Impact Study For Generation Interconnection Request GEN-2007-001

SPP Tariff Studies

(#GEN-2007-001)

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-2007-001.

Interconnection Facilities

The Impact Study has conducted using the data provided for by the Customer. The Customer's transmittal indicated that a 230kV, 30 Mvar capacitor bank will be installed in the Customer's substation. This bank shall be switched in stages of industry accepted sizes as to prevent excessive voltage rise on the 230kV bus at the Seven Rivers substation.

The Impact Study has determined that if the Customer uses the studied General Electric 1.5MW wind turbines with the LVRT II low voltage ride through package, 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 General Electric turbines are used with the manufacturer's LVRT II low voltage ride through package.

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) 230/34.5 kV Customer collector substation facilities.	*
Customer – (1) 230 kV transmission line from Customer collector substation to the Seven Rivers Interchange.	*
Customer – 230 kV, 30 Mvar capacitor bank(s) to be installed in the Customer 230/34.5 kV collector substation.	*
Customer – Right-of-Way for all Customer facilities.	*
TOTAL	*****

** Estimates of cost to be determined.*

TABLE 2: Required Interconnection Network Upgrade Facilities

FACILITY	ESTIMATED COST (2007 DOLLARS)
SPS – Reconfigure 230 kV facilities for breaker-and-a-half and add (1) 230 kV line terminal to the Seven Rivers Interchange.	$1,644,138
TOTAL	**$1,644,138**

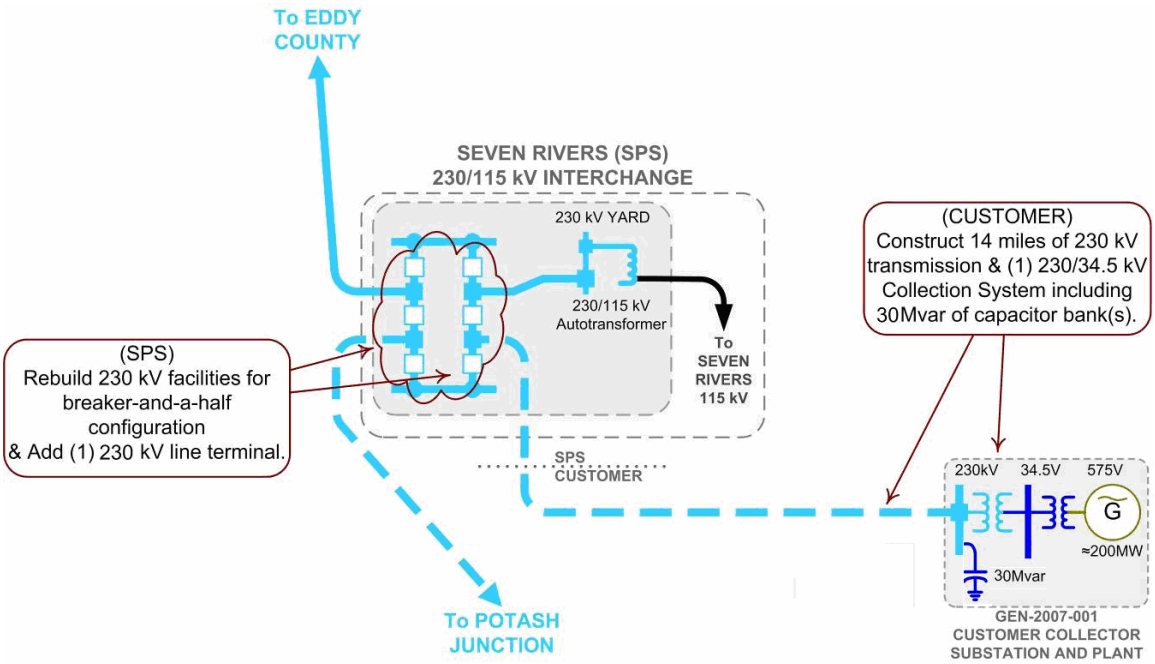

FIGURE 1: Proposed Method of Interconnection
(Final design to be determined)

Point of Interconnection Area Map

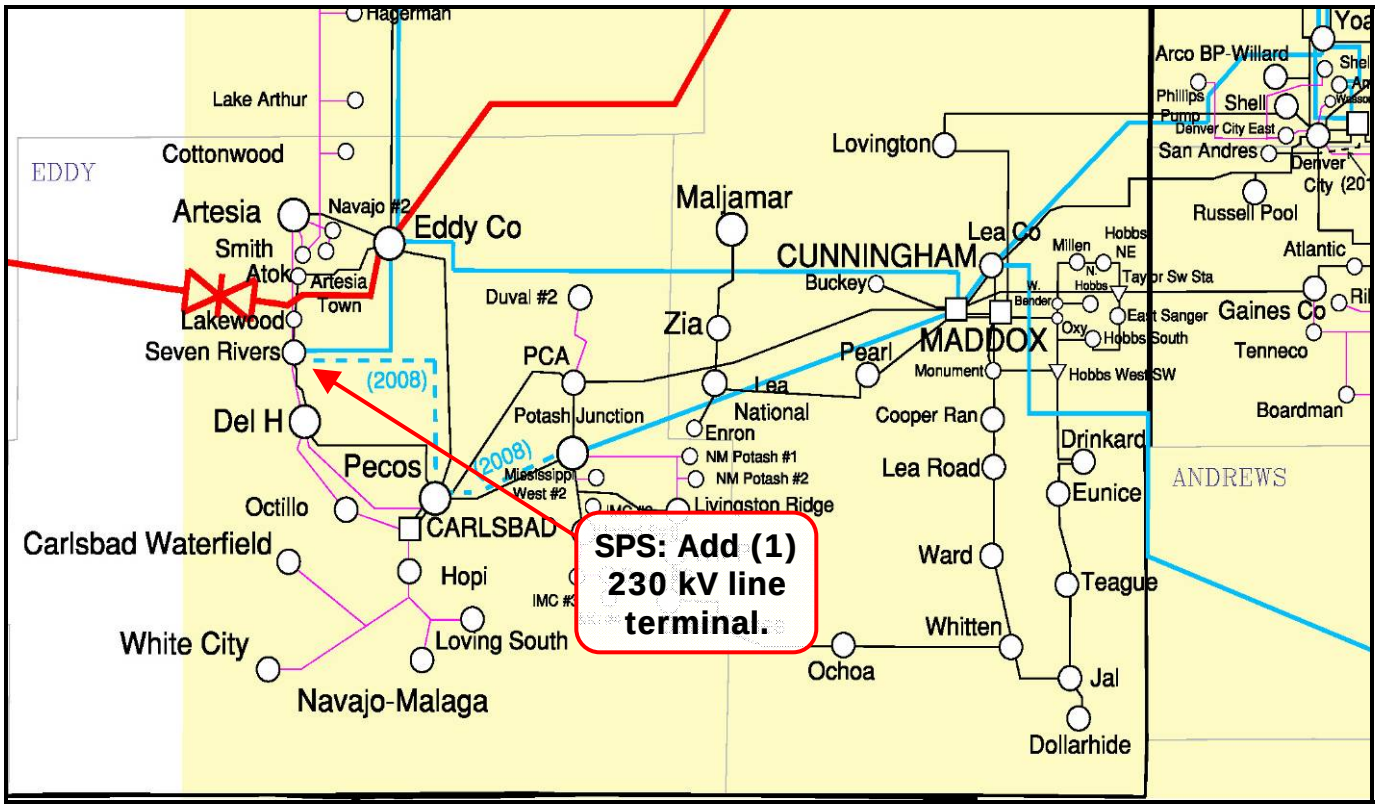

FIGURE 2. Point of Interconnection

IMPACT STUDY FOR SPP GENERATION QUEUE POSITION GEN-2007-001

SOUTHWEST POWER POOL (SPP)
November 30, 2007

By

BLACK & VEATCH

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EXECUTIVE SUMMARY

A transient stability study has been performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2007-001 as part of the System Impact Study. The Interconnection Queue Position GEN-2007-001 is a wind farm of 200 MW capacity proposed to be connected to existing Seven Rivers 230/115/69kV substation owned by Southwestern Public Service. The wind farm would be interconnected to the 230 kV bus.

Transient Stability studies were conducted with the full output of 200 MW (100%). The wind farm was considered to contain G.E -1.5 MW turbines.

Transient Stability studies were conducted with the full output of 200 MW (100%) for Summer Case and for Winter Case. The wind farm was considered to contain GE -1.5 MW turbines with the low voltage ride through package in the study.

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 GE wind turbine models available within the PSS/E program.

Transient Stability studies were conducted with the GEN-2007-001 output at 200 MW (100%) for summer load scenario and for winter load scenario. Twenty (20) contingencies were considered for each of the scenarios.

GEN-2007-001 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-2007-001 for the contingencies analyzed in both the scenarios.

The study was conducted assuming the Customer will install a 230kV, 30 Mvar capacitor bank as provided for in the Customer transmittal.

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-2007-001.

The Interconnection Queue Position GEN-2007-001 is a wind farm of 200 MW capacity proposed to be connected to Seven Rivers substation, owned by Southwestern Public Service. The wind farm would be interconnected to the 230kV bus. The system one line diagram of the area near the Queue Position GEN-2007-001 is shown below.

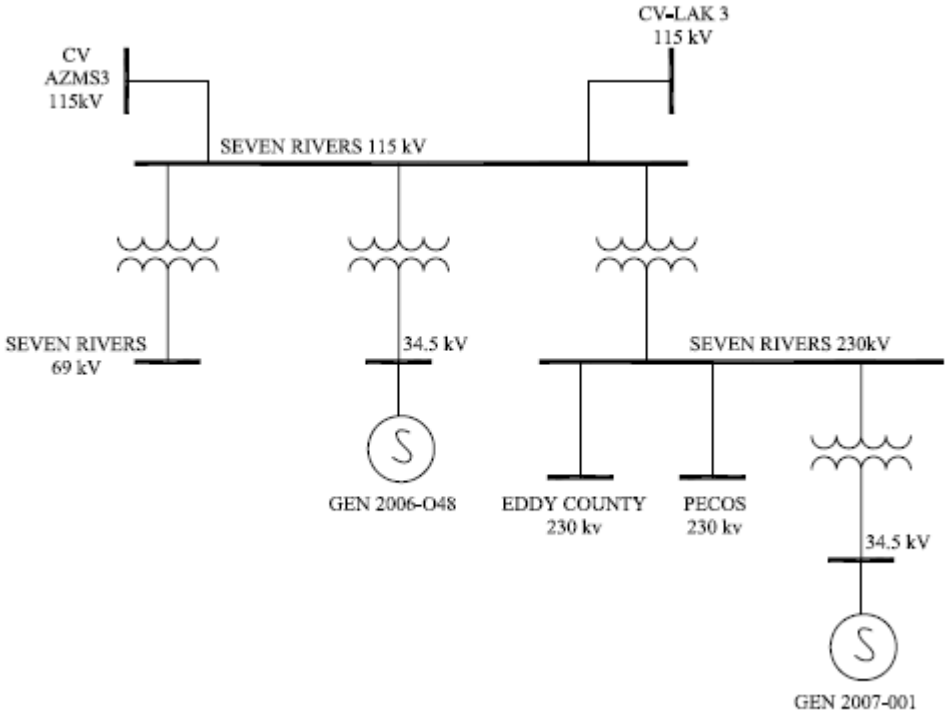

Figure 1: System One Line Diagram near GEN-2007-001

Transient Stability studies were conducted with the GEN-2007-001 output at 200 MW (100%) for summer load scenario and for winter load scenario.

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-2007-001 output at 200 MW (100%) for summer load scenario and for winter load scenario.

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 230kV bus.
FLT21PH	Single phase fault on the on the Seven Rivers 230/115kV autotransformer on the 230kV 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 GE Wind turbine with low voltage ride through (LVRT) option for the System Impact Study. The GE turbines are a three phase double fed induction generator. The following are the main electrical parameters of the GE 1.5 MW wind turbine.

Rated Power : 1.5 MW
Apparent Power : 1,670 kVA
Maximum Reactive Power Output : 490 kVAR
Maximum Reactive Power Consumption : 730 kVAR

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-2007-001 modeled.

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

Collector Bus	No. of generators aggregated
BP34 1	22
BP34 2	22
BP34 3	23
BP34 4	22
BP34 5	22
BP34 6	22

Table 2: Equivalent Generators with G.E -1.5 MW Turbines

The Customer provided the wind turbine feeder conductor types, lengths and impedance values. Line charging is negligible for the length of cables considered in the study and so was not included. 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)
4/0	0.107	0.049
1000 kcmil	0.028	0.037

Table 3: Cable impedance per 1000 feet

The Customer provided the following substation transformer's impedance:

Transformer Impedance: 10 % at 140 MVA

The Customer also provided the following shunt capacitor data:

Shunt Capacitor: 30 MVAR at 230kV.

The wind farm was modeled using the GE wind turbine model available in PSS/E. The effects of rotor current control and the turbine pitch control were also modeled. The generator data used in the study is as noted in Table 4.

The base case power flow diagram for the project GEN-2007-001 is shown in Figure 2.

Description	Value
Stator resistance, Ra	0.00706 pu
Stator inductance, La	0.1714 pu
Mutual inductance, Lm	2.904 pu
Rotor resistance	0.005 pu
Rotor inductance	0.1563 pu
Drive train inertia	0.64 sec
Shaft damping	0.73 pu
Shaft stiffness	0.6286 pu
Generator rotor inertia	0.57 sec
Number of generator pole pairs	3
Gear box ratio	72.0

Table 4: GE 1.5 MW Wind Turbine Generator Parameters

The prior queued projects Gen-2006-026 (502 MW), GEN-2004-015 (160MW), GEN-2006-015 (160MW), GEN-2001-033 (180MW) and GEN-2006-048 (150MW) were also included in the study model.

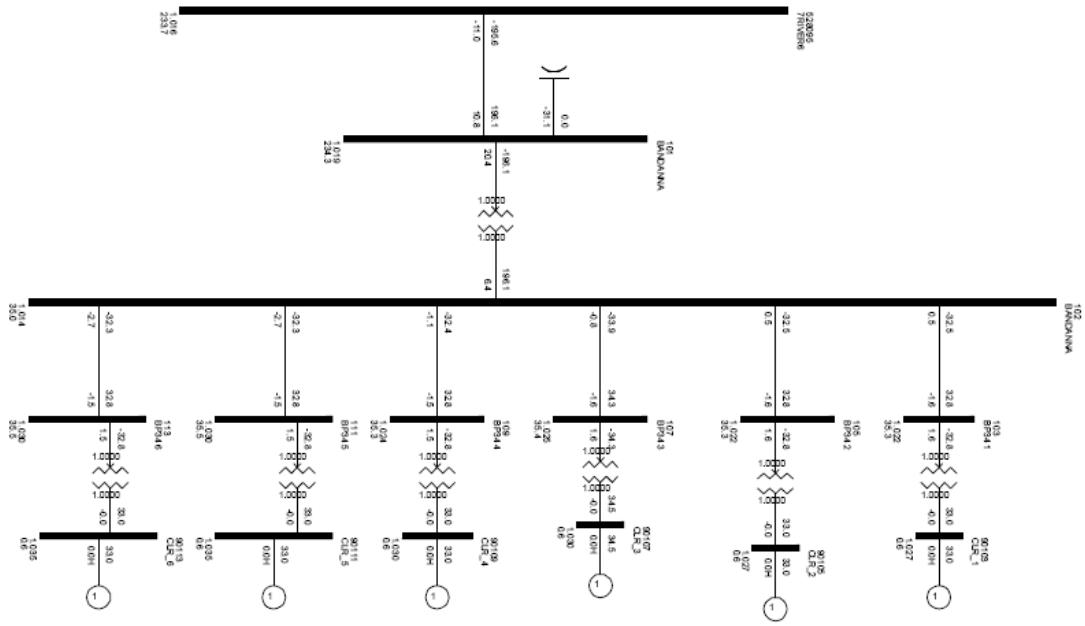

Figure 2: 100% Power Flow Base Case for GEN-2006-033

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. The turbine control models available within PSS/E such as CGECN2, TWIND1 and TGPTCH were used with their default values.
3. From the wind turbine data sheets the protection settings were used as and are shown in Table 5.
4. The other generators in the SPP control area were scaled down to accommodate the new generation as indicated in Table 6.

Protective Function	**Protection Setting**	**Time Delay**
Over Frequency	61.5 Hz	30 seconds
Over Frequency	62.5 Hz	0.02 seconds
Under Frequency	56.5 Hz	0.02 seconds
Under Frequency	57.5 Hz	10.0 seconds
Under Voltage	15%	0.625 seconds
Under Voltage	70%	0.625 seconds
Under Voltage	75%	1.0 second
Under Voltage	85%	10.0 seconds
Over Voltage	110%	1.0 second

Over Voltage	115%	0.1 seconds
Over Voltage	130%	0.02 seconds

Table 5: Protective Functions and Settings for LVRT GE 1.5 MW Turbines

Scenario	Generation within SPP	
	Summer	Winter
Without the Wind Farms	40639	28245
GEN-2007-001 at 100% output with the prior queued projects	40789	28445

Table 6: 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.

Table 7 provides the summary of the stability studies for GEN-2007-001.

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

UV : GEN-2007-001 Tripped due to low voltage
OV : Tripped due to high voltage
UF : Tripped due to low frequency
OF : Tripped due to high frequency
S : Stability issues encountered
- - : Wind Farm did not trip

Table 7: Stability Study Results Summary

GEN-2007-001 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-2007-001 for the contingencies analyzed in both the scenarios.

Figure 3 show the winter peak response for FLT3_3PH.

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position GEN-2007-001 consisting of GE 1.5 MW wind turbines with its output at 200 MW. The study was conducted for two different power flow scenarios, i.e., one for summer peak and one for winter peak.

The study was conducted assuming the Customer will install a 230kV, 30 Mvar capacitor bank as provided for in the Customer transmittal.

The study has not indicated any angular or voltage instability problem due to addition of GEN-2007-001 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 3 : System Responses with 100% output of GEN-2007-001 for FLT3-3PH

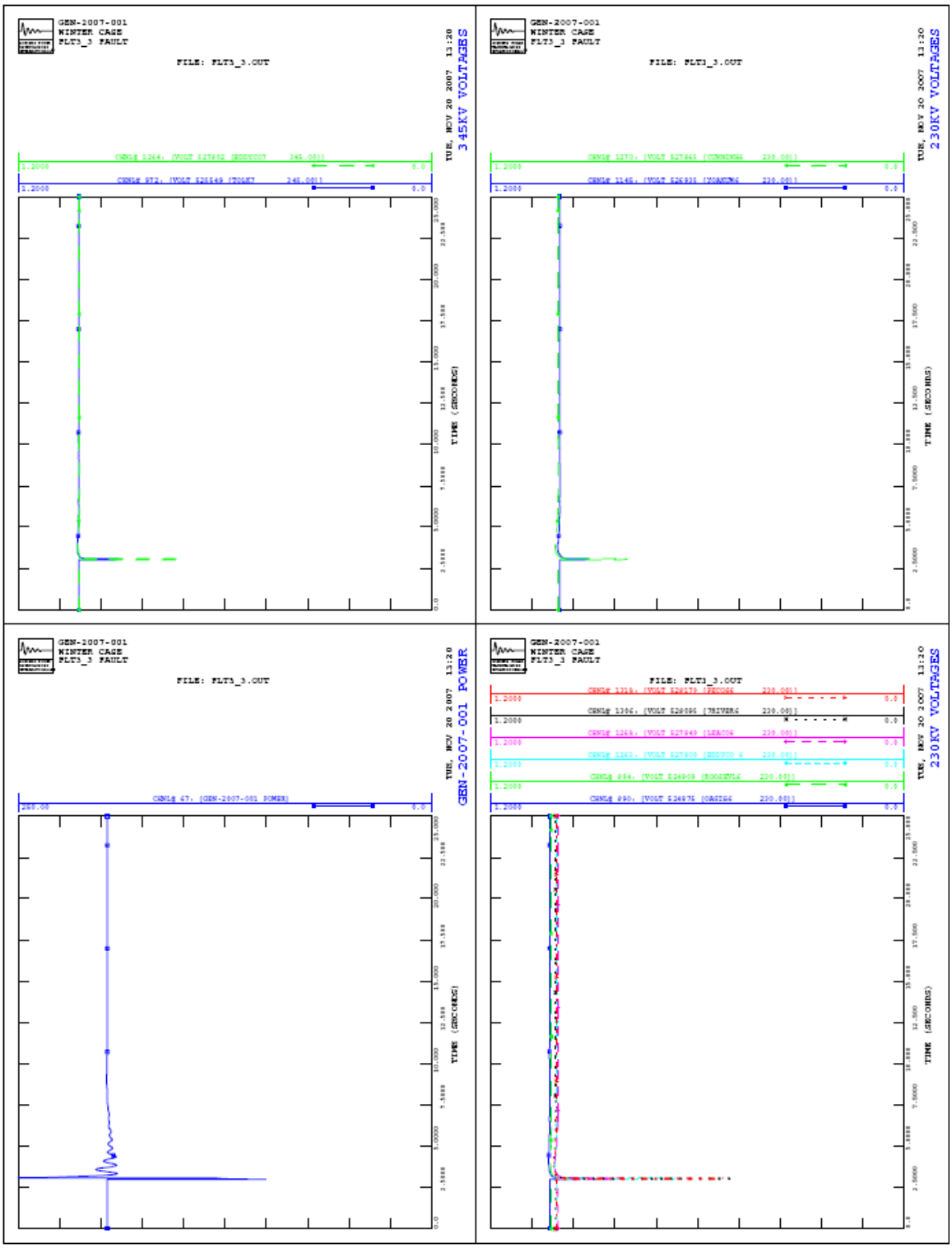

Figure 3 : System Responses with 100% output of GEN-2007-001 for FLT3-3PH (Cont'd)

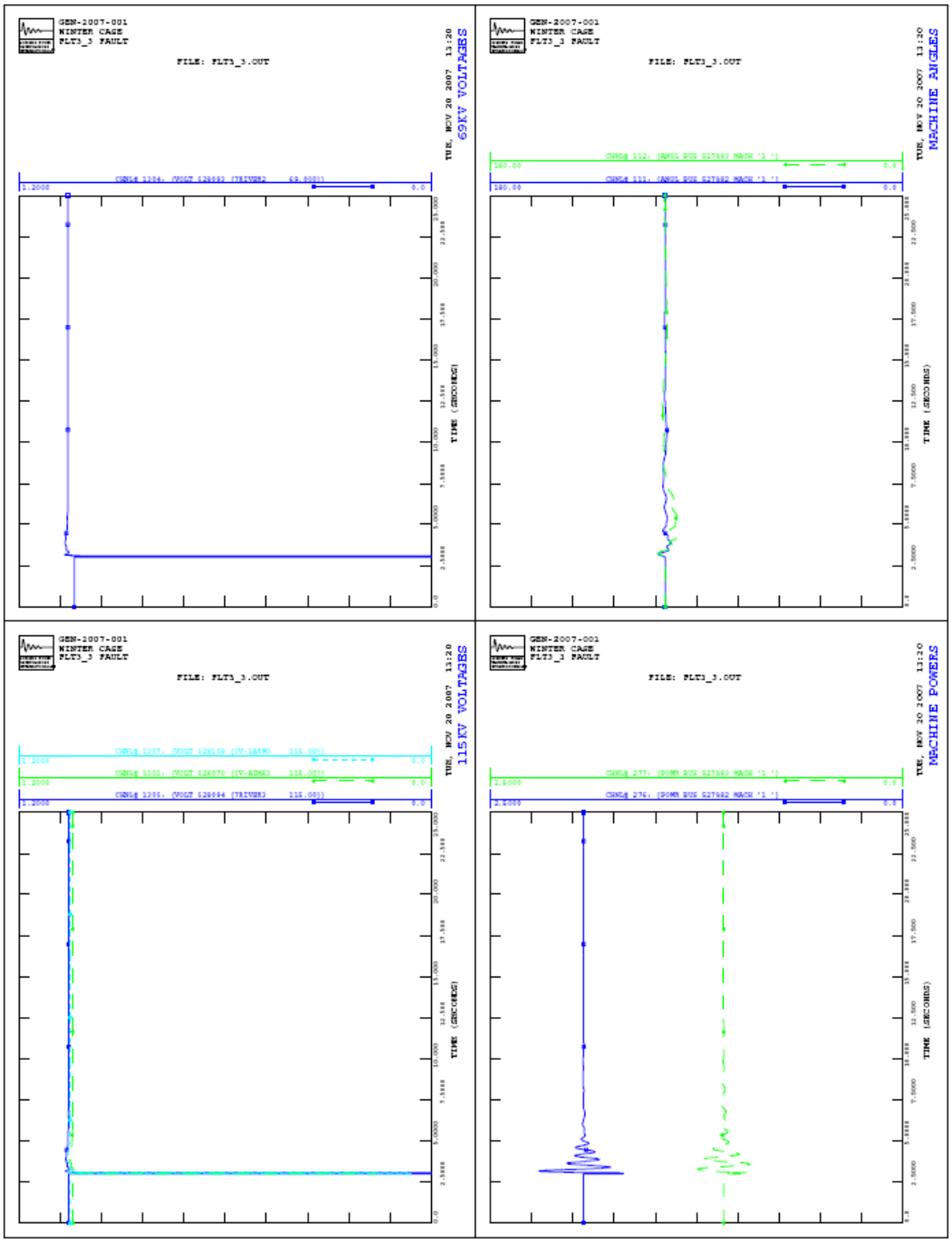

Figure 3 : System Responses with 100% output of GEN-2007-001 for FLT3-3PH (Cont'd)