Impact ReStudy For Generation Interconnection Request GEN-2004-014

SPP Tariff Studies

(#GEN-2004-014)

October 2007

Executive Summary

<OMITTED TEXT> (Customer) has requested an Impact Re-Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnection of a 154.5 MW wind powered generation facility in Ford County, Kansas to the transmission system of Mid Kansas Electric Company LLC (MKEC). The wind powered generation facility was studied with one-hundred-three (103) General Electric 1.5 sle wind turbines with the LVRT II low voltage ride through package. The studied point of interconnection was the Spearville 230kV bus.

The requirements for Interconnection are discussed in the Facility Study. The requirements consist of adding a 230kV line terminal at Spearville to the Customer's wind farm. The approximate cost of this 230kV terminal is $800,000.

Two base cases each comprising of a power flow and corresponding dynamics database for 2011 summer and 2007 winter were used for this analysis. Transient stability simulations were conducted with the proposed wind farm in service with full output of 154.5 MW. In order to integrate the proposed 154.5 MW wind farm in SPP system, the existing generation in the SPP footprint was re-dispatched.

Nineteen (19) faults were considered for the transient stability simulations which included 3-phase faults, as well as, 1-phase to ground faults.

The proposed 154.5 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 transformer.

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 154.5 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 of the Customer.

1.0 Introduction

<OMITTED TEXT> (Customer) has requested an Impact Re-Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnection of a 154.5 MW wind powered generation facility in Ford County, Kansas to the transmission system of Mid Kansas Electric Company LLC (MKEC). The wind powered generation facility was studied with one-hundred-three (103) General Electric 1.5 sle wind turbines with the LVRT II low voltage ride through package. The studied point of interconnection was the Spearville 230kV bus.

2.0 Project Information and Interconnection Facilities

The proposed 154.5 MW wind farm will be connected to the existing Spearville 230 kV Substation owned by Mid Kansas Electric Power Corporation. Figure 2-1 shows a schematic one line diagram of the proposed GEN-2004-014 project to SPP 230 kV transmission network. The detailed connection diagram of the wind farm was provided by SPP.

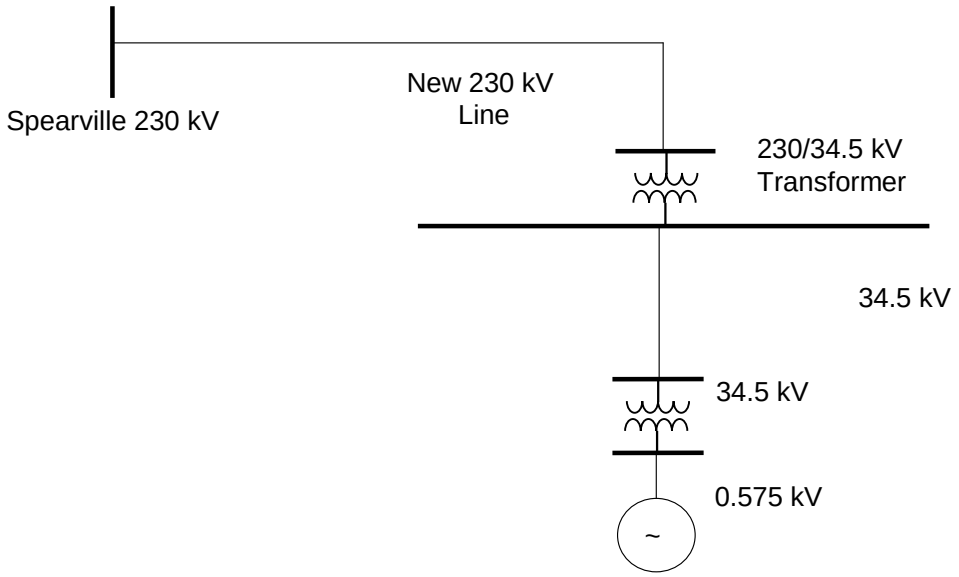
The Customer will be interconnecting into the Spearville 230kV substation owned by MKEC. The Customer will build a short 230kV line from their wind farm facilities to the Spearville substation.

The previously studied interconnection between North Kinsley and Spearville that has been associated with this request was not analyzed as part of this study.

The costs for the substation work at Spearville is estimated below:

- Installing 230kV line terminal including one (1) 230kV circuit breaker, three (3) 230kV disconnect switches and associated structural steel, foundations, and associated equipment

Subtotal	$ 800,000



Schematic Diagram for Gen 2004-014 Connection to
Spearville 230 kV substation

Figure 2-1 Interconnection Plan for GEN-2004-014

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 transformer.

In order to integrate the proposed 154.5 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 154.5 MW wind farm was modeled with 33 equivalent units as shown in Figure 2-2. The number in each circle in the diagram shows the number of individual wind turbine units that were aggregated at that bus.

The Customer provided the following data:

1. The impedance values for 34.5 kV feeders.
2. The data for the 230 kV/34.5 kV transformers.
3. The line parameters of the new 230 kV line.

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

A. Gray County Wind Farm – 110MW of Vestes V47 wind turbines
B. GEN-2001-039A – 115kV Wind Farm – 105 MW consisting of Clipper wind turbines and a +30/-10 Mvar SVC.
C. GEN-2002-025A – Spearville 230kV Wind Farm – 150 MW wind farm consisting of (100) GE turbines

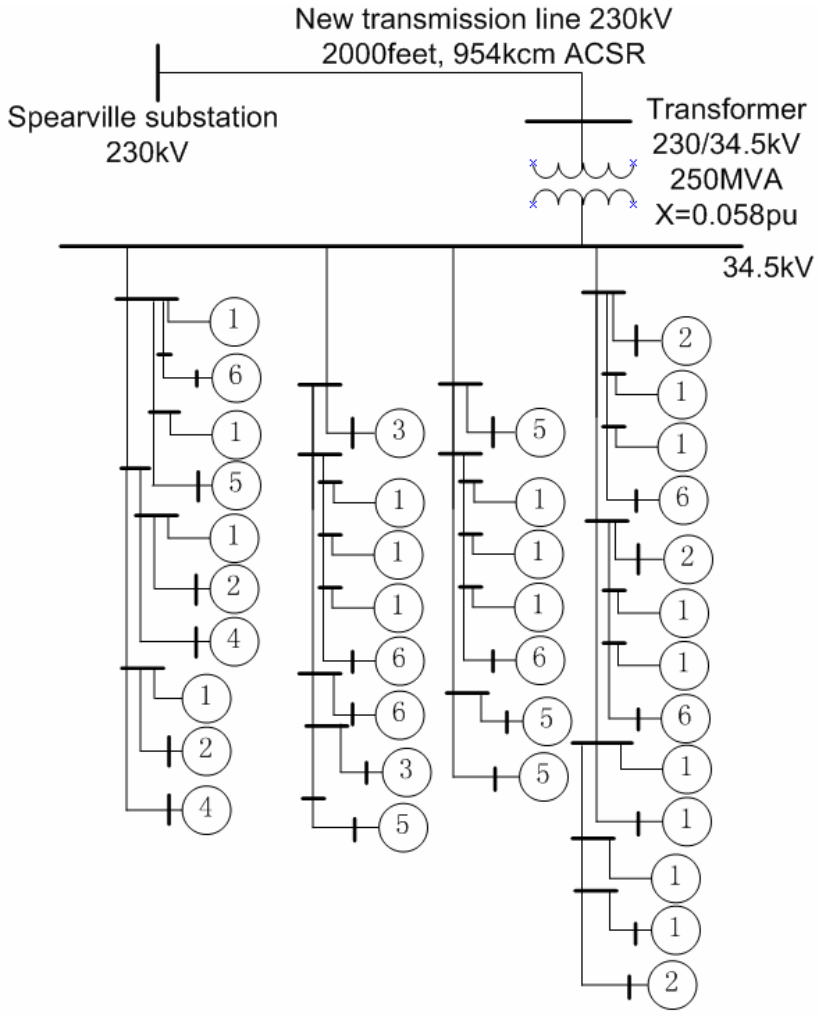


Figure 2-2 Wind Farm Equivalent Representation in Load Flow (GE 1.5 MW WTG)

3.0 Stability Analysis

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 3-1 shows the data for GE 1.5 MW WTG.

Table 3-1 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 were modeled to have ride-through capability for voltage and frequency; according to the manufacturer's LVRT II settings. Detailed relay settings are shown in Table 3-2 and 3-3.

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

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

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.

Nineteen (19) 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 3-1 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 3-1 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*

Cont. No.	Cont. Name	Description
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] - 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]

Cont. No.	Cont. Name	Description
		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	Place Holder – no 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

Simulations were performed with a 0.1-second steady-state run followed by the appropriate disturbance as described in Table 2-4. Simulations were run for a minimum 10-second duration to confirm proper machine damping.

The proposed 154.5 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. Prior Queued projects tripped as follow:

- Gray County Wind Farm (110 MW of Vestes V47 WTGs) tripped for simulated faults # 1, 3, 11, 13, 14, 15, and 17.

For the contingencies that showed tripping; the simulations were run again with Gray County Wind Farm low voltage tripping disabled. All runs were stable.

The study finds that the proposed 154.5 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 of the Customer.

4.0 Conclusion

The stability simulation findings of the impact study of a proposed interconnection (Gen-2004-014 were presented in this report. The study was conducted through the Southwest Power Pool Tariff for a 230 kV 154.5 MW wind farm in Ford County, Kansas. This wind farm was studied using GE 1.5 MW WTG.

The interconnection of the wind farm at the Spearville 230kV bus includes the addition of a 230kV terminal at Spearville. The cost of this terminal is $800,000.

The proposed 154.5 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 115/34.5 kV transformer.

The simulation results showed that no plant trips were encountered for the simulated faults. In addition, all oscillations are well damped. Prior Queued projects tripped as follow:

- Gray County Wind Farm (110 MW of Vestes V47 WTGs) tripped for simulated faults # 1, 3, 11, 13, 14, 15, and 17.

The study finds that the proposed 154.5 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 of the Customer.