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9004-PO4	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9005-PO4	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT17-PO5	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT18-PO5	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT23-PO5	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT25-PO5	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9004-PO5	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9005-PO5	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9007-PO5	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT23-PO6	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT25-PO6	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT32-PO6	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT33-PO6	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9005-PO6	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT9007-PO6	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable

* GEN-2015-064 tripped and may have to be curtailed

Figure 5-1 and Figure 5-2 show the GEN-2015-064, GEN-2015-065, & GEN-2016-067 performance in the base case and modification request case without curtailment for FLT25-PO2.

Figure 5-1: FLT25-PO2 Base Case (Before Curtailment)

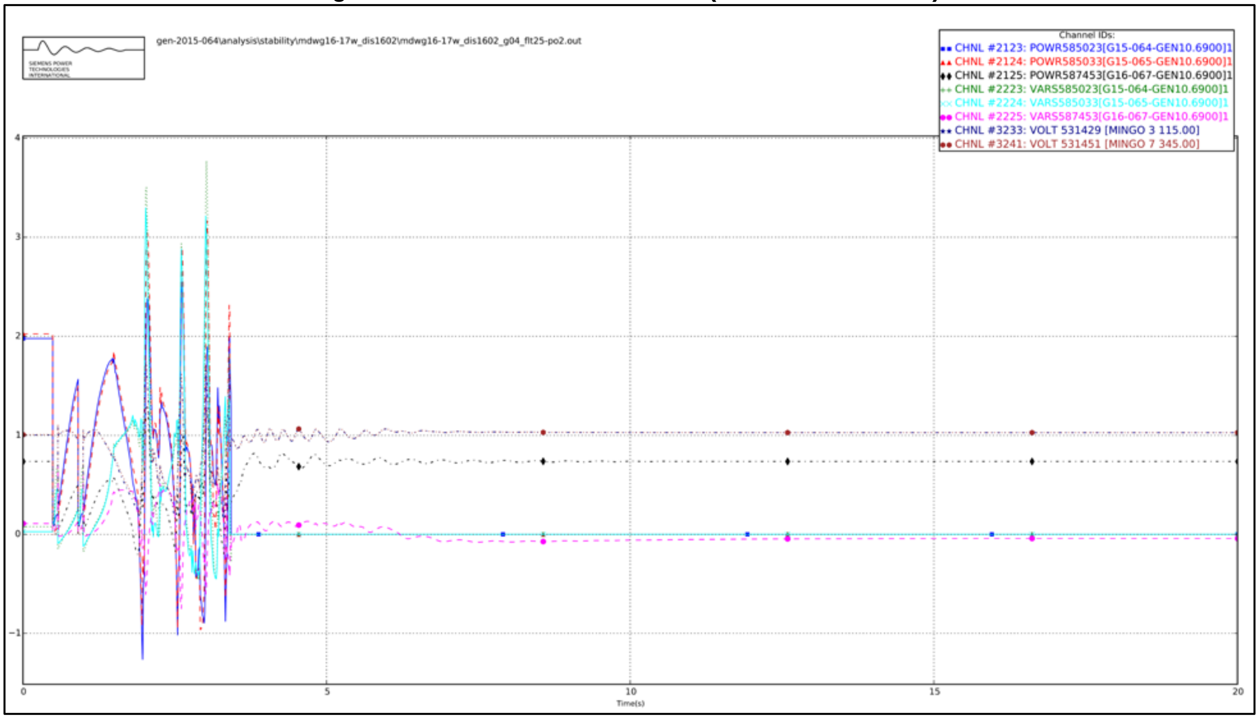
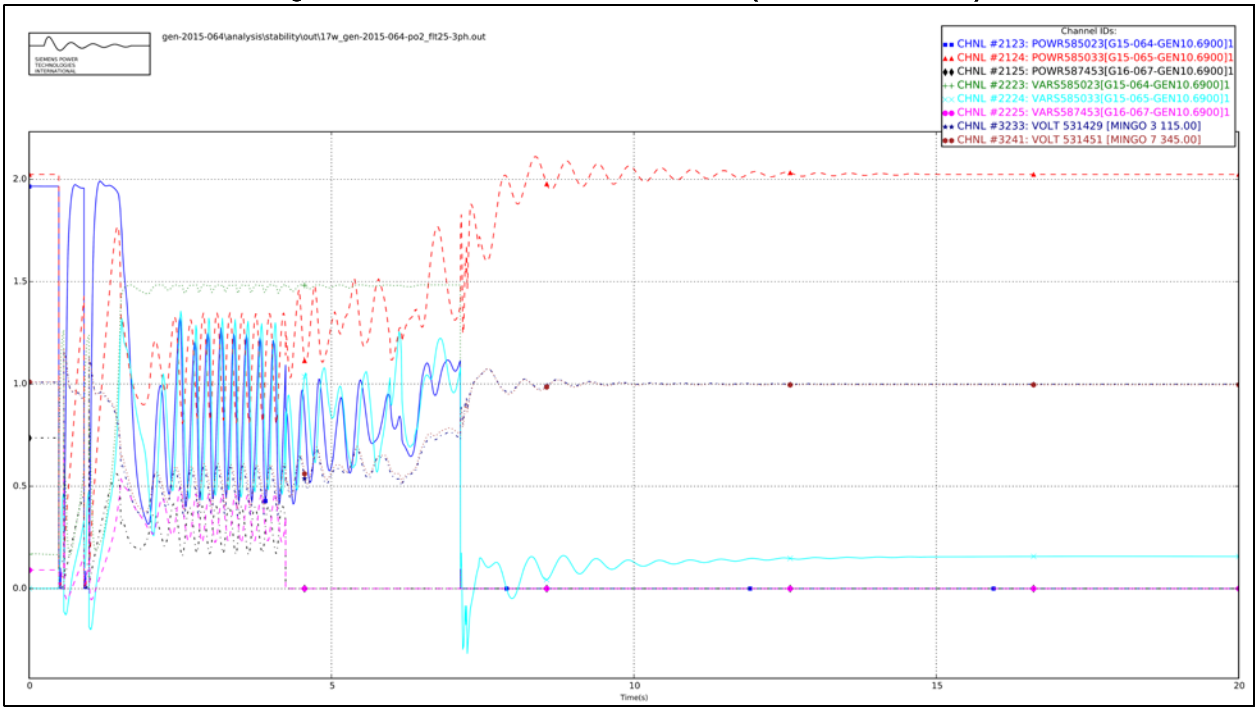


Figure 5-2: FLT25-PO2 Modification Case (Before Curtailment)



In order to mitigate the instability caused by the FLT25-PO2, a few curtailment scenarios were evaluated with combinations of the GEN-2016-067, GEN-2015-064 and GEN-2015-065 output reductions.

First, the output of the lower-queued project, GEN-2016-067 was evaluated and the results showed that the instability observed during FLT25-PO2 still persisted with GEN-2016-067 switched offline. As a result, GEN-2015-064 and GEN-2015-065 were also curtailed to mitigate the instability.

A curtailment analysis was performed with GEN-2015-064 output reduced with GEN-2016-067 already offline. The results of the curtailment analysis are shown in Table 5-3 below.

Similarly, a curtailment analysis was also performed with GEN-2015-065 output reduced with GEN-2016-067 already offline. The results of the curtailment analysis are shown in Table 5-3 below.

Finally, both GEN-2015-064 and GEN-2015-065 were proportionally scaled down with GEN-2016-067 already offline. The results of the curtailment analysis are shown in Table 5-3 below.

Table 5-3: FLT25-PO2 Curtailment Analysis Results

Curtailment Scenario	After Modification Request (MW)			Before Modification Request (MW)		
	17W	18S	26S	17W	18S	26S
GEN-2016-067 Only	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable
GEN-2016-067 + GEN-2015-064	170	160	160	230	220	220
GEN-2016-067 + GEN-2015-065	126	126	136	196	196	196
GEN-2016-067 + GEN-2015-064 + GEN-2015-065 Proportional Reduction	123	123	133	133	143	143
Minimum Curtailment	**123**	**123**	**133**	**133**	**143**	**143**

The results show that the lowest total combined curtailment required before and after the modification request are 133 MW and 123 MW respectively. These curtailment amounts include the complete curtailment of GEN-2016-067 output to 0 MW and proportional curtailment of GEN-2015-064 and GEN-2015-065 of just under 25 MW each in the post-modification case.

Figure 5-3 and Figure 5-4 shows that the effect of the curtailment in the 2017WP model before and after the modification request respectively.

Figure 5-3: FLT25-PO2 Base Case with Curtailment

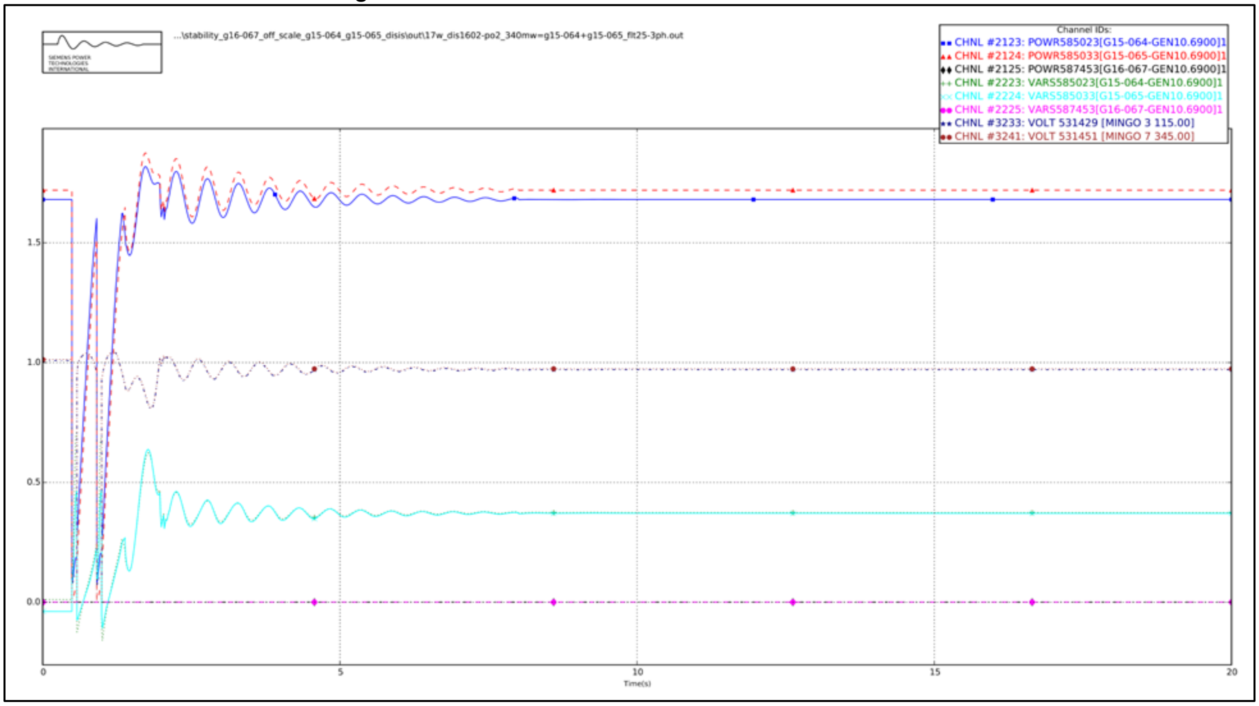
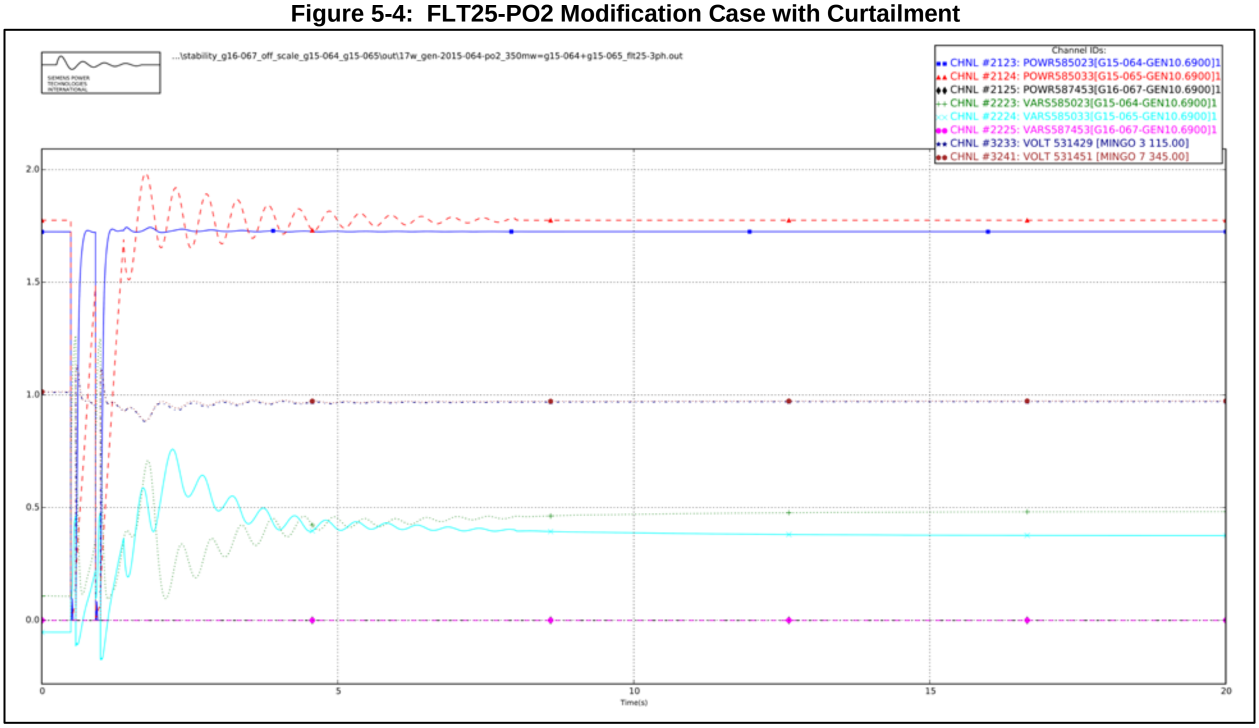


Figure 5-4: FLT25-PO2 Modification Case with Curtailment



There were no other damping or voltage recovery violations observed during the simulated faults. 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.

6.0 Conclusions

The Interconnection Customer for GEN-2015-064 requested a Modification Request Impact Study to assess the impact of the turbine and facility changes to a configuration with a total of 72 x GE 2.73 MW wind turbines for a total capacity of 196.56 MW. In addition, the modification request included changes to the collection system and the generator substation transformer.

A power factor analysis was not performed as there was no change in the point of interconnection for GEN-2015-064.

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 combined GEN-2015-064 project may require an 9.2 MVAr shunt reactor on the 115kV 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-2015-064 was approximately 2.42 kA for the 2018SP and 2.44 kA for 2026SP cases. All three-phase current levels with the GEN-2015-064 generator online were below 24 kA for the 2018SP models and 2026SP models.

The results of the dynamic stability analysis showed that there was one existing system performance violation that was not associated with the GEN-2015-064 modification. Generation interconnecting at Mingo substation (GEN-2015-064, GEN-2015-065, & GEN-2016-067) may have to be curtailed following the outage of either Mingo to Red Willow 345 kV line or Mingo to Setab 345 kV line in order to maintain system reliability. The three projects may have to be curtailed by a combined amount of approximately 123 MW (with GEN-2016-067 switched off first). This combined curtailment includes complete curtailment of GEN-2016-067 to 0 MW and approximately 25 MW curtailment of GEN-2015-064 and Gen-2015-065 each. The need for curtailment was observed both with the existing and post-modification project configurations.

With curtailment requirement described above, there were no other machine rotor angle damping or transient voltage recovery violations observed in the remaining simulated fault events associated with this modification request study. Additionally, the project wind farm was found to stay connected during the other 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-2015-064 Modification Request does not constitute a material modification.