Impact Study for Generation Interconnection Request GEN–2006–021

SPP Tariff Studies
(#GEN-2006-021)

June 5, 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-2006-021. 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.

Interconnection Facilities

The Impact Study determined that the facilities required by the Customer to provide necessary reactive compensation include two (2) +/- 50Mvar static var compensator (SVC) devices located on each of the Customer's 34.5kV buses of the substation transformers. Also, required are two (2) staged capacitor banks on each 34.5kV bus. The staged banks shall contain fourteen (14) Mvar each for a total of twenty-eight (28) Mvar.

The SVC devices and their size are necessary for a combination of reasons. The first reason is the need for the wind farm to meet FERC Order #661A for low voltage ride through considerations. The second reason is that enough capacitors cannot be installed at the wind farm before it causes voltages to be excessively high during system intact conditions. These conditions occur because of insufficient transmission facilities in the area of the generation interconnection request to deliver the requested output of 250MW into the transmission system. With adequate transmission system reinforcements that can be determined through a Transmission Service Request (TSR), the size of the SVCs may be reduced.

The Customer may ask for a restudy of the SVC requirements for this generation interconnection request if the transmission reinforcements in the area change due to a TSR made by the Customer or on the Customer's behalf.

The requirements for interconnection of the 250MW consist of building a new 138kV three breaker ring bus substation in the middle of the existing Medicine Lodge – Harper 138kV line owned by Mid Kansas Electric Corp. (MKEC) formerly West Plains Electric. This 138kV substation shall be constructed and maintained by MKEC. The Customer did not propose a route of its 138kV line to serve its 138/34.5kV facilities. It is assumed that obtaining all necessary right-of-way for the substation construction will not be a significant expense. Necessary construction also includes reconfiguring the protection of the 138/115kV autotransformer at Medicine Lodge substation.

The total cost for building a new 138kV 3-breaker ring switching station and reconfiguring the protection scheme at Medicine Lodge substation, the required interconnection facilities, was estimated in the Feasibility Study at $4,724,887. Please see the Feasibility Study for a more detailed description of this facility.

A preliminary one-line drawing of the interconnection and direct assigned facilities are shown in Figure 1.

Table 1: Direct Assignment Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
Customer – 138-34.5 kV Substation facilities.	*
Customer – 138kV transmission line facilities between Customer facilities and MKEC 138kV switching station	*
Customer - Right-of-Way for Customer facilities.	*
Customer – Two (2) staged 34.5kV, 14Mvar capacitor bank(s) in Customer substation	*
Customer – Two (2) +/- 50Mvar Static Var Compensator (SVC) Devices	
Total	*****

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

Table 2: Required Interconnection Network Upgrade Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
MKEC – Build 138kV, 3-breaker ring bus switching station. Station to include breakers, switches, control relaying, high speed communications, all structures and metering and other related equipment	$3,560,484
MKEC – Modify the existing Medicine Lodge substation to include a 138kV circuit switcher for autotransformer protection.	$376,922
Contribution in Aid of Construction (CIAC)	$787,481
Total	**$4,724,887**

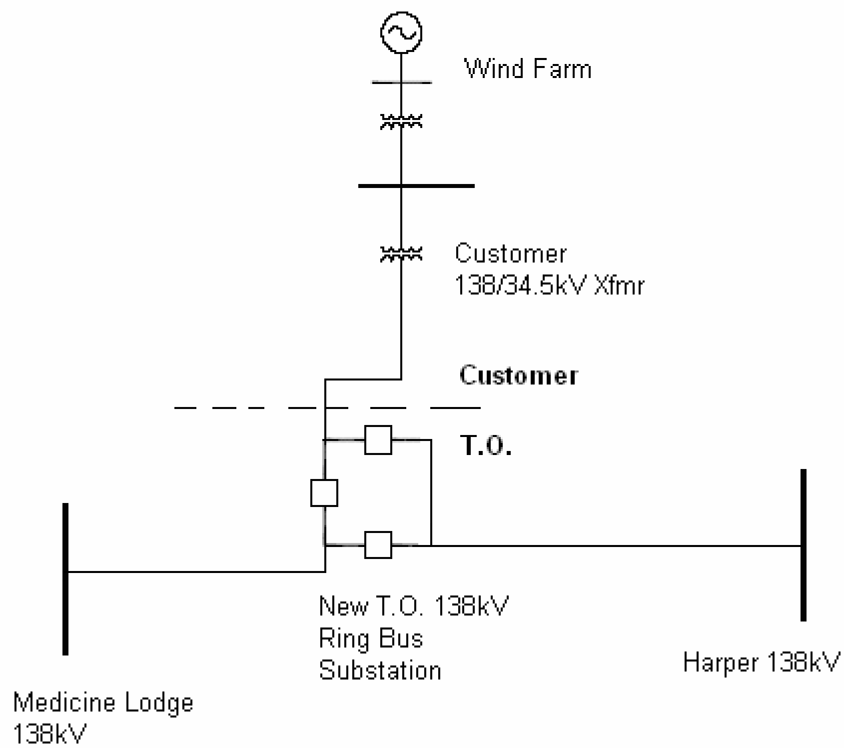

Figure 1: Proposed Interconnection
(Final substation design to be determined)

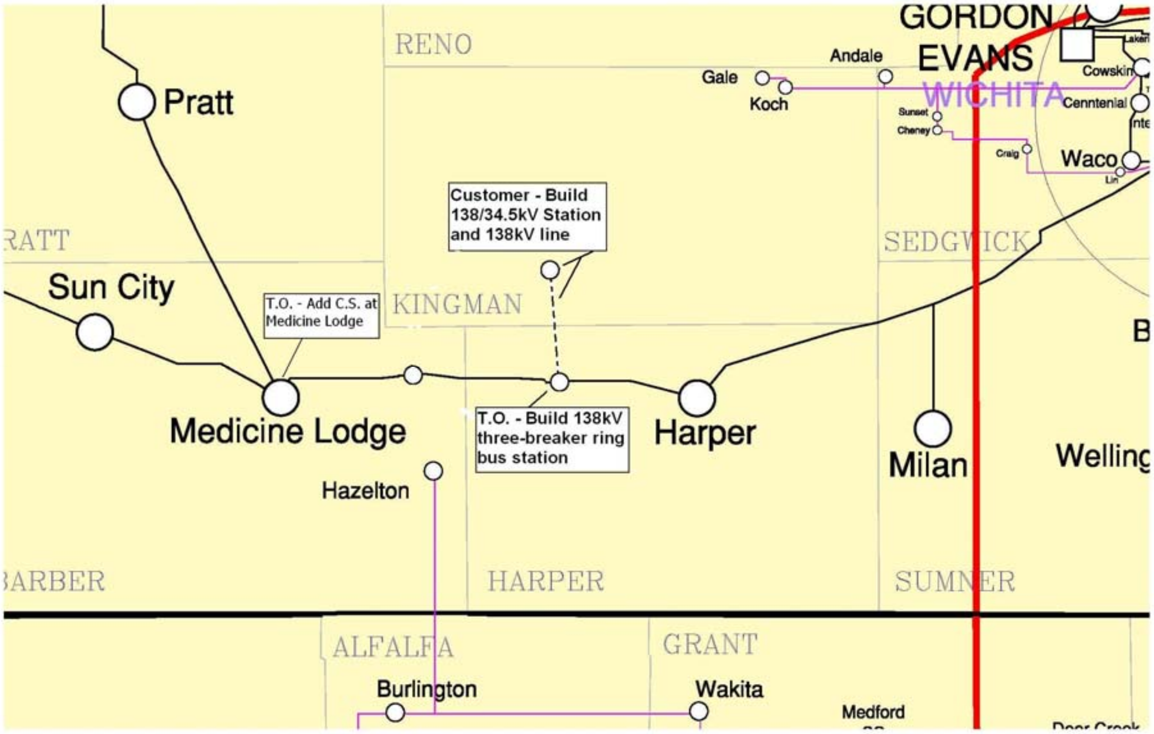

Figure 2: Map of the Local Area

POWER SYSTEMS DIVISION
GRID SYSTEMS CONSULTING

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2006-021

DRAFT REPORT

REPORT NO.: 2007-11460-R0
Issued: June 5, 2007

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

Legal Notice

This document, prepared by ABB Inc., is an account of work sponsored by Southwest Power Pool (SPP). Neither SPP nor ABB Inc, nor any person or persons acting on behalf of either party: (i) makes any warranty or representation, expressed or implied, with respect to the use of any information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights, or (ii) assumes any liabilities with respect to the use of or for damages resulting from the use of any information, apparatus, method, or process disclosed in this document.

Southwest Power Pool	No. 2007-11460-R0	
Impact Study for Generation Interconnection request GEN-2006-021	6/5/2007	# Pages 11

Author(s):	Reviewed by:	Approved by:
Bradley Johnson	Bill Quaintance	Willie Wong

Executive Summary

Southwest Power Pool (SPP) has commissioned ABB to perform a Generation Interconnection Impact study of a new 250 MW wind farm in Harper County, Kansas (GEN-2006-021). A new 6 mile 138 kV transmission line will connect the wind farm to the West Plains Electric transmission system. The new line will tap into the Medicine Lodge – Harper 138 kV transmission line, at a point approximately 26% of the distance from Medicine Lodge. The plant itself will have two 34.5 kV collector systems each with 50 Clipper 2.5 MW wind turbines.

This interconnection impact study includes only stability analysis. A 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 GEN-2006-021 and to determine its effect on the nearby transmission system and generating stations. The study is performed for two system scenarios: 2007 Winter Peak and the 2011 Summer Peak.

SPP normally requires wind farms to have at least enough shunt compensation to achieve 1.0 power factor at the point of interconnection. However, for this POI and MW injection level, 1.0 pf would cause the 138 kV voltages to go above 1.05 per unit pre-disturbance. Thus, shunt capacitors were added to the GEN-2006-021 34.kV buses to achieve 1.05 pu voltage on the wind farm 138 kV bus. For the Summer Peak case 8 MVARS of shunt capacitors are represented on each collector system. For the Winter Peak case 14 MVAR of shunt capacitors are represented on one collector system and 15 MVAR are represented on the other.

Based on the original transmission configuration, GEN-2006-021 generators will trip for both Summer Peak and Winter Peak conditions for the following faults:

- FLT_1_3PH (a three phase fault with unsuccessful re-closing, resulting in the loss of the Medicine Lodge – POI 138 kV line)
- FLT_3_3PH (a three phase fault with unsuccessful re-closing, resulting in the loss of the Harper – POI 138 kV line)

Rev No.	Revision Description	Date	Authored by	Reviewed by	Approved by
0	Draft Report	6/5/2007	Bradley Johnson	Bill Quaintance	Willie Wong
DISTRIBUTION: Charles Hendrix – Southwest Power Pool					

- FLT_2_1PH (a single phase fault with unsuccessful re-closing, resulting in the loss of the Medicine Lodge – POI 138 kV line)
- FLT_4_1PH (a single phase fault with unsuccessful re-closing, resulting in the loss of the Harper – POI 138 kV line)

GEN-2006-021 would remain on-line for the other simulated faults, and the SPP system would be stable following these faults for both Summer Peak and Winter Peak system conditions**.**

If two +30 MVAR static var controllers (SVCs) are installed, one attached to each wind plant collector system, GEN-2006-021 generators will only trip for the FLT_3_3PH fault (for both Summer Peak and Winter Peak conditions). However, the voltage will also be extremely high for several cycles immediately following the FLT_4_1PH fault.

If two +-50 MVAR static var controllers are installed, one attached to each wind plant collector system, GEN-2006-021 will remain on line for all the simulated faults for both Summer Peak and Winter Peak conditions.

Based on the results of stability analysis it can be concluded that the proposed GEN-2006-021 project would not adversely impact the stability of the SPP system if two +-50 MVAR static var controllers are installed, one attached to each wind plant collector 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.

TABLE OF CONTENTS

1 INTRODUCTION

Southwest Power Pool (SPP) has commissioned ABB Inc. to perform a Generation Interconnection Impact study of a new 250 MW wind farm in Harper County, Kansas. A new 6 mile 138 kV transmission line will connect the wind farm to the West Plains Electric transmission system. The new line will tap into the Medicine Lodge – Harper 138 kV transmission line, at a point approximately 26% of the distance from Medicine Lodge. The plant will have two 34.5 kV collector systems each with 50 Clipper 2.5 MW wind turbines.

The interconnection impact study includes only the stability analysis. A 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-2006-021 plant, and to determine its effect on the nearby transmission system and generating stations. The study is performed for two system scenarios: the 2007 Winter Peak and the 2011 Summer Peak.

2 STABILITY ANALYSIS

In this study, ABB investigated the stability of the system for a series of faults specified by SPP, which are in the vicinity of the proposed plant. Most of the simulations represent three-phase or single-phase faults cleared by primary protection in 5 cycles, re-closing after 20 more cycles with the fault still on, and then permanently clearing of the fault 5 cycles later 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.”

In addition, new wind generators (which are usually asynchronous) are required to stay on-line following normally cleared faults at the Point of Interconnection (POI).

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.

<u>Power Flow Case</u>

SPP provided two (2) Pre-project PSS/E power flow cases called “*gen06-21_11sp_base.sav*” representing the Summer Peak conditions of the SPP system for the year 2011 and the “*gen06-21_07wp_base.sav*” representing the Winter Peak conditions of the SPP system for the year 2007. Figure 2.2-1 and Figure 2.2-2 show the local system flows and voltages calculated for the base cases without the wind farm represented. Figure 2.2-1 is for the winter peak conditions and Figure 2.2-2 is for the summer peak conditions.

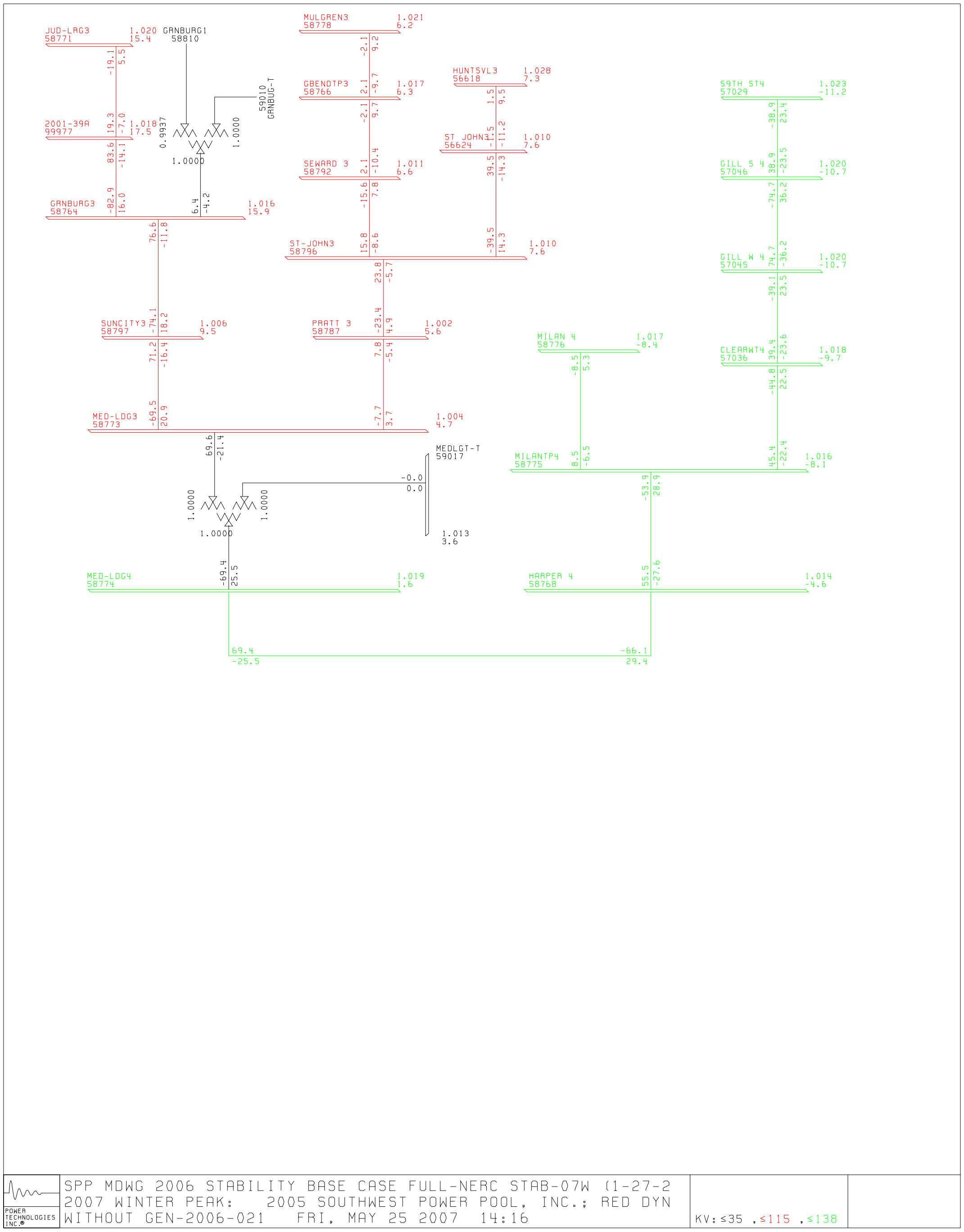

Figure 2.2-1 Winter Peak Flows and Voltages without GEN-2006-021

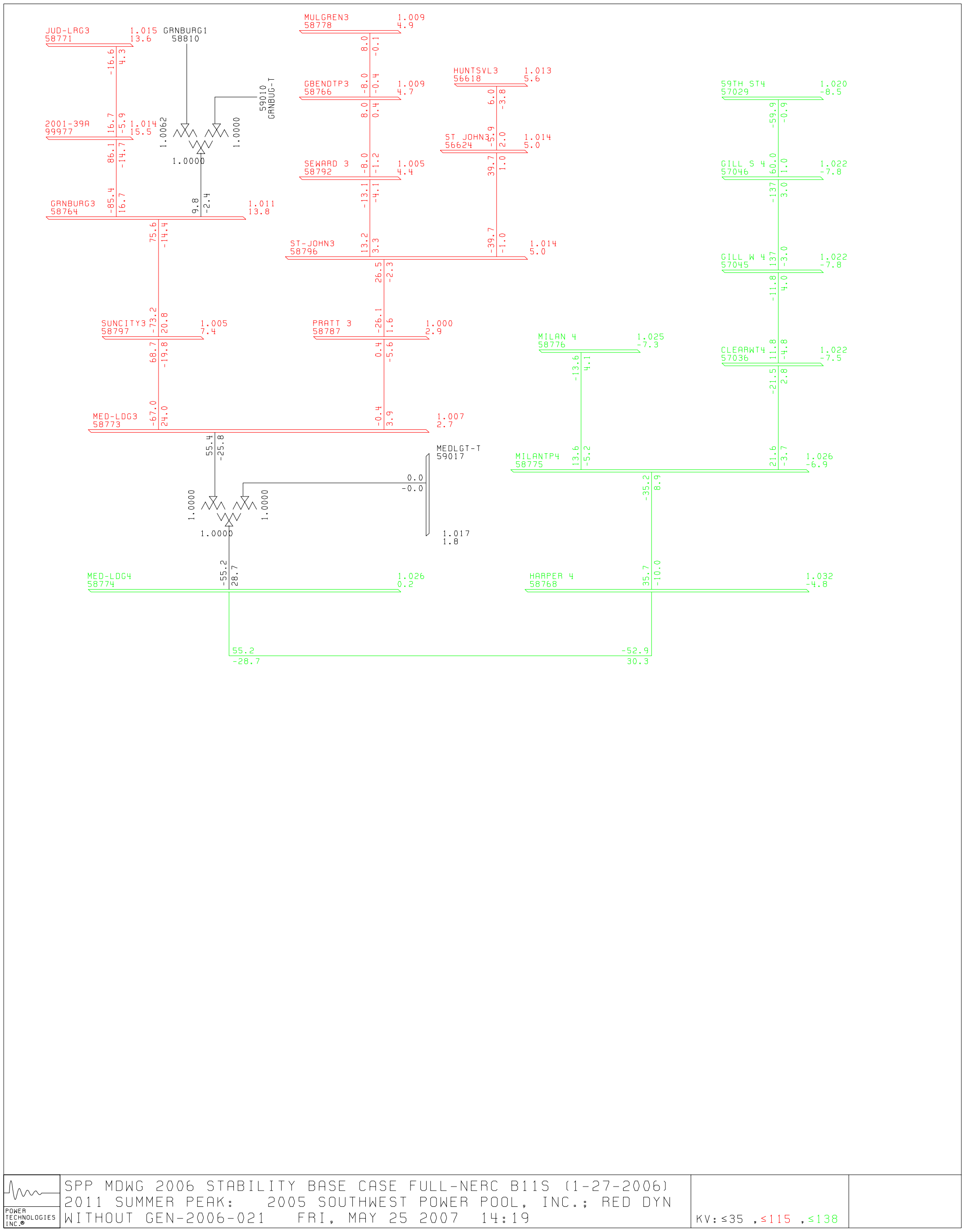

Figure 2.2-2 Summer Peak Flows and Voltages without GEN-2006-021

The proposed GEN-2006-021 project is comprised of 100 Clipper 2.5 MW wind turbine generators. The plant will be connected to the Medicine Lodge – Harper 138 kV transmission line by a new 6-mile transmission line and two two-winding 138/34.5 kV transformers. The proposed project was added to the Pre-project cases and the generation was dispatched by scaling down generation in areas 502 520 523 524 525 526 540 541 544 546 by 250 MW. See Table 2-1 for details. Two power flow cases with GEN-2006-021 were established:

- *SP021.SAV – a 2011 summer peak case*
- *WP021.SAV – a 2007 winter peak case*

Table 2-1: GEN-2006-021 project details

System condition	MW	Location	Point of Interconnection	Sink
Summer Peak	250	Harper County, Kansas	Medicine Lodge - Harper 138 kV transmission line	Areas 502 520 523 524 525 526 540 541 544 546
Winter Peak	250	Harper County, Kansas	Medicine Lodge - Harper 138 kV transmission line	Areas 502 520 523 524 525 526 540 541 544 546

Wind Farm Power Flow Model

The GEN-2006-021 wind farm has 100 Clipper 2.5 MW wind turbine generators. Two groups of wind turbine-generators with 50 turbines in each group are modeled as two equivalent machines. Each equivalent generator is connected to a 138/34.5 kV transformer through single equivalent GSU transformer and a single equivalent collector branch. These two 138/34.5 kV transformers are connected to the full SPP system model through a 6.0-mile 138 kV transmission line. The detailed process of wind farm model development is described in Appendix A. Figure 2.2-3 and Figure 2.2-4 show the local flows and voltages calculated with the wind farm represented. Figure 2.2-3 is for the winter peak conditions and Figure 2.2-4 is for the summer peak condition.

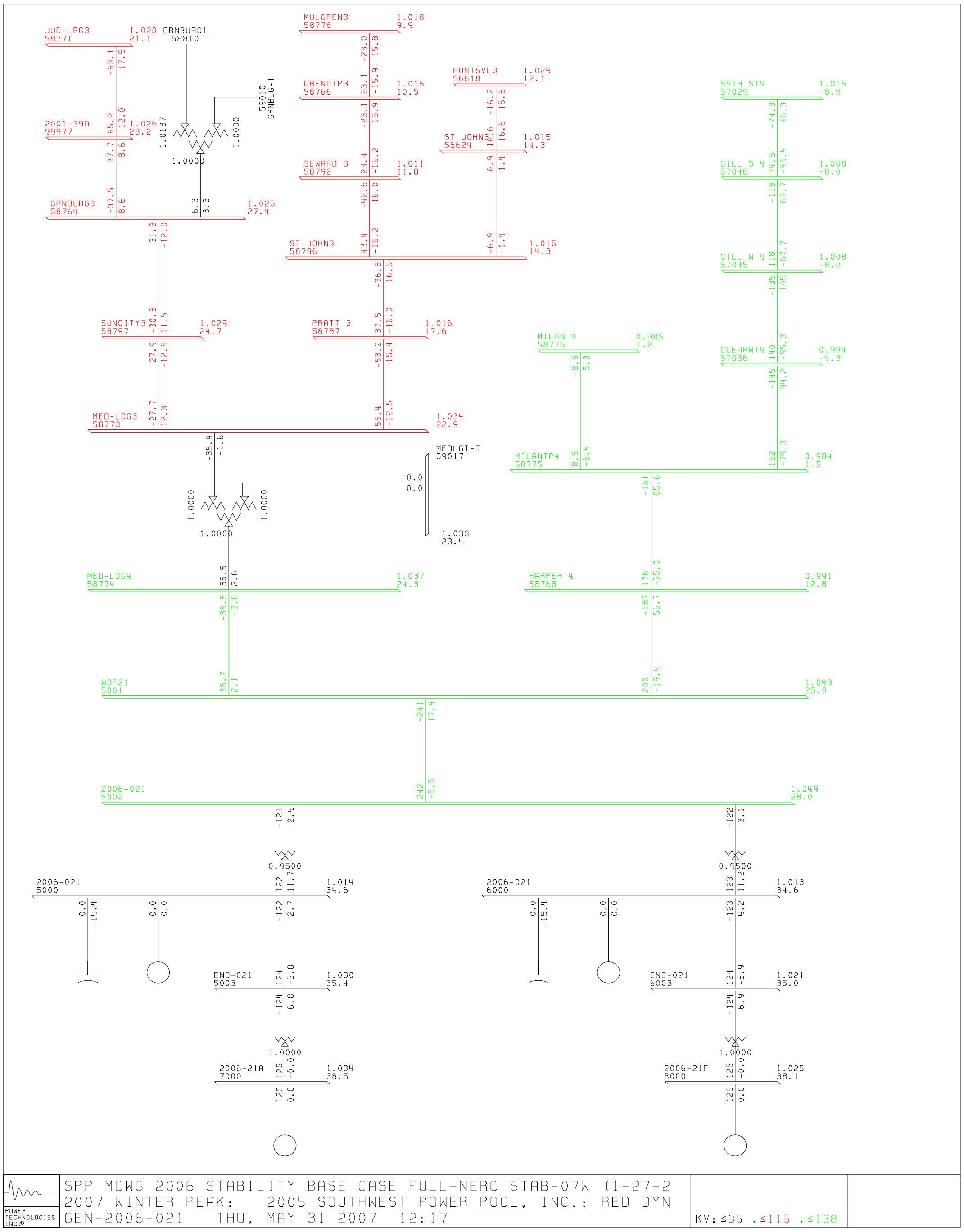

Figure 2.2-3 Winter Peak Flows and Voltages with GEN-2006-021

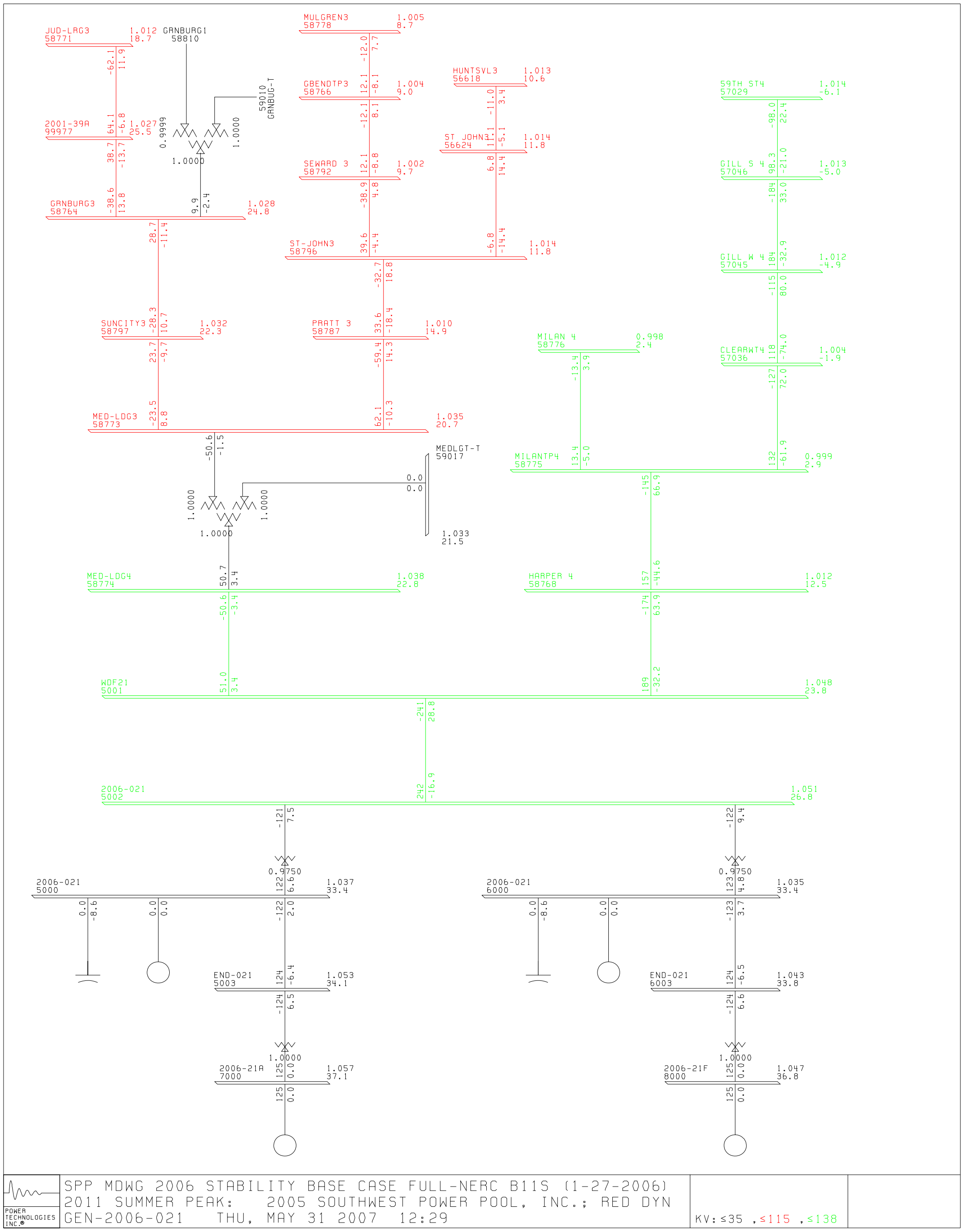

Figure 2.2-4 Summer Peak Flows and Voltages with GEN-2006-021

ABB

Stability Database

SPP provided the stability database in the form of PSS/E dynamic data files, "*gen06-21_11sp_base.dyr*" to model the 2011 Summer Peak configuration, and "*gen06-21_07wp_base.dyr*" to model the 2007 Winter Peak configuration. Command files were also provided to compile and link user-written models. These files are compatible with PSS/E version 29.

The stability data for GEN-2006-021 was appended to the Pre-project data. The stability model incorporates the ride-through capability that allows wind turbine generator operation below 90% terminal voltage for up to 3 seconds and fast tripping (100 ms) for terminal voltages below 10%. The voltage trip settings are hard-coded in the model's FLECS code.

For some of the simulations static var controllers (SVCs) were also represented in the wind plant. These were modeled using a standard PSS/E model, CSVGN4. During the simulated faults the output admittances of these static var controllers are fixed by setting their time constant to a very large value. This emulates a control feature found on most static var controllers. Emulating this control action provides a more accurate representation of the expected SVC response during and immediately following the fault.

The power flow and stability model representations for GEN-2006-021 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 2 seconds.

Table 2-2: List of Faults for Stability Analysis

FAULT	FAULT DESCRIPTION
FLT_1_3PH	a. Apply a 3-phase fault at the POI (bus 5001) on the 138 kV line to Medicine Lodge. b. Clear fault after 5 cycles by removing the line from 5001 to 58768. 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 POI (bus 5001) on the 138 kV line to Medicine Lodge. b. Clear fault after 5 cycles by removing the line from 5001 to 58758. 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 POI (bus 5001) on the 138 kV line to Harper. b. Clear fault after 5 cycles by removing the line from 5001 to 58768. 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 POI (bus 5001) on the 138 kV line to Harper. b. Clear fault after 5 cycles by removing the line from 5001 to 58768. 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 Pratt 115 kV bus (58787) on the line to St John. b. Clear fault after 5 cycles by removing the line from 58787 to 58796. 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 Pratt 115 kV bus (58787) on the line to St John. b. Clear fault after 5 cycles by removing the line from 58787 to 58796. 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 Judson Large 115 kV bus (58771) on the line to GEN-2001-039A. b. Clear fault after 5 cycles by removing the line from 58771 to 99977. 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 Judson Large 115 kV bus (58771) on the line to GEN-2001-039A. b. Clear fault after 5 cycles by removing the line from 58771 to 99977. 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 Medicine Lodge 115 kV bus (58773) on the line to Sun City (58797). b. Clear fault after 5 cycles by removing the line from 58773 to 58797. 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 Medicine Lodge 115 kV bus (58773) on the line to Sun City (58797). b. Clear fault after 5 cycles by removing the line from 58773 to 58797. 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 Medicine Lodge 115 kV bus (58773) on the line to Pratt (58787). b. Clear fault after 5 cycles by removing the line from 58773 to 58787. 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 Medicine Lodge 115 kV bus (58773) on the line to Pratt (58787). b. Clear fault after 5 cycles by removing the line from 58773 to 58787. 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 Kinsley Tap 230 kV bus (100) on the line to Spearville (58795). b. Clear fault after 5 cycles by removing the line from 100 to 58795. 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 Kinsley Tap 230 kV bus (100) on the line to Spearville (58795). b. Clear fault after 5 cycles by removing the line from 100 to 58795. 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 Kinsley Tap 230 kV bus (100) on the line to Mullergren (58779). b. Clear fault after 5 cycles by tripping the line from bus 100 to 58779. 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 the fault.
FLT_16_1PH	a. Apply 1-phase fault at the Kinsley Tap 230 kV bus (100) on the line to Mullergren (58779). b. Clear fault after 5 cycles by tripping the line from bus 100 to 58779. 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 the fault.
FLT_17_3PH	a. Apply 3-phase fault at the Kinsley Tap 230 kV bus (100). b. Clear fault after 5 cycles by tripping the autotransformer (56619).
FLT_18_1PH	a. Apply 1-phase fault at the Medicine Lodge 115 kV bus (58773) on the line to Sun City. b. After 7 cycles open the Medicine Lodge breaker. c. After 20 cycles, open the Sun City (58797) to Greenburg (58764) line clearing the fault.

2.3 STUDY RESULTS

2.3.1 SIMULATIONS WITHOUT DYNAMIC SHUNT COMPENSATION

For the initial series of simulations the wind plant was represented with the static shunt compensation needed to maintain 1.05 per unit voltage at the 138 kV wind farm bus for the pre-fault condition. A voltage of 1.05 per unit can be maintained at the wind farm 138 kV bus by adding 8 MVAR of capacitors at each of the two GEN-2006-021 collector system 34.5 kV buses for the Summer Peak case. For the Winter Peak case 14 MVAR of capacitors are connected at one 34.5 kV bus and 15 MVAR are connected at the other.

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

The plots showing the simulation results are included in Appendix C.

Table 2-3: Results of Initial Stability Simulations

FAULT	Summer Peak 2011	Winter Peak 2007
FLT_1_3PH	GEN-2006-021 Tripped	GEN-2006-021 Tripped
FLT_2_1PH	GEN-2006-021 Tripped	GEN-2006-021 Tripped
FLT_3_3PH	GEN-2006-021 Tripped	GEN-2006-021 Tripped
FLT_4_1PH	GEN-2006-021 Tripped	GEN-2006-021 Tripped
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

The results of the initial simulations indicate that units of GEN-2006-021 will be tripped by voltage relay action following FLT_1_3PH, FLT_2_1PH, FLT_3_3PH, and FLT_4_1PH for both Summer Peak and Winter Peak system conditions.

2.3.2 SIMULATIONS WITH SVCS ADDED

The wind farm was simulated with two 30 MVAR static var compensators added, each connected to the low side of one of the wind farm's 138/34.5 kV transformers. This compensation was included along with the static compensation required to maintain 1.05 per unit voltage on the 138 kV bus at the wind farm. The simulation results with the 30 MVAR SVCs are summarized in Table 2-4.

Table 2-4: Results for Stability Analysis with Two 30 MVAR SVCs

FAULT	Summer Peak 2011	Winter Peak 2007
FLT_1_3PH	STABLE	STABLE
FLT_2_1PH	STABLE	STABLE
FLT_3_3PH	GEN-2006-021 Tripped	GEN-2006-021 Tripped
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

The system with the two 30 MVAR SVCs is stable for FLT_1_3PH and FLT_2_1PH, but the wind farm units still trip for FLT_3_3PH. For FLT_4_1PH the wind farm units do not trip, but the voltage is quite high for several cycles following the initial clearing of the fault.

The plots for the simulations with two 30 MVAR SVCs are included in Appendix D.

The wind farm was also simulated with two +-50 MVAR static var compensators added along with the fixed and mechanically switched shunt compensation included in the initial simulations. Each SVC is connected to the low side of one of the wind farm's 138/34.5 kV transformers. The simulation results with the +-50 MVAR SVCs are summarized in **Table 2-4**. The plots for the simulations with two +-50 MVAR SVCs are included in Appendix E. For these simulations plots are included for a wider range of variables to demonstrate that the impact on the surrounding area is minimal.

Table 2-4: Results for Stability Analysis with Two +-50 MVAR SVCs

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

With two +-50 MVAR SVCs the GEN-2006-021 wind farm would remain on-line through all the specified faults and the SPP system would be stable following all these faults for both Summer Peak and Winter Peak conditions.

3 CONCLUSIONS

The objective of this study is to evaluate the power system stability with the GEN-2006-021 wind farm. The study is performed for two system scenarios: the 2007 Winter Peak and the 2011 Summer Peak.

A voltage of 1.05 per unit can be maintained at the wind farm 138 kV bus by adding 8 MVAR of capacitors at each of the two GEN-2006-021 collector system 34.5 kV buses for the Summer Peak case. For the Winter Peak case 14 MVAR of capacitors are needed at one 34.5 kV bus and 15 MVAR are needed at the other.

With only fixed or mechanically switched shunt compensation, units of GEN-2006-021 would trip during both Summer Peak and Winter Peak conditions for the following faults:

- FLT_1_3PH (a three phase fault with unsuccessful re-closing, resulting in the loss of the Medicine Lodge – POI 138 kV line)
- FLT_3_3PH (a three phase fault with unsuccessful re-closing, resulting in the loss of the Harper – POI 138 kV line)
- FLT_2_1PH (a single phase fault with unsuccessful re-closing, resulting in the loss of the Medicine Lodge – POI 138 kV line)
- FLT_4_1PH (a single phase fault with unsuccessful re-closing, resulting in the loss of the Harper – POI 138 kV line)

GEN-2006-021 would remain on-line for the other faults specified, and the SPP system will be stable following these faults in both Summer Peak and Winter Peak system conditions**.**

The GEN-2006-021 plant was also simulated with a 30 MVAR SVC connected to each collector system along with the fixed and mechanically switched shunt capacitors mentioned above. With the 30 MVAR SVCs the system would also be stable for FLT-1-3PH and FLT_2_1PH, but the wind plant generators would still trip for FLT_3_3PH and very high voltages would be present for several cycles after FLT_4_1PH is initially cleared.

Finally, the GEN-2006-021 plant was also simulated with a +-50 MVAR SVC connected to each collector system. Based on the results of stability analysis it can be concluded that the proposed GEN-2006-021 project does not adversely impact the stability of the SPP system if two +- 50 MVAR SVCs are installed one on each wind farm collector bus along with the fixed and mechanically switched shunt capacitors mentioned above.

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 - Plots for Stability Simulations Representing the Gen-2006-021 Plant without SVCs

APPENDIX D - Plots for Stability Simulations Representing the Gen-2006-021 Plant with Two 30 MVAR SVCs

APPENDIX E - Plots for Stability Simulations Representing the Gen-2006-021 Plant with Two +-50 MVAR SVCs