SPP Southwest Power Pool

Impact Study For Generation Interconnection Request GEN-2001-039M

SPP Tariff Studies

(#GEN-2001-039M)

December 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-2001-039M. This generation interconnection was originally requested through Sunflower Electric and the request currently has a valid Interconnection Agreement.

The purpose of this restudy is to evaluate the Customer's request to use Vestes V-90 wind turbines for the proposed generation. This study addressed the stability and reactive compensation required for the Vestes wind turbines.

The Impact Study determined that the Vestes V-90 wind turbines, as represented in the model provided to SPP by Vestes, will meet FERC Order #661A requirements for low voltage ride through.

The Impact Study determined that a minimum of 12 Mvar of capacitors are necessary for the interconnection of the wind farm, not withstanding the power factor requirements of the valid Interconnection Agreement between the Interconnection Customer and Sunflower Electric. This 12 Mvar capacitor bank shall be composed of two stages of 6 Mvar each in order to limit voltage rise on the Sunflower Electric transmission system.

Pterra Consulting

Technical Report R144-07

Impact Study for Generation Interconnection Request GEN-2001-039M

Submitted to

Southwest Power Pool

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Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (Gen-2001-039M). The analysis was conducted through the Southwest Power Pool Tariff for a 115 kV interconnection for 99 MW wind farm in Wichita County, Kansas. This wind farm will be connected to a new substation along the Setab-Tribune 115 kV line owned by Sunflower Electric Power Corp. (SUNC). The customer requested that Vestes V-90 3.0 MW wind turbines generators (WTGs) should be studied using the Advanced Grid Option (AGO) protection package.

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 99 MW. In order to integrate the proposed 99 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched.

Twenty two (22) faults were considered for the transient stability simulations which included 3-phase faults, as well as, 1-phase to ground faults.

The proposed 99 MW wind farm was modeled with V-90 3.0 MW WTG with ride-through capability for voltage and frequency; the settings were in accordance with the manufacturer's settings for the Advanced Grid Option (AGO) package. Unity power factor at the point of interconnection was achieved by placing a 12 MVAR capacitor bank at the low voltage side of the 115/34.5 kV transformer.

The simulation results showed no Customer wind farm trips were encountered for the studied faults. In addition, all oscillations were well damped. Prior Queued project, Gray County Wind Farm (110 MW of Vestes V47 WTGs), tripped for faults #17, #19 and #21 for the summer peak base case and for faults #17 and #19 for winter peak base case. The trippings were because of relay actuation due to low voltage. According to the scope of work, simulations for these faults were repeated with the LVRT protection disabled; the simulations showed stable performance.

The study finds that the proposed 99 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.

1.1. Project Overview

The proposed 99 MW wind farm will be connected to a new substation along the Setab-Tribune 115 kV line owned by Sunflower Electric Power Corp. (SUNC). Figure 1-1 shows a schematic one line diagram of the proposed GEN-2001-039M project to SPP 115 kV transmission network. The detailed connection diagram of the wind farm was provided by SPP.

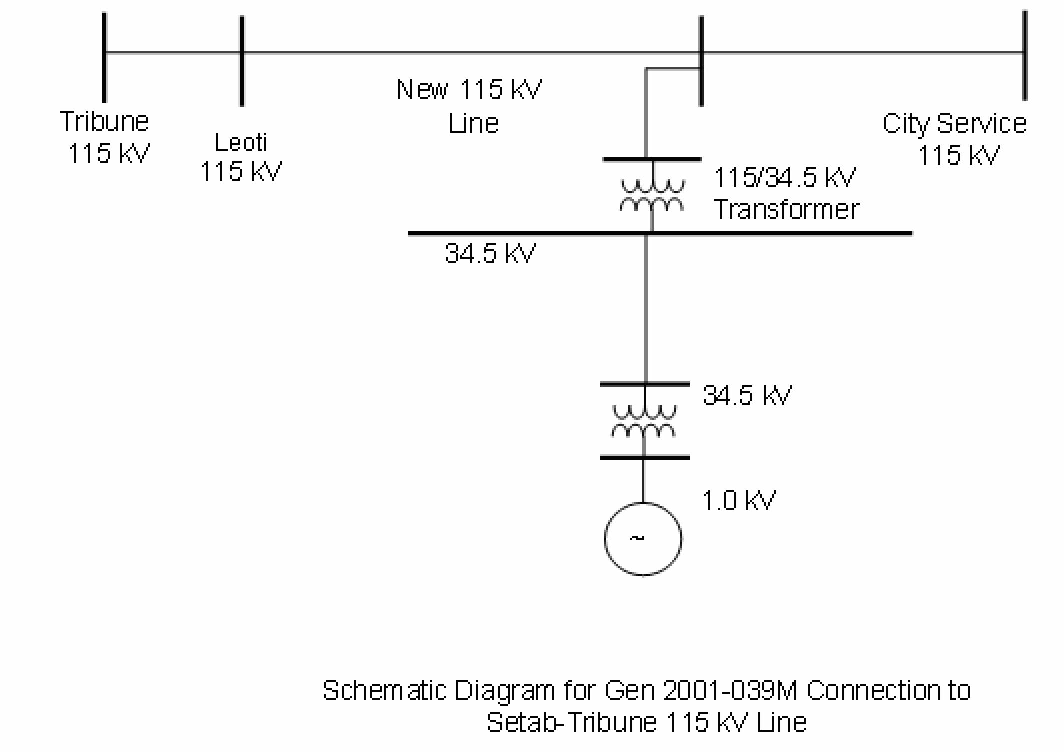

Figure 1-1 Interconnection Plan for GEN-2001-039M to SPP's 115 kV System

Unity power factor at the point of interconnection was achieved by placing a 12 MVAR capacitor bank at the low voltage side of the 115/34.5 kV transformer.

In order to integrate the proposed 99 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 34.5 kV 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 99 MW wind farm was modeled with 16 equivalent units as shown in Figure 1-2. 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 115 kV/34.5 kV transformers.
3. The line parameters of the new 115 kV line.

The following prior queued projects were already modeled in the provided power flow cases:

A. Gray County Wind Farm – 110 MW of Vestes V47 wind turbines.
B. Sunflower Queue – 600MW coal fired unit.

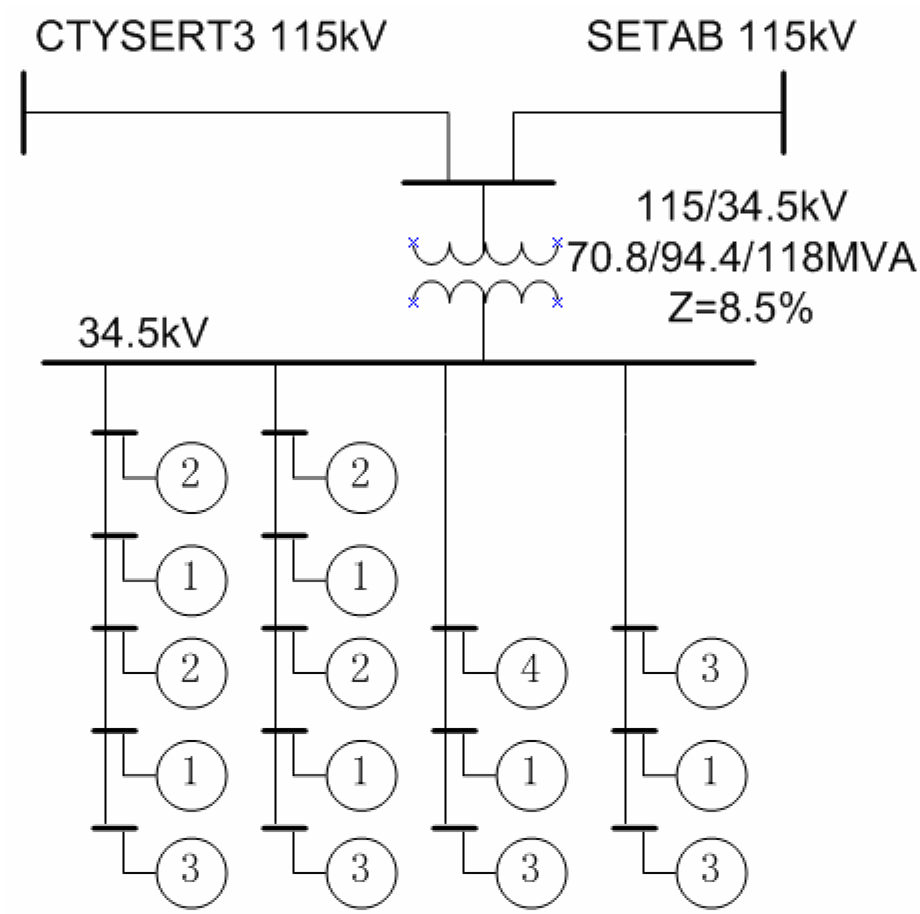

Figure 1-2 Wind Farm Equivalent Representation in Load Flow

1.2. Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 99 MW wind farm to SPP's 115 kV transmission system.

Section 2. Stability Analysis

2.1. Modeling of the Vestes V-90 3.0 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 V-90 3.0 MW WTGs were modeled using the latest wind turbine model set. Table 2-1 shows the data for V-90 3.0 MW WTG.

Table 2-1 V-90 3.0 MW Wind Generator Data

Parameter	Value
BASE (KV)	1.0
Rating (MVA)	3.0
TRANSFORMER MBASE (MVA)	3.16
TRANSFORMER R ON TRANSFORMER BASE	0.0065362
TRANSFORMER X ON TRANSFORMER BASE	0.0947749
GTAP	1.0
PMAX (MW)	3.0
PMIN	0.0
Power factor Range	0.98 (Lead) -0.96 (Lag)
Speed (RPM)	1800
INERTIA (kW/Sec/kVA)	0.958
QMIN (MVAR)	

The wind turbine generators have ride-through capability for voltage and frequency. Detailed relay settings are shown in
Table 2-2 and Table 2-3 for the AGO package.

Table 2-2 Over/Under Frequency Relay Settings for V-90 3.0 MW

Frequency Settings in Hertz	Time Delay in Seconds	Breaker time in Seconds
F ≤ 52.5	0.2	0.08
55.5 < F ≤ 57.0	2.0	0.08
63.0 > F ≥ 62.0	90.0	0.08
F ≥ 62.5	0.2	0.08

Table 2-3 Over/Under Voltage Relay Settings for V-90 3.0 MW

Voltage Settings Per Unit	Time Delay in Seconds	Breaker time in Seconds
V ≤ 0.15	0.35	0.08

Voltage Settings Per Unit	Time Delay in Seconds	Breaker time in Seconds
0.15 < V ≤ 0.75	2.65	0.08
0.75 < V ≤ 0.85	10.0	0.08
0.85 < V ≤ 0.90	300	0.08
1.10 > V ≥ 1.15	60	0.08
1.15 > V ≥ 1.2	2.0	0.08
1.2 > V ≥ 1.25	0.08	0.08

2.2. 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.

2.3. Faults Simulated

Twenty two (22) 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 2-4 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 2-4 List of the Simulated Faults

Cont. No.	Cont. Name	Description
1	FLT13PH	Fault on the Wind Farm to Setab 115 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 Wind Farm – Setab. 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.

Cont. No.	Cont. Name	Description
2	FLT21PH	*Single phase fault and sequence like Cont. No. 1*
3	FLT33PH	3 phase Fault on the Wind Farm to Tribune 115 kV substation 115 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 Wind Farm – Tribune. 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 Setab 345/115 kV autotransformer on the 115 kV side a. Apply Fault at the Setab 115kV bus. b. Clear Fault after 5 cycles by removing the autotransformer from service
6	FLT61PH	*Single phase fault and sequence like Cont. No. 5*
7	FLT73PH	*3-phase fault on the Ruleton to Lawn Ridge 115 kV line, near Ruleton* *a. Apply Fault at the Ruleton bus.* *b. Clear Fault after 5 cycles by removing the line from Ruleton-Lawn Springs* *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	F09-3PH	3-phase fault on the Ruleton to Goodland 115 kV line, near Ruleton a. Apply Fault at the Ruleton bus. b. Clear Fault after 5 cycles by removing the line from Ruleton-Lawn Springs 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	F10-SLG	*Single phase fault and sequence like Cont. No. 9*
11	F11-3PH	3-phase fault Fault on the Tribune to Syracuse 115 kV line, near Tribune a. Apply Fault at the Tribune bus. b. Clear Fault after 5 cycles by removing the line from Tribune - Syracuse 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	F12-SLG	*Single phase fault and sequence like Cont. No. 11*

Cont. No.	Cont. Name	Description
13	F13-3PH	3-phase fault Fault on the Tribune Switch to Palmer 115 kV line, near Tribune a. Apply Fault at the Tribune bus. b. Clear Fault after 5 cycles by removing the line from Tribune – Palmer 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	F14-SLG	*Single phase fault and sequence like Cont. No. 13*
15	F15-3PH	3-phase fault on the Mingo 345/115 kV autotransformer on the 115 kV bus a. Apply Fault at the Mingo 115 kV bus. b. Clear Fault after 5 cycles by removing the autotransformer from service
16	F16-SLG	*Single phase fault and sequence like Cont. No. 15*
17	F17-3PH	3-phase fault on the Holcomb to Finney 345 kV line, near Holcomb a. Apply Fault at the Holcomb bus. b. Clear Fault after 5 cycles by removing the line from Holcomb - Finney 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	F18-SLG	*Single phase fault and sequence like Cont. No. 17*
19	FLT19-3PH	3-phase fault on the Holcomb to Spearville 345 kV line, near Holcomb a. Apply Fault at the Holcomb bus. b. Clear Fault after 5 cycles by removing the line from Holcomb - Spearville 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	FLT20-SLG	*Single phase fault and sequence like Cont. No. 19*
21	FLT21-3PH	3-phase fault on the Holcomb 345/115kV autotransformer on the 115kV side a. Apply Fault at the Holcomb 115kV bus. b. Clear Fault after 5 cycles by removing the autotransformer from service
22	FLT22-SLG	*Single phase fault and sequence like Cont. No. 21*

2.4. 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 99 MW wind farm was modeled with V-90 3.0 MW WTGs with voltage and frequency ride through protection. The protection settings were in accordance with the manufacturer's AGO package.

The simulation results showed no Customer wind farm trips were encountered for the studied faults. In addition, all oscillations were well damped. Prior Queued project, Gray County Wind Farm (110 MW of Vestes V47 WTGs), tripped for faults #17, #19 and #21 for the summer peak base case and for faults #17 and #19 for winter peak base case. The trippings were because of relay actuation due to low voltage. According to the scope of work, simulations for these faults were repeated with the LVRT protection disabled; the simulations showed stable performance.

The study finds that the proposed 99 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. No dynamic reactive compensation is required of the Customer.

Section 3. Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2001-039M were presented in this report. The study was conducted through the Southwest Power Pool Tariff for a 115 kV 99 MW wind farm in Wichita County, Kansas. This wind farm was studied using Vestes V-90 3.0 MW WTG.

The proposed 99 MW wind farm was modeled with V-90 3.0 MW WTG with under/over voltage/frequency ride through protection. The protection settings were in accordance with the manufacturer's AGO settings. Unity power factor at the point of interconnection was achieved by placing a 12 MVAR capacitor bank at the low voltage side of the 115/34.5 kV transformer.

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