Southwest Power Pool

Impact Study For Generation Interconnection Request GEN-2003-019

SPP Tariff Studies

(#GEN-2003-019)

November 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-2003-019.

The Customer had previously studied this request and executed an Interconnection Agreement using G.E. 1.5MW turbines. The Customer later asked for a restudy assuming that the entire wind farm would consist of Vestes V-80 wind turbines. The Customer has now asked to study the wind farm assuming a phase one of 100.8 MW of Vestes V-80 wind turbines and a phase two of 148.5 MW of General Electric 1.5 MW wind turbines. This study addressed the stability and reactive compensation required for the entire wind farm.

<u>Reactive Compensation Required</u>

The Impact Study determined that the Customer will be required to install at least two 34.5kV capacitor banks for the wind farm. One 34.5kV capacitor bank of 8 Mvar will be required on the substation transformer station which collects the energy from fifty-six (56) Vestes turbines for a total 100.8MW. The second transformer station which collects energy from the remaining 148.5MW (99 General Electric turbines) will be required to have a 34.5kV, 12 MVAR capacitor bank. The 34.5kV, 9 Mvar reactor required in the last Impact Study is still needed for phase 1 operation.

The General Electric wind turbines will need to be purchased with the manufacturer's LVRT II package for low voltage ride through. The Vestes V-80 wind turbine will need to be purchased with the manufacturer's AGO-4 package for low voltage ride through. The Impact Study indicates that with the studied wind turbine allocation; 100.8 MW Vestes V-80 and 148.5 MW General Electric 1.5 sle, that no STATCOM or SVC device is necessary for low voltage ride through provisions to meet FERC Order 661A.

Pterra Consulting

Report No. R139-07

“Impact Study for Generation Interconnection Request GEN-2003-019”

Submitted to

The Southwest Power Pool

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Pterra

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Report No. R139-07

"Impact Study for Generation Interconnection Request GEN-2003-019"

1. Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (GEN-2003-019). The analysis is conducted through the Southwest Power Pool Tariff for a proposed 250 MW wind farm located in Lincoln County, Kansas. This wind farm will be connected to a new 230 kV three-breaker ring bus on the Knoll to Summit line jointly owned by WERE and MIDW. The Customer has previously studied this request with all GE 1.5 MW wind turbines with the standard ride through package and with all Vestas V-80 with AGO-4.

For this re-study, the Customer is asking to retain 100 MW of the project capacity with fifty-six (56) Vestes V-80 wind turbines with AGO-4, designated as Phase 1, and re-study the remaining 148.5 MW of project capacity with ninety-nine (99) GE 1.5 MW turbines, designated as Phase 2.

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

Twenty two (22) 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. 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 22 disturbances. The study finds that the proposed 148.5 MW project shows stable performance of SPP system for the contingencies tested on the supplied base cases. Therefore, no dynamic reactive compensation is required of the Customer.

2. Introduction

2.1 Project Overview

This is a re-study of a proposed 250 MW wind farm located in Lincoln County, Kansas. The Customer is asking to retain 100 MW of the project capacity with fifty-six (56) Vestes V-80 wind turbines with AGO-4, designated as Phase 1, and re-study the remaining 148.5 MW of project capacity with ninety-nine (99) GE 1.5 MW turbines, designated as Phase 2.

The 148.5 MW capacity for Phase 2 of the proposed wind farm will be connected to a new ring position on the on the Knoll to Summit line. Figure 1 shows a conceptual interconnection diagram of the proposed GEN-2003-019 project to the 230 kV transmission network. The detailed connection diagram of the wind farm was provided by SPP.

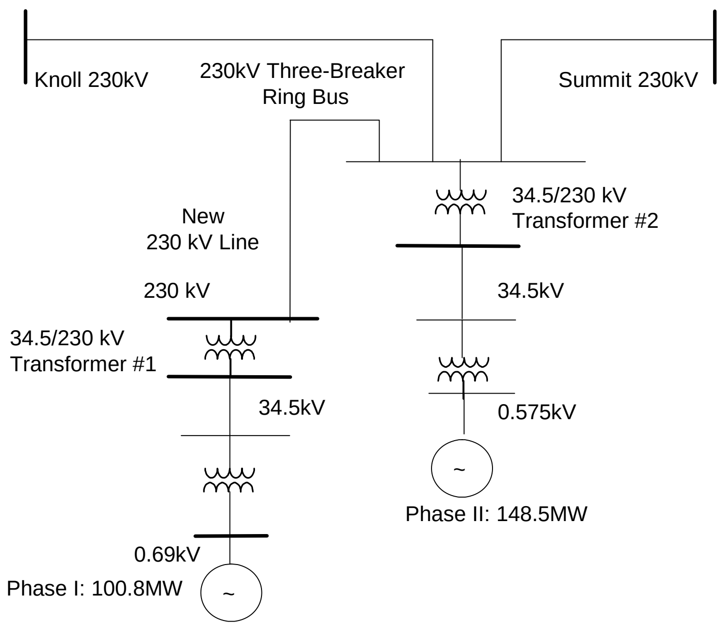

Figure 1 Interconnection Plan for GEN-2006-032 to the 230 kV System

In order to integrate the proposed wind farm in SPP system as an Energy Resource, generation in SPP footprint was re-dispatched to maintain current area interchange totals.

Unity power factor at the point of interconnection was accomplished by a 12 MVAR capacitor at the low voltage side of the 230/34.5 kV transformer while setting the transformer tap at 5 % off the nominal value.

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 34.5 kV 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 148.5 MW for Phase 2 of the wind farm was modeled with 33 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 34.5 kV 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.

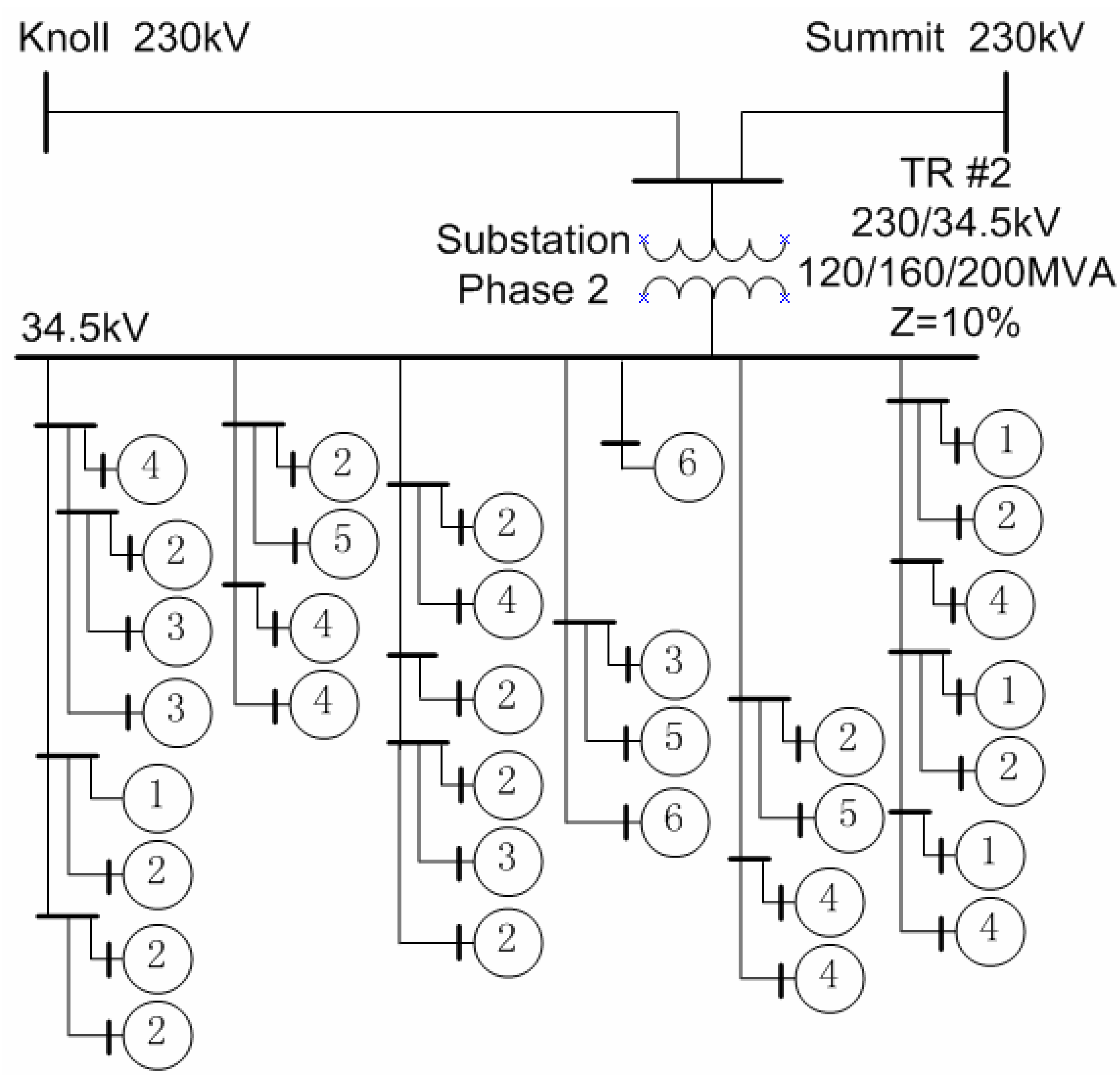

Figure 2 Wind Farm Model in Load Flow (99 GE 1.5 MW WTGs)

2.2 Objective

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

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 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 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

Twenty two (22) disturbances were considered for the transient stability simulations which included three phase faults, as well as single phase faults, at the locations defined by SPP. Single-phase 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.

Table 4 List of Simulated Disturbances

Cont. No.	***Cont. Name***	***Description***
1	FLT13PH	Fault on the Wind Farm Gen-2003-019 Switching Station to Summit 230 kV line, near Wind Farm a) Apply Fault at the Wind Farm bus. b) Clear Fault after 5 cycles by removing the line from Gen-2003-019 Switching Station to Summit 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	Fault on the Wind Farm Gen-2003-019 Switching Station to Knoll 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm bus. b) Clear fault after 5 cycles by removing the line from the Gen-2003-019 Switching Station to Knoll. c) Wait 20 cycles, and then re-close the line in (b) 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	Fault on the Circle to Mullergren 230 kV line, near Circle. a) Apply Fault at the Circle bus. b) Clear fault after 5 cycles by removing the line from Circle to Mullergren. c) Wait 20 cycles, and then re-close the line in (b) 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	Fault on the Heizer to Mullergren 230 kV line, near Heizer. a) Apply Fault at the Heizer bus. b) Clear fault after 5 cycles by removing the line Heizer to Mullergren. c) Wait 20 cycles, and then re-close the line in (b) 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	Fault on the Manhattan to Concordia 230 kV line, near Manhattan. a) Apply fault at the Manhattan bus. b) Clear fault after 5 cycles by tripping the line from Manhattan to Concordia. 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	Fault on the Jefferies Energy Center to Summit 345 kV line, near Summit. a) Apply fault at the Summit bus. b) Clear fault after 5 cycles by tripping the line from Jefferies Energy Center (56766) to Summit. c) Wait 30 cycles, and then re-close the line in (b) back into the fault.

Cont. No.	*Cont. Name*	*Description*
		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	Fault on the Morris to Summit 230 kV line, near Summit. a) Apply fault at the Summit bus. b) Clear fault after 5 cycles by tripping the line Morris to Summit. c) Wait 20 cycles, and then re-close 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	Fault on the Knoll to Redline 115 kV line, near Knoll. a) Apply fault at the Knoll bus. b) Clear fault after 5 cycles by tripping the line from Knoll to Redline. c) Wait 15 cycles, and then re-close 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.15*
17	FLT173PH	Fault on the Hays to Vine 115 kV line, near Hays. a) Apply fault at the Hays bus. b) Clear fault after 5 cycles by tripping the line from Hays to Vine. c) Wait 15 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*
19	FLT193PH	Fault on the Knoll to South Hays 230 kV line, near Knoll. a) Apply fault at the Knoll bus. b) Clear fault after 5 cycles by tripping the line from Knoll to South Hays. 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	Fault on the Knoll (56561) to Saline 115 kV line, near Knoll. a) Apply fault at the Knoll bus. b) Clear fault after 5 cycles by tripping the line from Knoll to Saline. c) Wait 15 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*

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 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 SPP system or with the proposed project's WTGs. Furthermore, no dynamic reactive compensation is required of the Customer.

4. Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2003-019 (Phase 2)) were presented in this report. The impact study case considered 100% MW of the wind farm's proposed output. GE 1.5 MW WTGs were studied according to the customer request.

The 2011 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 148.5 MW for Phase 2. In order to integrate the proposed 148.5 MW wind farm in SPP system, existing generation in SPP footprint was re-dispatched.

Twenty two (22) 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 associated with the proposed project's GE 1.5 MW WTGs. The study finds that the proposed project shows stable performance of SPP system for the contingencies tested on the supplied base cases. No dynamic reactive compensation is required of the Customer.