Impact Study
For
Generation Interconnection Request
GEN-2007-011

SPP Tariff Studies
(#GEN-2007-011)

May 2008

Summary

Pursuant to the tariff and at the request of 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-2007-011. 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.

<OMITTED TEXT> (Customer) has requested an Impact Study for the purpose of interconnecting 135 MW of wind generation within the control area of Sunflower Electric Power Corporation (SUNC) located in Hamilton County, Kansas. The proposed method of interconnection is to add a new 115 kV breaker and line terminal at the existing Syracuse switching station, owned by SUNC. The proposed in-service date is November 1, 2008.

Power Factor Requirements

The Customer has requested to study Acciona 1.5 MW wind turbines for this generation interconnection request. The Acciona wind turbines have capability of +/- 95% lead/lag power factor at the generator terminals. An analysis was conducted to determine whether the Acciona turbines are sufficient to meet the power factor criteria for the wind farm in lieu of the earlier specified 25 Mvars of 34.5kV capacitors specified in the Feasibility Study.

The interconnection generators were set to hold a voltage schedule at the point of interconnection, the Syracuse 115kV substation, of 1.0 per unit voltage under system intact conditions and the two most stringent contingencies that the wind farm will be subjected. The analysis was conducted for both the 2012 summer and 2012 winter peak. The results of the analysis are below.

SEASON	CONTINGENCY	PF @POI	PF	MW @POI	Mvars @POI
12SP	NONE	0.981	Lag	130.3	-25.6
12SP	Syracuse - Williamson 115kV	0.998	Lag	130.8	-0.8
12SP	Syracuse – Tribune 115kV	0.987	Lag	130.5	-17.4
12SP	GEN-2001-039M – Setab 115kV	0.999	Lag	130.4	-2.5
12WP	NONE	0.981	Lag	129.9	-25.9
12WP	Syracuse - Williamson 115kV	0.994	Lag	130.0	-13.7
12WP	Syracuse – Tribune 115kV	0.986	Lag	130.0	-21.9

The analysis determined that the customer will need to be able to provide unity power factor at the point of interconnection for any system configuration. The Customer will determine the needed setting for the turbines to hold the required voltage schedule at the

point of interconnection without the addition of external capacitor banks while maintaining acceptable voltages at its generator terminals. If the voltage schedule cannot be maintained, then the capacitor banks will be required.

Interconnection Facilities

The requirements for interconnection of the 135 MW consist of adding a new 115 kV breaker and line terminal at the existing Syracuse substation, owned by SUNC. A preliminary one-line drawing of the interconnection facilities are shown in Figure 1. The Customer did not propose a specific route of its 115 kV line to serve its 115/34.5 kV collection system facilities. It is assumed that obtaining all necessary right-of-way for construction of the Customer 115 kV transmission line and the 115/34.5 kV collector substation will not be a significant expense.

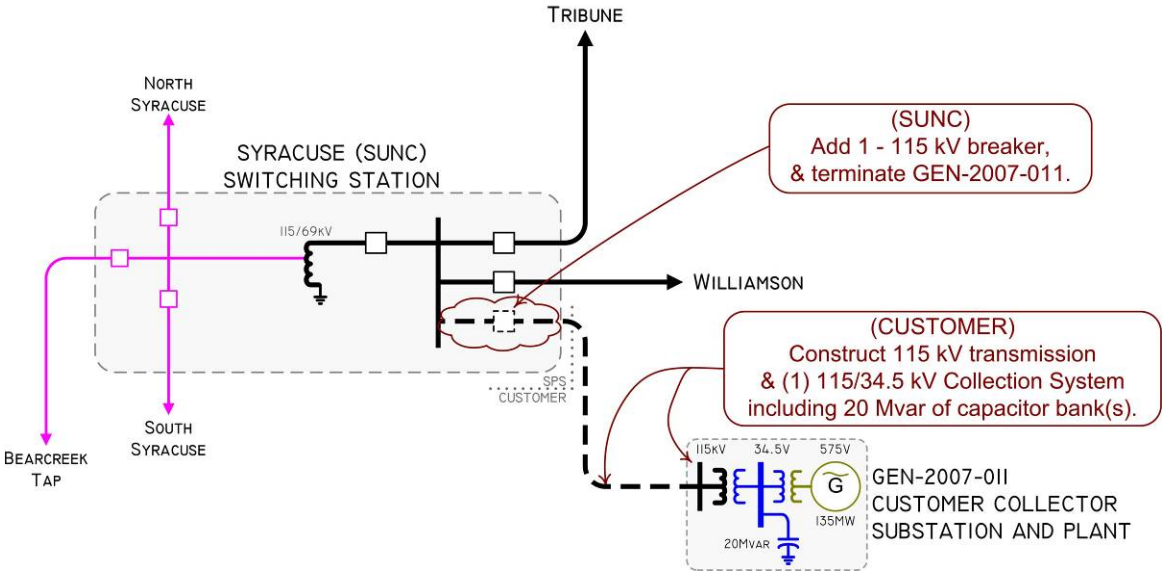

Figure 1: Proposed Method of Interconnection

(Final design to be determined)

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 Syracuse switching station.	*
CUSTOMER – Right-of-Way for all Customer facilities.	*
SUNC – (1) 115 kV breaker and terminal for GEN-2007-011 at Syracuse substation.	$625,000
TOTAL	*

** Estimates of cost to be determined.*

IMPACT STUDY FOR SPP GENERATION QUEUE POSITION GEN-2007-011

SOUTHWEST POWER POOL (SPP)
May 12, 2008

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-2007-011 as part of the System Impact Study. The Interconnection Queue Position GEN-2007-011 is a wind farm of 135 MW capacity proposed to be connected through a ten (10) mile 115kV line to Syracuse substation owned by Sunflower Electric Power Corp (SUNC).

Transient Stability studies were conducted with the full output of 135 MW (100%). The wind farm was considered to contain Acciona 1.5 MW turbines.

A modified 2012 summer load flow case and 2008 winter load flow case together with the SPP MDWG 2006 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.

Transient Stability studies were conducted with the GEN-2007-011 output at 135 MW (100%) for two scenarios, i.e., (i) summer peak load and (ii) winter peak load. Twenty six (26) contingencies were considered for each of the scenarios.

GEN-2007-011 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-2007-011 for the contingencies analyzed in both the scenarios.

If any of the 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-2007-011.

The Interconnection Queue Position GEN-2007-011 is a wind farm of 135 MW capacity proposed to be connected to Syracuse substation owned by Sunflower Electric Power Corp (SUNC). The wind farm would be interconnected to the 115kV bus at the Syracuse substation through a ten (10) mile 115kV transmission line. The system one line diagram of the area near the Queue Position GEN-2007-011 is shown below.

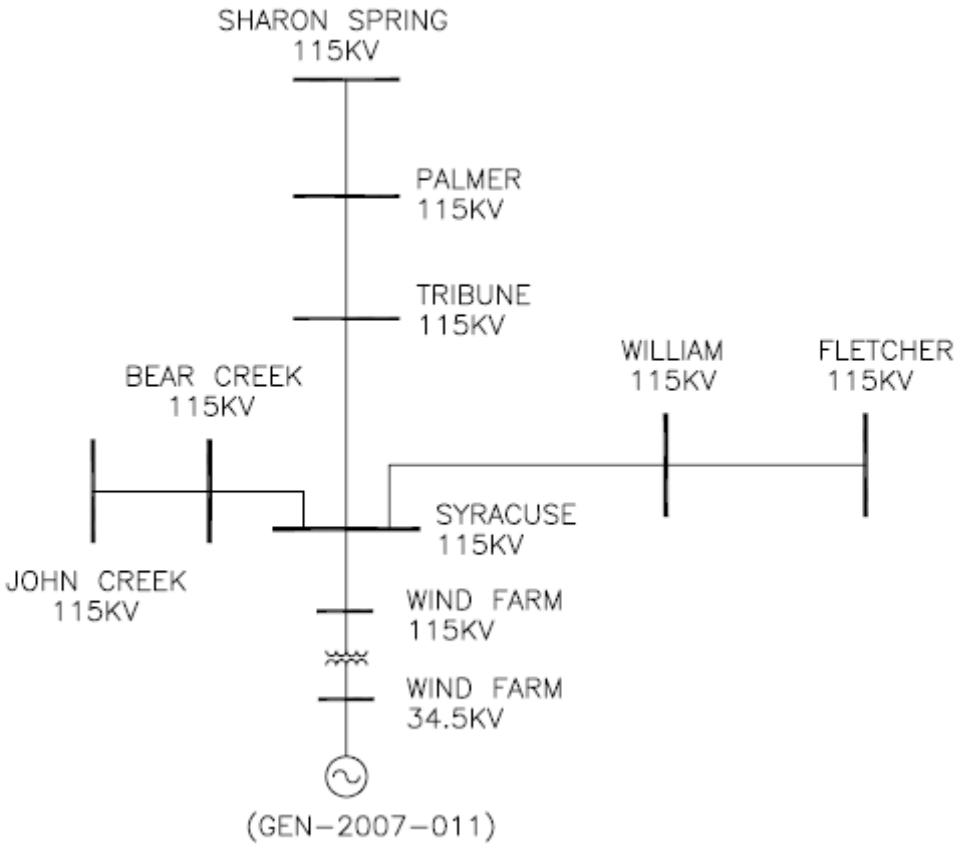

Figure 1: System One Line Diagram near GEN-2007-011

Transient Stability studies were conducted with the full output of 135 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 peak load flow and 2008 winter peak load flow cases together with the SPP MDWG 2006 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-2007-011 output at 135 MW for (i) 2012 summer peak and (ii) 2008 winter peak 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 Syracuse- Tribune 115 kV line, near Syracuse, with one shot reclosing after 20 cycles.
FLT21PH	Single phase fault on Syracuse- Tribune 115 kV line, near Syracuse, with one shot reclosing after 20 cycles.
FLT33PH	Three phase fault on Syracuse- Williams 115 kV line, near Syracuse, with one shot reclosing after 20 cycles.
FLT41PH	Single phase fault on Syracuse- Williams 115 kV line, near Syracuse, with one shot reclosing after 20 cycles.
FLT53PH	Three phase fault on Syracuse- Bear Creek 115 kV line, near Syracuse, with one shot reclosing after 20 cycles.
FLT61PH	Single phase fault on Syracuse- Bear Creek 115 kV line, near Syracuse, with one shot reclosing after 20 cycles.

FLT73PH	Three phase fault on the G06-34 Sub 115 kV line, near Sharon Springs, with one shot reclosing after 20 cycles.
FLT81PH	Single phase fault on the G06-34 Sub 115 kV line, near Sharon Springs, with one shot reclosing after 20 cycles.
FLT93PH	Three phase fault on the Tribune Switch to Selkirk 115 kV line, near Tribune Switch, with one shot reclosing after 20 cycles.
FLT101PH	Single phase fault on the Tribune Switch to Selkirk 115 kV line, near Tribune Switch, with one shot reclosing after 20 cycles.
FLT113PH	Three phase fault on Setab to City Service 115 kV line, near Setab, with one shot reclosing after 20 cycles.
FLT121PH	Single phase fault on Setab to City Service 115 kV line, near Setab, with one shot reclosing after 20 cycles.
FLT133PH	Three phase fault on the Williams - Fletcher 115 kV line, near Fletcher, with one shot reclosing after 20 cycles.
FLT141PH	Single phase fault on the Williams - Fletcher 115 kV line, near Fletcher, with one shot reclosing after 20 cycles.
FLT153PH	Three phase fault on the 345kV side of Setab Autotransformer.
FLT161PH	Single phase fault on the 345kV side of Setab Autotransformer.
FLT173PH	Three phase fault on the 345kV side of Mingo Autotransformer.
FLT181PH	Single phase fault on the 345kV side of Mingo Autotransformer.
FLT193PH	Three phase fault on the Mingo - Setab 345 kV line, near Setab, with no reclose.
FLT201PH	Single phase fault on the Mingo - Setab 345 kV line, near Setab, with no reclose.
FLT213PH	Three phase fault on the Atwood Switch - Hemdon 115 kV line, near Atwood Switch, with one shot reclosing after 20 cycles.
FLT221PH	Single phase fault on the Atwood Switch - Hemdon 115 kV line, near Atwood Switch, with one shot reclosing after 20 cycles.
FLT233PH	Three phase fault on the Setab – Scot City 115 kV line, near Scot City, with one shot reclosing after 20 cycles.
FLT241PH	Single phase fault on the Setab – Scot City 115 kV line, near Scot City, with one shot reclosing after 20 cycles.
FLT253PH	Three phase fault on the 115kV side of Pioneer Autotransformer.

FLT261PH	Single phase fault on the 115kV side of Pioneer Autotransformer.

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 20 cycles.

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-2007-011 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
MainWest	25
MainEast	21
Cable 1	6
Cable 2	11
Cable 3	6
Cable 4	21

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)
500kcmil	0.028	0.039
1000 kcmil	0.016	0.036

Table 3: Cable impedance per 1000 feet

The PSS/E model for Acciona wind turbines was provided by the customer. Subsequent model revisions were also provided.

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

Conductor Size	Resistance (p.u)	Reactance (p.u)	Charging (p.u)
1033 MCM	0.0068	0.0588	0.0076

Table 4: 115kV transmission line impedance in per unit

The base case power flow diagram for the project GEN-2007-011 is shown in Figure 2.

The prior queued projects GEN-2001-039M, GEN-2006-034, GEN-2006-040, GEN-2006-032, and GEN-2003-013 were also included in the study model.

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 5.
3. The other generators in the SPP control area were scaled down to accommodate the new generation as indicated in Table 6.
4. Accionia generators were considered to be operating in voltage control mode.

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 5: Standard protective functions and settings for Acciona 1.5 MW Turbines

Scenario	Generation within SPP	
	Summer	Winter
Without the Wind Farms	41536	28802
GEN-2007-013 at 100% output with the prior queued projects	41671	28937

Table 6: Generation in SPP Area

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 that the Accionia machines were tripped on over voltage caused by the voltage spikes during switching. It was established that these spikes were due to modeling inaccuracies and hence the over voltage protections were disabled in the subsequent simulations.

Other difficulties with the model were encountered with the voltage recovery ability of the Acciona machines. The Customer and manufacturer provided subsequent updates of the user model that showed the machine responded acceptably.

Table 7 provides the summary of the stability studies for GEN-2007-011.

GEN-2007-011 generators were found to stay connected to the grid for all the contingencies that were studied.

Fault Number	Summer Peak Load Case	Winter Peak Load Case
FLT13PH	- -	- -
FLT21PH	- -	- -
FLT33PH	- -	- -
FLT41PH	- -	- -
FLT53PH	- -	- -
FLT61PH	- -	- -
FLT73PH	- -	- -
FLT81PH	- -	- -
FLT93PH	- -	- -
FLT101PH	- -	- -
FLT113PH	- -	- -
FLT121PH	- -	- -
FLT133PH	- -	- -
FLT141PH	- -	- -
FLT153PH	- -	- -

FLT161PH	- -	- -
FLT173PH	- -	- -
FLT181PH	- -	- -
FLT193PH	- -	- -
FLT201PH	- -	- -
FLT213PH	- -	- -
FLT221PH	- -	- -
FLT233PH	- -	- -
FLT241PH	- -	- -
FLT253PH	- -	- -
FLT261PH	- -	- -

UV : GEN-2007-011 Tripped due to low voltage
OV : GEN-2007-011 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 7: Stability Study Results Summary

The system responses corresponding to FLT13PH for Winter Case are shown in Figure 3.

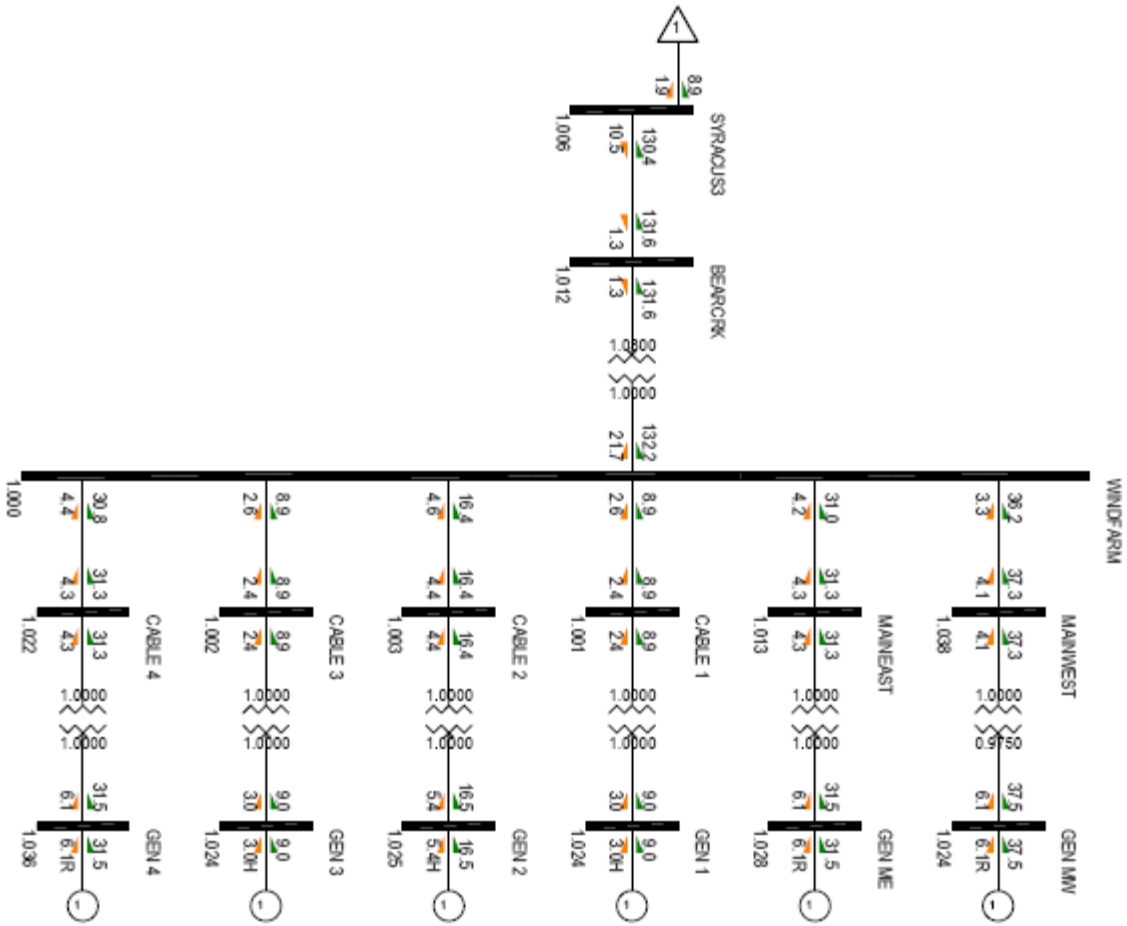

Figure 2: 100% Power Flow Base Case for GEN-2007-011

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position GEN-2007-011 consisting of Acciona 1.5 MW wind turbines, for an aggregate output of 135 MW. The study was conducted for two different power flow scenarios, i.e., one for summer peak and one for winter peak load cases.

The study has not indicated any angular or voltage instability problem due to the addition of GEN-2007-011 for the contingencies that were analyzed.

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.

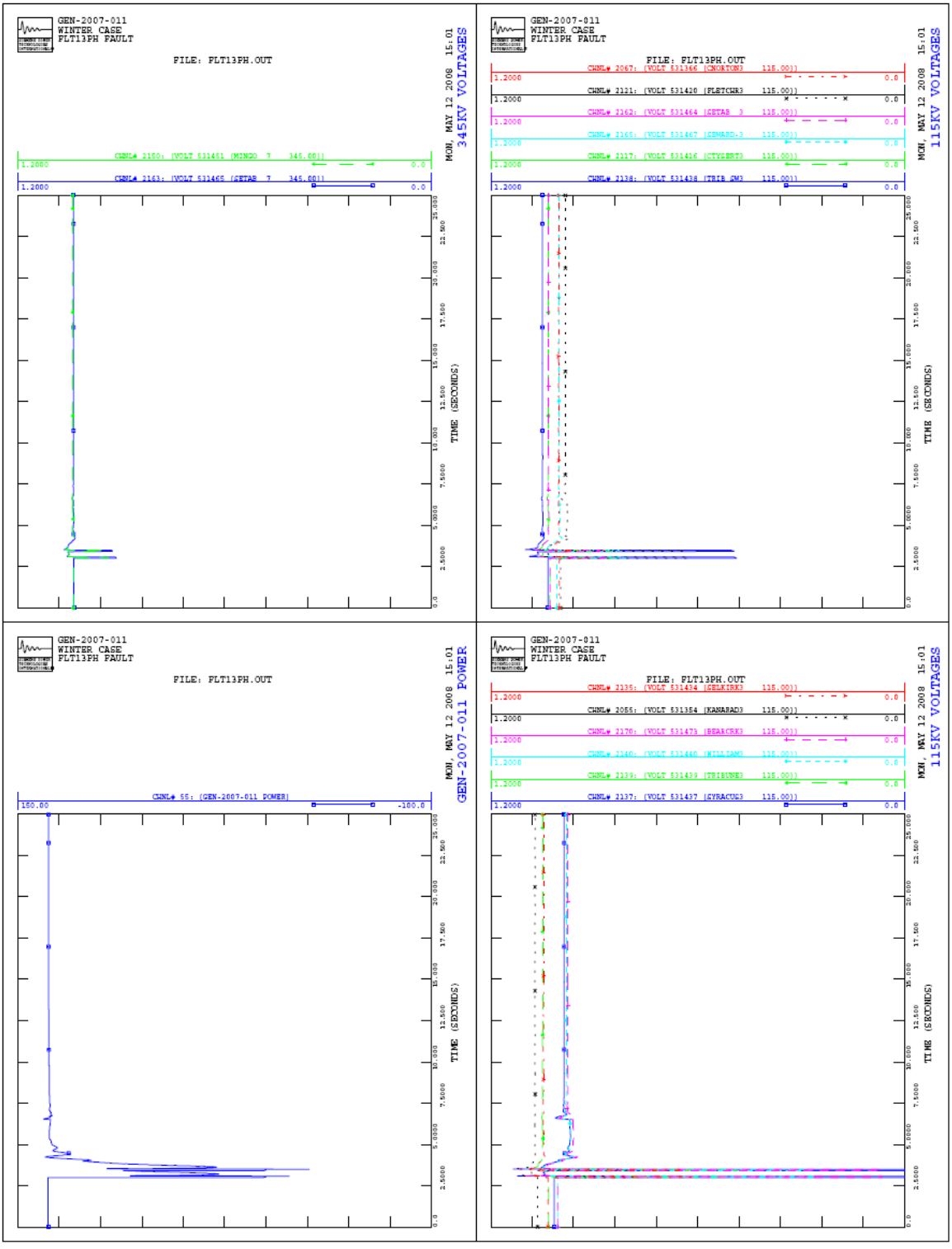

Figure 3: System Responses with 100% output of GEN-2007-011 for FLT13PH

Figure 3: System Responses with 100% output of GEN-2007-011 for FLT13PH (Cont'd)

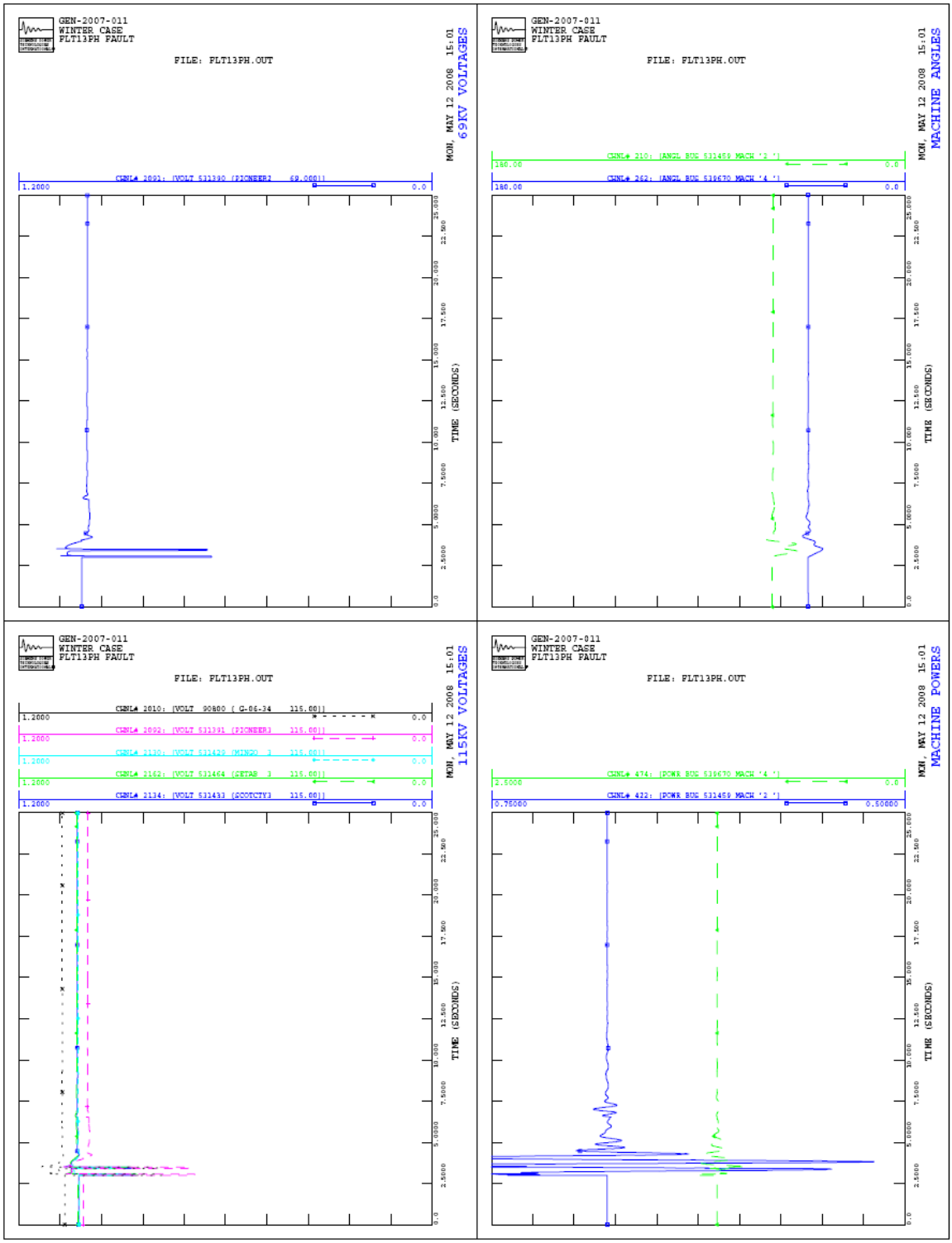

Figure 3: System Responses with 100% output of GEN-2007-011 for FLT13PH (Cont'd)