Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2005–021

SPP Coordinated Planning
(#GEN-2005-021)

September 2006

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), ABB Inc. Electric 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-2005-021. 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.

Additional Items

This Interconnection Request was originally for 150MW. After the Feasibility Study was conducted, the Customer asked to reduce the queue position to 85.5MW. This Impact Study reflects the new queue position output of 85.5MW.

Per the study, the Customer will be required to buy the proposed G.E. wind turbines with the LVRT II low voltage ride through package to comply with FERC Order #661A.

Due to the G.E. wind turbines being used, the Customer will not need to install a Static Var Compensator (SVC). However, the Customer will be required to install a 34.5kV, 12Mvar capacitor bank in the Customer substation in order to accommodate losses on the wind turbine feeder collector system.

Facilities

Interconnection Facilities were discussed and estimated in the Feasibility Study for this request. Those costs are listed below in Table 1. These costs will be further refined in a Facility Study if the Customer chooses to execute a Facility Study Agreement.

Table 1: Direct Assignment Facilities

Facility	ESTIMATED COST (2006 DOLLARS)
Customer – 115-34.5kV Substation facilities including one 34.5kV 12MVAR capacitor bank.	*
Customer – 115kV line between Customer substation and upgraded SPS Kirby Substation.	*
Customer - Right-of-Way for Customer Substation & Line.	*
SPS - New 115kV bus, breaker, etc. in existing Kirby Substation.	350,000
Total	*****

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

POWER SYSTEMS DIVISION
GRID SYSTEMS - CONSULTING

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2005-021

FINAL REPORT

REPORT NO.: 2006-11338-R0
Issued: September 7, 2006

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Legal Notice

Southwest Power Pool	No. 2006-11338-R0	
Impact Study for Generation Interconnection request GEN-2005-021	September 7, 2006	# Pages 17

Author(s):	Reviewed by:	Approved by:
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Executive Summary

Southwest Power Pool (SPP) has commissioned ABB Inc., to perform a Generation Interconnection Impact study of a new 85.5 MW wind farm in Donley and Gray Counties, Texas. This wind farm will be interconnected into the existing Kirby 115 kV substation, which is owned by Xcel Energy (d/b/a SWPS). This plant will comprise 57 GE 1.5 MW wind turbine generators. The interconnection impact study includes 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-2005-021 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 SPP system will be stable following all the simulated faults with the proposed GEN-2005-021 project in-service.

GEN-2005-021 will be tripped due to low voltage for faults at the interconnection point. Undervoltage protection trip settings are the major factor influencing the GEN-2005-021 tripping.

With an upgraded low voltage ride-through package (LVRT II), GEN-2005-021 will stay on-line for faults at the interconnection point and SPP system will be stable.

Based on the results of this stability analysis it can be concluded that the proposed GEN-2005-021 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	9/7/2006	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 85.5 MW wind farm in Donley and Gray Counties, Texas. This wind farm will be interconnected into the existing Kirby 115 kV substation, which is owned by Xcel Energy (d/b/a SWPS). This plant will comprise fifty seven GE 1.5 MW wind turbine generators. 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-2005-021 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-2005-021. Figure 1-2 shows the schematic diagram for the interconnection of GEN-2005-021.

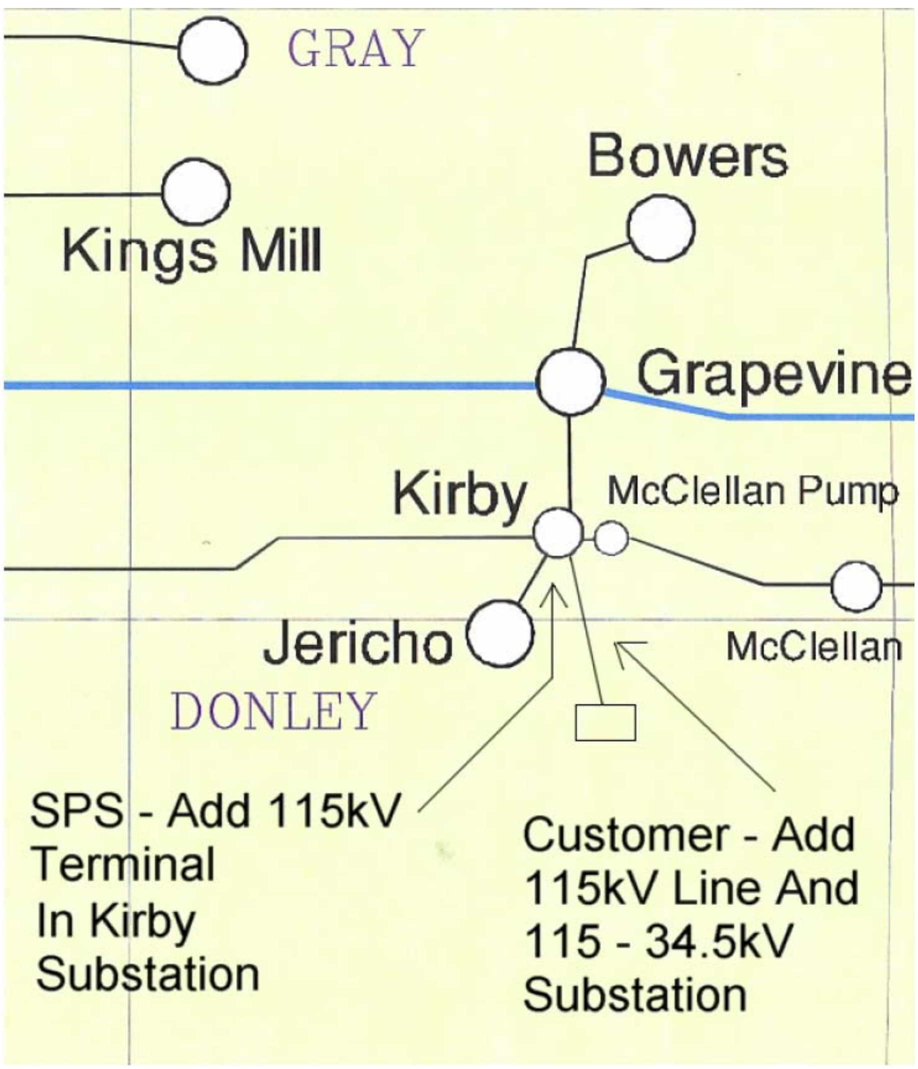

Figure 1-1: GEN-2005-021 Point of Interconnection

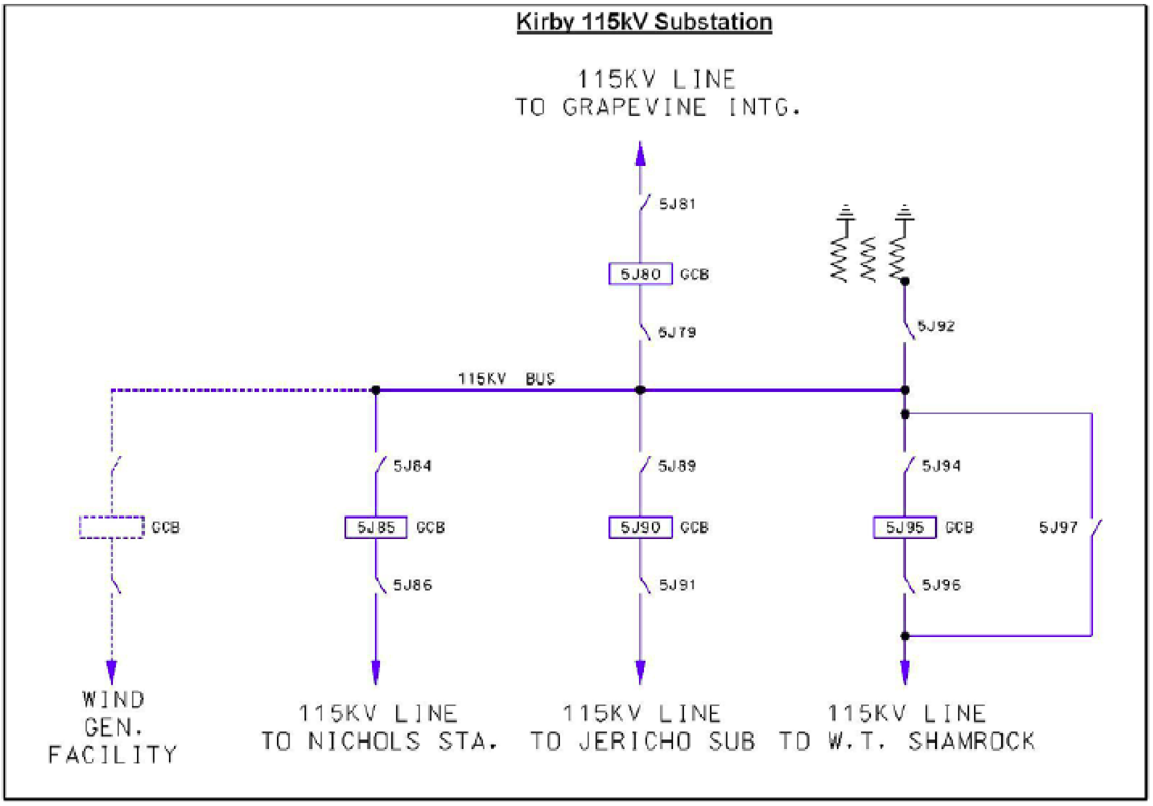

Figure 1-2: Schematic diagram for the interconnection of GEN-2005-021

2 STABILITY ANALYSIS

In this study, ABB investigated the stability of the system for the 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. Disturbances such as 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.

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.

<u>Power Flow Case</u>

SPP provided two (2) Pre-project PSS/E power flow cases called "*gen05-21_11sp_base.sav*" representing the Summer Peak conditions of the SPP system for the year 2011 and the "*gen05-21_07wp_base.sav*" representing the Winter Peak conditions of the SPP system for the year 2007.

The proposed GEN-2005-021 project is comprised of fifty seven GE 1.5 MW wind turbine generators. The units will be connected to the Kirby 115kV substation 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 scaling up load in WERE (area 536, 30MW), KACP (area 541, 20MW), and AEPW (area 520, 35MW). See Table 2-1 for details. Two power flow cases with GEN-2005-021 were established:

SP011-GEN-2005-021.SAV
WP07-GEN-2005-021.SAV

Figure 2-1 and Figure 2-2 shows the power flow diagram for the local area of Kirby substation with GEN-2005-021 in-service (Summer Peak 2011 and Winter Peak 2007 system conditions, respectively).

Table 2-1: GEN-2005-021 project details

System condition	MW	Location	Point of Interconnection	Sink
Summer Peak	85.5	Donley and Gray Counties, Texas	Kirby Substation 115kV	WERE, KACP, and AEPW
Winter Peak	85.5	Donley and Gray Counties, Texas	Kirby Substation 115kV	WERE, KACP, and AEPW

Wind Farm Power Flow Model

The GEN-2005-021 wind farm has fifty seven GE 1.5 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 "*gen05-21_11sp_base.dyr*" to model the Summer Peak stability dynamics database for 2011 and "*gen05-21_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-2005-021 was appended to the Pre-GEN-2005-021 snapshot. The stability model parameters were based on default data provided with the PTI GE Wind model. This model incorporates the standard ride-through capability that allows wind turbine generator operation below 70% terminal voltage for up to 100ms and instantaneous tripping (20ms) for terminal voltages below 30%. The wind farm was modeled assuming generator terminal voltage control.

A 34.5kV, 12 Mvar capacitor bank will be required in the Customer substation for reactive compensation of losses on the wind turbine collector feeder system.

The Power flow and stability model representation for GEN-2005-021 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 Fault at Kirby (50932). b. Clear Fault after 5 cycles by removing the line from (50932-50928). 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	SLG fault same as FLT_1_3PH
FLT_3_3PH	a. Apply Fault at Kirby (50932). b. Clear fault after 5 cycles by removing the line from (50932-50826). 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	SLG fault same as FLT_3_3PH
FLT_5_3PH	a. Apply fault at the Kirby bus (50932) b. Clear fault after 5 cycles by removing the line from (50932-50838). 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	SLG same as FLT_5_3PH
FLT_7_3PH	a. Apply fault at the Bowers bus (50820) b. Clear fault after 5 cycles by removing the line from (50826-50820). 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	SLG same as FLT_7_3PH
FLT_9_3PH	a. Apply fault at the Mclean Rural bus (50840) b. Clear fault after 5 cycles by removing the line from (50838-50840). 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	SLG same as FLT_9_3PH
FLT_11_3PH	a. Apply fault at the Elk City bus (54153). b. Clear fault after 5 cycles by removing the line from (50827-54153). 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	SLG same as FLT_11_3PH
FLT_13_3PH	a. Apply Fault at the Mid-line bus (50828). b. Clear Fault after 5 cycles by removing the line from (50915-50828-50827). 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_14_1PH	SLG same as FLT_13PH
FLT_15_3PH	a. Apply Fault at the Hutchison County Interchange bus (50751). b. Clear fault after 5 cycles by removing the line from (50915-50751). 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	SLG same as FLT_15_3PH
FLT_17_3PH	a. Apply Fault at the Whitaker bus (50922). b. Clear fault after 5 cycles by removing the line from (50914-50922). 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	SLG same as FLT_17_3PH
FLT_19_3PH	a. Apply Fault at the East Plant Interchange bus (50956). b. Clear fault after 5 cycles by removing the line from (50922-50956). 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_20_1PH	SLG same as FLT_19_3PH

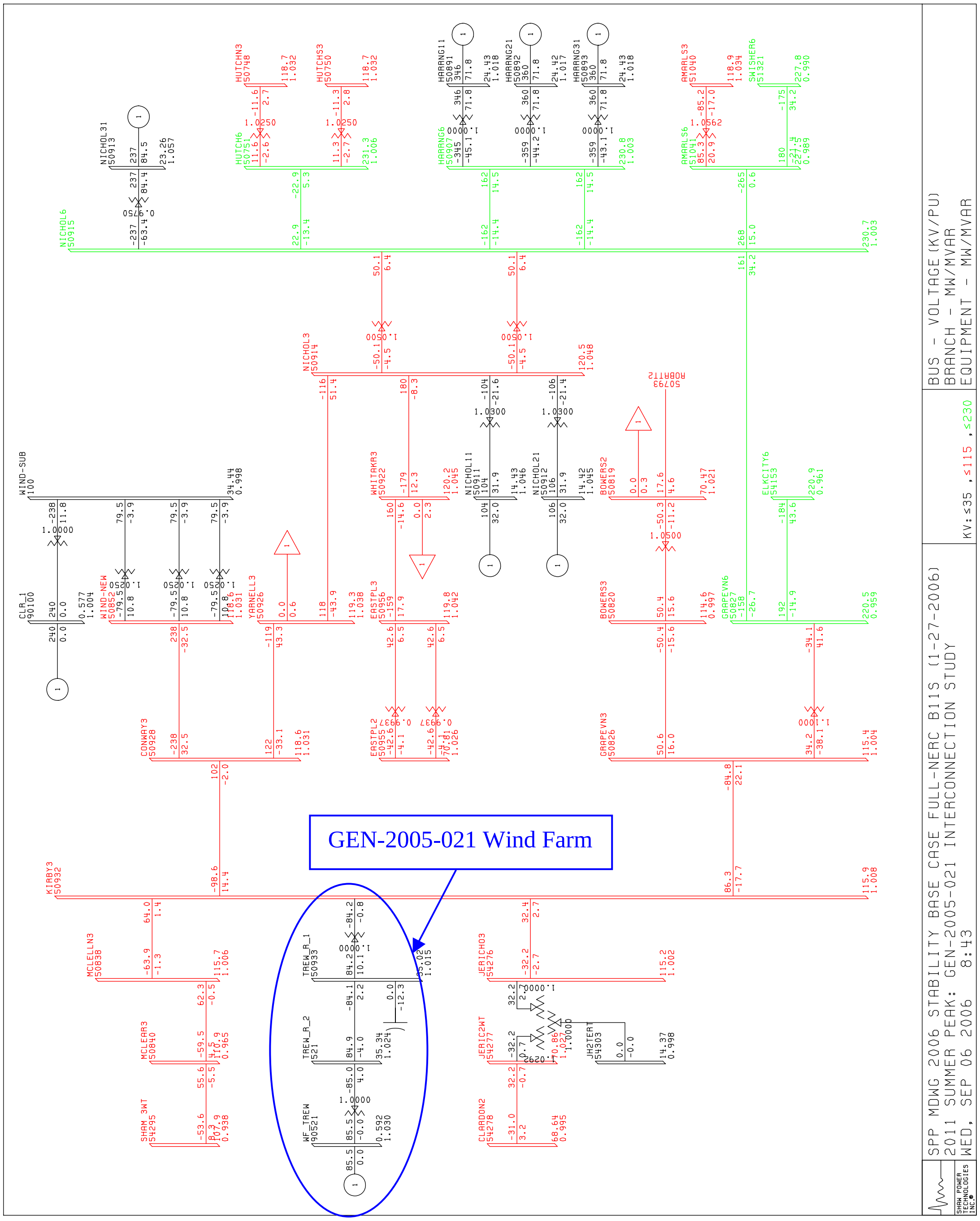

Figure 2-1: Power flow diagram for GEN-2005-021 (Summer Peak 2011)

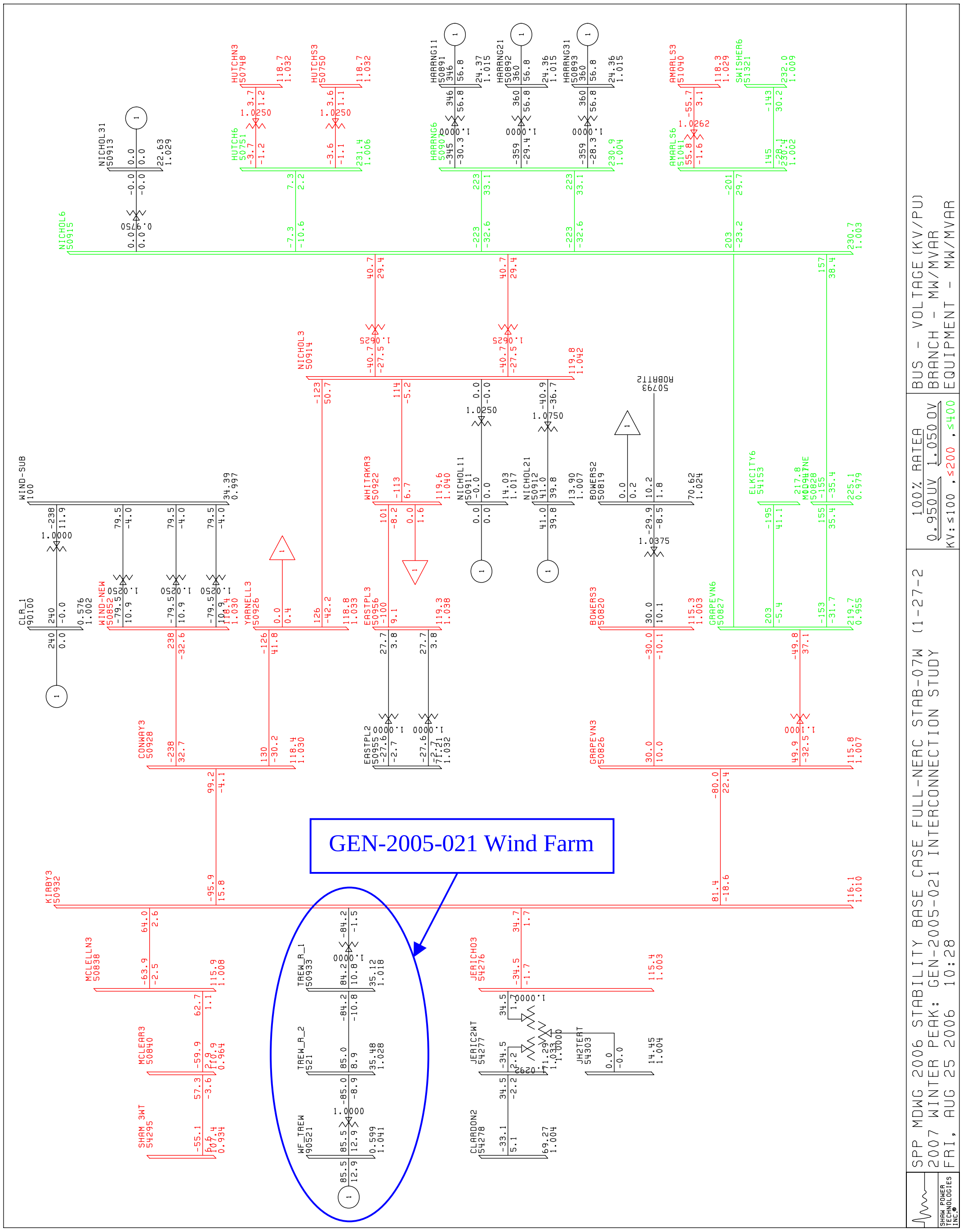

Figure 2-2: Power flow diagram for GEN-2005-021 (Winter Peak 2007)

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 the SPP system will be stable following all the simulated faults in both Summer Peak and Winter Peak system conditions**.**

For both 2007 WP and 2011 SP cases, faults at the interconnection point will cause GEN-2005-021 to be tripped by undervoltage protection scheme. These faults were repeated with new undervoltage ride-through settings (named with extension "-NT" to the fault ID) as follows:

Default Setting of VTGTPA Model		Changed Trip Settings	
Voltage below 30%	0.02 Sec	Voltage below 15%	0.02 Sec
Voltage below 70%	0.10 Sec	Voltage below 70%	0.625 Sec

With the new undervoltage ride-through settings the GEN-2005-021 remained on-line through the faults and the SPP system were stable following these faults.

Table 2-3: Results for Stability Analysis

FAULT	Summer Peak 2011	Winter Peak 2007
FLT_1_3PH	STABLE GEN-2005-021 tripped for Undervoltage (below 30%)	STABLE GEN-2005-021 tripped for Undervoltage (below 30%)
FLT_1_3PH_NT	STABLE	STABLE
FLT_2_1PH	STABLE	STABLE
FLT_3_3PH	STABLE GEN-2005-021 tripped for Undervoltage (below 30%)	STABLE GEN-2005-021 tripped for Undervoltage (below 30%)
FLT_3_3PH_NT	STABLE	STABLE
FLT_4_1PH	STABLE	STABLE
FLT_5_3PH	STABLE GEN-2005-021 tripped for Undervoltage (below 30%)	STABLE GEN-2005-021 tripped for Undervoltage (below 30%)
FLT_5_3PH_NT	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
FLT_19_3PH	STABLE	STABLE
FLT_20_1PH	STABLE	STABLE

3 CONCLUSIONS

The objective of this study is to evaluate the impact on system stability after connecting the GEN-2005-021 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 SPP system will be stable following all the simulated faults with the proposed GEN-2005-021 project in-service.

GEN-2005-021 will be tripped due to low voltage for faults at the interconnection point. Undervoltage protection trip settings are the major factor influencing the GEN-2005-021 tripping.

With an updated low voltage ride-through setting (LVRT II), GEN-2005-021 will stay on-line for faults at the interconnection point and SPP system will be stable.

Based on the results of stability analysis it can be concluded that the proposed GEN-2005-021 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