Southwest Power Pool

Impact Re-Study For Generation Interconnection Request GEN-2007-025 & GEN-2010-005

SPP Generation Interconnection

(GEN-2007-025 & GEN-2010-005)

September 2011

Executive Summary

Pursuant to the Southwest Power Pool (SPP) Open Access Transmission Tariff (OATT), Excel Engineering, Inc. (Excel) performed the following Impact Restudy to satisfy the Impact Study Agreement executed by the requesting Customer and SPP Generation Interconnection requests GEN-2007-025 and GEN-2010-005. Both GEN-2007-025 and GEN-2010-005 were originally studied with Clipper 2.5 MW wind turbines at a capacity of 300 MW each. The customer has subsequently requested a restudy assuming both facilities (GEN-2007-025 and GEN-2010-005) will contain GE 1.6MW wind turbines at a capacity of 299.2 MW each in this restudy.

This impact restudy addresses the dynamic stability effects of interconnecting the two facilities on the transmission system as a result of changing the wind turbine generator vendor. The stability study results show that with the customer requested GE wind turbines the transmission system remains stable for all simulated contingencies studied. In addition, consistent with Order #661A, the facility will be required to maintain a 95% lagging (providing vars) and 95% leading (absorbing vars) power factor at the point of interconnection.

If the customer changes the manufacturer or type of wind turbines from the GE 1.6 MW, a new impact study will be required.

The Interconnection Agreements for GEN-2007-025 and GEN-2010-005 will need to be modified to reflect the results of this study.

Nothing in this study should be construed as a guarantee of transmission service. If the customer wishes to sell power from the facility, a separate request for transmission service shall be requested on Southwest Power Pool’s OASIS by the Customer.

SPP GEN-2007-025 and GEN-2010-005 Impact Restudy

Final Report for

Southwest Power Pool

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September 13, 2011

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0. Certification

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the Laws of the State of **Kansas**.

William Quaintance
Kansas License Number: 20756

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1. Background and Scope

The GEN-2007-025_2010-005 Impact Restudy is a generation interconnection study performed by Excel Engineering, Inc. for its non-affiliated client, Southwest Power Pool (SPP). Its purpose is to study the impacts of interconnecting the projects shown in Table 1-1. The in-service date assumed for the generation addition was 2011.

Table 1-1. Interconnection Requests Evaluated in this Study

Request	Size (MW)	Generator Model	Point of Interconnection	POI Bus	Gen Bus
GEN-2007-025	300	GE 1.6MW	Wichita-Woodring 345kV	532781	1251 1252
GEN-2010-005	300	GE 1.6MW	Wichita-Woodring 345kV	532781	576100 576110

The concurrent requests shown in Table 1-2 and the prior-queued requests shown in Table 1-3 were included in this study and dispatched at 100% of rated capacity.

The study included stability analysis of each proposed interconnection request. Contingencies that resulted in a prior-queued project tripping off-line, if any, were re-run with the prior-queued project's voltage and frequency tripping disabled. A power factor analysis was performed for the wind farms in Table 1-1.

ATC (Available Transfer Capability) studies were not performed as part of this study. These studies will be required at the time transmission service is actually requested. Additional transmission upgrades may be required based on that analysis.

Study assumptions in general have been based on Excel's knowledge of the electric power system and on the specific information and data provided by SPP. The accuracy of the conclusions contained within this study is sensitive to the assumptions made with respect to generation additions and transmission improvements being contemplated. Changes in the assumptions of the timing of other generation additions or transmission improvements will affect this study's conclusions.

Table 1-2. Nearby Interconnection Requests Concurrent with Study Generation

Request	Size (MW)	Generator Model	Point of Interconnection	POI Bus	Gen Bus
GEN-2008-071	76.8	GE 1.6MW	Newkirk 138kV	577003	577000
GEN-2008-098	100.8	Vestas V90 1.8MW	Wolf Creek– LaCygne 345kV	572091	572094
GEN-2010-003	100.8	Vestas V90 1.8MW	Gen-2008-098 addition	572090	577200

Table 1-3. Nearby Interconnection Requests Already in the Queue

Request	Size (MW)	Generator Model	Point of Interconnection	POI Bus	Gen Bus
GEN-2002-004	199.5	GE 1.5MW	Latham 345kV (ELKRVR-547501)	547501	547504 547505
GEN-2005-013	199.8	Vestas V90 1.8MW	Latham – Neosho 345kV	574000	574004
GEN-2008-013	300	GE 1.5MW	Wichita – Woodring 345kV	210130	1131 1132 1133
GEN-2008-021	1250	Nuclear Steam Turbine	Wolf Creek 345kV (532751)	532797	532751
GEN-2008-127	200.1	Siemens 2.3MW	Sooner – Rose Hill 345kV	573039	573033 573036
GEN-2009-025	59.4	Vestas V90 1.8MW	Deerck – Sincblk2 69kV	573049	573053

2. Executive Summary

The GEN-2007-025_2010-005 Impact Restudy evaluated the impacts of interconnecting the Table 1-1 study projects to the SPP transmission system.

No stability problems were found during summer or winter peak conditions due to the addition of these generators.

Final power factor requirements for the study projects are listed in Table 4-2.

With the assumptions described in this report, the study projects should be able to connect without causing any stability problems on the SPP transmission grid.

Any change in system or wind farm models or assumptions could change these results.

3. Study Development and Assumptions

3.1 Simulation Tools

The Siemens Power Technologies, Inc. PSS/E power system simulation program Version 30.3.3 was used in this study.

3.2 Models Used

SPP provided its latest stability database cases for both summer and winter peak seasons.

The model included the study and prior-queued projects.

Power flow one-line diagrams of the study projects in summer peak conditions are shown in Figure 3-1. As the figure shows, each wind farm model includes explicit representation of the radial transmission line, if any; the substation transformer(s) from transmission voltage to 34.5kV; and the substation reactive power device(s), if any. The remainder of each wind farm is represented by one or more lumped equivalents including a generator, a step-up transformer, and a collector system impedance, if any.

Steady-state and dynamic model data for the study plants are given in Appendix D.

No special modeling is required of line relays in these cases, except for the special modeling related to the wind-turbine tripping.

3.3 Monitored Facilities

All generators and transmission buses in Areas 520, 523, 524, 525, 536, 540, and 541 were monitored.

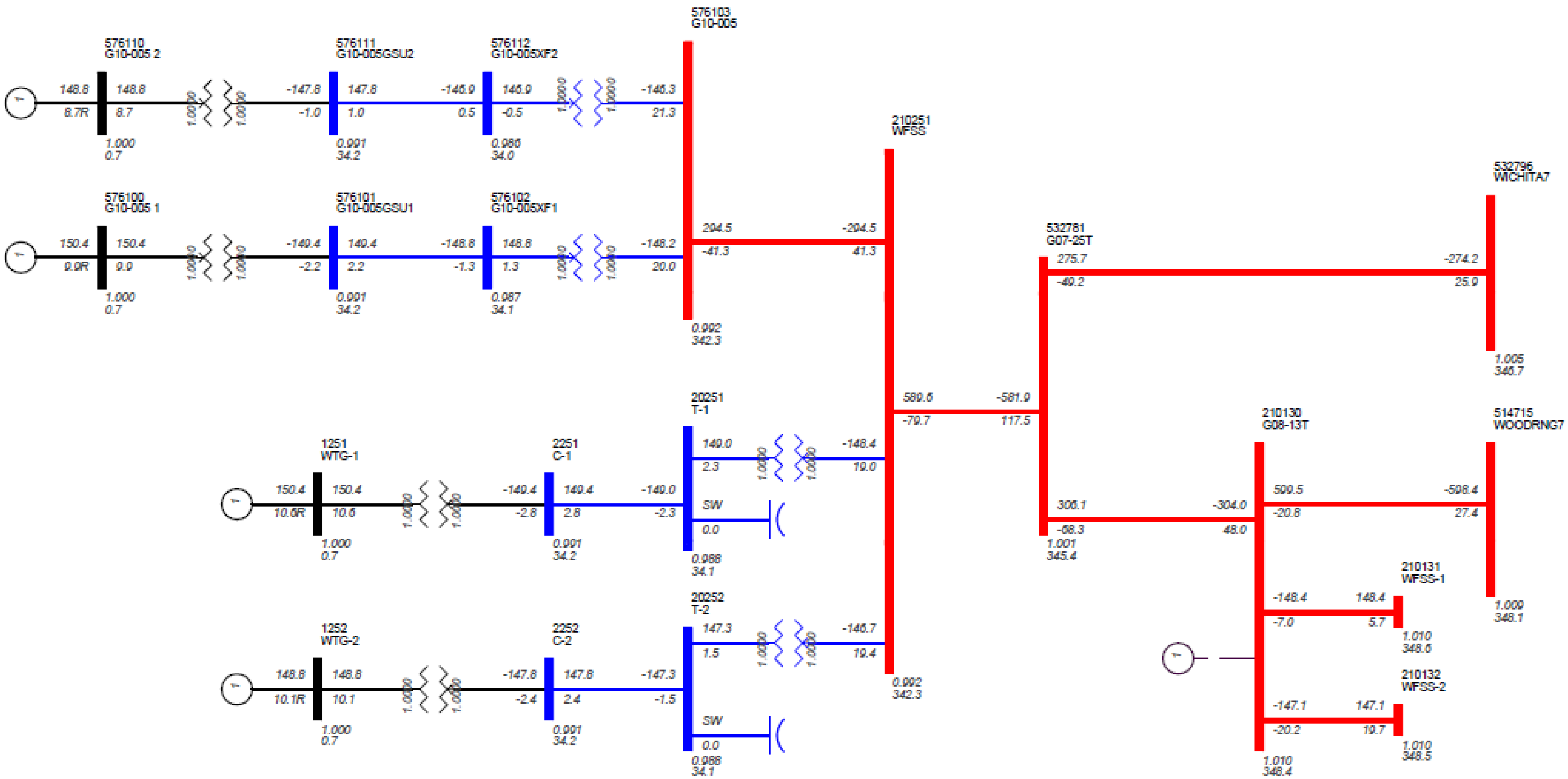

Figure 3-1. Power Flow One-line for GEN-2007-025, GEN-2010-005 and adjacent equipment

3.4 Performance Criteria

Wind generators must comply with FERC Order 661A on low voltage ride through for wind farms. Therefore, the wind generators should not trip off line for faults for under voltage relay actuation. If a wind generator trips off line, an appropriately sized SVC or STATCOM device may need to be specified to keep the wind generator on-line for the fault. SPP was consulted to determine if the addition of an SVC or STATCOM is warranted for the specific condition.

Contingencies that resulted in a prior-queued project tripping off-line, if any, were re-run with the prior-queued project's voltage and frequency tripping disabled to check for stability issues.

3.5 Performance Evaluation Methods

A power factor analysis was performed for all study projects that are wind farms. The power factor analysis consisted of modeling a var generator in each wind farm holding a voltage schedule at the POI. The voltage schedule was set to the higher of the voltage with the wind farm off-line or 1.0 per unit.

If the required power factor at the POI is beyond the capability of the studied wind turbines, then capacitor banks would be considered for the stability analysis. Factors used in sizing capacitor banks would include two requirements of FERC Order 661A: the ability of the wind farm to ride through low voltage with and without capacitor banks and the ability of the wind farm to recover to pre-fault voltage. If a wind generator trips on high voltage, a leading power factor may be required.

ATC studies were not performed as part of this study. These studies will be required at the time transmission service is actually requested. Additional transmission facilities may be required based on subsequent ATC analysis.

Stability analysis was performed for each proposed interconnection request. Faults were simulated on transmission lines at the POIs and on other nearby transmission equipment. The faults in Table 3-1 were run for each case (three phase and single phase as noted).

Table 3-1. Fault Definitions for GEN-2007-025_2010-005 Impact Restudy

Cont. No.	Cont. Name	Description
1	FLT01-3PH	3 phase fault on the Wichita (532796) – Reno (532771) 345kV line near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line and remove the fault.
2	FLT02-1PH	Single-phase fault on the Wichita (532796) – Reno (532771) 345kV line near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles and reclose Reno 345 kV end back into the fault. d. Leave fault on for 5 cycles, then trip the line and remove the fault.
3	FLT03-3PH	3 phase fault on the Wichita (532796) – Benton (532791) 345kV line near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line and remove the fault.
4	FLT04-1PH	Single-phase fault on the Wichita (532796) – Benton (532791) 345kV line near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles and reclose Benton 345 kV end back into the fault. d. Leave fault on for 5 cycles, then trip the line and remove the fault.
5	FLT05-3PH	3 phase fault on the Wichita (532796) – Medicine Lodge (765342) 345kV ckt 1 line near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted line and remove the fault.
6	FLT06-3PH	3 phase fault on the Wichita (532796) – Medicine Lodge (765342) 345kV ckt 1&2 line near Wichita. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted lines (ckt 1&2) and remove the fault.
7	FLT07-3PH	Three phase fault on the Wichita (532796) – Evans (533040/532830) 345/139/13.8kV transformer. a. Apply fault at the Wichita 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
8	FLT08-3PH	3 phase fault on the Rose Hill (532794) to GEN-2008-127 (573039) 345kV line, near Rose Hill. a. Apply fault at the Rose Hill 345kV bus. b. Clear fault after 3.6 cycles by tripping the faulted line.
9	FLT09-1PH	Single-phase fault on the Rose Hill (532794) to GEN-2008-127 (573039) 345kV line, near GEN-Rose Hill. a. Apply fault at the Rose Hill 345kV bus. b. Clear fault after 3.6 cycles by tripping the faulted line. c. Wait 300 cycles, and then re-close the Rose Hill end of the line in (b) back into the fault. d. Leave fault on for 3.6 cycles, then trip the line in (b) and remove fault.
10	FLT10-3PH	3 phase fault on the Sooner (514803) to Woodring (514715) 345kV line, near Woodring. a. Apply fault at the Woodring 345kV bus. b. Clear fault after 3 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 3 cycles, then trip the line in (b) and remove fault.
11	FLT11-1PH	*Single phase fault and sequence like previous*
12	FLT12-3PH	3 phase fault on the Sooner (514803) to Cleveland (512694) 345kV line, near Cleveland. a. Apply fault at the Cleveland 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.
13	FLT13-1PH	*Single phase fault and sequence like previous*

Cont. No.	Cont. Name	Description
14	FLT14-3PH	3 phase fault on the Rose Hill (532794) to Latham (532800) 345kV line, near Rose Hill. a. Apply fault at the Rose Hill 345V bus. b. Clear fault after 4 cycles by tripping the faulted line and remove the fault.
15	FLT15-1PH	Single-phase fault on the Rose Hill (532794) to Latham (532800) 345kV line, near Rose Hill. a. Apply fault at the Rose Hill 345V bus. b. Clear fault after 4 cycles by tripping the faulted line. c. Wait 30 cycles, and then re-close the Rose Hill end of the line in (b) back into the fault. d. Leave fault on for 4 cycles, then trip the line in (b) and remove fault.
16	FLT16-3PH	3 phase fault on the Rose Hill (532794) to Benton (532791) 345kV line, near Rose Hill. a. Apply fault at the Rose Hill 345V bus. b. Clear fault after 4 cycles by tripping the faulted line and remove the fault.
17	FLT17-1PH	Single-phase fault on the Rose Hill (532794) to Benton (532791) 345kV line, near Rose Hill. a. Apply fault at the Rose Hill 345V bus. b. Clear fault after 4 cycles by tripping the faulted line. c. Wait 30 cycles, and then re-close the Rose Hill end of the line in (b) back into the fault. d. Leave fault on for 4 cycles, then trip the line in (b) and remove fault.
18	FLT18-3PH	Three phase fault on the Woodring (514715) – 345/230kV autotransformer. a. Apply fault at the Woodring 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
19	FLT19-3PH	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.
20	FLT20-1PH	*Single phase fault and sequence like previous*
21	FLT21-3PH	3 phase fault on the Emporia (532768) – Wichita (532796) 345kV line near Emporia. a. Apply fault at the Emporia 345kV bus. b. Clear fault after 3.6 cycles by tripping the faulted line and remove the fault.
22	FLT22-1PH	Single phase fault on the Emporia (532768) – Wichita (532796) 345kV line near Emporia. a. Apply fault at the Emporia 345kV bus. b. Clear fault after 3.6 cycles by tripping the faulted line and remove the fault. c. Wait 300 cycles and reclose d. Clear fault after 3.6 cycles
23	FLT23-3PH	3 phase fault on the Woodring (514715) to GEN-2008-013 (210130) 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.
24	FLT24-1PH	*Single phase fault and sequence like previous*
25	FLT25-3PH	3 phase fault on the GEN-2008-013 (210130) to GEN-2007-025 (532781) 345kV line, near GEN-2007-025. a. Apply fault at the GEN-2007-025 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.
26	FLT26-1PH	*Single phase fault and sequence like previous*

Cont. No.	Cont. Name	Description
27	FLT27-3PH	3 phase fault on the Woodring (514715) to Cimarron (514901) 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.
28	FLT28-1PH	Single phase fault and sequence like previous
29	FLT29-3PH	3 phase fault on the Wichita (532796) to GEN-2007-025 (532781) 345kV line, near GEN-2007-025. a. Apply fault at the GEN-2007-025 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.
30	FLT30-1PH	Single phase fault and sequence like previous

4. Results and Observations

4.1 Stability Analysis Results

Table 4-1 summarizes the results. Figure 4-1 through Figure 4-3 show representative summer peak season plots for faults at the POI's of the study projects. Complete sets of plots for both summer and winter peak seasons for each fault and each project are included in Appendices A and B.

Table 4-1. Summary of Stability Results

Cont. No.	Cont. Name	Description	Summer Peak Results	Winter Peak Results
1	FLT01-3PH	3 phase fault on the Wichita (532796) – Reno (532771) 345kV line near Wichita.	OK	OK
2	FLT02-1PH	Single-phase fault on the Wichita (532796) – Reno (532771) 345kV line near Wichita.	OK	OK
3	FLT03-3PH	3 phase fault on the Wichita (532796) – Benton (532791) 345kV line near Wichita.	OK	OK
4	FLT04-1PH	Single-phase fault on the Wichita (532796) – Benton (532791) 345kV line near Wichita.	OK	OK
5	FLT05-3PH	3 phase fault on the Wichita (532796) – Medicine Lodge (765342) 345kV ckt 1 line near Wichita.	OK	OK
6	FLT06-3PH	3 phase fault on the Wichita (532796) – Medicine Lodge (765342) 345kV ckt 1&2 line near Wichita.	OK	OK
7	FLT07-3PH	Three phase fault on the Wichita (532796) – Evans (533040/532830) 345/139/13.8kV transformer.	OK	OK
8	FLT08-3PH	3 phase fault on the Rose Hill (532794) to GEN-2008-127 (573039) 345kV line, near Rose Hill.	OK	OK
9	FLT09-1PH	Single-phase fault on the Rose Hill (532794) to GEN-2008-127 (573039) 345kV line, near GEN-Rose Hill.	OK	OK
10	FLT10-3PH	3 phase fault on the Sooner (514803) to Woodring (514715) 345kV line, near Woodring.	OK	OK
11	FLT11-1PH	Single phase fault and sequence like previous	OK	OK
12	FLT12-3PH	3 phase fault on the Sooner (514803) to Cleveland (512694) 345kV line, near Cleveland.	OK	OK
13	FLT13-1PH	Single phase fault and sequence like previous	OK	OK
14	FLT14-3PH	3 phase fault on the Rose Hill (532794) to Latham (532800) 345kV line, near Rose Hill.	OK	OK
15	FLT15-1PH	Single-phase fault on the Rose Hill (532794) to Latham (532800) 345kV line, near Rose Hill.	OK	OK
16	FLT16-3PH	3 phase fault on the Rose Hill (532794) to Benton (532791) 345kV line, near Rose Hill.	OK	OK
17	FLT17-1PH	Single-phase fault on the Rose Hill (532794) to Benton (532791) 345kV line, near Rose Hill.	OK	OK
18	FLT18-3PH	Three phase fault on the Woodring (514715) – 345/138kV autotransformer.	OK	OK

Cont. No.	Cont. Name	Description	Summer Peak Results	Winter Peak Results
19	FLT19-3PH	3 phase fault on the Sooner (514803) to Spring Creek (514881) 345kV line, near Sooner.	OK	OK
20	FLT20-1PH	Single phase fault and sequence like previous	OK	OK
21	FLT21-3PH	3 phase fault on the Emporia (532768) – Wichita (532796) 345kV line near Emporia.	OK	OK
22	FLT22-1PH	Single phase fault on the Emporia (532768) – Wichita (532796) 345kV line near Emporia.	OK	OK
23	FLT23-3PH	3 phase fault on the Woodring (514715) to GEN-2008-013 (210130) 345kV line, near Woodring.	OK	OK
24	FLT24-1PH	Single phase fault and sequence like previous	OK	OK
25	FLT25-3PH	3 phase fault on the GEN-2008-013 (210130) to GEN-2007-025 (532781) 345kV line, near GEN-2007-025.	OK	OK
26	FLT26-1PH	Single phase fault and sequence like previous	OK	OK
27	FLT27-3PH	3 phase fault on the Woodring (514715) to Cimarron (514901) 345kV line, near Woodring.	OK	OK
28	FLT28-1PH	Single phase fault and sequence like previous	OK	OK
29	FLT29-3PH	3 phase fault on the Wichita (532796) to GEN-2007-025 (532781) 345kV line, near GEN-2007-025.	OK	OK
30	FLT30-1PH	Single phase fault and sequence like previous	OK	OK

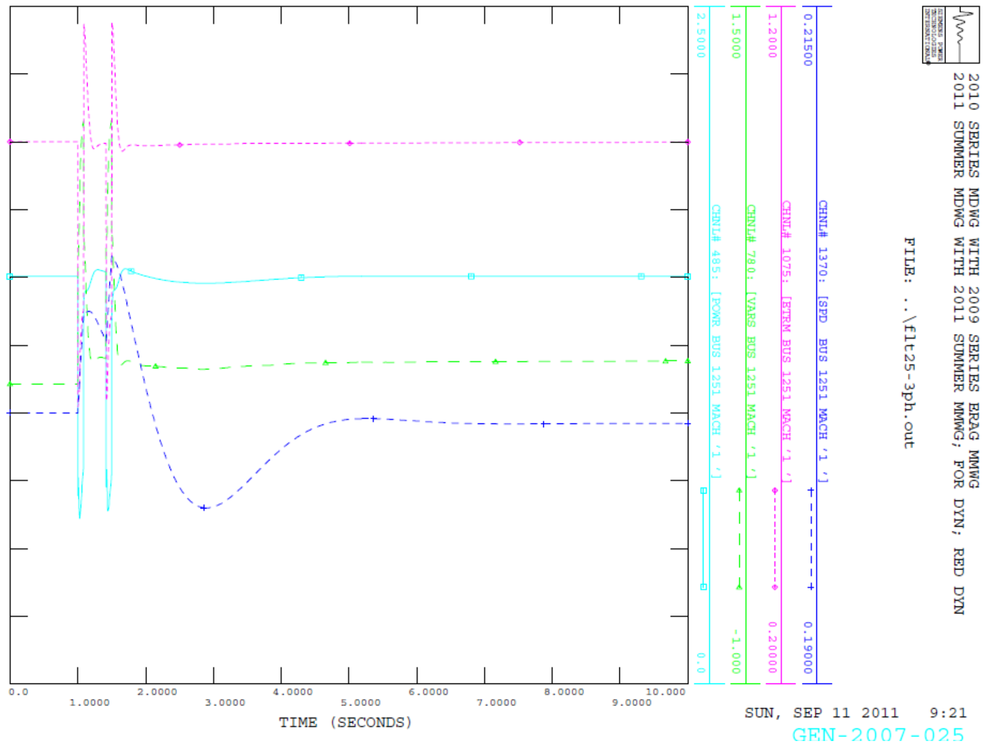

Figure 4-1. GEN-2007-025 Plot for Fault 25 – 3-Phase fault on the G08-013 Tap to G07-025 Tap 345kV line, near G07-025 Tap

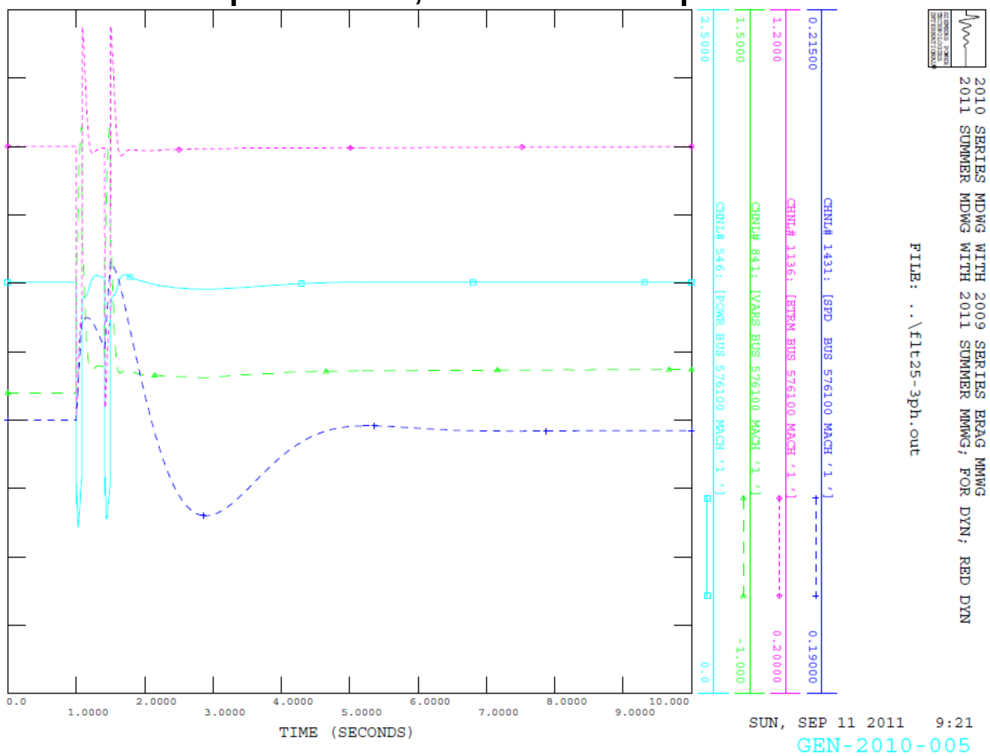

Figure 4-2. GEN-2010-005 Plot for Fault 25 – 3-Phase fault on the G08-013 Tap to G07-025 Tap 345kV line, near G07-025 Tap

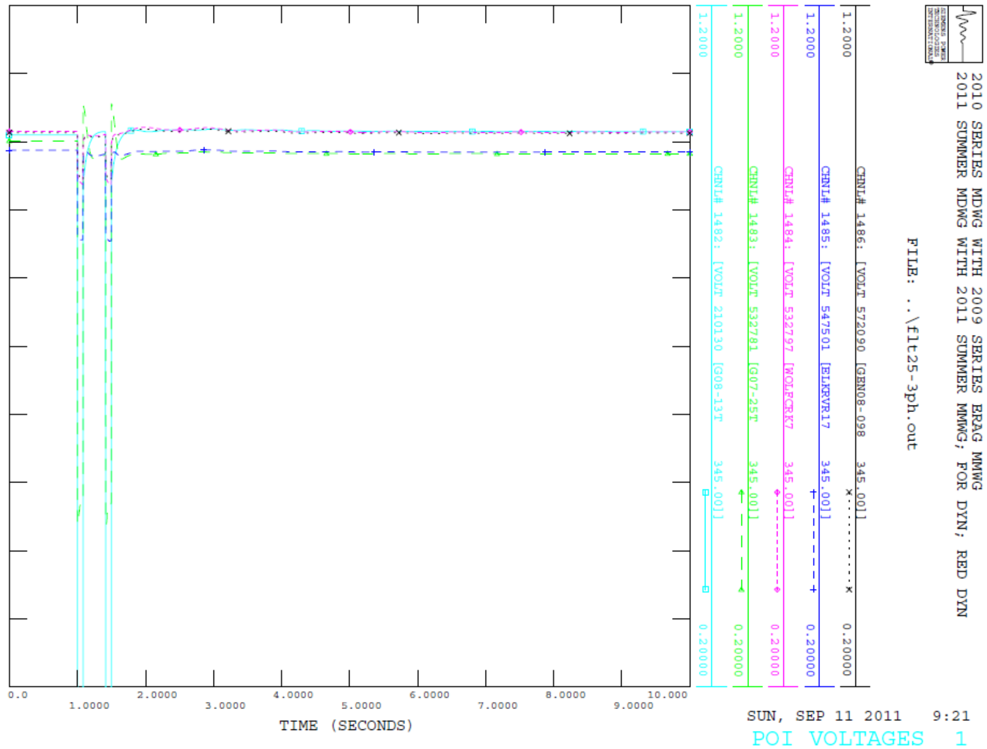

Figure 4-3. POI Voltages for Fault 25 – 3-Phase fault on the G08-013 Tap to G07-025 Tap 345kV line, near G07-025 Tap

4.2 Power Factor Requirements

All stability faults were tested as power flow contingencies to determine the power factor requirements for the wind farm study projects to maintain scheduled voltage at their respective points of interconnection (POI). The voltage schedules are set equal to the voltages at the POIs before the projects are added, with a minimum of 1.0 per unit. Fictitious reactive power sources were added to the study projects to maintain scheduled voltage during all studied contingencies. The MW and Mvar injections from the study projects at the POIs were recorded and the resulting power factors were calculated for all contingencies for summer peak and winter peak cases. The most leading and most lagging power factors determine the minimum power factor range capability that the study projects must install before commercial operation.

Because these study projects share a single POI, the projects were grouped together and a common power factor requirement was determined for those study projects. This ensures that none of the study projects is required to provide more or less than its fair share of the reactive power requirements at a single POI.

Per FERC and SPP Tariff requirements, if the power factor needed to maintain scheduled voltage is less than 0.95 lagging, then the requirement is limited to 0.95 lagging. The lower limit for leading power factor requirement is also 0.95. If a project never operated leading under any contingency, then the leading requirement is set to 1.0. The same applies on the lagging side.

The final power factor requirements are shown in Table 4-2 below. These are only the minimum power factor ranges based on steady-state analysis.

The full details for each contingency in summer and winter peak cases are given in Appendix C.

Table 4-2. Power Factor Requirements [1]

Request	Size (MW)	Generator Model	Point of Interconnection	Study PF Requirement at the POI	
				Lagging [2]	Leading [3]
GEN-2007-025	300	GE 1.6MW	Wichita-Woodring 345kV	0.990	0.992
GEN-2010-005	300	GE 1.6MW	Wichita-Woodring 345kV		

Notes:

1. For each plant, the table shows the minimum calculated power factor capability at the point of interconnection that must be designed and installed with the plant. The power factor capability at the POI includes the net effect of the generators, transformers, line impedances, and any reactive compensation devices installed on the plant side of the meter.
2. Lagging is when the generating plant is supplying reactive power to the transmission grid. In this situation, the alternating current sinusoid "lags" behind the alternating voltage sinusoid, meaning that the current peaks shortly after the voltage.
3. Leading is when the generating plant is taking reactive power from the transmission grid. In this situation, the alternating current sinusoid "leads" the alternating voltage sinusoid, meaning that the current peaks shortly before the voltage.

5. Conclusions

The GEN-2007-025_2010-005 Impact Restudy evaluated the impacts of interconnecting the projects shown below.

Table 5-1. Interconnection Requests Evaluated in this Study

Request	Size (MW)	Generator Model	Point of Interconnection	POI Bus	Gen Bus
GEN-2007-025	300	GE 1.6MW	Wichita-Woodring 345kV	532781	1251 1252
GEN-2010-005	300	GE 1.6MW	Wichita-Woodring 345kV	532781	576100 576110

No stability problems were found during summer or winter peak conditions due to the addition of these generators.

Final power factor for the study projects are listed in Table 4-2.

With the assumptions described in this report, the study projects should be able to connect without causing any stability problems on the SPP transmission grid.

Any change in system or wind farm models or assumptions could change these results.

Appendix A –Summer Peak Plots

See attachments.

Appendix B –Winter Peak Plots

See attachments.

Appendix C – Power Factor Details

See attachment.

Appendix D – Project Model Data

See attachment.