Southwest Power Pool

Impact Study
For
Generation Interconnection Request
GEN-2006-014

SPP Tariff Studies

(#GEN-2006-014)

February, 2007

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Pterra Consulting Inc. (Pterra) performed the following Impact Study to satisfy the Impact Study Agreement executed by the requesting Customer and SPP for SPP Generation Interconnection request #GEN-2006-014.

Reactive Compensation Required

The Impact Study determined that a total of 75Mvar of 34.5kV substation capacitor banks are necessary for the interconnection of the proposed wind farm. This amount of capacitors is due mainly to the size of the proposed wind farm (300MW) and the distance of the wind farm substation from the proposed interconnection substation (28 miles).

The Customer wind farm was studied with the assumption that the Customer will be using General Electric 1.5 MW wind turbines, per Customer request. In order to comply with FERC Order 661 A low voltage ride through provisions, the Customer shall purchase the wind turbines with the manufacturer's LVRT II package, which allows the wind turbines to withstand voltage below 0.15 pu for 625 milliseconds. When this LVRT package is in use, no SVC or STATCOM device will be necessary.

Interconnection Facilities

The estimated Customer Facility costs were given in the Feasibility Study. These costs have been restated below in Table 1. and Table 2. These costs will be estimated in detail by the Transmission Owner during a Facility Study, if the Customer wishes to execute a Facility Study Agreement for this generation interconnection request.

Table 1. Customer Interconnection Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
Customer – 161-34.5 kV Substation facilities.	*
Customer – 161kV transmission line facilities between Customer facilities and MIPU 161kV switching station	*
Customer - Right-of-Way for Customer facilities	*
Customer – 34.5kV, 75MVAR capacitor bank(s) in Customer substation	*
Total	*****

Table 2. Network Upgrades

Facility	ESTIMATED COST (2007 DOLLARS)
MIPU – Build 161kV, 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**

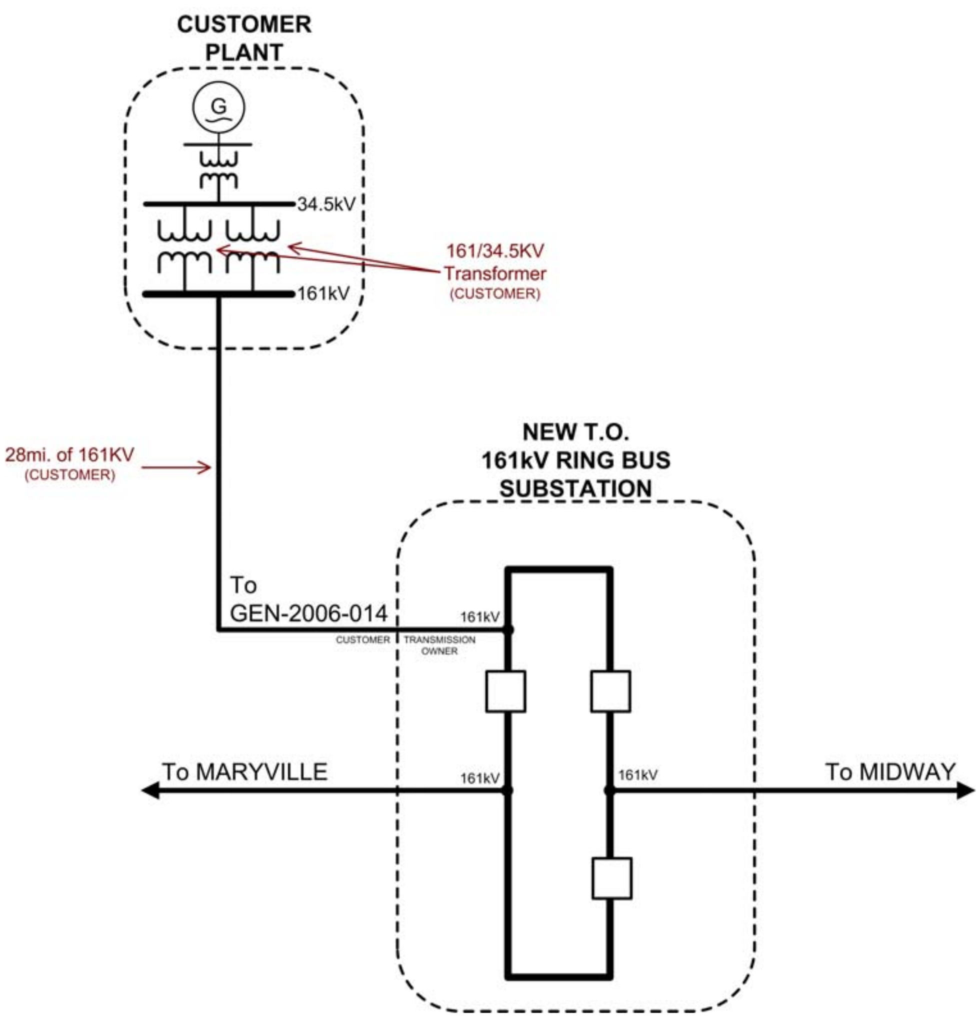

Figure 1: Proposed Interconnection
(Final substation design to be determined

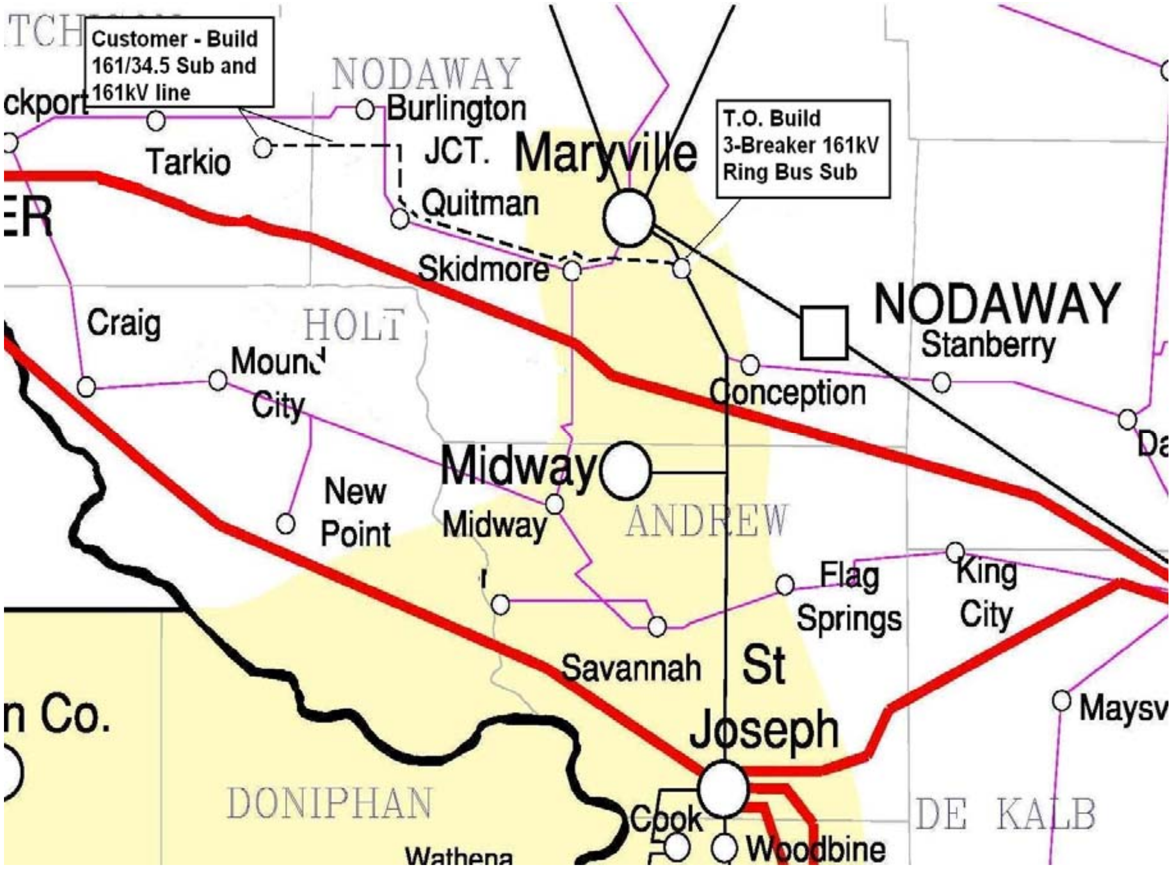

FIGURE 2. MAP OF THE LOCAL AREA

Pterra Consulting

Report No. R109-07

"Impact Study for Generation Interconnection Request GEN-2006-014"

Submitted to

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Report No. R109-07

"Impact Study for Generation Interconnection Request GEN-2006-014"

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1. Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (GEN-2006-014). The analysis was conducted through the Southwest Power Pool Tariff for a 161 kV interconnection for a 300 MW wind farm in Nodaway County Missouri. This wind farm will be interconnected into a new station on the Maryville-Midway 161 transmission line at a point as close to Maryville as practical. This line is owned by Aquila. The customer has asked for an Impact study case of 100% MW. GE 1.5 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 2011 summer and 2007 winter were provided by SPP. Transient stability simulations were conducted with the proposed wind farm in service with a full output of 300 MW. In order to integrate the proposed 300 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 was achieved by using 75 MVAR capacitor located on the 34.5kV Customer side

Eighteen (18) 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 GE WTGs were modeled with under/over voltage/frequency ride through protection package II in order to comply with FERC Order 661A provisions for low voltage ride through (LVRT). The settings were in accordance with standard or default settings. The simulations conducted in the study using the GE 1.5 MW WTGs did not find any angular or voltage instability problems for the eighteen disturbances. The study finds that the proposed 300 MW project shows stable performance of SPP system for the contingencies tested on the supplied base cases.

2. Introduction

2.1 Project Overview

The proposed 300 MW wind farm will be interconnected between the Maryville and Midway 161kV substations. Figure 1 shows a conceptual interconnection diagram of the proposed GEN-2006-014 project to the 161 kV sub-transmission network. The wind farm substation will be connected to the interconnection substation via approximately 28 miles of 161kV transmission line constructed by the Customer. The detailed connection diagram of the wind farm was provided by SPP.

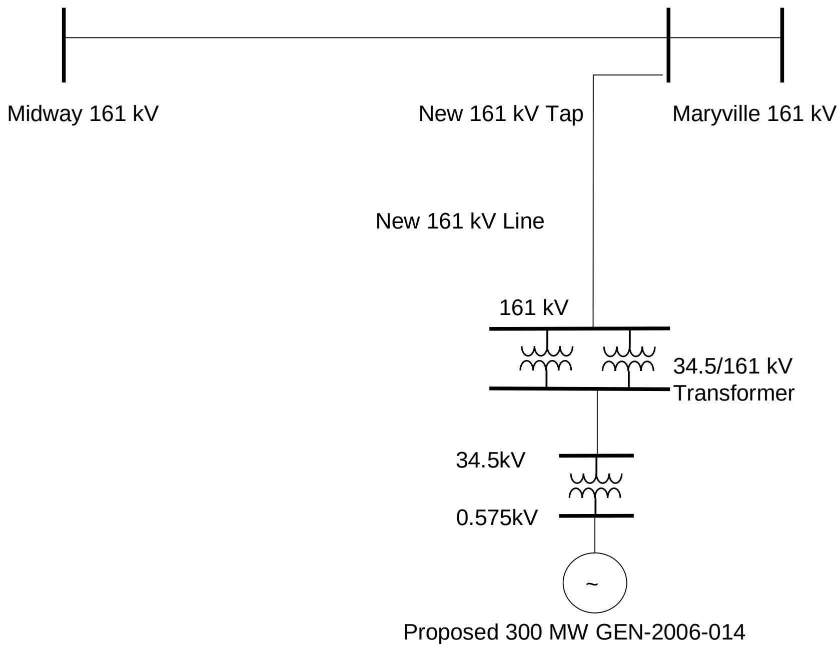

Figure 1 Interconnection Plan for GEN-2006-014 to the 161 kV System

In order to integrate the proposed 300 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 was represented by taking the equivalent series impedances of the different feeders connecting the wind turbines. Using this approach, the proposed 300 MW wind farm was modeled with 36 equivalent units (GE 1.5 MW 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. 161/34.5 kV transformers

Unity power factor was achieved at the interconnection point using 75 MVAR capacitor located at the 34.5 kV side of the 161/34.5 kV Transformer.

2.2 Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 300 MW wind farm to SPP's 161 kV sub-transmission system.

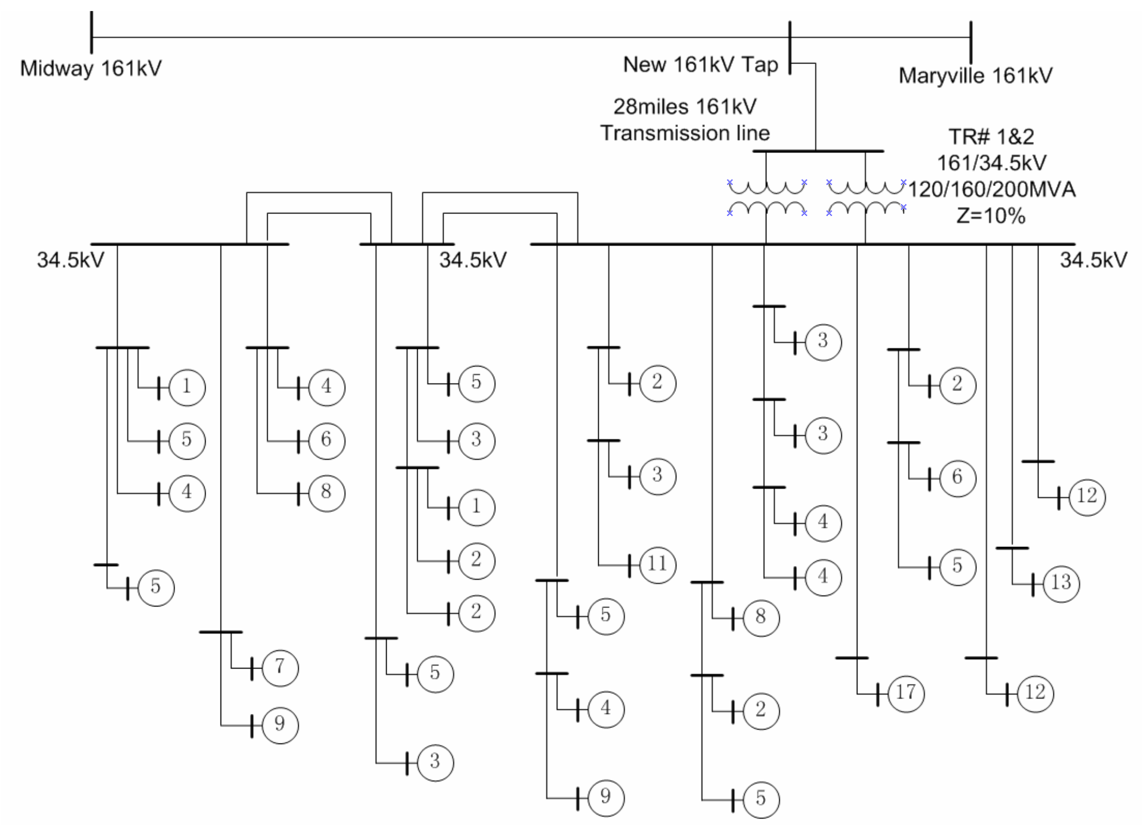

Figure 2 Wind Farm Model in Load Flow (200 GE 1.5 MW WTGs)

3. Stability Analysis

3.1 Modeling of the General Electric 1.5 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 GE 1.5 MW WTGs were modeled using the provided GE 1.5 MW wind turbine dynamic model set.

Table 1 GE 1.5 MW WTGs Data

Parameter	Value
BASE KV	0.575
WTG MBASE	1.667
TRANSFORMER MBASE	1.750
TRANSFORMER R ON TRANSFORMER BASE	0.0077
TRANSFORMER X ON TRANSFORMER BASE	0.0579
GTAP	1.0
PMAX (MW)	1.5
PMIN(MW)	0.0
XEQ, PU	0.8
LA	0.1714
LM	2.904
R1	0.005
L1	0.1563
INERTIA	0.558
DAMPING	0.0
QMAX(MVAR)	0.490
QMIN(MVAR)	-0.730

The wind turbine generators were studied to have the manufacturer's second tier LVRT II package for ride-through capability for voltage and frequency. It was determined this LVRT package was necessary for the wind turbines to meet FERC Order #661A provisions for low voltage ride through (LVRT). Detailed relay settings are shown in the following tables:

Table 2 Over/Under Frequency Relay Settings for GE 1.5 MW WTGs

Frequency Settings in Hertz	Time Delay in Seconds	Breaker time in Seconds
f≤56.5	0.02	0.08
56.5<f≤57.5	10	0.08
61.5≤f<62.5	30	0.08
f≥62.5	0.02	0.08

Table 3 Over/Under Voltage Relay Settings for GE 1.5 MW WTGs

Voltage Settings Per Unit	Time Delay in Seconds	Breaker time in Seconds
V ≤ 0.3	0.625	0.08
0.3 < V ≤ 0.70	0.625	0.08
0.70 < V ≤ 0.75	1.0	0.08
0.75 < V ≤ 0.85	10	0.08
1.1 < V ≤ 1.15	1.0	0.08
1.15 < V ≤ 1.3	0.1	0.08

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

Eighteen (18) 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.

The prior queued projects in the base cases monitored were the following:

- GEN-2006-003; 36 MW wind farm with Gamesa WTGs
- AECI prior queued project #1, #2 and #3 – each with 50 MW of Suzlon 2.1 MW WTGs.

Table 4 List of Simulated Disturbances

Cont. No.	***Cont. Name***	***Description***
1	FLT13PH	3 phase fault on the Wind Farm (572) - Maryville (59251) 161kV 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 - 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.
2	FLT21PH	*Single phase fault and sequence like Cont. No. 1*
3	FLT33PH	3 phase fault on the Wind Farm (572) - Midway (59252) 161kV 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 - 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.
4	FLT41PH	*Single phase fault and sequence like Cont. No.3*
5	FLT53PH	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.
6	FLT61PH	*Single* phase *fault and sequence like Cont. No.5*
7	FLT73PH	3 phase fault on the Maryville (59251) to Clarinda (63826) 161kV line, near Maryville. a. Apply fault at 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.
8	FLT81PH	*Single phase fault and sequence like Cont. No.7*

Cont. No.	*Cont. Name*	*Description*
9	FLT93PH	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.
10	FLT101PH	*Single phase fault and sequence like Cont. No.9*
11	FLT113PH	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 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*
13	FLT133PH	3 phase fault on the Midway (#59252) – St. Joseph (59253) 161kV line, near the Midway. a. Apply fault at the Midway. b. Clear fault after 5 cycles by tripping the line from the Midway – St. Joe 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 a St. Joe 345/161kV autotransformer a. Apply fault at St. Joe 345kV (#59199). b. Clear fault after 5 cycles by tripping the auto c. no reclose
16	FLT161PH	*Single phase fault and sequence like Cont. No.15*
17	FLT173PH	3 phase fault on the Fairport – AECI PQ wind farm 161kV bus at Fairport (96076) a. Apply fault at Fairport (#96076). b. Clear fault after 5 cycles b tripping the line from Fairport to AECI Wind Farm 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.
18	FLT181PH	*Single phase fault and sequence like Cont. No.17*

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 GE 1.5 MW WTGs.

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 eighteen (18) disturbances with the proposed 300 MW wind farm in service, are in an electronic format on the accompanying CD.

Table 5 shows a summary of the simulation results where the proposed project and the monitored prior queued projects shows stable performance with no tripping.

Table 5 Summary of the Simulation Results

Cont. No.	***Cont. Name***	***Project 2006-014***	***Prior Queued Projects***
1	FLT13PH	*SNT*	*SNT*
2	FLT21PH	*SNT*	*SNT*
3	FLT33PH	*SNT*	*SNT*
4	FLT41PH	*SNT*	*SNT*
5	FLT53PH	*SNT*	*SNT*
6	FLT61PH	*SNT*	*SNT*
7	FLT73PH	*SNT*	*SNT*
8	FLT81PH	*SNT*	*SNT*
9	FLT93PH	*SNT*	*SNT*
10	FLT101PH	*SNT*	*SNT*
11	FLT113PH	*SNT*	*SNT*
12	FLT121PH	*SNT*	*SNT*
13	FLT133PH	*SNT*	*SNT*
14	FLT141PH	*SNT*	*SNT*
15	FLT153PH	*SNT*	*SNT*
16	FLT161PH	*SNT*	*SNT*
17	FLT173PH	*SNT*	*SNT*
18	FLT181PH	*SNT*	*SNT*

SNT: Stable no tripping

4. Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2006-014) were presented in this report. The impact study case considered 100% MW of the wind farm proposed output. The Customer requested the use of GE turbines. GE 1.5 MW WTGs with the manufacturer's LVRT II package were studied to accommodate FERC Order 661A provisions for LVRT.

The 20011 summer and 2007 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 300 MW. In order to integrate the proposed 300 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 was achieved by adding 75 MVAR capacitor at the 34.5kV side of the project substation.

Eighteen (18) 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 GE 1.5 MW WTGs. The study finds that the proposed 300 MW project shows stable performance of SPP system for the contingencies tested on the supplied base cases.