GEN-2015-047 Impact Restudy for Generator Modification (Turbine Change)

May 2017
Generator Interconnection

Southwest Power Pool

Revision History

Date	Author	Change Description
5/25/2017	SPP	GEN-2015-047 Impact Restudy for Generator Modification Report Issued

Executive Summary

The GEN-2015-047 Interconnection Customer has requested a modification to its Generator Interconnection Request to change wind turbine generators for its project. Originally, it consisted of one hundred fifty (150) Vestas V110 VCSS 2.0 MW wind turbine generators for a total nameplate capacity of 300.0 MW. The requested change is for one hundred nine (109) GE 2.5 MW wind turbines and eleven (11) GE 2.3 MW for a total nameplate capacity of 297.8 MW. The point of interconnection (POI) is the Oklahoma Gas & Electric (OKGE) Sooner 345kV substation.

The study models used were the 2016 winter, 2017 summer, and 2025 summer models that included Interconnection Requests and assigned network upgrades through DISIS-2015-002-2.

Stability analysis has determined with all assigned Network Upgrades in service, generators in the monitored areas remained stable and within the pre-contingency, voltage recovery, and post fault voltage recovery criterion of 0.7pu to 1.2pu for the entire modeled disturbances. Additionally, the project wind farm was found to stay connected during the contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A.

Power factor analysis for each generation project was performed on the current study 2016 winter peak, 2017 summer peak, and 2025 summer peak cases with identified system upgrades. As reactive power is required for GEN-2015-047, the final requirement in the GIA will be the pro-forma 95% lagging to 95% leading at the point of interconnection.

An analysis was conducted to determine the capacitive effects on the transmission system caused by the generator lead and collector system during periods of reduced generation. The generating facility is required to provide reactive compensation that can inject approximately 37 MVAR of inductive reactance during periods of reduced generation. Such compensation can be provided either by discrete reactive devices or by the generator itself if it possesses that capability.

Short Circuit analysis was conducted using the current study upgrade 2017 summer peak and 2025 summer peak cases.

With the assumptions outlined in this report and with all the required network upgrades from the DISIS-2015-002-2 in place, GEN-2015-047 with the GE 2.5 MW and GE 2.3 MW wind turbine generators should be able to interconnect reliably to the SPP transmission grid. The proposed change in wind turbine generators is not a Material Modification.

It should be noted that this study analyzed the requested modification to change inverter technology, manufacturer, and layout. Power flow 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 delivery or transmission service. If the customer wishes to sell power from the facility, a separate request for transmission service must be requested on Southwest Power Pool's OASIS by the Customer.

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1. Introduction

The GEN-2015-047 Interconnection Customer has requested a modification to its Generator Interconnection Request to change wind turbine generators from Vestas V110 VCSS 2.0 MW wind turbines to GE 2.5 MW and GE 2.3 MW wind turbines. Originally, it consisted of one hundred fifty (150) Vestas V110 VCSS 2.0MW wind turbines for a total 300.0 MW. The requested change is shown in **Table 1-1**.

Table 1-1: Interconnection Request

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2015-047	297.8	109 x GE 2.5 MW wind turbines, and 11 x GE 2.3 MW wind turbines	Sooner 345kV (514803)

The POI is the OKGE Sooner 345kV substation. Other queued generation projects in the model are listed in **Table 1-2**.

Table 1-2: Other Queued Interconnection Requests in the Model

Request	Capacity (MW)	Generator Model	Point of Interconnection
ASGI-2010-006	150	GE 1.5MW	Remington 138kV (301369)
ASGI-2014-014	54.3 Summer 56.4 Winter	GENSAL	Ferguson 69kV (512664)
ASGI-2015-004	54.3 Summer 56.364 Winter	GENSAL	Coffeyville Municipal Light & Power Northern Industrial Park Substation 69kV (512735)
GEN-2002-004	199.5	GE 1.5MW	Lathams 345kV (532800)
GEN-2005-013	199.8	Vestas V90 1.8MW	Caney River 345kV (532780)
GEN-2007-025	299.2	GE 1.6MW	Viola 345kV (532798)
GEN-2008-013	300	GE 1.68MW	Hunter 345kV (515476)
GEN-2008-021	1261 Summer 1283 Winter	GENROU	Wolf Creek 345kV (532797)
GEN-2008-098	100.8	Gamesa 2.0MW, and Gamesa 2.1MW	Tap Wolf Creek to LaCygne 345kV line (560004)
GEN-2009-025	59.8	Siemens 2.3MW	Tap Deer Creek to Sinclair Blackwell 69kV (Nardins 515528)
GEN-2010-003 (Phase II to GEN-2008-098)	100.8	Gamesa 2.0MW, and Gamesa 2.1MW	Tap Wolf Creek to LaCygne 345kV line (560004)
GEN-2010-005	299.2	GE 1.6MW	Viola 345kV (532798)
GEN-2010-055	4.8	GENROU	Wekiwa 138kV (509757)
GEN-2011-057	150	Vestas V110 2.0MW	Creswell 138kV (532981)
GEN-2012-032	299	Siemens 2.3MW	Tap Rose Hill-Sooner 345kV (Open Sky 515621)
GEN-2012-033	98.055	GE 1.715MW, and GE 1.79MW	Breckenridge 138kV (514815)
GEN-2012-041	85 Summer 121.5 Winter	GENROU	Tap Rose Hill-Sooner 345kV (Ranch Road 515576)
GEN-2013-012	4 x 168MW Summer 4 x 215MW Winter	GENROU (514910) (514911) (514912) (514942)	Redbud 345kV (514909)

Table 1-2: Other Queued Interconnection Requests in the Model

Request	Capacity (MW)	Generator Model	Point of Interconnection
GEN-2013-028	516.4 Summer 559.5 Winter	GENROU (583743, 583746)	Tap on Tulsa N to GRDA1 345kV (512865)
GEN-2013-029	299	Siemens 2.3MW	Renfrow 345kV (515543)
GEN-2014-001	199.5	Gamesa 2.1MW	Tap Wichita to Emporia Energy Center 345kV (562476)
GEN-2014-028 (Uprate to GEN-2004-017)	35 (uprate) (256 summer 259 winter)	GENROU	Riverton 161kV (547469)
GEN-2014-064	248.4	GE 2.3MW	Otter 138kV (514708)
GEN-2015-001	199.8	Vestas V126 3.3MW, and Vestas V126 3.3MW de-rated to 3.0MW	Ranch Road 345kV (515576)
GEN-2015-015	154.56	Siemens 2.3MW with Power Boost (115kW => 2.415MW)	Tap Medford Tap to Coyote 138kV (560031)
GEN-2015-016	200.0	Vestas V110 2.0MW	Tap Centerville to Marmaton 161kV (560029)
GEN-2015-024	217.8	GE 1.8MW	Tap Thistle to Wichita 345kV, ckt1&2 (560033)
GEN-2015-025	215.95	GE 1.8MW, and GE 1.79MW	Tap Thistle to Wichita 345kV, ckt1&2 (560033)
GEN-2015-030	200.1	GE 2.3MW	Sooner 345kV (514803)
GEN-2015-034	200	Vestas V110 2.0MW	Ranch Road 345kV (515576)
GEN-2015-052	300	Vestas V110 2.0MW	Tap Opensky to Rose Hill 345 kV (560053)
GEN-2015-062 (Uprate to GEN-2012-033)	4.505	GE 1.8MW (uprated 53 GE 1.715MW)	Breckenridge 138kV (514815)
GEN-2015-063	300	Vestas V110 2.0MW	Tap Woodring to Mathewson 345 kV (560055)
GEN-2015-066	248.4	GE 2.3MW	Tap Cleveland to Sooner 345 kV (560056)
GEN-2015-069	300	Vestas V110 2.0MW	Union Ridge 230kV (532874)
GEN-2015-073	200.1	Siemens 2.3MW	Emporia 345kV (532768)
GEN-2015-083	124.2	GE 2.3MW	Belle Plain 138kV (533063)
GEN-2015-090	220	GE 2.0MW	Tap Wichita to Thistle 345kV at GEN-2015-024 (584660) 345kV

A stability analysis was performed for the change in wind turbines. The analysis was performed on three (3) seasonal models including 2016 winter peak (16WP), the 2017 summer peak (17SP), and the 2025 summer peak (25SP) cases. These cases are modified versions of the 2015 model series of Model Development Working Group (MDWG) dynamic study models that included upgrades and Interconnection Requests through DISIS-2015-002-2.

Stability Analysis determines the impacts of the new interconnecting project on the stability and voltage recovery of the nearby systems and the ability of the interconnecting project to meet FERC Order 661A. If problems with stability or voltage recovery are identified, the need for reactive compensation or system upgrades is investigated. The contingencies listed in **Table 3-1** were used in the stability analysis.

Power Factor Analysis determines the power factor at the point of interconnection (POI) for the interconnection projects for pre-contingency and post-contingency conditions. The contingencies used in the power factor analysis are a subset of the stability analysis contingencies shown in **Table 3-1**.

Reduced Generation Analysis was performed to determine reactor inductive amounts to compensate for the capacitive effects on the transmission system caused by the interconnecting project's generator lead transmission line and collector systems during low or reduced generation conditions. The results of the analysis are illustrated in **Figure 5-2**.

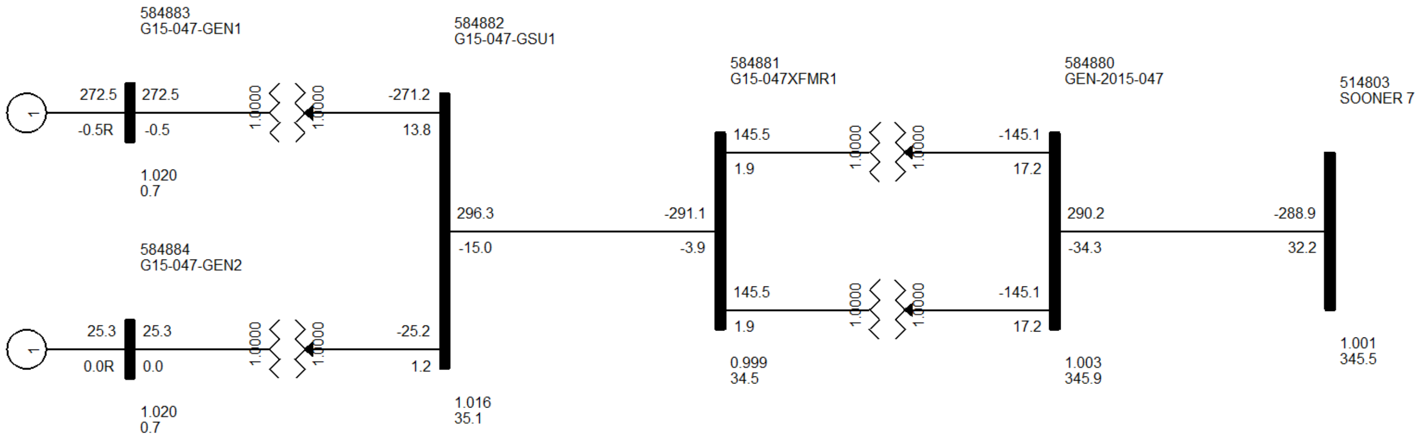
Short Circuit Analysis was conducted using the current study upgrade 2017 summer peak and 2025 summer peak cases. The results from the Short circuit analysis are shown in **Appendix E**.

Nothing in this System Impact Study constitutes a request for transmission service or grants the Interconnection Customer any rights to transmission service. If the customer wishes to sell power from the facility, a separate request for transmission service must be requested on Southwest Power Pool's OASIS by the Customer.

2. Facilities

A one-line PSS/E slider drawing from the 16WP case is shown in **Figure 2-1** for GEN-2015-047. The POI is the OKGE Sooner 345kV substation.

Figure 2-1: GEN-2015-047 One-line Diagram



3. Stability Analysis

Transient stability analysis is used to determine if the transmission system can maintain angular stability and ensure bus voltages stay within planning criteria bandwidth during and after a disturbance while considering the addition of a generator interconnection request.

Model Preparation

Transient stability analysis was performed using modified versions of the 2015 series of Model Development Working Group (MDWG) dynamic study models including the 2016 winter peak, 2017 summer peak, and the 2025 summer peak seasonal models. The cases are then loaded with prior queued interconnection requests and network upgrades assigned to those interconnection requests through DISIS-2015-002-2. Finally the prior queued and study generation are dispatched into the SPP footprint. Initial simulations are then carried out for a no-disturbance run of twenty (20) seconds to verify the numerical stability of the model.

Disturbances

Twenty-five (25) contingencies were identified for use in this study and are listed in **Table 3-1**. These contingencies are faults at locations defined by SPP Generation Interconnection Staff. These contingencies include three-phase and single-phase N-1. Single-phase line faults were simulated by applying fault impedance to the positive sequence network at the fault location to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice.

Except for transformer faults, the typical sequence of events for a three-phase and single-phase fault is as follows:

1. apply fault at particular location
2. continue fault for five (5) cycles, clear the fault by tripping the faulted facility
3. after an additional twenty (20) cycles, re-close the previous facility back into the fault
4. continue fault for five (5) additional cycles
5. trip the faulted facility and remove the fault

Transformer faults are typically modeled as three-phase faults, unless otherwise noted. The sequence of events for a transformer fault is as follows:

1. apply fault for five (5) cycles
2. clear the fault by tripping the affected transformer facility (unless otherwise noted there will be no re-closing into a transformer fault)

The SPP areas monitored during the stability analysis were:

- 330: Associated Electric Cooperative Inc. (AECI)
- 520: American Electric Power (AEPW)
- 523: Grand River Dam Authority (GRDA)
- 524: Oklahoma Gas and Electric Company (OKGE)
- 525: Western Farmers Electric Cooperative (WFEC)

- 527: Oklahoma Municipal Power Authority (OMPA)
- 536: Westar Energy, Inc. (WERE)

Table 3-1: Contingencies Evaluated

Cont. No.	Contingency Name	Description
0	FLT_00_NOFAULT	No Fault Conditions
1	FLT_01_SOONER7_RANCHRD7_345kV_3PH	3 phase fault on the Sooner (514803) to Ranch Road (515576) 345kV line, near Sooner. a. Apply fault at the Sooner 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.
2	FLT_02_SOONER7_RANCHRD7_345kV_1PH	Single phase fault on the Sooner (514803) to Ranch Road (515576) 345kV line, near Sooner. a. Apply fault at the Sooner 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.
3	FLT_03_SOONER7_G16061TAP_345kV_3PH	3 phase fault on the Sooner (514803) to G16-061 Tap (560084) 345kV line, near Sooner. a. Apply fault at the Sooner 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.
4	FLT_04_SOONER7_SPRNGCK7_345kV_3PH	3 phase fault on the Sooner (514803) to Spring Creek (514881) 345kV line, near Sooner. a. Apply fault at the Sooner 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.
5	FLT_05_SOONER7_G15066T_345kV_3PH	3 phase fault on the Sooner (514803) to G15-066 Tap (560056) 345kV line, near Sooner. a. Apply fault at the Sooner 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.
6	FLT_06_G16061TAP_WOODRNG7_345kV_3PH	3 phase fault on the G16-061 Tap (560084) to Woodring (514715) 345kV line, near G16-061 Tap. a. Apply fault at the G16-061 Tap 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.
7	FLT_07_WOODRNG7_G15063T_345kV_3PH	3 phase fault on the Woodring (514715) to G15-063 Tap (560055) 345kV line, near Woodring. a. Apply fault at the Woodring 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.
8	FLT_08_WOODRNG7_HUNTERS7_345kV_3PH	3 phase fault on the Woodring (514715) to Hunters (515476) 345kV line, near Woodring. a. Apply fault at the Woodring 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 3-1: Contingencies Evaluated

Cont. No.	Contingency Name	Description
9	FLT_09_G15066T_CLEVLND7_345kV_3PH	3 phase fault on the G15-066 Tap (560056) to Cleveland (512694) 345kV line, near G15-066 Tap. a. Apply fault at the G15-066 Tap 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.
10	FLT_10_SPRNGCK7_NORTWST7_345kV_3PH	3 phase fault on the Spring Creek (514881) to Northwest (514880) 345kV line, near Spring Creek. a. Apply fault at the Spring Creek 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.
11	FLT_11_RANCHRD7_OPENSKY7_345kV_3PH	3 phase fault on the Ranch Road (515576) to Open Sky (515621) 345kV line, near Ranch Road. a. Apply fault at the Ranch Road 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.
12	FLT_12_SOONER4_SNRPMPT4_138kV_3PH	3 phase fault on the Sooner (514802) to Sooner Pump Tap (514798) 138kV line, near Sooner. a. Apply fault at the Sooner 138kV 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.
13	FLT_13_SOONER4_PERRY4_138kV_3PH	3 phase fault on the Sooner (514802) to Perry (514707) 138kV line, near Sooner. a. Apply fault at the Sooner 138kV 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.
14	FLT_14_SOONER4_MILLERT4_138kV_3PH	3 phase fault on the Sooner (514802) to Miller Tap (514704) 138kV line, near Sooner. a. Apply fault at the Sooner 138kV 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.
15	FLT_15_SOONER4_MORISNT4_138kV_3PH	3 phase fault on the Sooner (514802) to Morrison Tap (515447) 138kV line, near Sooner. a. Apply fault at the Sooner 138kV 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.
16	FLT_16_SOONER7_RANCHRD7SB_345kV_1PH	**Single phase fault with stuck breaker** on the Sooner (514803) to Ranch Road (515576) 345kV line, near Sooner. a. Apply fault at the Sooner 345kV bus. b. Clear fault after 16 cycles by tripping the faulted line.
17	FLT_17_RANCHRD7_OPENSKY7SB_345kV_1PH	**Single phase fault with stuck breaker** on the Ranch Road (515576) to Open Sky (515621) 345kV line, near Ranch Road. a. Apply fault at the Ranch Road 345kV bus. b. Clear fault after 16 cycles by tripping the faulted line.
18	FLT_18_SOONER4_SNRPMPT4SB_138kV_1PH	**Single phase fault with stuck breaker** on the Sooner (514802) to Sooner Pump Tap (514798) 138kV line, near Sooner. a. Apply fault at the Sooner 138kV bus. b. Clear fault after 16 cycles by tripping the faulted line.

Table 3-1: Contingencies Evaluated

Cont. No.	Contingency Name	Description
19	FLT_19_SOONER7_SPRNGCK7PO_345kV_3PH	**Prior outage** on the Sooner (514803) to Ranch Road (515576) 345kV line: 3 phase fault on the Sooner (514803) to Spring Creek (514881) 345kV line, near Sooner 345kV. a. Prior Outage Sooner to Ranch Road 345kV. b. Apply fault at the Sooner 345kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (b) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
20	FLT_20_SOONER7_RANCHRD7PO_345kV_3PH	**Prior outage** on the Sooner (514803) to Spring Creek (514881) 345kV line: 3 phase fault on the Sooner (514803) to Ranch Road (515576) 345kV line, near Sooner 345kV. a. Prior Outage Sooner to Spring Creek 345kV. b. Apply fault at the Sooner 345kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (b) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
21	FLT_21_SOONER7_G16061TAPPO_345kV_3PH	**Prior outage** on the Sooner (514803) to Spring Creek (514881) 345kV line: 3 phase fault on the Sooner (514803) to G16-061 Tap (560084) 345kV line, near Sooner 345kV. a. Prior Outage Sooner to Spring Creek 345kV. b. Apply fault at the Sooner 345kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (b) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
22	FLT_22_SOONER7_SPRNGCK7PO_345kV_3PH	**Prior outage** on the Sooner 345kV (514803) to Sooner 138kV (514802) to Sooner 13.8kV (515760) transformer: 3 phase fault on the Sooner (514803) to Spring Creek (514881) 345kV line, near Sooner 345kV. a. Prior Outage Sooner 345kV to Sooner 138kV transformer. b. Apply fault at the Sooner 345kV bus. c. Clear fault after 5 cycles by tripping the faulted line. d. Wait 20 cycles, and then re-close the line in (b) back into the fault. e. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
23	FLT_23_SOONER4_SOONER7SB_138_345kV_1PH	**Single phase fault with stuck breaker** on the Sooner 138kV (514802) to Sooner 345kV (514803) to Sooner 13.8kV (515760) transformer, near Sooner. a. Apply fault at the Sooner 138kV bus. b. Clear fault after 16 cycles by tripping the faulted line.
24	FLT_24_SOONER7_SOONER4_345_138kV_3PH	3 phase fault on the Sooner 345kV (514803) to Sooner 138kV (514802) to Sooner 13.8kV (515760) transformer, near Sooner 345kV. a. Apply fault at the Sooner 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
25	FLT_25_WOODRNG7_WOODRNG4_345_138kV_3PH	3 phase fault on the Woodring 345kV (514715) to Woodring 138kV (514715) to Woodring 13.8kV (515770) transformer, near Woodring 345kV. a. Apply fault at the Woodring 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.

Results

The stability analysis was performed and the results are summarized in ***Table 3-2***. The stability plots will be available upon customer request.

Table 3-2: Contingency Results

Contingency Number and Name		Three Phase		
		2016WP	2017SP	2025SP
0	FLT_00_NOFAULT	STABLE	STABLE	STABLE
1	FLT_01_SOONER7_RANCHRD7_345kV_3PH	STABLE	STABLE	STABLE
2	FLT_02_SOONER7_RANCHRD7_345kV_1PH	STABLE	STABLE	STABLE
3	FLT_03_SOONER7_G16061TAP_345kV_3PH	STABLE	STABLE	STABLE
4	FLT_04_SOONER7_SPRNGCK7_345kV_3PH	STABLE	STABLE	STABLE
5	FLT_05_SOONER7_G15066T_345kV_3PH	STABLE	STABLE	STABLE
6	FLT_06_G16061TAP_WOODRNG7_345kV_3PH	STABLE	STABLE	STABLE
7	FLT_07_WOODRNG7_G15063T_345kV_3PH	STABLE	STABLE	STABLE
8	FLT_08_WOODRNG7_HUNTERS7_345kV_3PH	STABLE	STABLE	STABLE
9	FLT_09_G15066T_CLEVLND7_345kV_3PH	STABLE	STABLE	STABLE
10	FLT_10_SPRNGCK7_NORTWST7_345kV_3PH	STABLE	STABLE	STABLE
11	FLT_11_RANCHRD7_OPENSKY7_345kV_3PH	STABLE	STABLE	STABLE
12	FLT_12_SOONER4_SNRPMPT4_138kV_3PH	STABLE	STABLE	STABLE
13	FLT_13_SOONER4_PERRY4_138kV_3PH	STABLE	STABLE	STABLE
14	FLT_14_SOONER4_MILLERT4_138kV_3PH	STABLE	STABLE	STABLE
15	FLT_15_SOONER4_MORISNT4_138kV_3PH	STABLE	STABLE	STABLE
16	FLT_16_SOONER7_RANCHRD7SB_345kV_1PH	STABLE	STABLE	STABLE
17	FLT_17_RANCHRD7_OPENSKY7SB_345kV_1PH	STABLE	STABLE	STABLE
18	FLT_18_SOONER4_SNRPMPT4SB_138kV_1PH	STABLE	STABLE	STABLE
19	FLT_19_SOONER7_SPRNGCK7PO_345kV_3PH	STABLE	STABLE	STABLE
20	FLT_20_SOONER7_RANCHRD7PO_345kV_3PH	STABLE	STABLE	STABLE
21	FLT_21_SOONER7_G16061TAPPO_345kV_3PH	STABLE	STABLE	STABLE
22	FLT_22_SOONER7_SPRNGCK7PO_345kV_3PH	STABLE	STABLE	STABLE
23	FLT_23_SOONER4_SOONER7SB_138_345kV_1PH	STABLE	STABLE	STABLE
24	FLT_24_SOONER7_SOONER4_345_138kV_3PH	STABLE	STABLE	STABLE
25	FLT_25_WOODRNG7_WOODRNG4_345_138kV_3PH	STABLE	STABLE	STABLE

FERC LVRT Compliance

FERC Order 661A places specific requirements on wind farms through its Low Voltage Ride Through (LVRT) provisions. For Interconnection Agreements signed after December 31, 2006, wind farms shall stay on line for faults at the POI that draw the voltage down at the POI to 0.0 pu. The faults listed below in **Table *3-3*** were tested to meet Order 661A LVRT provisions. GEN-2015-047 was found to be in compliance with FERC Order 661A.

Table 3-3 LVRT Contingencies

Contingency Name	Description
FLT_01_SOONER7_RANCHRD7_345kV_3PH	3 phase fault on the Sooner (514803) to Ranch Road (515576) 345kV line, near Sooner. a. Apply fault at the Sooner 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.
FLT_03_SOONER7_G16061TAP_345kV_3PH	3 phase fault on the Sooner (514803) to G16-061 Tap (560084) 345kV line, near Sooner. a. Apply fault at the Sooner 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 3-3 LVRT Contingencies

Contingency Name	Description
FLT_04_SOONER7_SPRNGCK7_345kV_3PH	3 phase fault on the Sooner (514803) to Spring Creek (514881) 345kV line, near Sooner. a. Apply fault at the Sooner 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.
FLT_05_SOONER7_G15066T_345kV_3PH	3 phase fault on the Sooner (514803) to G15-066 Tap (560056) 345kV line, near Sooner. a. Apply fault at the Sooner 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.

4. Power Factor Analysis

The power factor analysis was performed for each project included in this study and is designed to demonstrate the reactive power requirements at the point of interconnection (POI) using the current study upgrade cases. For all projects that require reactive power, the final requirement in the GIA will be the pro-forma 95% lagging to 95% leading at the POI.

Model Preparation

For each project included in this study, as well as previous queued projects modeled at the same POI, the projects were turned off for the power factor analysis. The projects were replaced by an equivalent generator located at the POI producing the total MW of the projects at that POI and 0.0 Mvar capability.

A Mvar generator without limits was modeled at the interconnection project POI to hold a voltage schedule at the POI consistent with the greater of the voltage schedule in the base case or unity (1.0 pu) voltage.

Disturbances

Each N-1 contingency evaluated in the Stability Analysis found in **Table 3-1** was also included in the determination of the power factor requirements.

Results

The power factor ranges are summarized in **Table 4-1** and the resultant ranges are shown **Table D-1**. The analysis showed that reactive power is required for the study project, the final requirement in the Generation Interconnection Agreement (GIA) for each project will be the pro-forma 95% lagging to 95% leading at the POI.

For analyzing power factor results a positive Q (Mvar) output indicates that the equivalent generator is supplying reactive power to the system, implying a lagging power factor. A negative Q (Mvar) output indicates that the equivalent generator is absorbing reactive power from the system, implying a leading power factor.

Table 4-1*: Summary of Power Factor Analysis at the POI*

Request	Capacity (MW)	Point of Interconnection (POI)	Fuel	Generator	Lagging (providing Mvars)	Leading (absorbing Mvars)
GEN-2015-047	297.8	Sooner 345kV (514803)	Wind	109 x GE 2.5MW = 272.5MW, and 11 x GE 2.3MW = 25.3MW	0.95	0.95

NOTE: As reactive power is required for the project, the final requirement in the GIA will be the pro-forma 95% lagging to 95% leading at the point of interconnection.

5. Reduced Generation Analysis

A low generation analysis was performed for GEN-2015-047 to determine the capacitive charging current injected at the POI from the generation facility.

The project inverters and capacitors (if any) were turned off in the study case. **Figure 5-1** shows the resulting reactive power injection (approximately 37 Mvar) at the POI that is due to the capacitance of the project's 34.5 kV collector system transmission lines and of the transmission lead that connects the 345/34.5 kV transformer to the POI.

A shunt reactor was added at the GEN-2015-047 project substation 34.5 kV bus to bring the Mvar flow into the POI down to approximately zero as shown in **Figure 5-2**. A reactor of approximately 37 Mvar installed on the low side of the 345/34.5 kV transformer will negate the capacitive effect of the project at the POI.

Figure 5-1*:* GEN-2015-047 with inverters turned off

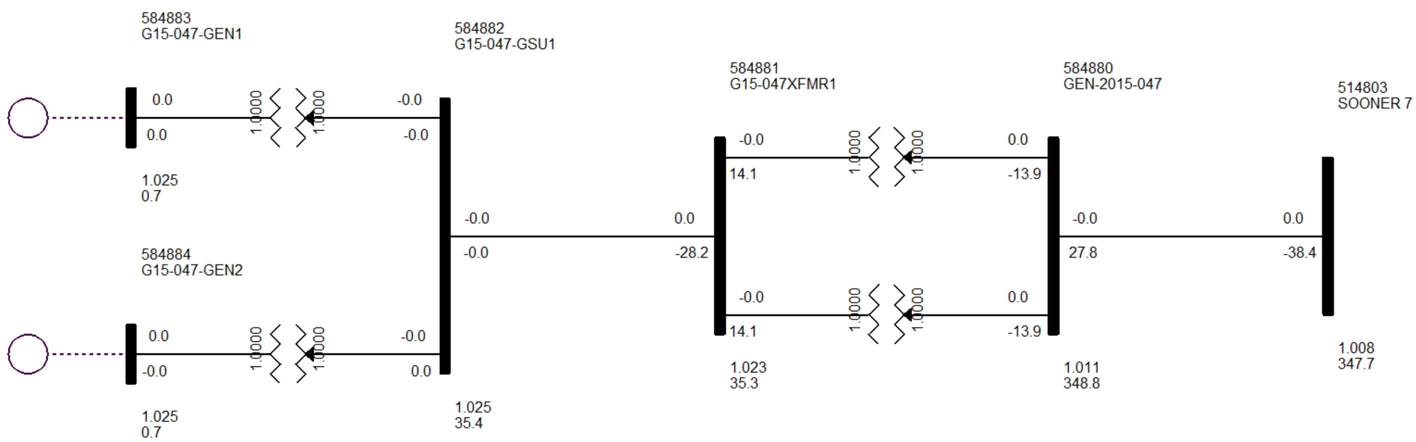
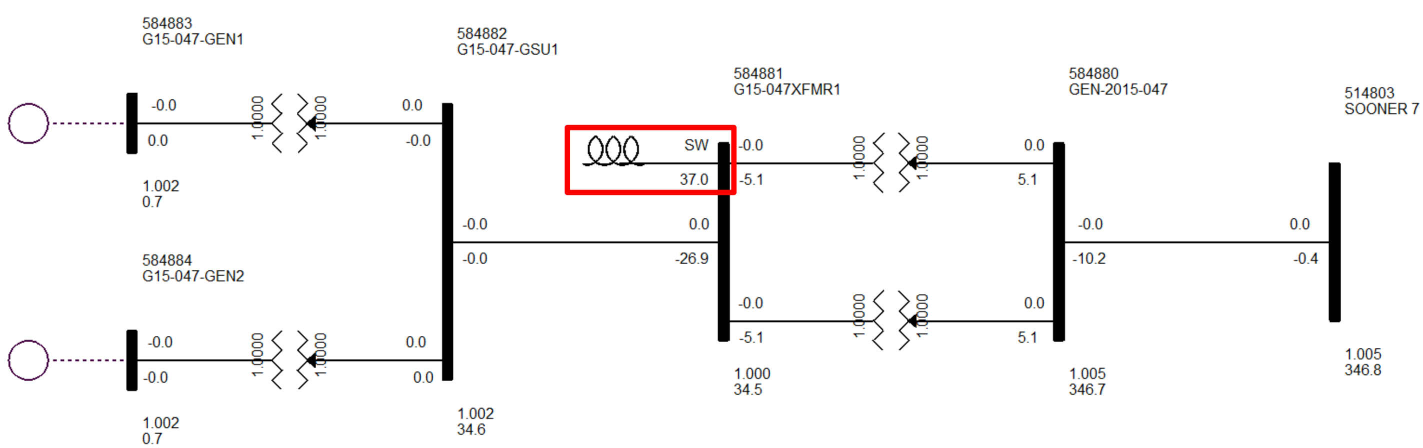


Figure 5-2*:* GEN-2015-047 with inverters turned off and 37 Mvar reactor at 34.5kV bus



6. Short Circuit Analysis

The short circuit analysis was performed on the 2017 & 2025 Summer Peak power flow cases using the PSS/E ASCC program. Since the power flow model does not contain negative and zero sequence data, only three-phase symmetrical fault current levels were calculated at the point of interconnection up to and including five levels away.

Short Circuit Analysis was conducting using flat conditions with the following PSS/E ASCCC program settings:

- BUS VOLTAGES SET TO 1 PU AT 0 PHASE ANGLE
- GENERATOR P=0, Q=0
- TRANSFORMER TAP RATIOS=1.0 PU and PHASE ANGLES=0.0
- LINE CHARGING=0.0 IN +/-/0 SEQUENCE
- LOAD=0.0 IN +/- SEQUENCE, CONSIDERED IN ZERO SEQUENCE
- LINE/FIXED/SWITCHED SHUNTS=0.0 AND MAGNETIZING ADMITTANCE=0.0 IN +/-/0 SEQUENCE
- DC LINES AND FACTS DEVICES BLOCKED
- TRANSFORMER ZERO SEQUENCE IMPEDANCE CORRECTIONS IGNORED

Results

The results of the short circuit analysis are shown in **Appendix E**; 2017 summer peak results in **Table *E-1*** and 2025 summer peak results in **Table *E-2***.

7. Conclusion

The GEN-2015-047 Interconnection Customer has requested a modification to its Generator Interconnection Request to change from Vestas V110 2.0 MW wind turbines to GE 2.5 MW and GE 2.3 MW wind turbines. Originally, it consisted of one hundred fifty (150) Vestas V110 VCSS 2.0MW wind turbines for a total 300.0 MW. The requested change is one hundred nine (109) GE 2.5 MW wind turbines and eleven (11) GE 2.3 MW for a total nameplate capacity of 297.8 MW. The point of interconnection (POI) is the Oklahoma Gas & Electric (OKGE) Sooner 345kV substation.

Stability analysis has determined that with all previously assigned Network Upgrades in service, generators in the monitored areas remained stable and within the pre-contingency, voltage recovery, and post fault voltage recovery criterion of 0.7pu to 1.2pu for the entire modeled disturbances. Additionally, the project 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.

A power factor analysis was performed for the modification request. As reactive power is required for GEN-2015-047, the final requirement in the GIA will be the pro-forma 95% lagging to 95% leading at the POI.

An analysis was conducted to determine the capacitive effects on the transmission system caused by the generator lead and collector system during periods of reduced generation. The generating facility is required to provide reactive compensation that can inject approximately 37 MVAR of inductive reactance during periods of reduced generation. Such compensation can be provided either by discrete reactive devices or by the generator itself if it possesses that capability.

Short Circuit analysis was conducted using the current study upgrade 2017 summer peak and 2025 summer peak cases.

With the assumptions outlined in this report and with all the required network upgrades from the DISIS 2015-002-2 in place, GEN-2015-047 with the GE 2.5 MW and GE 2.3 MW wind turbine generators should be able to interconnect reliably to the SPP transmission grid. The proposed change in wind turbine generators is not a Material Modification.

It should be noted that this study analyzed the requested modification to change generator technology, manufacturer, and layout. Power flow 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 delivery or transmission service. If the customer wishes to sell power from the facility, a separate request for transmission service must be requested on Southwest Power Pool's OASIS by the Customer.

Appendix A – 2016 Winter Peak Stability Plots

(Available on request)

Appendix B – 2017 Summer Peak Stability Plots

(Available on request)

Appendix C – 2025 Summer Peak Stability Plots

(Available on request)

Appendix D – Power Factor Analysis Results

Table D-1: GEN-2015-047 Power Factor Analysis Results

Leading power factor is absorbing vars; Lagging power factor is providing vars										
	GEN-2015-047 POI: Sooner 345 kV (514803) Power at POI (MW): 297.8	2016 Winter Peak POI Voltage = 1.006 pu			2017 Summer Peak POI Voltage = 1.010 pu			2025 Summer Peak POI Voltage = 1.010 pu		
	Contingency Name	**Mvars at POI**	**Power Factor**		**Mvars at POI**	**Power Factor**		**Mvars at POI**	**Power Factor**	
0	FLT_00_NOFAULT	120.5741	0.92691	LAG	116.8946	0.93085	LAG	117.4945	0.93022	LAG
1	FLT_01_SOONER7_RANCHRD7_345kV_3PH	75.02146	0.96970	LAG	80.09245	0.96568	LAG	79.32642	0.96631	LAG
2	FLT_02_SOONER7_RANCHRD7_345kV_1PH	75.02146	0.96970	LAG	80.09245	0.96568	LAG	79.32642	0.96631	LAG
3	FLT_03_SOONER7_G16061TAP_345kV_3PH	143.7941	0.90052	LAG	139.2509	0.90586	LAG	142.3507	0.90222	LAG
4	FLT_04_SOONER7_SPRNGCK7_345kV_3PH	149.2601	0.89399	LAG	150.2515	0.89280	LAG	149.1773	0.89409	LAG
5	FLT_05_SOONER7_G15066T_345kV_3PH	81.29441	0.96470	LAG	64.51218	0.97733	LAG	63.69373	0.97788	LAG
6	FLT_06_G16061TAP_WOODRNG7_345kV_3PH	133.7865	0.91218	LAG	129.0923	0.91750	LAG	132.1771	0.91402	LAG
7	FLT_07_WOODRNG7_G15063T_345kV_3PH	155.456	0.88649	LAG	145.1789	0.89888	LAG	142.147	0.90246	LAG
8	FLT_08_WOODRNG7_HUNTERS7_345kV_3PH	125.6757	0.92132	LAG	117.2663	0.93046	LAG	118.9421	0.92867	LAG
9	FLT_09_G15066T_CLEVLND7_345kV_3PH	109.0616	0.93901	LAG	91.87397	0.95556	LAG	90.6787	0.95664	LAG
10	FLT_10_SPRNGCK7_NORTWST7_345kV_3PH	121.8746	0.9255	LAG	163.1816	0.87697	LAG	165.8819	0.87361	LAG
11	FLT_11_RANCHRD7_OPENSKY7_345kV_3PH	115.6959	0.93213	LAG	116.4239	0.93136	LAG	116.261	0.93153	LAG
12	FLT_12_SOONER4_SNRPMPT4_138kV_3PH	122.9784	0.92429	LAG	118.9708	0.92864	LAG	119.6059	0.92795	LAG
13	FLT_13_SOONER4_PERRY4_138kV_3PH	122.8982	0.92438	LAG	119.2488	0.92834	LAG	120.0462	0.92748	LAG
14	FLT_14_SOONER4_MILLERT4_138kV_3PH	122.5473	0.92476	LAG	118.5246	0.92912	LAG	119.2483	0.92834	LAG
15	FLT_15_SOONER4_MORISNT4_138kV_3PH	130.3849	0.91605	LAG	125.5912	0.92141	LAG	126.1918	0.92075	LAG
16	FLT_16_SOONER7_RANCHRD7SB_345kV_1PH	75.02146	0.96970	LAG	80.09245	0.96568	LAG	79.32642	0.96631	LAG
17	FLT_17_RANCHRD7_OPENSKY7SB_345kV_1PH	115.6959	0.93213	LAG	116.4239	0.93135	LAG	116.261	0.93153	LAG
18	FLT_18_SOONER4_SNRPMPT4SB_138kV_1PH	122.9784	0.92429	LAG	118.9708	0.92864	LAG	119.6059	0.92795	LAG
19	FLT_19_SOONER7_SPRNGCK7PO_345kV_3PH	149.2601	0.89399	LAG	150.2515	0.89280	LAG	149.1773	0.89409	LAG
20	FLT_20_SOONER7_RANCHRD7PO_345kV_3PH	75.02146	0.96970	LAG	80.09245	0.96568	LAG	79.32642	0.96631	LAG
21	FLT_21_SOONER7_G16061TAPPO_345kV_3PH	143.7941	0.90052	LAG	139.2509	0.90586	LAG	142.3507	0.90222	LAG
22	FLT_22_SOONER7_SPRNGCK7PO_345kV_3PH	149.2601	0.89399	LAG	150.2515	0.89280	LAG	149.1773	0.89409	LAG
23	FLT_23_SOONER4_SOONER7SB_138_345kV_1PH	117.9939	0.92968	LAG	109.0629	0.93901	LAG	109.8501	0.93821	LAG
24	FLT_24_SOONER7_SOONER4_345_138kV_3PH	117.9939	0.92968	LAG	109.0629	0.93901	LAG	109.8501	0.93821	LAG
25	FLT_25_WOODRNG7_WOODRNG4_345_138kV_3PH	125.9128	0.92106	LAG	119.6444	0.92791	LAG	118.2651	0.92939	LAG

Appendix E – Short Circuit Analysis Results

Table E-1: GEN-2015-047 Short Circuit Analysis Results (2017SP)

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                              PSS®E-32.2.0 ASCC SHORT CIRCUIT CURRENTS          THU, MAY 25 2017   7:47
2015 MDWG FINAL WITH 2013 MMWG, UPDATED WITH 2014 SERC & MRO
MDWG 17S WITH MMWG 15S, MRO 16W TOPO/16S PROF, SERC 16S

OPTIONS USED:
    - FLAT CONDITIONS
    - BUS VOLTAGES SET TO 1 PU AT 0 PHASE ANGLE
    - GENERATOR P=0, Q=0
    - TRANSFOMRER TAP RATIOS=1.0 PU and PHASE ANGLES=0.0
    - LINE CHARGING=0.0 IN +/-/0 SEQUENCE
    - LOAD=0.0 IN +/- SEQUENCE, CONSIDERED IN ZERO SEQUENCE
    - LINE/FIXED/SWITCHED SHUNTS=0.0 AND MAGNETIZING ADMITTANCE=0.0 IN +/-/0 SEQUENCE
    - DC LINES AND FACTS DEVICES BLOCKED
    - TRANSFORMER ZERO SEQUENCE IMPEDANCE CORRECTIONS IGNORED

                                   THREE PHASE FAULT
X---------- BUS ----------X          /I+/    AN(I+)
514803 [SOONER 7    345.00] AMP    24534.4   -86.49
514802 [SOONER 4    138.00] AMP    31297.0   -86.78
514881 [SPRNGCK7    345.00] AMP    21409.2   -85.53
515576 [RANCHRD7    345.00] AMP    13729.5   -86.67
560056 [G15-066T    345.00] AMP    17948.8   -86.54
560084 [G16-061-TAP 345.00] AMP    14700.4   -84.90
584690 [GEN-2015-030345.00] AMP    18698.3   -85.92
584880 [GEN-2015-047345.00] AMP    10996.2   -83.66
512694 [CLEVLND7    345.00] AMP    14816.8   -86.33
514704 [MILLERT4    138.00] AMP    20113.8   -85.57
514707 [PERRY  4    138.00] AMP    10934.9   -83.28
514715 [WOODRNG7    345.00] AMP    16932.2   -84.82
514798 [SNRPMPT4    138.00] AMP    20130.2   -85.54
514880 [NORTWST7    345.00] AMP    29358.0   -86.05
515447 [MORISNT4    138.00] AMP    13644.9   -82.93
515621 [OPENSKY7    345.00] AMP    12743.4   -86.64
529200 [OMCDLEC7    345.00] AMP    13704.2   -86.67
584450 [G1501-G1631 345.00] AMP    11047.1   -85.63
584770 [GEN-2015-034345.00] AMP    11035.0   -85.68
585040 [GEN-2015-066345.00] AMP    17784.4   -86.52
509852 [T.NO.--7    345.00] AMP    23393.4   -86.30
512729 [CLEVLND 4   138.00] AMP    16665.4   -85.45
514706 [COWCRK 4    138.00] AMP    11232.5   -82.99
514714 [WOODRNG4    138.00] AMP    18616.4   -83.30
514737 [OTOE   4    138.00] AMP    16080.7   -83.28
514743 [OSAGE  4    138.00] AMP    15537.9   -81.75
514799 [SNRPMP 4    138.00] AMP    11172.4   -80.57
514825 [KAYWIND7    345.00] AMP    12710.4   -86.63
514879 [NORTWST4    138.00] AMP    42443.1   -85.92
514901 [CIMARON7    345.00] AMP    29721.7   -85.77
514908 [ARCADIA7    345.00] AMP    24878.1   -86.46
515006 [MORRISN4    138.00] AMP    13614.8   -82.92
515011 [STILWTR4    138.00] AMP    13289.3   -80.15
515412 [DMNCRKT4    138.00] AMP    13448.6   -84.33
515476 [HUNTERS7    345.00] AMP    12038.8   -84.70
515497 [MATHWSN7    345.00] AMP    27538.0   -85.77
560053 [G15-052T    345.00] AMP    13112.9   -86.46
560055 [G15-063T    345.00] AMP    16812.0   -84.90
300138 [4CLEVLND    138.00] AMP    16667.4   -85.42
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509755 [WEKIWA-7    345.00] AMP    18588.2   -86.20
509895 [T.NO.2-4    138.00] AMP    34189.2   -84.98
510376 [WEBBTAP4    138.00] AMP     7472.0   -78.68
510406 [N.E.S.-7    345.00] AMP    18715.1   -86.41
512865 [GREC TAP5   345.00] AMP    25558.3   -87.32
514705 [COWCRK 2    69.000] AMP     4043.2   -86.74
514708 [OTTER  4    138.00] AMP     9516.2   -82.41
514709 [FRMNTAP4    138.00] AMP    17442.3   -82.88
514711 [WAUKOTP4    138.00] AMP    14921.6   -81.72
514713 [WRVALLY4    138.00] AMP     8652.3   -82.15
514733 [MARSHL 4    138.00] AMP     7782.0   -80.53
514742 [OSGE   2    69.000] AMP    14627.2   -84.40
514758 [STDBEAR4    138.00] AMP    13170.8   -81.68
514761 [WHEAGLE4    138.00] AMP    14865.3   -81.80
514770 [MARLNDT4    138.00] AMP    10521.7   -76.97
514801 [MINCO  7    345.00] AMP    16168.3   -85.16
514828 [KETCHTP4    138.00] AMP    26011.1   -84.56
514854 [BRADEN 4    138.00] AMP    30756.0   -85.14
514873 [LNEOAK 4    138.00] AMP    26423.9   -84.57
514898 [CIMARON4    138.00] AMP    42068.0   -85.00
514907 [ARCADIA4    138.00] AMP    40833.3   -85.64
514909 [REDBUD 7    345.00] AMP    23849.0   -86.78
514934 [DRAPER 7    345.00] AMP    20374.3   -85.15
515045 [SEMINOL7    345.00] AMP    25903.4   -86.18
515181 [UNVRSTY4    138.00] AMP    13411.5   -79.89
515400 [DMANCRK4    138.00] AMP     7954.9   -80.21
515407 [TATONGA7    345.00] AMP    10482.6   -86.78
515471 [NW164TH4    138.00] AMP    34845.8   -85.66
515477 [CHSHLMV7    345.00] AMP    12022.9   -84.70
515512 [SPVALLY4    138.00] AMP     8666.7   -77.82
515610 [FSHRTAP7    345.00] AMP    15920.3   -85.09
532794 [ROSEHIL7    345.00] AMP    18818.1   -85.81
560086 [G16-072-TAP 345.00] AMP    11100.0   -84.64
584900 [GEN-2015-052345.00] AMP    13062.8   -86.43
585010 [GEN-2015-063345.00] AMP    16753.6   -84.87
300140 [4SILVCTY    138.00] AMP    15768.5   -82.23
300996 [4JAVINE     138.00] AMP     6523.9   -82.69
301429 [4CLEVLNDXFMR138.00] AMP    16667.4   -85.42
509757 [WEKIWA-4    138.00] AMP    31241.6   -84.89
509782 [R.S.S.-7    345.00] AMP    30803.7   -86.91
509807 [ONETA--7    345.00] AMP    29567.7   -86.67
509817 [T.NO.--4    138.00] AMP    34247.5   -84.89
509870 [SAPLPRD7    345.00] AMP    21070.7   -86.50
510377 [FAIRFXT4    138.00] AMP     7502.6   -78.75
510380 [DELWARE7    345.00] AMP    11395.6   -84.84
510432 [SHIDWFC4    138.00] AMP     5327.6   -75.96
510907 [PITTSB-7    345.00] AMP    13045.9   -84.54
511425 [TUTCONT4    138.00] AMP    10601.6   -80.92
512650 [GRDA1  7    345.00] AMP    25990.4   -87.32
512749 [PAWNSW4     138.00] AMP     9911.0   -83.58
514710 [WAUKOMI4    138.00] AMP     9512.8   -80.46
514712 [FAIRMON4    138.00] AMP    13624.6   -82.24
514731 [SO4TH  4    138.00] AMP    14797.2   -81.23
514748 [CONTEMP4    138.00] AMP    12831.1   -81.68
514753 [CONORTH4    138.00] AMP    12870.8   -81.68
514760 [KILDARE4    138.00] AMP    10139.5   -79.53
514768 [WF KAY 2    69.000] AMP     2949.1   -81.29
514819 [EL-RENO4    138.00] AMP    15222.9   -80.01
514820 [JENSENT4    138.00] AMP    14999.8   -79.44
514827 [CTNWOOD4    138.00] AMP    16549.7   -80.44
514834 [KETCH  4    138.00] AMP    26476.6   -84.56
514851 [QUAILCK4    138.00] AMP    28916.5   -83.27
514852 [SLVRLAK4    138.00] AMP    32142.8   -83.89
514863 [HAYMAKR4    138.00] AMP    26014.5   -82.45
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514864 [PIEDMNT4    138.00] AMP    22046.2   -84.44
514894 [CZECHAL4    138.00] AMP    28021.0   -82.98
514895 [SARA   4    138.00] AMP    18585.5   -84.10
514906 [JNSKAMO4    138.00] AMP    20532.9   -81.91
514933 [DRAPER 4    138.00] AMP    38552.0   -85.17
515009 [MCELROY4    138.00] AMP    13527.4   -79.75
515039 [PAYNESB4    138.00] AMP     7618.3   -77.28
515044 [SEMINOL4    138.00] AMP    39082.3   -85.70
515224 [MUSKOGE7    345.00] AMP    28777.4   -86.76
515402 [CONBLKT2    69.000] AMP    13283.8   -82.81
515444 [MCNOWND7    345.00] AMP    16123.3   -85.15
515448 [CRSRDSW7    345.00] AMP     8151.6   -85.99
515461 [RNDBARN4    138.00] AMP    38843.2   -85.56
515465 [LGARBER4    138.00] AMP    21021.6   -82.40
515466 [MITCHSB4    138.00] AMP    21064.9   -83.35
515514 [KNIPE  4    138.00] AMP     5016.4   -78.92
515542 [CWBOYHT4    138.00] AMP     7841.1   -74.45
515543 [RENFROW7    345.00] AMP    11135.5   -84.66
515549 [MNCWND37    345.00] AMP    11274.4   -84.89
515582 [SLNGWND7    345.00] AMP     7041.9   -85.75
515585 [MAMTHPW7    345.00] AMP     9281.9   -86.61
515600 [KNGFSHR7    345.00] AMP    11008.2   -84.89
515800 [GRACMNT7    345.00] AMP    14770.3   -85.24
521006 [MARSHAL4    138.00] AMP     7745.8   -80.48
521007 [MARLAND_138 138.00] AMP     7239.7   -74.55
521100 [WARREN 4    138.00] AMP     8652.3   -82.15
529241 [OMMORANT    69.000] AMP     9136.5   -83.31
529249 [OMWW        69.000] AMP    11261.5   -83.58
532791 [BENTON 7    345.00] AMP    19012.8   -85.72
532797 [WOLFCRK7    345.00] AMP    15970.0   -86.82
532800 [LATHAMS7    345.00] AMP    10459.0   -85.56
533062 [ROSEHIL4    138.00] AMP    30985.5   -86.17
560077 [G16-032-TAP 345.00] AMP     3366.3   -79.62
562075 [G15-081-TAP 345.00] AMP    11375.4   -86.55
562790 [G15-038T    345.00] AMP    13236.4   -84.93
584170 [GEN-2014-064138.00] AMP     9444.1   -82.38
584700 [GEN-2015-029345.00] AMP     7355.4   -85.26
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Table E-2: GEN-2015-047 Short Circuit Analysis Results (2025SP)

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                              PSS®E-32.2.0 ASCC SHORT CIRCUIT CURRENTS          THU, MAY 25 2017   7:50
2015 MDWG FINAL WITH 2013 MMWG, UPDATED WITH 2014 SERC & MRO
MDWG 2025S WITH MMWG 2024S, MRO & SERC 2025 SUMMER

OPTIONS USED:
    - FLAT CONDITIONS
    - BUS VOLTAGES SET TO 1 PU AT 0 PHASE ANGLE
    - GENERATOR P=0, Q=0
    - TRANSFOMRER TAP RATIOS=1.0 PU and PHASE ANGLES=0.0
    - LINE CHARGING=0.0 IN +/-/0 SEQUENCE
    - LOAD=0.0 IN +/- SEQUENCE, CONSIDERED IN ZERO SEQUENCE
    - LINE/FIXED/SWITCHED SHUNTS=0.0 AND MAGNETIZING ADMITTANCE=0.0 IN +/-/0 SEQUENCE
    - DC LINES AND FACTS DEVICES BLOCKED
    - TRANSFORMER ZERO SEQUENCE IMPEDANCE CORRECTIONS IGNORED

                                   THREE PHASE FAULT
X--------- BUS ----------X            /I+/    AN(I+)
514803 [SOONER 7    345.00] AMP    24732.1   -86.49
514802 [SOONER 4    138.00] AMP    31800.8   -86.81
514881 [SPRNGCK7    345.00] AMP    21905.0   -85.53
515576 [RANCHRD7    345.00] AMP    13768.6   -86.67
560056 [G15-066T    345.00] AMP    18042.8   -86.54
560084 [G16-061-TAP 345.00] AMP    14855.5   -84.89
584690 [GEN-2015-030345.00] AMP    18811.9   -85.91
584880 [GEN-2015-047345.00] AMP    11030.4   -83.65
512694 [CLEVLND7    345.00] AMP    14881.0   -86.33
514704 [MILLERT4    138.00] AMP    20413.9   -85.61
514707 [PERRY  4    138.00] AMP    11005.9   -83.26
514715 [WOODRNG7    345.00] AMP    17285.2   -84.84
514798 [SNRPMPT4    138.00] AMP    20461.2   -85.59
514880 [NORTWST7    345.00] AMP    30528.4   -86.09
515447 [MORISNT4    138.00] AMP    13863.3   -82.89
515621 [OPENSKY7    345.00] AMP    12781.1   -86.64
529200 [OMCDLEC7    345.00] AMP    13743.2   -86.67
584450 [G1501-G1631 345.00] AMP    11071.7   -85.63
584770 [GEN-2015-034345.00] AMP    11059.7   -85.67
585040 [GEN-2015-066345.00] AMP    17876.7   -86.51
509852 [T.NO.--7    345.00] AMP    23592.9   -86.30
512729 [CLEVLND 4   138.00] AMP    16716.6   -85.45
514706 [COWCRK 4    138.00] AMP    11309.7   -82.96
514714 [WOODRNG4    138.00] AMP    18744.0   -83.29
514737 [OTOE   4    138.00] AMP    16272.1   -83.28
514743 [OSAGE  4    138.00] AMP    16531.6   -82.03
514799 [SNRPMP 4    138.00] AMP    11273.8   -80.55
514825 [KAYWIND7    345.00] AMP    12747.9   -86.63
514879 [NORTWST4    138.00] AMP    42927.3   -85.97
514901 [CIMARON7    345.00] AMP    31124.9   -85.95
514908 [ARCADIA7    345.00] AMP    26065.0   -86.55
515006 [MORRISN4    138.00] AMP    13831.9   -82.89
515011 [STILWTR4    138.00] AMP    13870.8   -80.01
515412 [DMNCRKT4    138.00] AMP    13715.2   -84.39
515476 [HUNTERS7    345.00] AMP    12408.1   -84.74
515497 [MATHWSN7    345.00] AMP    29678.5   -86.07
560053 [G15-052T    345.00] AMP    13184.2   -86.46
560055 [G15-063T    345.00] AMP    17246.6   -84.94
300138 [4CLEVLND    138.00] AMP    16718.6   -85.43
509755 [WEKIWA-7    345.00] AMP    18777.1   -86.22
509895 [T.NO.2-4    138.00] AMP    34376.8   -84.98
510376 [WEBBTAP4    138.00] AMP     7572.9   -78.68
510406 [N.E.S.-7    345.00] AMP    18841.4   -86.42
512865 [GREC TAP5   345.00] AMP    25882.3   -87.33
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514705 [COWCRK 2    69.000] AMP     4048.2   -86.74
514708 [OTTER  4    138.00] AMP     9546.1   -82.40
514709 [FRMNTAP4    138.00] AMP    17555.7   -82.87
514711 [WAUKOTP4    138.00] AMP    15009.6   -81.72
514713 [WRVALLY4    138.00] AMP     8688.9   -82.12
514733 [MARSHL 4    138.00] AMP     7799.4   -80.53
514742 [OSGE   2    69.000] AMP    17519.5   -84.60
514758 [STDBEAR4    138.00] AMP    13834.0   -81.86
514761 [WHEAGLE4    138.00] AMP    15608.1   -81.90
514770 [MARLNDT4    138.00] AMP    10903.7   -76.94
514801 [MINCO  7    345.00] AMP    16530.7   -85.20
514828 [KETCHTP4    138.00] AMP    26061.9   -84.56
514854 [BRADEN 4    138.00] AMP    30929.8   -85.16
514873 [LNEOAK 4    138.00] AMP    26554.6   -84.59
514898 [CIMARON4    138.00] AMP    42425.1   -85.06
514907 [ARCADIA4    138.00] AMP    41263.7   -85.71
514909 [REDBUD 7    345.00] AMP    25385.1   -86.83
514934 [DRAPER 7    345.00] AMP    20530.5   -85.12
515045 [SEMINOL7    345.00] AMP    26075.2   -86.15
515181 [UNVRSTY4    138.00] AMP    13707.3   -79.81
515400 [DMANCRK4    138.00] AMP     8047.6   -80.20
515407 [TATONGA7    345.00] AMP    15930.3   -86.55
515471 [NW164TH4    138.00] AMP    35155.3   -85.70
515477 [CHSHLMV7    345.00] AMP    12391.2   -84.74
515512 [SPVALLY4    138.00] AMP     8859.9   -77.69
515610 [FSHRTAP7    345.00] AMP    16269.5   -85.15
515644 [STLWTR2     69.000] AMP    16268.2   -78.22
532794 [ROSEHIL7    345.00] AMP    19116.6   -85.82
560086 [G16-072-TAP 345.00] AMP    11621.5   -84.72
584900 [GEN-2015-052345.00] AMP    13133.4   -86.44
585010 [GEN-2015-063345.00] AMP    17184.8   -84.91
300140 [4SILVCTY    138.00] AMP    15852.5   -82.25
300996 [4JAVINE     138.00] AMP     6531.1   -82.68
301429 [4CLEVLNDXFMR138.00] AMP    16718.6   -85.43
509757 [WEKIWA-4    138.00] AMP    31499.0   -84.89
509782 [R.S.S.-7    345.00] AMP    31489.1   -86.98
509807 [ONETA--7    345.00] AMP    29964.9   -86.69
509817 [T.NO.--4    138.00] AMP    34436.2   -84.89
509870 [SAPLPRD7    345.00] AMP    21376.2   -86.54
510377 [FAIRFXT4    138.00] AMP     7603.9   -78.75
510380 [DELWARE7    345.00] AMP    11493.8   -84.87
510432 [SHIDWFC4    138.00] AMP     5378.7   -75.94
510907 [PITTSB-7    345.00] AMP    13084.5   -84.54
511425 [TUTCONT4    138.00] AMP    10672.3   -80.90
512650 [GRDA1  7    345.00] AMP    26331.1   -87.34
512662 [STILWTP2    69.000] AMP    16283.3   -78.22
512749 [PAWNSW4     138.00] AMP     9946.4   -83.60
514710 [WAUKOMI4    138.00] AMP     9562.1   -80.48
514712 [FAIRMON4    138.00] AMP    13698.2   -82.22
514731 [SO4TH  4    138.00] AMP    14880.2   -81.21
514748 [CONTEMP4    138.00] AMP    13437.3   -81.82
514753 [CONORTH4    138.00] AMP    13487.3   -81.83
514760 [KILDARE4    138.00] AMP    10512.8   -79.43
514768 [WF KAY 2    69.000] AMP     2951.8   -81.29
514819 [EL-RENO4    138.00] AMP    15287.2   -80.04
514820 [JENSENT4    138.00] AMP    15063.7   -79.45
514827 [CTNWOOD4    138.00] AMP    16602.4   -80.44
514834 [KETCH  4    138.00] AMP    26520.7   -84.56
514851 [QUAILCK4    138.00] AMP    28978.1   -83.27
514852 [SLVRLAK4    138.00] AMP    32245.7   -83.91
514863 [HAYMAKR4    138.00] AMP    26070.9   -82.47
514864 [PIEDMNT4    138.00] AMP    22138.3   -84.46
514894 [CZECHAL4    138.00] AMP    27697.8   -83.00
514895 [SARA   4    138.00] AMP    18618.6   -84.10
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514906 [JNSKAMO4    138.00] AMP    20324.9   -81.88
514933 [DRAPER 4    138.00] AMP    38603.9   -85.15
515009 [MCELROY4    138.00] AMP    13731.5   -79.69
515039 [PAYNESB4    138.00] AMP     7749.7   -77.17
515044 [SEMINOL4    138.00] AMP    39221.2   -85.67
515224 [MUSKOGE7    345.00] AMP    28887.4   -86.76
515402 [CONBLKT2    69.000] AMP    15527.8   -82.74
515444 [MCNOWND7    345.00] AMP    16483.6   -85.19
515448 [CRSRDSW7    345.00] AMP    11103.5   -85.54
515461 [RNDBARN4    138.00] AMP    39224.0   -85.63
515465 [LGARBER4    138.00] AMP    20997.7   -82.39
515466 [MITCHSB4    138.00] AMP    21101.9   -83.35
515514 [KNIPE  4    138.00] AMP     5080.6   -78.86
515542 [CWBOYHT4    138.00] AMP     8006.3   -74.36
515543 [RENFROW7    345.00] AMP    11784.7   -84.77
515549 [MNCWND37    345.00] AMP    11440.9   -84.91
515582 [SLNGWND7    345.00] AMP     8983.9   -85.26
515585 [MAMTHPW7    345.00] AMP    13254.8   -86.34
515600 [KNGFSHR7    345.00] AMP    11159.7   -84.92
515800 [GRACMNT7    345.00] AMP    15205.9   -85.32
521006 [MARSHAL4    138.00] AMP     7763.0   -80.47
521007 [MARLAND_138 138.00] AMP     7418.2   -74.47
521100 [WARREN 4    138.00] AMP     8688.9   -82.12
529241 [OMMORANT    69.000] AMP    12304.5   -84.33
529249 [OMWW        69.000] AMP    13318.5   -83.72
532791 [BENTON 7    345.00] AMP    19372.9   -85.75
532797 [WOLFCRK7    345.00] AMP    16038.0   -86.82
532800 [LATHAMS7    345.00] AMP    10514.5   -85.56
533062 [ROSEHIL4    138.00] AMP    31764.9   -86.13
560077 [G16-032-TAP 345.00] AMP     3372.7   -79.62
562075 [G15-081-TAP 345.00] AMP    16230.3   -86.40
562790 [G15-038T    345.00] AMP    13473.6   -84.97
584170 [GEN-2014-064138.00] AMP     9473.5   -82.37
584700 [GEN-2015-029345.00] AMP     9603.6   -84.60
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