SPP Southwest Power Pool

Impact Re-Study
For
Generation Interconnection
Request
GEN-2006-002

SPP Generation
Interconnection Studies

(#GEN-2006-002)

September 2010

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Excel Engineering, Inc. (Excel) performed the following Impact restudy to satisfy the Impact Study Agreement executed by the requesting Customer and SPP for SPP Generation Interconnection request #GEN-2006-002. This generation interconnection request was originally studied with Gamesa G87 2.0 MW wind turbines at 150MW. The Customer has subsequently asked for a restudy assuming the facility will contain a mixture of GE 1.5 and 1.6 MW wind turbines at 101MW total capacity.

The purpose of this restudy is to evaluate the Customer’s request to use the GE 1.5 and 1.6 MW wind turbines for the proposed generation. This study addressed the stability and reactive compensation required for the GE wind turbines. The stability study shows that the interconnection of the proposed project does not have any adverse impact on the system stability in the SPP area.

SPP GEN-2006-002
Impact Restudy

Draft Report for

Southwest Power Pool

Prepared by:
Excel Field Services, Inc.

September 2010

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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-2006-002 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 project shown in Table 1-1. The in-service date assumed for the generation addition was 2010. The study project is located in Beckham County, Oklahoma.

Table 1-1. Interconnection Requests to be Evaluated

Request	Size (MW)	Wind Turbine Model	Point of Interconnection
GEN-2006-002	101	Mixture of GE 1.5 and 1.6 MW turbines	Sweetwater 230kV (#560012)

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

Table 1-2. Nearby Interconnection Requests Already in the Queue

Request	Size (MW)	Wind Turbine Model	Point of Interconnection
Blue Canyon I	74	CIMTR	Washita 138kV (521089)
Blue Canyon II (GEN-2003-004)	151	Vestas V80	Washita 138kV (521089)
Weatherford	147	G.E. 1.5MW	Weatherford 138kV (511506)
GEN-2003-005	100	G.E. 1.5MW	Anadarko – Paradise 138kV (560916)
GEN-2006-035	224	Gamesa	Sweetwater 230kV (560012)
GEN-2006-043	99	Siemens	Sweetwater 230kV (560012)

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.

2. Executive Summary

The GEN-2006-002 Impact Restudy evaluated the stability impacts of interconnecting project GEN-2006-002 to the SPP transmission system in Beckham County, Oklahoma.

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

Power factor requirements were determined, and the study plant must install sufficient reactive power resources to meet the requirements listed in Table 4-2. The analysis indicates that GEN-2006-002 should be able to meet the power factor requirements with the planned collector system and GE 1.5 and 1.6 MW wind turbines, without a need for additional reactive power compensation devices.

With the assumptions used in this study, GEN-2006-002 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 model for study plant GEN-2006-002 was developed as part of this study using data provided by the requester. The plan for GEN-2006-002 includes GE 1.5 MW turbines on three collector branches and GE 1.6 MW turbines on one collector branch. Separate equivalent generators and collector branches were developed for the 1.5 MW and 1.6 MW parts of the wind farm. Both turbine sizes were modeled with a 0.95 leading and lagging power factor capability at the generator terminals.

A power flow one-line diagram of the study project is shown in Figure 3-1. As the figure shows, the wind farm model includes explicit representation of the radial transmission line; the substation transformer 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.

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.

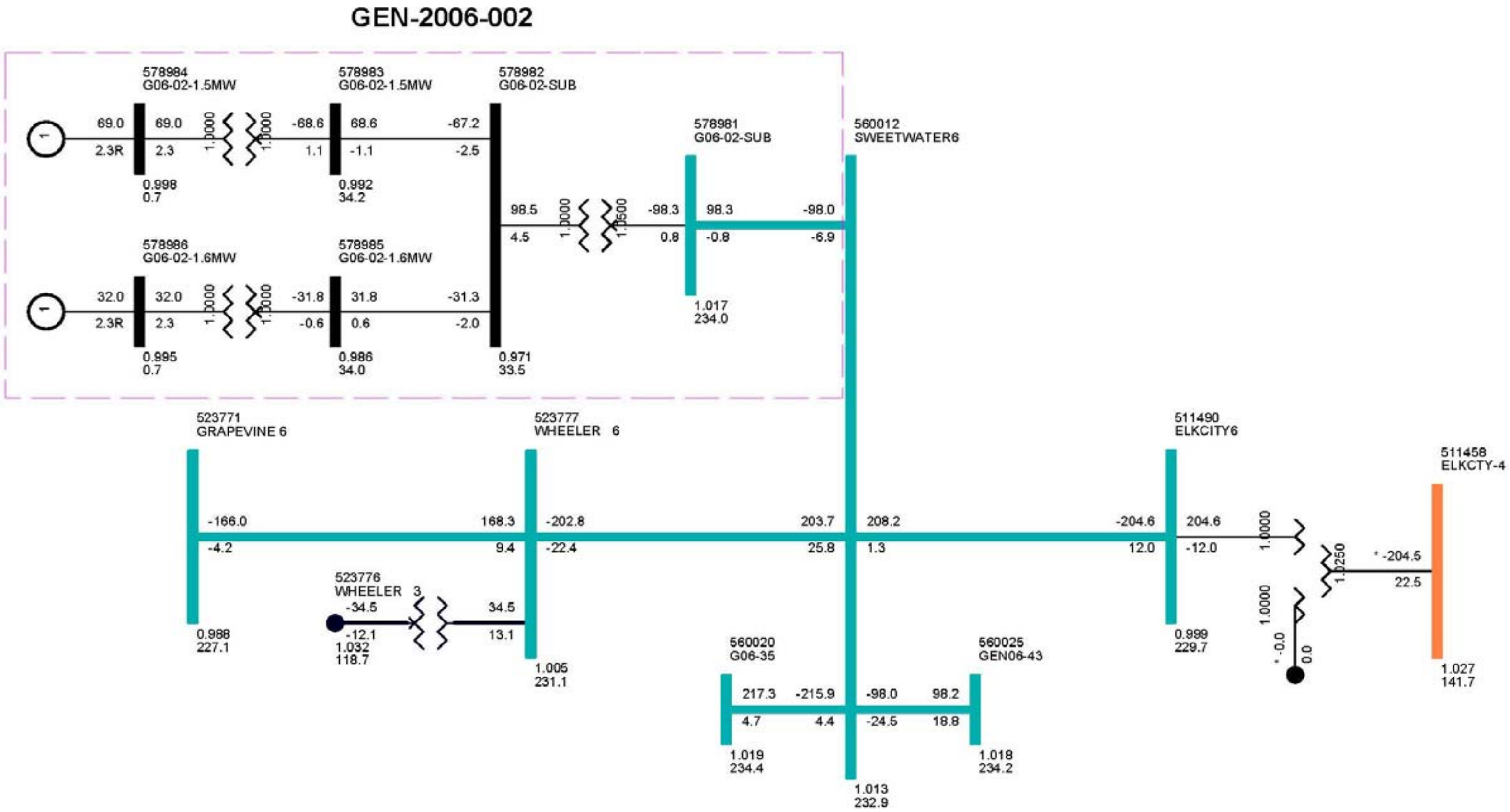

Figure 3-1. Power Flow One-line for GEN-2006-002

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). If a previously-queued generator tripped for any of these faults, the voltage and frequency tripping was disabled, and the fault was re-run to check for system stability.

Table 3-1. Fault Definitions for GEN-2006-002

Cont. No.	Cont. Name	Description
1	FLT01-3PH	3 phase fault on the Sweetwater (560012) to Wheeler (523777) 230 kV line, near Sweetwater. a. Apply fault at Sweetwater 230 kV bus. b. Clear fault after 5 cycles by tripping the line from the Sweetwater - Wheeler.
2	FLT02-1PH	Single phase fault and sequence like Cont. No. 1

Cont. No.	Cont. Name	Description
3	FLT03-3PH	3 phase fault on the Sweetwater (560012) to Elk City (511490) 230 kV line, near the Wind Farm. a. Apply fault at Sweetwater 230 kV bus. b. Clear fault after 5 cycles by tripping the line from the Sweetwater - Elk City.
4	FLT04-1PH	Single phase fault and sequence like Cont. No. 3
5	FLT05-3PH	3 phase fault on the Clinton Jct (511485) – Elk City (511458) 138 kV line, near Clinton Jct. a. Apply fault at the Clinton Jct 138 kV bus. b. Clear fault after 5 cycles by tripping the line from the Elk City – Clinton Jct. 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	FLT06-1PH	Single phase fault and sequence like Cont. No. 5
7	FLT07-3PH	3 phase fault on the RH Wind (521116) – Morewood (521001) 138 kV line, near Morewood. a. Apply fault at the Morewood 138 kV bus. b. Clear fault after 5 cycles by tripping the line from the RH Wind – Morewood 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	FLT08-1PH	Single phase fault and sequence like Cont. No.7
9	FLT09-3PH	3 phase fault on the Hobart Jct (511446) – Elk City (511458) 138 kV line, near Elk City. a. Apply fault at the Elk City 138 kV bus. b. Clear fault after 5 cycles by tripping the line from the Elk City – Clinton AFB (511446) - Hobart Jct 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 Cont. No.9
11	FLT11-3PH	3 phase fault on the Grapevine (523771) – Nichols (524044) 230 kV line near Grapevine. a. Apply fault at the Grapevine bus. b. Clear fault after 5 cycles by tripping the line Grapevine-Nichols 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 Cont. No.11
13	FLT13-3PH	3 phase fault on the Grapevine 230/115 kV autotransformer on the 230 kV bus a. Apply fault at the Grapevine 230 kV bus. b. Clear fault after 5 cycles by tripping the autotransformer c. No reclose
14	FLT14-1PH	Single phase fault and sequence like Cont. No.13
15	FLT15-3PH	3 phase fault on the Conway (524079)-Yarnell (524072) –Nichols (524043) 115 kV line near Nichols a. Apply fault at the Nichols bus. b. Clear fault after 5 cycles by tripping the line Conway-Yarnell-Nichols 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	FLT16-1PH	Single phase fault and sequence like Cont. No.15

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 project. Complete sets of plots for both summer and winter peak seasons for each fault and each project are included in Appendices A and B.

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

The only minor item of note is the speed oscillation seen in GEN-2003-004, as shown in Figure 4-4. These oscillations are found in the plots of most of the simulated three-phase faults. However, these oscillations do not show up in the active or reactive power output of this generator or any bus voltages. This behavior is typical of the Vestas V80 model used for this wind plant. Because there is no impact on the electric system, the oscillations are of no concern.

Table 4-1. Summary of Results

Cont. No.	Cont. Name	Description	Summer Peak Results	Winter Peak Results
1	FLT01-3PH	3 phase fault on the Sweetwater (560012) to Wheeler (523777) 230 kV line, near Sweetwater.	OK	OK
2	FLT02-1PH	Single phase fault and sequence like Cont. No. 1	OK	OK
3	FLT03-3PH	3 phase fault on the Sweetwater (560012) to Elk City (511490) 230 kV line, near the Wind Farm.	OK	OK
4	FLT04-1PH	Single phase fault and sequence like Cont. No. 3	OK	OK
5	FLT05-3PH	3 phase fault on the Clinton Jct (511485) – Elk City (511458) 138 kV line, near Clinton Jct.	OK	OK
6	FLT06-1PH	Single phase fault and sequence like Cont. No. 5	OK	OK
7	FLT07-3PH	3 phase fault on the RH Wind (521116) – Morewood (521001) 138 kV line, near Morewood.	OK	OK
8	FLT08-1PH	Single phase fault and sequence like Cont. No.7	OK	OK
9	FLT09-3PH	3 phase fault on the Hobart Jct (511446) – Elk City (511458) 138 kV line, near Elk City.	OK	OK
10	FLT10-1PH	Single phase fault and sequence like Cont. No.9	OK	OK
11	FLT11-3PH	3 phase fault on the Grapevine (523771) – Nichols (524044) 230 kV line near Grapevine.	OK	OK
12	FLT12-1PH	Single phase fault and sequence like Cont. No.11	OK	OK
13	FLT13-3PH	3 phase fault on the Grapevine 230/115 kV autotransformer on the 230 kV bus	OK	OK
14	FLT14-1PH	Single phase fault and sequence like Cont. No.13	OK	OK
15	FLT15-3PH	3 phase fault on the Conway (524079)-Yarnell (524072) –Nichols (524043) 115 kV line near Nichols	OK	OK
16	FLT16-1PH	Single phase fault and sequence like Cont. No.15	OK	OK

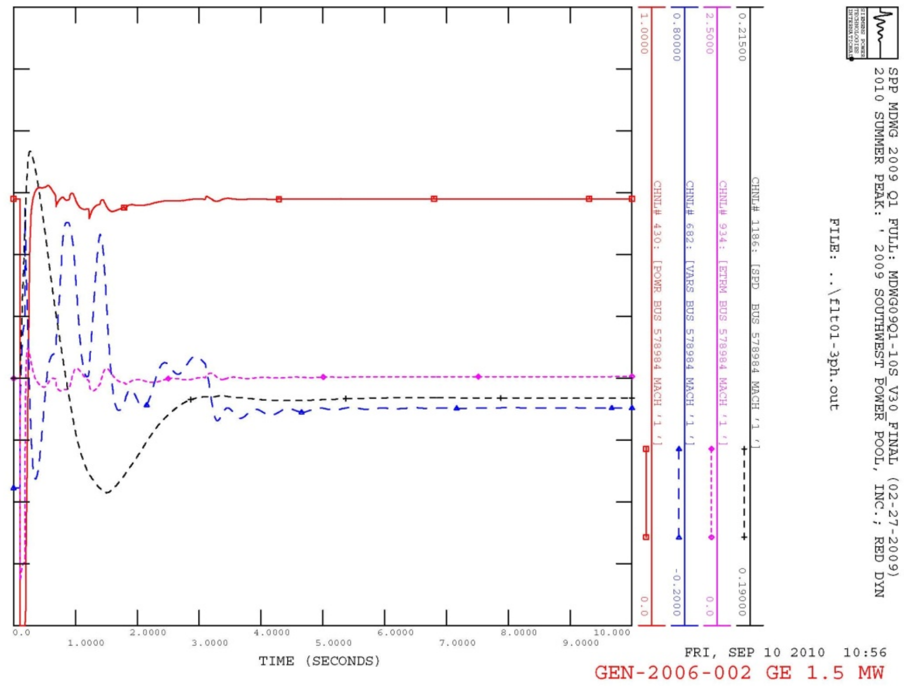

Figure 4-1. GEN-2006-002 1.5 MW Plot for Fault 1 – 3 phase fault on the Sweetwater to Wheeler 230 kV line, near Sweetwater

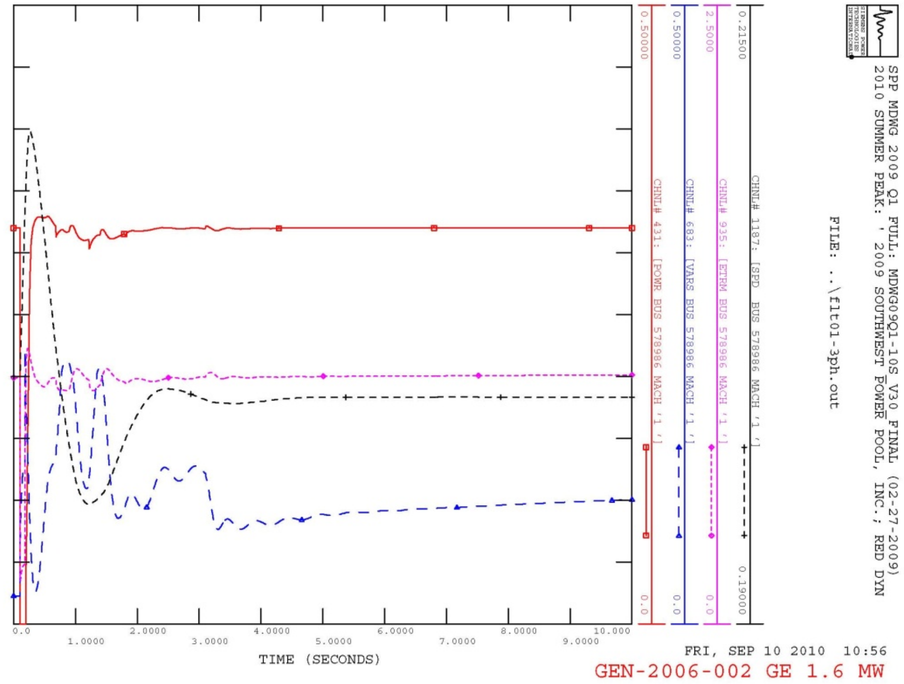

Figure 4-2. GEN-2006-002 1.6 MW Plot for Fault 1 – 3 phase fault on the Sweetwater to Wheeler 230 kV line, near Sweetwater

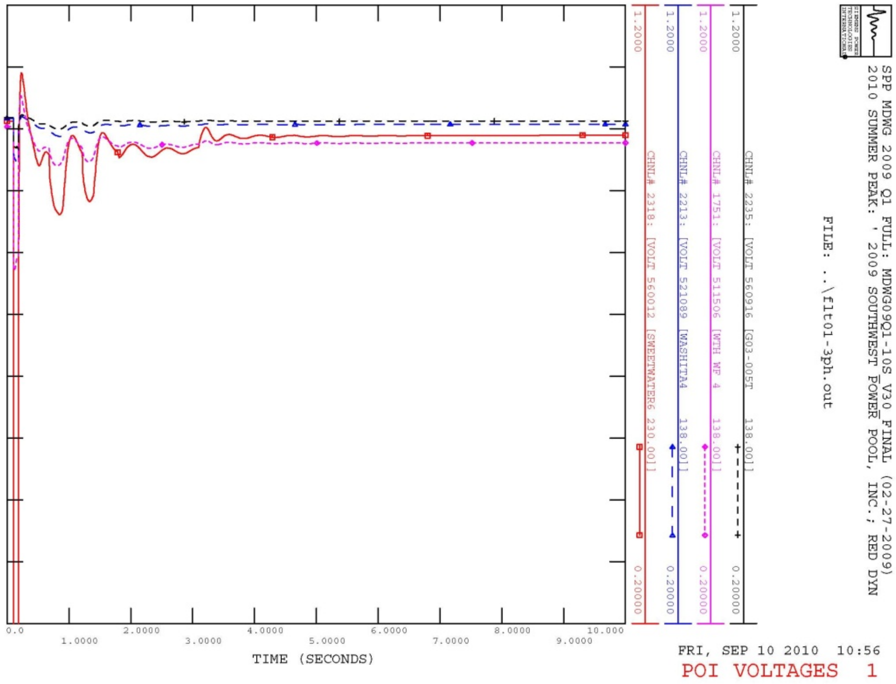

Figure 4-3. POI Voltages Plot for Fault 1 – 3 phase fault on the Sweetwater to Wheeler 230 kV line, near Sweetwater

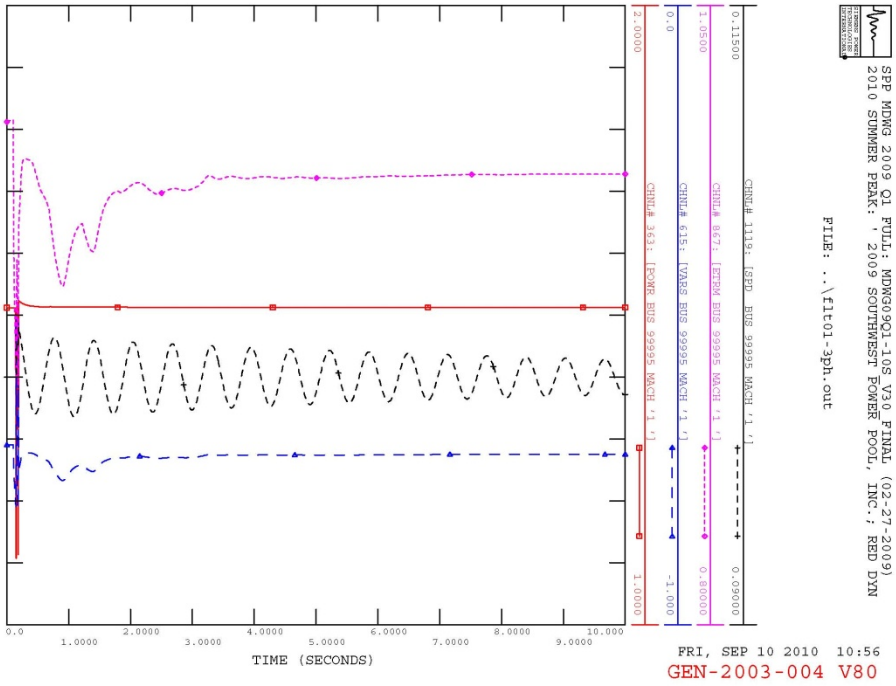

Figure 4-4. GEN-2003-004 Plot for Fault 1 – 3 phase fault on the Sweetwater to Wheeler 230 kV line, near Sweetwater

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.

If more than one study project shared a single POI (none in this case), 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 voltages 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 not reached for any study project. 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-2006-002 installs the planned GE 1.5 and 1.6 MW wind turbines, this analysis shows no 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 [1]

Request	Size (MW)	Wind Turbine Model	Point of Interconnection	Final PF Requirement	
				Lagging [2]	Leading [3]
GEN-2006-002	101	GE 1.5MW and 1.6MW	Sweetwater 230 kV	0.966	1.0

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-2006-002	101	Mixture of GE 1.5 and 1.6 MW turbines	Sweetwater 230kV (#560012)

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

Power factor requirements were determined, and the study plant must install sufficient reactive power resources to meet the requirements listed in Table 4-2. The analysis indicates that GEN-2006-002 should be able to meet the power factor requirements with the planned collector system and GE 1.5 and 1.6 MW wind turbines, without a need for additional reactive power compensation devices.

With the assumptions used in this study, GEN-2006-002 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.