GEN-2007-062
GEN-2011-019
GEN-2011-020
Impact Restudy for Generator Modification (Turbine Change)

September 2016
Generator Interconnection

Revision History

Date	Author	Change Description
9/29/2016	SPP	Restudy for Generator Modification issued.

Executive Summary

A Modification Request has been made by the Interconnection Customers for GEN-2007-062, GEN-2011-019, and GEN-2011-020 Interconnection Requests (Combined Generating Facility). The Customers have requested to combine the three Interconnection Requests into a single generator lead and reduce the size of the three Interconnection Requests to be no larger than the original size of GEN-2007-062.

The new generator configuration of the Combined Generating Facility is as shown in the following table.

Interconnection Request Phase	Generators	Aggregate Nameplate Power
GEN-2007-062 (Phase I)	Sixty-three (63) Vestas V100 2.0MW (126.0MW), and Thirty (30) Vestas V117 3.3 MW (99.0MW)	225.0MW
GEN-2007-062 (Phase II)	Eighty-three (83) GE 2.4MW	199.2MW
GEN-2011-019	Eighty-seven (87) Vestas V100 2.0MW	174.0MW
GEN-2011-020	Sixty-nine (69) GE 2.4MW	165.6MW
	Project total power	**763.8MW**

The point of interconnection (POI) is the Oklahoma Gas and Electric (OKGE) Woodward EHV 345kV Substation. S&C Electric Company (S&C) performed the study for this modification request, and S&C's report on the study follows this summary. The S&C study refers to the entire Combined Generating Facility as GEN-2007-062, but includes the generator configuration as listed above and was studied on the basis that the three Interconnection Requests do not exceed 765MW. If these parameters are not met, this study will be considered invalid and will need be restudied for the correct generator configuration of the Combined Generating Facility.

The study models used were the 2016 winter, the 2017 summer, and the 2025 summer cases and included Interconnection Requests through DISIS-2015-002. The study showed that no stability problems were found with the contingencies studied during the summer and the winter peak conditions as a result of changing to the GE 2.4MW, the Vestas V100 2.0MW and the Vestas V117 3.3MW wind turbines. Additionally, the Combined Generating Facility was found to stay connected during the contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements.

A power factor analysis was performed for the study and it was found that the GEN-2007-062, GEN-2011-019, and GEN-2011-020 Interconnection Requests will be required to meet the 0.95 power factor lagging (providing vars) and 0.95 power factor leading (absorbing vars) at the POI. A short circuit analysis was performed and is detailed in the S&C report.

A low wind/no wind condition analysis was performed for this modification request. The analysis showed that the project will inject approximately 57Mvars into the POI during periods of low wind/no wind. The Combined Generating Facility will be required to have approximately 57MVars of shunt reactors to offset the capacitive injection. The following table shows the approximate reactors necessary for each phase.

Phase	**Description (approximate line charging factors)**	**Approximate reactor**
GEN-2007-062 (Phase I)	1. Line from Interconnection Customer's transmission line collection switchyard to POI (5Mvars) 2. Line from GEN-2007-062 (Phase I) substation to transmission line collection switchyard (5Mvars) 3. Collector subsystem (12Mvars)	22Mvars
GEN-2011-019	1. Line from GEN-2011-019 substation to GEN-2007-062 (Phase I) (6Mvars) 2. Collector subsystem (8Mvars)	14Mvars
GEN-2007-062 (Phase II)	1. Line from GEN-2007-062 (Phase II) substation to transmission line collection switchyard (2Mvars) 2. Collector subsystem (9Mvars)	11Mvars
GEN-2011-020	1. Line from GEN-2011-020 substation to GEN-2007-062 (Phase II) substation (1Mvar) 2. Collector subsystem (9Mvars)	10Mvars
	Total reactors (approximate)	**57Mvars**

With the assumptions outlined in this report and with all required network upgrades in place, the Combined Generating Facility will be able to reliably interconnect to the SPP transmission grid with the GE 2.4MW, the Vestas V100 2.0MW and the Vestas V117 3.3MW wind turbine generators.

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

Nothing in this study should be construed as a guarantee of transmission service. If the Customer wishes to obtain deliverability to a specific customer, a separate request for transmission service shall be requested on Southwest Power Pool's OASIS.

S&C ELECTRIC COMPANY
Excellence Through Innovation

GEN-2007-062 MODIFICATION

LITTLE ROCK, AR

SOUTHWEST POWER POOL

DEFINITIVE INTERCONNECTION SYSTEM IMPACT RE-STUDY

S&C PROJECT NUMBER: 10812

DOCUMENT NUMBER: E-857

REVISION: 0

FINAL REPORT

CONFIDENTIAL

SEPTEMBER 7, 2016

REPORT REVISION HISTORY:

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A	09/02/2016	MA	SK	SK	Preliminary report issued
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1. Executive Summary

S&C Electric Company (S&C) has performed a Definitive Interconnection System Impact Re-Study in response to a request through Southwest Power Pool (SPP) Tariff. The re-study is driven by a modification to interconnection request GEN-2007-062. The modification involves a change from the GE 1.5 MW wind turbines to a combination of GE 2.4 MW, Vestas V100 2.0 MW, and Vestas V117 3.3 MW wind turbines.

S&C has performed a dynamic stability analysis for this modification. The study was performed using three (3) base cases (2016 Winter Peak, 2017 Summer Peak, and 2025 Summer Peak) provided by SPP. In the study, GEN-2007-062 and other other-queued projects in Group 1 were studied at 100% of nameplate MW capacity. The dynamic stability study revealed that Group 1 projects met the SPP transient voltage requirements, with the solutions illustrated in the dynamic stability results section of this report. 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.

S&C has performed power factor analysis for this modification. Power factor analysis reported the power factors at the GEN-2007-062 point of interconnection (POI) for all N-1 three-phase contingences and marked any contingencies at which the required power factor at the POI (to maintain the voltages at the desired level) is beyond the normal required capability (from 0.95 lagging to 0.95 leading). The power factor requirement for GEN-2007-062 is from 0.95 lagging to 0.95 leading power factor at the POI.

S&C has performed an analysis of low wind conditions for this modification. The low wind analysis was performed by taking GEN-2007-062 generation out of service and determining the Mvar size of a shunt reactor to offset the reactive power that comes from the capacitance of the project's transmission lines and collector cables. The shunt reactor Mvars are given in Section 8.

S&C has performed a short-circuit analysis for the 2017 Summer Peak and 2025 Summer Peak cases under this modification and reported short-circuit results at all buses up to five (5) levels away from the POI of project GEN-2007-062.

2. INTRODUCTION

S&C has performed a Definitive Interconnection System Impact Re-Study in response to a request through Southwest Power Pool (SPP) Tariff. The re-study focuses on a modification to GEN-2007-062 listed in

Table 1 and twenty-nine (29) other-queued projects listed in Table 2.

Table 1: Generation Interconnection Request

Project	Size (MW)	Generator Model	Generator Bus(es)	Point of Interconnection (POI)	POI Bus
GEN-2007-062	765	GE 2.4 MW, Vestas V100 2.0 MW, Vestas V117 3.3 MW	585413,585414, 585417,585418, 585423,585426, 585433,585436, 585443,585446	Woodward 345 kV	515375

Table 2: Other-Queued Projects

Request	Size (MW)	Generator Model	Point of Interconnection
GEN-2001-014	94.5	Suzlon 2.1 MW	Fort Supply 138 kV (520920)
GEN-2001-037	102	GE 1.5 MW	Moorland – Woodward 138 kV (515785)
GEN-2005-008	120	GE 1.5 MW	Woodward 138 kV (514785)
GEN-2006-024S	18.9	Suzlon 2.1 MW	Buffalo Bear 69 kV (521120)
GEN-2006-046	132	Mitsubishi 2.4 MW	Dewey 138 kV (514787)
GEN-2007-021	200	GE 1.6 MW	Tatonga 345 kV (515407)
GEN-2007-043	200	GE 1.6 MW	Minco 345 kV (514801)
GEN-2007-044	299.2	GE 1.6 MW	Tatonga 345 kV (515407)
GEN-2007-050	170.2	Siemens 2.3 MW	Woodward 138 kV (515376)
GEN-2008-003	101.2	Siemens 2.3 MW	Woodward 138 kV (515376)
GEN-2008-044	197.8	Siemens SWT 2.3 MW	Tatonga 345 kV (515407)
GEN-2010-011	29.7	Siemens SWT 2.3 MW	Tatonga 345 kV (515407) (Addition to Gen-2008-044 34.5 kV bus (515450)
GEN-2010-040	298.5	RePower 2.05 MW	Cimarron 345 kV (514901)
GEN-2011-010	100.8	GE 1.6 MW	Minco 345 kV (514801)
GEN-2011-051	104.4	Vestas V90 1.8 MW	Tap on the Woodward - Tatonga 345kV line (G11_051-TAP, 562075)
GEN-2011-054	298	Vestas V100 2.0 MW	Cimarron 345 kV (514901)
GEN-2014-002	10.53 increase (Pmax=209.4)	GE 97.4m 1.79 MW (579256)	Tatonga 345 kV (515407)
GEN-2014-003	15.84 increase (Pmax=315)	GE 97.4m 1.79 MW (579271,579275)	Tatonga 345 kV (515407)
GEN-2014-005	5.67 increase (Pmax=106.5)	GE 97.4m 1.79 MW (514113)	Minco 345 kV (514801)
GEN-2014-020	100.0	Vestas V110 2.0 MW	Tuttle 138 kV (511501)

GEN-2014-056	250.0	GE 2.0 MW	Minco 345 kV (514801)
GEN-2015-029	161.0	GE 2.3 MW	Tatonga 345 kV (515407)
GEN-2015-048	200	Vestas V110 (wind)	Cleo Corner 138 kV (514778)
GEN-2015-057	100	G.E. 2.3 MW (wind)	Minco 345 kV (514801)
GEN-2015-059	6.3	G.E. 1.79 MW (wind)	Minco 345 kV (514801)
GEN-2015-060	250	G.E. 1.79 MW (wind)	Woodward EHV District 138 kV (515376)
GEN-2015-081	180	Vestas V110 (wind)	Tap on the Woodward - Tatonga 345 kV line (G11_051-TAP, 562075)
GEN-2015-093	250	G.E. 2 MW (wind)	Gracemont 345 kV (515800)
GEN-2015-095	176	Vestas V110 (wind)	Tap on Mooreland-Noel Switch 138 kV (560066)

3. Transmission System and Study Area

The GEN-2007-062 interconnection request will interconnect into Oklahoma Gas & Electric (OKGE, Area #524). In addition to Area #524, the following areas were monitored also:

- American Electric Power West (AEPW, Area #520)
- Western Farmers Electric Cooperative (WFEC, Area #525)
- Southwestern Public Service (SPS, Area #526)
- Midwest Energy (MIDW, Area #531)
- Sunflower Electric Power Corporation (SUNC, Area #534)
- Westar Energy, Inc. (WERE, Area #536)

4. Power Flow Base Cases

GEN-2007-062 and other other-queued projects were modeled as aggregated generating units in the base cases from SPP.

Base Case Scenarios

- **MDWG15-16WP_DIS15021_G01.sav** – 2016 Winter Peak Base Case for Group 1. GEN-2007-062 and other-queued projects at 100% output power.
- **MDWG15-17SP_DIS15021_G01.sav** – 2017 Summer Peak Base Case for Group 1. GEN-2007-062 and other-queued projects at 100% output power.
- **MDWG15-25SP_DIS15021_G01.sav** – 2025 Summer Peak Base Case for Group 1. GEN-2007-062 and other-queued projects at 100% output power.

5. Power Flow Model

SPP's base case power flow models were built in PSS/E 32.2.1. In PSS/E of the same version, S&C created a one-line diagram depicted in Figure 1 for GEN-2007-062.

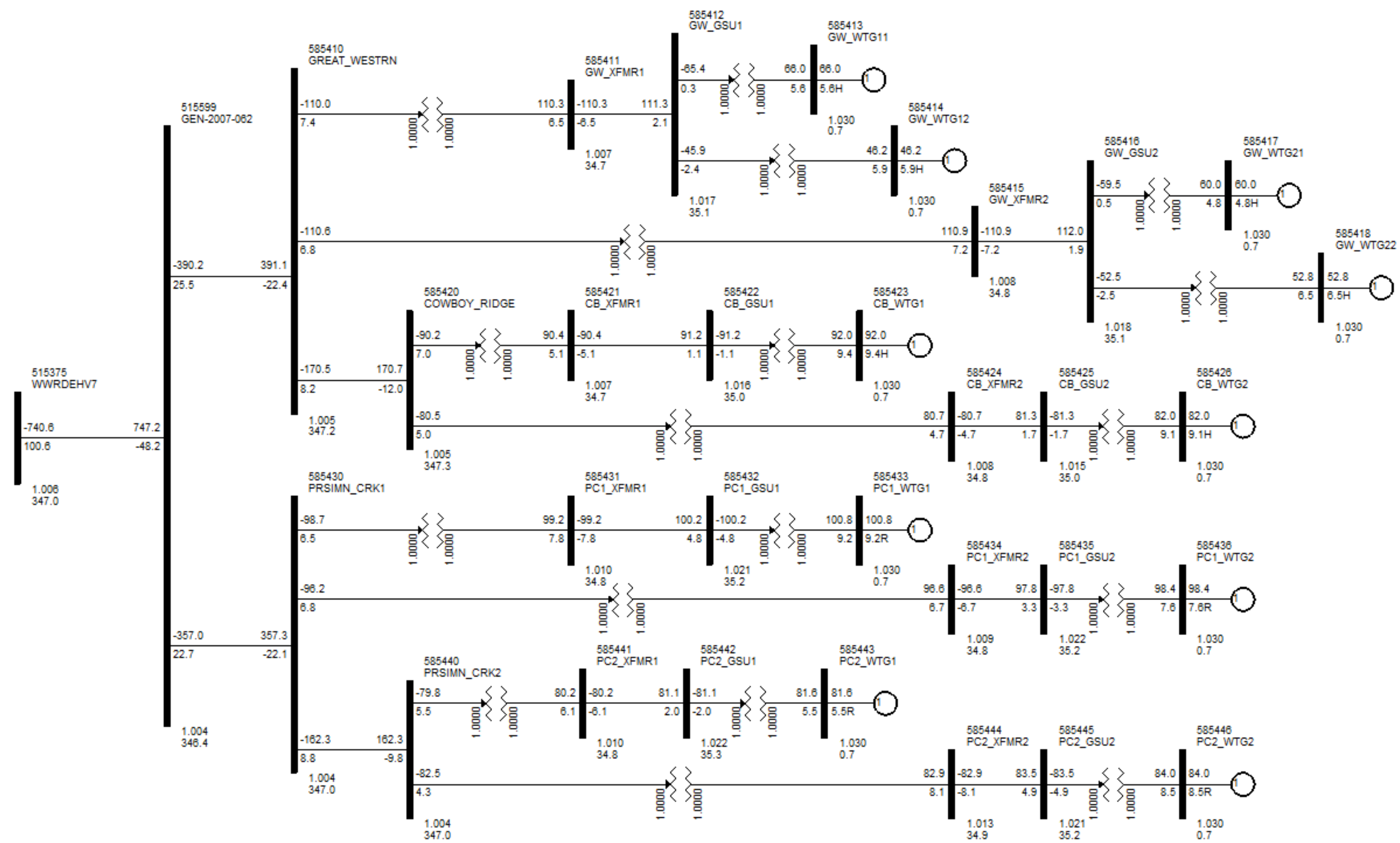

Figure 1: One-line Diagram of GEN-2007-062

6. Dynamic Stability Analysis

6.1. Assumptions

Dynamic stability analysis was performed for all the SPP contingencies listed in Appendix A. Three-phase faults were simulated as bolted faults, while single line-to-ground faults were simulated under the assumption that a single line-to-ground fault will cause a 60% drop in the positive-sequence voltage at the fault location.

6.2. Stability Criteria

A dynamic stability study was performed to ensure system stability following critical faults on the system. The system is considered stable if the following conditions are met:

(1) Disturbances including three-phase and single-phase to ground faults, should not cause synchronous and asynchronous plants to disconnect from the transmission grid.

(2) The angular positions of synchronous machine rotor become constant following an aperiodic system disturbance.

(3) Voltage magnitudes and frequencies at terminals of asynchronous generators should not exceed magnitudes and durations that will cause protection elements to operate. Furthermore, the response after the disturbance needs to be studied at the terminals of the machine to ensure that there are no sustained oscillations in power output, speed, frequency, etc.

(4) Voltage magnitudes and angles after the disturbance should settle to a constant and acceptable operating level. Frequencies should settle to the acceptable range within nominal 60 Hz power frequency.

In addition, performance of the transmission system is measured against the SPP Disturbance Criteria Requirements on Angular oscillations and Transient Voltage Recovery, detailed in Appendix B.

6.3. Dynamic Stability Results

Table 3 below summarizes the dynamic stability results for each contingency and each season.

Table 3: Group 1 Dynamic Stability Results
(YES = STABLE, NO = UNSTABLE, '-' Not applicable)

Cont. No.	Cont. Name	16WP	17SP	25SP
1	FLT01-3PH	-	-	-
2	FLT02-3PH	-	-	-
3	FLT03-3PH	-	-	-
4	FLT04-3PH	-	-	-
5	FLT05-3PH 2025SP Only	-	-	-
6	FLT06-3PH	-	-	-
7	FLT07-3PH	-	-	-
8	FLT08-3PH	-	-	-
9	FLT09-3PH	-	-	-
10	FLT10-3PH	-	-	-
11	FLT11-3PH	-	-	-
12	FLT12-3PH	-	-	-
13	FLT13-3PH	-	-	-
14	FLT14-3PH	-	-	-
15	FLT15-3PH 2025SP Only	-	-	-
16	FLT16-3PH	-	-	-
17	FLT17-3PH	-	-	-
18	FLT18-3PH	-	-	-
19	FLT19-3PH	-	-	-
20	FLT20-3PH	-	-	-
21	FLT21-3PH	-	-	-
22	FLT22-SB	-	-	-
23	FLT23-SB	-	-	-
24	FLT24-PO	-	-	-
25	FLT25-PO	-	-	-
26	FLT26-PO	-	-	-
27	FLT27-3PH	-	-	-
28	FLT28-3PH 2025SP Only	-	-	-
29	FLT29-3PH	-	-	-
30	FLT30-SB	-	-	-
31	FLT31-SB	-	-	-
32	FLT32-PO	-	-	-
33	FLT33-3PH	-	-	-
34	FLT34-3PH	-	-	-
35	FLT35-3PH	-	-	-

Cont. No.	Cont. Name	16WP	17SP	25SP
36	FLT36-3PH	-	-	-
37	FLT37-3PH	-	-	-
38	FLT38-3PH	-	-	-
39	FLT39-3PH	-	-	-
40	FLT40-PO	-	-	-
41	FLT41-PO	-	-	-
42	FLT42-3PH	YES	YES	YES[1]
43	FLT43-3PH	YES	YES	YES [1]
44	FLT44-3PH	YES	YES	YES [1]
45	FLT45-3PH	YES	YES	YES [1]
46	FLT46-3PH	YES	YES	YES [1]
47	FLT47-3PH	YES	YES	YES [1]
48	FLT48-3PH	YES	YES	YES [1]
49	FLT49-3PH	YES	YES	YES [1]
50	FLT50-3PH	-	-	-
51	FLT51-3PH	-	-	-
52	FLT52-3PH	-	-	-
53	FLT53-SB	YES	YES	YES [1]
54	FLT54-SB	YES	YES	YES [1]
55	FLT55-PO	YES	YES	YES [1]
56	FLT56-PO	-	-	-
57	FLT57-3PH	YES	YES	YES [1]
58	FLT58-3PH 2025SP Only	-	-	YES [1]
59	FLT59-3PH 2025SP Only	-	-	YES [1]
60	FLT60-3PH 2025SP Only	-	-	YES [1]
61	FLT61-SB 2025SP Only	-	-	YES [1]
62	FLT62-PO 2025SP Only	-	-	YES [1]
63	FLT63-3PH	-	-	-
64	FLT64-3PH	-	-	-
65	FLT65-3PH	-	-	-
66	FLT66-3PH	-	-	-
67	FLT67-3PH	-	-	-
68	FLT68-3PH	-	-	-
69	FLT69-3PH	-	-	-
70	FLT70-3PH	-	-	-
71	FLT71-3PH	-	-	-
72	FLT72-3PH	-	-	-

[1] Machine power kept at P=200 MW and reactive power set to Q=40 Mvar at Bus #584893 (Other-Queued Proj. GEN-2015-048)

Cont. No.	Cont. Name	16WP	17SP	25SP
73	FLT73-3PH	-	-	-
74	FLT74-3PH	-	-	-
75	FLT75-3PH	-	-	-
76	FLT76-3PH	-	-	-
77	FLT77-3PH	-	-	-
78	FLT78-3PH	-	-	-
79	FLT79-3PH	-	-	-
80	FLT80-3PH	-	-	-
81	FLT81-SB	-	-	-
82	FLT82-SB	-	-	-
83	FLT83-SB	-	-	-
84	FLT84-SB	-	-	-
85	FLT85-SB	-	-	-
86	FLT86-SB	-	-	-
87	FLT87-SB	-	-	-
88	FLT88-SB	-	-	-
89	FLT89-SB	-	-	-
90	FLT90-3PH	YES	YES	YES [1]
91	FLT91-3PH	YES	YES	YES [1]
92	FLT92-3PH	YES	YES	YES [1]
93	FLT93-3PH	YES	YES	YES [1]
94	FLT94-3PH	YES	YES	YES [1]
95	FLT95-3PH	YES	YES	YES [1]
96	FLT96-3PH	YES	YES	YES [1]

Considering the results in the table above, stability analysis thus concluded that GEN-2007-062 is expected to successfully ride-through all contingencies specified by SPP. Additionally, the project wind farm was found to stay connected during the contingencies that were studied and, therefore, will meet the LVRT requirements of FERC Order #661A. Detailed plots of dynamic stability results for each contingency and each peak season, are given in Appendix C.

7. Power Factor Analysis

The power factor analysis was performed for all N-1 three-phase contingencies shown in the Fault Definition table in Appendix A. Single-phase contingencies, N-1-1 contingencies and N-2 contingencies were excluded from the study. Prior to the run, the base cases were altered, by turning off the reactive capability of GEN-2007-062 and by placing a new var generator at the project's high voltage bus for supporting the reactive power. The var generator was set to hold the voltage schedule at GEN-2007-062 consistent with the voltage schedules in the provided base case or 1.0 p.u. voltage (whichever is higher).

Table 4 gives the voltage schedule for GEN-2007-062 in the original base cases.

Table 4: Base Case Voltages at the GEN-2007-062 POI Bus

Request	POI	2016 Winter Peak (p.u.)	2017 Summer Peak (p.u.)	2025 Summer Peak (p.u.)
GEN-2007-062	515375	1.006	1.001	1.010

The power factor analysis results for GEN-2007-062 for each N-1 three phase contingency are presented in Appendix D. Any contingencies at which the required power factor at the POI is beyond the normal required capability (from 0.95 lagging to 0.95 leading), are marked in pink. A summary of the maximum reactive power demand values at the POI are provided in Table 5. The power factor requirement for GEN-2007-062 is considered to be 0.95 lagging to 0.95 leading at the POI.

Table 5: Summary of Power Factor Analysis at the POI

Request	Capacity	POI	Reactive Power/Power Factor at POI	
			Leading (absorbing vars / power factor)	Lagging (providing vars / power factor)
GEN-2007-062	765 MW	515375	-167.0 Mvar / 0.98	12.5 Mvar / 1.00

NOTE: Per the SPP Tariff as reactive power is required for all projects, the final requirement in the GIA will be the pro-forma 95% lagging to 95% leading at the point of interconnection.

8. Low Wind/No Wind Conditions Analysis

S&C has performed an analysis of low wind conditions for GEN-2007-062. The low wind analysis was performed by taking GEN-2007-062 out of service and placing a shunt reactor at the project substation high side bus to offset the reactive power that comes from the capacitance of the project's transmission lines and collector cables. The size of the shunt reactor was adjusted such that the net Mvar flow into the POI from GEN-2007-062 was approximately zero. Table 6 gives the shunt reactor Mvars for GEN-2007-062.

Table 6: Shunt Reactor Mvar Determined by Low Wind/No Wind Study

Request	POI	2016 Winter Peak	2017 Summer Peak	2025 Summer Peak
GEN-2007-062	515375	56.8 Mvar	56.8 Mvar	56.8 Mvar

9. Short-Circuit Study

A short-circuit study has been performed on the power flow models for the 2017 Summer Peak and 2025 Summer Peak Seasons. Short-circuit analysis includes applying a 3-phase fault on buses up to 5 levels away from the POI of GEN-2007-062. PSS/E "Automatic Sequence Fault Calculation (ASCC)" fault analysis module was used for the purpose of short-circuit analysis. The results of the short-circuit analysis have been recorded for all the buses up to five levels away from the point of interconnection of GEN-2007-062. Detailed results of the short-circuit study are provided in Appendix E.

10. Conclusions and Recommendations

With the adjustments mentioned in Section 6, Group 1's dynamic results indicated that GEN-2007-062 is expected to successfully ride through all N-1 and N-2 fault contingencies specified by SPP, retaining angular, frequency and voltage stability at the nearby areas and meeting the transient voltage recovery requirement by SPP. It is thus concluded that GEN-2007-062 is expected to successfully interconnect into the transmission system at its desired location for 100% power output. Additionally, the project wind farm was found to stay connected during the contingencies that were studied and, therefore, will meet the Low Voltage Ride Through (LVRT) requirements of FERC Order #661A.

The results of power factor analysis indicate that GEN-2007-062 is required to maintain a power factor of 0.95 lagging to 0.95 leading at the POI to meet SPP's requirements.

The low wind study suggested that to offset the reactive power from the capacitance of the project's transmission lines and collector cables during the low wind conditions, the GEN-2007-062 project requires a 56.8 Mvar shunt reactor.

A short-circuit study has been performed on the power flow models for the 2017 Summer Peak Season and 2025 Summer Peak Season. A 3-phase fault was applied on buses up to 5 levels away from the POI of GEN-2007-062 and the results of the study have been presented.

Appendix A

SPP Group 1 Fault Definitions (Submitted in a Separate File)

Appendix B

Southwest Power Pool Disturbance Performance Requirements (Submitted in a Separate File)

APPENDIX C

DYNAMIC STABILITY PLOTS (SUBMITTED IN SEPARATE FILES FROM APPENDIX C-1 TO C-3)

C-1 Group 1 Dynamic Stability Plots For 2016 Winter Peak Case

C-2 Group 1 Dynamic Stability Plots For 2017 Summer Peak Case

C-3 Group 1 Dynamic Stability Plots For 2025 Summer Peak Case

Each contingency consists of (49) subplots:

- Subplot #1 shows the system phase angle channels
- Subplot #2 to Subplot #43 are results for (42) generators in the scope of study.
- Subplots #44 to Subplot #46 are voltages at the POI buses in the scope of study.
- Subplots #47 to Subplot #49 are frequencies at the POI buses in the scope of study.

APPENDIX D

POWER FACTOR ANALYSIS RESULTS (SUBMITTED IN A SEPARATE FILE)

APPENDIX E

SHORT-CIRCUIT STUDY RESULTS (SUBMITTED IN A SEPARATE FILE FROM APPENDIX E-1 TO E-2)

E-1 17SP Short-Circuit Study Results

E-2 25SP Short-Circuit Study Results