Impact Study
For
Generation Interconnection
Request
GEN-2006-032

SPP Tariff Studies

(#GEN-2006-032)

January 2008

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-2006-032. This generation interconnection request was originally studied with General Electric 1.5 MW wind turbines. The Customer has subsequently asked for a restudy assuming the facility will contain Gamesa G80 2.0 MW wind turbines.

The purpose of this restudy is to evaluate the Customer's request to use the Gamesa G80 wind turbines for the proposed generation. This study addressed the stability and reactive compensation required for the Gamesa wind turbines.

The Impact Study determined that the Gamesa G80 wind turbines, with the manufacturer's ride through system as represented in the model provided to SPP by the Customer, will meet FERC Order #661A requirements for low voltage ride through.

The Impact Study determined that a minimum of 50 Mvar of capacitors are necessary for the interconnection of the wind farm. These capacitor banks will be located on the 34.5kV buses of the Interconnection Customer substation and should be sized in stages as to prevent voltage excursions on the South Hays 230kV bus.

Pterra Consulting

Technical Report R151-07

Impact Study for Generation Interconnection Request GEN-2006-032 (Re-Study)

Submitted to

Southwest Power Pool

December 2007

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Executive Summary

This report presents the stability simulation findings of the impact study of a proposed interconnection (GEN-2006-032). The analysis was conducted through the Southwest Power Pool Tariff for a 230 kV interconnection for 200 MW wind farm in Ellis County, Kansas. This wind farm would be interconnected to a new position into the planned 230/115 kV substation at South Hays owned by Midwest Electric Cooperative (MIDW). South Hays 230 kV substation will include a 230 kV line terminal to Mullergren (West Plains) and a 230 kV line terminal to Summit (via Knoll). Customer has previously studied this request with GE 1.5 MW wind turbine generators (WTGs). For this re-study, the Customer is asking to study the project with Gamesa G80 2.0 MW WTGs.

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 a full output of 200 MW. In order to integrate the proposed 200 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 a 50 MVAR capacitor located on the 34.5 kV Customer side.

Twenty four (24) 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 Gamesa WTGs were modeled with voltage and frequency ride through protection. The settings were in accordance with standard or default settings. The simulations conducted in the study using the G80 2.0 MW WTGs did not find any angular or voltage instability problems for the 24 disturbances. The study finds that the proposed 200 MW project shows stable performance of SPP system for the contingencies tested on the supplied base cases.

Section 1. Introduction

1.1. Project Overview

The proposed 200 MW wind farm will interconnect via a new ring position on the planned South Hays 230kV substation ring substation. Figure 1 shows a conceptual interconnection diagram of the proposed GEN-2006-032 project to the 230 kV transmission network. The detailed connection diagram of the wind farm was provided by SPP

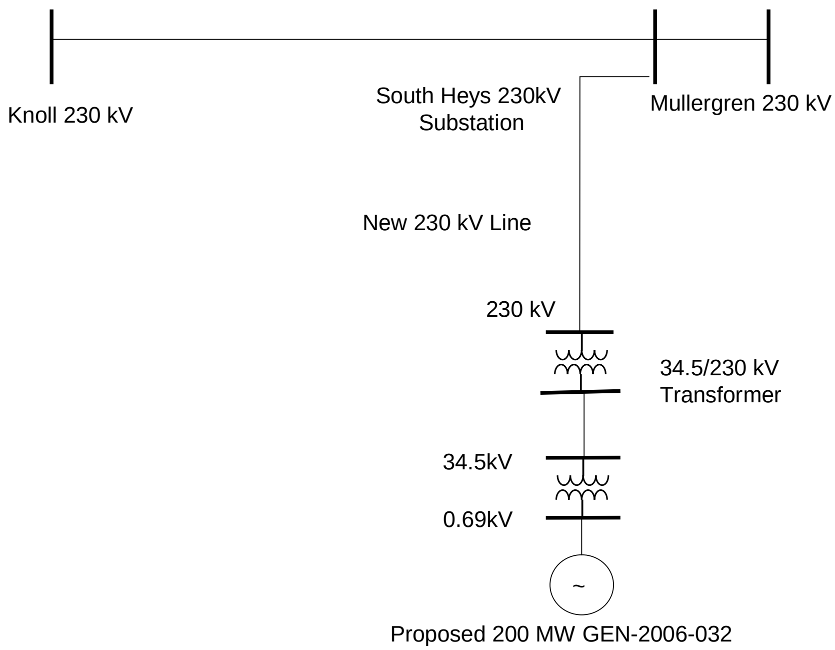

Figure 1-1 Interconnection Plan for GEN-2006-032 to SPP's 230 kV System

In order to integrate the proposed 200 MW 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 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 200 MW wind farm was modeled with 44 equivalent units (G80 2.0 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 34.5kV level. SPP provided the data for the following equipment:

1. 34.5 kV feeders.
2. The new 230 kV line.
3. Generating unit step up transformers.
4. 230/34.5 kV transformers.

Unity power factor was achieved at the interconnection point using 50 MVAR capacitor located at the 34.5 kV side of the 230/34.5 kV Transformer.

The following prior queued projects are included in the base case. These projects are:

A. GEN-2003-019; 250 MW wind farm on the Summitt-Knoll 230 kV line. Wind farm consists of 100.8 MW of Vestes V80 turbines and 150 MW of GE turbines.
B. GEN-2004-014 154 MW wind farm consists of 103 GE 1.5 MW turbines on the Mullergren-Spearville 230 kV line
C. GEN-2004-016 150 MW wind farm on the Summitt-E McPherson 230 kV line
D. GEN-2006-031; 75 MW of internal combustion turbines at Hays 115 kV substation

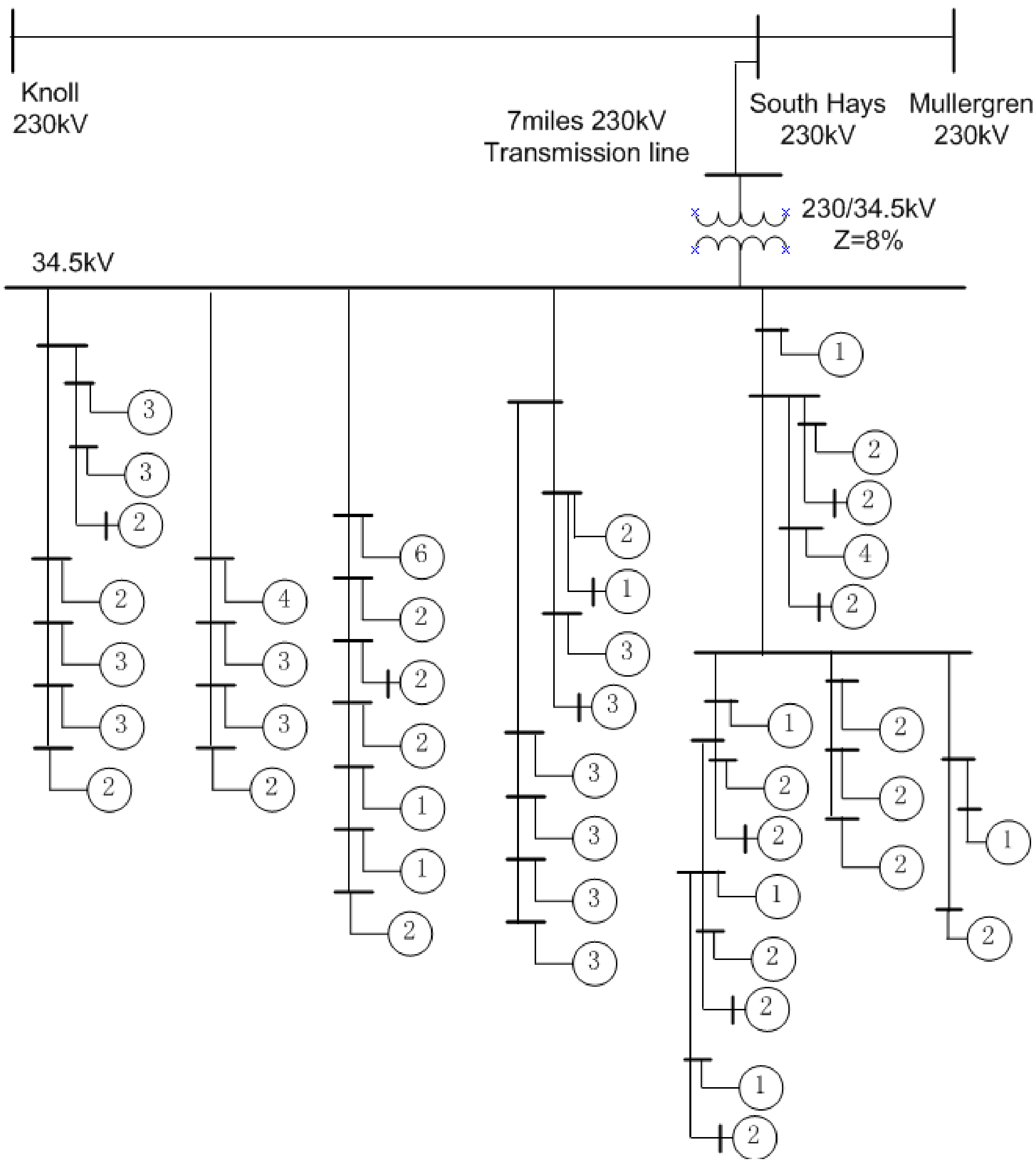

Figure 1-2 Wind Farm Equivalent Representation in Load Flow (G80 2.0 MW WTG)

1.2. Objective

The objective of the study is to determine the impact on system stability of connecting the proposed 200 MW wind farm to SPP's 230 kV transmission system.

Section 2. Stability Analysis

2.1. Modeling of the Gamesa G80 2.0 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 Gamesa G80 2.0 MW wind turbine generators were modeled using the provided Gamesa G80 2.0 MW wind turbine dynamic model set. Table 2-1 shows the data for G80 2.0 MW WTG.

Table 2-1 G80 2.0 MW Wind Generator Data

Parameter	Value
BASE KV	0.69
WTG MBASE	2.00
TRANSFORMER MBASE	2.50
TRANSFORMER R ON TRANSFORMER BASE	0.006
TRANSFORMER X ON TRANSFORMER BASE	0.060
GTAP	1.00
PMAX (MW)	2.00
PMIN	0.0
RA	0.01022
LA	0.14238
LM DELTA	7.21137
LM D Y	6.94532
L1	0.17503
RMACH	0.01008

The wind turbine generators have ride-through capability for voltage and frequency; according to the manufacturer's settings. Detailed relay settings are shown in Table 2-2 and Table 2-3.

Table 2-2 Over/Under Frequency Relay Settings for G80 2.0 MW

Frequency Settings in Hertz	Time Delay in Seconds	Breaker time in Seconds
F ≤ 57.0	Instantaneous	0.05
F ≥ 62.0	Instantaneous	0.05

Table 2-3 Over/Under Voltage Relay Settings for G80 2.0 MW

Voltage Settings Per Unit	Time Delay in Seconds	Breaker time in Seconds
V ≤ 0.15	0.04	0.05
0.15 < V ≤ 0.30	0.625	0.05
0.30 < V ≤ 0.45	1.10	0.05
0.45 < V ≤ 0.60	0.06	0.05
0.60 < V ≤ 0.75	2.050	0.05
0.75< V ≤ 0.90	2.525	0.05
V ≥ 1.10	1.00	0.05

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 four (24) 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 2-4Table 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

Fault #	Fault Description
FLT_1_3PH	Fault on the South Hays (56599) to Mullergren (58779) 230 kV line, near South Hays a. Apply Fault at the South Hays bus (56599). b. Clear Fault after 5 cycles by removing the line from South Hays to Mullergen 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.

Fault #	Fault Description
FLT_2_1PH	Same as FLT13PH above
FLT_3_3PH	Fault on the South Hays (56599) to Knoll (56558) 230 kV line, near South Hays a. Apply Fault at the S Hays (565599). b. Clear Fault after 5 cycles by removing the line from South Hays - Knoll 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.
FLT_4_1PH	Same as FLT33PH above
FLT_5_3PH	Fault on the Wind Farm Gen-2003-019 Switching Station (99950) to Knoll (56558) 230 kV line, near the Knoll. a. Apply fault at the Knoll bus (56558). b. Clear fault after 5 cycles by removing the line from the Gen-2003-019 Switching Station (99950) to Knoll (56558). 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.
FLT_6_1PH	Same as FLT53PH above
FLT_7_3PH	Fault on the Circle (56871) to Mullergren (58799) 230 kV line, near Circle. a. Apply Fault at the Circle bus (56871). b. Clear fault after 5 cycles by removing the line from Circle (56871) to Mullergren (58799). 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.
FLT_8_1PH	Same as FLT73PH above
FLT_9_3PH	Fault on the Spearville (58795) to GEN-2004-014 tap (90) 230 kV line, near GEN-2004-014 tap. a. Apply Fault at the GEN-2004-014 Tap bus (90). b. Clear fault after 5 cycles by removing the line 04-14 tap - Spearville. 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.
FLT_10_1PH	Same as FLT93PH above
FLT_11_3PH	Fault on the Manhattan (56861) to Concordia (58758) 230 kV line, near Manhattan. a. Apply fault at the Manhattan bus (56861). b. Clear fault after 5 cycles by tripping the line from Manhattan (56861) to Concordia (58758). 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.
FLT_12_1PH	Same as FLT113PH above
FLT_13_3PH	Fault on the Jefferies Energy Center (56766) to Summit (56773) 345 kV line, near Summit. a. Apply fault at the Summit bus (56773). b. Clear fault after 5 cycles by tripping the line from Jefferies Energy Center (56766) to Summit (56773). c. Wait 30 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.
FLT_14_1PH	Same as FLT133PH above

Fault #	Fault Description
FLT_15_3PH	Fault on the Morris (56863) to Summit (56873) 230 kV line, near Summit. a. Apply fault at the Summit bus (56873). b. Clear fault after 5 cycles by tripping the line Morris (56863) to Summit (56873). 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.
FLT_16_1PH	Same as FLT153PH above
FLT_17_3PH	Fault on the Knoll (56561) to Redline (56605) 115 kV line, near Knoll. a. Apply fault at the Knoll bus (56561). b. Clear fault after 5 cycles by tripping the line from Knoll (56561) to Redline (56605). 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.
FLT_18_1PH	Same as FLT173PH above
FLT_19_3PH	Fault on the Knoll (56561) to Vine (56591) 115 kV line, near Knoll. a. Apply fault at the Knoll bus (56561). b. Clear fault after 5 cycles by tripping the line from Hays (56562) to Vine (56591). 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.
FLT_20_1PH	Same as FLT193PH above
FLT_21_3PH	Fault on the Knoll (56561) to Saline (56551) 115 kV line, near Knoll. a. Apply fault at the Knoll bus (56561). b. Clear fault after 5 cycles by tripping the line from Knoll (56561) to Saline (56551). 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.
FLT_22_1PH	Same as FLT213PH above
FLT_23_3PH	Fault on the Knoll 230/115kV autotransformer. a. Apply fault at the Knoll bus (56558). b. Clear fault after 5 cycles by tripping the auto
FLT_24_1PH	Same as FLT233PH above

2.4. Simulation Results

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 simulations conducted in the study using the G80 2.0 MW WTGs did not find any angular or voltage instability problems for the 24 disturbances. The study finds that the proposed 200 MW project shows stable performance 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-2006-032) were presented in this report. The impact study case considered 100% MW of the wind farm proposed output. Gamesa G80 2.0 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 200 MW. In order to integrate the proposed 200 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 50 MVAR capacitor at the 34.5 kV side of the project substation.

Twenty four (24) 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 with the Gamesa G80 2.0 MW WTGs. The study finds that the proposed 200 MW project shows stable performance of SPP system for the contingencies tested on the supplied base cases.