GEN-2015-048

Impact Restudy for Generator Modification

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By SPP Generator Interconnections Dept.

REVISION HISTORY

DATE OR VERSION NUMBER	AUTHOR	CHANGE DESCRIPTION
06/12/2020	SPP	Initial report issued.

CONTENTS

SUMMARY

The GEN-2015-048 Interconnection Customer has requested a modification to its 200 MW Interconnection Request. This system impact restudy was performed to determine the effects of changing turbines from 100 Vestas V110 2.0 MW wind turbine generators (for a total of 200 MW) to 65 GE 2.82 MW and 7 GE 2.3 MW wind turbine generators (for a total of 199.4 MW). In addition, the modification request included changes to the collection system, generator substation transformer, generation interconnection line, and main substation transformer. The point of interconnection (POI) for GEN-2015-048 remains at the Cleo Corner 138kV Substation.

A system impact restudy was performed by Aneden Consulting to help determine whether the requested modification is a Material Modification. A Material Modification shall mean those modifications that have a material impact on the cost or timing of any Interconnection Request with a later Queue priority date. Dynamic stability analysis and low-wind/no-wind condition analysis was performed for this modification request. The full study report follows this executive summary.

The results of the dynamic stability analysis showed that a fault event resulting in the loss of the Mooreland to Iodine 138 kV line caused the GEN-2001-014 and GEN-2006-024S Generating Facilities to trip in response to a fault event on this circuit. The loss of the Mooreland to Iodine 138 kV line isolates the tripped generators from the transmission system near GEN-2015-048 and the problem occurs in the existing base case model, with GEN-2015-048 offline, and in the model with the requested modification. As the tripping response is present in each model variation, this issue is not caused by the GEN-2015-048 modification.

A combination of the loss of the Cleo Corner to Cleoplt 138 kV line and a loss of the Cleo Corner to Glass Mountain 138 kV line may cause the updated GEN-2015-048 to become unstable and require curtailment of up to 80 MW (generating 120 MW) after the prior outage of either circuit. With the existing model and the Vestas high voltage protection relays disabled, GEN-2015-048 needed to be curtailed by up to 140 MW (generating 60 MW) to remain stable following the prior outage of either circuit. The difference in curtailment between the existing and updated models can be attributed to the turbine model change.

Given the results of the impact analysis, the requested modification is not considered a Material Modification; the requested modification does not have a material impact on the cost or timing of any Interconnection Request with a later Queue priority date.

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 9.81 MVArs of reactor shunts on the 34.5 kV bus of the generator project substation 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.

It should be noted that this study analyzed the requested modification to change generator technology and layout. Power flow analysis was not performed. In real-time operation, 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.

In addition, 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-2015-048
Modification Request Impact Study

Revision R1

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anedenconsulting.com

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Executive Summary

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2015-048, an active generation interconnection request with a point of interconnection (POI) at the Cleo Corner 138 kV substation.

The GEN-2015-048 project is proposed to interconnect in the Oklahoma Gas & Electric (OKGE) control area with a capacity of 200 MW as shown in Table ES-1 below. This Study has been requested to evaluate the modification of GEN-2015-048 to a turbine configuration of 65 x GE 2.82 MW + 7 x GE 2.3 MW wind turbines, for a total capacity reduced to 199.4 MW. In addition, the modification request included changes to the collection system, generator substation transformer, generation interconnection line, and main substation transformer. The modification request changes are shown in Table ES-2 below.

Table ES-1: GEN-2015-048 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-048	200	100 x Vestas V110 2.0MW = 200	Cleo Corner 138 kV (514778)

Table ES-2: GEN-2015-048 Modification Request

<table>
<tr><th>Facility</th><th>Existing</th><th colspan="2">Modification</th></tr>
<tr><td>Point of Interconnection</td><td>Cleo Corner 138 kV (514778)</td><td colspan="2">Cleo Corner 138 kV (514778)</td></tr>
<tr><td>Configuration/Capacity</td><td>100 x Vestas V110 2.0MW = 200 MW</td><td colspan="2">65 x GE 2.82 MW + 7 x GE 2.3 MW = 199.4 MW</td></tr>
<tr><td>Generation Interconnection Line</td><td>Length = 19.8 miles
R = 0.005150 pu
X = 0.060490 pu
B = 0.027990 pu</td><td colspan="2">Length = 14.69 miles
R = 0.002989 pu
X = 0.039182 pu
B = 0.023340 pu</td></tr>
<tr><td>Main Substation Transformer</td><td>X = 8.5%, R = 0.19%, Winding 150 MVA, Rate A 200 MVA, Rate B 250 MVA</td><td colspan="2">X = 9%, R = 0.25%, Winding 141 MVA, Rating 235 MVA</td></tr>
<tr><td>GSU Transformer</td><td>Gen 1 Equivalent Qty: 100:
X = 7.8%, R = 0.804%, Rating 210 MVA</td><td>Gen 1 Equivalent Qty: 65:
X = 6.97%, R = 0.67%, Rating 204.1 MVA</td><td>Gen 2 Equivalent Qty: 7:
X = 6.31%, R = 0.667%, Rating 18.2 MVA</td></tr>
<tr><td>Equivalent Collector Line</td><td>R = 0.006600 pu
X = 0.010500 pu
B = 0.173130 pu</td><td colspan="2">R = 0.004066 pu
X = 0.004946 pu
B = 0.074708 pu</td></tr>
<tr><td>Reactive Power Devices</td><td>N/A</td><td colspan="2">3 x 11.25 MVAR 34.5 kV Capacitor Bank</td></tr>
</table>

Aneden performed reactive power analysis, short circuit analysis, and dynamic stability analysis using the modification request data on the initial DISIS-2016-002 Group 1 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-2015-048.

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-2015-048 project may require a 9.81 MVAr shunt reactor, a reduction from the previously identified value of 20.3 MVAr in the DISIS-2015-001[1] Group 1 report, on the 34.5 kV bus of the project substation. The shunt reactor is needed to reduce the reactive power transfer at the POI to approximately zero during low/no wind conditions while the generation interconnection project remains connected to the grid.

The results from the short circuit analysis with the updated topology showed that the maximum GEN-2015-048 contribution to three-phase fault currents in the immediate systems at or near GEN-2015-048 was not greater than 1.80 kA for the 2018SP and 2026SP cases. All three-phase fault current levels, within 5 buses of the POI, with the GEN-2015-048 generator online were below 23 kA for the 2018SP models and 2026SP models.

The dynamic stability analysis was performed using the three DISIS-2016-002-1 models 2017 Winter Peak, 2018 Summer Peak, 2026 Summer Peak. Up to 37 events 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 a fault event resulting in the loss of the Mooreland to Iodine 138 kV line caused the GEN-2001-014 and GEN-2006-024S Generating Facilities, comprised of Suzlon S88 Wind Turbine Generators represented with the WT2G1 generic model, to trip in response to a fault event on this circuit. The loss of the Mooreland to Iodine 138 kV line isolates the tripped generators from the transmission system near GEN-2015-048 and the problem occurs in the existing base case model, the model with GEN-2015-048 offline, and the model with the requested modification. As the tripping response is present in each model variation, this issue is not caused by the GEN-2015-048 modification.

A combination of the loss of the Cleo Corner to Cleoplt 138 kV line and a loss of the Cleo Corner to Glass Mountain 138 kV line caused the updated GEN-2015-048 to become unstable and require curtailment of up to 80 MW (generating 120 MW) after the prior outage of either circuit. With the existing model and the Vestas high voltage protection relays disabled, GEN-2015-048 needed to be curtailed by up to 140 MW (generating 60 MW) to remain stable following the prior outage of either circuit. The difference in curtailment between the existing and updated models can be attributed to the turbine model change.

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

[1] DISIS-2015-002-1, August 2016

1.0 Introduction

Aneden Consulting (Aneden) was retained by the Southwest Power Pool (SPP) to perform a Modification Request Impact Study (Study) for GEN-2015-048, an active generation interconnection request with a point of interconnection (POI) at the Cleo Corner 138 kV Substation.

The GEN-2015-048 project is proposed to interconnect in the Oklahoma Gas & Electric (OKGE) control area with a combined capacity of 200 MW as shown in Table 1-1 below. Details of the modification request is provided in Section 2.0 below.

Table 1-1: Existing GEN-2015-048 Configuration

Request	Capacity (MW)	Existing Generator Configuration	Point of Interconnection
GEN-2015-048	200	100 x Vestas V110 2.0MW = 200	Cleo Corner 138 kV (514778)

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 completed using a set of modified study models developed using the modification request data and the three 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.

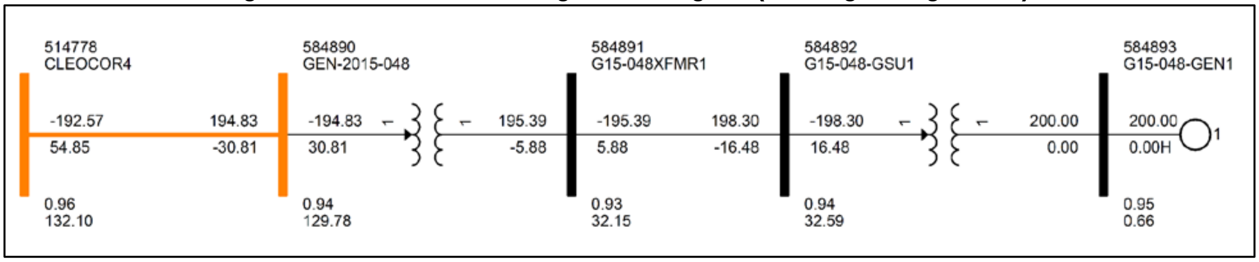
1.2 Study Limitations

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

GEN-2015-048 was originally studied as part of Group 1 in the DISIS-2015-002 study. Figure 2-1 shows the power flow model single line diagram for the existing GEN-2015-048 configuration modeled in the DISIS-2016-002 models.

Figure 2-1: GEN-2015-048 Single Line Diagram (Existing Configuration)



The GEN-2015-048 Modification Request included a turbine configuration change to a total of 65 x GE 2.82 MW + 7 x GE 2.3 MW wind turbines, for a total capacity of 199.4 MW. In addition, the modification request also included changes to the collection system, generator substation transformer, generation interconnection line, and main substation transformer. The major modification request changes are shown in Figure 2-2 and Table 2-1 below.

Figure 2-2: GEN-2015-048 Single Line Diagram (MRIS Configuration)

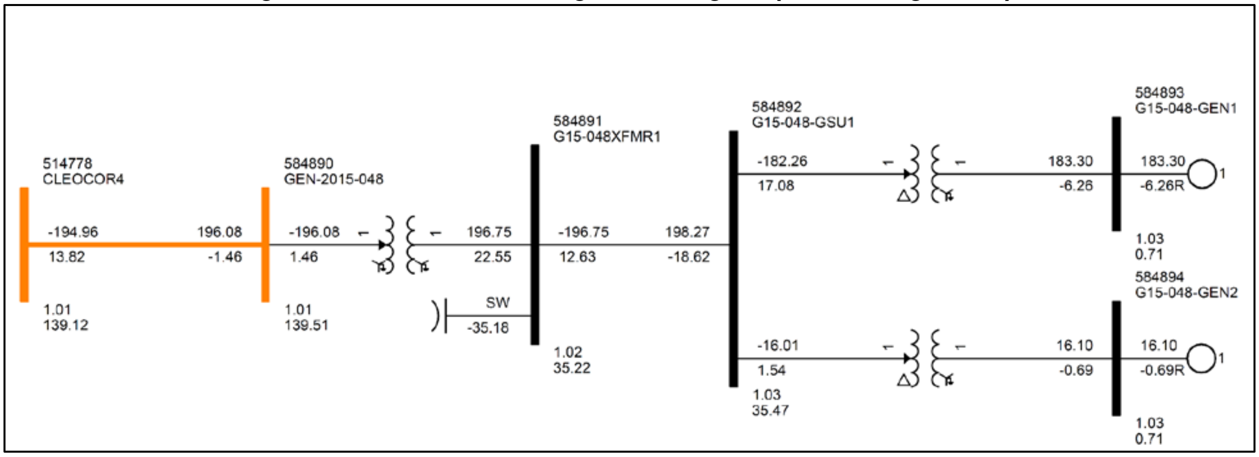


Table 2-1: GEN-2015-048 Modification Request

Facility	Existing	Modification	
Point of Interconnection	Cleo Corner 138 kV (514778)	Cleo Corner 138 kV (514778)	
Configuration/Capacity	100 x Vestas V110 2.0MW = 200 MW	65 x GE 2.82 MW + 7 x GE 2.3 MW = 199.4 MW	
Generation Interconnection Line	Length = 19.8 miles R = 0.005150 pu X = 0.060490 pu B = 0.027990 pu	Length = 14.69 miles R = 0.002989 pu X = 0.039182 pu B = 0.023340 pu	
Main Substation Transformer	X = 8.5%, R = 0.19%, Winding 150 MVA, Rate A 200 MVA, Rate B 250 MVA	X = 9%, R = 0.25%, Winding 141 MVA, Rating 235 MVA	
GSU Transformer	Gen 1 Equivalent Qty: 100: X = 7.8%, R = 0.804%, Rating 210 MVA	Gen 1 Equivalent Qty: 65: X = 6.97%, R = 0.67%, Rating 204.1 MVA	Gen 2 Equivalent Qty: 7: X = 6.31%, R = 0.667%, Rating 18.2 MVA
Equivalent Collector Line	R = 0.006600 pu X = 0.010500 pu B = 0.173130 pu	R = 0.004066 pu X = 0.004946 pu B = 0.074708 pu	
Reactive Power Devices	N/A	3 x 11.25 MVAR 34.5 kV Capacitor Bank	

3.0 Reactive Power Analysis

The reactive power analysis, also known as the low-wind/no-wind condition analysis, was performed for GEN-2015-048 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. This project was previously studied in DISIS-2015-002-1[2] Group 1 and it was determined that an approximately 20.3 MVAr shunt reactor located at the high voltage side of project substation would provide the required compensation.

3.1 Methodology and Criteria

For the GEN-2015-048 project, the generators and reactive power devices were switched out of service while other collector system elements remained in-service. A shunt reactor was tested at the collection substation 34.5 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-2015-048 project required an approximately 9.81 MVAr shunt reactor at the project substation, to reduce the POI MVAr to zero. 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-2015-048 Single Line Diagram (Shunt Reactor)

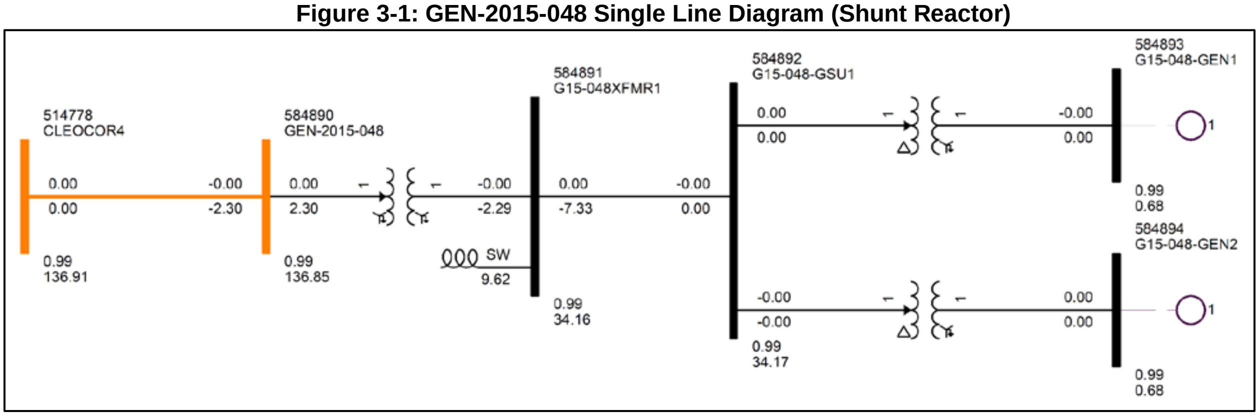


Table 3-1 shows the shunt reactor size determined for the three study models used in the assessment.

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

Machine	POI Bus Number	POI Bus Name	Reactor Size (MVAr)		
			17WP	18SP	26SP
GEN-2015-048	514778	Cleo Corner 138 kV	9.81	9.81	9.81

[2] DISIS-2015-002-1, August 2016

4.0 Short Circuit Analysis

A short-circuit study was performed using the 2018SP and 2026SP models for GEN-2015-048 with the updated topology. 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 138 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 through Table 4-3 respectively. The GEN-2015-048 POI bus fault current magnitudes are provided in Table 4-1 showing a maximum fault current of 6.61 kA.

The maximum fault current calculated within 5 buses with GEN-2015-048 was less than 23 kA for the 2018SP and 2026SP models respectively. The maximum GEN-2015-048 contribution to three-phase fault currents was about 37.4% and 1.80 kA.

Table 4-1: POI Short Circuit Results

Case	GEN-OFF Current (kA)	GEN-ON Current (kA)	Max kA Change	Max %Change
2018SP	4.82	6.61	1.79	37.2%
2026SP	4.80	6.59	1.80	37.4%

Table 4-2: 2018SP Short Circuit Results

Voltage (kV)	Max. Current (kA)	Max kA Change	Max %Change
69	14.0	0.89	15.6%
138	22.6	1.79	37.2%
345	4.4	0.02	0.5%
Max	**22.6**	**1.79**	**37.2%**

Table 4-3: 2026SP Short Circuit Results

Voltage (kV)	Max. Current (kA)	Max kA Change	Max %Change
69	14.0	0.90	15.8%
138	22.7	1.80	37.4%
345	4.5	0.02	0.4%
Max	**22.7**	**1.80**	**37.4%**

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-2015-048 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 65 x GE 2.82 MW and 7 x GE 2.3 MW turbine configuration for the GEN-2015-048 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 1. The modifications requested to project GEN-2015-048 were used to create modified stability models for this impact study.

The modified dynamics model data for the DISIS-2016-002 Group 1 request, GEN-2015-048, 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-2015-048 and other equally and prior queued projects in Group 1. In addition, voltages of five (5) buses away from the POI of GEN-2015-048 were monitored and plotted. The machine rotor angle for synchronous machines and speed for asynchronous machines within this study area including 520 (AEPW), 524 (OKGE), 525 (WFEC), 526 (SPS), 531 (MIDW), 534 (SUNC), 536 (WERE), were monitored. In addition, the voltages of all 100 kV and above buses within the study area were monitored.

5.2 Fault Definitions

Aneden simulated the faults previously simulated for GEN-2015-048 and selected additional fault events for GEN-2015-048 as required. The new set of faults were simulated using the modified study models. The fault events included 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 which includes the NERC TPL-001-4 Standard planning event categories. 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	Planning Event	Fault Descriptions
FLT33-3PH	P1	3 phase fault on Cleo Corner 138kV (514778) to Cleo Corner 69kV (514777) to Cleo Corner 13.8kV (515716) XFMR CKT 1, near Cleo Corner 138kV. a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip the faulted transformer.
FLT34-3PH	P1	3 phase fault on Glasmtn 138kV (514788) to Mooreland 138kV (520999) CKT 1, near Glasmtn. a. Apply fault at the Glasmtn 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Cleoplt 138kV (515562) to Menotap 138kV (514789) CKT 1, near Cleoplt. a. Apply fault at the Cleoplt 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Cleo Corner 138kV (514778) to Glass Mountain 138kV (514788) CKT 1, near Cleo Corner. a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Cleo Corner 138kV (514778) to Cleoplt 138kV (515562) CKT 1, near Cleo Corner. a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Cleo Corner 69kV (514777) to Cleopt 2 69kV (515804) CKT 1, near Cleo Corner. a. Apply fault at the Cleo Corner 69kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Cleo Corner 69kV (514777) to Cleo JT2 69kV (520855) CKT 1, near Cleo Corner. a. Apply fault at the Cleo Corner 69kV bus. b. Clear fault after 5 cycles and trip 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	P6	**Prior Outage of Cleo Corner 138kV (514778) – Cleoplt 138kV (515562);** 3 phase fault on Cleo Corner 138kV (514778) to Cleo Corner 69kV (514777) to Cleo Corner 13.8kV (515716) XFMR CKT 1, near Cleo Corner 138kV a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip the faulted line.
FLT37-PO2	P6	**Prior Outage of Cleo Corner 138kV (514778) to Cleo Corner 69kV (514777) to Cleo Corner 13.8kV (515716) XFMR CKT;** 3 phase fault on Cleo Corner 138kV (514778) to Cleoplt 138kV (515562), near Cleo Corner 138kV a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip the faulted line.
FLT68-3PH	P1	3 phase fault on G15-095 Tap 138kV (560066) to Mooreland 138kV (520999) CKT 1, near G15-095 Tap. a. Apply fault at the G15-095 Tap 138kV bus. b. Clear fault after 5 cycles and trip the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT70-3PH	P1	3 phase fault on Mooreland 138kV (520999) to Windfarm 138kV (515785) CKT 1, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT72-3PH	P1	3 phase fault on Mooreland 138kV (520999) to Taloga 138kV (521065) CKT 1, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip 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	Planning Event	Fault Descriptions
FLT73-3PH	P1	3 phase fault on the Mooreland 138kV (520999) to Mooreland 69kV (520995) to Mooreland Tertiary 13.8kV (521180) XFMR CKT 1, near Mooreland 138kV. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip the faulted transformer.
FLT75-3PH	P1	3 phase fault on Mooreland 138kV (520999) to PIC 138kV (520425) CKT 1, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip 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.
FLT76-3PH	P1	3 phase fault on Mooreland 138kV (520999) to Bearcat 138kV (520500) CKT 1, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT77-3PH	P1	3 phase fault on Mooreland 138kV (520999) to Iodine 138kV (520957) CKT 1, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT83-SB	P4	**Stuck Breaker at CLEOCOR4 (514778)** a. Apply single phase fault at CLEOCOR4 138kV bus. b. Clear fault after 16 cycles and trip the following elements c. CLEOCOR4 (514778) – GLASMTN4 (514788) 138kV line d. CLEOCOR4 138kV (514778) to CLEOCOR2 69kV (514777) to CLEOCOR1 13.8kV (515716) XFMR CKT 1
FLT9001-3PH	P1	3 phase fault on Cleo Jt2 69kV (520855) to RNGWOOD2 69kV (521040) CKT 1, near Cleo Jt2. a. Apply fault at the Cleo Jt2 69kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on RNGWOOD2 69kV (521040) to NASH 69kV (521008) CKT 1, near RNGWOOD2. a. Apply fault at the RNGWOOD2 69kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Cleopt 69kV (515804) to Alinetp 69kV (515803) CKT 1, near Cleopt. a. Apply fault at the Cleopt 69kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Cleopt 69kV (515804) to Cleo 69kV (514791) CKT 1, near Cleopt. a. Apply fault at the Cleopt 69kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Alinetp 69kV (515803) to Aline 69kV (514793) CKT 1, near Alinetp. a. Apply fault at the Alinetp 69kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Alinetp 69kV (515803) to Alvaoge 69kV (514792) CKT 1, near Alinetp. a. Apply fault at the Alinetp 69kV bus. b. Clear fault after 5 cycles and trip 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	Planning Event	Fault Descriptions
FLT9007-3PH	P1	3 phase fault on Cleoplt 138kV (515562) to Cleopl4 138kV (515553) CKT 1, near Cleoplt. a. Apply fault at the Cleoplt 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Menotap 138kV (514789) to IMO 138kV (514790) CKT 1, near Menotap. a. Apply fault at the Menotap 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Mooreland 138kV (520999) to GEN-2016-020 345kV (587140) CKT 1, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Mooreland 138kV (520999) to G15-095T 138kV (560066) CKT 1, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip 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	P1	3 phase fault on Mooreland 138kV (520999) to Morlnd3 18kV (520998) CKT 1, near Mooreland 138kV. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip the faulted transformer.
FLT9012-3PH	P1	3 phase fault on Mooreland 138kV (520999) to Morlnd2 18kV (520997) CKT 1, near Mooreland 138kV. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip the faulted transformer.
FLT9013-3PH	P1	3 phase fault on Mooreland 138kV (520999) to Morlnd1 13.8kV (520996) CKT 1, near Mooreland 138kV. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles and trip the faulted transformer.
FLT36-PO1	P6	**Prior Outage of Cleo Corner 138kV (514778) – Cleoplt 138kV (515562);** 3 phase fault on Cleo Corner 138kV (514778) to Glass Mountain 138kV (514788) CKT 1, near Cleo Corner. a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip 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-PO2	P6	**Prior Outage of Cleo Corner 138kV (514778) to Cleo Corner 69kV (514777) to Cleo Corner 13.8kV (515716) XFMR CKT;** 3 phase fault on Cleo Corner 138kV (514778) to Glass Mountain 138kV (514788) CKT 1, near Cleo Corner. a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip 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-PO3	P6	**Prior Outage of Cleo Corner 138kV (514778) – Glasmtn4 138kV (514788);** 3 phase fault on Cleo Corner 138kV (514778) to Cleo Corner 69kV (514777) to Cleo Corner 13.8kV (515716) XFMR CKT 1, near Cleo Corner 138kV. a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip the faulted transformer.

Table 5-1 continued

Fault ID	Planning Event	Fault Descriptions
FLT37-PO3	P6	**Prior Outage of Cleo Corner 138kV (514778) – Glasmtn4 138kV (514788);** 3 phase fault on Cleo Corner 138kV (514778) to Cleoplt 138kV (515562) CKT 1, near Cleo Corner. a. Apply fault at the Cleo Corner 138kV bus. b. Clear fault after 5 cycles and trip 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	P4	**Stuck Breaker at Cleoplt4 (515562)** a. Apply single phase fault at Cleoplt4 138kV bus. b. Clear fault after 16 cycles and trip the following elements. c. Cleo Corner (515562) – Cleo Corner (514778) 138kV CKT 1 line. d. Cleoplt 138 kV (515562) to Menotap 138kV (514789) CKT 1 line.
FLT1002-SB	P4	**Stuck Breaker at Glasmtn4 (514788)** a. Apply single phase fault at Glasmtn4 138kV bus. b. Clear fault after 16 cycles and trip the following elements. c. Glasmtn4 (514788) – Cleo Corner (514778) 138kV CKT 1 line. d. Glasmtn 138kV (514788) to Mooreland 138kV (520999) CKT 1 line.
FLT1003-SB	P4	**Stuck Breaker at Cleo Corner (514777)** a. Apply single phase fault at Cleo Corner 69kV bus. b. Clear fault after 16 cycles and trip the following elements. c. Cleo Corner 138kV (514778) – Cleo Corner 69kV (514777) - Cleo Corner 13.8kV (515716) transformer. d. Cleo Corner 69kV (514777) to Cleo JT2 69kV (520855) CKT 1 line.

5.3 Results

Table 5-2 shows the results of the fault events simulated for each of the three modified cases. The associated stability plots are provided in Appendix D.

Table 5-2: GEN-2015-048 Dynamic Stability Results

Fault ID	17WP			18SP			26SP		
	Voltage Recovery	Voltage Violation	Stable	Voltage Recovery	Voltage Violation	Stable	Voltage Recovery	Voltage Violation	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
FLT68-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT70-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT72-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT73-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT75-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT76-3PH	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT77-3PH	Fail	Pass	Stable*	Fail	Pass	Stable*	Fail	Pass	Stable*
FLT83-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

Table 5-2 continued

Fault ID	17WP			18SP			26SP		
	Voltage Recovery	Voltage Violation	Stable	Voltage Recovery	Voltage Violation	Stable	Voltage Recovery	Voltage Violation	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
FLT1001-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT1002-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT1003-SB	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT33-PO1	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT36-PO1	Fail	Fail	Unstable**	Fail	Fail	Unstable**	Fail	Fail	Unstable**
FLT36-PO2	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT37-PO2	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT33-PO3	Pass	Pass	Stable	Pass	Pass	Stable	Pass	Pass	Stable
FLT37-PO3	Fail	Fail	Unstable***	Fail	Fail	Unstable***	Fail	Fail	Unstable***

***Generator 599002 SLPBER-WTG1 and 599057 BUFBER-WTGA1 tripped after fault. Existing base case issue.**
****GEN-2015-048 may need to be curtailed to 130 MW for 17WP, 130 MW for 18SP, and 120 MW for 26SP.**
*****GEN-2015-048 may need to be curtailed to 130 MW for 17WP, 130 MW for 18SP, and 130 MW for 26SP.**

The results of the dynamic stability analysis showed that the loss of the Mooreland to Iodine 138 kV line caused the GEN-2001-014 and GEN-2006-024S Generating Facilities, comprised of Suzlon S88 Wind Turbine Generators represented with the WT2G1 generic model, to trip in response to a fault event on this circuit as shown in Figure 5-1. This problem also occurs for both generators in the existing base case model as shown in Figure 5-2, and GEN-2001-014 trips in the model with GEN-2015-048 offline as shown in Figure 5-3. This particular contingency isolated the tripped generators from the transmission system near GEN-2015-048. As the tripping response is present in each model variation it is not caused by the GEN-2015-048 modification.

Figure 5-1: FLT77-3PH SLPBER-WTG1 & BUFBER-WTGA1 Response (17WP MRIS Case)

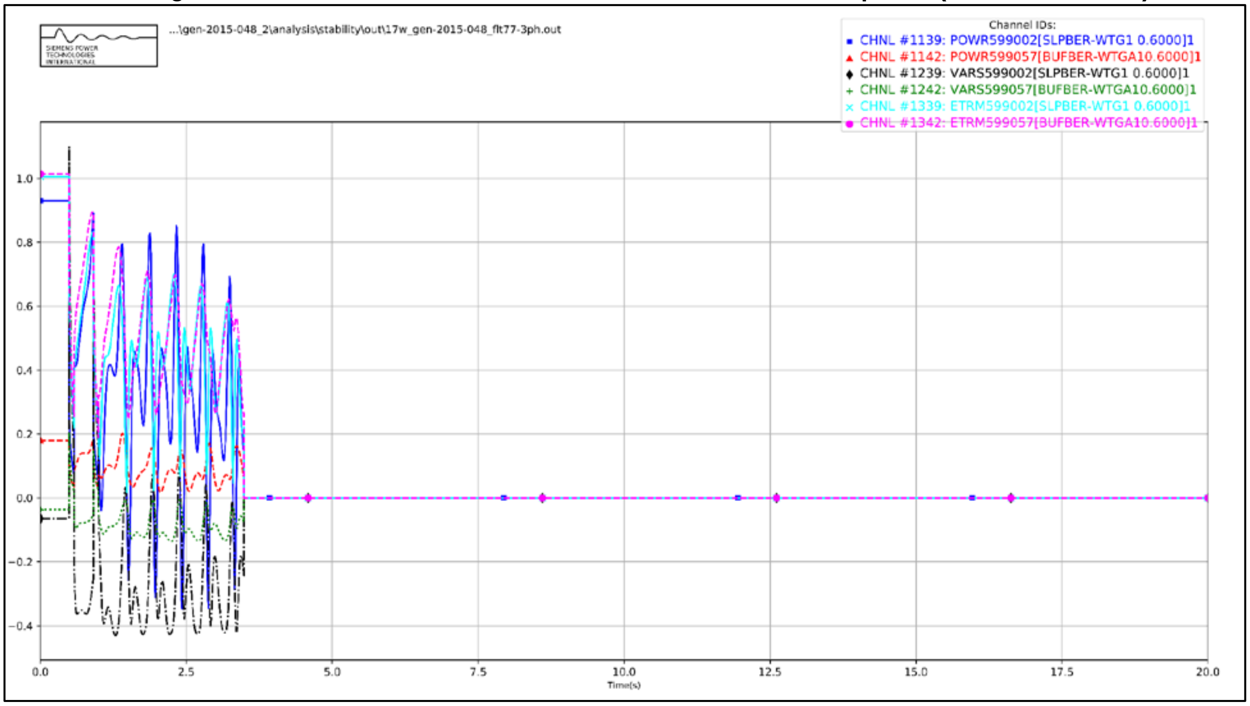


Figure 5-2: FLT77-3PH SLPBER-WTG1 & BUFBER-WTGA1 Response (17WP Base Case)

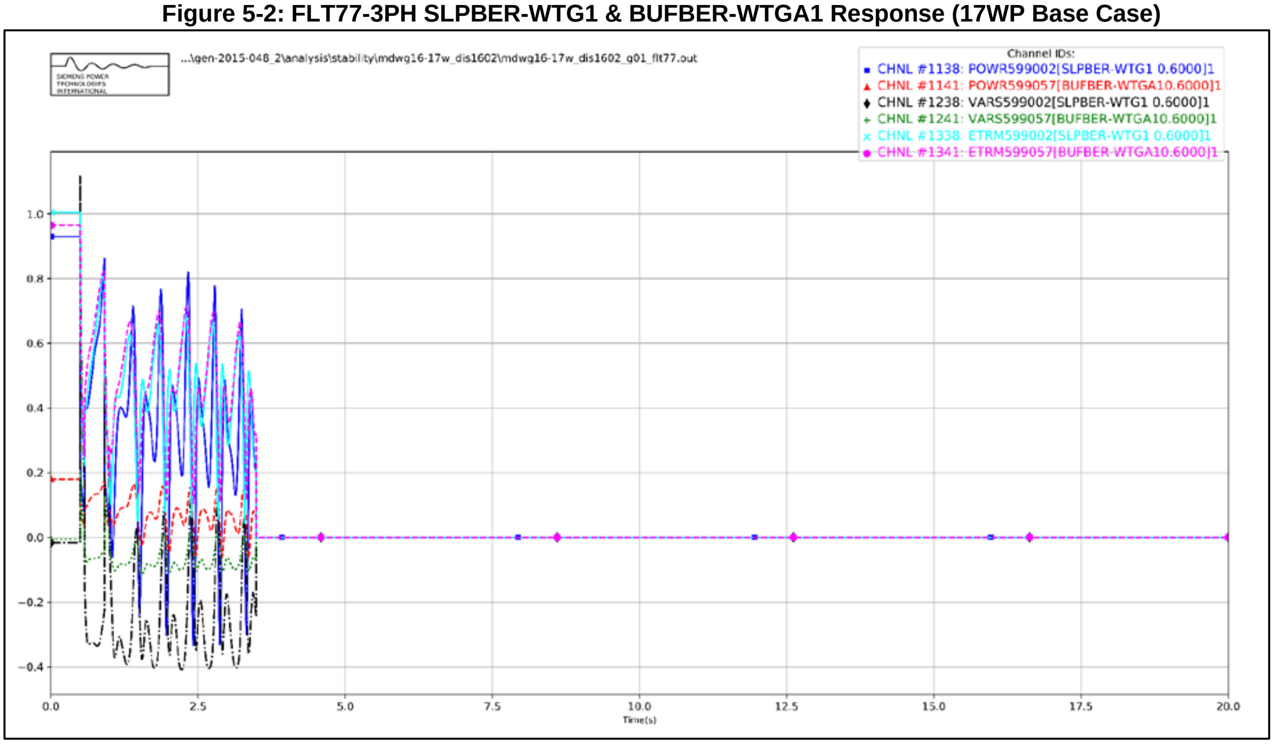
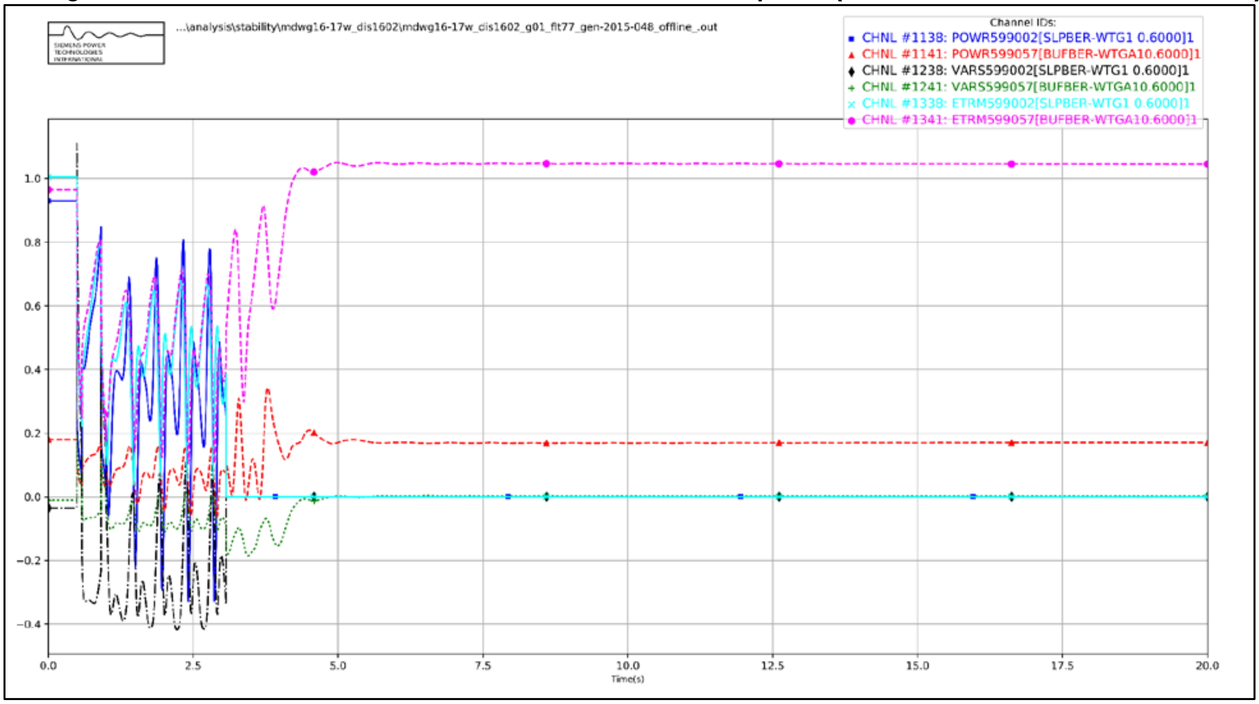


Figure 5-3: FLT77-3PH SLPBER-WTG1 & BUFBER-WTGA1 Response (17WP Base w/ GEN-2015-048 Offline)



In addition, a combination of the loss of the Cleo Corner to Cleoplt 138 kV line and the loss of the Cleo Corner to Glass Mountain 138 kV line caused GEN-2015-048 to become unstable and require curtailment after the prior outage in all three cases.

GEN-2015-048 may need to be curtailed to 130 MW in the 17WP and 18SP cases, and 120 MW in the 26SP case after the prior outage of either the Cleo Corner POI bus to Glass Mountain 138 kV line or Cleo Corner to Cleoplt 138 kV line to remain stable following the fault on the other circuit. Figure 5-4 and Figure 5-5 show the updated GEN-2015-048 response to FLT36-PO1 before and after curtailment respectively. Figure 5-6 and Figure 5-7 show the updated GEN-2015-048 response to FLT37-PO3 before and after curtailment respectively.

Figure 5-4: FLT36-PO1 GEN-2015-048 Response (17WP MRIS Case)

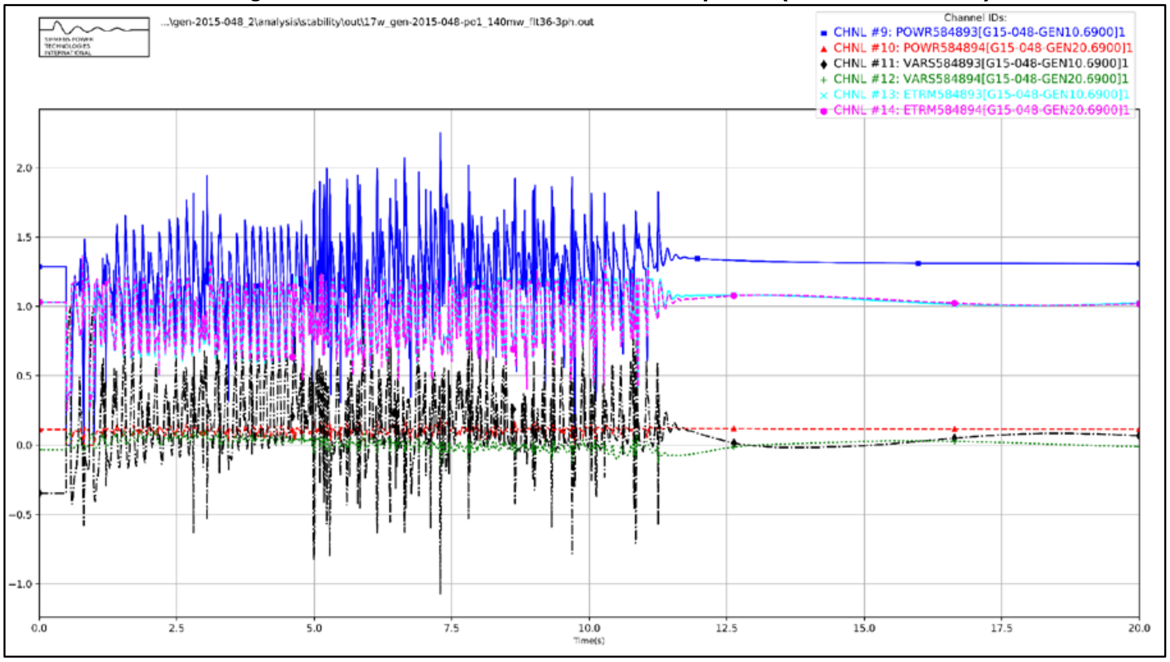


Figure 5-5: FLT36-PO1 GEN-2015-048 Response After Curtailed to 130 MW (17WP MRIS Case)

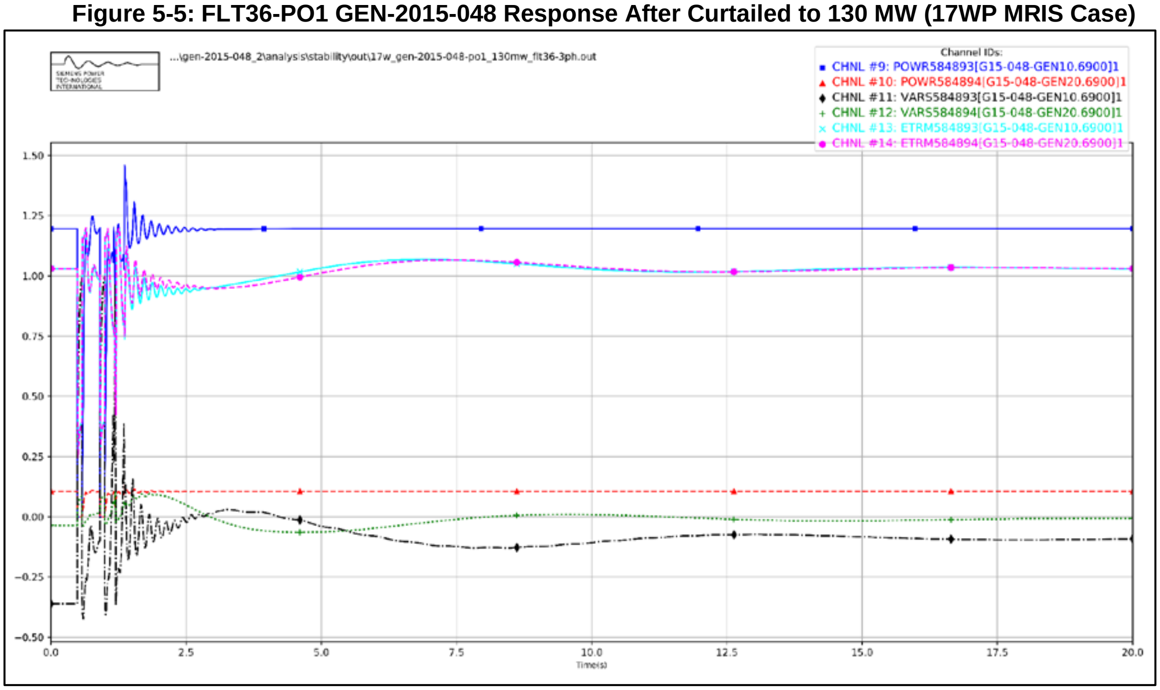


Figure 5-6: FLT37-PO3 GEN-2015-048 Response (17WP MRIS Case)

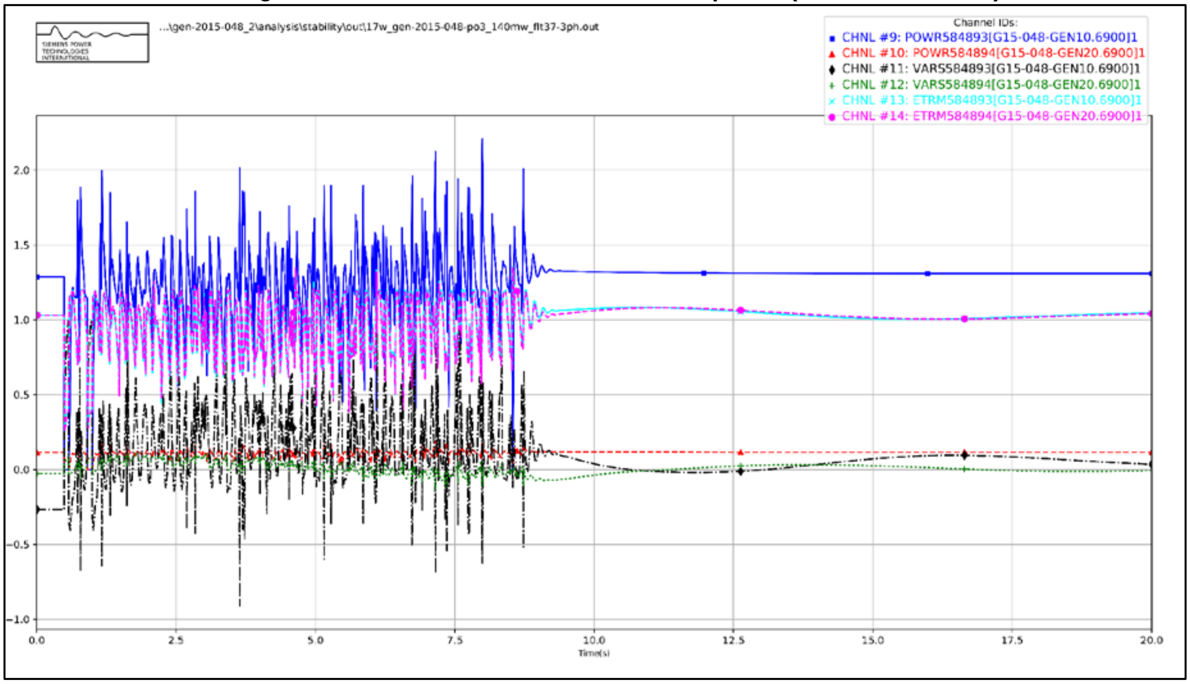
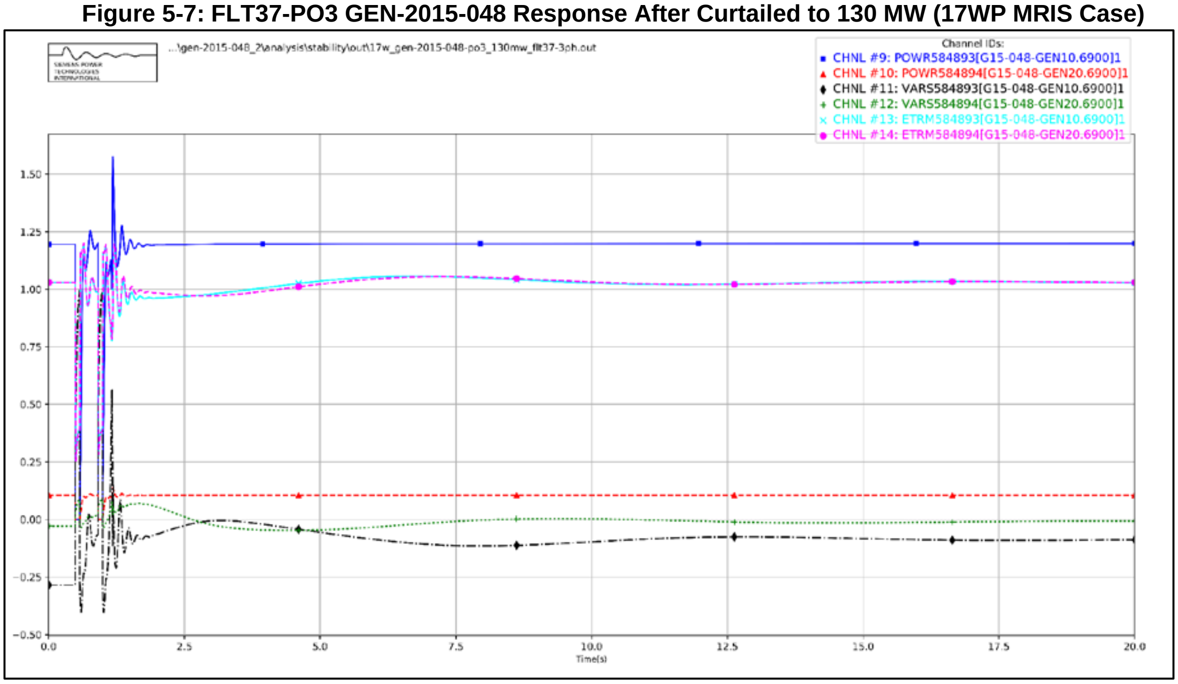


Figure 5-7: FLT37-PO3 GEN-2015-048 Response After Curtailed to 130 MW (17WP MRIS Case)



This outage combination was not simulated previously with the existing case configuration. With the existing configuration settings GEN-2015-048 tripped offline due to high voltage after the prior outage of either the Cleo Corner POI bus to Glass Mountain 138 kV line or Cleo Corner to Cleoplt 138 kV line. When the existing Vestas high voltage protection relays were disabled, GEN-2015-048 needed to be curtailed to 60 MW in the 17WP and 70 MW in the 18SP and 26SP cases to remain stable following the prior outage of either the Cleo Corner POI bus to Glass Mountain 138 kV line or Cleo Corner to Cleoplt 138 kV line. Figure 5-8 and Figure 5-9 show the existing GEN-2015-048 response to FLT36-PO1 before and after curtailment respectively. Figure 5-10 and Figure 5-11 show the existing GEN-2015-048 response to FLT37-PO3 before and after curtailment respectively. The Qgen set points for these curtailment values are shown in Table 5-3. The difference in curtailment between the existing and updated models can be attributed to the turbine model change.

Table 5-3: Curtailment Qgen Set Points (Base Case)

Case Year	FLT36-PO1		FLT37-PO3	
	Curtailed by (MW)	Qgen Set Point (MVAr)	Curtailed by (MW)	Qgen Set Point (MVAr)
2017WP	140	-22.5	130	-18.9
2018SP	130	-17.7	130	-16.8
2026SP	130	-15.1	130	-14.7

Figure 5-8: FLT36-PO1 GEN-2015-048 Response (17WP Base Case)

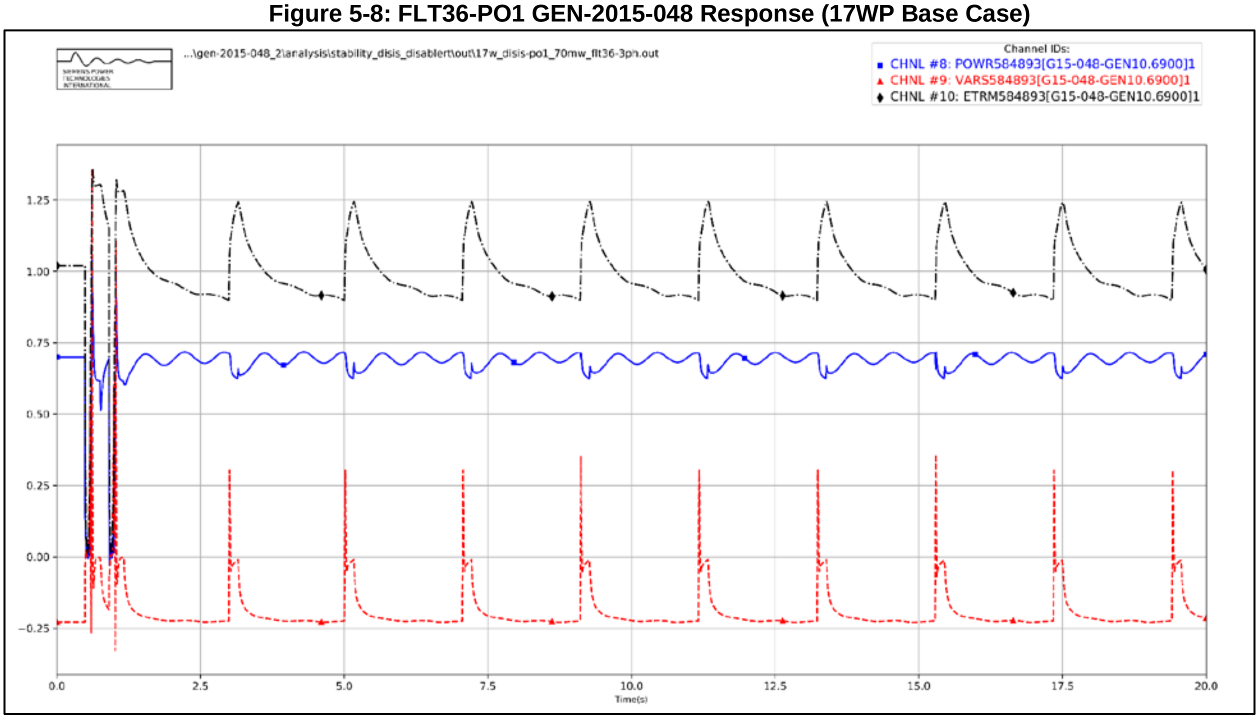


Figure 5-9: FLT36-PO1 GEN-2015-048 Response After Curtailed to 60 MW (17WP Base Case)

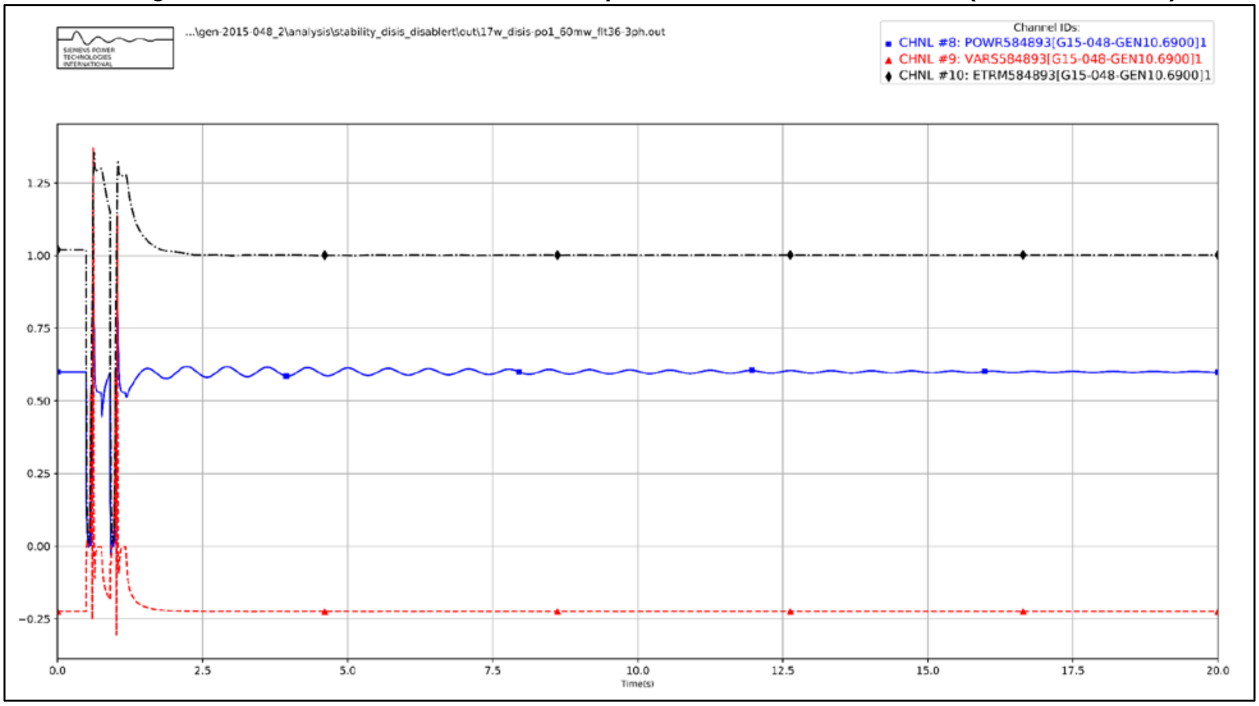


Figure 5-10: FLT37-PO3 GEN-2015-048 Response (17WP Base Case)

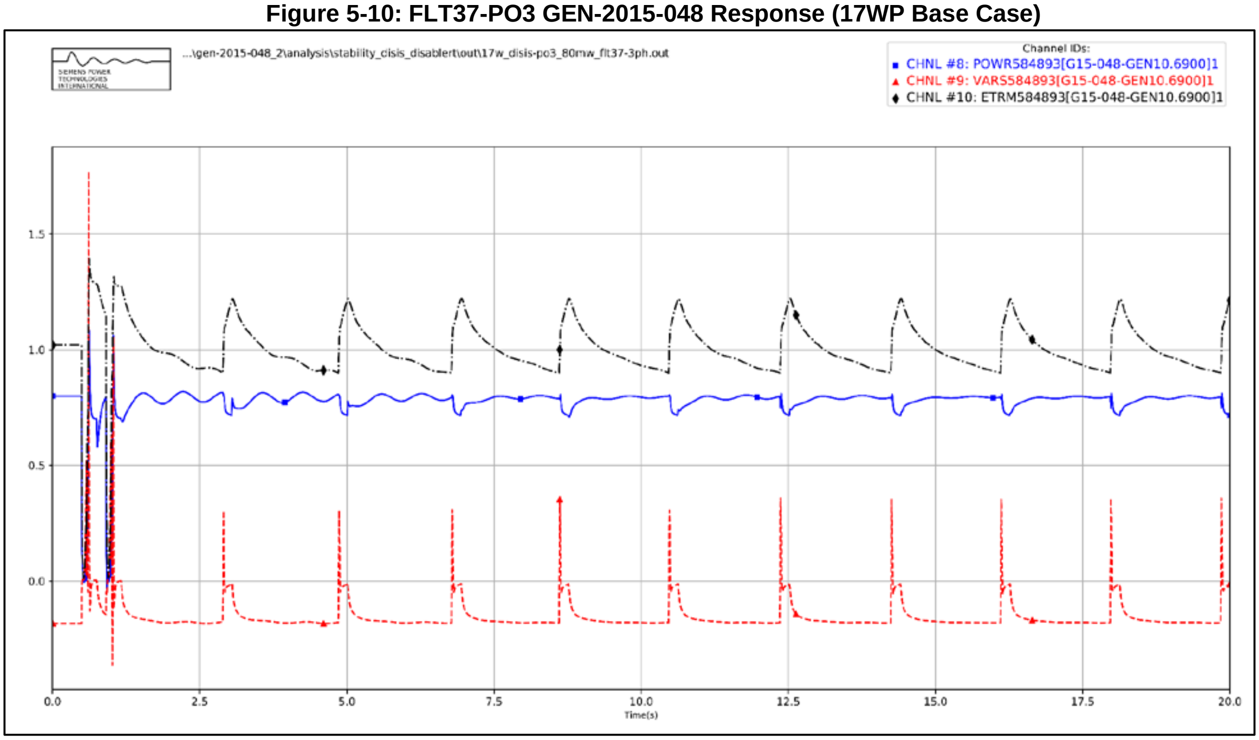
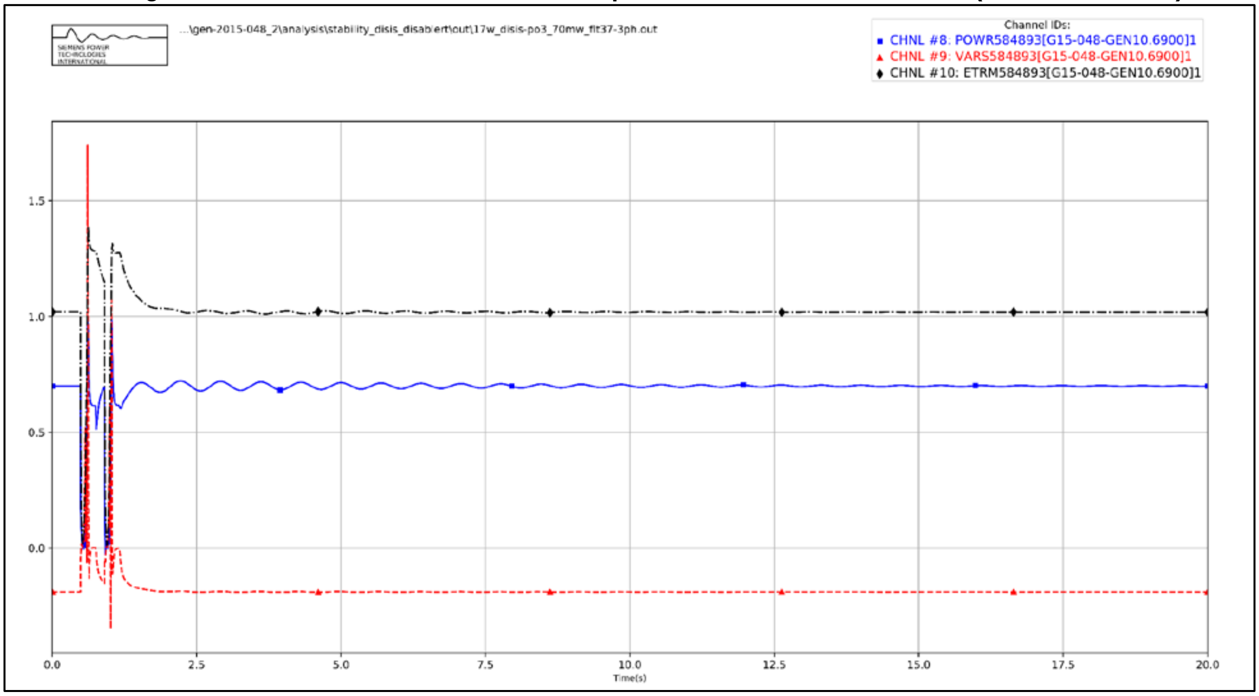


Figure 5-11: FLT37-PO3 GEN-2015-048 Response After Curtailed to 70 MW (17WP Base Case)



There were no other damping or voltage recovery violations observed during the simulated faults. Additionally, the project 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-2015-048 requested a Modification Request Impact Study to assess the impact of the turbine and facility changes to a configuration with a total of 65 x GE 2.82 MW + 7 x GE 2.3 MW wind turbines for a total capacity of 199.4 MW. In addition, the modification request included changes to the collection system, generator substation transformer, generation interconnection line, and main substation transformer.

A power factor analysis was not performed as there was no change in the point of interconnection for GEN-2015-048.

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-2015-048 project may require a 9.81 MVAr shunt reactor, a reduction from the previously identified value of 20.3 MVAr in the DISIS-2015-001[3] Group 1 report, on the 34.5 kV bus of the project substation. The shunt reactor is needed to reduce the reactive power transfer at the POI to approximately zero during low/no wind conditions while the generation interconnection project remains connected to the grid.

The results from the short circuit analysis with the updated topology showed that the maximum GEN-2015-048 contribution to three-phase fault currents in the immediate systems at or near GEN-2015-048 was not greater than 1.80 kA for the 2018SP and 2026SP cases. All three-phase fault current levels within 5 buses of the POI with the GEN-2015-048 generator online were below 23 kA for the 2018SP models and 2026SP models. The GEN-2015-048 POI bus had a maximum fault current of 6.61 kA.

The results of the dynamic stability analysis showed that a fault event resulting in the loss of the Mooreland to Iodine 138 kV line caused the GEN-2001-014 and GEN-2006-024S Generating Facilities to trip in response to a fault event on this circuit. The loss of the Mooreland to Iodine 138 kV line isolates the tripped generators from the transmission system near GEN-2015-048 and the problem occurs in the existing base case model, with GEN-2015-048 offline, and in the model with the requested modification. As the tripping response is present in each model variation, this issue is not caused by the GEN-2015-048 modification.

A combination of the loss of the Cleo Corner to Cleoplt 138 kV line and a loss of the Cleo Corner to Glass Mountain 138 kV line may cause the updated GEN-2015-048 to become unstable and require curtailment of up to 80 MW (generating 120 MW) after the prior outage of either circuit. With the existing model and the Vestas high voltage protection relays disabled, GEN-2015-048 needed to be curtailed by up to 140 MW (generating 60 MW) to remain stable following the prior outage of either circuit. The difference in curtailment between the existing and updated models can be attributed to the turbine model change.

There were no other damping or voltage recovery violations observed during the simulated faults. Additionally, the project was found to stay connected during the contingencies that were studied

[3] DISIS-2015-002-1, August 2016

and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A.