SPP Southwest Power Pool

Impact Study For Generation Interconnection Request GEN-2006-006

SPP Tariff Studies

(#GEN-2006-006)

February 2008

Summary

Pursuant to the tariff and at the request of Southwest Power Pool (SPP), Pterra Consulting Inc. (Pterra) conducted the following Impact Study to satisfy the Impact Study Agreement executed by the requesting customer and SPP for SPP Generation Interconnection Request #GEN-2006-006. The request for interconnection was placed with SPP in accordance SPP's Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system.

Facilities

<OMITTED TEXT> (Customer) has requested an Impact Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnection of a 205 MW wind powered generation facility in Ford County, Kansas to the transmission system of Mid Kansas Electric Power Corporation (MKEC). The wind powered generation facility was studied with one-hundred-thirty-six (136) individual General Electric 1.5MW wind turbines.

The generation facility was studied to interconnect into the MKEC Spearville 230kV substation bus. There are several existing and prior queued wind farms in the immediate vicinity of Spearville. An Impact Restudy of GEN-2005-012 posted in November, 2007 has indicated the need for a 345kV transmission line from Spearville to Wichita via Commanche County, Kansas. Please see the GEN-2005-012 study for more information.

At this time, the cost of the Spearville – Wichita 345kV line is assigned to GEN-2005-012. However, if GEN-2005-012 withdraws or lowers the queue position from 400MW to 330MW, the Spearville – Wichita 345kV line will be assigned to GEN-2006-006. The Spearville – Wichita 345kV line is estimated at approximately 160 miles of 345kV transmission line from Spearville – Wichita substations which is necessary for the 205 MW of interconnection service. Approximate cost is $160,000,000. This is not a detailed estimate. Whether the customer is responsible for this cost and a more detailed estimate will be determined in the Facility study.

Using the Customer requested General Electric turbines with the LVRT II low voltage ride through package and with the 345kV line in service, no capacitor bank will be required. Also, the Customer will meet FERC Order #661A low voltage ride through requirements under these conditions.

Changes that occur to higher queued projects in the queue will require a restudy of this generation interconnection request.

Nothing in this study should be construed as a guarantee of transmission service. If the customer wishes to sell power from the facility, a separate request for transmission service shall be requested on Southwest Power Pool's OASIS by the Customer.

Pterra Consulting

Technical Report R102-08

Impact Study for Generation Interconnection Request GEN-2006-006

Submitted to

Southwest Power Pool

February 2008

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Contents

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Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (Gen-2006-006). The analysis was conducted through the Southwest Power Pool (SPP) Tariff for a 230 kV interconnection for 205 MW wind farm in Ford County, Kansas. This wind farm will be connected to existing Spearville 230 kV Substation owned by West Plains Electric / Sunflower Electric Power Corp. 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 205 MW. In order to integrate the proposed 205 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched.

Twenty (20) faults were considered for the transient stability simulations which included 3-phase faults, as well as, 1-phase to ground faults.

The proposed 205 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. Unity power factor at the point of interconnection was achieved by placing a 25 MVAR capacitor bank at the low voltage side of the 230/34.5 kV transformers and setting the tap of the transformers at 2.5% of the nominal. The 115 kV line from Spearville to Kinsley was modeled out of service.

The simulation results showed that:

- The project was tripped due to relay actuation because of low voltage for faults #1, 2 and 19.
- Prior queued projects Gen 2002-025A, Gen 2004-014, and Gen 2005-012 were tripped due to relay actuation because of low voltage for faults #1, #2 and #19.
- Gray County wind farm tripped for all simulated faults except for faults # 6, 7, 8, 13, 14, and 18.

A 100 MVAR SVC was proposed at Spearville 230 kV to address these low voltage trippings of the project and the prior queued projects. The simulation results showed that there are still trippings for Gen 2004-014, Gen 2005-012, Gen 2002-025A, and the Gray County wind farm.

With a proposed 345 kV line from Spearville to Wichita, the simulation results showed that no plant trips were encountered for the simulated faults. In addition, all oscillations are well damped. However, prior queued projects tripped as follow:

- For the Summer Peak Case:
  - Gray County 110 MW Wind Farm (Vestes V47 WTGs) tripped for all simulated faults except for faults # 2, 4, 7, 13, 14, 19 and 20.
  - Gen 2001-039A; 105 MW Wind Farm (Clipper WTG) tripped for fault # 16 (SLG fault at Judson Large on 115 kV line to GEN-2001-039A Tap, Breaker failure at Judson Large, [CB3629]).

- For the Winter Peak Case:
  - Gray County 110 MW Wind Farm (Vestes V47 WTGs) tripped for all simulated faults except for faults # 2, 4, 6, 7, 8, 9, 10, 12, 13, 14, 18, 19 and 20.
  - Gen 2001-039A; 105 MW Wind Farm (Clipper WTG) tripped for fault # 16 (SLG fault at Judson Large on 115 kV line to GEN-2001-039A Tap, Breaker failure at Judson Large, [CB3629]).

Stability simulations for the aforementioned prior queued projects trippings were repeated with the LVRT disabled. The study finds that the proposed 205 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.

Section 1. Introduction

1.1. Project Overview

The proposed 205 MW wind farm will be connected to the existing Spearville 230 kV Substation owned by West Plains Electric / Sunflower Electric Power Corp. Figure 1-1 shows a schematic one line diagram of the proposed GEN-2006-006 project to SPP 230 kV transmission network. The detailed connection diagram of the wind farm was provided by SPP.

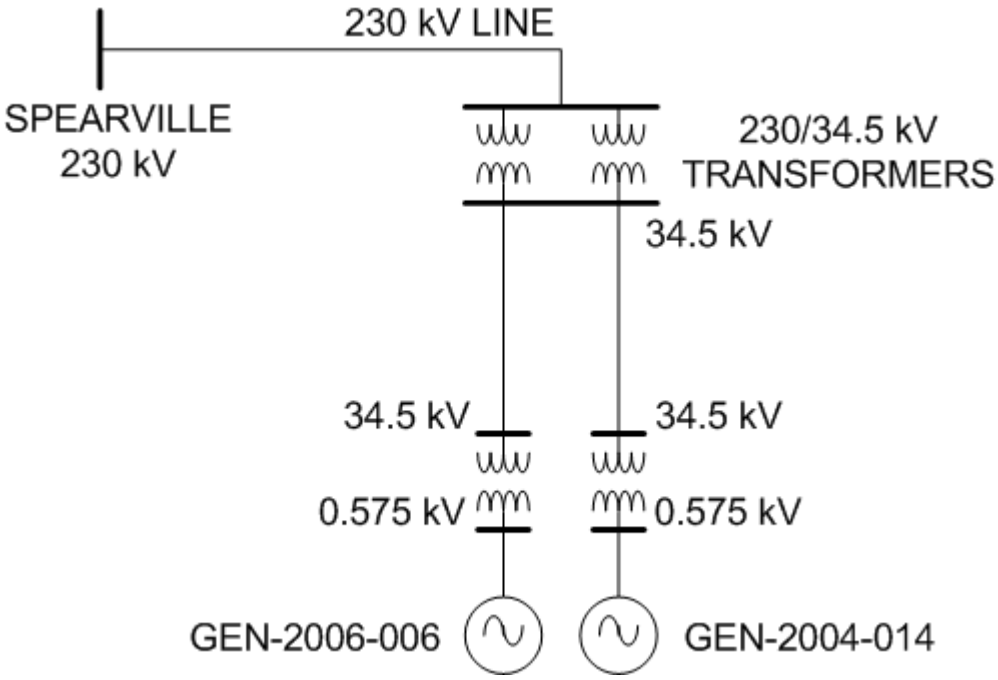

Figure 1-1 Interconnection Plan for GEN-2006-006 to SPP's 230 kV System

Unity power factor at the point of interconnection was achieved by placing an additional 25 MVAR capacitor bank at the low voltage side of the 230/34.5 kV transformers and setting the tap of the transformers at 2.5% of the nominal.

In order to integrate the proposed 205 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched.

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 205 MW wind farm was modeled with 42 equivalent units as shown in Figure 1-2. This wind farm is in addition to the existing 154 MW wind farm (Gen-2004-014) connected to the Spearville 230 kV bus.

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 230/34.5 kV transformers.
3. The line parameters of the 230 kV line.
4. The line parameters of the new 345 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. GEN-2001-039A – 115 kV Wind Farm – 105 MW consisting of Clipper wind turbines and a +30/-10 MVAR SVC.
C. GEN-2002-025A – Spearville 230 kV Wind Farm – 150 MW wind farm consisting of (100) GE turbines
D. GEN-2004-014 – 154.5 MW wind farm on the Spearville 230 kV bus consisting of (103) General Electric 1.5MW turbines
E. GEN-2005-012 – 330 MW wind farm on the Spearville 345 kV bus consisting of (165) Gamesa turbines and two +/- 8 MVA STATCOM devices.

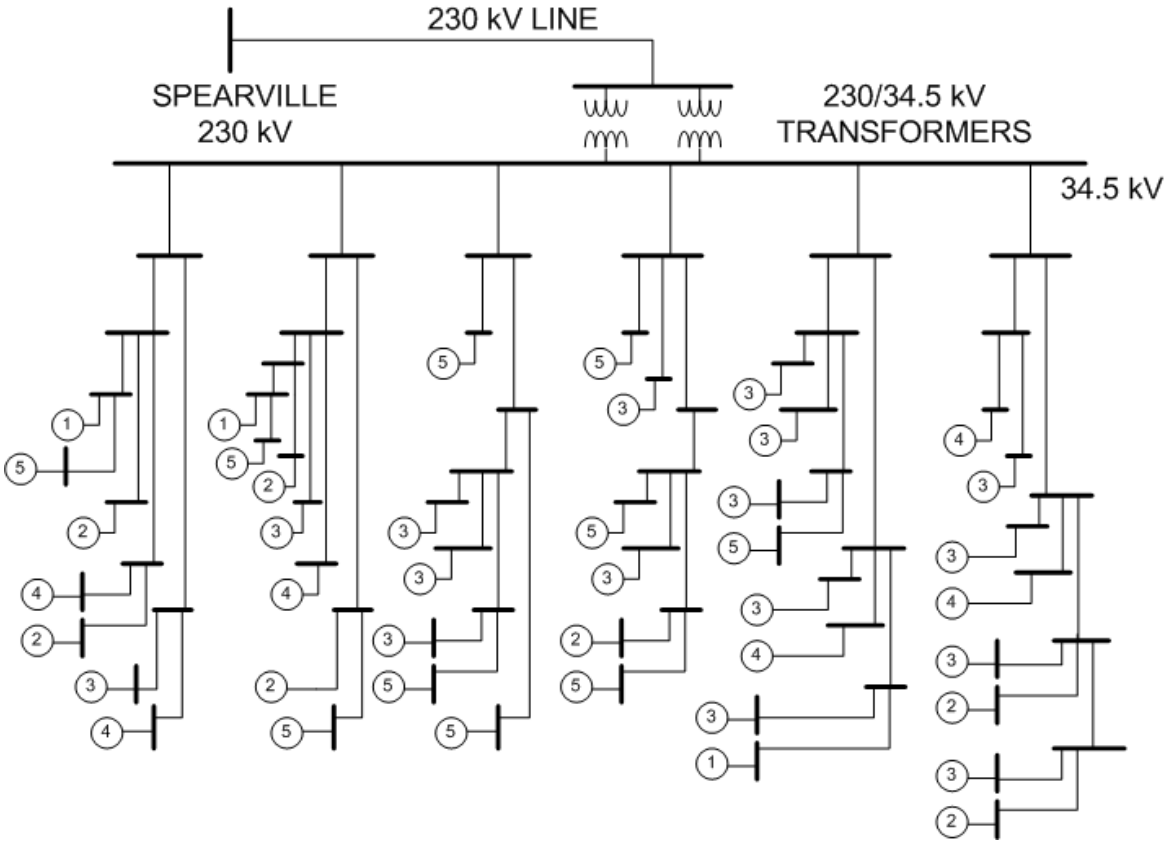

Figure 1-2 Gen 2006-006 Equivalent Representation in Load Flow (GE 1.5 MW WTG)

1.2. Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 205 MW wind farm to SPP's 230 kV transmission system.

2.1. 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 2-1 shows the data for GE 1.5 MW WTG.

Table 2-1 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 Table 2-2 and Table 2-3.

Table 2-2 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 2-3 Over/Under Voltage Relay Settings for GE 1.5 MW (LVRT II)

Voltage Settings in 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

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 (20) 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	3 phase fault on the Spearville (56469) to Holcomb (56449) 345 kV line, near Spearville. a. Apply fault at the Spearville bus (56469). b. Clear fault after 5 cycles by tripping the line from Spearville (56469) to Holcomb (56449). 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 Spearville (58795) to Mullergen (58779) 230 kV line, near Spearville. a. Apply fault at the Spearville bus (58795). b. Clear fault after 5 cycles by tripping the line from Spearville (58795) to Mullergren (58779). 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 Spearville 345kV bus a. Apply fault at the Spearville bus. b. Clear fault after 5 cycles by tripping the Spearville 345/230kV autotransformer from service.
6	FLT61PH	Single phase fault and sequence like Cont. No. 5
7	FLT73PH	3 phase fault on the Greensburg (58764) to Sun City (58797) 115 kV line, near Greensburg. a. Apply fault at Greenburg. b. Clear fault after 5 cycles by tripping the line from Sun City – Greenburg 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. 1
9	F09-3PH	3-phase fault at Mullergren on 230 kV line to Spearville Time Fault Clearing 5 Trip breaker at Mullergren for line 58779[MULGREN6] - 58795[SPEARVL6] 7 Clear fault
10	F10-SLG	SLG fault at Mullergren on 230 kV line to Spearville, Breaker failure at Mullergren, [CB6012] Time Fault Clearing 7 Trip breaker at Spearville for line [MULGREN6]-

Cont. No.	Cont. Name	Description
		58795[SPEARVL6] 16 Trip line 58779[MULGREN6]-56871[CIRCLE6] Clear fault
11	F11-3PH	3-phase fault at Spearville on 230 kV line to Mullergren Time Fault Clearing 5 Trip breaker at Spearville for line 58779[MULGREN6] – [SPEARVL6] 7 Clear fault
12	F12-SLG	SLG fault at Spearville on 230 kV line to Mullergren, Breaker failure at Mullergren, [CB6012] Time Fault Clearing 5 Trip breaker at Spearville for line 58795[SPEARVL6]-[MULGREN6] 16 Trip line 58779[MULGREN6]-56871[CIRCLE6] Clear fault
13	F13-3PH	3-phase fault at North Judson Large on 115 kV line to Spearville Time Fault Clearing 7 Trip breaker at North Judson Large for line 58871[NOR-JUD3] - SVL3] 9 Clear fault
14	F14-SLG	SLG fault at North Judson Large on 115 kV line to Spearville Breaker failure at North Judson Large, [CB3071] Time Fault Clearing 9 Trip breaker at Spearville for line 58871[NOR-JUD3]-58794[SPEARVL3] 20 Trip line 58871[NOR-JUD3]-58771[JUD-LRG3] Trip line 58767[HAGGARD3]-58799[W-DODGE3] Clear fault
15	F15-3PH	3-phase fault at Judson Large on 115 kV line to GEN-2001-039A Tap Time Fault Clearing 7 Trip breaker at Judson Large for line 58771[JUD-LRG3]-103[SSTAR_4] 9 Clear fault
16	F16-SLG	SLG fault at Judson Large on 115 kV line to GEN-2001-039A Tap Breaker failure at Judson Large, [CB3629] Time Fault Clearing 9 Trip breaker at Spearville for 58771[JUD-LRG3]-103[SSTAR_4] 20 Trip line 58771[JUD-LRG3]-58871[NOR-JUD3] Trip line 58771[JUD-LRG3]-58840[EDODGE3] Trip line 58754[CIM-PLT3]-58752[CMRIVTP3] Trip line 58772[E-LIBER3]-58752[CMRIVTP3]

Cont. No.	Cont. Name	Description
		30 Trip generator at 58770[JUD-LRG1] Clear fault
17	F17-3PH	3-phase fault at GEN-2001-039A on 115 kV line to Greensburg Time Fault Clearing 7 Trip breaker at Clipper Tap for line 103[SSTAR_4]-58764[GRNBURG3] 9 Clear fault
18	F18-SLG	SLG fault at GEN-2001-039A on 115 kV line to Greensburg Breaker failure at Medicine Lodge, [CB3102] Time Fault Clearing 7 Trip breaker at Clipper Tap for line 103[SSTAR_4]-58764[GRNBURG3] 20 Trip line 58773[MED-LDG3] -58797[SUNCITY3] Clear fault
19	FLT19	Open 345kV line from Spearville (#56469)-Holcomb (#56447) with no fault
20	FLT20	Open 230kV line from Spearville (#58795)-Mullergren (#58779) with no fault

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 205 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. In order to integrate the proposed 205 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched. The 115 kV line from Spearville to Kinsley was modeled out of service.

The simulation results showed that:

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Stability simulations for the aforementioned prior queued projects trippings were repeated with the LVRT disabled. The study finds that the proposed 205 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.

Section 3. Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2006-006 were presented in this report. The study was conducted through the Southwest Power Pool Tariff for a 230 kV 205 MW wind farm in Ford County, Kansas. This wind farm was studied using GE 1.5 MW WTG.

The proposed 205 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. Unity power factor at the point of interconnection was achieved by placing an additional 25 MVAR capacitor bank at the low voltage side of the 230/34.5 kV transformers and setting the tap of the transformers at 2.5% of the nominal. In order to integrate the proposed 205 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched. The 115 kV line from Spearville to Kinsley was modeled out of service.

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farm project shows stable performance with the aforementioned operating schemes and reinforcement of SPP system for the contingencies tested on the supplied base cases.