



***Impact Re-Study  
For  
Generation Interconnection  
Request  
GEN-2007-021 & GEN-2007-044***

***SPP Generation Interconnection Studies***

***(GEN-2007-021 & GEN-2007-044)***

**December 2010**

## 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-2007-021 and GEN-2007-044. Both GEN-2007-021 and GEN-2007-044 were originally studied with GE 1.5 MW wind turbines. GEN-2007-021 was originally studied at 201 MW and GEN-2007-044 was originally studied at 300 MW. The customer has subsequently requested a restudy assuming both facilities (GEN-2007-021 and GEN-2007-044) will contain GE 1.6MW wind turbines. GEN-2007-021 was studied at a capacity of 200 MW and GEN-2007-044 was studied at 299.2 MW in this restudy.

The original study posting for these generation interconnection requests can be found at: <http://sppoasis.spp.org/documents/swpp/transmission/GENInterPAGE.CFM> under “2008 Impact Studies”, cluster study number “ICT-2008-001-3” posted 8/23/2010.

The purpose of this restudy is to evaluate the Customer’s request to use the GE 1.6 MW wind turbines for the proposed generation. This study addressed the stability and reactive compensation required for the GE wind turbines. The study shows that the turbine change can be accommodated.

# SPP GEN-2007-021 and GEN-2007-044 Impact Restudy

Final Report for  
Southwest Power Pool

Prepared by:  
Excel Field Services, Inc.

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Principal Contributor:  
William Quaintance, P.E.



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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 **Oklahoma**.

William Quaintance  
Oklahoma License Number: 24320

Excel Field Services, Inc.  
Oklahoma Registration Number: 5844

## 1. Background and Scope

The GEN-2007-021 and GEN-2007-044 Impact Restudy is a generation interconnection study performed by Excel Field Services 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 2010. The study projects are located in Dewey County, Oklahoma.

**Table 1-1. Interconnection Requests to be Evaluated**

<b>Request</b>	<b>Size (MW)</b>	<b>Wind Turbine Model</b>	<b>Point of Interconnection</b>
GEN-2007-021	200.0	GE 1.6MW	Tatonga 345kV (515378)
GEN-2007-044	299.2	GE 1.6MW	Tatonga 345kV (515378)

The prior-queued requests shown in Table 1-2 were included in this study and dispatched at 100% of rated capacity. Plants marked with an asterisk (\*) were included in the stability analysis but not in the power factor analysis.

The study included stability analysis of each proposed interconnection request. A power factor analysis was performed for the requests in Table 1-1 that are wind farms.

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 Already in the Queue**

<b>Request</b>	<b>Size (MW)</b>	<b>Wind Turbine Model</b>	<b>Point of Interconnection</b>
GEN-2001-014	94.5	Suzlon 2.1MW	Fort Supply 138kV (520920)
GEN-2001-037	102.0	GE 1.5MW	Woodward-Mooreland 138kV (515785)
GEN-2002-005	118.5	Acciona 1.5MW	Moorewood – Elk City 138kV (521116)
GEN-2005-005	18.4	Siemens SWT 2.3MW	Woodward-Mooreland 138kV (515785)
GEN-2005-008	120.0	GE 1.5MW	Woodward 138kV (514785)
GEN-2006-024S	18.9	Suzlon 2.1MW	Buffalo Bear 69kV (521120)
GEN-2006-046	132.0	Mitsubishi 2.3MW	Dewey 138kV (514787)
GEN-2007-006	161.7	Suzlon 2.1MW	Roman Nose 138kV (514823)
GEN-2007-050	172.5	Siemens 2.3MW	Woodward 138kV (515376)
GEN-2007-051	199.5	GE 1.5MW	Mooreland 138kV (520999)
GEN-2007-062	765.0	GE 1.5MW	Woodward 345kV (515375)
GEN-2008-003	101.2	Siemens 2.3MW	Woodward 138kV (515376)
GEN-2008-019	300.0	Mitsubishi 2.3MW	Tatonga 345kV (515378)
GEN-2008-029	250.5	GE 1.5MW	Woodward 138kV (515376)
GEN-2008-044*	197.8	Siemens SWT 2.3MW	Tatonga 345kV (515378)
GEN-2010-008*	64.4	Vestas V90 1.8MW	Fargo Jct 69kV (521196)
GEN-2010-011*	29.7	Siemens SWT 2.3MW	Addition to Gen-2008-044 34.5kV bus (576503)

\*not included in power factor analysis



## **2. Executive Summary**

The GEN-2007-021 and GEN-2007-044 Impact Restudy evaluated the stability impacts of interconnecting project these projects to the SPP transmission system in Dewey County, Oklahoma.

Project GEN-2008-019 tripped off-line due to high voltage following a single phase fault on the Tatonga-Woodward 345 kV line (fault 10). Everything else was stable for this fault. If tripping of GEN-2008-019 is blocked, the results are also stable. If the transformer taps in GEN-2008-019 are changed by a total of 5%, then these generators do not trip and everything is stable.

No other major stability problems were found in this study. The study and prior-queued plants remain on-line and stable for all other simulated disturbances.

Power factor requirements were determined, and the study plants must install sufficient reactive power resources to meet the requirements listed in Table 4-2. The analysis indicates that GEN-2007-021 and GEN-2007-044 should be able to meet the power factor requirements with the planned collector system and GE 1.6 MW 0.9 power factor wind turbines without a need for additional reactive power compensation devices.

With the assumptions used in this study, GEN-2007-021 and GEN-2007-044 should be able to reliably connect to the SPP transmission grid.

### **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 prior-queued plant models were included in the system models provided by SPP. The models for the study plants were developed as part of this study using data provided by the requesters. Both plants will use GE 1.6 MW wind turbines with 0.90 power factor capability.

A power flow one-line diagram of the study projects is shown in Figure 3-1. Prior-queued projects at the same POI are also shown. The wind farm models include explicit representation of the radial transmission lines, the substation transformers from transmission voltage to 34.5 kV, 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. Steady-state and dynamic model data for the study plants are given in Appendix D. Figure 3-2 shows a one-line diagram of the 345 kV transmission system around Tatonga.

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, 524, 525, 526, 531, 534, and 536 were monitored.

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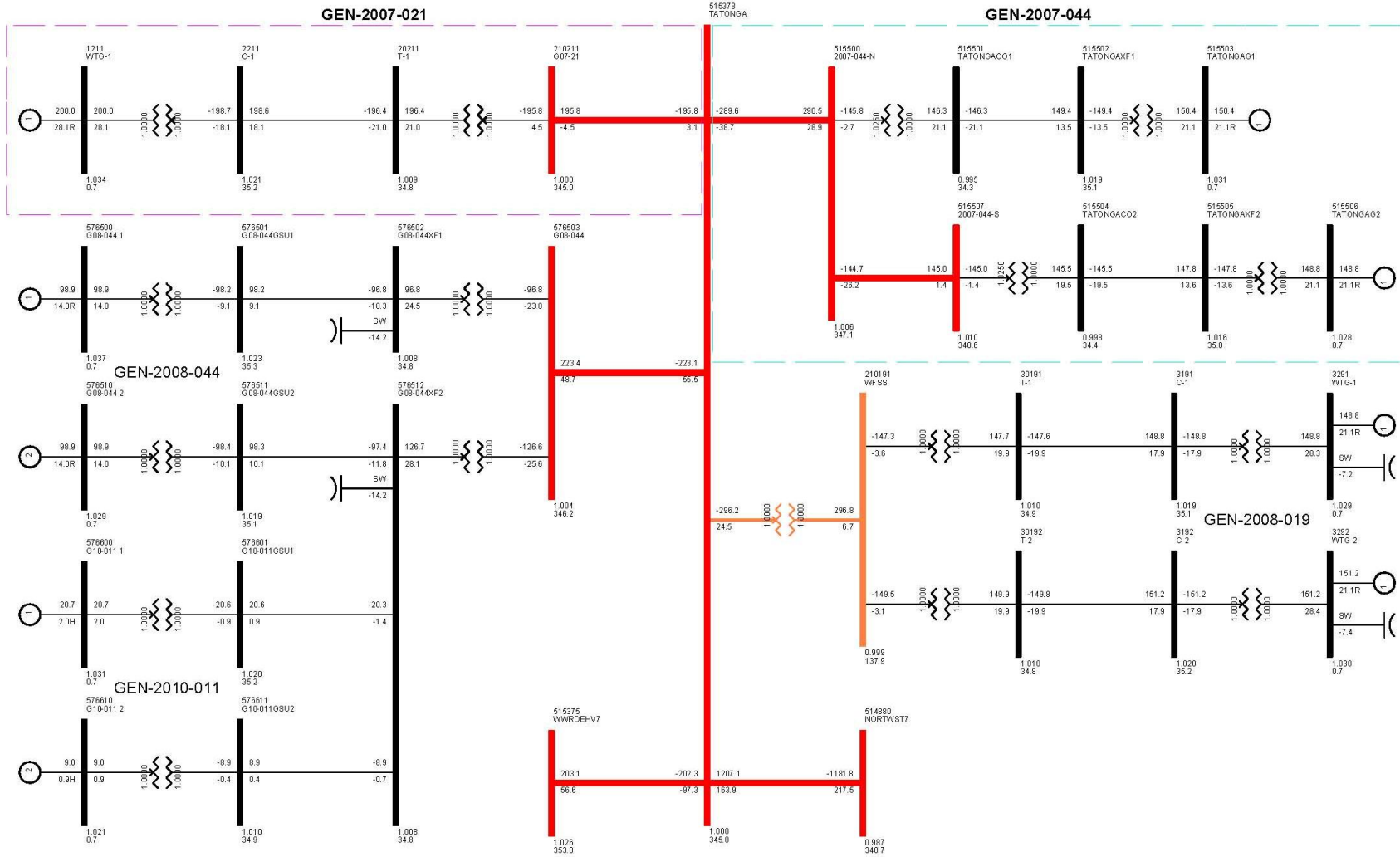


Figure 3-1. Power Flow One-line for Wind Plants at Tatonga 345 kV

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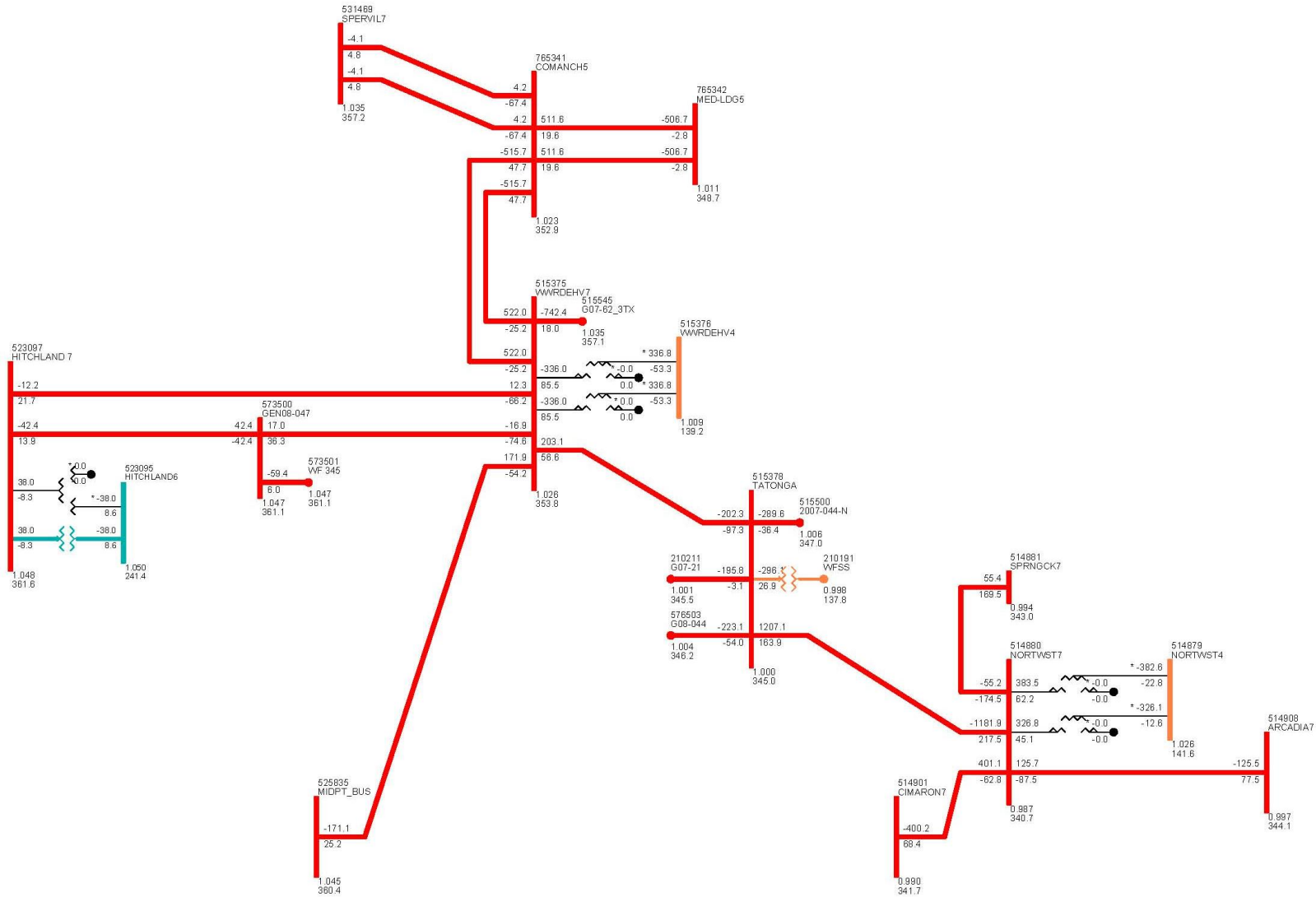


Figure 3-2. Power Flow One-line for 345 kV System near Tatonga 345 kV

### 3.4 Performance Criteria

The 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 on the transmission grid at or near the POI. 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

Since all of the interconnection requests are wind projects, a power factor analysis was performed. 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. 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-2007-021/044 Restudy**

Cont. No.	Cont. Name	Description
1	FLT01-3PH	3 phase fault on one of the Tatonga (515378) to Woodward (515375) 345kV lines, near Tatonga. a. Apply fault at the Tatonga 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	FLT02-1PH	Single phase fault and sequence like previous

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Cont. No.	Cont. Name	Description
3	FLT03-3PH	3 phase fault on one of the Woodward (515375) to Hitchland (523097) 345kV double circuit lines, near Woodward. a. Apply fault at the Woodward 345kV bus. b. Clear fault after 5 cycles by tripping both lines.
4	FLT04-1PH	Single phase fault and sequence like previous
5	FLT05-3PH	3 phase fault on one of the Woodward (515375) to Comanche (765341) double circuit 345kV lines, near Woodward. a. Apply fault at the Woodward 345kV bus. b. Clear fault after 5 cycles by tripping both lines
6	FLT06-1PH	Single phase fault and sequence like previous
7	FLT07-3PH	3 phase fault on the Woodward 345kV (515375) to 138kV (515376) transformer, near the 345 kV bus. a. Apply fault at the Woodward 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
8	FLT08-1PH	Single phase fault and sequence like previous
9	FLT09-3PH	3 phase fault on the Tatonga (515378) to Northwest (514880) 345kV line, near Tatonga. a. Apply fault at the Tatonga 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	FLT10-1PH	Single phase fault and sequence like previous
11	FLT11-3PH	3 phase fault on the Northwest (514880) to Spring Creek (514881) 345kV line, near Northwest. a. Apply fault at the Northwest 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	FLT12-1PH	Single phase fault and sequence like previous
13	FLT13-3PH	3 phase fault on the Northwest (514880) to Cimarron (514901) 345kV line, near Northwest. a. Apply fault at the Northwest 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.
14	FLT14-1PH	Single phase fault and sequence like previous
15	FLT15-3PH	3 phase fault on Northwest 345kV (514880) to 138kV (514879) transformer T2, near the 345 kV bus. a. Apply fault at the Northwest 345kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
16	FLT16-1PH	Single phase fault and sequence like previous
17	FLT17-3PH	3 phase fault on one of the Comanche (765341) to Medicine Lodge (765342) 345kV double circuit lines, near Comanche. a. Apply fault at the Comanche 345kV bus. b. Clear fault after 5 cycles by tripping both lines.
18	FLT18-1PH	Single phase fault and sequence like previous

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Cont. No.	Cont. Name	Description
19	FLT19-3PH	3 phase fault on the Arcadia (514908) to Northwest (514880) 345kV line, near Arcadia. a. Apply fault at the Arcadia 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 Woodward EHV (515376) to Iodine (514796) 138kV line, near Woodward EHV. a. Apply fault at the Woodward EHV 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.
22	FLT22-1PH	Single phase fault and sequence like previous
23	FLT23-3PH	3 phase fault on the Woodward (514785) to GEN-2001-037 (515785) 138kV line, near Woodward. a. Apply fault at the Woodward 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.
24	FLT24-1PH	Single phase fault and sequence like previous
25	FLT25-3PH	3 phase fault on the Mooreland (520999) to GEN-2001-037 (515785) 138kV line, near Mooreland. a. Apply fault at the Mooreland 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.
26	FLT26-1PH	Single phase fault and sequence like previous
27	FLT27-3PH	3 phase fault on the Mooreland (520999) to Glass Mountain (514788) 138kV line, near Mooreland. a. Apply fault at the Mooreland 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.
28	FLT28-1PH	Single phase fault and sequence like previous
29	FLT29-3PH	3 phase fault on the Mooreland (520999) to Morewood (521001) 138kV line, near Mooreland. a. Apply fault at the Mooreland 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.
30	FLT30-1PH	Single phase fault and sequence like previous
31	FLT31-3PH	3 phase fault on the Taloga (521065) to Dewey (514787) 138kV line, near Taloga. a. Apply fault at the Taloga 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.
32	FLT32-1PH	Single phase fault and sequence like previous

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Cont. No.	Cont. Name	Description
33	FLT33-3PH	3 phase fault on the Dewey (514787) to Southard (514822) 138kV line, near Dewey. a. Apply fault at the Dewey 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.
34	FLT34-1PH	Single phase fault and sequence like previous
35	FLT35-3PH	3 phase fault on the Woodward (515375) to Midpoint/Wheeler (525835) 345kV line, near Woodward. a. Apply fault at the Woodward 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.
36	FLT36-1PH	Single phase fault and sequence like previous
37	FLT37-3PH	3 phase fault on the Hitchland (523095) 230kV to Hitchland (523097) 345kV transformer, 230 kV bus. a. Apply fault at the Hitchland 230kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
38	FLT38-1PH	Single phase fault and sequence like previous
39	FLT39-3PH	3 phase fault on the Cedardale (520848) to Mooreland (520999) 138kV line, near Cedardale. a. Apply fault at Cedardale 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.
40	FLT40-1PH	Single phase fault and sequence like previous
41	FLT41-3PH	3 phase fault on the Iodine (520957) to Mooreland (520999) 138kV line, near Iodine. a. Apply fault at Iodine 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.
42	FLT42-1PH	Single phase fault and sequence like previous
43	FLT43-3PH	3 phase fault on the Taloga (521065) to Mooreland (520999) 138kV line, near Taloga. a. Apply fault at Taloga 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.
44	FLT44-1PH	Single phase fault and sequence like previous
45	FLT45-3PH	3 phase fault on one of the Ft. Supply (520920) 138kV to Ft. Supply (520919) 69kV transformer, 138kV bus. a. Apply fault at the Ft. Supply 138kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
46	FLT46-1PH	Single phase fault and sequence like previous



## **4. Results and Observations**

### **4.1 Stability Analysis Results**

All faults were run for both summer and winter peak conditions. Table 4-1 summarizes the overall results for all faults. Figure 4-1 through Figure 4-3 show representative summer peak season plots for a fault at the POI 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.

Following fault 10, a single-phase fault on the Tatonga-Northwest 345 kV line, the two wind generators of GEN-2008-019 trip on high voltage. GEN-2008-019 has an unusual system design with transformers in series at the substation. Whereas other plants at this POI have transformers directly connecting 345 kV to 34.5 kV, GEN-2008-019 has a 345/138 kV transformer and then two 138/34.5 kV transformers. This results in extra impedance between the wind turbines and the transmission grid, giving more voltage rise from the POI back to the generators. These wind turbines use the Mitsubishi M9295 dynamic model. They will trip if the voltage goes over 110% for more than 0.02 seconds, which happens right after clearing Fault 10. This overvoltage setting is more sensitive than many wind turbine designs. Fault 10 was repeated with tripping disabled, and everything was stable. Separately, Fault 10 was rerun after changing the taps 2.5% on the 138/34.5 kV transformers at GEN-2008-019 as well as the 34.5/0.69 kV transformers at the turbines. All generators stayed on-line and stable with this option.

Following faults 41 and 42, the voltages at Ft. Supply 138, Buffalo Bear 69, Fargo Jct 69, GEN-2001-014, GEN-2006-024S, GEN-2010-008 take about 1.5 seconds to recover after fault clearing, then the voltages settle to as high as 110%. These faults remove the only 138 kV connection to the grid for GEN-2001-014 and Ft. Supply 138, so this wind power feeds down to the 69 kV system after the fault. These three wind plants do not have high-speed voltage control capability. The responses are ultimately stable.

For all other simulations, all plants stayed on-line and stable. No stability problems were found.

### **4.2 Wind Plant Performance**

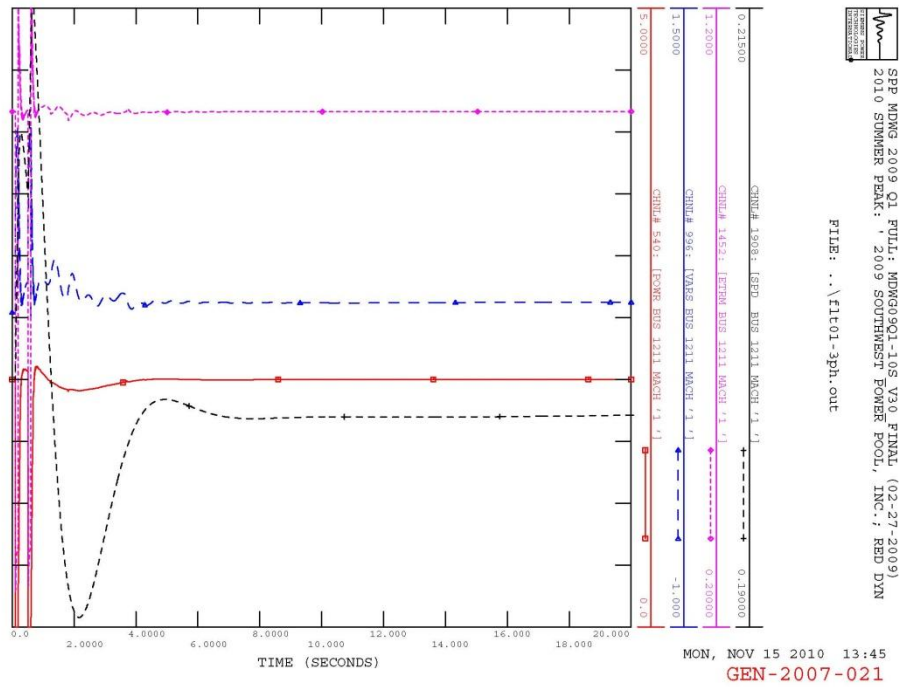
The Suzlon S88 wind turbines at projects GEN-2001-014, GEN-2006-024S, and GEN-2007-006 show poorly damped oscillations in their machine speeds for many of the faults. This is a known issue with the S88 wind turbine model. The active and reactive power outputs of these wind turbines have slight oscillations that should not impact the system. The oscillations are mostly gone by  $t=20s$ , although the oscillations linger longer for GEN-2007-006 in some faults. For a few faults (5, 6, 17, and 18), the S88 turbines have some small, high-frequency oscillations in active power that could be numerical in nature.

**Table 4-1. Summary of Results**

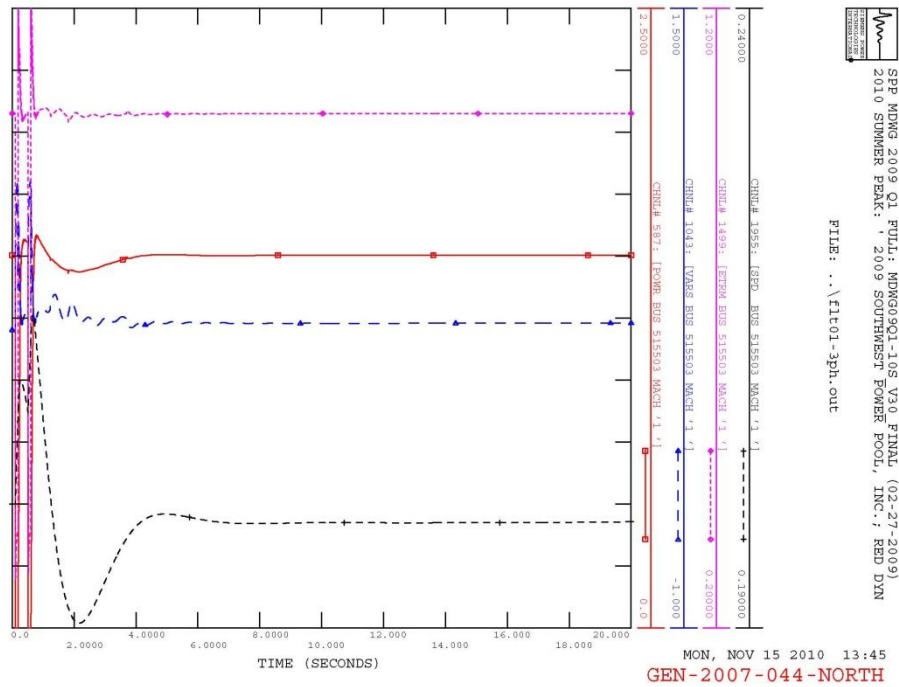
Cont. No.	Cont. Name	Description	Summer Peak Results	Winter Peak Results
1	FLT01-3PH	3 phase fault on one of the Tatonga (515378) to Woodward (515375) 345kV lines, near Tatonga.	OK	OK
2	FLT02-1PH	Single phase fault and sequence like previous	OK	OK
3	FLT03-3PH	3 phase fault on one of the Woodward (515375) to Hitchland (523097) 345kV double circuit lines, near Woodward.	OK	OK
4	FLT04-1PH	Single phase fault and sequence like previous	OK	OK
5	FLT05-3PH	3 phase fault on one of the Woodward (515375) to Comanche (765341) double circuit 345kV lines, near Woodward.	OK	OK
6	FLT06-1PH	Single phase fault and sequence like previous	OK	OK
7	FLT07-3PH	3 phase fault on the Woodward 345kV (515375) to 138kV (515376) transformer, near the 345 kV bus.	OK	OK
8	FLT08-1PH	Single phase fault and sequence like previous	OK	OK
9	FLT09-3PH	3 phase fault on the Tatonga (515378) to Northwest (514880) 345kV line, near Tatonga.	OK	OK
10	FLT10-1PH	Single phase fault and sequence like previous	G08-19 Trips	G08-19 Trips
10nt	FLT10-1PH-nt	Single phase fault and sequence like previous, tripping blocked	OK	OK
11	FLT11-3PH	3 phase fault on the Northwest (514880) to Spring Creek (514881) 345kV line, near Northwest.	OK	OK
12	FLT12-1PH	Single phase fault and sequence like previous	OK	OK
13	FLT13-3PH	3 phase fault on the Northwest (514880) to Cimarron (514901) 345kV line, near Northwest.	OK	OK
14	FLT14-1PH	Single phase fault and sequence like previous	OK	OK
15	FLT15-3PH	3 phase fault on Northwest 345kV (514880) to 138kV (514879) transformer T2, near the 345 kV bus.	OK	OK
16	FLT16-1PH	Single phase fault and sequence like previous	OK	OK
17	FLT17-3PH	3 phase fault on one of the Comanche (765341) to Medicine Lodge (765342) 345kV double circuit lines, near Comanche.	OK	OK
18	FLT18-1PH	Single phase fault and sequence like previous	OK	OK
19	FLT19-3PH	3 phase fault on the Arcadia (514908) to Northwest (514880) 345kV line, near Arcadia.	OK	OK
20	FLT20-1PH	Single phase fault and sequence like previous	OK	OK
21	FLT21-3PH	3 phase fault on the Woodward EHV (515376) to Iodine (514796) 138kV line, near Woodward EHV.	OK	OK
22	FLT22-1PH	Single phase fault and sequence like previous	OK	OK
23	FLT23-3PH	3 phase fault on the Woodward (514785) to GEN-2001-037 (515785) 138kV line, near Woodward.	OK	OK

SPP GEN-2007-021 and GEN-2007-044 Impact Restudy

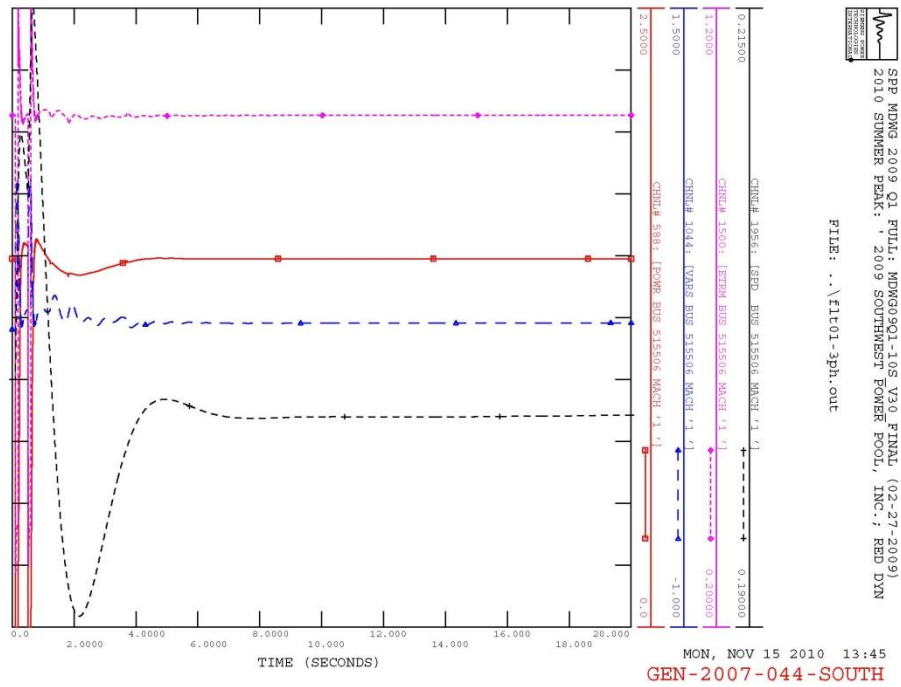
Cont. No.	Cont. Name	Description	Summer Peak Results	Winter Peak Results
24	FLT24-1PH	Single phase fault and sequence like previous	OK	OK
25	FLT25-3PH	3 phase fault on the Mooreland (520999) to GEN-2001-037 (515785) 138kV line, near Mooreland.	OK	OK
26	FLT26-1PH	Single phase fault and sequence like previous	OK	OK
27	FLT27-3PH	3 phase fault on the Mooreland (520999) to Glass Mountain (514788) 138kV line, near Mooreland.	OK	OK
28	FLT28-1PH	Single phase fault and sequence like previous	OK	OK
29	FLT29-3PH	3 phase fault on the Mooreland (520999) to Morewood (521001) 138kV line, near Mooreland.	OK	OK
30	FLT30-1PH	Single phase fault and sequence like previous	OK	OK
31	FLT31-3PH	3 phase fault on the Taloga (521065) to Dewey (514787) 138kV line, near Taloga.	OK	OK
32	FLT32-1PH	Single phase fault and sequence like previous	OK	OK
33	FLT33-3PH	3 phase fault on the Dewey (514787) to Southard (514822) 138kV line, near Dewey.	OK	OK
34	FLT34-1PH	Single phase fault and sequence like previous	OK	OK
35	FLT35-3PH	3 phase fault on the Woodward (515375) to Midpoint/Wheeler (525835) 345kV line, near Woodward.	OK	OK
36	FLT36-1PH	Single phase fault and sequence like previous	OK	OK
37	FLT37-3PH	3 phase fault on the Hitchland (523095) 230kV to Hitchland (523097) 345kV transformer, 230 kV bus.	OK	OK
38	FLT38-1PH	Single phase fault and sequence like previous	OK	OK
39	FLT39-3PH	3 phase fault on the Cedardale (520848) to Mooreland (520999) 138kV line, near Cedardale.	OK	OK
40	FLT40-1PH	Single phase fault and sequence like previous	OK	OK
41	FLT41-3PH	3 phase fault on the Iodine (520957) to Mooreland (520999) 138kV line, near Iodine.	OK	OK
42	FLT42-1PH	Single phase fault and sequence like previous	OK	OK
43	FLT43-3PH	3 phase fault on the Taloga (521065) to Mooreland (520999) 138kV line, near Taloga.	OK	OK
44	FLT44-1PH	Single phase fault and sequence like previous	OK	OK
45	FLT45-3PH	3 phase fault on one of the Ft. Supply (520920) 138kV to Ft. Supply (520919) 69kV transformer, 138kV bus.	OK	OK
46	FLT46-1PH	Single phase fault and sequence like previous	OK	OK



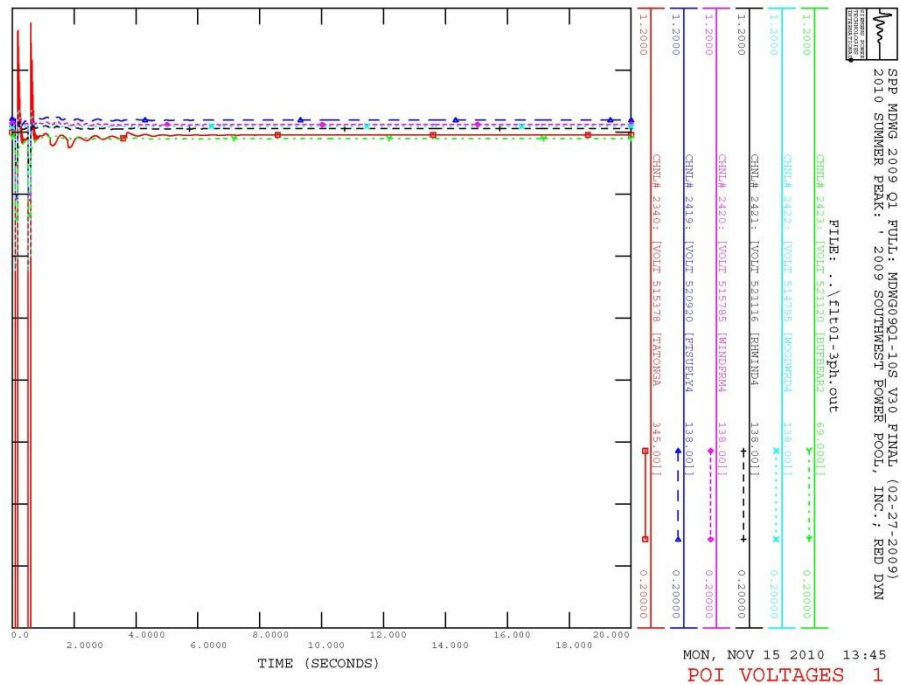
**Figure 4-1. GEN-2007-021 Plot for Fault 1 – 3 phase fault on the Tatonga to Woodward 345 kV lines, near Tatonga**



**Figure 4-2. GEN-2007-044 North Plot for Fault 1 – 3 phase fault on the Tatonga to Woodward 345 kV lines, near Tatonga**



**Figure 4-3. GEN-2007-044 South Plot for Fault 1 – 3 phase fault on the Tatonga to Woodward 345 kV lines, near Tatonga**



**Figure 4-4. POI Voltages Plot for Fault 1 – 3 phase fault on the Tatonga to Woodward 345 kV lines, near Tatonga**

### **4.3 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 voltage. 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.

If more than one study project shared 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. *Prior-queued* projects at the same POI, if any, were not grouped with the study projects because their interconnection requirements were determined in previous studies. The voltage schedules of prior-queued and study projects at the same POI were coordinated.

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 set to 0.95 lagging. This limit was reached for both study projects. Both projects would need to go below 0.95 lagging to maintain scheduled voltage for some studied contingencies, but the requirement is set to 0.95. The limit for leading power factor requirement is also 0.95, and this limit was not reached for any study project. If the project never operated leading under any contingency, then the leading requirement is set to 1.0. Similar for lagging.

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. A project developer may install more capability than this if desired.

Assuming that GEN-2007-021 and GEN-2007-044 install the planned GE 1.6 MW wind turbines with 0.90 power factor capability at the generator terminals, this analysis does not show the need for additional capacitors or other reactive power compensation devices.

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

**Table 4-2. Power Factor Requirements <sup>1</sup>**

Request	Size (MW)	Generator Model	Point of Interconnection	Final PF Requirement		Estimated Capacitor Requirement (Mvar)
				Lagging <sup>2</sup>	Leading <sup>3</sup>	
GEN-2007-021	200.0	GE 1.6MW	Tatonga 345kV	0.95	0.95	0
GEN-2007-044	299.2	GE 1.6MW	Tatonga 345kV	0.95	0.95	0

Notes:

1. For each plant, the table shows the minimum required 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. Installing more capability than the minimum requirement is acceptable.
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

This Impact Restudy evaluated the impacts of interconnecting each of the projects shown below.

**Table 5-1. Interconnection Requests Evaluated in this Study**

Request	Size (MW)	Wind Turbine Model	Point of Interconnection
GEN-2007-021	200.0	GE 1.6MW	Tatonga 345kV (515378)
GEN-2007-044	299.2	GE 1.6MW	Tatonga 345kV (515378)

Project GEN-2008-019 tripped off-line due to high voltage following a single phase fault on the Tatonga-Woodward 345 kV line (fault 10). Everything else was stable for this fault. If tripping of GEN-2008-019 is blocked, the results are also stable. If the transformer taps in GEN-2008-019 are changed by a total of 5%, then these generators do not trip and everything is stable.

No other major stability problems were found in this study. The study and prior-queued plants remain on-line and stable for all other simulated disturbances.

Power factor requirements were determined, and the study plants must install sufficient reactive power resources to meet the requirements listed in Table 4-2. The analysis indicates that GEN-2007-021 and GEN-2007-044 should be able to meet the power factor requirements with the planned collector system and GE 1.6 MW 0.9 power factor wind turbines without a need for additional reactive power compensation devices.

With the assumptions used in this study, GEN-2007-021 and GEN-2007-044 should be able to reliably connect to the SPP transmission grid.



## **Appendix A – Summer Peak Plots**

See attachment.

## **Appendix B – Winter Peak Plots**

See attachment.

## **Appendix C – Power Factor Details**

See attachment.

## **Appendix D – Project Model Data**

See attachment.