Impact Study For Generation Interconnection Request GEN-2006-020S

SPP Tariff Studies

(#GEN-2006-020S)

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-2006-020S. This generation interconnection request currently has an executed Interconnection Agreement that was was signed assuming the facility would contain Suzlon S88 2.1 MW wind turbines. The Customer has subsequently asked for a restudy assuming the facility will contain Vestes V-80 1.8 MW wind turbines.

The purpose of this restudy is to evaluate the Customer's request to use Vestes V-80 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-80 wind turbines, with the Advanced Protection System 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 3 Mvar of capacitors are necessary for the interconnection of the wind farm.

Pterra Consulting

Final Report No. R146-07

"Impact Study for Generation Interconnection Request GEN-2006-020"

Submitted to

The Southwest Power Pool

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Report No. R146-07

"Impact Study for Generation Interconnection Request GEN-2006-020"

1. Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection plant (GEN-2006-020). The analysis was conducted through the Southwest Power Pool Tariff for a 115 kV interconnection for 19.8 MW wind farm in Sherman County, Texas. This wind farm would be interconnected on the 115kV transmission line between Texas County and Sherman substations in Sherman County, Texas. This line is owned by Southwestern Public Service (SPS). The customer has asked for a study case of 100% MW output. The customer has requested using Vestas V80 1.8 MW wind turbine-generator units (WTGs) with the Vestas Advanced Protection low voltage ride through package.

Two base cases each comprising of a power flow and corresponding dynamics database for 2011 summer peak and 2007 winter peak were provided by SPP. Transient stability simulations were conducted with the proposed wind farm in service with a full output of 19.8 MW. In order to integrate the proposed 19.8 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 3 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 Vestas V80 1.8 MW WTGs were modeled with under/over voltage/frequency ride through protection in compliance with FERC Order 661-A. The simulations conducted in the study using the Vestas V80 1.8 MW WTGs model provided by the customer did not find any angular or voltage instability problems for the disturbances.

In conclusion, the study finds that the proposed 19.8 MW project shows stable performance of SPP system for the contingencies tested on the supplied base cases.

2. Introduction

2.1 Project Overview

Pterra, LLC was contracted by Southwest Power Pool (SPP) to perform a 115kV interconnection study for a 19.8 MW wind farm (GEN-2006-020) in Sherman County, Texas. This wind farm will be interconnected into the Texas County – Sherman 115kV transmission line. This line is owned by Southwestern Public Service (SPS). Figure 1 shows a conceptual interconnection diagram of the proposed GEN-2006-020 project to the 115 kV sub-transmission network. The detailed connection diagram of the wind farm was provided by SPP.

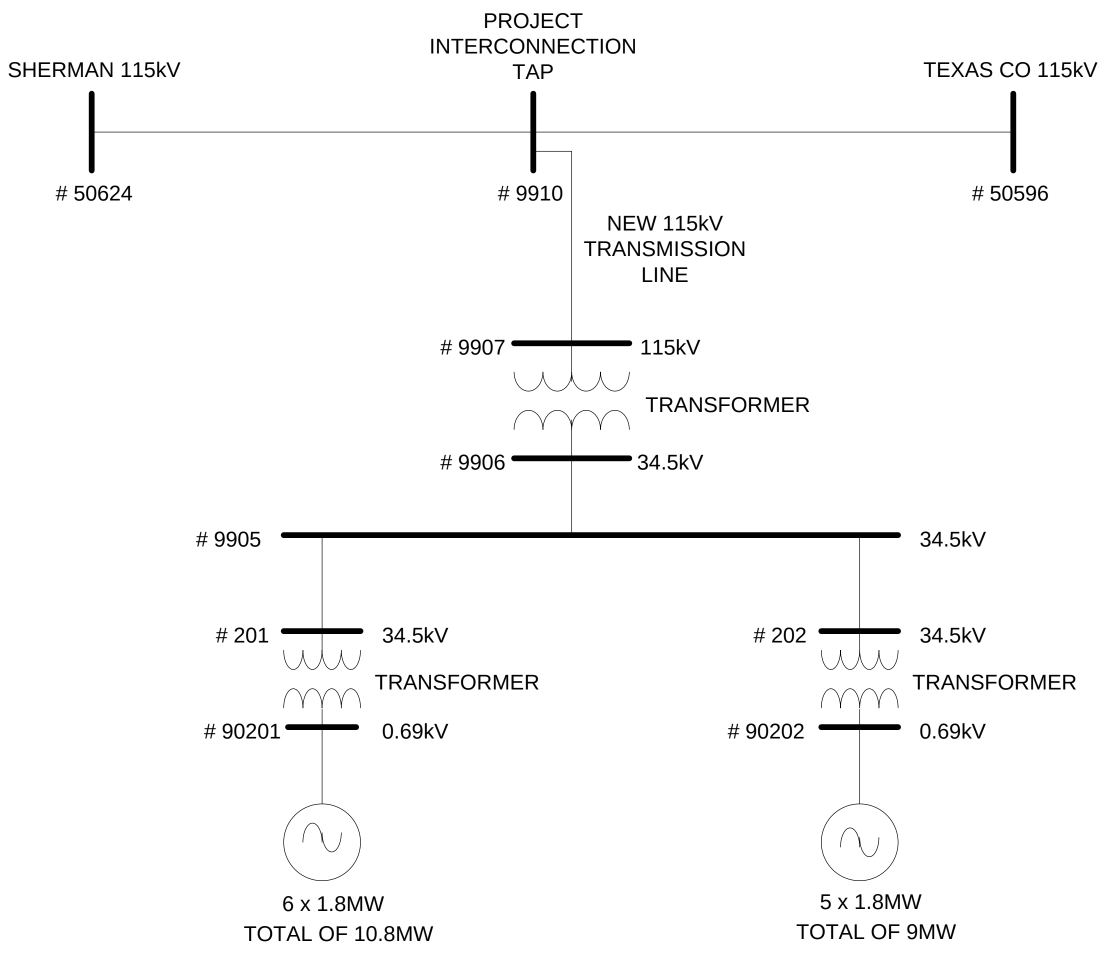

Figure 1. Interconnection Point for GEN-2006-040 to the 115 kV System

In order to integrate the proposed 19.8MW wind farm in SPP system as an energy resource, existing generation in the SPP footprint is displaced.

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 eleven

(11) wind turbines, using Vestas V80 1.8 MW WTG units, connected to the same 34.5kV feeder were aggregated into two equivalent units. 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 19.8 MW wind farm was modeled with two (2) equivalent units as shown in Figure 1. 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. 115/34.5 kV transformers
4. 115 kV line from the high side of 115/34.5 kV transformers (mentioned above) to the point of interconnection.

Unity power factor was achieved at the interconnection point using 3 MVAR capacitor located at the 34.5 kV side of the 115/34.5 kV Transformer.

2.2 Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 19.8 MW wind farm to SPP's 115 kV sub-transmission system.

3. Stability Analysis

3.1 Modeling of the Vestas V80 1.8 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 Vestas V80 1.8 MW WTGs were modeled using the provided Vestas V80 1.8 MW wind turbine dynamic model set, as shown in Table 1.

Table 1. Vestas V80 1.8 MW WTGs Data

Parameter	Value
Base kV	0.690
WTG Mbase	2.0
Transformer Base	1.85
Transformer R on Transformer Base	0
Transformer X on Transformer Base	0.075
Gtap	1.0
Pmax	1.8
Pmin	0
Ra	0.00489
La	0.12602
Lm	6.8399
R1	0.004419
L1	0.18084
Inertia	0.644
Damping	0

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 Vestas V80 1.8 MW WTGs

Frequency Settings in Hertz	Time Delay in Seconds	Breaker Time in Seconds
$f \leq 55.2$	0.20	0.08
$55.2 < f \leq 57$	2.0	0.08
$62.0 \leq f < 63.0$	90.0	0.08
$63.0 \leq f$	0.20	0.08

Table 3. Over/Under Voltage Relay Settings for Vestas V80 1.8 MW WTGs

(Advanced Protection Package)

Voltage Settings Per Unit	Time Delay in Seconds	Breaker Time in Seconds
$V \leq 0.15$	0.35	0.08
$0.15 < V \leq 0.75$	2.65	0.08
$0.75 < V \leq 0.85$	10	0.08
$0.85 < V \leq 0.90$	300	0.08
$1.10 \leq V \leq 1.15$	60.0	0.08
$1.15 < V \leq 1.20$	60.0	0.08
$1.20 < V \leq 1.25$	2.0	0.08
$1.25 \leq V$	0.08	0.08

3.2 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.

Table 4. List of Simulated Disturbances

Disturbance No.	Disturbance Name	Description
1	FLT_1_3_PH	Three- phase fault on the Wind Farm (9910) – Texas County (50596) 115kV line a) Apply fault at the Wind Farm 115kV bus (9910). b) Clear fault after 5 cycles by removing the line from service. c) Wait 20 cycles, and then re-close the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
2	FLT_2_1_PH	Single Line to Ground (SLG) fault same as FLT_1_3_PH
3	FLT_3_3_PH	Three- phase fault on the Wind Farm (9910) – Sherman (50624) 115kV line a) Apply fault at the Sherman 115kV bus (50624). b) Clear fault after 5 cycles by removing the line from service. c) Wait 20 cycles, and then re-close the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
4	FLT_4_1_PH	Single Line to Ground (SLG) fault same as FLT_3_3_PH
5	FLT_5_3_PH	Three- phase fault on the Moore (50669) – Potter (50887) 230kV line a) Apply fault at the Moore 230kV bus (50669). b) Clear fault after 5 cycles by removing the line from service. c) Wait 20 cycles, and then re-close the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
6	FLT_6_1_PH	Single Line to Ground (SLG) fault same as FLT_5_3_PH
7	FLT_7_3_PH	Three- phase fault on the Texas County (50596) – Guymon (50602) 115kV line a) Apply fault at the Guymon 115kV bus (50602). b) Clear fault after 5 cycles by removing the line from service. c) Wait 20 cycles, then reclose the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
8	FLT_8_1_PH	Single Line to Ground (SLG) fault same as FLT_7_3_PH

Disturbance No.	Disturbance Name	Description
9	FLT_9_3_PH	Three- phase fault on the Spearman (50628) – GEN-2002-009 Wind Farm (66668) 115kV line a) Apply fault at the Spearman 115kV bus (50628). b) Clear fault after 5 cycles by removing the line from service. c) Wait 20 cycles, and then re-close the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
10	FLT_10_1_PH	Single Line to Ground (SLG) fault same as FLT_9_3_PH
11	FLT_11_3_PH	Three- phase fault on the Spearman (50628) – Pringle (50652) 115kV line a) Apply fault at the Spearman 115kV bus (50628). b) Clear fault after 5 cycles by removing the line from service. c) Wait 20 cycles, and then re-close the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
12	FLT_12_1_PH	Single Line to Ground (SLG) fault same as FLT_11_3_PH
13	FLT_13_3_PH	Three- phase fault on the Plant X (51419) – Potter (50887) 230kV line a) Apply fault at the Plant X 230kV bus (51419) b) Clear fault after 5 cycles by tripping the Plant X - Potter 230kV line c) Wait 20 cycles, then reclose the line into the fault d) Leave fault on for 5 cycles, then trip and lock out the line
14	FLT_14_1_PH	Single Line to Ground (SLG) fault same as FLT_13_3_PH
15	FLT_15_3_PH	Three- phase fault on the Pringle (50652) – Blackhawk (50718) 115kV line a) Apply fault at the Blackhawk 115kV bus (50718). b) Clear fault after 5 cycles by tripping the Pringle-Blackhawk 115kV line. c) Wait 20 cycles, then reclose the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
16	FLT_16_1_PH	Single Line to Ground (SLG) fault same as FLT_15_3_PH
17	FLT_17_3_PH	Three- phase fault on the Pringle (50653) – Harrington (50907) 230kV line a) Apply fault at the Pringle 230kV bus (50653). b) Clear fault after 5 cycles by tripping the Pringle-Harrington 230kV line. c) Wait 20 cycles, then reclose the line into the fault. d) Leave fault on for 5 cycles, then trip and lock out the line.
18	FLT_18_1_PH	Single Line to Ground (SLG) fault same as FLT_17_3_PH

3.3 Simulation Results

Simulations were performed with a 0.5-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 Vestas V80 1.8 MW WTGs.

4. Conclusion

The stability simulation findings of the impact study of a proposed interconnection plant (GEN-2006-020) were presented in this report. The impact study case considered 100% MW output of the proposed 19.8 MW wind farm. Interconnection of Vestas V80 1.8 MW WTGs between Texas Co and Sherman 115kV line was studied according to the customer request.

The 2011 summer and 2007 winter peak 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 19.8 MW. In order to integrate the proposed 19.8 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 3 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 simulations conducted in the study using the Vestas V80 1.8 MW WTGs model with the Vestas Advanced Protection settings provided by the customer did not find any angular or voltage instability problems for the disturbances.

In conclusion, the study reveals that the proposed 19.8 MW wind farm project shows stable performance of SPP system for the contingencies tested on the supplied base cases.

Appendix A. Project Data

Vestas V80
1.8 MW WTGs

Base and Loadflow Information	Value		Description
	Bus 90201	Bus 90202	
Prated	10.79	9.00	Machine Active Power Rating (MW)
Vrated	0.69	0.69	Stator Voltage Rating (kV)
Busbar	90201	90202	Connection busbar number
Gen ID	1	1	Generator Identifier
Rg	0	0	Generator Resistance in Loadflow (pu, Rs)
Xg	0.3022	0.3022	Generator Reactance in Loadflow (pu, Xs+(Xr*Xm)/(Xr+Xm))
Srated	11.1	9.25	Unit Transformer Rating (MVA)
Rt	0	0	Unit Transformer Resistance (pu)
Xt	0.67568	0.81081	Unit Transformer Reactance (pu)

CIMTSC (Bus 90201), Induction Generator with Variable Rotor Resistance

ICONs	Value		Description
	Bus 90201	Bus 90202	
M	0	0	Memory
M+1	80	80	WT type: 80 for V80 4760 for V47 60Hz 4750 for V47 50Hz
M+2	6	5	Number of lumped machines
M+3	1	1	=1/0 – two-mass shaft module enabled/disabled

VSAERC, Wind Turbine Aerodynamics

ICONs	Value	Description
M	90201/90202	Machine Bus #
M+1	‘1’	Machine ID
M+2	0	Memory

VSPCHC , Pitch Control

CONs	Value		Description
	Bus 90201	Bus 90202	
J	45.000		TetaMax, maximum pitch angle, degrees
J+1	-5.0000		TetaMin, minimum pitch angle, degrees
J+2	10.000		RTetaMax, maximum pitch angle rate of change, deg/sec
J+3	-10.000		RTetaMin, minimum pitch angle rate of change, deg/sec
J+4	-5.0000		PID_Ki, PID controller integrator gain, pu
J+5	-100.00		PID_Kp, PID controller proportional gain, pu
J+6	0.10000E-02		PID_Kd, PID controller derivative gain, pu
J+7	1.0000		PID_Td, PID controller derivative equivalent time constant, sec.
J+8	0.25000E-01		T_Delay, Actuator and feedback delay, sec.
J+9	1.0000		TRAP_Ti, integrator time constant, sec.

WGUSTC, Wind Velocity

CONs	Value		Description
	Bus 90201	Bus 90202	
J	26.000		Maximum wind speed, m/sec
J+1	9999.0		T1g, Gust start time, sec.
J+2	2.5000		Tg, Gust duration, sec.
J+3	2.0000		MAXG, Gust peak over initial wind speed, m/sec
J+4	9999.0		T1r, Ramp start time, sec.
J+5	9999.0		T2r, Ramp Max time, sec.
J+6	30.000		MAXR, Ramp maximum over initial wind speed, m/sec.

WVRCC, VRCC Current Controller

CONs	Value		Description
	Bus 90201	Bus 90202	
J	0.5000		Master_Kp, master controller common gain, pu
J+1	0.000		Master_Gain, master controller proportional gain, pu
J+2	0.3500E-01		Master_Ti, master controller integrator time constant, sec.
J+3	-0.9084		Slave_Kp, slave controller common gain, pu
J+4	1.000		Slave_Gain, slave controller proportional gain, pu
J+5	1.151		Slave _Ti, slave controller integrator time constant, sec.
J+6	0.000		Tf, filter time constant, sec.

WVPWC, VRCC Power Controller

CONs	Value		Description
	Bus 90201	Bus 90202	
J	0.000		WVPWC_Gain, common gain, pu
J+1	0.000		WVPWC_Kp, proportional gain, pu
J+2	0.000		WVPWC_Ti, time constant, sec.