Impact Study for Generation Interconnection Request GEN–2006–020

SPP Tariff Studies
(#GEN-2006-020)

January 17, 2007

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), ABB Grid Systems Consulting (ABB) performed the following Impact Study to satisfy the Impact Study Agreement executed by the requesting customer and SPP for SPP Generation Interconnection request GEN-2006-020. 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.

Interconnection Facilities

Per the Impact Study, the Customer will be required to install at least 2500 kVar of capacitors at the Customer's 34.5kV substation bus. Per the Impact Study, the Suzlon S88 wind turbines do not require the addition of an SVC or STATCOM device in order to comply with FERC Order #661A. If the Customer changes the turbine manufacturer at a later time, the request will have to be restudied and this issue will be revisited.

Facility estimates were given in the Feasibility Study. No new facilities were required by the Impact Study. The Facility estimates given in the Feasibility Study are restated below in Table 1 and Table 2. These costs will be refined if the Customer executes a Facility Study Agreement. These costs do not include facilities that may be required after a fault study analysis. This analysis will be conducted if the Customer executes a Facility Study Agreement.

Table 1: Direct Assignment Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
Customer – 115-34.5 kV Substation facilities,	*
Customer – 115kV line between Customer substation and new SPS 115kV switching station.	*
Customer - Right-of-Way for Customer Substation & Line.	*
Customer – 34.5kV, 2500kVar staged capacitor bank	*
Total	*

Note: *Estimates of cost to be determined by Customer.

Table 2: Required Interconnection Network Upgrade Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
SPS - Add 3-breaker ring 115kV switching station in Sherman – Texas County 115kV line	$2,266,369
SPS - Right-of-Way for SPS Switching Station (site cost, surveying, permitting, etc.).	$105,000
SPS - 115kV Transmission Line Re-Termination	$219,121
Total	**$2,590,490**

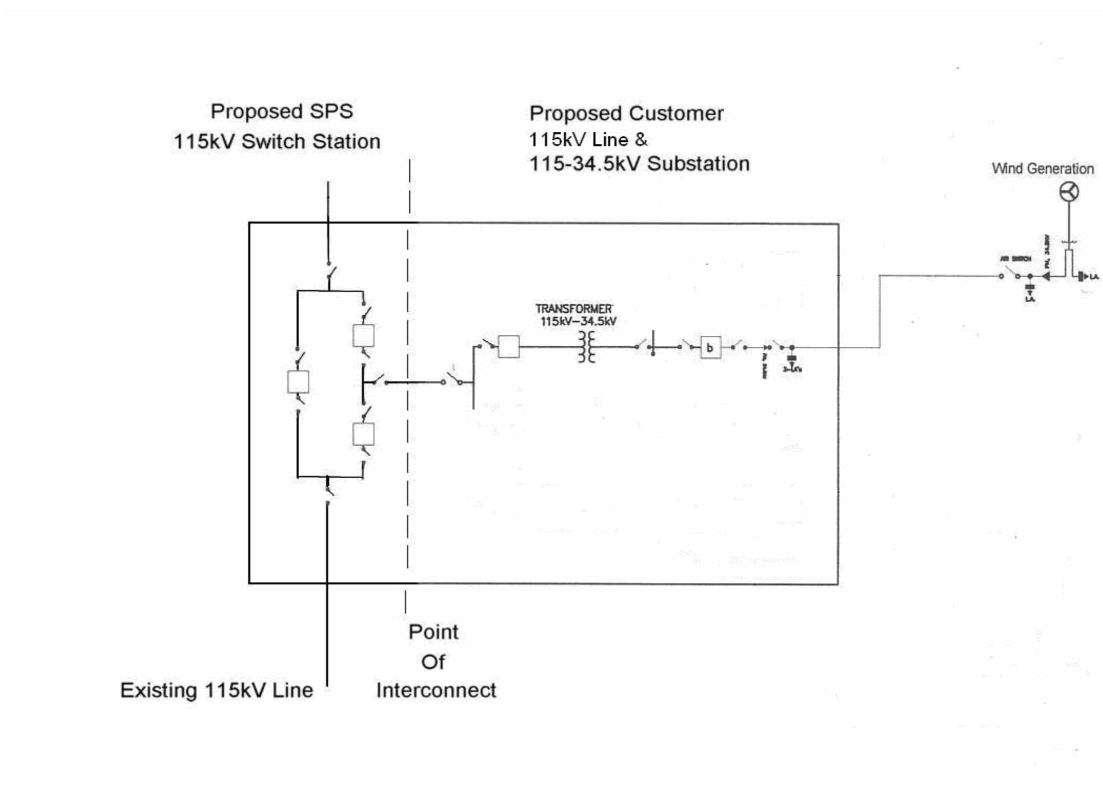

FIGURE 1. ONE-LINE OF THE INTERCONNECTION

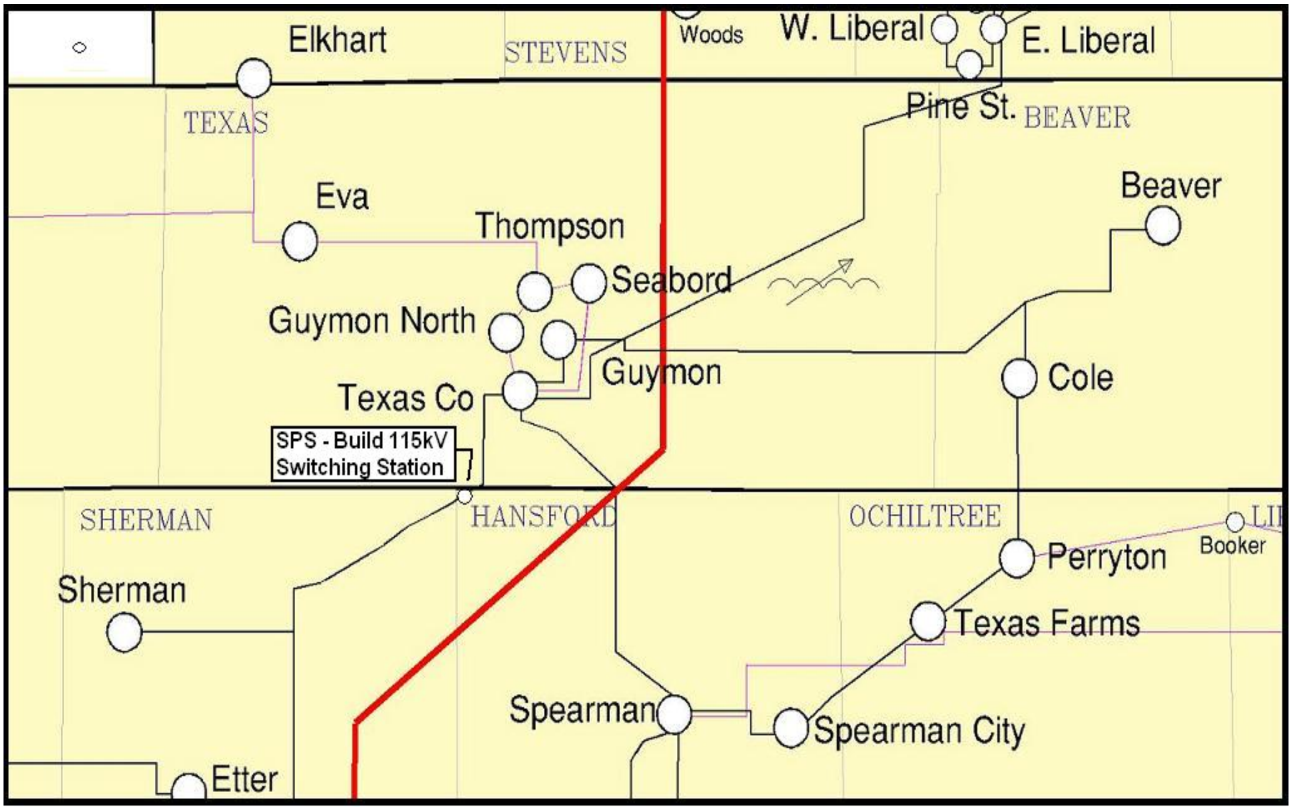

FIGURE 2. MAP OF THE LOCAL AREA

POWER SYSTEMS DIVISION
GRID SYSTEMS CONSULTING

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2006-020

FINAL REPORT

REPORT NO.: 2007-10623-R0
Issued: January 17, 2007

ABB Inc.
Power Systems Division
Grid Systems Consulting
940 Main Campus Drive, Suite 300
Raleigh, NC 27606

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Southwest Power Pool	**No.** 2006-10623-R0	
Impact Study for Generation Interconnection request GEN-2006-020	1/17/2007	# Pages 11

Author(s):	**Reviewed by:**	**Approved by:**
Shu Liu	Bill Quaintance	Willie Wong

Executive Summary

Southwest Power Pool (SPP) has commissioned ABB Inc. to perform a Generation Interconnection Impact study of a new 18.9 MW wind farm in Sherman County, Texas. This wind farm will be interconnected to the middle of the existing Sherman – Texas County 115 kV transmission line, which is owned by Xcel Energy (d/b/a SWPS). This plant will comprise nine Suzlon S88 2.1 MW wind turbine generators. The interconnection impact study includes only the stability analysis. The feasibility (power flow) study was not performed as a part of this study.

The objective of this study is to evaluate the impact on system stability after connecting the GEN-2006-020 to the interconnection point and its effect on the nearby transmission system and generating stations. The study is performed on two system scenarios: 2007 Winter Peak and the 2011 Summer Peak, provided by SPP.

The GEN-2006-020 wind farm will remain on-line through all the simulated faults, and the SPP system will be stable following all these faults in both Summer Peak and Winter Peak system conditions**.**

To keep GEN-2006-020 at 1.0 power factor, while also achieving 1.0 power factor at the POI, 2.5 MVAR of capacitors are required at the wind farm 34.5 kV bus.

Based on the results of this stability analysis, it can be concluded that the proposed GEN-2006-020 project does not adversely impact the stability of the SPP system.

The results of this analysis are based on available data and assumptions made at the time of conducting this study. If any of the data and/or assumptions made in developing the study model change, the results provided in this report may not apply.

Rev No.	Revision Description	Date	Authored by	Reviewed by	Approved by
0	Final Report	1/17/2007	Shu Liu	Bill Quaintance	Willie Wong
DISTRIBUTION: Charles Hendrix – Southwest Power Pool					

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1 INTRODUCTION

Southwest Power Pool (SPP) has commissioned ABB Inc., to perform a Generation Interconnection Impact study of a new 18.9 MW wind farm in Sherman County, Texas. This wind farm will be interconnected into the middle of the existing Sherman – Texas County 115 kV transmission line, which is owned by Xcel Energy (d/b/a SWPS). This plant will comprise nine Suzlon S88 2.1 MW wind turbines. The interconnection study includes the stability analysis. The feasibility (power flow) study was not performed as a part of this study.

The objective of the impact study is to evaluate the impact on system stability after connecting the GEN-2006-020 to the interconnection point and its effect on the nearby transmission system and generating stations. The study is performed on two system scenarios: 2007 Winter Peak and the 2011 Summer Peak. Figure 1-1 shows the Point of interconnection for the GEN-2006-020.

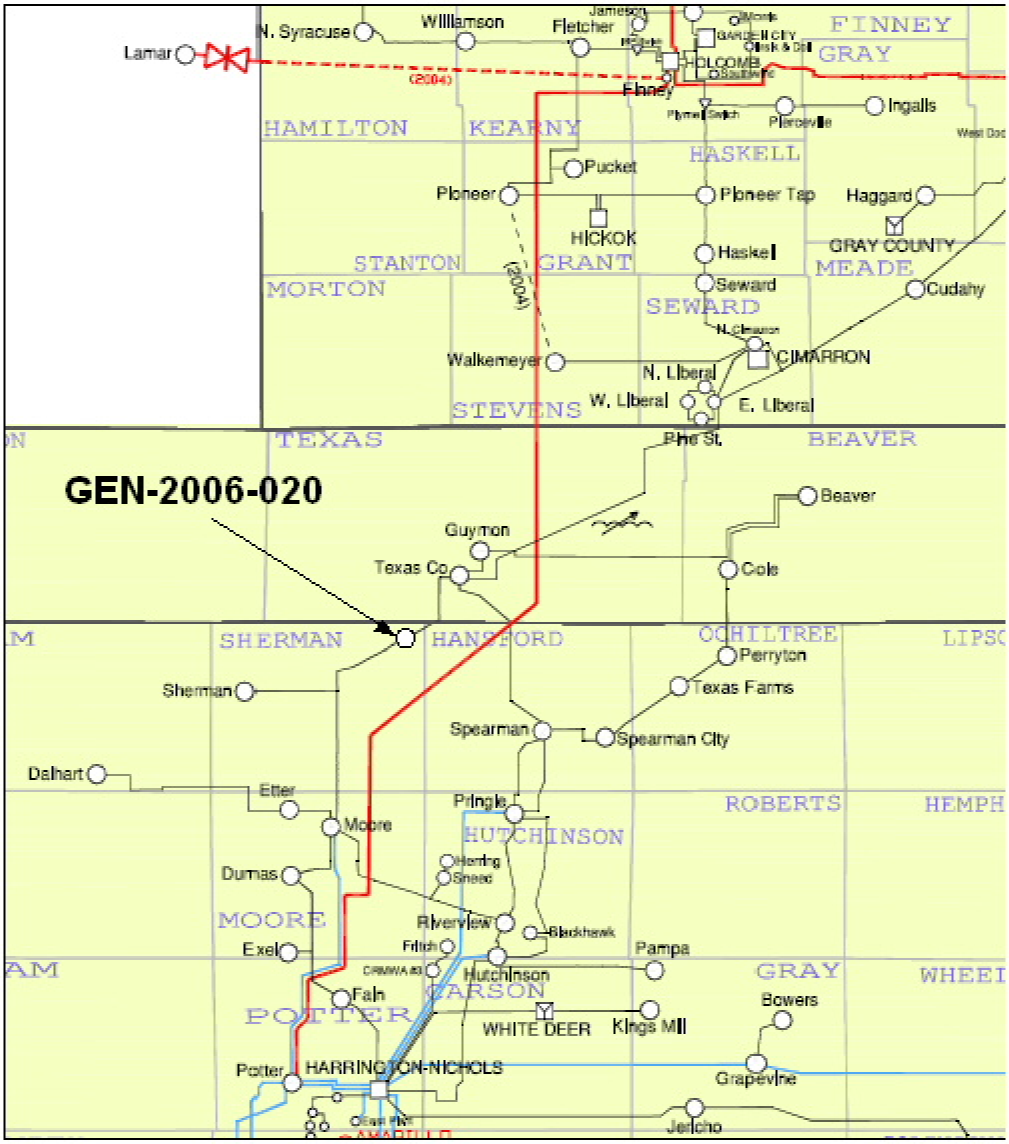

Figure 1-1: GEN-2006-020 Point of Interconnection

2 STABILITY ANALYSIS

In this study, ABB investigated the stability of the system for faults in the vicinity of the proposed plant as defined by SPP. The faults involve three-phase and single-phase faults cleared by primary protection, re-closing with the fault still on, and then permanently clearing the fault with primary protection.

2.1 STABILITY ANALYSIS METHODOLOGY

Using Planning Standards approved by NERC, the following stability definition was applied in the Transient Stability Analysis:

"Power system stability is defined as that condition in which the differences of the angular positions of synchronous machine rotors become constant following an aperiodic system disturbance."

Stability analysis was performed using Siemens-PTI's PSS/E dynamics program V29. Three-phase and single-phase line faults were simulated for the specified durations, including re-closing, and the synchronous machine rotor angles were monitored to make sure they maintained synchronism following the fault removal. Stability of asynchronous machines was monitored as well.

Single-phase line faults were simulated with the standard method of applying fault impedance to the positive sequence network 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 fault location of approximately 60% of pre-fault voltage, which is a typical value.

2.2 STUDY MODEL DEVELOPMENT

The study model consists of power flow cases and dynamics databases, developed as follows.

Power Flow Case

SPP provided two (2) Pre-project PSS/E power flow cases called "*gen06-20_11sp_base.sav*" representing the Summer Peak conditions of the SPP system for the year 2011 and the "*gen06-20_07wp_base.sav*" representing the Winter Peak conditions of the SPP system for the year 2007.

The proposed GEN-2006-020 project is comprised of nine Suzlon S88 2.1 MW wind turbine generators. The units will be connected to the middle of the Sherman – Texas County 115 kV transmission line by a two-winding 115/34.5 kV transformer. The proposed project was added to the Pre-project cases and the generation was dispatched by lowering generation at Tolk #1 (bus 51441, reduced by 18.9 MW). See Table 2-1 for details. Two power flow cases with GEN-2006-020 were established:

SP11-GEN-2006-020.SAV
WP07-GEN-2006-020.SAV

Figure 2-1 and Figure 2-2 show the power flow diagrams for the local area of Sherman – Texas County 115 kV transmission line with GEN-2006-020 in-service (Summer Peak 2011 and Winter Peak 2007 system conditions, respectively).

Table 2-1: GEN-2006-020 project details

System condition	MW	Location	Point of Interconnection	Sink
Summer Peak	18.9	Sherman County, Texas	Sherman-Texas County 115 kV transmission line	Tolk #1
Winter Peak	18.9	Sherman County, Texas	Sherman-Texas County 115 kV transmission line	Tolk #1

Wind Farm Power Flow Model

The GEN-2006-020 wind farm has nine Suzlon S88 2.1 MW wind turbine generators. The entire wind farm is modeled as a single machine for the impact study. A single equivalent generator and a single equivalent GSU transformer are added to the full SPP system model through a single equivalent collector branch and the 115/34.5 kV substation transformer. The detailed process of wind farm model development is included in Appendix A.

Stability Database

SPP provided the stability database in the form of a PSS/E dynamic dyr data file "*gen06-20_11sp_base.dyr*" to model the Summer Peak stability dynamics database for 2011 and "*gen06-20_07wp_base.dyr*" to model the Winter Peak stability dynamics database for the year 2007. Along with the above-mentioned files, idev and batch files were also provided to compile and link user-written models. The provided files required the use of PSS/E version 29.

The stability data for GEN-2006-020 was appended to the Pre-GEN-2006-020 snapshot. The stability model incorporates the standard ride-through capability that allows wind turbine generator operation below 40% terminal voltage for up to 700ms and fast tripping (80ms) for terminal voltages below 15%. The wind farm was modeled assuming generator terminal voltage control.

The Power flow and stability model representations for GEN-2006-020 are included in Appendix B.

Table 2-2 lists the disturbances simulated for stability analysis. All transmission lines were assumed to have re-closing enabled. All faults were simulated for 10 seconds.

Table 2-2: List of Faults for Stability Analysis

FAULT	FAULT DESCRIPTION
FLT_1_3PH	a. Apply 3-phase fault at the GEN-2006-020 bus (50620). b. Clear fault after 5 cycles by removing the line from 50620 to 50596. 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_2_1PH	a. Apply 1-phase fault at the GEN-2006-020 bus (50620). b. Clear fault after 5 cycles by removing the line from 50620 to 50596. 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_3_3PH	a. Apply 3-phase fault at the Sherman bus (50624). b. Clear fault after 5 cycles by removing the line from 50620 to 50624. 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_4_1PH	a. Apply 1-phase fault at the Sherman bus (50624). b. Clear fault after 5 cycles by removing the line from 50620 to 50624. 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_5_3PH	a. Apply 3-phase fault at the Moore bus (50669). b. Clear fault after 5 cycles by removing the line from 50669 to 50887. 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	a. Apply 1-phase fault at the Moore bus (50669). b. Clear fault after 5 cycles by removing the line from 50669 to 50887. 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_7_3PH	a. Apply 3-phase fault at the Guymon bus (50602). b. Clear fault after 5 cycles by removing the line from 50596 to 50602. 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	a. Apply 1-phase fault at the Guymon bus (50602). b. Clear fault after 5 cycles by removing the line from 50596 to 50602. 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_9_3PH	a. Apply 3-phase fault at the Spearman bus (50628). b. Clear fault after 5 cycles by removing the line from 50628 to 66668. 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.

FAULT	FAULT DESCRIPTION
FLT_10_1PH	a. Apply 1-phase fault at the Spearman bus (50628). b. Clear fault after 5 cycles by removing the line from 50628 to 66668. 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_11_3PH	a. Apply 3-phase fault at the Spearman bus (50628). b. Clear fault after 5 cycles by removing the line from 50628 to 50652. 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_12_1PH	a. Apply 1-phase fault at the Spearman bus (50628). b. Clear fault after 5 cycles by removing the line from 50628 to 50652. 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_13_3PH	a. Apply 3-phase fault at the Plant X bus (51419). b. Clear fault after 5 cycles by removing the line from 51419 to 50887. 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_14_1PH	a. Apply 1-phase fault at the Plant X bus (51419). b. Clear fault after 5 cycles by removing the line from 51419 to 50887. 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_15_3PH	a. Apply 3-phase fault at the Blackhawk bus (50718). b. Clear fault after 5 cycles by removing the line from 50652 to 50718. 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_16_1PH	a. Apply 1-phase fault at the Blackhawk bus (50718). b. Clear fault after 5 cycles by removing the line from 50652 to 50718. 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_17_3PH	a. Apply 3-phase fault at the Pringle bus (50653). b. Clear fault after 5 cycles by removing the line from 50653 to 50907. 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_18_1PH	a. Apply 3-phase fault at the Pringle bus (50653). b. Clear fault after 5 cycles by removing the line from 50653 to 50907. 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.

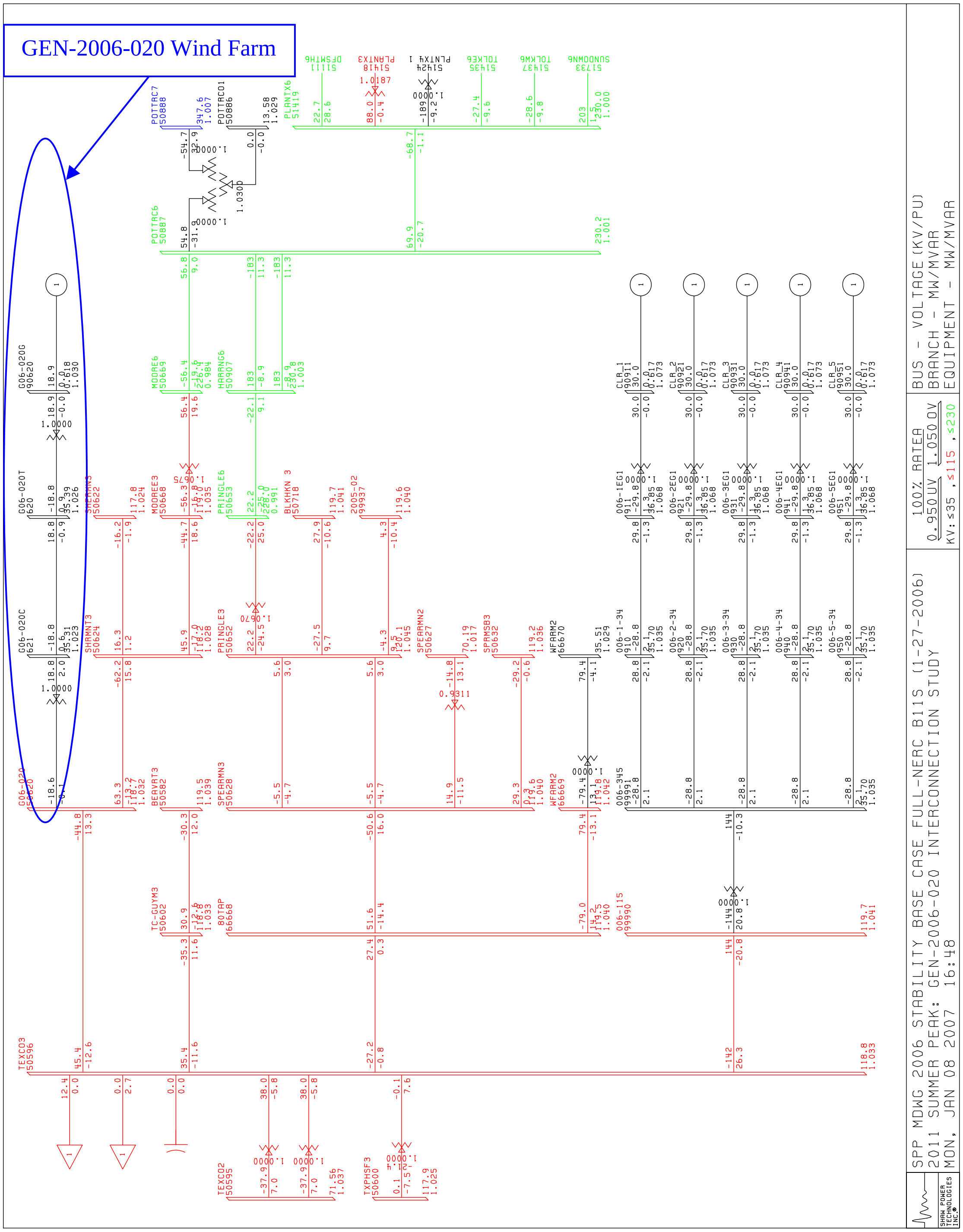

Figure 2-1: Power flow diagram for GEN-2006-020 (Summer Peak 2011)

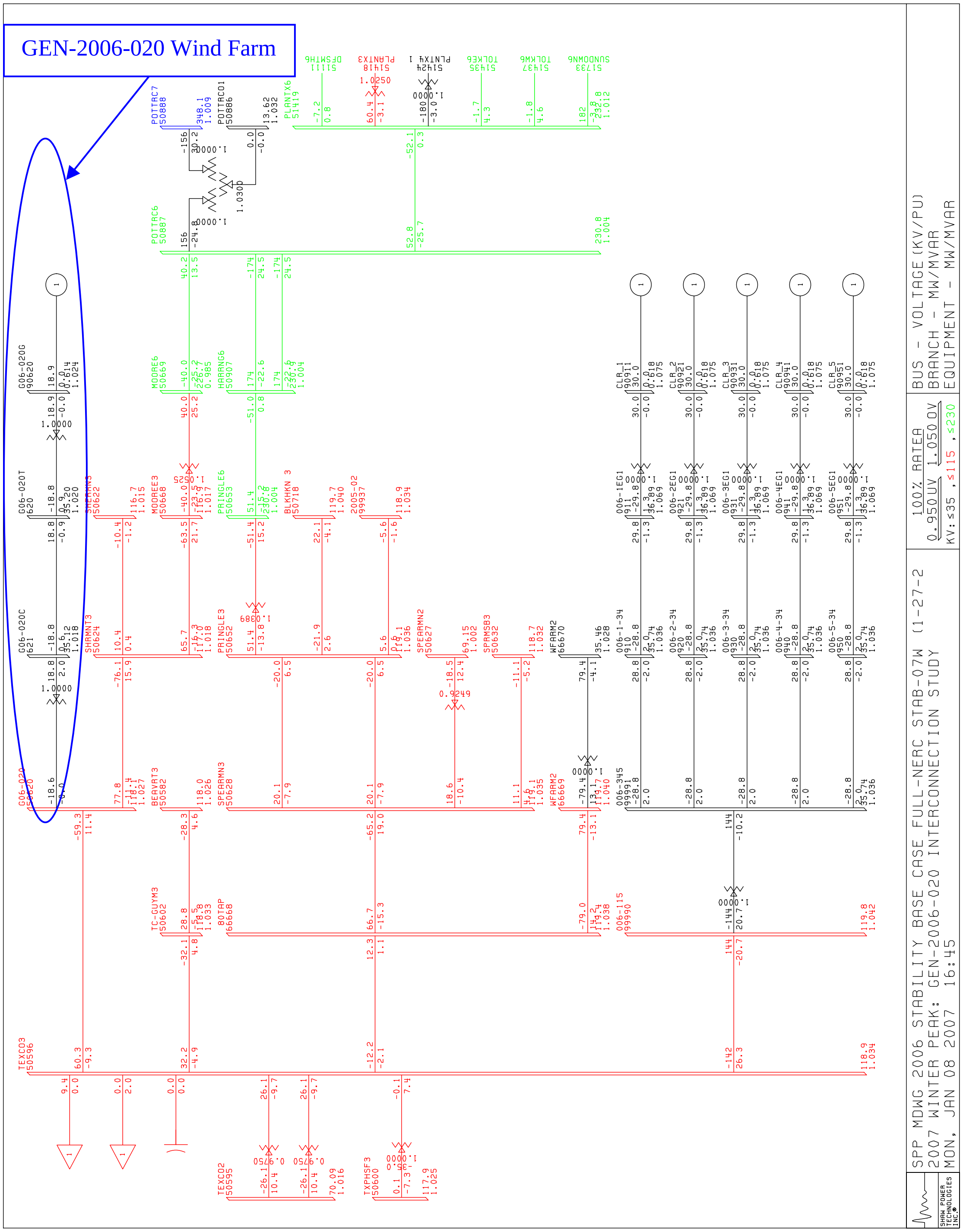

Figure 2-2: Power flow diagram for GEN-2006-020 (Winter Peak 2007)

2.3 STUDY RESULTS

The results for all the disturbances simulated are summarized in Table 2-3.

The plots for all the simulated faults are included in Appendix C.

The results of the simulation indicate that GEN-2006-020 will remain on-line through all the simulated faults, and the SPP system will be stable following these faults in both Summer Peak and Winter Peak system conditions**.**

Table 2-3: Results for Stability Analysis

FAULT	Summer Peak 2011	Winter Peak 2007
FLT_1_3PH	STABLE	STABLE
FLT_2_1PH	STABLE	STABLE
FLT_3_3PH	STABLE	STABLE
FLT_4_1PH	STABLE	STABLE
FLT_5_3PH	STABLE	STABLE
FLT_6_1PH	STABLE	STABLE
FLT_7_3PH	STABLE	STABLE
FLT_8_1PH	STABLE	STABLE
FLT_9_3PH	STABLE	STABLE
FLT_10_1PH	STABLE	STABLE
FLT_11_3PH	STABLE	STABLE
FLT_12_1PH	STABLE	STABLE
FLT_13_3PH	STABLE	STABLE
FLT_14_1PH	STABLE	STABLE
FLT_15_3PH	STABLE	STABLE
FLT_16_1PH	STABLE	STABLE
FLT_17_3PH	STABLE	STABLE
FLT_18_1PH	STABLE	STABLE

2.4 ADDITIONAL REACTIVE POWER REQUIREMENTS

The Suzlon S88 2.1 MW wind turbine generator does not have reactive power capability. To keep these generators at 1.0 power factor, while also achieving 1.0 power factor at the POI, a 2.5 MVAR of capacitors at the wind farm 34.5 kV bus are required.

3 CONCLUSIONS

The objective of this study is to evaluate the impact on system stability after connecting the GEN-2006-020 to the interconnection point and its effect on the nearby transmission system and generating stations. The study is performed on two system scenarios: 2007 Winter Peak and the 2011 Summer Peak, provided by SPP.

The GEN-2006-020 will remain on-line through all the simulated faults and the SPP system will be stable following all these faults in both Summer Peak and Winter Peak system conditions**.**

To keep GEN-2006-020 at 1.0 power factor, while also achieving 1.0 power factor at the POI, a 2.5 MVAR of capacitors at the wind farm 34.5 kV bus are required.

Based on the results of stability analysis it can be concluded that the proposed GEN-2006-020 project does not adversely impact the stability of the SPP system.

The results of this analysis are based on available data and assumptions made at the time of conducting this study. If any of the data and/or assumptions made in developing the study model change, the results provided in this report may not apply.

APPENDIX A - WIND FARM MODEL DEVELOPMENT

APPENDIX B - LOAD FLOW AND STABILITY DATA

APPENDIX C - SIMULATION PLOTS FOR STABILITY ANALYSIS