SPP
Southwest
Power Pool

Impact Study for Generation Interconnection Request
GEN–2006–046

SPP Tariff Studies
(#GEN-2006-046)

April 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. The Impact Study for GEN-2006-046 was originally studied with Suzlon S88 2.1 MW wind turbines. This restudy analyzed the use of both Clipper 2.5MW wind turbines and Mitsubishi 2.3MW wind turbines.

Interconnection Facilities

The Impact Study has determined that a total of 23 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 has determined that a total of 28 Mvars of 34.5kV capacitor banks are necessary for the operation of GEN-2006-046 with Clipper 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 Clipper or 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 now posted in the Facility Study for GEN-2006-046. Please refer to the Facility Study for these costs.

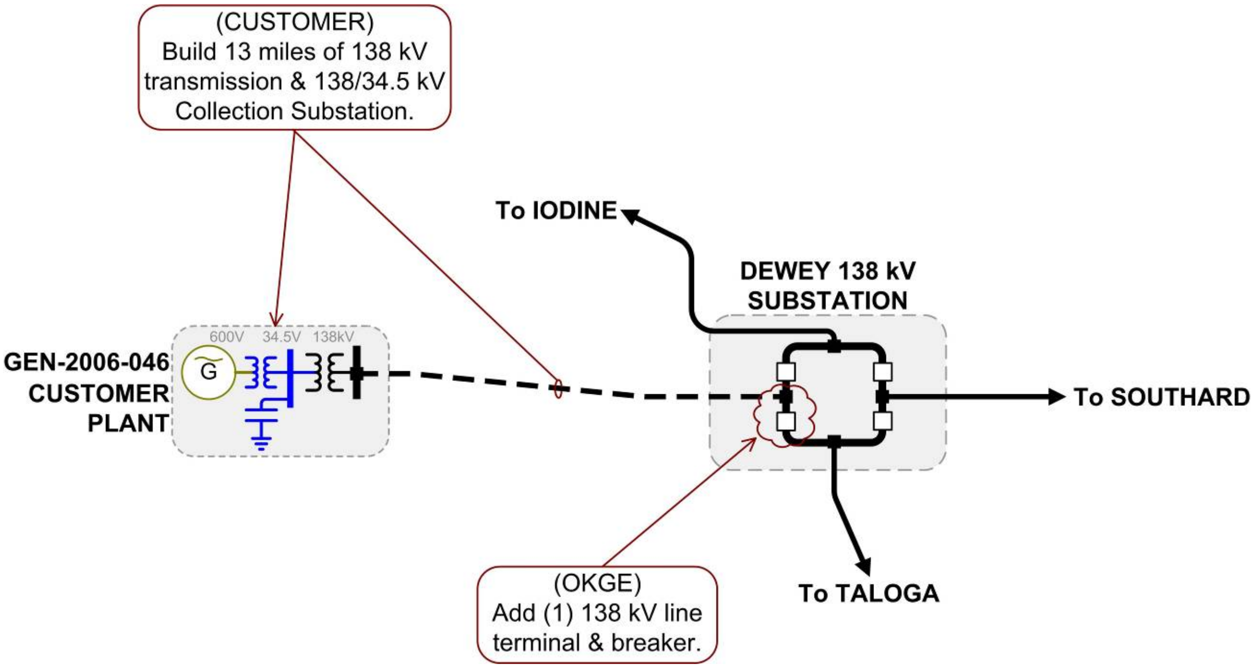
Table 1: Direct Assignment Facilities

FACILITY	ESTIMATED COST (2007 DOLLARS)
Customer – 138/34.5 kV Substation facilities.	*
Customer – 138 kV transmission line facilities between Customer facilities and the Dewey Substation.	*
Customer - Right-of-Way for Customer facilities.	
Customer – 34.5 kV capacitor bank(s) in Customer substation.	*
OKGE – Add 138 kV line terminal equipment including revenue metering at Dewey Substation	$589,697
Total	$589,697

Note: * Estimates of cost to be determined by Customer.

Table 2: Required Interconnection Network Upgrade Facilities

FACILITY	ESTIMATED COST (2007 DOLLARS)
OKGE – Add 138 kV circuit breaker, disconnect switches, and associated equipment at Dewey Substation	$135,000
Total	$135,000



(CUSTOMER)
Build 13 miles of 138 kV transmission & 138/34.5 kV Collection Substation.

(OKGE)
Add (1) 138 kV line terminal & breaker.

Figure 1: Proposed Interconnection
(Final substation design to be determined)

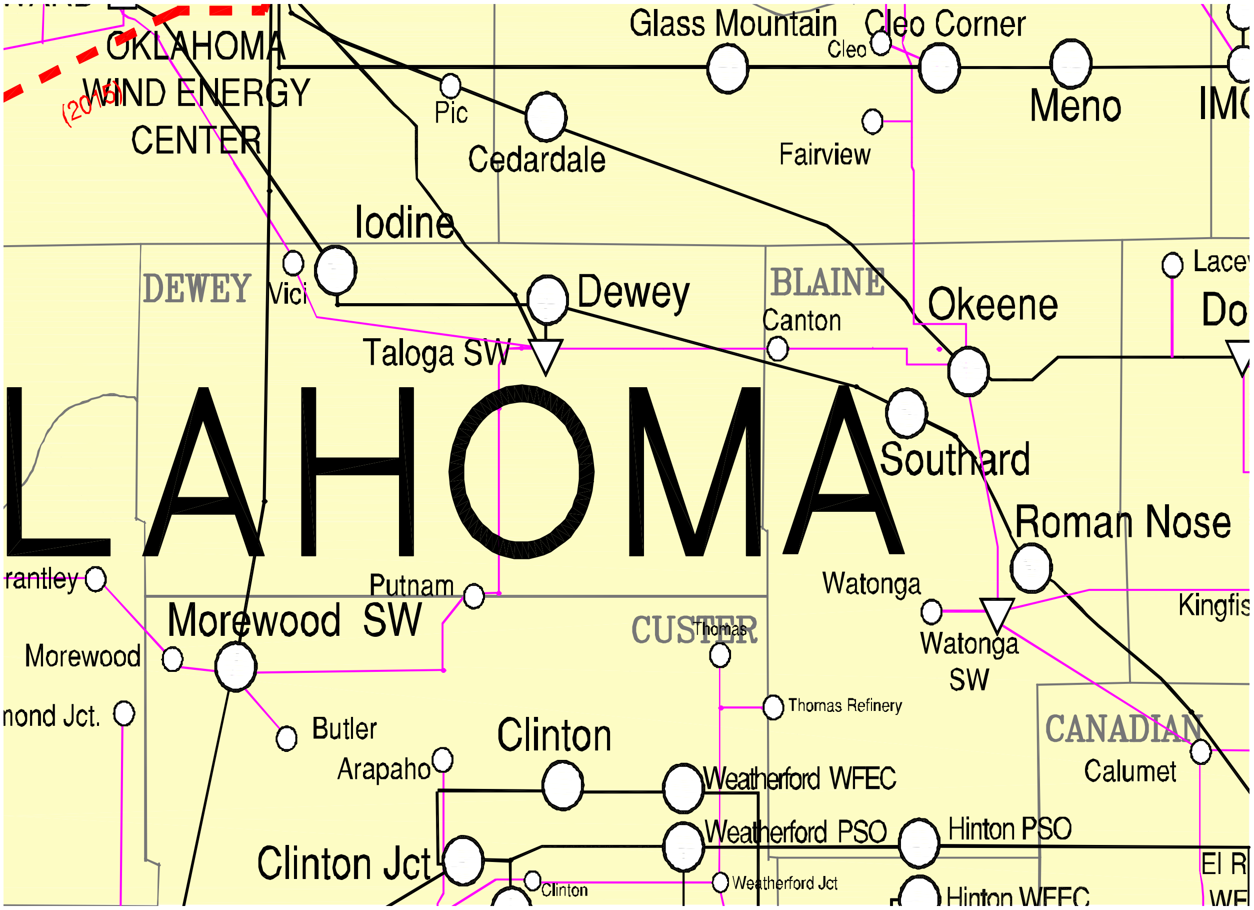


FIGURE 2. MAP OF THE LOCAL AREA

Report

For

Southwest Power Pool

From

S&C Electric Company

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

S&C Project No. 2775

March 9, 2007

S&C Electric Company

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

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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 for GEN-2006-046, a wind farm in Dewey County, Oklahoma with projected output of 122 MW to 130 MW to be interconnected to the existing Dewey 138 kV substation owned by (OKGE) Oklahoma Gas & Electric.

The main purpose of this study is to evaluate the impact of interconnecting GEN-2006-046 on electrical system stability and determine additional reactive compensation requirements to keep the project and prior queued wind farms connected after fault disturbances. 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. The studies were completed using 2.5 MW Clipper Liberty Series wind turbine generators per scope of work. The studies were also completed using 2.4 MW Mitsubishi MWT-95 wind turbine generators. SPP provided seasonal power flow cases for winter peak 2008 and summer peak 2012, wind turbine models, and project data.

The study results indicate that static shunt capacitors located at the 34.5 kV collector bus are needed to compensate for transmission and transformation losses given that the project is required to operate at unity power factor at the POI. During normal system contingency, wind farm rated output power, and with wind turbine generators operating at default unity power factor at the 690 V bus, this requirement is 28 MVARs at the 34.5 kV collector bus with the Clipper 2.5 MW turbines and 23 MVARs at 34.5 kV with the Mitsubishi 2.4 MW turbines. The composition of static shunt capacitors should consist of appropriately sized steps that can be switched in and out automatically by 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 with either 2.5 MW Clipper Liberty Series wind turbine generators or 2.4 MW Mitsubishi MWT-95 wind turbine generators 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 a collector system layout and impedance information. Each feeder is represented as a lumped generator to simplify representation in PSS/E. Shunt capacitance was added to each 34.5 kV collector bus and fixed transformer tap setting selected after looking at operating voltages within the wind farm.

Table 1: Power flow model parameters for GEN-2006-046 (Clipper wind turbines)

Feeder 1	Parameters
11 Clipper C93 2.5 MW wind turbine generators at 690 V	11 * 2.5 MW = 27.5 MW 11 * 2.5 MVA = 27.5 MVA Power factor at 690 V bus: 1.0
11 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	11 * 2.65 MVA = 29.15 MVA Z1 = 5.5% X/R = 4.9 (assumed) Z1 = 0.01100 + 0.05389j p.u. on 29.15 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.0214203+0.0215996j p.u. on 100 MVA base B1 = 0.00421 p.u. on 100 MVA base

Feeder 2	Parameters
12 Clipper C93 2.5 MW wind turbine generators at 690 V	12 * 2.5 MW = 30 MW 12 * 2.5 MVA = 30 MVA Power factor at 690 V bus: 1.0
12 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	12 * 2.65 MVA = 31.8 MVA Z1 = 5.5% X/R = 4.9 (assumed) Z1 = 0.01100 + 0.05389j p.u. on 31.8 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.01934371+0.01766742j p.u. on 100 MVA base B1 = 0.00418 p.u. on 100 MVA base

Feeder 3	Parameters
12 Clipper C93 2.5 MW wind turbine generators at 690 V	12 * 2.5 MW = 30 MW 12 * 2.5 MVA = 30 MVA Power factor at 690 V bus: 1.0
12 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	12 * 2.65 MVA = 31.8 MVA Z1 = 5.5% X/R = 4.9 (assumed) Z1 = 0.01100 + 0.05389j p.u. on 31.8 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.01813848+0.01890634j p.u. on 100 MVA base B1 = 0.00408 p.u. on 100 MVA base

Table 1: Power flow model parameters for GEN-2006-046 (Clipper wind turbines)

Feeder 4	Parameters
16 Clipper C93 2.5 MW wind turbine generators at 690 V	16 * 2.5 MW = 40 MW 16 * 2.5 MVA = 40 MVA Power factor at 690 V bus: 1.0
16 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	16 * 2.65 MVA = 42.4 MVA Z1 = 5.5% X/R = 4.9 (assumed) Z1 = 0.01100 + 0.05389j p.u. on 42.4 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.02540736+0.01884322j p.u. on 100 MVA base B1 = 0.00870 p.u. on 100 MVA base

Substation	Parameters
34.5 / 138 kV main transformer GSU	MVA ratings = 90/120/150 MVA Z1 = 10 % on self-cooled MVA rating X/R = 27.67 (assumed) Z1 = 0.00361 + j0.09993 p.u. on 90 MVA base Fixed HV tap setting = 5% above (144.9 kV)
Switched Shunt Capacitor at T1 34.5 kV collector bus	27 MVAR
Switched Shunt Capacitor at T2 34.5 kV collector bus	28 MVAR
138 kV transmission line, 13 miles, 795 MCM ACSR	Z1 = 0.00900 + j0.04917 p.u. on 100 MVA base (assumed) B1 = 0.01458 p.u. on 100 MVA base (assumed)

Table 2: Power flow model parameters for GEN-2006-046 (Mitsubishi wind turbines)

Feeder 1	Parameters
11 Mitsubishi MWT-85 2.4 MW wind turbine generators at 690 V	11 * 2.4 MW = 26.4 MW 11 * 2.52 MVA = 27.72 MVA Power factor at 690 V bus: 1.0
11 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	11 * 2.7 MVA = 29.7 MVA Z1 = 0.08j p.u. on 29.7 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.0214203+0.0215996j p.u. on 100 MVA base B1 = 0.00421 p.u. on 100 MVA base

Feeder 2	Parameters
12 Mitsubishi MWT-85 2.4 MW wind turbine generators at 690 V	12 * 2.4 MW = 28.8 MW 12 * 2.52 MVA = 30.24 MVA Power factor at 690 V bus: 1.0
12 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	12 * 2.7 MVA = 32.4 MVA Z1 = 0.08j p.u. on 32.4 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.01934371+0.01766742j p.u. on 100 MVA base B1 = 0.00418 p.u. on 100 MVA base

Feeder 3	Parameters
12 Mitsubishi MWT-85 2.4 MW wind turbine generators at 690 V	12 * 2.4 MW = 28.8 MW 12 * 2.52 MVA = 30.24 MVA Power factor at 690 V bus: 1.0
12 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	12 * 2.7 MVA = 32.4 MVA Z1 = 0.08j p.u. on 32.4 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.01813848+0.01890634j p.u. on 100 MVA base B1 = 0.00408 p.u. on 100 MVA base

Feeder 4	Parameters
16 Mitsubishi MWT-85 2.4 MW wind turbine generators at 690 V	16 * 2.4 MW = 38.4 MW 16 * 2.52 MVA = 40.32 MVA Power factor at 690 V bus: 1.0
16 Pad mounted wind turbine generator transformers 0.69 / 34.5 kV transformers	16 * 2.7 MVA = 43.2 MVA Z1 = 0.08j p.u. on 43.2 MVA base
Equivalent 34.5 kV collector system	Z1 = 0.02540736+0.01884322j p.u. on 100 MVA base B1 = 0.00870 p.u. on 100 MVA base

Table 2: Power flow model parameters for GEN-2006-046 (Mitsubishi wind turbines)

Substation	Parameters
34.5 / 138 kV main transformer GSU	MVA ratings = 90/120/150 MVA Z1 = 10 % on self-cooled MVA rating X/R = 27.67 (assumed) Z1 = 0.00361 + j0.09993 p.u. on 90 MVA base Fixed HV tap setting = 5% above (144.9 kV)
Switched Shunt Capacitor at T1 34.5 kV collector bus	22 MVAR
Switched Shunt Capacitor at T2 34.5 kV collector bus	23 MVAR
138 kV transmission line, 13 miles, 795 MCM ACSR	Z1 = 0.00900 + j0.04917 p.u. on 100 MVA base (assumed) B1 = 0.01458 p.u. on 100 MVA base (assumed)

2.1. Modeling of Wind Turbine Generators in Dynamics

Clipper Windpower Liberty Series Wind Turbine

The Clipper Windpower Liberty series is a 690 V, 2.5 MW inverter-based wind turbine generator. During steady-state, the inverters will operate at fixed power factor setpoint from 0.95 inductive to 0.95 capacitive. The wind turbine generators can be operated at capacitive power factor to compensate for collector, transformation and transmission losses thus requiring no additional switched capacitor banks to meet unity power factor at the POI. However, provision must be made to adjust the fixed power factor setpoint in response to varying wind farm output power levels and transmission system variations. Another option to meet unity power factor at the POI is to fix the power factor setpoint and automatically switch on and off capacitor bank steps with a SCADA/PLC system. The default power factor of the Clipper wind turbine generators is unity at the 690 V terminals. During normal system contingency, wind farm rated output power, and <u>fixed unity power factor at the 690 V bus</u>, there is a requirement of 28 MVARs at the 34.5 kV collector bus to compensate for transformation and transmission losses.

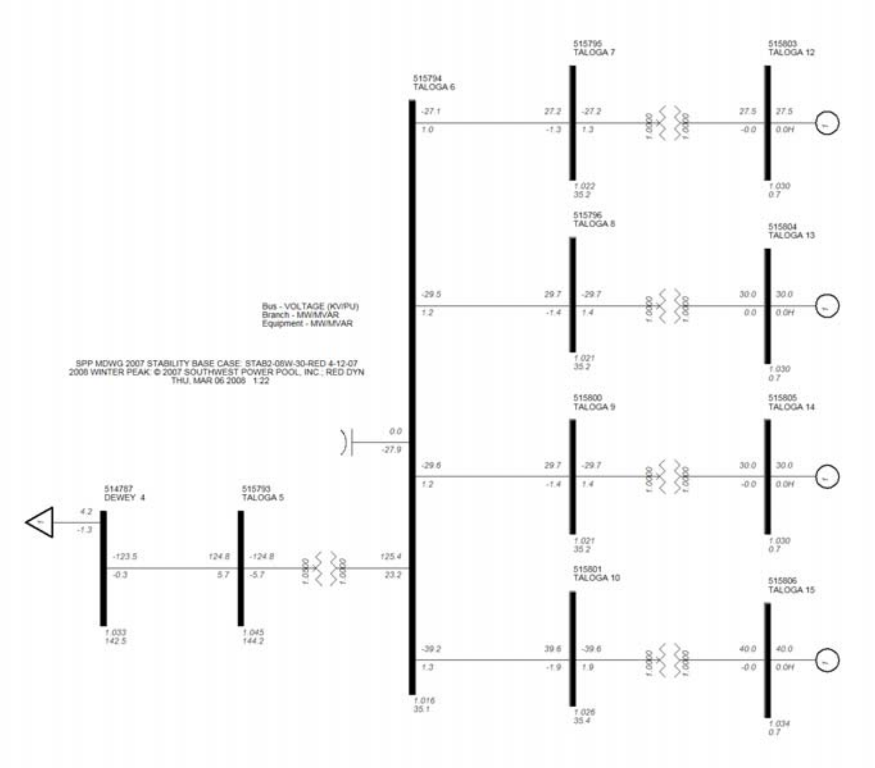

Figure 1: Winter peak 2008 power flow diagram with Clipper 2.5 MW turbines

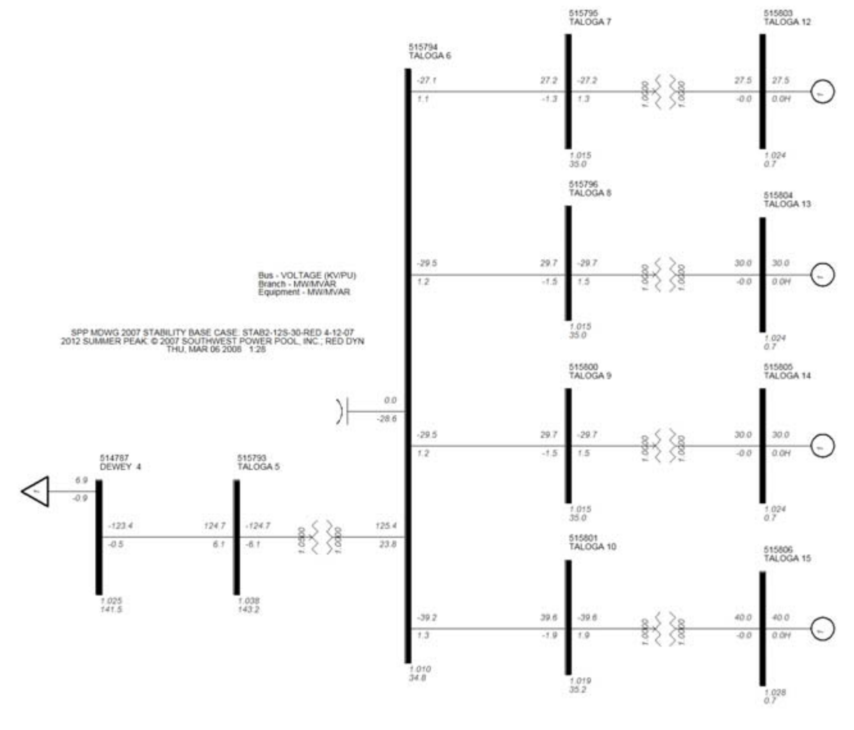

Figure 2: Summer peak 2012 power flow diagram with Clipper 2.5 MW turbines

Mitsubishi MWT-95 wind turbine generator

The Mitsubishi MWT-95 wind turbine generator is a 690 V, 2.4 MW DFIG (doubly-fed induction generator). Shunt capacitor banks of 0.11 MVAR, at 1 pu voltage are added to the 690 kV bus for each wind turbine generator. During steady-state, the wind turbine generators will operate with fixed power factor setpoint from 0.90 inductive to 0.95 capacitive. The wind turbine generators can be operated at capacitive power factor to compensate for all collector, transformation and transmission losses thus requiring no additional switched capacitor banks to meet unity power factor at the POI. However, provision must be made to adjust the fixed power factor setpoint in response to varying wind farm output power levels and transmission system variations. During normal system contingency, wind farm rated output power, and <u>fixed unity power factor at the 690 V bus</u>, there is a requirement of 23 MVARs at the 34.5 kV collector bus to compensate for transformation and transmission losses.

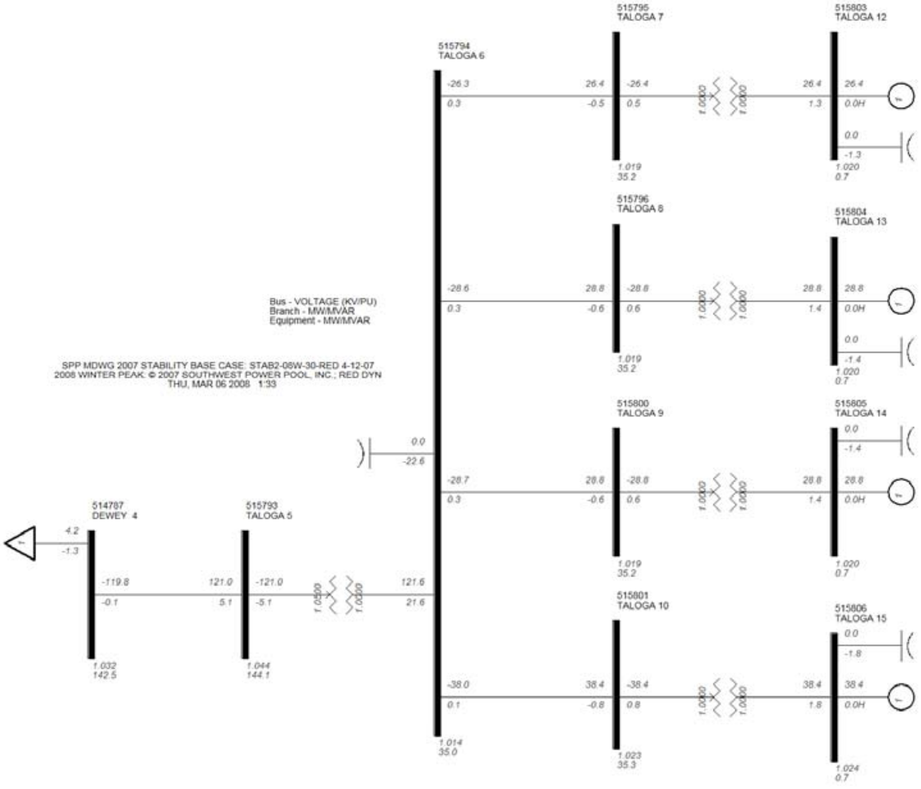

Figure 3: Winter peak 2008 power flow diagram with Mitsubishi 2.4 MW turbines

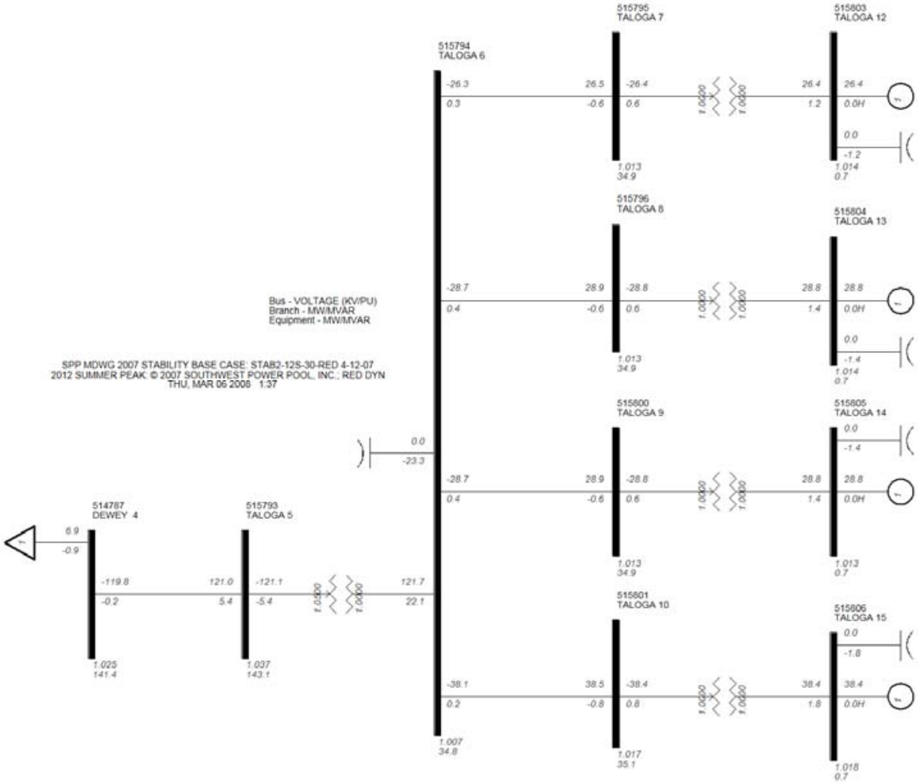

Figure 4: Summer peak 2012 power flow diagram with Mitsubishi 2.4 MW turbines

3. Dynamic Simulations and Voltage Stability Results

Dynamic simulations were performed for fault contingencies in Table 3 with and without GEN-2006-046.

Table 3: 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.

Cont. No.	*Cont. Name*	*Description*
12	FLT121PH	*Single phase fault and sequence like Cont. No.11*
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: 520, 526, 525, 524, 536, 539, 541

Prior queued projects monitored:

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. Pre-Project Dynamic Simulation

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.

PSS/E version 30.2.1 was used to perform dynamic stability studies.

Winter Peak 2008

Evaluation of SPP dynamic files for fault contingencies in Table 3 revealed tripping of prior queued project GEN-2005-008 for three-phase faults at Mooreland with tripping and reclosing of the Mooreland to GEN-2001-037 138 kV line (FLT193PH). The original GEN-2005-008 VTGTPA settings were replaced with new settings:

Before: 70% for 100 ms **After:** 70% for 625 ms

Also a 12 MVAR shunt capacitor was added to GEN-2001-014, 34.5 kV collector bus and main transformer tap set to 5% buck.

Wind turbine generators at GEN-2001-037 did not behave properly after a disturbance. Change to a GE wind turbine model input parameter was made per SPP input.

Pre-project study results indicate that GEN-2001-037 will trip off on the 70%, 100 ms under voltage setting for permanent three-phase faults at Mooreland with tripping and reclosing of the Mooreland to GEN-2001-037 138 kV line (FLT193PH).

Pre-project study results are summarized in Table 6 and re-listed in Table 7.

Summer Peak 2012

Permanent 3-phase faults at Iodine with tripping and reclosing of the Mooreland – Iodine 138kV line near Iodine (FLT213PH) will cause the output power of GEN-2001-014 Suzlon S88 wind turbine generators to chatter as the terminal voltages settle to 0.90 pu after fault clearing. It is possible that the chatter is the result of mode switching within the Suzlon S88 user-written model. The Suzlon S88 will trip off for voltages less than 0.90 pu. The following changes were made to raise the voltages above 0.90 pu and prevent output power chatter:

1. Set GEN-2001-014 main GSU primary winding tap to 5% buck.
2. Added a 12 MVAR switched shunt capacitor on GEN-2001-014 34.5 kV bus.

3. Added a 70 MVA, 138/69 kV transformer in parallel with existing transformer at FTSUPLY area.

GEN-2001-037 will trip off on the 70%, 100 ms under voltage setting for contingencies FLT133PH and FLT193PH. FLT133PH corresponds to permanent 3-phase faults at Woodward with tripping and reclosing of the 138 kV line from Woodward to Iodine (OG&E).

Pre-project study results are summarized in Table 6 and re-listed in Table 7.

3.2. Modeling of Wind Turbine Generators in Dynamics

Clipper Windpower Liberty Series Wind Turbine

The inverter-based design of Clipper wind turbine generators provides high performance voltage support for fault disturbances. Per direction from SPP, the power factor at 690 V is fixed at unity for these studies. Re-study may be required if assumptions on power factor at 690 V are different. For these studies, the default 93-m rotor length option was used for the inertia constant.

The PSS/E model of the Clipper wind turbine generator comes with built-in protection package. Voltage and frequency relay settings are summarized in Table 4.

Table 4: Clipper Windpower Liberty Series Wind Turbine trip settings

Relay type	Description	Trip setting and time delay	units
1st Undervoltage (27-1)	Relay trips if |Vbus|<	0.90	pu
	for t =	3.00	s
2nd Undervoltage (27-2)	Relay trips if |Vbus|<	0.10	pu
	for t =	0.10	s
1st Overvoltage (59-1)	Relay trips if |Vbus|>	1.10	pu
	for t =	5.00	s
2nd Overvoltage (59-2)	Relay trips if |Vbus|>	1.20	pu
	for t =	0.50	s
3rd Overvoltage (59-3)	Relay trips if |Vbus|>	1.30	pu
	for t =	0.10	s
Overfrequency (81O)	Relay trips if Fbus >	63.00	Hz
	for t =	0.10	s
Underfrequency (81U)	Relay trips if Fbus <	57.00	Hz
	for t =	0.10	s

PSS/E model C93g2 was used for dynamic stability analysis.

Mitsubishi MWT-95 Wind Turbine

The wind turbine generator will engage in Network Voltage Drop Help (NDH) when terminal voltages of the MWT-95 are outside of 0.9 pu to 1.1 pu. Reactive power output takes priority over real power to meet short-time reactive power demands. In steady-state, the NDH will not normally be active and active power will take priority over reactive power. The Mitsubishi wind turbine generator also feature crowbar protection. Voltage and frequency relay settings of the MWT-95 are summarized in Table 5.

Table 5: Mitsubishi MWT-95 trip settings

Relay type	Description	Trip setting and time delay	units
Undervoltage (27-1)	Relay trips if |Vbus|<	0.90	pu
	for t =	3.00	s
Undervoltage (27-2)	Relay trips if |Vbus|<	0.85	pu
	for t =	2.842	s
Undervoltage (27-3)	Relay trips if |Vbus|<	0.75	pu
	for t =	2.525	s
Undervoltage (27-4)	Relay trips if |Vbus|<	0.65	pu
	for t =	2.208	s
Undervoltage (27-5)	Relay trips if |Vbus|<	0.55	pu
	for t =	1.892	s
Undervoltage (27-6)	Relay trips if |Vbus|<	0.45	pu
	for t =	1.575	s
Undervoltage (27-7)	Relay trips if |Vbus|<	0.35	pu
	for t =	1.258	s
Undervoltage (27-8)	Relay trips if |Vbus|<	0.25	pu
	for t =	0.942	s
Undervoltage (27-9)	Relay trips if |Vbus|<	0.20	pu
	for t =	0.783	s
Undervoltage (27-10)	Relay trips if |Vbus|<	0.025	pu
	for t =	0.15	s
Overvoltage (59-1)	Relay trips if |Vbus|>	1.10	pu
	for t =	0.020	s
Overfrequency (81O)	Relay trips if Fbus >	61.00	Hz
	for t =	0.30	s
Underfrequency (81U)	Relay trips if Fbus <	59.00	Hz
	for t =	0.30	s

Per direction from SPP, the power factor at 690 V is fixed at unity for these studies. Re-study may be required if assumptions on power factor at 690 V are different.

PSS/E model MWT9295_PSSE30-2_rev3.lib was used for dynamic stability analysis.

3.3 Dynamic Simulations with GEN-2006-046

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 3 were studied for winter peak 2008 and summer peak 2012 with Mitsubishi MWT-95 2.4 MW and Clipper 2.5 MW wind turbines. Voltage recovers quickly after fault clearing and the project will survive all fault contingencies and thus comply with FERC Order 661A. Clipper and Mitsubishi output power, speed, terminal voltage, and frequency return to normal operating levels after the disturbance. The transmission system will retain voltage and frequency stability. 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 Clipper 2.5 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

Table 7: 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 Clipper 2.5 MW Wind Turbine Generators

WINTER PEAK 2008

SUMMER PEAK 2012

APPENDIX B

DYNAMIC SIMULATION PLOTS

With Clipper 2.5 MW Wind Turbine Generators

With GEN-2001-037 Protection Disabled

WINTER PEAK 2008

SUMMER PEAK 2012

APPENDIX C

DYNAMIC SIMULATION PLOTS

With Mitsubishi 2.4 MW Wind Turbine Generators

Winter Peak 2008

Summer Peak 2012

APPENDIX D

DYNAMIC SIMULATION PLOTS

With Mitsubishi 2.4 MW Wind Turbine Generators

With GEN-2001-037 Protection Disabled

Winter Peak 2008

Summer Peak 2012