SPP Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2006–046

SPP Tariff Studies
(#GEN-2006-046)

August 2008

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), S&C Electric Company (S&C) performed the following Impact Study to satisfy the Impact Study Agreement executed by the requesting customer and SPP for SPP Generation Interconnection request GEN-2006-046. The request for interconnection was placed with SPP in accordance SPP's Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system. This interconnection request has been studied with Suzlon, Mitsubishi, and Clipper wind turbines. This Impact Study addresses an error in the original Customer submission to study the Mitsubishi wind turbines. This study addresses the installation of fifty-four (54) Mitsubishi wind turbines.

Interconnection Facilities

The Impact Study has determined that a total of 25.4 Mvars of 34.5kV capacitor banks are necessary for the operation of GEN-2006-046 with Mitsubishi turbines. This capacitor bank(s) should be staged so that excessive voltage variations are not experienced on the OG&E transmission system.

The Impact Study determined that a STATCOM or SVC device was not necessary for the studied Mitsubishi turbines to meet FERC Order #661A low voltage ride through provisions.

The interconnection facilities necessary for this generation interconnection request have been updated and are posted in the Facility Study for GEN-2006-046. Please refer to the Facility Study for these costs.

Final Report

For

Southwest Power Pool

From

S&C Electric Company

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2006-046 RESTUDY

S&C Project No. 3244

August 25, 2008

S&C Electric Company

S&C Electric Company, Chicago, IL 60626-3997, Phone: (773) 338-1000
Power Systems Services Division Fax: (773) 338-4254

Table of Contents

Report prepared by:

George Tsai
Project Engineer
Consulting and Analytical Services

1. Executive Summary

This system impact study was performed in response to a generation interconnection study request through the Southwest Power Pool Tariff for a wind farm in Dewey County, Oklahoma with projected output of 130 MW to be interconnected to the existing Dewey 138 kV substation owned by (OKGE) Oklahoma Gas & Electric. The study was previously performed for 51 Mitsubishi 2.4 MW MWT-95 wind turbine generators. The customer has increased the number of turbines in the wind project and requested a restudy for 54 Mitsubishi 2.4 MW MWT-95 wind turbine generators.

Steady-state and dynamic studies were performed at 100% MW output (full load) per original request. Dynamic simulations were conducted for three-phase and single-phase to ground faults at locations specified by SPP. Seasonal power flow cases for winter peak 2008 and summer peak 2012, stability models and equipment data used for the previous study were reused for this restudy.

During normal system contingency, rated output power, and unity power factor at the 690 V generator buses, this project will require 25.40 MVAR of static shunt capacitors located at the 34.5 kV collector bus in order to compensate for transmission and transformation losses given that the project is required to operate at unity power factor at the point of interconnection (POI). The composition of static shunt capacitors should consist of appropriately sized steps that can be switched in and out automatically by a SCADA/PLC system in response to changes in transmission grid power flow and variations in wind farm production levels.

Dynamic stability analysis shows that following faults on the transmission system, the wind farm project will remain connected thus comply with FERC's Order 661A requirement on LVRT of wind plants. The transmission system retains voltage and frequency stability.

There is no need for STATCOM or SVC for voltage support.

Significant voltage overshoot (>1.4 pu) immediately after fault clearing is seen at the generator terminals for some contingencies when using the Mitsubishi MWT-95 model. The overshoot is of short duration (less than 20 milliseconds) and will not result in overvoltage relay actuation (1.1 pu, 20 ms trip setting). The customer should discuss with Mitsubishi the possibility of extending the relay actuation time beyond 20 ms for added safety margin.

Stability analysis shows that GEN-2001-037 will trip off for a number of contingencies for winter and summer peak with and without the project. For winter and summer with and without the project, GEN-2001-037 will trip off on low voltage relay actuation for the following fault contingencies:

1. Permanent three-phase fault on the Mooreland to Glass Mountain 138 kV line with tripping and reclosing of the Mooreland to Glass Mountain 138 kV line.

2. Permanent three-phase fault on the Mooreland to GEN-2001-037 138 kV with tripping and reclosing of the Mooreland to GEN-2001-037 138 kV line.

For summer, pre-project and project cases GEN-2001-037 will trip off on low voltage relay actuation for the following fault contingencies:

1. Permanent three-phase fault on the Woodward to Iodine 138 kV line with tripping and reclosing of the Woodward to Iodine 138 kV line.

2. Permanent three-phase fault on the Mooreland to Iodine 138 kV line with tripping and reclosing of the Mooreland to Iodine 138 kV line.

The cases above with the project were re-run with wind turbine protection at GEN-2001-037 disabled. Results show that in the event that GEN-2001-037 was to remain connected after the above disturbances, the transmission grid will retain voltage stability.

2. Load Flow Model

The customer provided revised collector system layout and impedance information. Feeders are represented as aggregated generators to simplify representation in PSS/E. Revisions to model parameters are summarized in Table 1.

Table 1: Revised power flow model parameters for the GEN-2006-046 re-study

Feeder 4	Parameters
19 Mitsubishi MWT-85 2.4 MW wind turbine generators at 690 V	19 * 2.4 MW = 45.6 MW 19 * 2.52 MVA = 47.88 MVA Power factor at 690 V bus: 1.0
19 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	19 * 2.7 MVA = 51.3 MVA Z1 = 0.08j p.u. on 51.3 MVA base
Equivalent 34.5 kV collector system	Z1 =0.01643+0.01648j p.u. on 100 MVA base B1 = 0.01115 p.u. on 100 MVA base

Substation	Parameters
Switched Shunt Capacitor at 34.5 kV collector bus	25.4 MVAR @ 34.5 kV

3. Dynamic Simulations and Voltage Stability Results

Dynamic simulations were performed for fault contingencies in Table 2 with and without GEN-2006-046.

Table 2: Contingencies Evaluated

Cont. No.	*Cont. Name*	*Description*
1	*FLT13PH*	3 phase fault on the Dewey (514787) to Iodine (514796) 138kV line, near Dewey. a. Apply fault at Dewey. b. Clear fault after 5 cycles by tripping the line from Dewey to Iodine. 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	FLT21PH	*Single phase fault and sequence like Cont. No. 1*
3	*FLT33PH*	3 phase fault on the Dewey (514787) to Taloga (521065) 138 kV line, near Dewey. a. Apply fault at Dewey. b. Clear fault after 5 cycles by tripping the line from Dewey to Taloga. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
4	FLT41PH	*Single phase fault and sequence like Cont. No. 3*
5	*FLT53PH*	3 phase fault on the Dewey (514787) to Southard (514822) 138 kV line, near Dewey. a. Apply fault at Dewey. b. Clear fault after 5 cycles by tripping the line from Dewey to Southard. 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	FLT61PH	*Single phase fault and sequence like Cont. No.5*
7	FLT73PH	3 phase fault on the Elk City (511458) to GEN-2002-005T (521001) 138 kV line, near Elk City. a. Apply fault at the Elk City 138kV bus. b. Clear fault after 5 cycles by tripping the line from Elk City – GEN-2002-005T. 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	FLT81PH	*Single phase fault and sequence like Cont. No. 7*
9	FLT93PH	3 phase fault on the Mooreland (520999) – Cedardale (520848) 138 kV line, near Cedardale. a. Apply fault at the Cedardale 138 kV bus. b. Clear fault after 5 cycles by tripping the line from Mooreland - Cedardale. 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	FLT101PH	*Single phase fault and sequence like Cont. No. 9*
11	FLT113PH	3 phase fault on the Mooreland (520999) – Glass Mtn. (514788) 138 kV line, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles by tripping the line from Mooreland – Glass Mtn. 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	FLT121PH	*Single phase fault and sequence like Cont. No.11*

Cont. No.	*Cont. Name*	*Description*
13	FLT133PH	3 phase fault on the Woodward (514785) – Iodine (OG&E) (514796) 138kV line near Woodward. a. Apply fault at the Woodward bus. b. Clear fault after 5 cycles by tripping the line from Woodward-Iodine. 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	FLT141PH	*Single phase fault and sequence like Cont. No.13*
15	FLT153PH	3 phase fault on the Cimarron autotransformer (514898-514901-515715) a. Apply fault at the Cimaron 138kV bus. b. Clear fault after 5 cycles by taking the auto out of service
16	FLT161PH	*Single phase fault and sequence like Cont. No.15*
17	FLT173PH	3 phase fault on the Woodring autotransformer (514715-514714-515770) a. Apply fault at the Woodring 138kV bus. b. Clear fault after 5 cycles by taking the auto out of service
18	FLT181PH	*Single phase fault and sequence like Cont. No.17*
19	FLT193PH	3 phase fault on the Mooreland (520999) – GEN-2001-037 (515785) 138 kV line, near Mooreland. a. Apply fault at the Mooreland 138kV bus. b. Clear fault after 5 cycles by tripping the line from Mooreland – GEN-2001-037. 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	FLT201PH	*Single phase fault and sequence like Cont. No.19*
21	FLT213PH	3 phase fault on the Mooreland (520999) – Iodine (520957) 138kV line near Iodine. a. Apply fault at the Iodine bus. b. Clear fault after 5 cycles by tripping the line from Mooreland-Iodine. 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	FLT221PH	*Single phase fault and sequence like Cont. No.21*

Sink areas monitored are 520, 526, 525, 524, 536, 539, 541

Prior queued projects monitored are:

a. GEN-2001-037; 102MW of GE turbines
b. GEN-2001-014; 94MW of Suzlon turbines
c. GEN-2002-005; 120MW of wind turbines (CIMTR3)
d. GEN-2003-022/GEN-2004-020; 147MW of GE turbines
e. GEN-2005-008; 120MW of GE turbines
f. GEN-2006-024; 20MW of Suzlon turbines

3.1 Post-Project Dynamic Stability Results

Non-disturbance runs of 20 second were carried out on Winter Peak 2008 and Summer Peak 2012 base cases to verify proper initialization of dynamic models and valid power flow cases.

Fault contingencies in Table 2 were studied for winter peak 2008 and summer peak 2012 with 54 Mitsubishi MWT-95 2.4 MW wind turbine generators. Voltage recovers quickly after fault clearing and the project will survive all fault contingencies and thus comply with FERC Order 661A. Mitsubishi output power, speed, terminal voltage, and frequency return to normal operating levels after the disturbance. With the exception of GEN-2001-037, none of the other wind farms monitored will trip off. None of the wind farms monitored will become unstable.

Stability analysis also showed that GEN-2001-037 will trip off for a number of contingencies for winter and summer peak with and without the project. For winter and summer with and without the project, GEN-2001-037 will trip off on low voltage relay actuation for the following fault contingencies:

3. Permanent three-phase fault on the Mooreland to Glass Mountain 138 kV line with tripping and reclosing of the Mooreland to Glass Mountain 138 kV line.

4. Permanent three-phase fault on the Mooreland to GEN-2001-037 138 kV with tripping and reclosing of the Mooreland to GEN-2001-037 138 kV line.

For summer, pre-project and project cases GEN-2001-037 will trip off on low voltage relay actuation for the following fault contingencies:

3. Permanent three-phase fault on the Woodward to Iodine 138 kV line with tripping and reclosing of the Woodward to Iodine 138 kV line.

4. Permanent three-phase fault on the Mooreland to Iodine 138 kV line with tripping and reclosing of the Mooreland to Iodine 138 kV line.

The cases above with the project were re-run with wind turbine protection at GEN-2001-037 disabled. Results show that in the event that GEN-2001-037 were to remain connected after the above disturbances, the transmission grid will retain voltage stability.

Table 6: Summary of Fault Simulation Results with Mitsubishi 2.4 MW turbines

Cont. No.		*Description*	Winter Peak 2008			Summer Peak 2012		
			Pre-Project	With GEN-2006-046	With GEN-2006-046 and with GEN-2001-037 Trip disabled	Pre-Project	With GEN-2006-046	With GEN-2006-046 and with GEN-2001-037 Trip disabled
1	*FLT13PH*	3 phase fault on the Dewey (514787) to Iodine (514796) 138kV line, near Dewey.	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
2	FLT21PH	*Single phase fault and sequence like Cont. No. 1*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
3	*FLT33PH*	3 phase fault on the Dewey (514787) to Taloga (521065) 138 kV line, near Dewey.	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
4	FLT41PH	*Single phase fault and sequence like Cont. No. 3*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
5	*FLT53PH*	3 phase fault on the Dewey (514787) to Southard (514822) 138 kV line, near Dewey.	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
6	FLT61PH	*Single phase fault and sequence like Cont. No. 3*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
7	FLT73PH	3 phase fault on the Elk City (511458) to GEN-2002-005T (560000) 138 kV line, near Elk City.	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
8	FLT81PH	*Single phase fault and sequence like Cont. No. 7*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE

Cont. No.		Description	Winter Peak 2008			Summer Peak 2012		
			Pre-Project	With GEN-2006-046	With GEN-2006-046 and with GEN-2001-037 Trip disabled	Pre-Project	With GEN-2006-046	With GEN-2006-046 and with GEN-2001-037 Trip disabled
9	FLT93PH	3 phase fault on the Mooreland (520999) – Cedardale (520848) 138 kV line, near Cedardale.	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
10	FLT101PH	*Single phase fault and sequence like Cont. No. 9*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
11	FLT113PH	3 phase fault on the Mooreland (520999) – Glass Mtn. (514788) 138 kV line, near Mooreland.	STABLE GEN-2001-037 Trips off	STABLE GEN-2001-037 Trips off	STABLE	STABLE GEN-2001-037 Trips off	STABLE GEN-2001-037 Trips off	STABLE
12	FLT121PH	*Single phase fault and sequence like Cont. No.11*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
13	FLT133PH	3 phase fault on the Woodward (514785) – Iodine (OG&E) (514796) 138kV line near Woodward.	STABLE	STABLE	STABLE	STABLE GEN-2001-037 Trips off	STABLE GEN-2001-037 Trips off	STABLE
14	FLT141PH	*Single phase fault and sequence like Cont. No.13*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
15	FLT153PH	3 phase fault on the Cimarron autotransformer (514898-514901-515715)	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
16	FLT161PH	*Single phase fault and sequence like Cont. No.15*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
17	FLT173PH	3 phase fault on the Woodring autotransformer (514715-514714-515770)	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
18	FLT181PH	*Single phase fault and sequence like Cont. No.17*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE

Cont. No.		Description	Winter Peak 2008			Summer Peak 2012		
			Pre-Project	With GEN-2006-046	With GEN-2006-046 and with GEN-2001-037 Trip disabled	Pre-Project	With GEN-2006-046	With GEN-2006-046 and with GEN-2001-037 Trip disabled
19	FLT193PH	3 phase fault on the Mooreland (520999) – GEN-2001-037 (514785) 138 kV line, near Mooreland.	STABLE GEN-2001-037 Trips off	STABLE GEN-2001-037 Trips off	STABLE	STABLE GEN-2001-037 Trips off	STABLE GEN-2001-037 Trips off	STABLE
20	FLT201PH	*Single phase fault and sequence like Cont. No.11*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE
21	FLT213PH	3 phase fault on the Mooreland (520999) – Iodine (520957) 138kV line near Iodine.	STABLE	STABLE	STABLE	STABLE GEN-2001-037 Trips off	STABLE GEN-2001-037 Trips off	STABLE
22	FLT221PH	*Single phase fault and sequence like Cont. No.13*	STABLE	STABLE	STABLE	STABLE	STABLE	STABLE

APPENDIX A

DYNAMIC SIMULATION PLOTS

With Mitsubishi 2.4 MW Wind Turbine Generators

Winter Peak 2008

Summer Peak 2012

APPENDIX B

DYNAMIC SIMULATION PLOTS

With Mitsubishi 2.4 MW Wind Turbine Generators

With GEN-2001-037 Protection Disabled

Winter Peak 2008

Summer Peak 2012