Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2006–003

SPP Tariff Studies
(#GEN-2006-003)

January, 2007

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-2006-003. The Customer originally requested interconnection of 50MW into the Tarkio-Burlington Jct. 69kV line on the Aquila transmission system. After the Feasibility Study, the Customer requested to lower the request to 36MW. 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.

<u>Interconnection Facilities</u>

The Impact Study determined that the Customer's wind farm will draw approximately 5MVar during normal operation. The Customer is responsible for maintaining a power factor in the range of 95% lagging to 95% leading for conditions in which a lower than normal voltage may occur. For this situation, the Customer will be required to install a 34.5kV, 4800kVar capacitor bank on the 34.5kV substation bus of the Customer's substation. The Customer's capacitor bank shall have a minimum of two stages of 2400kVar each in order to accommodate for reactive power losses on the wind turbine collector circuits and associated transformers when system conditions allow the operation of the capacitor bank. The Impact Study determined the capacitor bank may not be placed in operation during normal operations, but could be needed for low voltage conditions. 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.

<u>Table 1: Direct Assigned Facilities</u>

Facility	ESTIMATED COST (2006 DOLLARS)
Customer – 69-34.5 kV Substation facilities.	*
Customer – 69kV transmission line facilities between Customer facilities and AQU 69kV switching station	*
Customer - Right-of-Way for Customer facilities.	*
Customer – 34.5kV, 4.8MVar staged capacitor bank in Customer substation	*
Total	

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

Table 2: Interconnection Facility Network Upgrades

Facility	ESTIMATED COST (2006 DOLLARS)
AQU – Build 69kV switching station. Station to include breakers, switches, control relaying, high speed communications, all structures and metering and other related equipment	$1,100,000
Total	**$1,100,100**

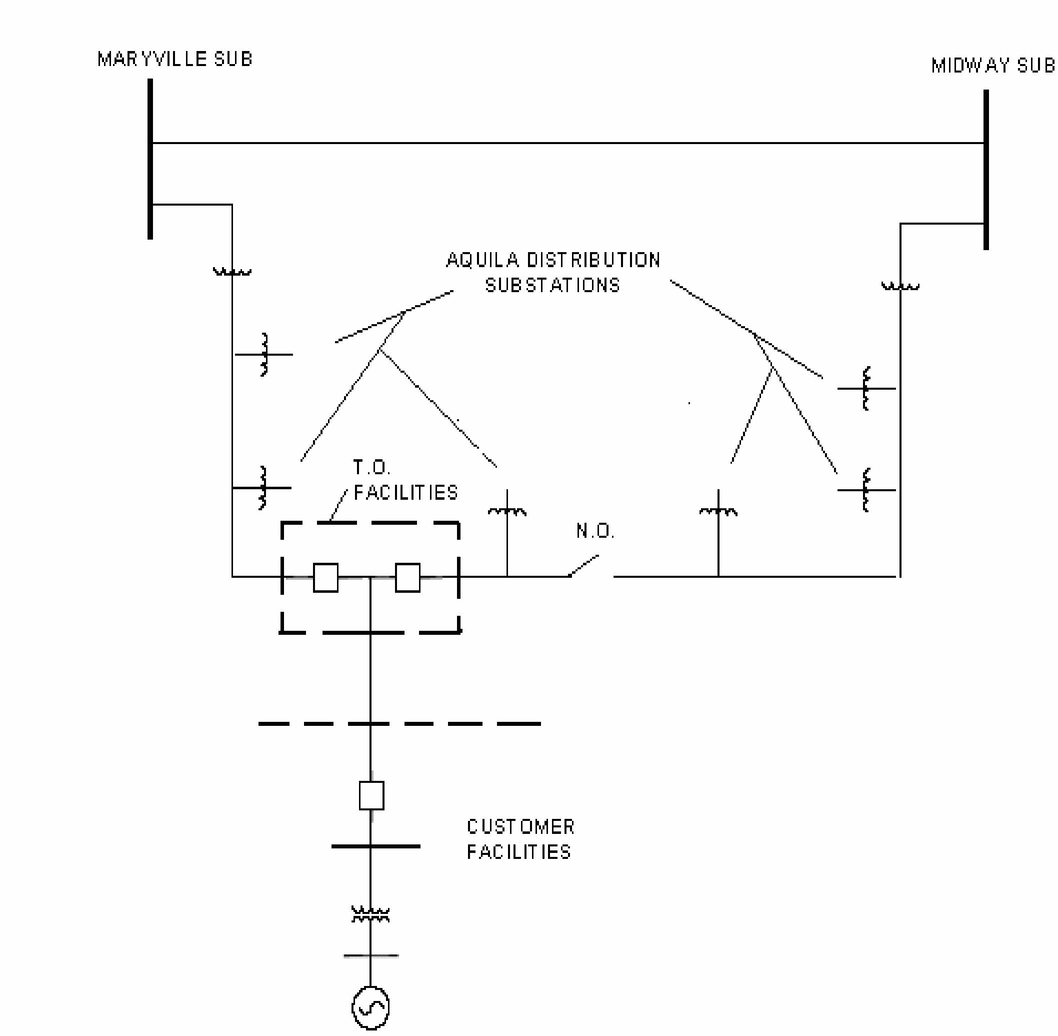

Figure 1: Proposed Interconnection (Final substation design to be determined

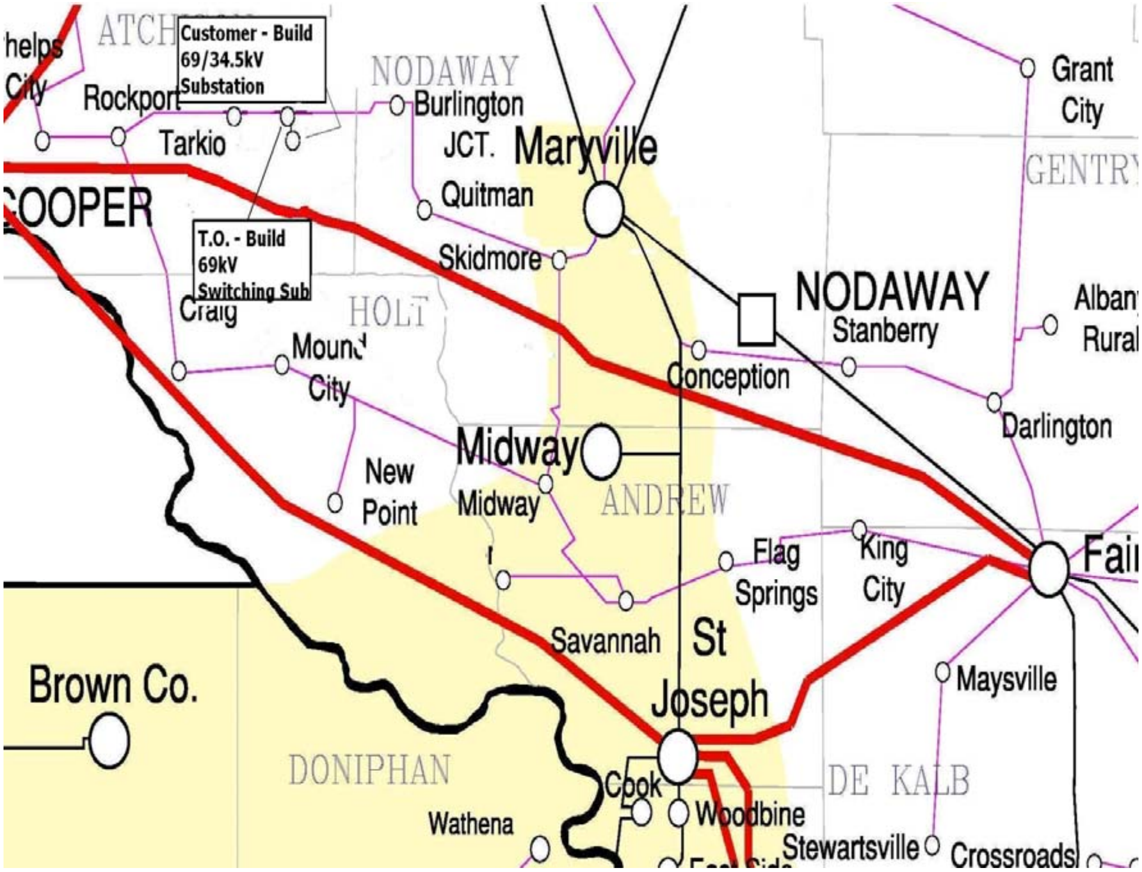

Figure 2: Map of the Local Area

Pterra Consulting

Report No. R144-06

"Impact Study for Generation Interconnection Request GEN-2006-003"

Submitted to

The Southwest Power Pool

December 2006

Pterra

4 Automation Lane, Ste.250, Albany, NY 12205 Tel: 518-724-3832 Web: www.pterra.us

Report No. R144-06

"Impact Study for Generation Interconnection Request GEN-2006-003"

1. Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (GEN-2006-003). The analysis was conducted through the Southwest Power Pool Tariff for a 69 kV interconnection for a 36 MW wind farm in Atchison County, Missouri. This wind farm will be interconnected into the Tarkio – Burlington Jct. 69kV transmission line. This line is owned by Aquila. 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 36 MW. In order to integrate the proposed 36 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched as provided by SPP. Unity power factor at the interconnection point, could not be achieved by using capacitor banks because of high voltage criteria violations in the neighborhood of the interconnection point.

Fifteen (15) 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 fifteen disturbances. However, for peak summer and winter loading conditions, tripping of the projects was observed when changing the wind farm from Maryville source to Midway source (Disturbance #15) because of relay actuation for low voltage. It should be noted that, the detected low voltage condition following disturbance #15 is not related to the addition of the proposed 36 MW wind farm since it's an existing pre-project condition; therefore, no dynamic reactive compensation is required by the Customer.

2. Introduction

2.1 Project Overview

The proposed 36 MW wind farm will be midway between the Tarkio and Burlington Jct. 69kV. Figure 1 shows the interconnection diagram of the proposed GEN-2006-003 project to the 69 kV sub-transmission network. The detailed connection diagram of the wind farm was provided by SPP.

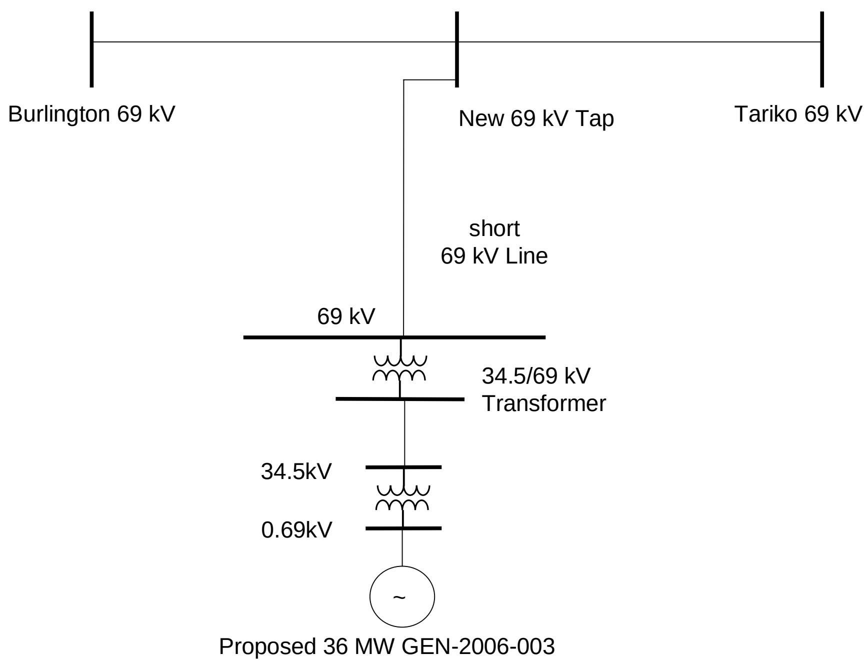

Figure 1 Interconnection Plan for GEN-2006-003 to the 69 kV System

In order to integrate the proposed 36 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 36 MW wind farm was modeled with 4 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. 69/34.5 kV transformers

Unity power factor could not be achieved at the interconnection point using capacitor banks because of high voltage criteria violations in the neighborhood of the interconnection point.

2.2 Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 36 MW wind farm to SPP's 69 kV sub-transmission system.

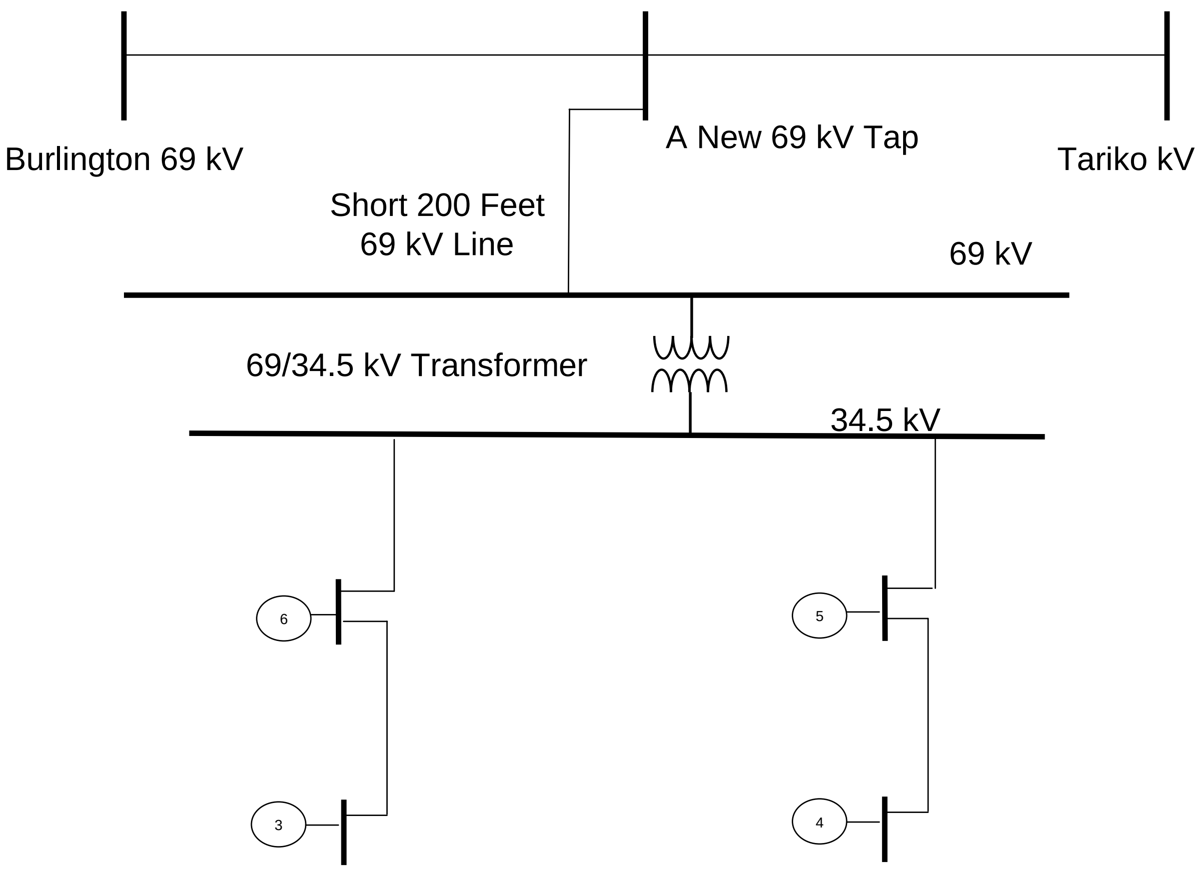

Figure 2 Wind Farm Model in Load Flow (18 Gamesa G87 2.0 MW WTGs)

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	1.575	0.05
0.60 < V ≤ 0.75	2.050	0.05
0.75< V ≤ 0.90	2.525	0.05
V ≥ 1.10	0.06	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

Fifteen (15) 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.

No prior queued projects in the base cases were monitored.

Table 4 List of Simulated Disturbances

Cont. No.	***Cont. Name***	***Description***
1	*FLT13PH*	3 phase fault on the Maryville (59251) to Midway (59252) 161kV line, near Maryville. a. Apply fault at the Maryville. b. Clear fault after 5 cycles by tripping the line from Maryville-Midway 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 Maryville (59251) to AECI Maryville (96097) 161kV line, near Maryville. a. Apply fault at the Maryville. b. Clear fault after 5 cycles by tripping the line from Maryville- AECI Maryville 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 Maryville (59251) to Clarinda (63826) 161kV line, near Maryville. a. Apply fault at the Maryville. b. Clear fault after 5 cycles by tripping the line from Maryville- Clarinda 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 AECI Maryville (96097) to AECI Nodaway (96104) 161kV line, near AECI Maryville. a. Apply fault at the AECI Maryville. b. Clear fault after 5 cycles by tripping the line from AECI Maryville- Nodaway 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 AECI Maryville (96097) to Creston (66560) 161kV line, near AECI Maryville. a. Apply fault at the AECI Maryville. b. Clear fault after 5 cycles by tripping the line from AECI Maryville- Creston

Cont. No.	Cont. Name	Description
		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.7*
11	FLT113PH	3 phase fault on the AECI Maryville (96097) to Creston (66560) 161kV line, near AECI Maryville. a. Apply fault at the Creston. b. Clear fault after 5 cycles by tripping the line from AECI Maryville- Creston 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.7*
13	FLT133PH	3 phase fault on the Wind Farm (96015) to Tarkio (59363) 69kV line, near the Wind Farm. a. Apply fault at the Wind Farm. b. Clear fault after 5 cycles by tripping the line from the Wind Farm-Tarkio 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.7*
15	FLT15SW	Change wind farm from Maryville source to Midway source a. Close switch between Craig (59365) and Mound City (59366) b. Wait 300 cycles and open switch between Maryville (59359) and Pickering (59379)

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 the projects was observed when changing the wind farm from Maryville source to Midway source (Disturbance #15) because of relay actuation for low voltage. The voltage at the collector buses is 0.749 P.U. The low voltage condition is not related to the addition of the proposed 36 MW wind farm. It’s an existing pre-project condition; therefore, no dynamic reactive compensation is required by the Customer.

For the two base cases studied, a complete set of the transient stability plots for rotor angle, speed, frequency, and voltages for the monitored buses in SPP for the simulated (15) disturbances with the proposed 36 MW wind farm in service, are in an electronic format on the accompanying CD.

4. Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2006-003) 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 36 MW. In order to integrate the proposed 36 MW wind farm in SPP system, re-dispatch for the existing SPP footprint generation was provided by SPP. Unity power factor at the interconnection point could not be achieved because of high voltage criteria violations in the neighborhood of the interconnection point.

Fifteen (15) 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 the projects was observed when changing the wind farm from Maryville source to Midway source (Disturbance #15) because of relay actuation for low voltage. The detected low voltage condition following disturbance #15 is not related to the addition of the proposed 36 MW wind farm since it’s an existing pre-project condition; therefore, no dynamic reactive compensation is required by the Customer.