Impact Study For Generation Interconnection Request GEN-2006-048

SPP Tariff Studies

(#GEN-2006-048)

December 2007

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Black & Veatch performed the following Impact Study to satisfy the Impact Study Agreement executed by the requesting Customer and SPP for SPP Generation Interconnection request #GEN-2006-048.

Interconnection Facilities

The Impact Study has determined that a 34.5kV, 40 Mvar capacitor bank is required for the wind farm. This bank shall be switched in stages of industry accepted sizes as to prevent excessive voltage rise on the 115kV bus at the Seven Rivers substation.

The Impact Study has determined that if the Customer uses the studied Acciona 1.5MW wind turbines, that no SVC or STATCOM device will be required for interconnection. The wind farm will comply with FERC Order #661A low voltage ride through provisions if the Acciona turbines are used.

The estimate of interconnection facilities was given in the Feasibility Study. These costs are repeated below in Table 1 and 2. If the Customer executes a Facility Study Agreement, a more detailed estimate will be made. These facilities do not include the results of short circuit analysis. A short circuit analysis will be completed for the Facility Study.

Table 1: Direct Assignment Facilities

FACILITY	ESTIMATED COST (2007 DOLLARS)
Customer – (1) 115/34.5 kV Customer collector substation facilities.	*
Customer – (1) 115 kV transmission line from Customer collector substation to the Seven Rivers Interchange.	*
Customer – 34.5 kV, 40 Mvar capacitor bank(s) to be installed in the Customer 115/34.5 kV collector substation.	*
Customer – Right-of-Way for all Customer facilities.	*
SPS – Add (1) 115 kV line terminal to the Seven Rivers Interchange.	$805,679
TOTAL	*

** Estimates of cost to be determined.*

Table 2: Required Interconnection Network Upgrade Facilities

FACILITY	ESTIMATED COST (2007 DOLLARS)
None at this time	
TOTAL	

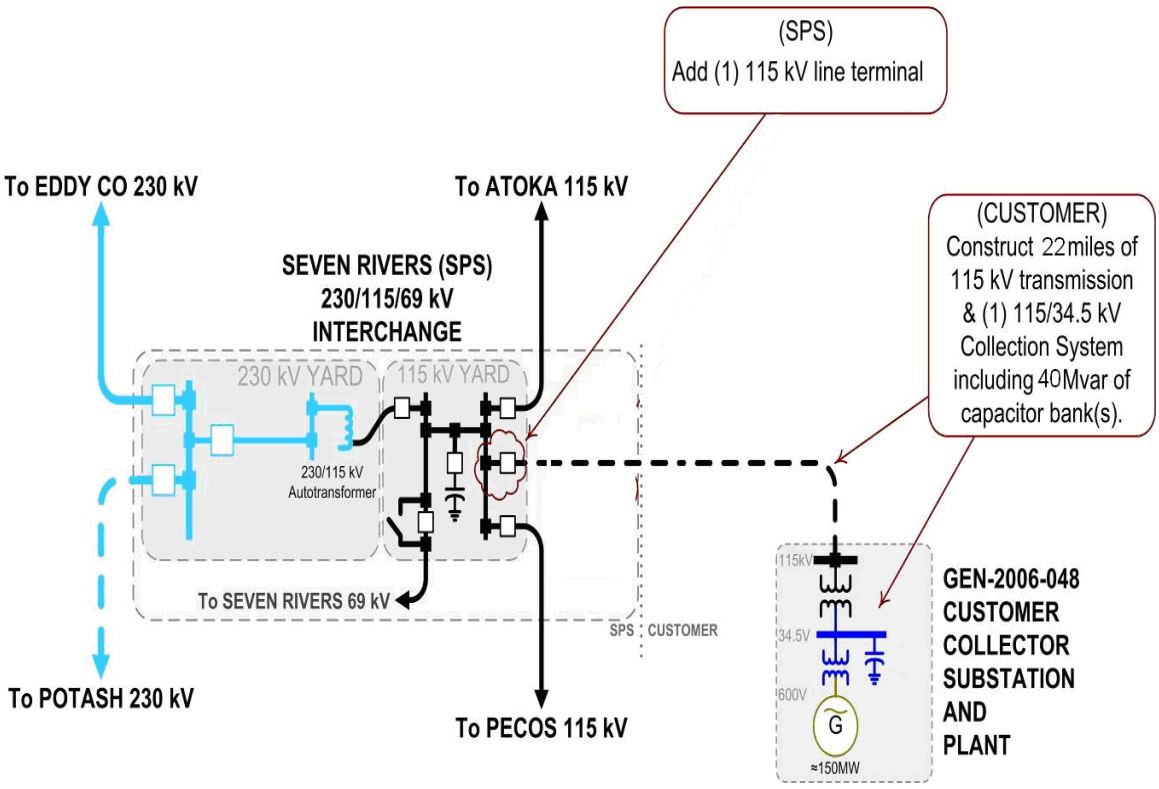

Figure 1: Proposed Method of Interconnection
(Final substation design to be determined)

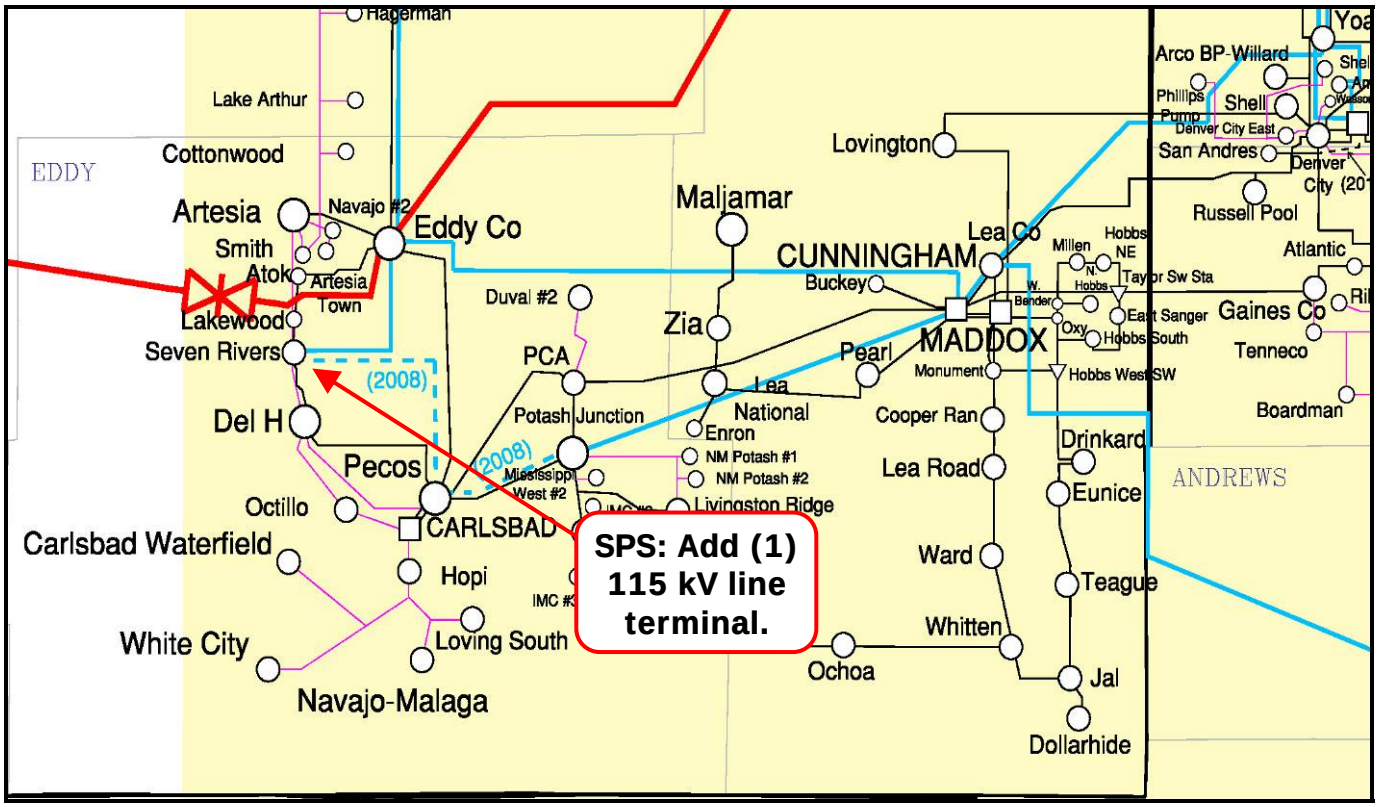

FIGURE 2. Point of Interconnection Area Map

IMPACT STUDY FOR SPP GENERATION QUEUE POSITION GEN-2006-048

SOUTHWEST POWER POOL (SPP)
December 4, 2007

Final Report

By

BLACK & VEATCH

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EXECUTIVE SUMMARY

A transient stability study was performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2006-048 as part of the System Impact Study. The Interconnection Queue Position GEN-2006-048 is a wind farm of 150 MW capacity proposed to be connected through a twenty two (22) mile 115kv line to Seven Rivers 230/115/69kV substation owned by Southwestern Public Service, New Mexico. The wind farm would be interconnected to the 115 kV bus.

Transient Stability studies were conducted with the full output of 150 MW (100%). The wind farm was considered to contain Acciona 1.5 MW turbines.

The 2012 summer load flow case and 2008 winter load flow case together with the SPP MDWG 2007 stability model were used as the base case for the transient stability analysis. The study was performed using PTI's PSS/E program, which is an industry-wide accepted power system simulation program. The wind farm was modeled using the Acciona wind turbine models provided by the customer.

Prior to the transient stability analysis, a power flow analysis was conducted to estimate the amount of additional shunt capacitors that would be needed at the wind farm 34.5 kV collector buses so as to have zero reactive power exchange between wind farm and the grid. It was found that about 40 MVAR shunt capacitors would be needed for both summer and winter peak load case.

Transient Stability studies were conducted with the GEN-2006-048 output at 150 MW (100%) for two scenarios, i.e., (i) summer load and (ii) winter load. Twenty (20) contingencies were considered for each of the scenarios.

GEN-2006-048 generators were found to stay connected to the grid for all the contingencies that were studied.

The study has not indicated any angular or voltage instability problem due to addition of GEN-2006-048 for the contingencies analyzed in both the scenarios.

If any previously queued projects that were included in this study drop out then this System Impact Study may have to be revised to determine the impacts of this Interconnection Customer's project on SPS transmission facilities.

1. INTRODUCTION

This report discusses the results of a transient stability study performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2006-048.

The Interconnection Queue Position GEN-2006-048 is a wind farm of 150 MW capacity proposed to be connected to existing Seven Rivers 230/115/69kV substation owned by Southwestern Public Service, New Mexico. The wind farm would be interconnected to the 115kV bus at the seven rivers substation through a twenty two (22) mile 115kV transmission line. The system one line diagram of the area near the Queue Position GEN-2006-048 is shown below.

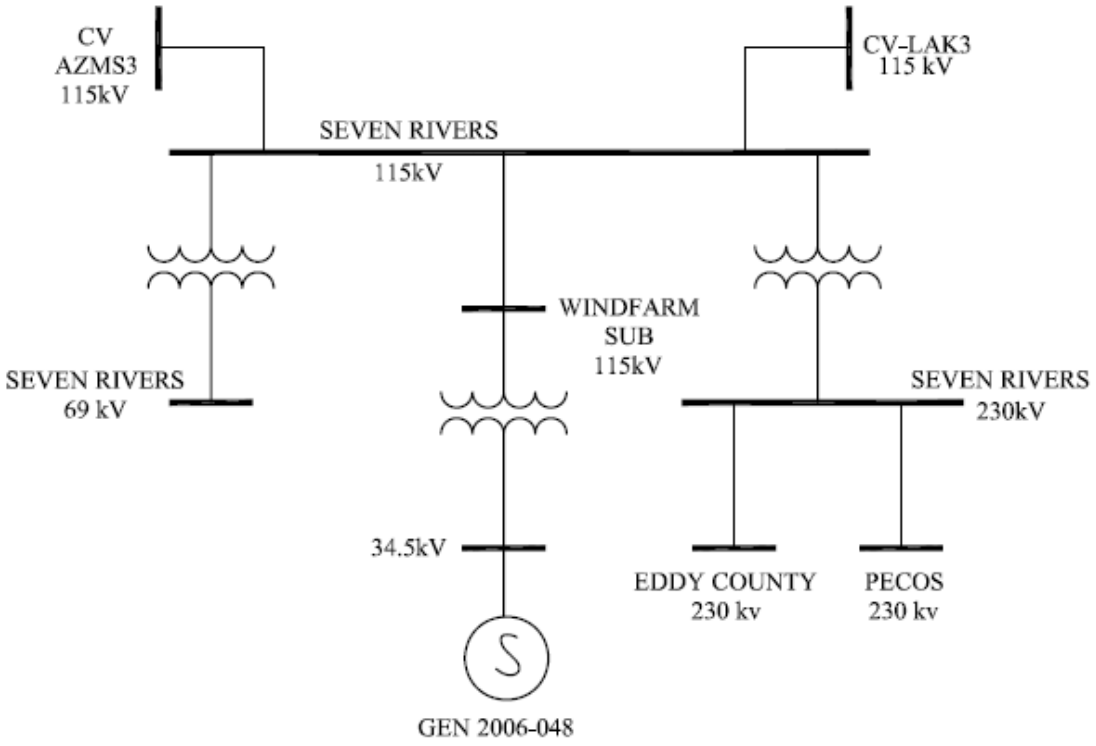

Figure 1: System One Line Diagram near GEN-2006-048

Transient Stability studies were conducted with the full output of 150 MW (100%). The wind farm was considered to contain Acciona -1.5 MW wind turbines in the study.

2. STABILITY STUDY CRITERIA

The 2012 summer load flow and 2008 winter load flow cases together with the SPP MDWG 2007 stability model were used as the base case for the transient stability analysis. These models were provided by SPP.

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 difference of the angular positions of synchronous machine rotor becomes constant following an aperiodic system disturbance."

Disturbances such as three phase and single phase line faults were simulated for a specified duration and the synchronous machine rotor angles were monitored for their synchronism following the fault removal.

The ability of the wind generators to stay connected to the grid during the disturbances and during the fault recovery was also monitored.

3. SIMULATION CASES

Transient Stability studies were conducted with the GEN-2006-048 output at 150 MW for (i) 2012 summer and (ii) 2008 winter load flow cases.

Table 1 indicates the contingencies which were studied for each of the two cases.

Fault	Fault Definition
FLT13PH	Three phase fault on the Seven Rivers 230/115kV autotransformer on the 115kV bus.
FLT21PH	Single phase fault on the on the Seven Rivers 230/115kV autotransformer on the 115kV bus.
FLT33PH	Three phase fault on the Seven Rivers 115/69kV autotransformer on the 115kV bus.
FLT41PH	Single phase fault on the Seven Rivers 115/69kV autotransformer on the 115kV bus.
FLT53PH	Three phase fault on the Seven Rivers- CV-AZMS 115 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.
FLT61PH	Single phase fault on the Seven Rivers- CV-AZMS 115 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.

FLT73PH	Three phase fault on the Seven Rivers- CV-LAKW 115 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.
FLT81PH	Single phase fault on the Seven Rivers- CV-LAKW 115 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.
FLT93PH	Three phase fault on the Seven Rivers to Eddy 230 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.
FLT101PH	Single phase fault on the Seven Rivers to Eddy 230 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.
FLT113PH	Three phase fault on the Seven Rivers to Pecos 230 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.
FLT121PH	Single phase fault on the Seven Rivers to Pecos 230 kV line, near Seven Rivers, with one shot reclosing after 20 cycles.
FLT133PH	Three phase fault on the Eddy - Tolk 345 kV line, near Eddy, with one shot reclosing after 30 cycles.
FLT141PH	Single phase fault on Eddy - Tolk 345 kV line, near Eddy, with one shot reclosing after 30 cycles.
FLT153PH	Three phase fault on the Oasis to Roosevelt 230 kV line, near Oasis, with one shot reclosing after 20 cycles.
FLT161PH	Single phase fault on the Oasis to Roosevelt 230 kV line, near Oasis, with one shot reclosing after 20 cycles.
FLT173PH	Three phase fault on the Lea County to Yoakum 230 kV line, near Lea County, with one shot reclosing after 20 cycles.
FLT181PH	Single phase fault on the Lea County to Yoakum 230 kV line, near Lea County, with one shot reclosing after 20 cycles.
FLT193PH	Three phase fault on the Eddy - Cunningham 230 kV line, near Cunningham, with one shot reclosing after 20 cycles.
FLT201PH	Single phase fault on the Eddy - Cunningham 230 kV line, near Cunningham, with one shot reclosing after 20 cycles.

Table 1: Study Cases

In all of the simulations, the fault duration was considered to be 5 cycles. One shot re-closing into the fault was also considered in the study with the re-closure dead time of 30 cycles for 345 kV lines and 20 cycles for the other lines.

4. SIMULATION MODEL

The customer requested to use Acciona Wind turbine (AW 1500) for the System Impact Study. The Acciona turbines are a double fed induction generator with the stator winding connected directly to the grid and the rotor winding connected to the grid through a bidirectional power electronic converter. The following are the main electrical parameters of the Acciona 1.5 MW wind turbine.

Rated Power : 1.5 MW
Operating Nominal Voltage : 12 kV
Operating Power Factor : 0.95 Lead to 0.95 Lag.

The models of the Wind Farm equipment such as generators, transformers and cables were added to the base case for the purpose of this study. The equivalent generators of the wind farm were based on the number of collector circuits shown on the Customer provided single line diagram. Figure 2 shows the one line diagram of GEN-2006-048 modeled.

Table 2 provides the number of Acciona 1.5 MW wind generators modeled as equivalents at each collector buses of the wind farm.

Collector Bus	No. of generators aggregated
GEN-T-8182	2
GEN-T-8395	2
GEN-T-9394"	2
GEN-T-85"	1
GEN-T-84	1
GEN-T-86	1
GEN-T-8788	2
GEN-T-92	1
GEN-T-89	1
GEN-T-71	2
GEN-T-616265	3
GEN-T-66	1
GEN-T-9091	2
GEN-T-6367	2
GEN-T-68	1
GEN-T-646970	4
GEN-T-4547	2
GEN-T-324429	3
GEN-T-33	1
GEN-T-78	1

GEN-T-53	1
GEN-T-5152	2
GEN-T-7374	2
GEN-T-72	2
GEN-T-24	1
GEN-T-4041	2
GEN-T-39	1
GEN-T-38	1
GEN-T-D43-57	6
GEN-T-5556	2
GEN-T-54	2
GEN-T-020304	3
GEN-T-0123	2
GEN-T-22	1
GEN-T-202125	3
GEN-T-181926	3
GEN-T-2717	3
GEN-T-56789	5
GEN-T-12	1
GEN-T-F28-16	5
GEN-T-35	1
GEN-T-3637	2
GEN-T-1011	2
GEN-T-30	1
GEN-T-3146	2
GEN-T-484950	3
GEN-T-7576	2
GEN-T-77	1
GEN-T-787980	3

Table 2: Equivalent Generators with Acciona -1.5 MW Turbines

The Customer provided the wind turbine feeder conductor types, lengths and impedance values. Table 3 indicates the transmission line parameters, as provided by the Customer, were used in the model for the underground lines within the Wind Farm.

Conductor Size	Resistance (Ohms per 1000 ft)	Reactance (Ohms per 1000 ft)
1/0	0.213	0.0522
4/0	0.1086	0.0467
500kcmil	0.0476	0.0416
1000 kcmil	0.0257	0.0373

Table 3: Cable impedance per 1000 feet

The PSS/E model for Acciona wind turbines was provided by the customer.

The customer provided the data for 115kV transmission line from the wind farm site to the Seven Rivers Substation. Table 4 indicates the transmission line parameters, as provided by the Customer.

Conductor Size	Resistance (p.u)	Reactance (p.u)	Charging (p.u)
954 MCM	0.0188	0.1165	0.0663

Table 4: 115kV transmission line impedance in per unit

The base case power flow diagram for the project GEN-2006-048 is shown in Figure 2.

The prior queued projects Gen-2006-026 (604 MW), GEN-2004-015 (160MW), GEN-2006-015 (160MW) and GEN-2001-033 (180MW) were also included in the study model.

Prior to the transient stability analysis, a power flow analysis was conducted to estimate the amount of additional shunt capacitors that would be needed at the wind farm 34.5 kV collector buses so as to have zero reactive power exchange between wind farm and the grid. It was found that about 40 MVAR shunt capacitors would be needed in the summer and winter load case.

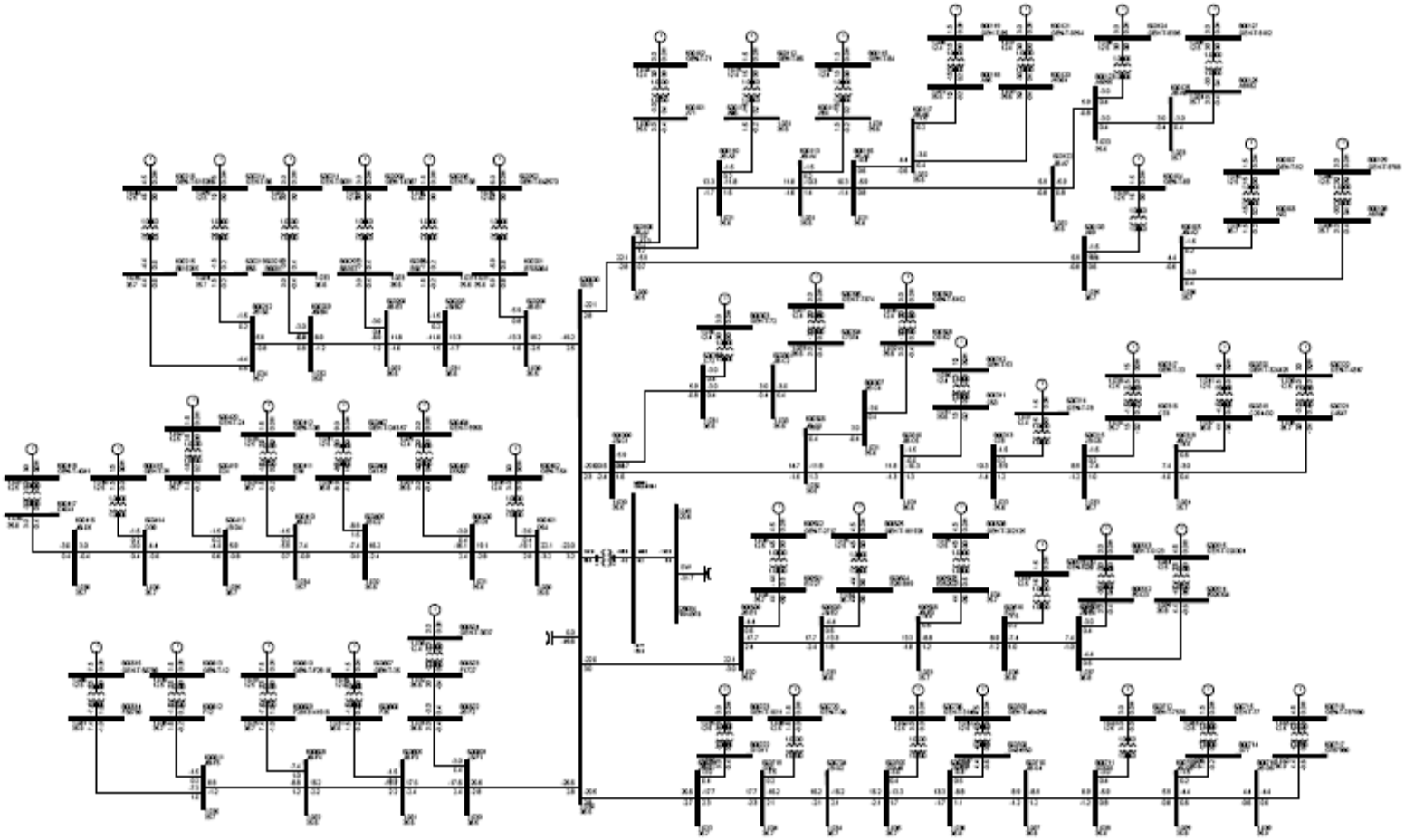

Figure 2: 100% Power Flow Base Case for GEN-2006-048

5. STUDY ASSUMPTIONS

The following assumptions were made in the Study:

1. The wind speed over the entire wind farm was assumed to be uniform and constant during the study period.
2. From the wind turbine data sheets the protection settings were used as and are shown in Table 4.
3. The other generators in the SPP control area were scaled down to accommodate the new generation as indicated in Table 5.

Protective Function	Protection Setting	Time Delay
Over Frequency	63.0 Hz	5 seconds
Under Frequency	57.0 Hz	5 seconds
Under Voltage	15%	0.5 seconds
Under Voltage	80%	1 second
Under Voltage	85%	15.0 second
Under Voltage	90%	210.0 seconds
Over Voltage	110%	5.0 second
Over Voltage	120%	0.1 seconds

Table 4: Protective Functions and Settings for Acciona 1.5 MW Turbines

Scenario	Generation within SPP	
	Summer	Winter
Without the Wind Farms	40639	28245
GEN-2006-048 at 100% output with the prior queued projects	40789	28395

Table 5: SPP Dispatches

6. SIMULATION RESULTS

Initial simulation was carried out without any disturbance to verify the numerical stability of the model and was confirmed to be stable.

It was noticed during the simulations that for certain contingency cases, i.e for cases when the voltages at the generator terminals dip to about 0.4 p.u, there were some voltage spikes following the fault clearance. These spikes caused the wind turbine generator over-voltage protective relays to operate. Figure 3 shows the voltages at Gen-2006-048

generator terminal and at the 34.5 kV collector bus for one such case. The voltage spikes were not found to be present if the voltages reduced below 0.3 p.u during the disturbances. Hence it was concluded that the observed voltage spikes were due to modeling inaccuracies and did not represent the actual situation.

Generator over voltage protective relays were disabled in all the simulations and Table 6 provides the summary of the stability studies.

GEN-2006-048 generators were found to stay connected to the grid for all the contingencies that were studied.

Fault Number	**Summer Load**	**Winter Load**
FLT13PH	- -	- -
FLT21PH	- -	- -
FLT33PH	- -	- -
FLT41PH	- -	- -
FLT53PH	- -	- -
FLT61PH	- -	- -
FLT73PH	- -	- -
FLT81PH	- -	- -
FLT93PH	- -	- -
FLT101PH	- -	- -
FLT113PH	- -	- -
FLT121PH	- -	- -
FLT133PH	- -	- -
FLT141PH	- -	- -
FLT153PH	PQ	- -
FLT161PH	- -	- -
FLT173PH	- -	- -
FLT181PH	- -	- -
FLT193PH	- -	- -
FLT201PH	- -	- -

UV : GEN-2006-048 Tripped due to low voltage
OV : Tripped due to high voltage
UF : Tripped due to low frequency
OF : Tripped due to high frequency
PQ : Prior Queued Projects Tripped
S : Stability issues encountered
- - : Wind Farm did not trip

Table 6: Stability Study Results Summary

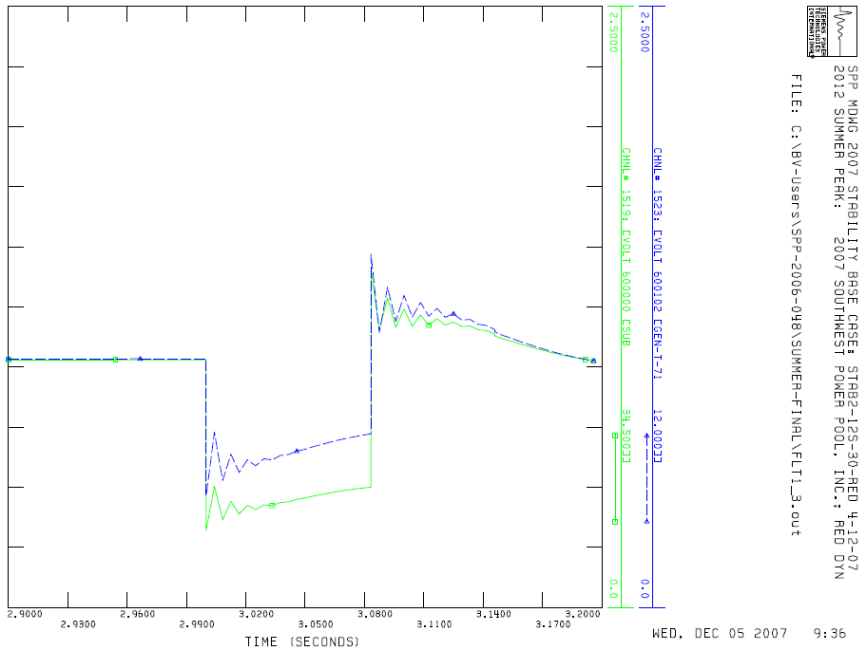

Figure 3: Generator Terminal and 34.5 kV Bus Voltage

For FLT15_3PH, the prior Queued project GEN-2001-033 was found to be tripped in the summer case due to under voltage. The study was repeated for summer case and winter case with under voltage protection settings disabled for GEN-2001-033 and this wind farm was found to stay connected.

Figure 4 shows the summer peak response for FLT15_3PH scenario. Figure 5 shows the summer peak response for FLT15_3 with voltage setting disabled for Gen-2001-033.

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position GEN-2006-048 consisting of Acciona 1.5 MW wind turbines, with the wind farm aggregate output of 150 MW. The study was conducted for two different power flow scenarios, i.e., one for summer peak and one for winter peak.

The study has not indicated any angular or voltage instability problem due to the addition of GEN-2006-048 for the contingencies analyzed in both the scenarios.

Disclaimer

If any previously queued projects that were included in this study drop out, then this System Impact Study may have to be revised to determine the impacts of this Interconnection Customer's project on SPS transmission facilities. Since this is also a preliminary System Impact Study, not all previously queued projects were assumed to be

in service in this System Impact Study. If any of those projects are constructed, then this System Impact Study may have to be revised to determine the impacts of this Interconnection Customer's project on SPS transmission facilities. In accordance with FERC and SPP procedures, the study cost for restudy shall be borne by the Interconnection Customer.

Figure 4 : System Responses with 100% output of GEN-2006-048 for FLT15-3PH

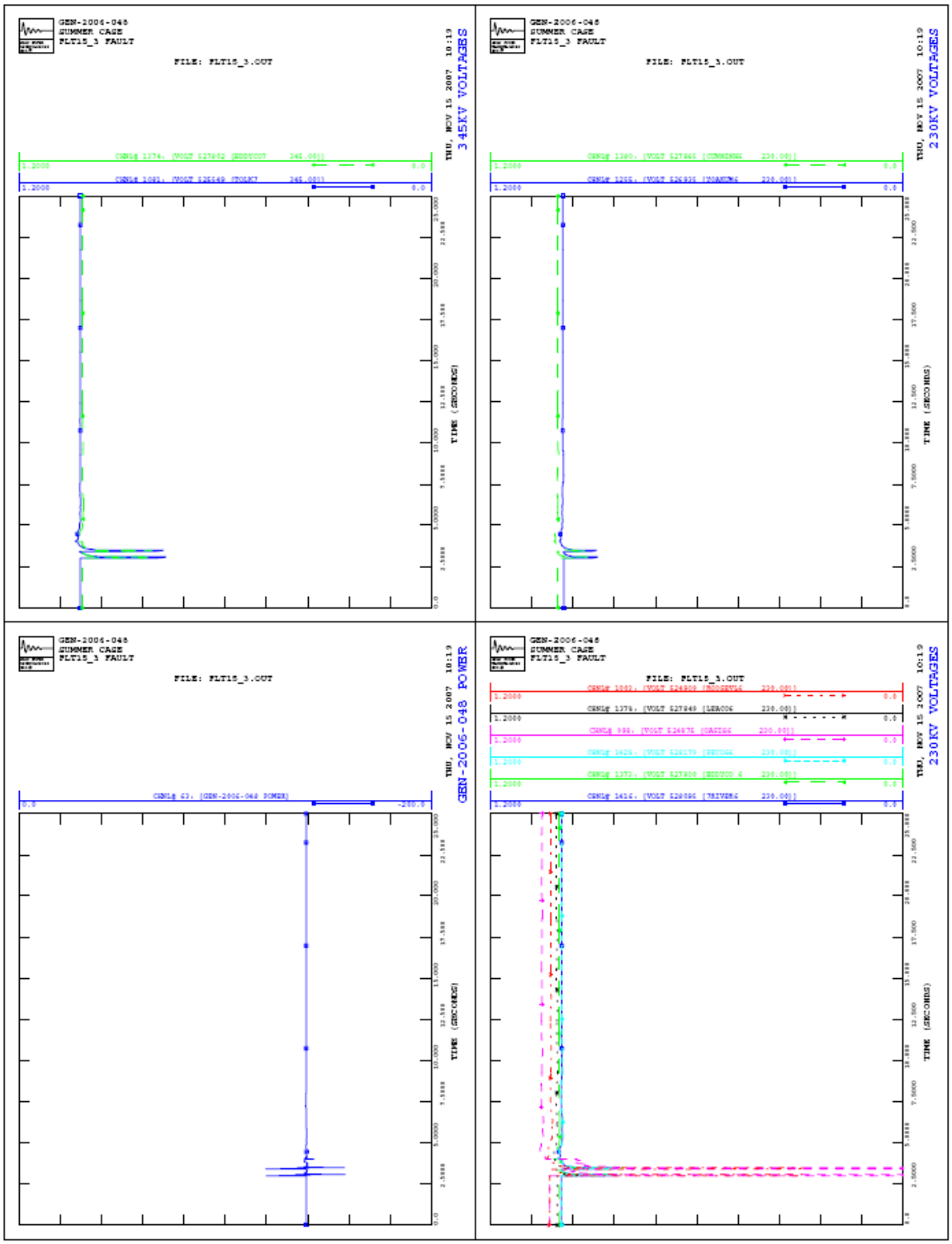

Figure 4 : System Responses with 100% output of GEN-2006-048 for FLT15-3PH (Cont'd)

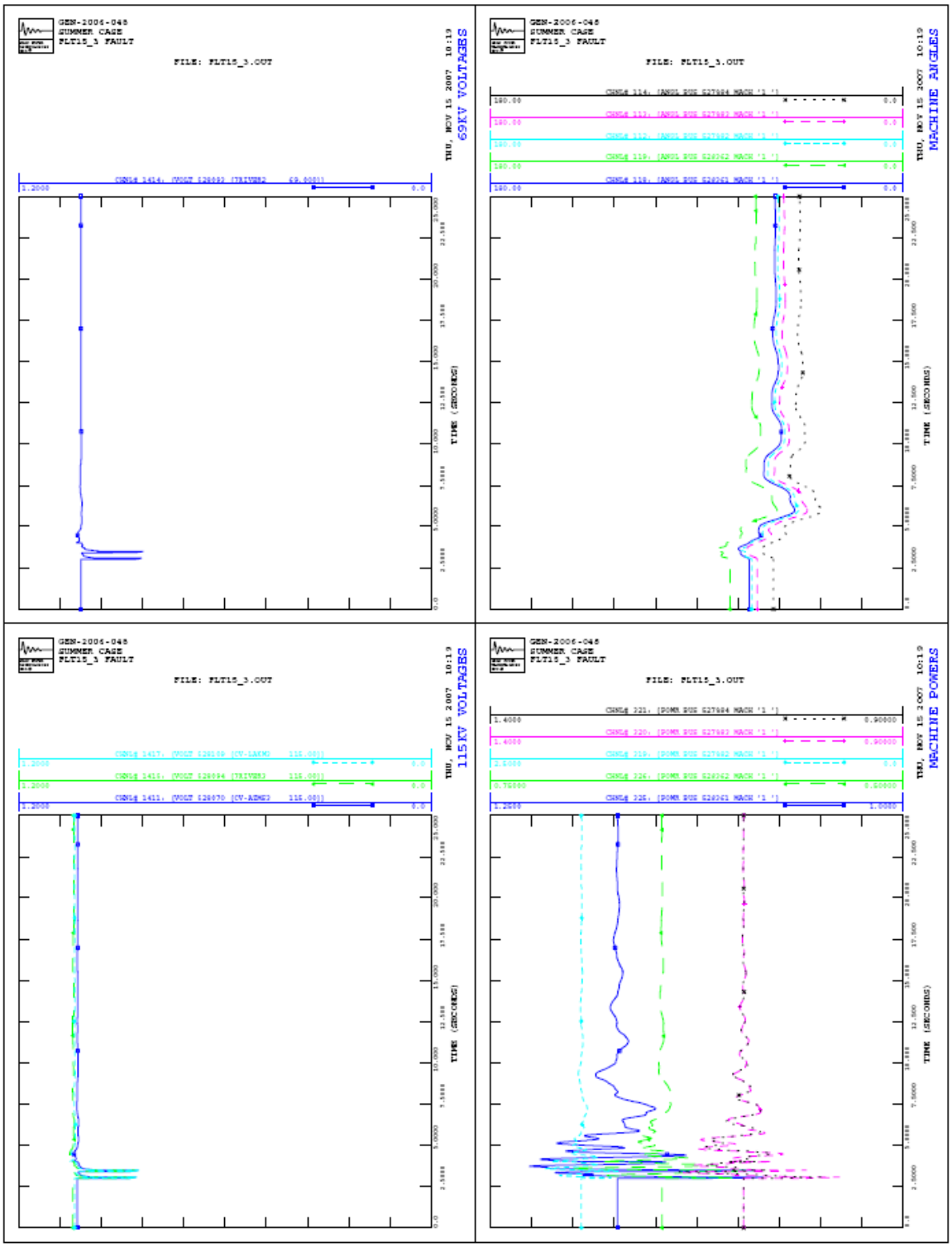

Figure 4 : System Responses with 100% output of GEN-2006-048 for FLT15-3PH (Cont'd)

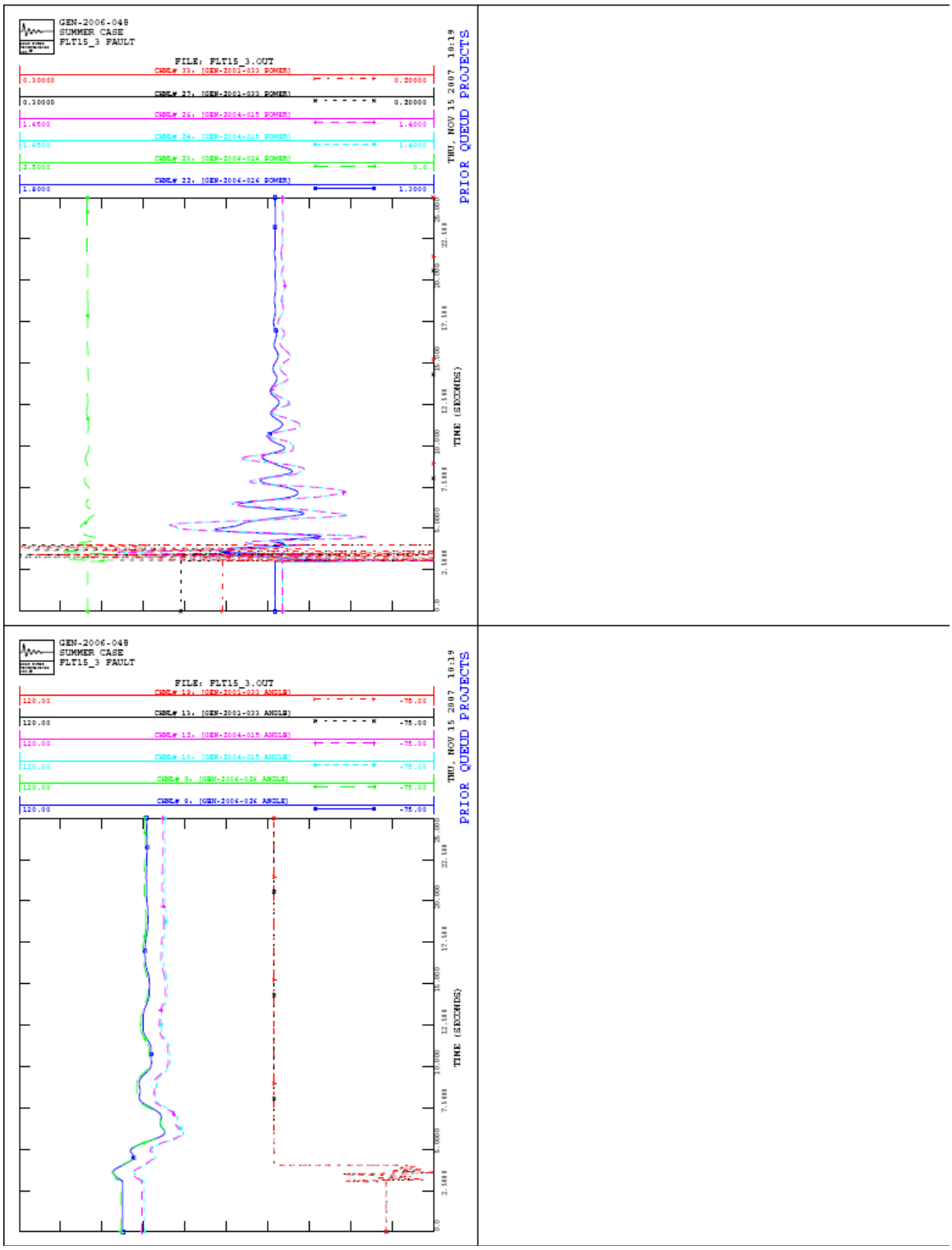

Figure 5 : System Responses with 100% output of GEN-2006-048 for FLT15-3PH with Voltage Tripping Disabled for Gen-2001-033

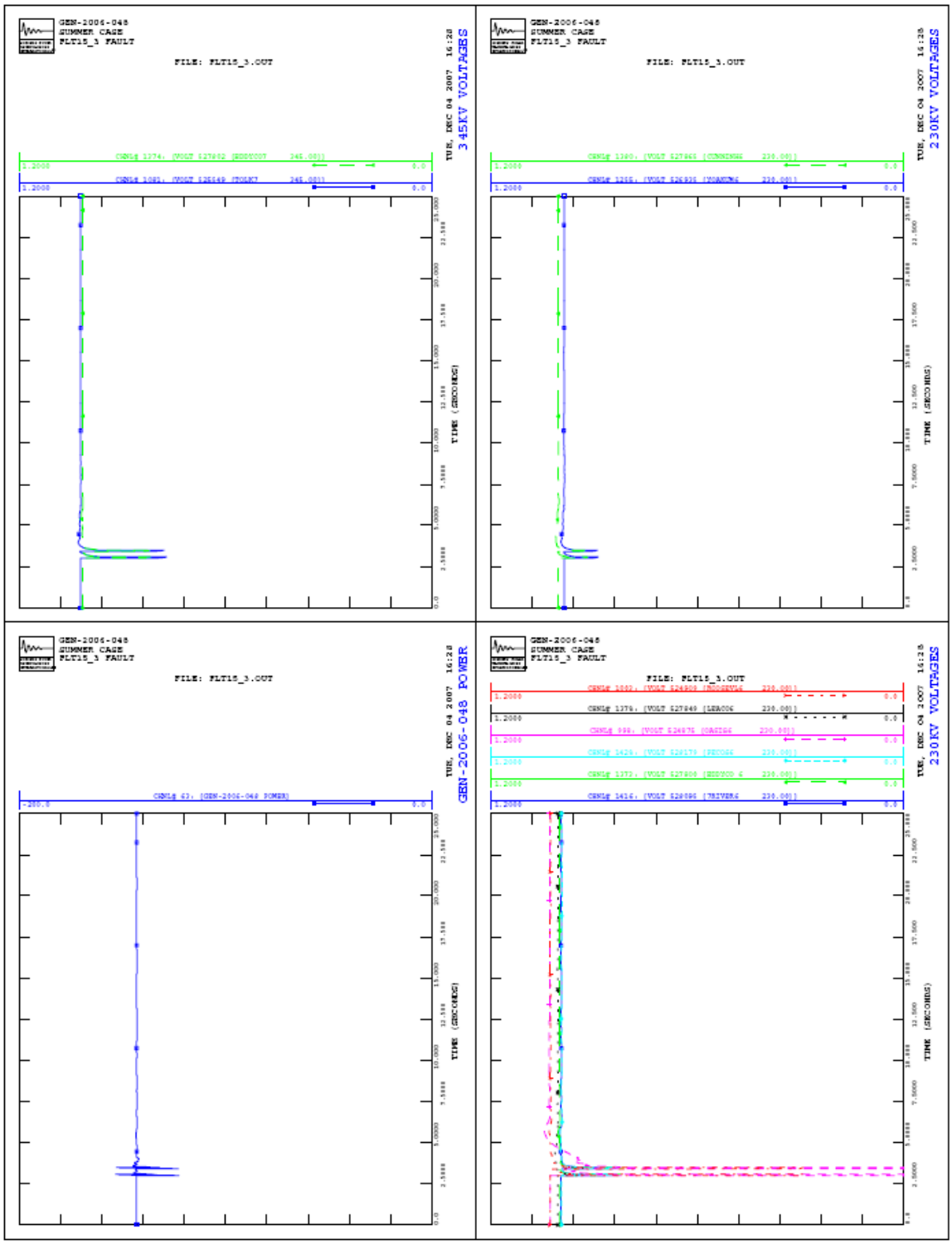

Figure 5: System Responses with 100% output of GEN-2006-048 for FLT15-3PH with Voltage Tripping Disabled for Gen-2001-033(Cont.)

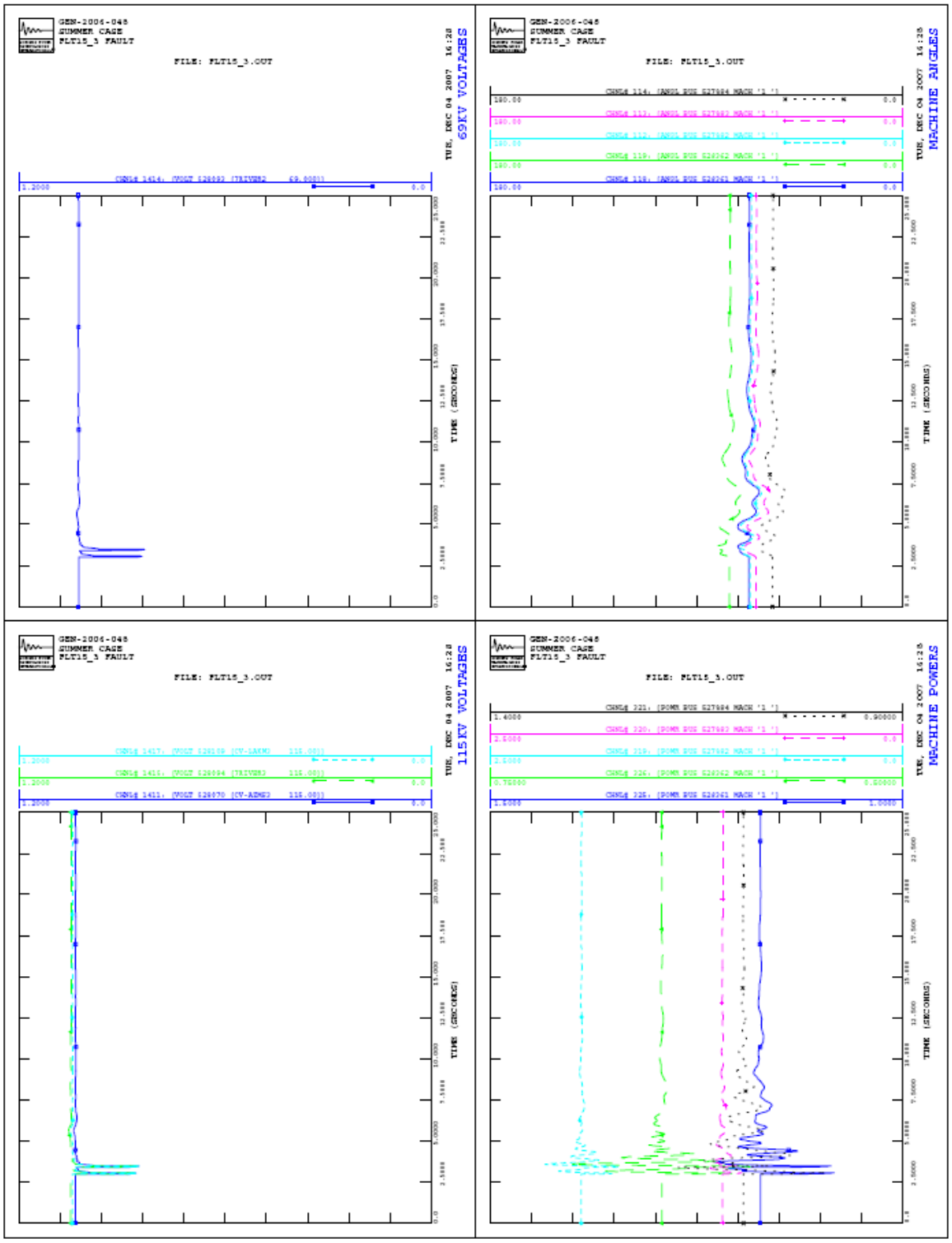

Figure 5 : System Responses with 100% output of GEN-2006-048 for FLT15-3PH with Voltage Tripping Disabled for Gen-2001-033(Cont.)