Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2006–002

SPP Tariff Studies
(#GEN-2006-002)

December, 2006

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Pterra Consulting (Pterra) conducted the following Impact Study to satisfy the Impact Study Agreement executed by the requesting customer and SPP for SPP Generation Interconnection request GEN-2006-002. 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.

Interconnection Facilities

The Impact Study determined that a 34.5kV, 28MVAR capacitor bank is required to be installed in the Customer interconnection substation in order to accommodate for reactive power losses on the wind turbine collector circuits and associated transformers. The Impact Study determined that no SVC or STATCOM is required for the interconnection request to comply with FERC Order #661A. Estimates for the Interconnection Facilities were given in the Feasibility Study. These estimates are given again in Table 1 and Table 2. **These costs do not include any cost that might be associated with short circuit study results**. These costs and a further refinement of the facilities listed in Table 1 and Table 2 will be determined when and if a Facility Study is conducted.

Table 1: Direct Assigned Facilities

Facility	ESTIMATED COST (2006 DOLLARS)
Customer – 230-34.5 kV Substation facilities.	*
Customer – 230kV transmission line facilities between Customer facilities and AEP 230kV switching station	*
Customer - Right-of-Way for Customer facilities.	*
Customer – 34.5kV, 30MVAR capacitor bank in Customer substation	
Total	*****

Table 2: Interconnection Facility Network Upgrades

Facility	ESTIMATED COST (2006 DOLLARS)
AEP – Build 230kV, 3-breaker ring bus switching station. Station to include breakers, switches, control relaying, high speed communications, all structures and metering and other related equipment	$3,500,000
Total	**$3,500,000**

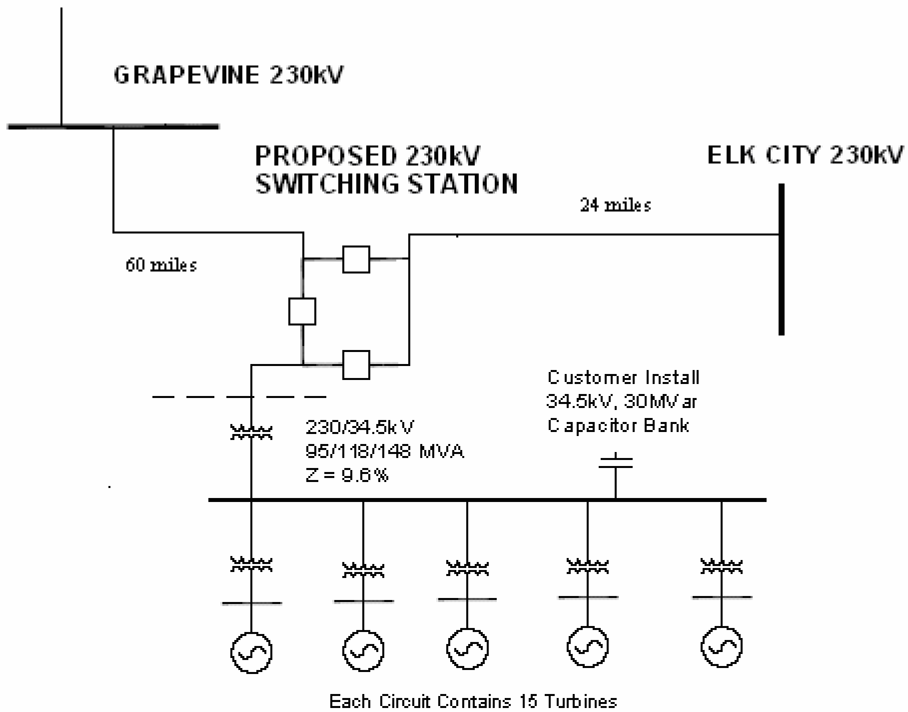

Figure 1: Proposed Interconnection
(Final substation design to be determined

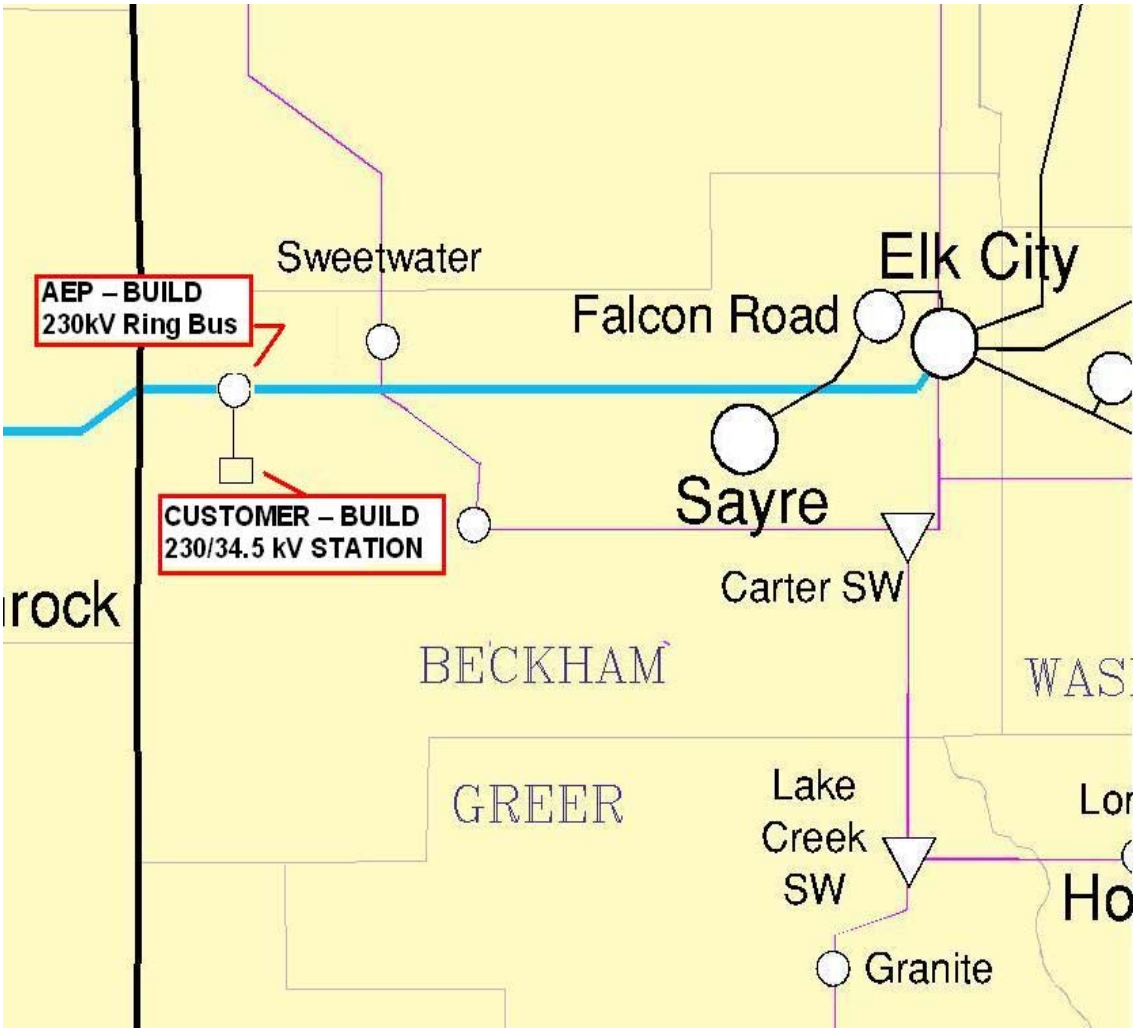

Figure 2: Map Of The Surrounding Area

Pterra Consulting

Report No. R139-06

"Impact Study for Generation Interconnection Request GEN-2006-002"

Submitted to

The Southwest Power Pool

November 2006

Pterra

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"Impact Study for Generation Interconnection Request GEN-2006-002"

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1. Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (GEN-2006-002). The analysis was conducted through the Southwest Power Pool Tariff for a 230 kV interconnection for 150 MW wind farm in Beckham County, Oklahoma. This wind farm will be interconnected into the existing Grapevine – Elk City 230 kV transmission line which is a tie line partially owned by American Electric Power (AEP) and Southwestern Public Service. The wind farm will be interconnected to a new substation located on the AEP portion of the line. The customer has asked for an Impact study case of 100% MW. Gamesa G87 2.0 MW wind turbine generators (WTGs) were studied according to the customer's request.

Two base cases each comprising of a power flow and corresponding dynamics database for 2006 summer and winter were provided by SPP. Transient stability simulations were conducted with the proposed wind farm in service with a full output of 150 MW. In order to integrate the proposed 150 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched as provided by SPP. In order to achieve unity power factor at the interconnection point, a capacitor bank of 28 MVAR would be needed.

Sixteen (16) disturbances were considered for the transient stability simulations which included 3-phase faults, as well as, 1-phase to ground faults, at the locations defined by SPP.

The proposed WTGs were modeled with under/over voltage/frequency ride through protection. The settings were in accordance with standard or default settings. The simulations conducted in the study using the Gamesa G87 2.0 MW WTGs did not find any angular or voltage instability problems for the sixteen disturbances. However, for peak summer and winter loading conditions, tripping of two prior queued projects was observed as follows:

- For disturbance #9, (3-phase fault Elk City 138kV bus), prior queued projects GEN-2003-022 and GEN-2004-020 (147.5 MW of GE turbines) tripped due to relay actuation for low voltage.

- Disturbance #15 (3-phase fault at Kirby 115 kV bus), prior queued project GEN-2005-021(85.5MW wind farm with (57) GE 1.5 MW turbines) tripped due to relay actuation for low voltage.

2. Introduction

2.1 Project Overview

The proposed 150 MW wind farm will be interconnected to a new 230 kV switching station on the Elk City– Grapevine 230 kV transmission line. A new 230 kV line from the new switching station to the wind farm collector bus will be built. Figure 1 shows the interconnection diagram of the proposed GEN-2006-002 project to the 230 kV transmission network. The detailed connection diagram of the wind farm was provided by SPP.

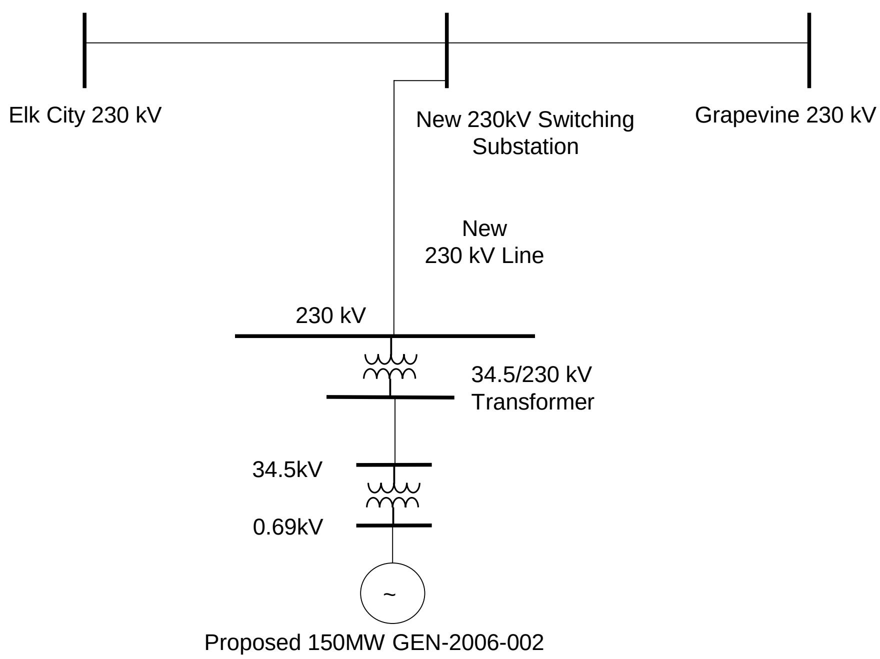

Figure 1 Interconnection Plan for GEN-2006-002 to the 230 kV System

In order to integrate the proposed 150 MW wind farm in SPP system as an Energy Resource, existing generation in the SPP footprint is displaced to maintain current area interchange totals.

To simplify the model of the wind farm while capturing the effect of the different impedances of cables (due to change of the conductor size and length), the wind turbines connected to the same 34.5kV feeder end points were aggregated into one equivalent unit. An equivalent impedance of that feeder is represented by taking the equivalent series impedances of the different feeders connecting the wind turbines. Using this approach, the proposed 150MW wind farm was modeled with 25 equivalent units (Gamesa G87 2.0MW WTGs) as shown in Figure 2. The number in each circle in the diagram shows the number of individual wind turbine units that were aggregated at that bus. SPP provided the impedance values for the different feeders at 34.5kV level. SPP provided the data for the following equipment:

1. 34.5 kV feeders
2. Generating unit step up transformers
3. 230/34.5 kV transformers
4. Parameters for the new 230 kV line.

In order to achieve unity power factor at the interconnection point, a capacitor bank of 28 MVAR would be needed.

2.2 Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 150 MW wind farm to SPP's 230 kV transmission system.

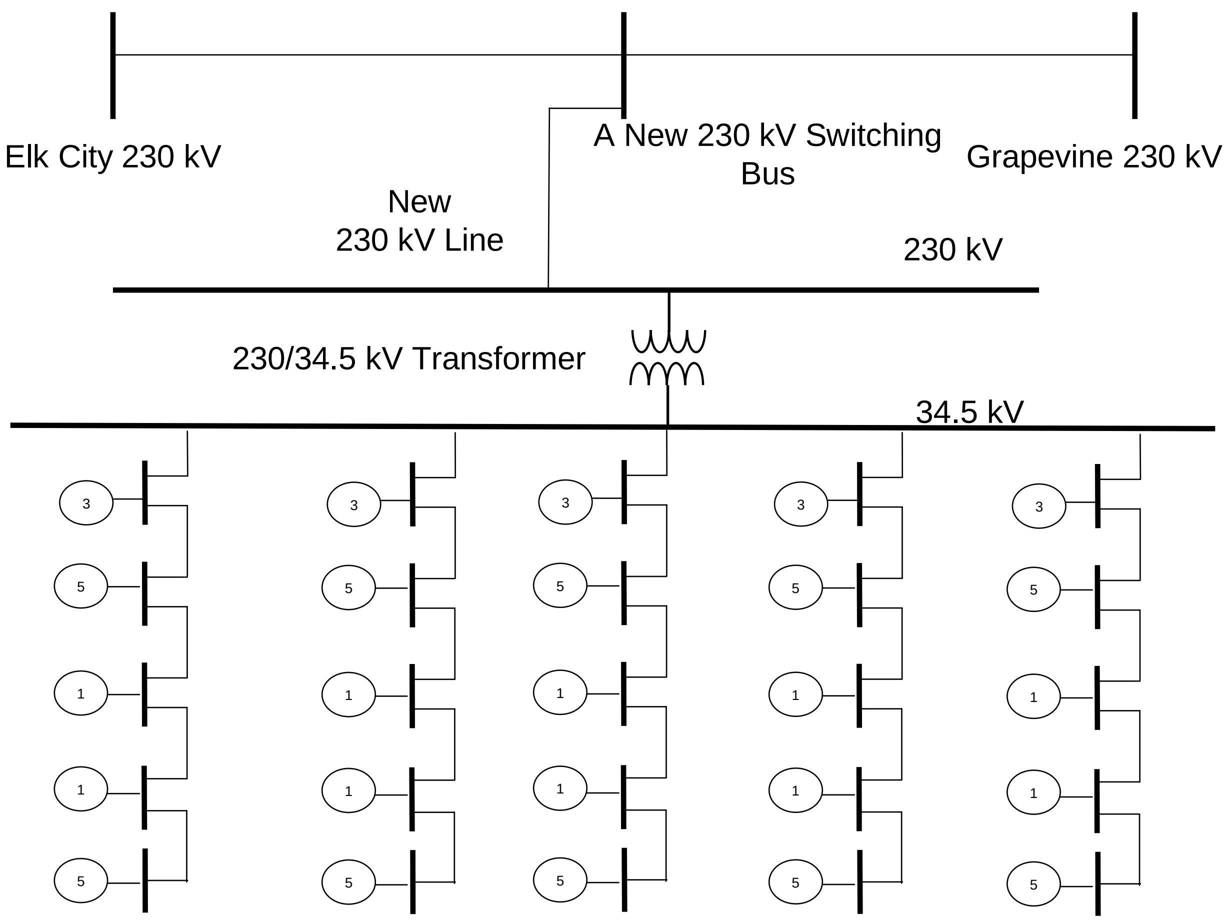

Figure 2 Wind Farm Model in Load Flow (75 Gamesa G87 2.0 MW WTGs)

3. Stability Analysis

3.1 Modeling of the Gamesa G87 2.0 MW Wind Turbine Generators

Equivalents for the wind turbine and generator step-up (GSU) transformer in the load flow case were modeled. For the stability simulations, the Gamesa G87 2.0 MW wind turbine generators were modeled using the provided Gamesa G87 2.0 MW wind turbine dynamic model set.

Table 1 Gamesa G87 2.0 MW Wind Generator Data

Parameter	Value
BASE KV	0.69
WTG MBASE	2.00
TRANSFORMER MBASE	2.50
TRANSFORMER R ON TRANSFORMER BASE	0.006
TRANSFORMER X ON TRANSFORMER BASE	0.060
GTAP	1.00
PMAX (MW)	2.00
PMIN	0.0
RA	0.01022
LA	0.14238
LM DELTA	7.21137
LM D Y	6.94532
L1	0.17503
RMACH	0.01008

The wind turbine generators have ride-through capability for voltage and frequency. Detailed relay settings are shown in the following tables:

Table 2 Over/Under Frequency Relay Settings for Gamesa G87 2.0 MW Wind Turbine Generators

Frequency Settings in Hertz	Time Delay in Seconds	Breaker time in Seconds
F ≤ 57.0	Instantaneous	0.05
F ≥ 62.0	Instantaneous	0.05

Table 3 Over/Under Voltage Relay Settings for Gamesa G87 2.0 MW Wind Turbine Generators

Voltage Settings Per Unit	Time Delay in Seconds	Breaker time in Seconds
V ≤ 0.15	0.04	0.05
0.15 < V ≤ 0.30	0.625	0.05
0.30 < V ≤ 0.45	1.10	0.05
0.45 < V ≤ 0.60	0.06	0.05
0.60 < V ≤ 0.75	2.050	0.05
0.75< V ≤ 0.90	2.525	0.05
V ≥ 1.10	1.00	0.05

3.2 Assumptions

The following assumptions were adopted for the study:

1. Constant maximum and uniform wind speed for the entire period of study.
2. Wind turbine control models with their default values.
3. Under/over voltage/frequency protection set to standard manufacturer data.

3.3 Disturbances Simulated

Sixteen (16) disturbances were considered for the transient stability simulations which included three phase faults, as well as single phase line faults, at the locations defined by SPP. Single-phase line faults were simulated by applying a fault impedance to the positive sequence network at the fault location to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice. Table 4 shows the list of simulated disturbances. The table also shows the fault clearing time and the time delay before re-closing for all the study disturbances.

Several prior queued projects in the base cases were monitored. These projects are:

a. GEN-2003-004,GEN-2004-023,GEN-2005-003; 151MW of Vestes V80 1.8MW turbines
b. GEN-2003-005, 100MW of Vestes V80 1.8MW turbines
c. GEN-2003-022, GEN-2004-020; 147.5 MW of GE turbines
d. GEN-2003-020; 160MW wind farm with (106) GE 1.5 MW turbines
e. GEN-2004-003; 240MW wind farm with (160) GE 1.5MW turbines
f. GEN-2005-021; 85.5MW wind farm with (57) GE 1.5 MW turbines
g. GEN-2005-022; two combustion turbines with a combined output of 180MW

Table 4 List of Simulated Disturbances

Cont. No.	Name	Description
1	FLT13PH	3 phase fault on the Wind Farm (54212) to Grapevine (50827) 230 kV line, near the Wind Farm. a. Apply fault at the Wind Farm 230kV bus. b. Clear fault after 5 cycles by tripping the line from the Wind Farm-Grapevine. 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 Wind Farm (54212) to Elk City (54153) 230 kV line, near the Wind Farm. a. Apply fault at the Wind Farm 230kV bus. b. Clear fault after 5 cycles by tripping the line from the Wind Farm-Grapevine. 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 Clinton Jct (54148) – Elk City (54121) 138kV line, near Clinton Jct. a. . Apply fault at the Clinton Jct 138kV bus. b. Clear fault after 3.5 cycles by tripping the line from the Elk City – Clinton Jct c. Use 3 shot re-closing at 6 cycles, 120 cycles, and 180 cycles for the line in (b) into the fault.. d. Leave fault on for 15 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 Moorewood (56001) – Elk City (54121) 138kV line, near Elk City. a. . Apply fault at the Elk City 138kV bus. b. Clear fault after 3.5 cycles by tripping the line from the Elk City – Moorewood c. Use 2 shot re-closing at 30 cycles, and 120 cycles for the line in (b) into the fault..

Cont. No.	Name	Description
		d. Leave fault on for 15 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 Hobart Jct – Elk City (54121) 138kV line, near Elk City. a. . Apply fault at the Elk City 138kV bus. b. Clear fault after 3.5 cycles by tripping the line from the Elk City – Hobart Jct c. Use 2 shot re-closing at 30 cycles, and 120 cycles for the line in (b) into the fault.. d. Leave fault on for 15 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 Grapevine (50827) – Nichols (50915) 230kV line near Grapevine. a. Apply fault at the Grapevine bus. b. Clear fault after 5 cycles by tripping the line Grapevine-Nicols 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	FLT101PH	Single phase fault and sequence like Cont. No.11
13	FLT133PH	3 phase fault on the Grapevine 230/115kV autotransformer on the 230kV bus a. Apply fault at the Grapevine 230kV bus. b. Clear fault after 5 cycles by tripping the autotransformer c. No reclose
14	FLT141PH	Single phase fault and sequence like Cont. No.13
15	FLT153PH	3 phase fault on the Kirby (50932) – Conway (50928) 115kV line near Kirby a. Apply fault at the Kirby bus. b. Clear fault after 5 cycles by tripping the line Kirby-Conway 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	FLT161PH	Single phase fault and sequence like Cont. No.13

3.5 Simulation Results

Simulations were performed with a 0.1-second steady-state run followed by the appropriate disturbance as described in Table 4. Simulations were run for a minimum 10-second duration to confirm proper machine damping.

The results of the stability simulations, for the disturbances listed in Table 4, did not find any angular or voltage instability problems with the Gamesa G87 2.0 MW WTGs. However, for peak summer and winter loading conditions, tripping of two prior queued projects was observed as follows:

- For disturbance #9, (3-phase fault Elk City 138kV bus), prior queued projects GEN 2003-022 and GEN 2004-020 (147.5 MW of GE turbines) tripped due to relay actuation for low voltage.

- For Disturbance #15 (3-phase fault at Kirby 115 kV bus), prior queued project GEN 2005-021(85.5MW wind farm with (57) GE 1.5 MW turbines) tripped due to relay actuation for low voltage.

4. Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2006-002) were presented in this report. The impact study case considered 100% MW of the wind farm proposed output. Gamesa G87 2.0 MW WTGs were studied according to the customer request.

The 2006 summer and winter load flow cases together with the necessary data needed for the transient stability simulations were provided by SPP. Transient stability simulations were conducted with the proposed wind farm in service with a full output of 150 MW. In order to integrate the proposed 150MW wind farm in SPP system, re-dispatch for the existing SPP footprint generation was provided by SPP. In order to achieve unity power factor at the interconnection point, a capacitor bank of 28 MVAR would be needed

Sixteen (16) disturbances were considered for the transient stability simulations which included three phase faults, as well as single line to ground faults, at the locations defined by SPP.

The results of the stability simulations for the studied disturbances did not find any angular or voltage instability problems with the Gamesa G87 2.0 MW WTGs. However, for peak summer and winter loading conditions, tripping of two prior queued projects was observed as follows:

- For disturbance #9, (3-phase fault Elk City 138kV bus), prior queued projects GEN 2003-022 and GEN 2004-020 (147.5 MW of GE turbines) tripped due to relay actuation for low voltage.

- For disturbance #15 (3-phase fault at Kirby 115 kV bus), prior queued project GEN 2005-021(85.5MW wind farm with (57) GE 1.5 MW turbines) tripped due to relay actuation for low voltage.