Southwest Power Pool

GEN-2009-025
Impact Restudy

SPP Tariff Studies
(GEN-2009-025)

June 2010

Summary

This report contains a restudy of Group 8 of the DISIS-2009-001 study. This restudy was done at the request of the Interconnection Customer for GEN-2009-025 to determine the effects of GEN-2009-025 switching wind turbines manufacturers from GE to Vestas. Stability analysis was carried out to determine these effects. Power factor analysis was done to determine the amount of reactive support required at the Points of Interconnection.

The study found a significant voltage drop and wind turbine instability and oscillations for the outage of the line from GEN-2009-025 to the Sinclair Blackwell substation and that additional reactive support is required at the substation. The Interconnection Customer will be required to install a 34.5kV +/- 10 MVA STATCOM device at the wind farm interconnection substation at the Interconnection Customer's expense.

R47-10

Generator Interconnection Impact Re-study for DISIS-2009-01 -Group 8

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Section

1

Introduction

1.1 Background

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Siemens PTI performed the Impact Study R01-10 *"Generator Interconnection Impact Study for DISIS-2009-001 - Group 8"* to satisfy the Impact Study Agreement executed by the customers. The requests for interconnection were placed with SPP in accordance to the Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system.

Along the interconnection process, Gen-2009-025 interconnection request has changed the WTG manufacturer from GE to Vestas, causing a need for this restudy to determine if the change is a material change. Therefore a re-evaluation is required to determine the system behavior under the new scenario.

The purpose of this report is to present the results of the stability and power factor analysis performed to re-evaluate the impact of the proposed cluster of interconnections of the DSIS-2009-001 with regard to Group 8 interconnection requests on the Southwest Power Pool transmission system. Indicative solutions to the identified issues are proposed based on the impact of each generation interconnection on the Southwest Power Pool system.

Four projects in this cluster are connected to four different Points of Interconnection (to be known hereafter as POI) at different voltage levels, ranging from 69 kV to 345 kV. Section 2 describes all proposed wind farms projects in detail.

Transient stability analysis was performed using the package provide by SPP. It contains the latest stability database in PSS®E version 30.3.3. The stability package also includes the dynamic data for the previously queued projects.

1.2 Purpose

The steady state and stability study was carried out to:

(a) Determine the ability of the proposed generation facilities to remain in synchronism and within applicable planning standards following system faults with unsuccessful reclosing.

(b) Determine the amount of reactive support required from the costumer to meet the power factor requirement at the POI.

(c) Determine the ability of the wind projects to meet FERC Order 661A (low voltage ride through and wind farm recovery to pre-fault voltage) with and without additional reactive support.

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Section
2

Model Development

The re-study has considered the 2009 winter peak and 2010 summer peak load flow models provided by SPP with the required interconnection generations modeled. The base cases also contain all the significant previous queued generation interconnection projects in the interconnection queue.

2.1 Power Flow Data

The Group 8 of DISIS-2009-001 contains three proposed wind generation projects and one nuclear power generation project. Table 2-1 presents the size of the nuclear and wind generation projects, the Wind Turbine Generator (WTGs) manufacturers, the reactive capability of the nuclear generator and wind farm as well as the point of interconnection and the PSS®E bus numbers in the load flow models. The manufacture for the project Gen-2009-025 is changed from GE to Vestas.

Table 2-1 – Details of the Interconnection Requests

Request	Size (MW)	Model	Reactive capability of Wind Farm		Point of Interconnection	Bus Number
			Max (Mvar)	Min (Mvar)		
GEN-2008-021	1250	Nuclear Steam Turbine	600.0	-425.0	Wolf Creek 345kV	532797
GEN-2008-38	150	G.E. 1.5MW	49.3	-49.3	Tap Shidler – Pawhuska 138kV	570838
GEN-2008-127	200	Siemens 2.3MW	65.25	-73.95	Tap Sooner – Rose Hill 345kV	573039
GEN-2009-025	59.4	Vestas 1.8MW	0 *	0 *	Tap Deerck – Sincblk2 69KV	573049

*** The Vestas WTG operates at unity power factor, according to the manufacturer's technical documentation**

The analysis was carried out using the database package provided by SPP which also includes the modeling data for the previously queued projects, as shown in Table 2-2:

Table 2-2 – Details of the Prior Queue Interconnection Requests

Request	Size	Wind Turbine Model	Point of Interconnection	Bus Number
GEN-2002-004	200	GE.1.5MW	Latham 345kV	532800
GEN-2004-010	300	Clipper 2.5MW	Latham 345kV	532800
GEN-2005-013	201	G.E. 1.5MW	Latham – Neosho 345kV	574000
GEN-2005-016	150	Gamesa 2MW	Latham – Neosho 345kV	574000
GEN-2007-025	300	Clipper 2.5MW	Wichita-Woodring 345kV	532781
GEN-2008-013	300	G.E. 1.5MW	Wichita – Woodring 345kV	210130

2.1.1 Gen-2009-025 Equivalent Model

The manufacturer change for Gen-2009-025 inherently implies in changing the feeder impedances, the distribution of the turbines, etc. To better take into account the related effects on the dynamic behavior; a new equivalent model was developed.

This equivalent represents the developer facilities, including all the WTG, GSU's, and collector impedances as a single equivalent generator, an equivalent GSU, and an equivalent collector subsystem impedance. The new model is added on the 34.5 kV side of the collector subsystem step up transformer.

Table 2-3 presents the collector system impedances as per the design of the new configuration. Table 2-4 shows the equivalency calculation performed in the collector system.

Table 2-3 – Collector System Impedance Data

From	To	Conductor Type	Approximate Length (miles)	R_1 (Ohms/kFt)	X_2 (Ohms/kFt)	X_c Capacitive Susceptance (x10^-6 mhos/kFt)	R_1 (Ohms)	X_2 (Ohms)	X_c (Ohms)
Feeder 1 (34.5 kV UG)									
T1	T2	4/0 AWG Al Triplexed	0.24	0.107	0.048	18.42	**0.138**	**0.062**	**42,020**
T2	T3	4/0 AWG Al Triplexed	0.24	0.107	0.048	18.42	**0.138**	**0.062**	**42,020**
T3	T4	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.146**	**0.065**	**39,860**
T4	T5	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.146**	**0.065**	**39,860**
T5	T6	4/0 AWG Al Triplexed	0.24	0.107	0.048	18.42	**0.138**	**0.062**	**42,020**
T6	T14	4/0 AWG Al Triplexed	0.86	0.107	0.048	18.42	**0.484**	**0.217**	**12,006**
T13	T14	4/0 AWG Al Triplexed	0.27	0.107	0.048	18.42	**0.150**	**0.067**	**38,779**
T14	Blackwell Sub	500 MCM Al Triplexed	1.47	0.048	0.042	24.93	**0.373**	**0.326**	**5,168**
Feeder 2 (34.5 kV UG)									
T7	T8	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T8	T9	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T9	T10	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T10	T11	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T11	T12	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T12	Blackwell Sub	4/0 AWG Al Triplexed	1.35	0.107	0.048	18.42	**0.763**	**0.342**	**7,616**
Feeder 3 (34.5 kV UG)									
T17	T18	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T18	T19	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T19	T20	4/0 AWG Al Triplexed	0.28	0.107	0.048	18.42	**0.157**	**0.070**	**36,982**

From	To	Conductor Type	Approximate Length (miles)	R_1 (Ohms/kFt)	X_2 (Ohms/kFt)	X_c Capacitive Susceptance (x10^-6 mhos/kFt)	R_1 (Ohms)	X_2 (Ohms)	X_c (Ohms)
T20	T21	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T21	T22	4/0 AWG Al Triplexed	0.30	0.107	0.048	18.42	**0.167**	**0.075**	**34,801**
T17	T29	4/0 AWG Al Triplexed	0.58	0.107	0.048	18.42	**0.328**	**0.147**	**17,728**
T29	T30	4/0 AWG Al Triplexed	0.45	0.107	0.048	18.42	**0.254**	**0.114**	**22,849**
T30	T31	4/0 AWG Al Triplexed	0.24	0.107	0.048	18.42	**0.136**	**0.061**	**42,580**
T31	T32	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T32	T33	4/0 AWG Al Triplexed	0.27	0.107	0.048	18.42	**0.151**	**0.068**	**38,476**
T29	Blackwell Sub	500 MCM Al Triplexed	0.12	0.048	0.042	24.93	**0.030**	**0.027**	**63,309**
Feeder 4 A (34.5 kV UG)									
T24	T25	4/0 AWG Al Triplexed	0.22	0.107	0.048	18.42	**0.126**	**0.056**	**46,204**
T25	T23	4/0 AWG Al Triplexed	0.55	0.107	0.048	18.42	**0.311**	**0.139**	**18,694**
T23	T27	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.147**	**0.066**	**39,546**
T27	T28	4/0 AWG Al Triplexed	0.26	0.107	0.048	18.42	**0.148**	**0.066**	**39,341**
T28	Blackwell Sub	4/0 AWG Al Triplexed	0.22	0.107	0.048	18.42	**0.124**	**0.056**	**46,736**
Feeder 4 B (34.5 kV UG)									
T26	T15	4/0 AWG Al Triplexed	0.24	0.107	0.048	18.42	**0.136**	**0.061**	**42,842**
T15	T16	4/0 AWG Al Triplexed	0.25	0.107	0.048	18.42	**0.141**	**0.063**	**41,128**
T16	Blackwell Sub	4/0 AWG Al Triplexed	1.46	0.107	0.048	18.42	**0.825**	**0.370**	**7,042**

Table 2-3 – Collector System Equivalency Calculation

R_1 (p.u.)	X_2 (p.u.)	B (p.u.)	Number of WTGs	$R_1 n^2$	$X_2 n^2$
Feeder 1 (34.5 kV UG)					
0.011614461	0.00521	0.000283	1	0.011614	0.00521
0.011614461	0.00521	0.000283	2	0.046458	0.020841
0.012243728	0.005493	0.000299	3	0.110194	0.049433
0.012243728	0.005493	0.000299	4	0.1959	0.08788
0.011614461	0.00521	0.000283	5	0.290362	0.130256
0.040650614	0.018236	0.000991	6	1.463422	0.656488
0.012585329	0.005646	0.000307	1	0.012585	0.005646
0.031300718	0.027388	0.002303	8	2.003246	1.75284

R_1 (p.u.)	X_2 (p.u.)	B (p.u.)	Number of WTGs	$R_1 n^2$	$X_2 n^2$
Feeder 2 (34.5 kV UG)					
0.012405539	0.005565	0.000303	1	0.012406	0.005565
0.012405539	0.005565	0.000303	2	0.049622	0.02226
0.012405539	0.005565	0.000303	3	0.11165	0.050086
0.012405539	0.005565	0.000303	4	0.198489	0.089042
0.012405539	0.005565	0.000303	5	0.310138	0.139128
0.064078639	0.028746	0.001563	6	2.306831	1.03484
Feeder 3 (34.5 kV UG)					
0.012405539	0.005565	0.000303	5	0.310138	0.139128
0.012405539	0.005565	0.000303	4	0.198489	0.089042
0.013196617	0.00592	0.000322	3	0.11877	0.05328
0.012405539	0.005565	0.000303	2	0.049622	0.02226
0.014023653	0.006291	0.000342	1	0.014024	0.006291
0.027530082	0.01235	0.000671	6	0.991083	0.444598
0.021359546	0.009582	0.000521	4	0.341753	0.15331
0.011461639	0.005142	0.00028	3	0.103155	0.046275
0.012405539	0.005565	0.000303	2	0.049622	0.02226
0.012684214	0.00569	0.000309	1	0.012684	0.00569
0.002555161	0.002236	0.000188	11	0.309174	0.270528
Feeder 4 A (34.5 kV UG)					
0.010562687	0.004738	0.000258	1	0.010563	0.004738
0.026106112	0.011711	0.000637	2	0.104424	0.046845
0.012341071	0.005536	0.000301	3	0.11107	0.049826
0.012405539	0.005565	0.000303	4	0.198489	0.089042
0.010442445	0.004684	0.000255	5	0.261061	0.117112
Feeder 4 B (34.5 kV UG)					
0.011391758	0.00511	0.000278	1	0.011392	0.00511
0.011866415	0.005323	0.000289	2	0.047466	0.021293
0.069299861	0.031088	0.00169	3	0.623699	0.27979
	Beq (p.u.)	0.015977		10.98959	5.915931
			Zeq (p.u.)	0.010091	0.005432

Figures 2-1 to 2-6 present the surrounding area of the Group 8 points of interconnection, showing the line flows and voltage profile for the load flow models considered in the study for summer and winter peak scenarios.

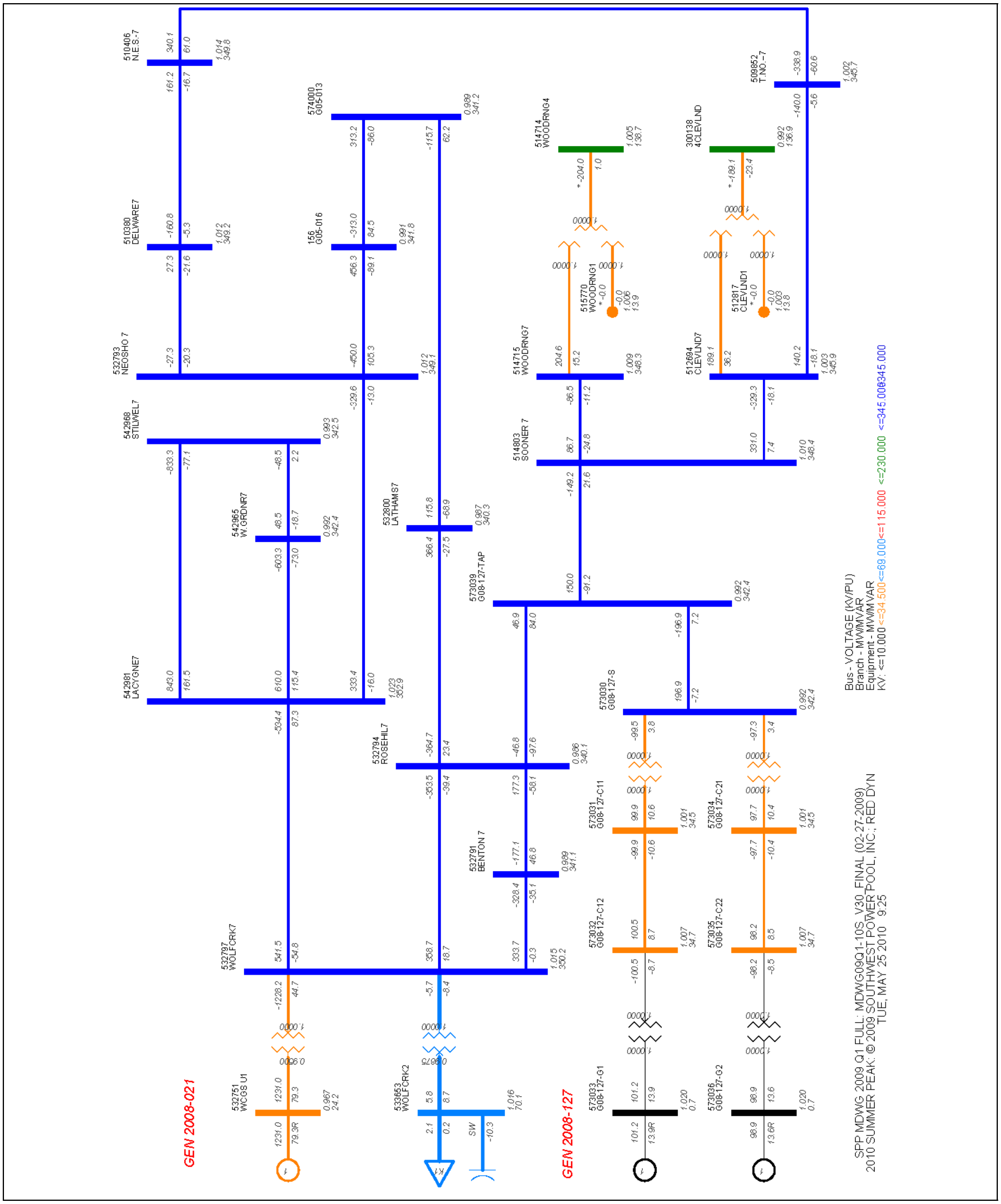

Figure 2-1 - Group 8 Points of Interconnection Surrounding Area – *Diagram1* Summer Peak

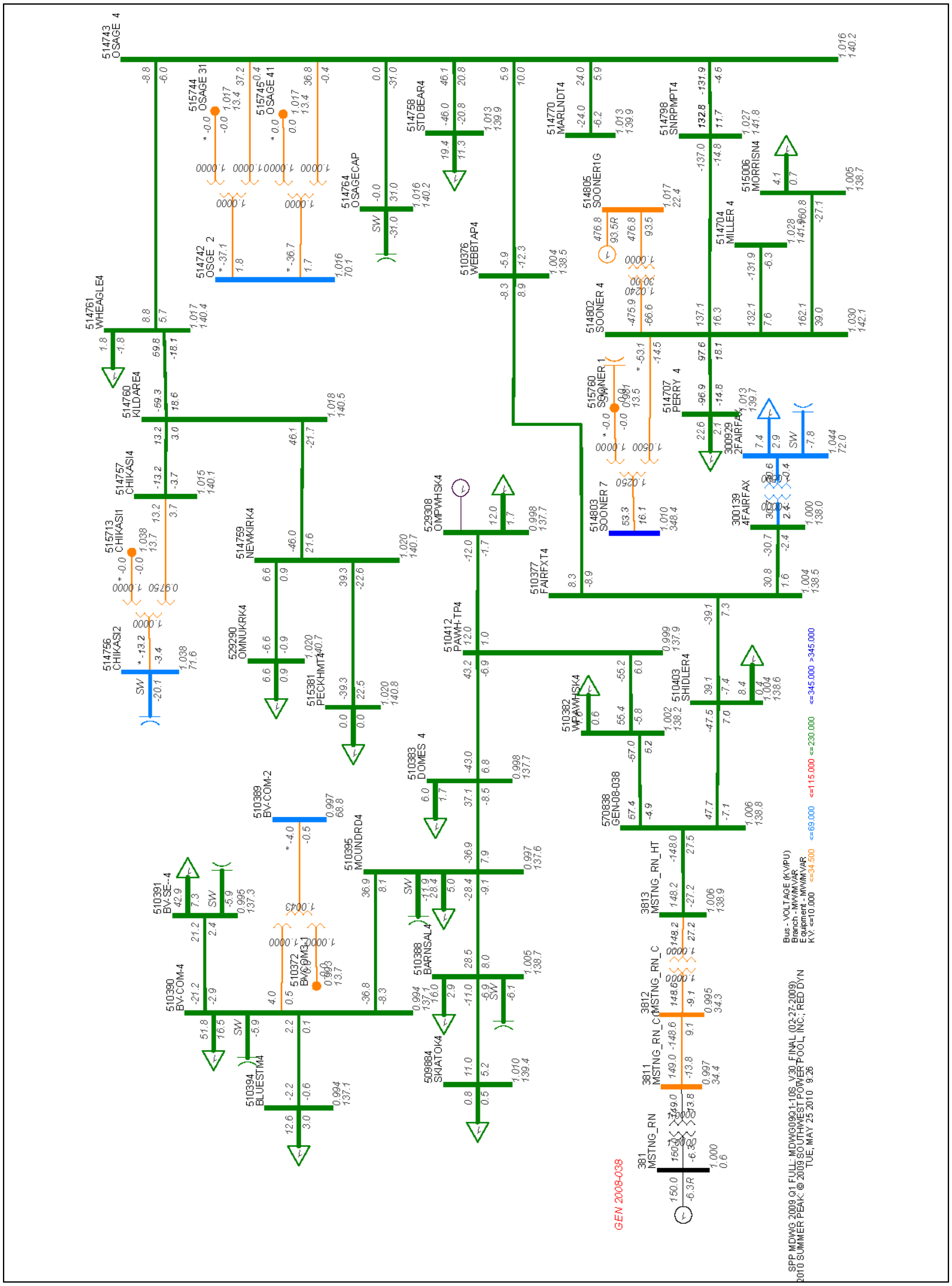

Figure 2-2 - Group 8 Points of Interconnection Surrounding Area – *Diagram2* Summer Peak

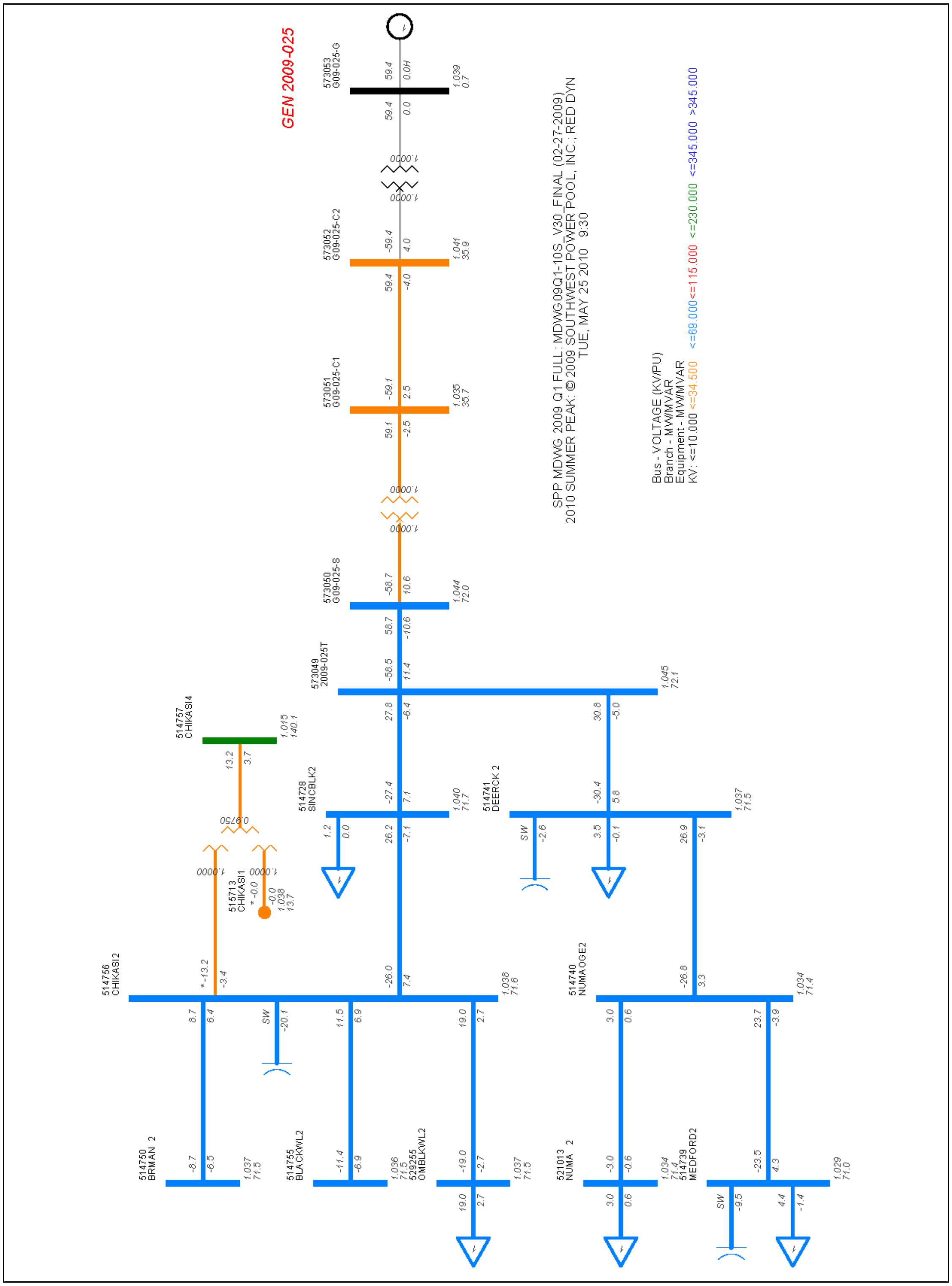

Figure 2-3 - Group 8 Points of Interconnection Surrounding Area – *Diagram3* Summer Peak

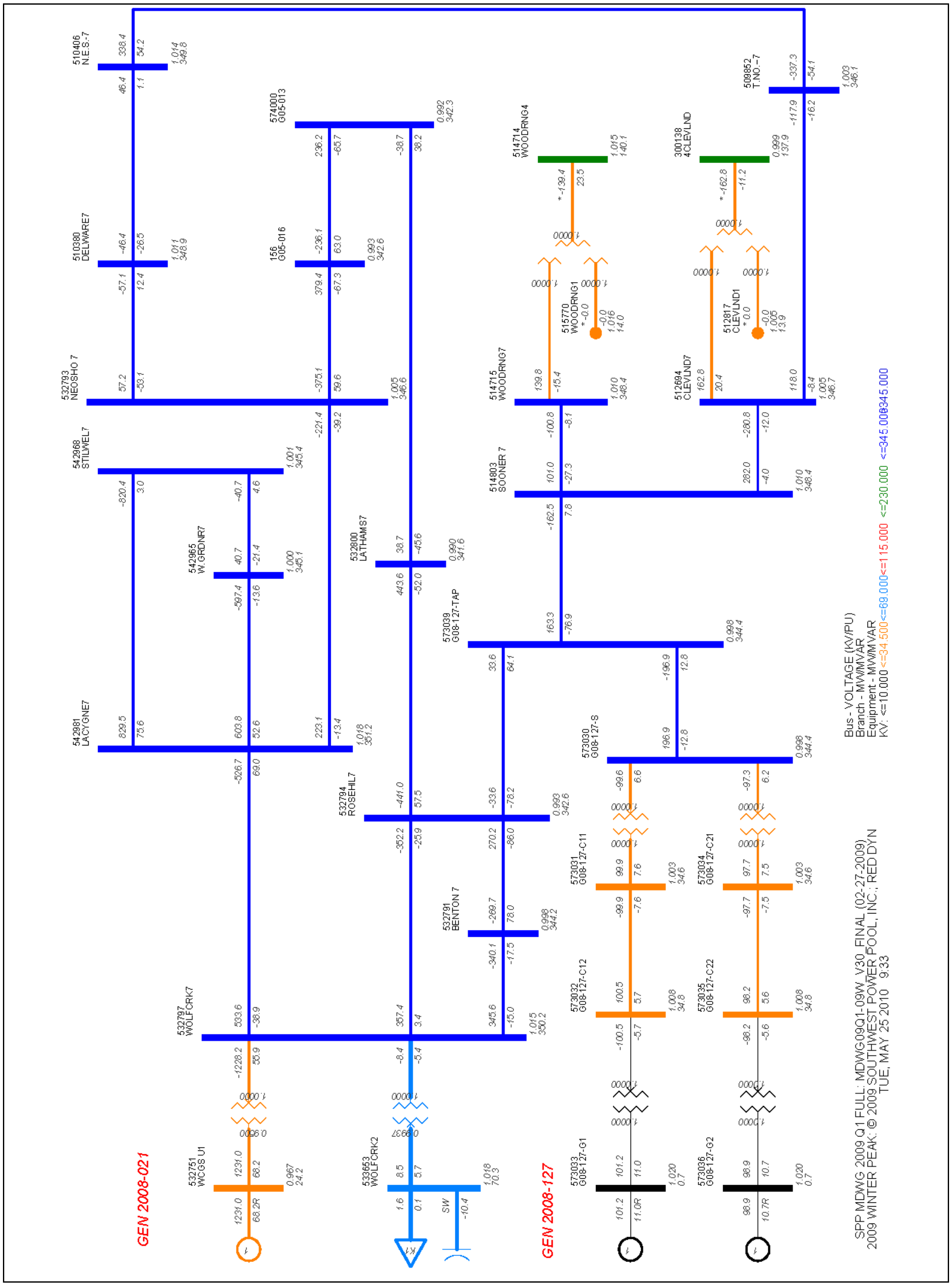

Figure 2-4 - Group 8 Points of Interconnection Surrounding Area – *Diagram1* Winter Peak

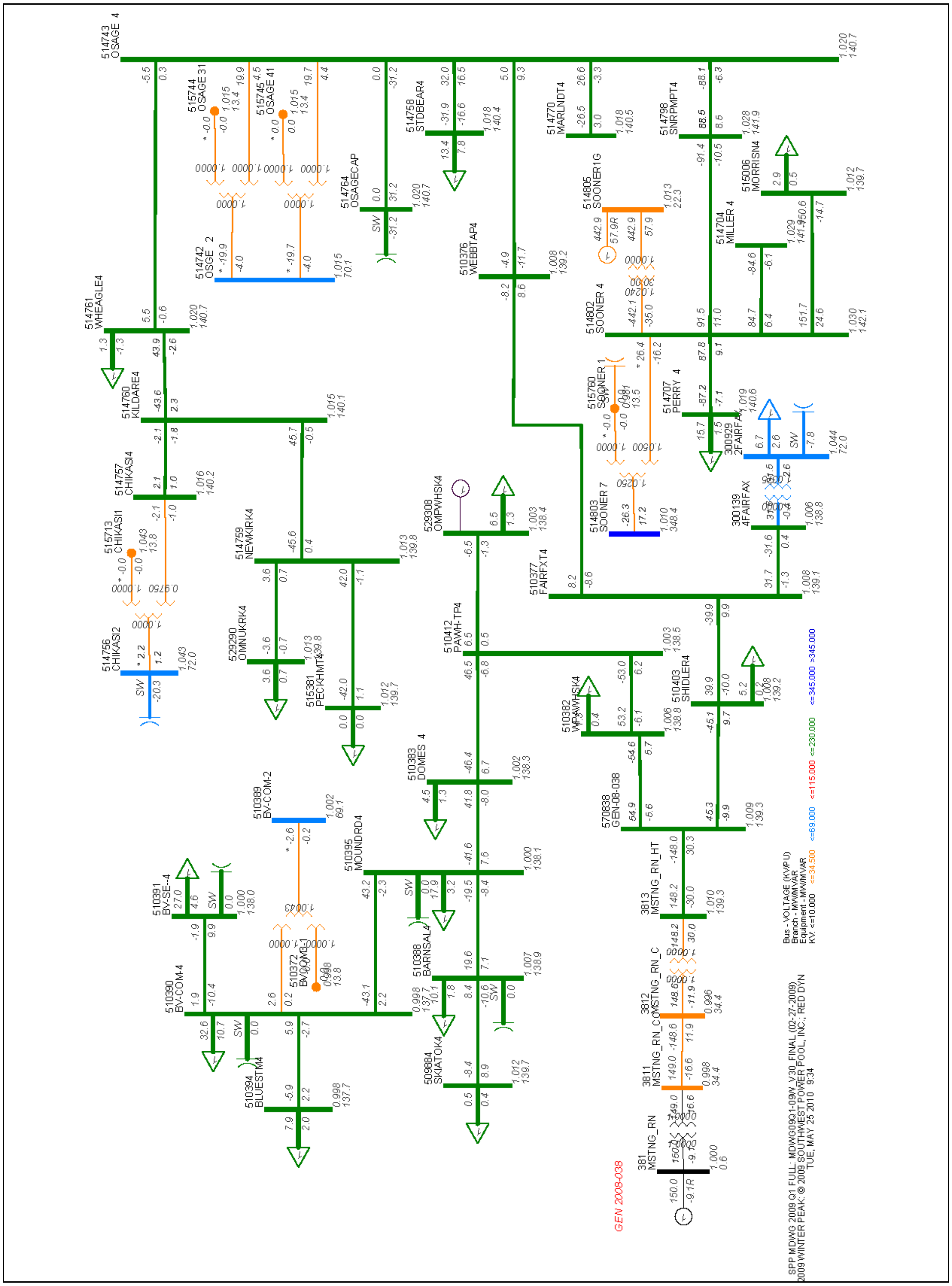

Figure 2-5 - Group 8 Points of Interconnection Surrounding Area – *Diagram2* Winter Peak

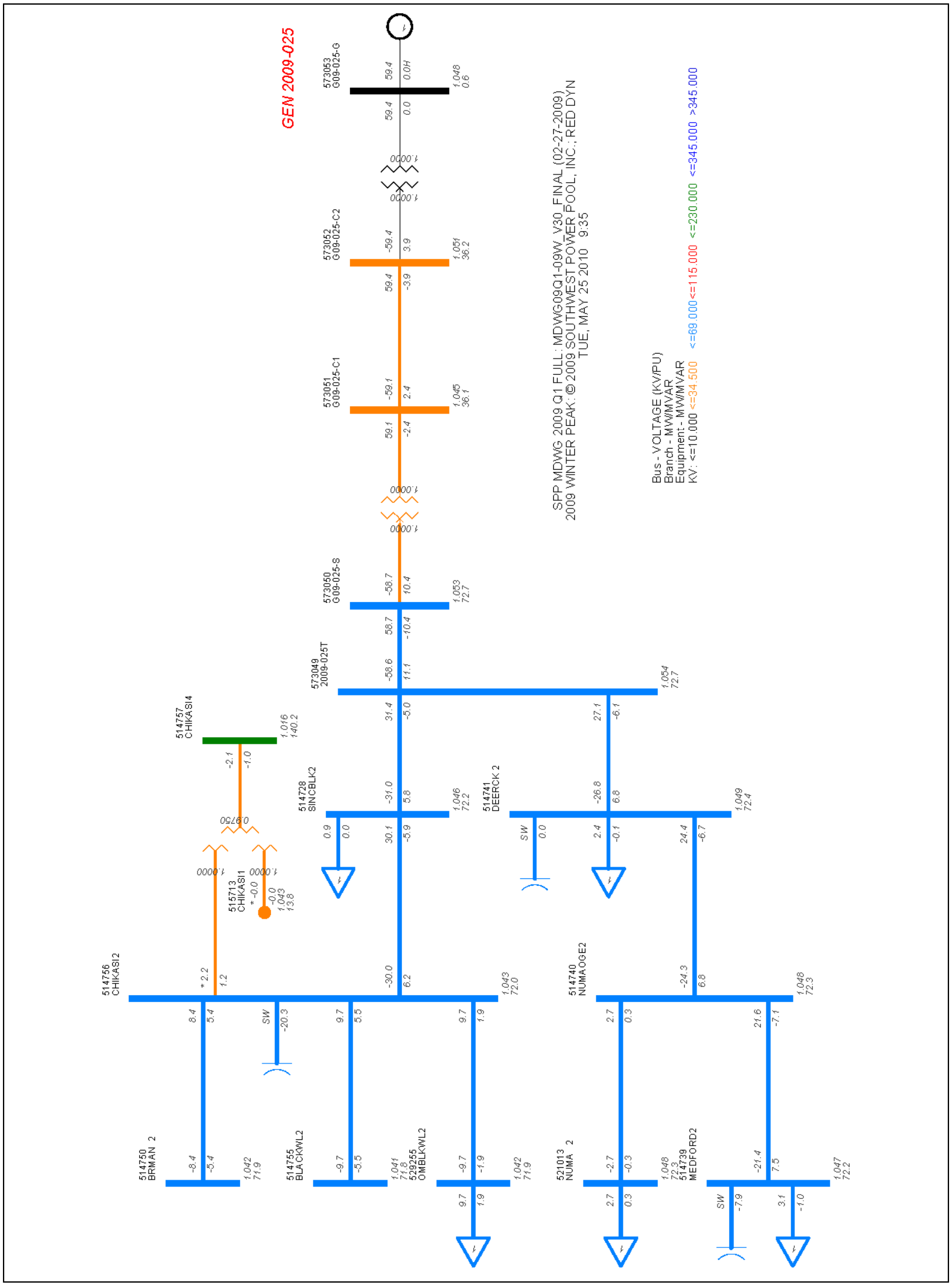

Figure 2-6 - Group 8 Points of Interconnection Surrounding Area – *Diagram3* Winter Peak

Figures A-1 to A-4 in Appendix A present the single line diagrams showing, for each of the Group 8 projects, the modeling details and impedance data of the transformers and collector systems.

2.2 Stability Database

The transient stability analysis was performed using the data base provided by SPP. Stability models for the Group 8 interconnection requests were added to the dynamic database, based on the technical documentation given. All turbine parameters used in the simulation models are the default parameters in the wind turbine package. It is assumed that each wind turbine generators (WTG's) is controlling the voltage of its own bus. The default voltage protection model set points recommended by the manufacturer were used, that is, the wind units were modeled with their built-in voltage ride through capability.

Like in the steady state analysis, the wind generation projects are modeled using equivalents representing groups of turbines and the respective collector systems.

Also, the default frequency protection model set points recommended by the manufacturer were used.

The PSS®E dynamic models output list is shown in Appendix B, documenting the model parameters of each one of the Group 8 interconnection requests modeled in the stability analysis.

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Section

3

Methodolgy and Assumptions

The re-study considered the 2009 and 2010 power flow cases with the required interconnection generation requests modeled as described in Section 2. The base case also contains all the significant previous queued projects in the interconnection queue.

The monitored areas in this study are shown in Table 3-1.

Table 3-1 – Areas of Interest

Area Number	Area Name
520	AEPW
523	GRDA
524	OKGE
525	WFEC
536	WERE
540	MIPU
541	KACP

3.1 Methodology

3.1.1 Steady State Simulations

3.1.1.1 N-1 Contingency Analysis

An N-1 contingency analysis was performed to evaluate voltage violations, if any, caused by disturbances (tripping of the faulted line). The voltages at each POI were monitored for deviations from the base case voltage and the percentage deviations were documented.

The summer peak and winter peak load flow cases were adjusted to ensure there are no relevant pre contingency voltage criteria violations. During contingency analysis it was reported voltages of any monitored bus found to be outside the range of the post-contingency criteria and having more than 1% of project impact.

3.1.1.2 Power Factor Analysis

The analysis will determine what power factor is necessary at the POI for each contingency.

If the required power factor at the POI is beyond the capability of the studied wind turbines to meet the requirement at the POI, capacitor banks will be considered.

A QV analysis was performed to determine the reactive support requirement at each project's POI. Mvar injections, tabulated for base case and contingency conditions, are used to determine the reactive power support required at each POI, in order to maintain the bus scheduled pre contingency voltages.

These tables are obtained through a series of AC load flow calculations. Starting with no reactive support at a bus, the voltage is computed for a series of power flows as the reactive support is changed in steps, until the power flow experiences convergence difficulties as the system approaches the voltage collapse point.

3.1.2 Stability Simulations

The stability simulations were performed using the PSS®E version 30.3.3 with the latest stability database provided by SPP. Three-phase faults and single line to ground faults in the neighborhood of DISIS-2009-001 – Group 8 Points of Interconnection were simulated. Any adverse impact on the system stability was documented and further investigated with appropriate solutions to determine whether a static or dynamic VAR device is required or not.

The Group 8 projects were also evaluated on the matter of ability to meet FERC Order 661A (low voltage ride through and wind farm recovery to pre-fault voltage) with and without additional reactive support.

3.2 Disturbances for Stability Analysis

The faults simulated are single line to ground, and three phase faults. The fault clearing includes line reclosing. The complete fault clearing process includes the following sequence of events:

1) Line fault, cleared after 5 cycles by tripping the both line terminals

2) After 20 cycles the line is reclosed under fault conditions (unsuccessful reclosing)

3) The fault is cleared by tripping again both ends of the faulted line, 5 cycles later.

The disturbances evaluated are listed in the following Table 3-2:

Table 3-2: Disturbances for Stability Analysis

Cont. #	Fault Location	Fault Type	Fault Clearing
31	At Delaware end of 345 kV line to Northeastern	3PH	trip Delaware – Northeastern 345 kV
32	At Delaware end of 345 kV line to Northeastern	SLG	trip Delaware – Northeastern 345 kV
33	At Gen-2009-025 end of 69 kV line to Sinclair Blackwell	3PH	trip Gen-2009-025 – Sinclair Blackwell 69 kV

Cont. #	Fault Location	Fault Type	Fault Clearing
34	At Gen-2009-025 end of 69 kV line to Sinclair Blackwell	SLG	trip Gen-2009-025 – Sinclair Blackwell 69 kV
35	At Gen-2009-025 end of 69 kV line to Deer Creek	3PH	trip Gen-2009-025 – Deer Creek 69 kV
36	At Gen-2009-025 end of 69 kV line to Deer Creek	SLG	trip Gen-2009-025 – Deer Creek 69 kV
37	At Chikasia 138 kV end of 138/69 kV transformer	3PH	trip Chikasia 138/69 kV transformer
38	At Chikasia 138 kV end of 138/69 kV transformer	SLG	trip Chikasia 138/69 kV transformer
39	At Kildare end of 138 kV line to Newkirk	3PH	trip Kildare – Newkirk 138 kV
40	At Kildare end of 138 kV line to Newkirk	SLG	trip Kildare – Newkirk 138 kV
41	At Osage end of 138 kV line to Webb City tap	3PH	trip Osage – Webb City Tap 138 kV
42	At Osage end of 138 kV line to Webb City tap	SLG	trip Osage – Webb City Tap 138 kV
43	At Sooner end of 138 kV line to Sooner Pump Tap	3PH	trip Sooner – Sooner Pump Tap 138 kV
44	At Sooner end of 138 kV line to Sooner Pump Tap	SLG	trip Sooner – Sooner Pump Tap 138 kV
45	At Sooner end of 138 kV line to Miller	3PH	trip Sooner- Miller 138 kV
46	At Sooner end of 138 kV line to Miller	SLG	trip Sooner- Miller 138 kV
47	At Osage end of 138 kV line to Marland Tap	3PH	trip Osage – Marland Tap 138 kV
48	At Osage end of 138 kV line to Marland Tap	SLG	trip Osage – Marland Tap 138 kV
49	At Newkirk end of 138 kV line to Creswell	3PH	trip Newkirk-Creswell 138 kV
50	At Newkirk end of 138 kV line to Creswell	SLG	trip Newkirk-Creswell 138 kV

In order to simulate single line to ground faults, equivalent reactances were determined to be applied at the buses. Table 3-3 presents the equivalent reactances obtained for the summer and winter peak case.

Table 3-3: Equivalent Reactances – Line to Ground Faults
Summer and Winter Peak

Bus No.	Name	Equivalent Reactance (Mvar)	
		Summer Peak	Winter Peak
510380	Delaware 345 kV	4200	4000
573049	Gen-2009-025 69 kV	400	400
515713	Chikasia 13.2 kV	300	300
514760	Kildare 138 kV	1300	1200
514743	Osage 138 kV	2400	2200
514802	Sooner 138 kV	4500	4300
514759	Newkirk 138 kV	1100	1100

The following Figures 3-1 and 3-3 present the fault locations within the study area.

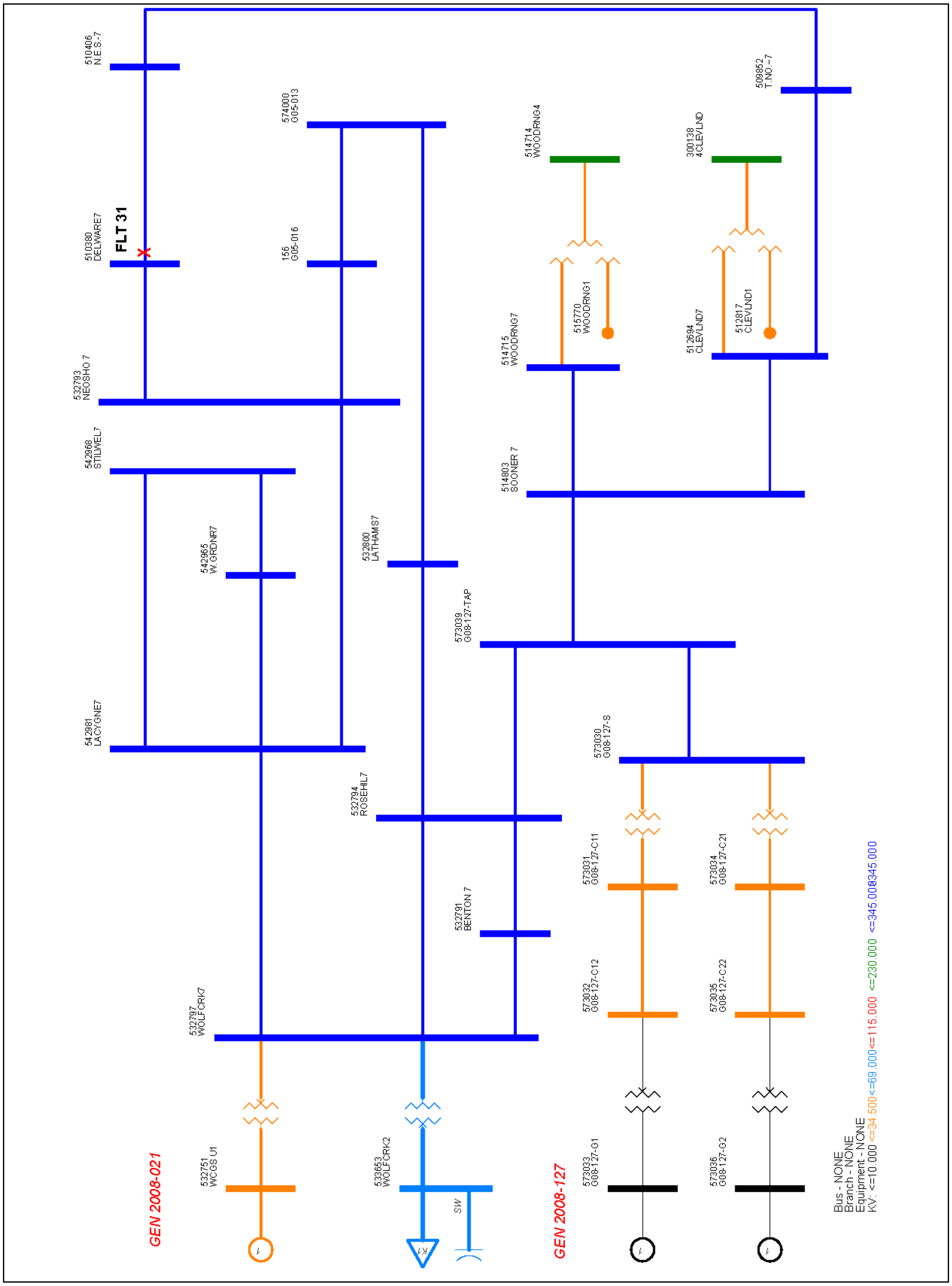

Figure 3-1 – Fault Locations in the Study Area – *Diagram1*

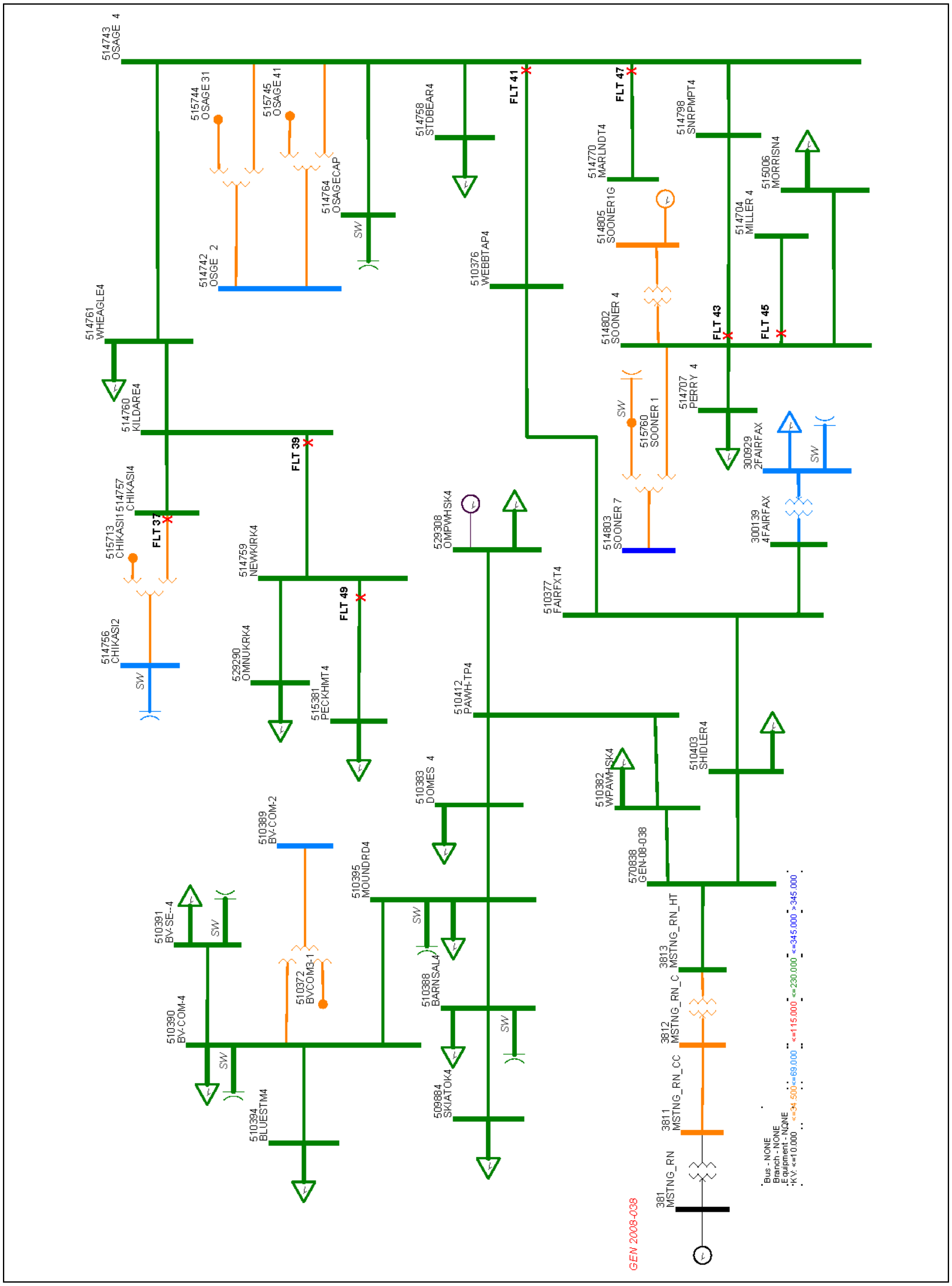

Figure 3-2 – Fault Locations in the Study Area – *Diagram2*

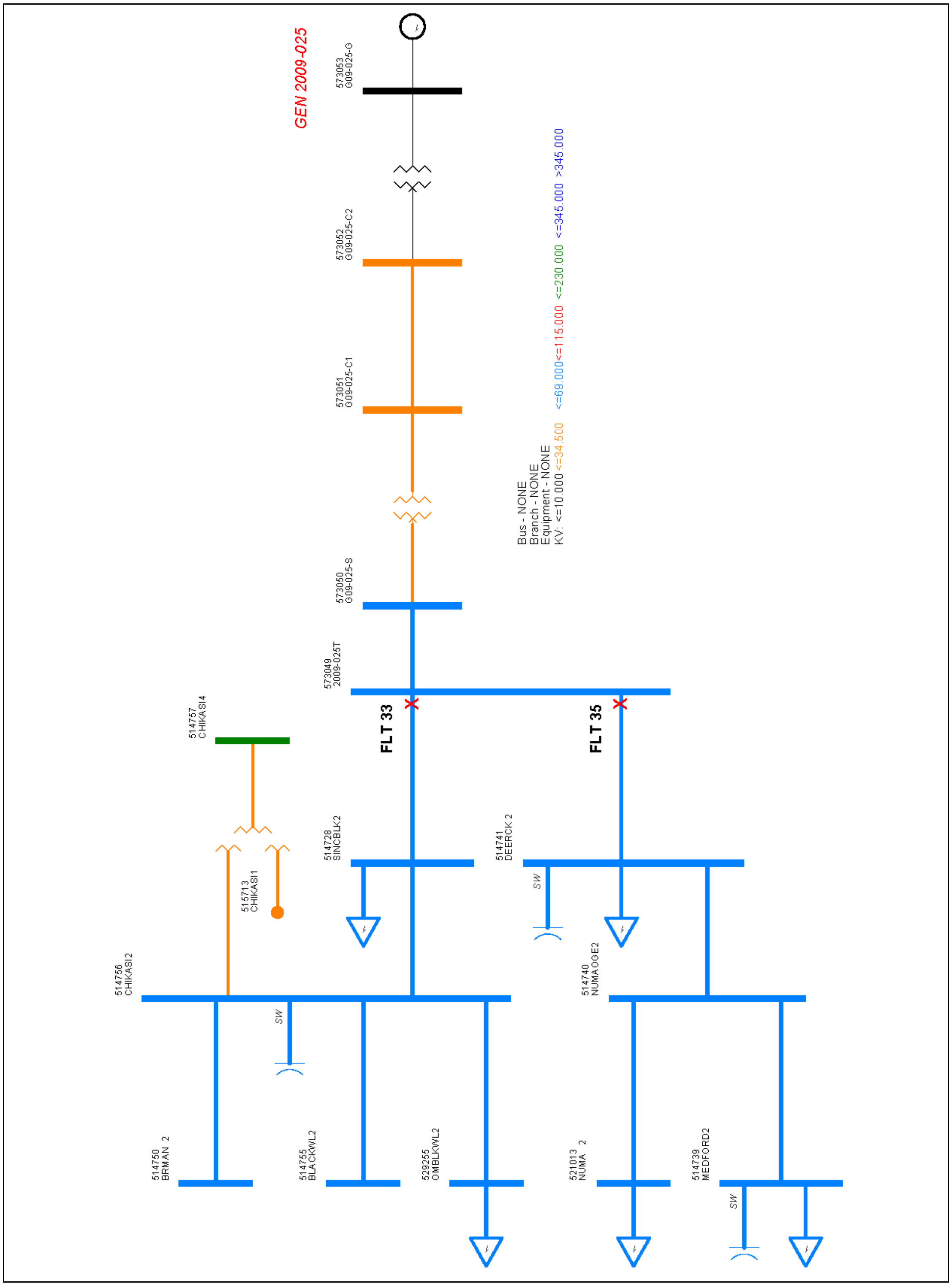

Figure 3-3 – Fault Locations in the Study Area – *Diagram3*

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Section

4

Analysis Performed

4.1 Steady State Performance

Table 4-1 and Table 4-2 summarize the results obtained from the steady state analysis for Summer Peak and Winter Peak base cases, respectively. The tables list the voltage deviations at the Points of Interconnection of the proposed study projects of Group 8, as well as the prior queued projects. Note that only the contingencies that cause a voltage criterion violation or have an impact of at least 1% in the POI's voltages are listed.

The complete set of results for both summer peak and winter peak scenarios are presented in Appendix C.

Table 4-1: Results Obtained – Steady State Analysis – Summer Peak

Bus #	Bus Name	kV	Contingency Voltage (p.u.)	Base Voltage (p.u.)	% Deviation
Base Case					
210130	G08-13T	345.0	-	1.0100	-
532781	G07-25T	345.0	-	1.0080	-
532797	WOLFCRK7	345.0	-	1.0150	-
532800	LATHAMS7	345.0	-	0.9865	-
570838	GEN-08-038	138.0	-	1.0058	-
573039	G08-127-TAP	345.0	-	0.9924	-
573049	2009-025T	69.0	-	1.0446	-
574000	G05-013	345.0	-	0.9891	-
FLT33_3PH					
Non Convergent					-
FLT37_3PH					
573049	2009-025T	69.0	1.0253	1.0446	-1.85

Table 4-2: Results Obtained – Steady State Analysis – Winter Peak

Bus #	Bus Name	kV	Contingency Voltage (p.u.)	Base Voltage (p.u.)	% Deviation
Base Case					
210130	G08-13T	345.0	-	1.0100	-
532781	G07-25T	345.0	-	1.0112	-
532797	WOLFCRK7	345.0	-	1.0150	-
532800	LATHAMS7	345.0	-	0.9903	-
570838	GEN-08-038	138.0	-	1.0092	-
573039	G08-127-TAP	345.0	-	0.9983	-
573049	2009-025T	69.0	-	1.0538	-
574000	G05-013	345.0	-	0.9921	-
FLT31_3PH					
573049	2009-025T	69.0	1.0537	1.0538	-0.01
FLT33_3PH					
573049	2009-025T	69.0	0.9772	1.0538	-7.27
FLT35_3PH					
573049	2009-025T	69.0	1.0543	1.0538	0.05
FLT37_3PH					
573049	2009-025T	69.0	1.0582	1.0538	0.42
FLT39_3PH					
573049	2009-025T	69.0	1.0593	1.0538	0.52
FLT41_3PH					
573049	2009-025T	69.0	1.0545	1.0538	0.07
FLT43_3PH					
573049	2009-025T	69.0	1.0513	1.0538	-0.24
FLT45_3PH					
573049	2009-025T	69.0	1.0507	1.0538	-0.29
FLT47_3PH					
573049	2009-025T	69.0	1.0532	1.0538	-0.06
FLT49_3PH					
573049	2009-025T	69.0	1.0588	1.0538	0.47

It can be seen from Table 4-2 that the voltage at the GEN-2009-025 POI is above the maximum limit in the base case. This minor overvoltage can be mitigated by using existing system voltage control resources, like the nearby shunt capacitor connected at 69 kV Chikasia substation. Despite the overvoltage in normal conditions (N-0), the impact on this POI is not significant under most of the contingencies.

In general, the Group 8 interconnection requests have impact less than 1% on the voltage profile of the monitored system under contingencies. However, there were few significant voltage criteria violations, caused by the projects, identified through the simulations performed. The results can be summarized as follows:

- The outage of 69 kV line between GEN-2009-025T to Sinclair Blackwell substations (FLT 33) results in considerable low voltages around the GEN-2009-025T POI, resulting in non-convergence of summer peak case. The convergence issue is mainly due the loss of reactive support from the system as the project's connection to the system becomes radial. In addition, the Vestas WTGs do not provide reactive support, which aggravates the situation. To prevent voltage issues a 10 Mvar additional reactive support is proposed at the project's 34.5 kV collector bus, to be confirmed by the power factor and stability analysis.

- Voltage deviation of about -7.27% for FLT 33 in winter peak. Once again, the significant voltage drop is due the loss of reactive support from the system as a consequence of this contingency. Unlike summer peak case, FLT 33 does not result in convergence issues.

4.2 Power Factor Analysis

A QV analysis was performed to determine the amount of reactive support required from the projects to maintain the scheduled voltages at the respective points of interconnection. The contingencies described in Table 3-2 were evaluated in steady state conditions for summer and winter peak base cases, with variable Mvar injection at the POI's.

Table 4-3 presents the Mvar requirements the projects must be able to provide under contingencies in order to meet the power factor. Tables showing the injected Mvar for each controlled voltage level in base case and contingencies are presented in Appendix D for both summer peak and winter peak scenarios. The values chosen are the highest between the two scenarios.

Table 4-3: Mvar Requirements and Power Factor at the POI for the Proposed Projects Interconnection

Project	POI	Voltage (p.u)	Project Injection at POI in Base Case(Mvar)	QV Injection (Mvar)	Project Requirement (Net Mvar at POI)	Contingency	Power Factor at POI (lagging)
GEN-2008-038	Shilder – Pawhuska 138 kV	1.006	-27.2	11.6	-15.6	FLT41(SP)	1.000
GEN-2008-127	Sooner – Rose Hill 345 kV	1.000	-7.3	77.8	70.5	FLT39 (SP)	0.943
GEN-2009-025	Deer Creek – Sinclair Blackwell 69 kV	1.045	-11.4	5.8	-5.6	FLT37 (SP)	1.000

According to SPP'S Open Access Transmission Tariff, the Gen-2008-127 power factor requirement will be limited to 95%.

4.3 Stability Results

The stability analysis was carried out for both summer and winter peak load flow models.

In order to determine the impact of the project on the overall system dynamics as well as to determine the requirements to meet the FERC Order 661-A Guidelines, 20 contingencies listed by Table 3-2 were simulated. The results obtained are described in this sub-section.

None of the contingency leads to trips due to LVRT or loss of synchronism neither in the studied projects nor in the prior queued ones. However, GEN-2009-025 is not settled down, as it presents undamped oscillations for two contingencies involving loss of 69 kV line between GEN-2009-025 and Sinclair Blackwell substation (FLT 33 and 34). Figure 4.1 and 4.2 present the dynamic performance of Gen-2009-025, for summer and winter peak cases respectively under FLT 33. The figure shows POI voltage and real power (P) of the project.

As identified and described in the steady state analysis, in both summer and winter peak scenarios, FLT 33 causes accentuated voltage dip in the Gen-2009-025 POI and in the substations on the same radial path, due to loss of reactive support from the system and also no support from the project itself. This leads to the dynamic behavior shown in Figure 4-1 and 4-2.

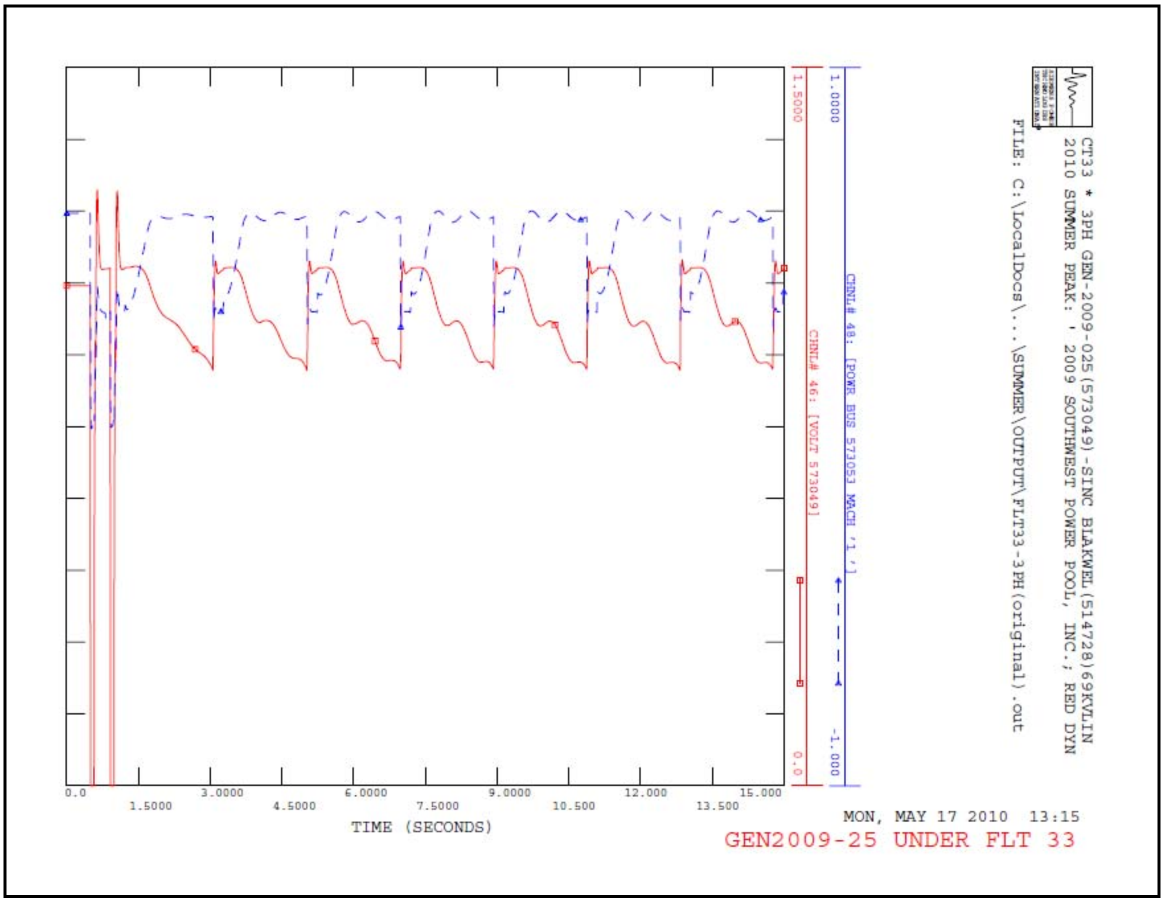

Figure 4-1: Gen-2009-025 Dynamic Performance under FLT33- Summer Peak

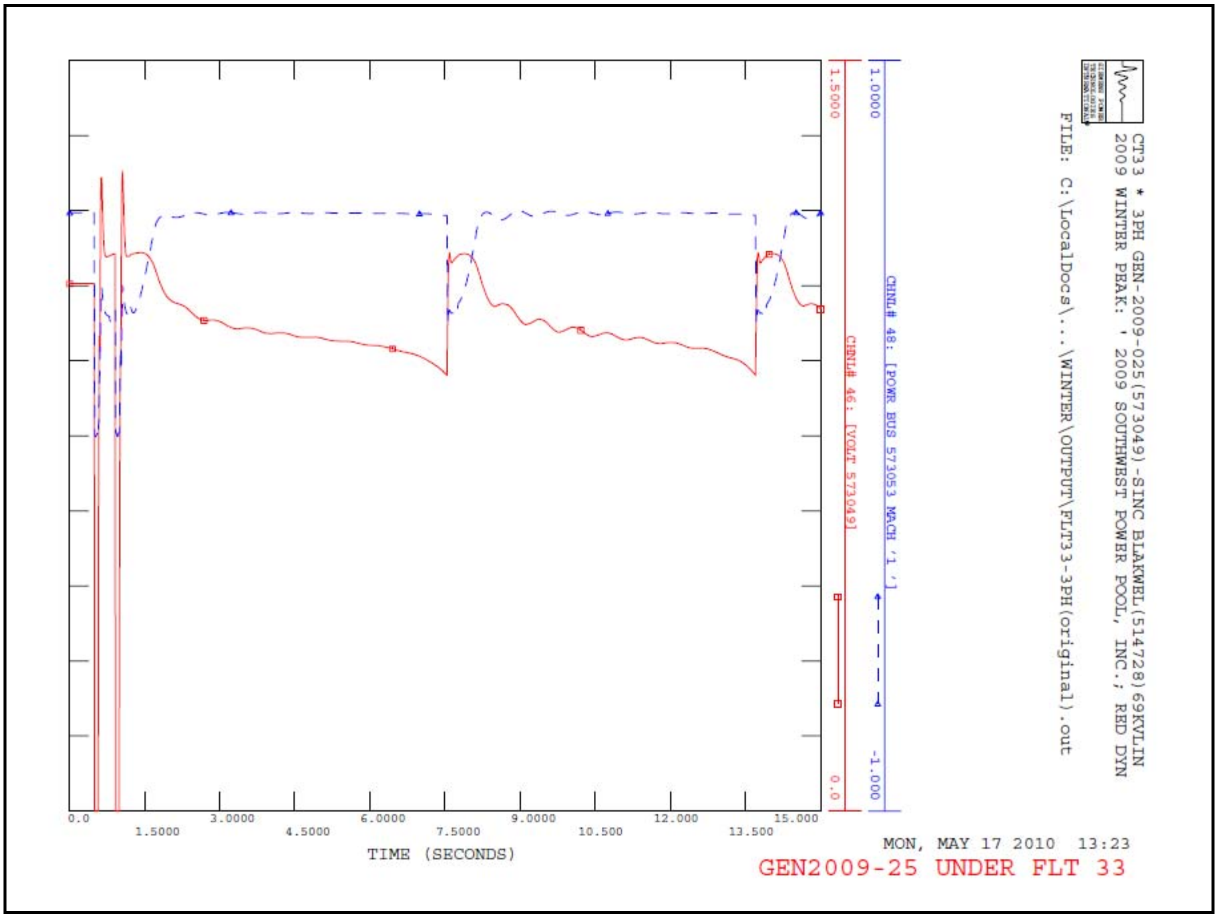

Figure 4-2: Gen-2009-025 Dynamic Performance under FLT33- Winter Peak

The attempts to address the stability issue evaluated additional reactive support to be provided by Gen-2009-025. A 10 Mvar SVC was added at the 34.5 kV collector bus in the costumer's side of the Gen-2009-025 project. Figure 4-3 shows the adequate Gen-2009-025 dynamic performance under the outage of 69 kV line between Gen-2009-025 and Sinclair Blackwell substations. Even though the transient support indicated is sufficient to address the stability issues in both scenarios, results for only winter peak case are shown.

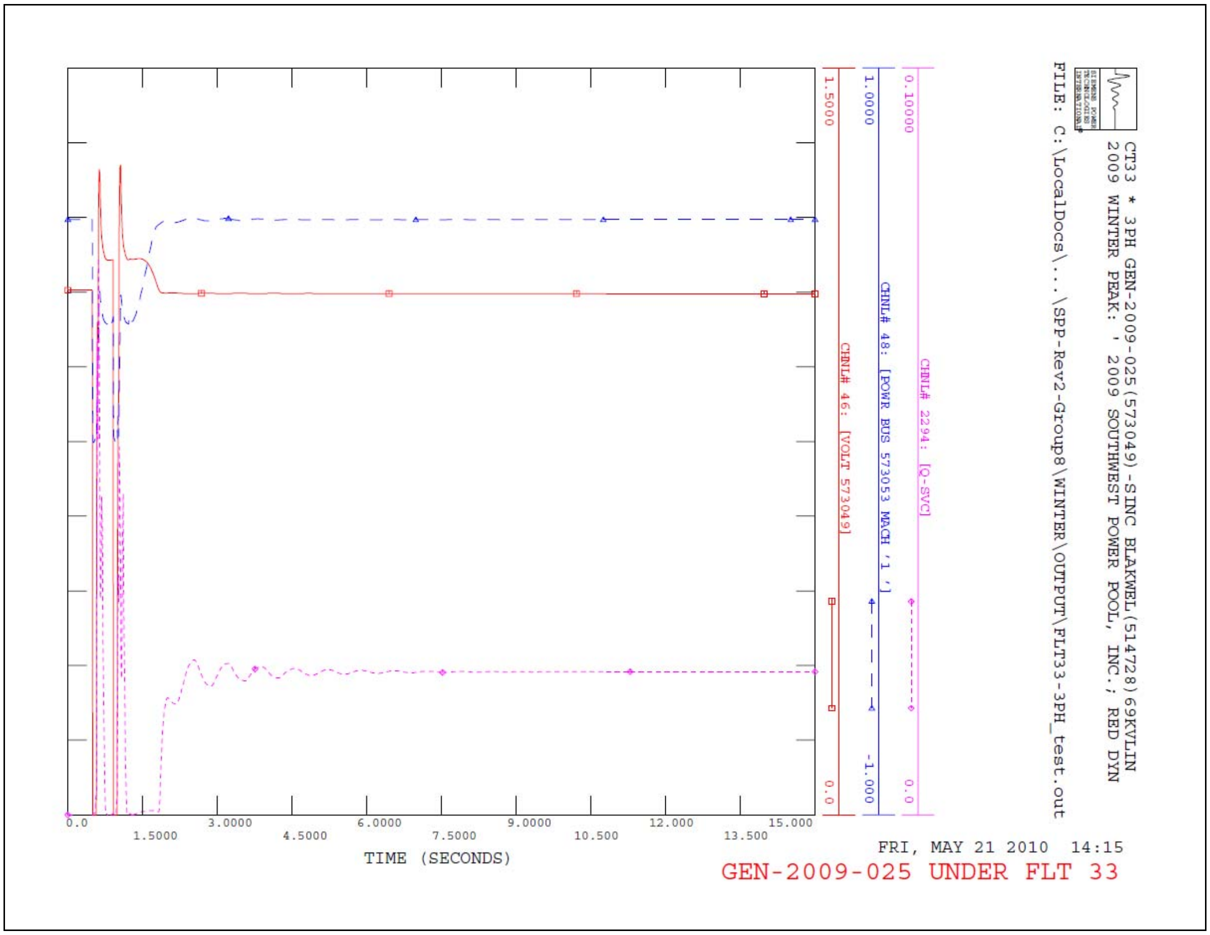

Figure 4-3: Gen-2009-025 Dynamic Performance under FLT33- Winter Peak (with 10 Mvar transient reactive support)

Besides the stability issue at Gen-2009-025 project, the results obtained show:

- The new proposed projects, did not trip during any of the contingencies tested, that is, no trips occurred due to LVRT or frequency protection.
- Furthermore, trips were not identified in the prior queued wind projects.
- All synchronous generators in the monitored areas were stable and remained in synchronism during all contingencies and the system conditions considered.
- Acceptable damping and voltage recovery was observed, within applicable standards.

Stability plots of the main contingencies evaluated for both summer peak and winter peak scenarios are presented in Appendix E.

Section

5

Conclusions

The four projects of DISIS-2009-001 Group 8 have been evaluated to determine the impact of the proposed cluster of interconnections on the Southwest Power Pool system.

Steady state and stability analysis were carried out to evaluate the system performance under contingencies. Also to identify the system requirements to meet the FERC Order 661-A Guidelines for Low Voltage Ride Through (LVRT) and therefore, to allow the Group 8 projects to deliver their full power to the SPP transmission system.

In general the Group 8 interconnection requests does not have significant impact on the voltage profile of the monitored system, either in base case conditions or under contingencies. Only exception was the outage of 69kV line between Gen-2009-025 and Sinclair Blackwell substations which results in significant voltage drop (≈ 7.0%). Additional reactive support is required at this substation to circumvent this voltage issue.

The power factor analysis determined the amount of reactive support required to maintain the scheduled voltages at each one of the points of interconnection under contingency conditions. The amount of reactive support indicated by Table 4-3 must be provided by each interconnection request using the wind turbine generator (WTG) capabilities and/or adding capacitor banks to the system. According to SPP'S Open Access Transmission Tariff, the Gen-2008-127 power factor requirement will be limited to 95%.

In general, the stability analysis demonstrates that none the new proposed or prior queued projects trip by voltage protection during any of the contingencies tested. That is, no trips occurred due to LVRT. Also, all other generators in the monitored areas were stable and remained in synchronism.

However, the outage of 69kV line between Gen-2009-025 and Sinclair Blackwell substations results in lack of reactive support and leads to a poor (undamped) dynamic response of the project Gen-2009-025. A 10 Mvar SVC at the 34.5 kV customer's collector bus is proposed to address the issue. Therefore, the Group 8 projects do not have an adverse impact on the dynamic performance of the SPP system, for the contingencies and system conditions tested.

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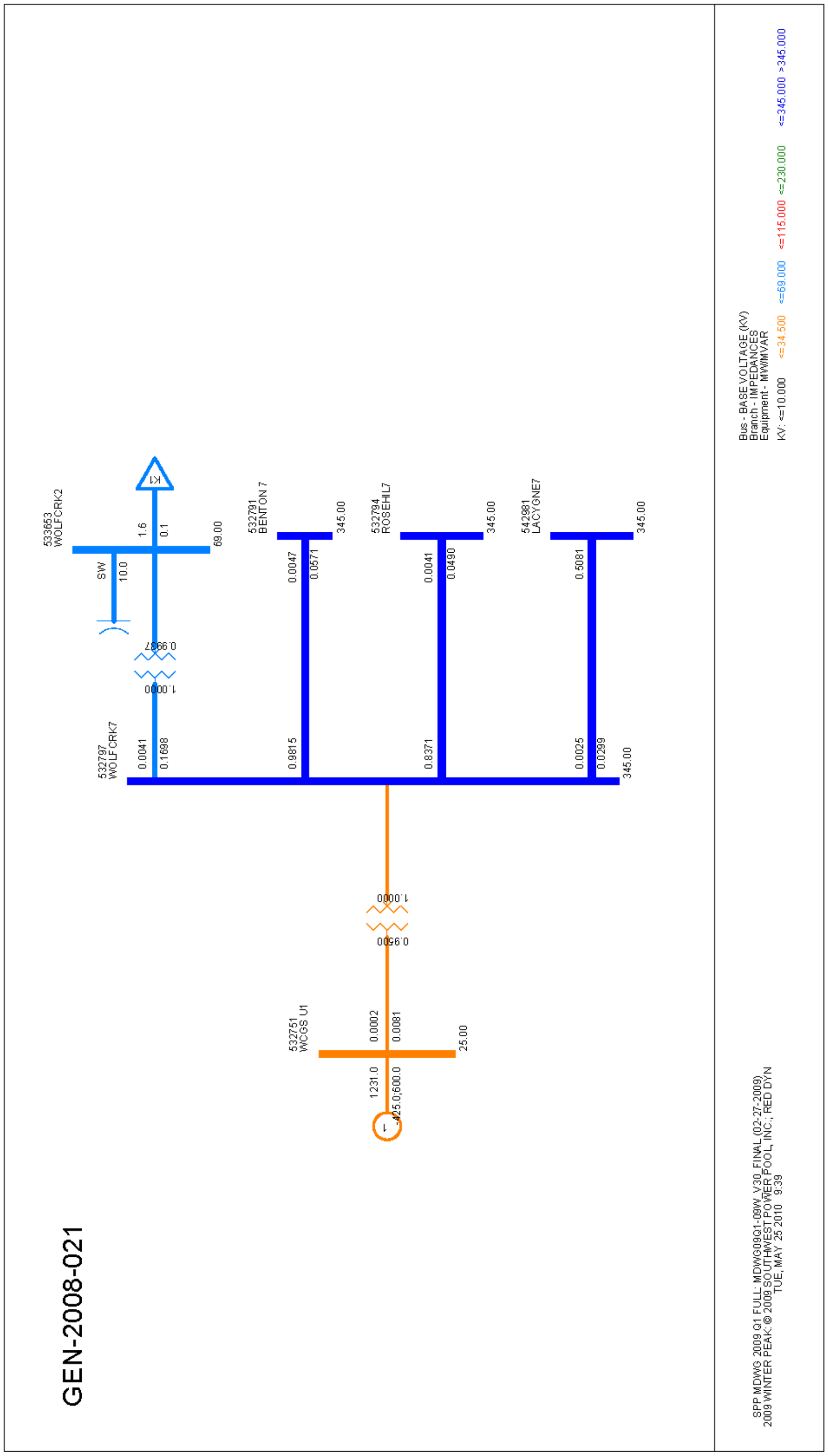
Appendix

A

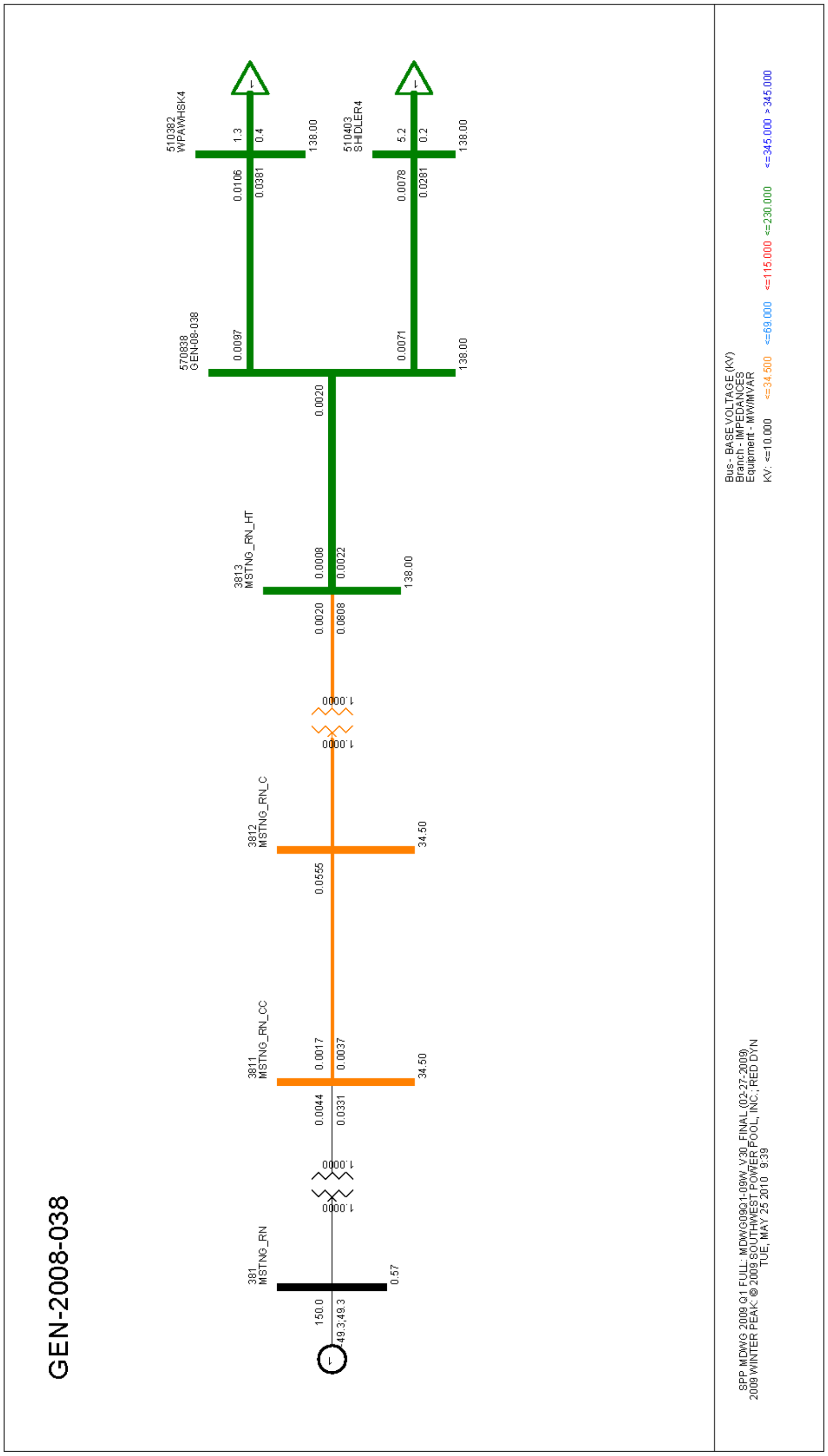
Nuclear STG and WTG Single Line Diagrams

This appendix contains single line diagrams for each one of the Group 8 projects, showing the modeling details and impedance data of the step-up transformers and collector systems.

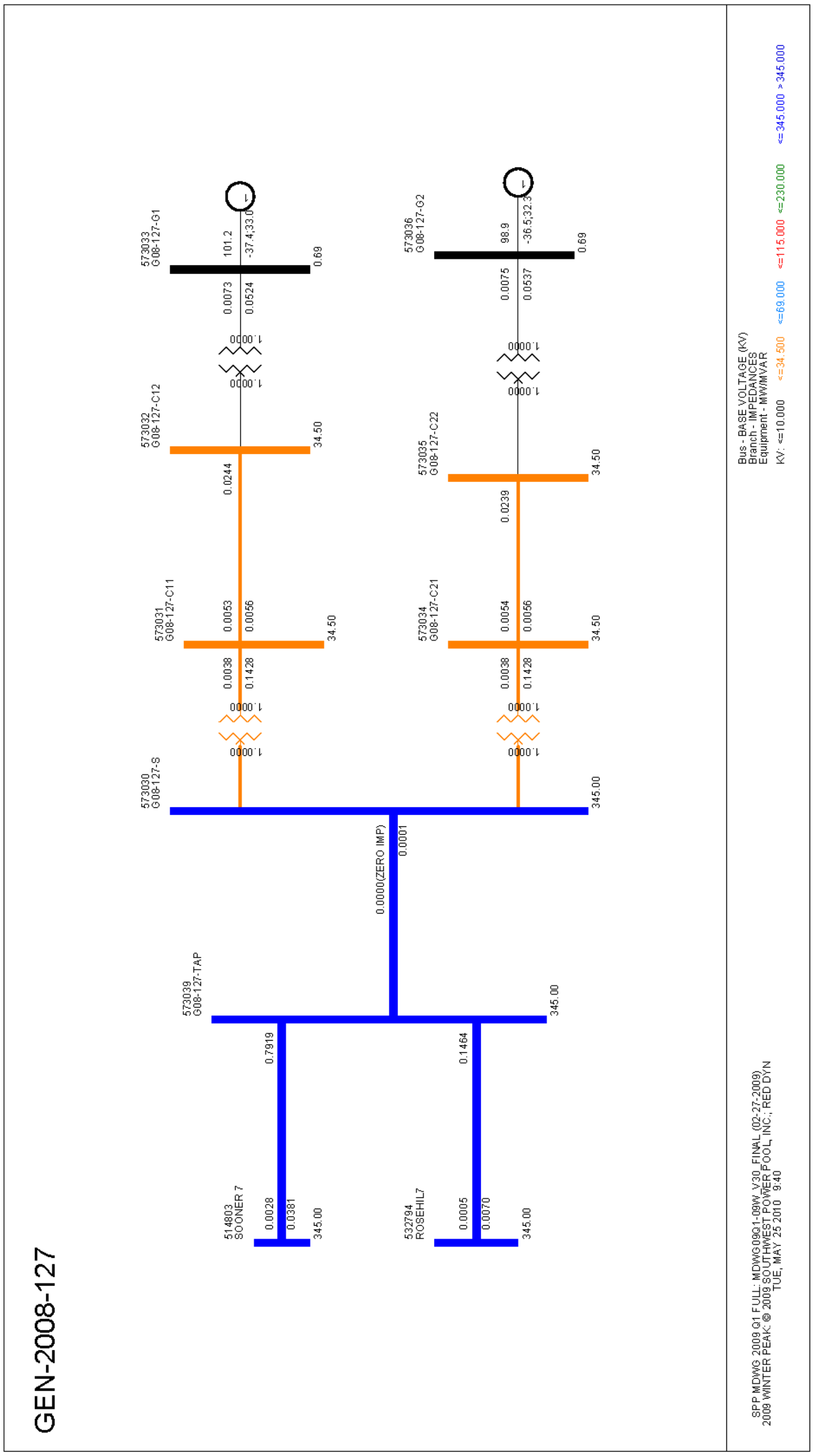
A.1 Gen-2008-021



A.2 Gen-2008-038



A.3 Gen-2008-127



A.4 Gen-2009-025