Southwest Power Pool

Impact Study For Generation Interconnection Request GEN-2002-008

SPP Tariff Studies

(#GEN-2002-008)

August, 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-2002-008.

The purpose of this restudy is to evaluate the Customer's request to change turbines and use the General Electric 1.5MW wind turbine for this generation interconnection request. This study addressed the stability and reactive compensation required for the General Electric wind turbines.

<u>Reactive Compensation Required</u>

The Impact Study determined that the G.E. turbines will need to be purchased with the manufacturer's LVRT II package in order to meet FERC Order #661A requirements for low voltage ride through.

It was determined that for potential voltage swings on the Potter-Finney 345kV line, that three (3) 34.5kV, 15Mvar capacitor banks request are necessary for reactive compensation of the collector feeders and step up transformers.

The Large Generation Interconnection Agreement for this generation interconnection request will need to be revised to reflect the wind turbine change analyzed in this Impact re-study.

Pterra Consulting

Report No. R131-07

"Impact Study for Generation Interconnection Request GEN-2002-008"

Submitted to

The Southwest Power Pool

August 2007

Pterra

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Report No. R131-07

"Impact Study for Generation Interconnection Request GEN-2002-008"

1. Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (Gen-2002-008). The analysis was conducted through the Southwest Power Pool Tariff for a 345 kV interconnection for 240 MW wind farm in Hansford County, Texas. This wind farm will be connected to a new station on the Potter – Finney 345 kV line owned by Southwestern Public Service (d/b/a Xcel Energy). The customer requested that GE 1.5 MW wind turbine generators (WTG) be studied.

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 full output of 240 MW. In order to integrate the proposed 240 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched.

Fourteen (14) faults were considered for the transient stability simulations which included 3-phase faults, as well as, 1-phase to ground faults.

The proposed 240 MW wind farm was modeled with GE 1.5 MW WTG with under/over voltage/frequency ride through protection. The protection settings were in accordance with the manufacturer's LVRT II settings.

The simulation results showed that no plant trips were encountered for the simulated faults. In addition, all oscillations are well damped. The study finds that the proposed 240 MW wind farm project shows stable performance with the aforementioned operating schemes and reinforcement of SPP system for the faults tested on the supplied base cases. Therefore, no dynamic reactive compensation is required by the Customer.

2. Introduction

2.1 Project Overview

The proposed 240 MW wind farm will be connected to a new substation on the Potter – Finney 345 kV line. Figure 1 shows the interconnection diagram of the proposed GEN-2002-008 project to the 345 kV transmission network. The detailed connection diagram of the wind farm was provided by SPP.

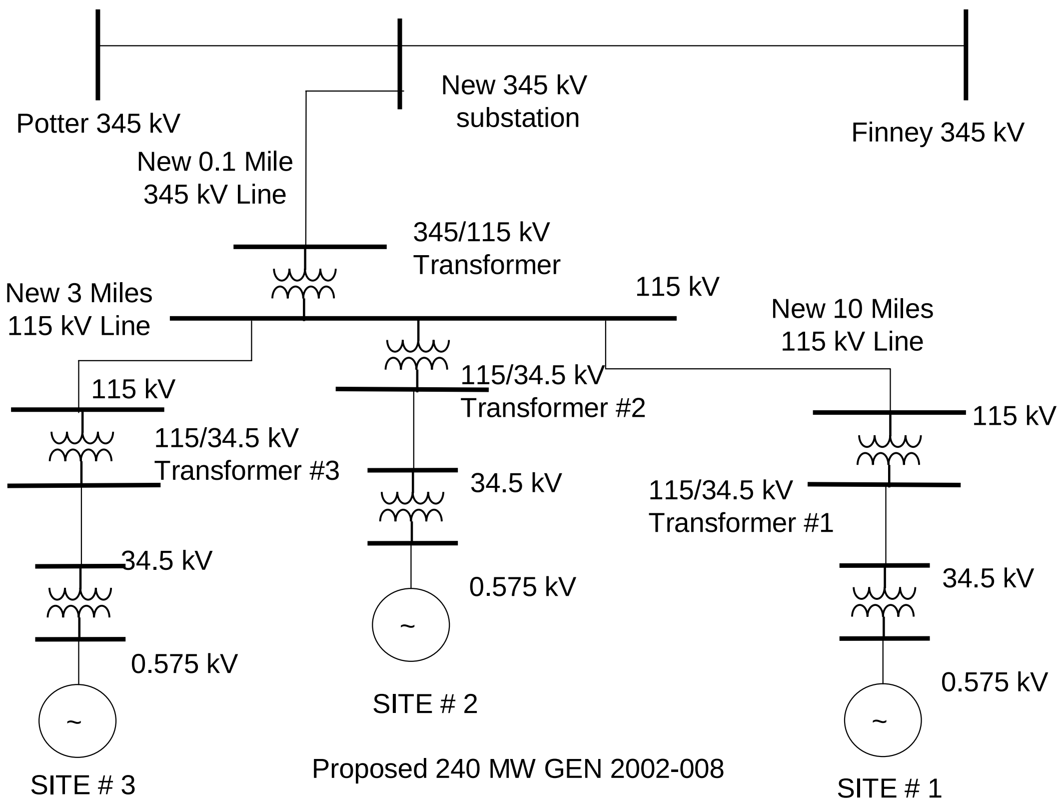

Figure 1 Interconnection Plan for GEN-2002-008 to the 345 kV System

The taps of the three 115/34.5 kV transformers were set to 1.05 P.U while the tap for the 345/115 kV transformer was set to 1.025 P.U.

In order to integrate the proposed 240 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched as provided by SPP.

In order 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 240 MW wind farm was modeled with

33 equivalent units as shown in Figures 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 following data:

1. The impedance values for 34.5 kV feeders.
2. The data for the 345/115 kV transformer and 115 kV/34.5kV transformers.
3. The line parameters of the new 345 kV and 115 kV lines.

Prior queued project, Gen 2002-006 was already modeled in the provided power flow cases. The project is a 150 MW wind farm consisting of Suzlon WTGs connected to Texas County substation.

2.2 Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 240 MW wind farm to SPP's 345 kV transmission system.

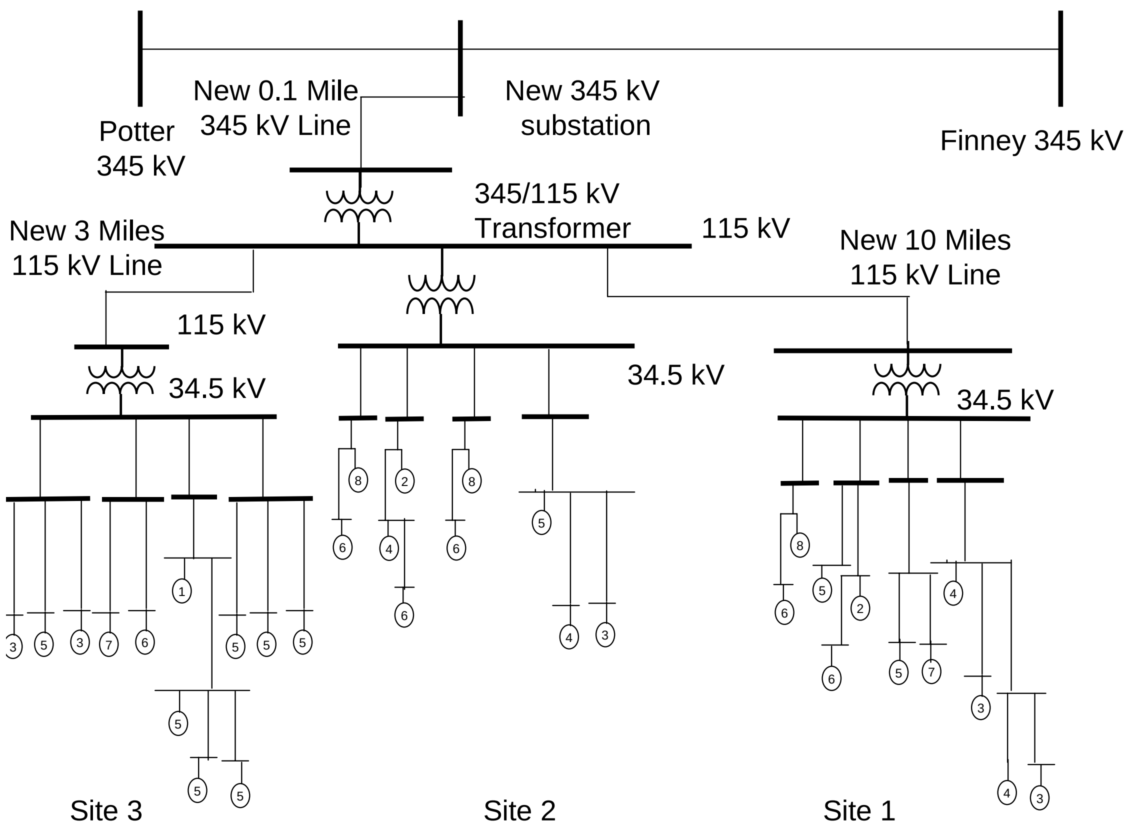

Figure 2 Wind Farm Equivalent Representation in Load Flow (GE 1.5 MW WTG)

3. Stability Analysis

3.1 Modeling of the GE 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 wind turbine generators were modeled using the latest wind turbine model set.

Table 1 GE 1.5 MW Wind Generator Data

Parameter	Value
BASE KV	0.575
WTG MBASE	1.667
TRANSFORMER MBASE	1.75
TRANSFORMER R ON TRANSFORMER BASE	0.0077
TRANSFORMER X ON TRANSFORMER BASE	0.0579
GTAP	1.05
PMAX (MW)	1.5
PMIN	0.0
RA	0.00706
LA	0.1714
LM	2.904
R1	0.005
L1	0.1563
INERTIA	0.57
DAMPING	0.0
QMAX (MVAR)	0.49
QMIN (MVAR)	-0.73

The wind turbine generators have ride-through capability for voltage and frequency according to the manufacturer's LVRT II settings. Detailed relay settings are shown in tables 2 and 3.

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

Frequency Settings in Hertz	Time Delay in Seconds	Breaker time in Seconds
$F \leq 56.5$	0.02	0.08
$56.5 < F \leq 57.5$	10.0	0.08
$61.5 < F \leq 62.5$	30.0	0.08
$F \geq 62.5$	0.02	0.08

Table 3 Over/Under Voltage Relay Settings for GE 1.5 MW (LVRT II)

Voltage Settings Per Unit	Time Delay in Seconds	Breaker time in Seconds
V ≤ 0.15	0.625	0.08
0.15 < V ≤ 0.70	0.625	0.08
0.70 < V ≤ 0.75	1.00	0.08
0.75 < V ≤ 0.85	10.0	0.08
1.15 > V ≥ 1.10	1.00	0.08
1.10 > V ≥ 1.15	0.10	0.08
1.15 > V ≥ 1.3	0.02	0.08

3.3 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.

3.4 Faults Simulated

Fourteen (14) faults 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 contingencies. The table also shows the fault clearing time and the time delay before re-closing for all the study contingencies.

Table 4 List of Contingencies

FAULT	FAULT DESCRIPTION
FLT_1_3PH	a. Apply 3-phase fault at the GEN-2002-008 bus (66661). b. Clear fault after 4 cycles by removing the line from GEN-2002-008 to Finney 345kV (66661 to 50858). c. Trip line from Finney-Lamar 345kV (50858-59998)
FLT_2_1PH	a. Apply 1-phase fault at the Finney bus (50858). b. Clear fault after 4 cycles by tripping the line from GEN-2002-008 to Finney 345kV (66661 to 50858). c. Wait 20 cycles, and then re-close the phase in (b) into the fault. d. Leave fault on for 4 cycles, then trip the line in (b), and remove fault. e. Trip line from Finney-Lamar (50858-59998)
FLT_3_3PH	a. Apply 3-phase fault at the GEN-2002-008 bus (66661). b. Clear fault after 4 cycles by removing the line from GEN-2002-008 to Potter 345kV (66661 – 50888). c. Trip line from Finney-Lamar 345kV (50858-59998)
FLT_4_1PH	a. Apply 1-phase fault at the GEN-2002-008 bus (66661). b. Clear fault after 4 cycles by tripping the line from GEN-2002-008 – Potter 345kV (66661 to 50888). c. Wait 20 cycles, and then re-close the line in (b) d. Leave fault on for 4 cycles, then trip the line in (b) and remove fault. e. Trip line from Finney-Lamar (50858-59998)
FLT_5_3PH	a. Apply 3-phase fault at the Holcomb bus (56449). b. Clear fault after 4 cycles by removing the line from 56449-50858.
FLT_6_1PH	a. Apply 1-phase fault at the Holcomb bus (56449). b. Clear fault after 4 cycles by tripping the line from Holcomb – Finney 345kV (56449-50858). c. Wait 20 cycles, and then re-close the phase in (b) into the fault. d. Leave fault on for 4 cycles, then trip the line in (b).
FLT_7_3PH	a. Apply 3-phase fault at the Grapevine bus (50827). b. Clear Fault after 5 cycles by removing line from Grapevine to Elk City (50827 – 54153). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_8_1PH	a. Apply 1-phase fault at the Grapevine bus (50827). b. Clear Fault after 5 cycles by removing line from Grapevine – Elk City (50827 – 54153). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_9_3PH	a. Apply 3-phase fault at the Plant X bus (51419). b. Clear Fault after 5 cycles by removing line from Potter – Plant X (50887 – 51419). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_10_1PH	a. Apply 1-phase fault at the Plant X bus (51419). b. Clear Fault after 5 cycles by removing line from Potter – Plant X (50887 – 51419). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

FAULT	FAULT DESCRIPTION
FLT_11_3PH	a. Apply 3-phase fault at the Blackhawk bus (50718). b. Clear Fault after 5 cycles by removing line from Blackhawk – Pringle (50652 – 50718). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_12_1PH	a. Apply 1-phase fault at the Blackhawk bus (50718). b. Clear Fault after 5 cycles by removing line from Blackhawk – Pringle (50652 – 50718). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_13_3PH	a. Apply 3-phase fault at the Potter 230kV bus (50887). b. Clear Fault after 5 cycles by removing line from Potter – Bushland 230kV (50887 – 50993). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_14_1PH	a. Apply 1-phase fault at the Potter 230kV bus (50887). b. Clear Fault after 5 cycles by removing line from Bushland – Potter 230kV (50887 – 50993). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

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 proposed 240 MW wind farm was modeled with GE 1.5 MW WTG with under/over voltage/frequency ride through protection. The protection settings were in accordance with the manufacturer's LVRT II settings.

The simulation results showed that no plant trips were encountered for the simulated faults. In addition, all oscillations are well damped. The study finds that the proposed 240 MW wind farm project shows stable performance with the aforementioned operating schemes and reinforcement of SPP system for the contingencies tested on the supplied base cases. Therefore, no dynamic reactive compensation is required by the Customer.

4. Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2002-008 were presented in this report. The study was conducted through the Southwest Power Pool Tariff for a 345 kV 240 MW wind farm in Hansford County, Texas. This wind farm was studied using GE 1.5 MW WTG.

The proposed 240 MW wind farm was modeled with GE 1.5 MW WTG with under/over voltage/frequency ride through protection. The protection settings were in accordance with the manufacturer's LVRT II settings. The taps of the three 115/34.5 kV transformers were set to 1.05 P.U while the tap for the 345/115 kV transformer was set to 1.025 P.U.

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