Southwest Power Pool

Impact Study For Generation Interconnection Request GEN-2006-033

SPP Tariff Studies

(#GEN-2006-033)

June, 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-2006-033.

Interconnection Facilities

The Impact Study determined that by using the Customer requested General Electric 1.5 MW wind turbine generators with the manufacturer's LVRT II package that no SVC or STATCOM device is necessary for the wind facility to meet FERC Order #661A provisions for low voltage ride-through (LVRT). See the study for details of the LVRT II package. The Impact Study determined that the Customer will be required to install a minimum of 20Mvars of 34.5kV capacitor bank(s) in the Customer's 115/ 34.5kV substation on the 34.5kV bus for reactive compensation of the wind farm and associated step up transformers. No other facilities were determined to be necessary by this Impact Study. The estimated Interconnection Facility and Network Upgrade Costs were given in the Feasibility Study. These costs are re-stated below in Table 1 and Table 2. These costs do not include the results of short circuit analysis. Detailed facility costs and a short circuit analysis will be conducted by the Transmission Owner during a Facility Study, if the Customer wishes to execute a Facility Study Agreement for this generation interconnection request.

Table 1: Direct Assignment Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
Customer – 115-34.5 kV Substation facilities.	*
Customer – 115kV transmission line facilities between Customer facilities and McDowell Creek Switching Station.	*
Customer - Right-of-Way for Customer facilities.	*
Customer – 34.5kV, 20Mvar capacitor bank(s) in Customer substation.	*
WESTAR – Add one 115kV terminal including one 115kV circuit breakers, associated switches, buswork, relaying and all miscellaneous equipment at McDowell Creek Switching Station.	$300,000
Total	*

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

Table 2: Required Interconnection Network Upgrade Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
None identified at this time.	*
Total	*

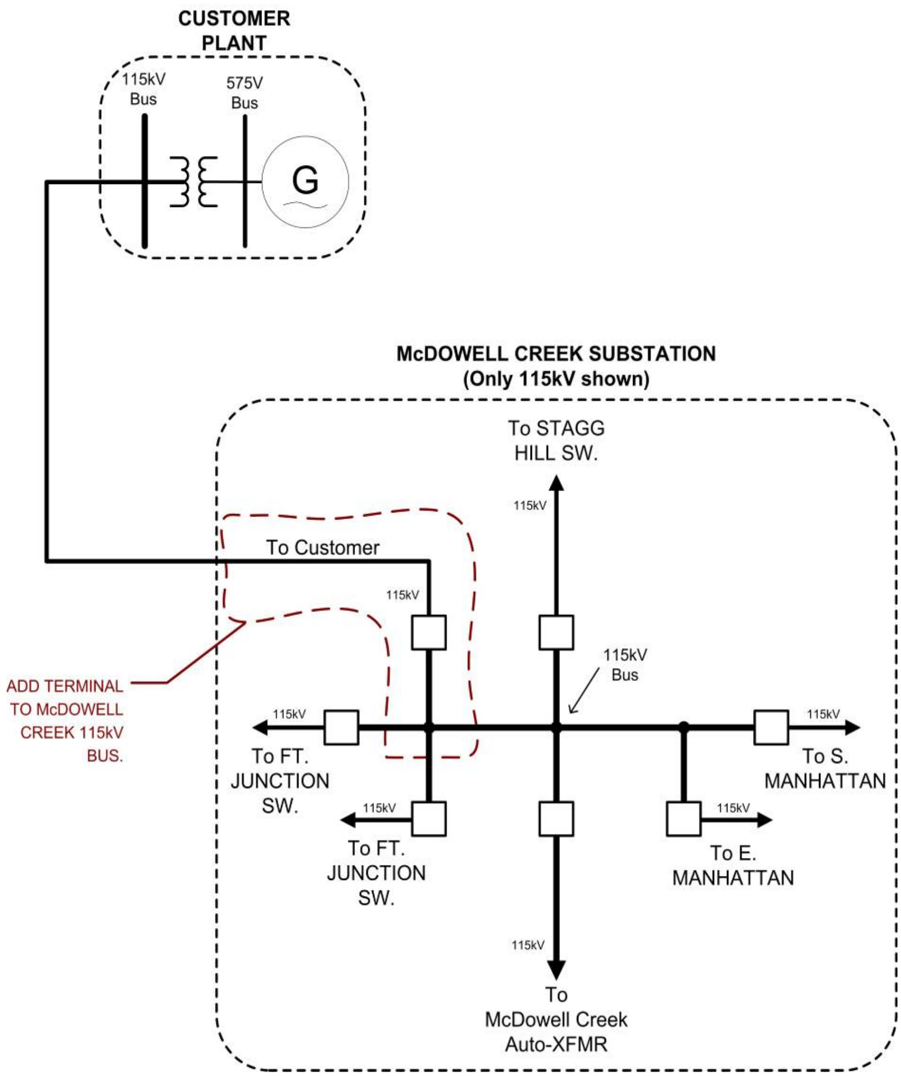

Figure 1: Proposed Interconnection
(Final substation design to be determined

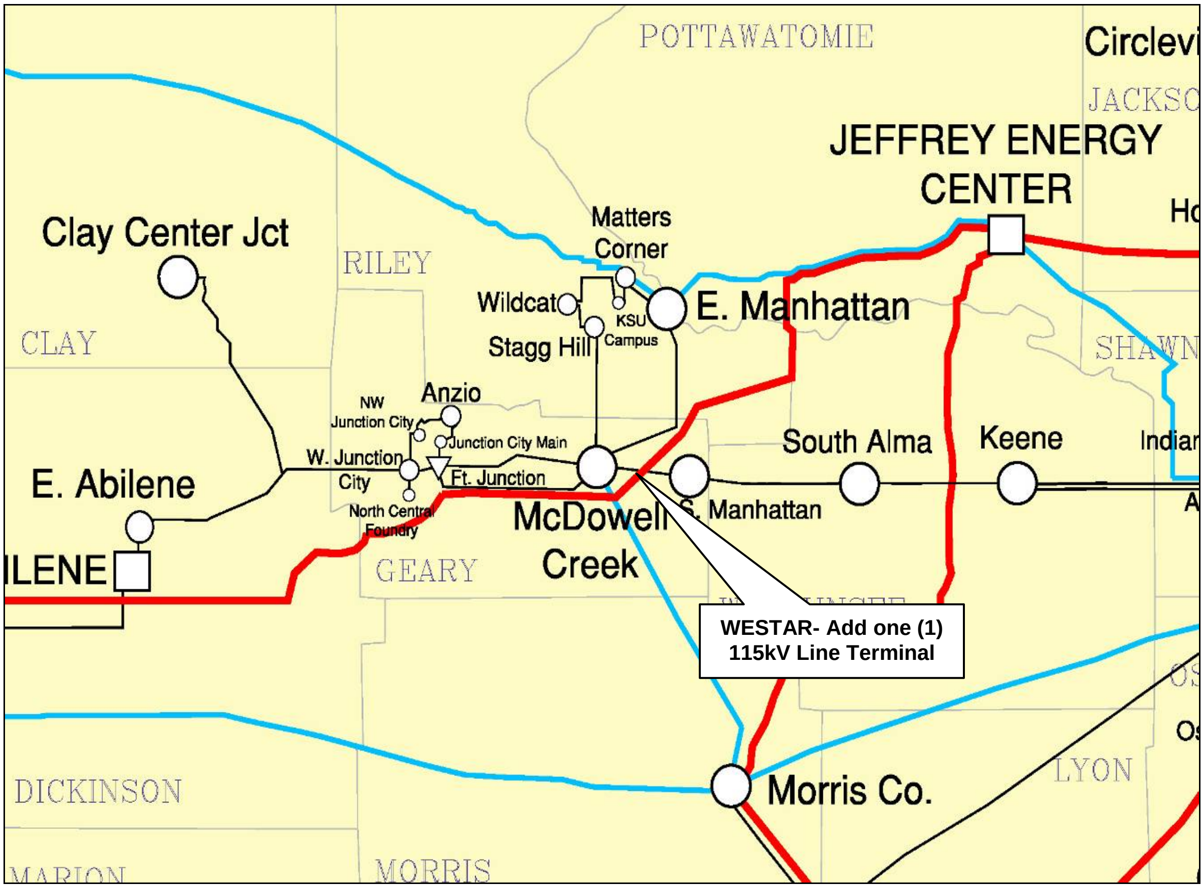

FIGURE 2. MAP OF THE LOCAL AREA

IMPACT STUDY FOR SPP GENERATION QUEUE POSITION GEN-2006-033

SOUTHWEST POWER POOL (SPP)
June 20, 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-2006-033 as part of the System Impact Study. The Interconnection Queue Position GEN-2006-033 is a wind farm of 150 MW capacity proposed to be connected to McDowell Creek Substation which is owned by Westar. 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 GE -1.5 MW turbines with the low voltage ride through package in the study.

The 2011 summer load flow case and 2007 winter load flow case together with the SPP MDWG 2005 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.

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 20 MVAR capacitors would be needed in the summer peak load case.

Transient Stability studies were conducted with the GEN-2006-033 output at 150 MW (100%) for two scenarios, i.e., (i) summer load and (ii) winter load. Twenty Four (24) contingencies were considered for each of the scenarios.

GEN-2006-033 generators were found to stay connected to the grid for all the contingencies that were studied.

System stability issues were found for a fault near JEC in the winter case. This issue was found to be present even prior to the addition of Gen-2006-033. The study has not indicated any angular or voltage instability problem due to addition of GEN-2006-033 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 SPP transmission facilities.

1. INTRODUCTION

This report discusses the results of a transient stability study performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2006-033.

The Interconnection Queue Position GEN-2006-033 is a wind farm of 150 MW capacity proposed to be connected to McDowell Creek substation, owned by Westar in Geary County, Kansas. The wind farm would be interconnected to the 115kV bus. The system one line diagram of the area near the Queue Position GEN-2006-033 is shown below.

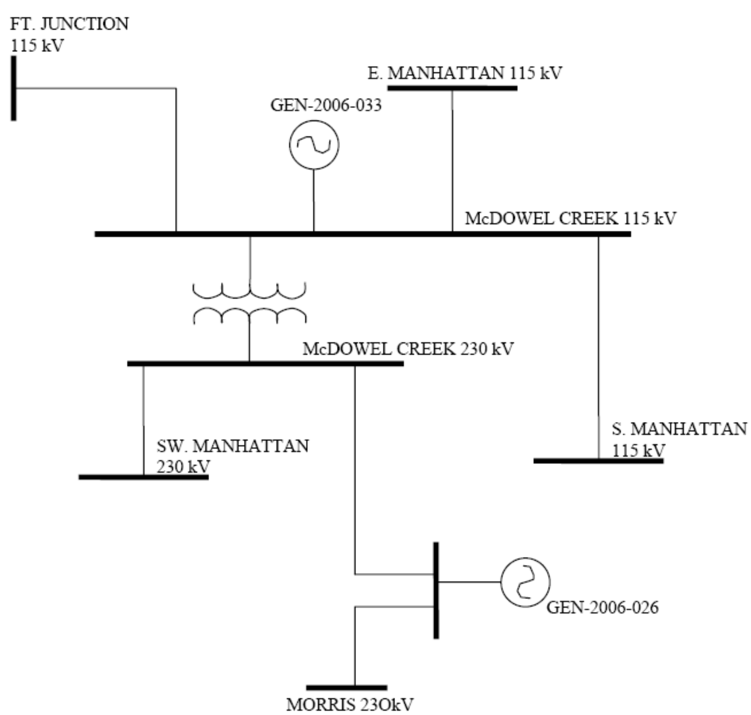

Figure 1: System One Line Diagram near GEN-2006-033

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

2. STABILITY STUDY CRITERIA

The 2011 summer load flow and 2007 winter load flow cases together with the SPP MDWG 2005 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-2006-033 output at 150 MW for (i) 2011 summer and (ii) 2007 winter load flow cases.

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

Fault Number	Fault Definition
FLT13PH	Three phase fault on the McDowell to GEN-2002-021 Wind Farm 230 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT21PH	Single phase fault on the McDowell to GEN-2002-021 Wind Farm 230 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT33PH	Three phase fault on the McDowell to Fort Junction 115 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT41PH	Single phase fault on the McDowell to Fort

	Junction 115 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT53PH	Three phase fault on the McDowell to E Manhattan 115 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT61PH	Single phase fault on the McDowell to E Manhattan 115 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT73PH	Three phase fault on the McDowell to S Manhattan 115 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT81PH	Single phase fault on the McDowell to S Manhattan 115 kV line, near McDowell, with one shot reclosing after 20 cycles.
FLT93PH	Three phase fault on the East Manhattan to Jefferey 230 kV line, near Jefferey, with one shot reclosing after 20 cycles.
FLT101PH	Single phase fault on the East Manhattan to Jefferey 230 kV line, near Jefferey, with one shot reclosing after 20 cycles.
FLT113PH	Three phase fault on the Manhattan to Concordia 230 kV line, near Manhattan, with one shot reclosing after 20 cycles.
FLT121PH	Single phase fault on the Manhattan to Concordia 230 kV line, near Manhattan, with one shot reclosing after 20 cycles.
FLT133PH	Three phase fault on the Jefferies Energy Center - Summit 345 kV line, near Summit, with one shot reclosing after 30 cycles.
FLT141PH	Single phase fault on the Jefferies Energy Center - Summit 345 kV line, near Summit, with one shot reclosing after 30 cycles
FLT153PH	Three phase fault on the Morris to Summit 230 kV line, near Summit, with one shot reclosing after 20 cycles.
FLT161PH	Single phase fault on the Morris to Summit 230 kV line, near Summit, with one shot reclosing after 20 cycles.
FLT173PH	Three phase fault on the McDowell 230/115kV autotransformer on the 115kV bus.
FLT181PH	Single phase fault on the McDowell 230/115kV autotransformer on the 115kV bus.
FLT193PH	Three phase fault on the Morris - Swissvale 230 kV line, near Morris, with one shot reclosing after 20 cycles.

FLT201PH	Single phase fault on the Morris - Swissvale 230 kV line, near Morris, with one shot reclosing after 20 cycles.
FLT213PH	Three phase fault on Knoll – Wind farm 230 kV line, near Knoll, with one shot reclosing after 20 cycles.
FLT221PH	Single phase fault on Knoll – Wind farm 230 kV line, near Knoll, with one shot reclosing after 20 cycles..
FLT233PH	Three phase fault on Wind Farm – E McPherson 230 kV line, near E McPherson, with one shot reclosing after 20 cycles.
FLT241PH	Single phase fault on Wind Farm – E McPherson 230 kV line, near E McPherson, 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-2006-033 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
EQ3132	2
EQ2830	3
EQ0708	2
EQ2223	2
NODE_A	3
EQ2427	4
EQ0106	6
EQ0918	10
EQ3840	3
EQ3637	2
NODE-F	4
EQ3335	3
EQ4144	4
EQ6166	6
EQ6973	5
EQ5660	5
EQ4552	8
EQ55	1
EQ7476	3
EQ7780	4
EQ8183	3
EQ9092	3
EQ8489	6
EQ9394	2
EQ9697	2
EQ98100	2
EQ99	1
EQ95	1

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)
1/0	0.102	0.09817
4/0	0.0509	0.08949
1000 kcmil	0.0216	0.07957
500 kcmil	0.0108	0.07156

Table 3: Cable impedance per 1000 feet

The Customer also provided the following substation transformer's impedance:

Transformer Impedance: 8.0 % at 150 MVA

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-2003-033 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-2002-026 (120 MW), GEN-2003-006A (200MW), GEN-2003-019 (250MW), GEN-2004-016 (150MW), GEN-2006-027 (310) and Gen-2006-028 (360 MW) 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 20 MVAR capacitors would be needed in the summer peak load case.

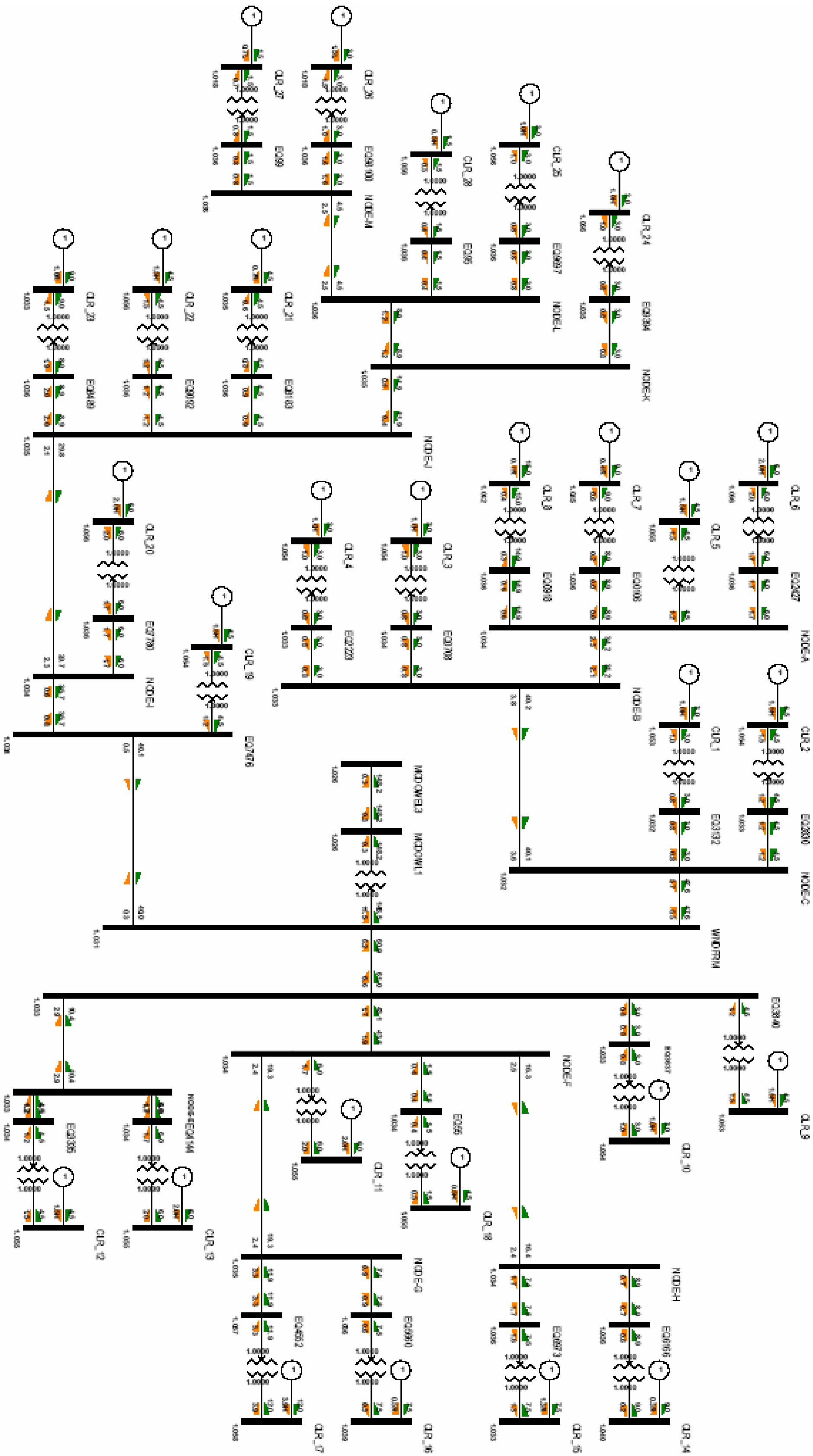

Figure 2: 100% Power Flow Base Case for GEN-2006-033

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	39610	29112
GEN-2006-033 at 100% output with the prior queued projects	39460	28962

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-2006-033.

Fault Number	Summer Load	Winter Load
FLT13PH	- -	- -
FLT21PH	- -	- -
FLT33PH	- -	- -
FLT41PH	- -	- -
FLT53PH	- -	- -
FLT61PH	- -	- -
FLT73PH	- -	- -
FLT81PH	- -	- -
FLT93PH	- -	S
FLT101PH	- -	- -
FLT113PH	- -	- -
FLT121PH	- -	- -
FLT133PH	- -	- -
FLT141PH	- -	- -
FLT153PH	- -	- -
FLT161PH	- -	- -
FLT173PH	- -	- -
FLT181PH	- -	- -
FLT193PH	- -	- -
FLT201PH	- -	- -
FLT213PH	- -	- -
FLT221PH	- -	- -
FLT233PH	- -	- -
FLT241PH	- -	- -

UV : GEN-2006-033 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-2006-033 generators were found to stay connected to the grid for all the contingencies that were studied.

System stability issues were found to occur for a fault near JEC in the winter case. This issue was found to be present even prior to the addition of Gen-2006-033.

Figure 3 and 4 show the winter peak response for FLT3_3PH and FLT9_3PH respectively.

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position Gen-2006-033 consisting of GE 1.5 MW wind turbines with its output at 150 MW. The study was conducted for two different power flow scenarios, i.e., one for summer peak and one for winter peak.

System stability issues were found to occur for a fault near JEC in the winter case. This issue was found to be present even prior to the addition of Gen-2006-033. The study has not indicated any angular or voltage instability problem due to addition of GEN-2006-033 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-2006-033 for FLT1-3PH

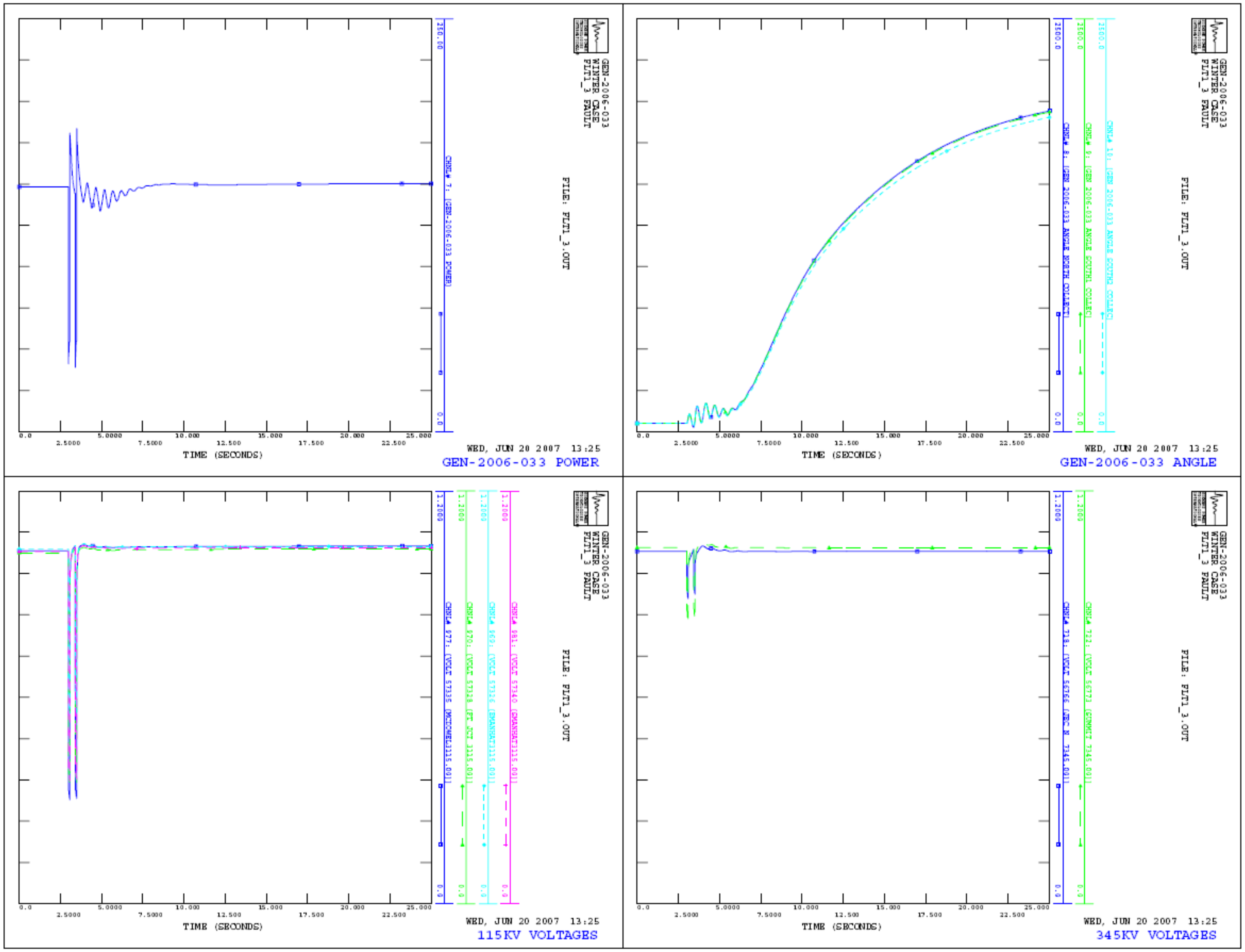

Figure 3 : System Responses with 100% output of GEN-2006-033 for FLT1-3PH (Cont'd)

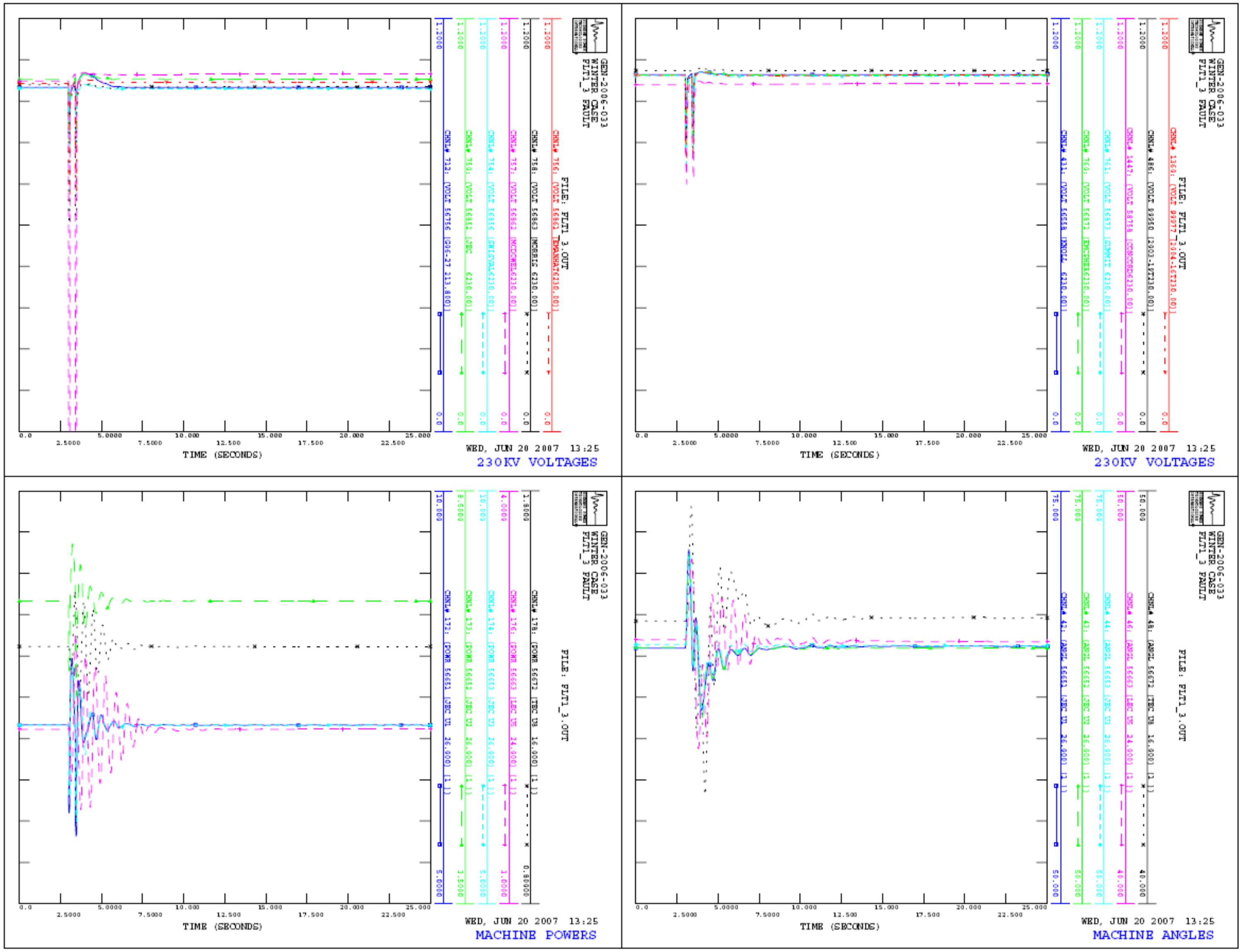

Figure 3 : System Responses with 100% output of GEN-2006-033 for FLT1-3PH (Cont’d)

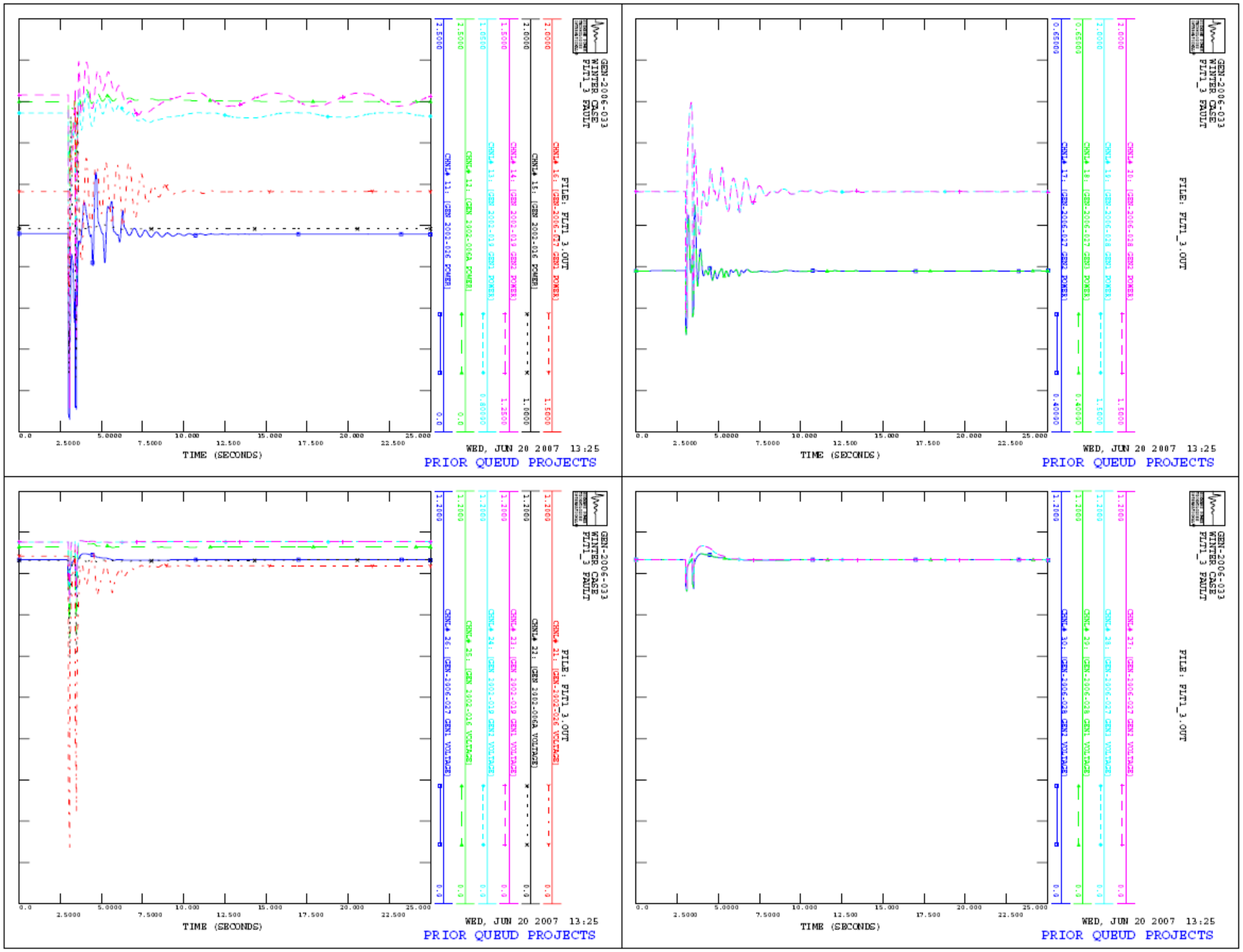

Figure 4 : System Responses with 100% output of GEN-2006-033 for FLT9-3PH

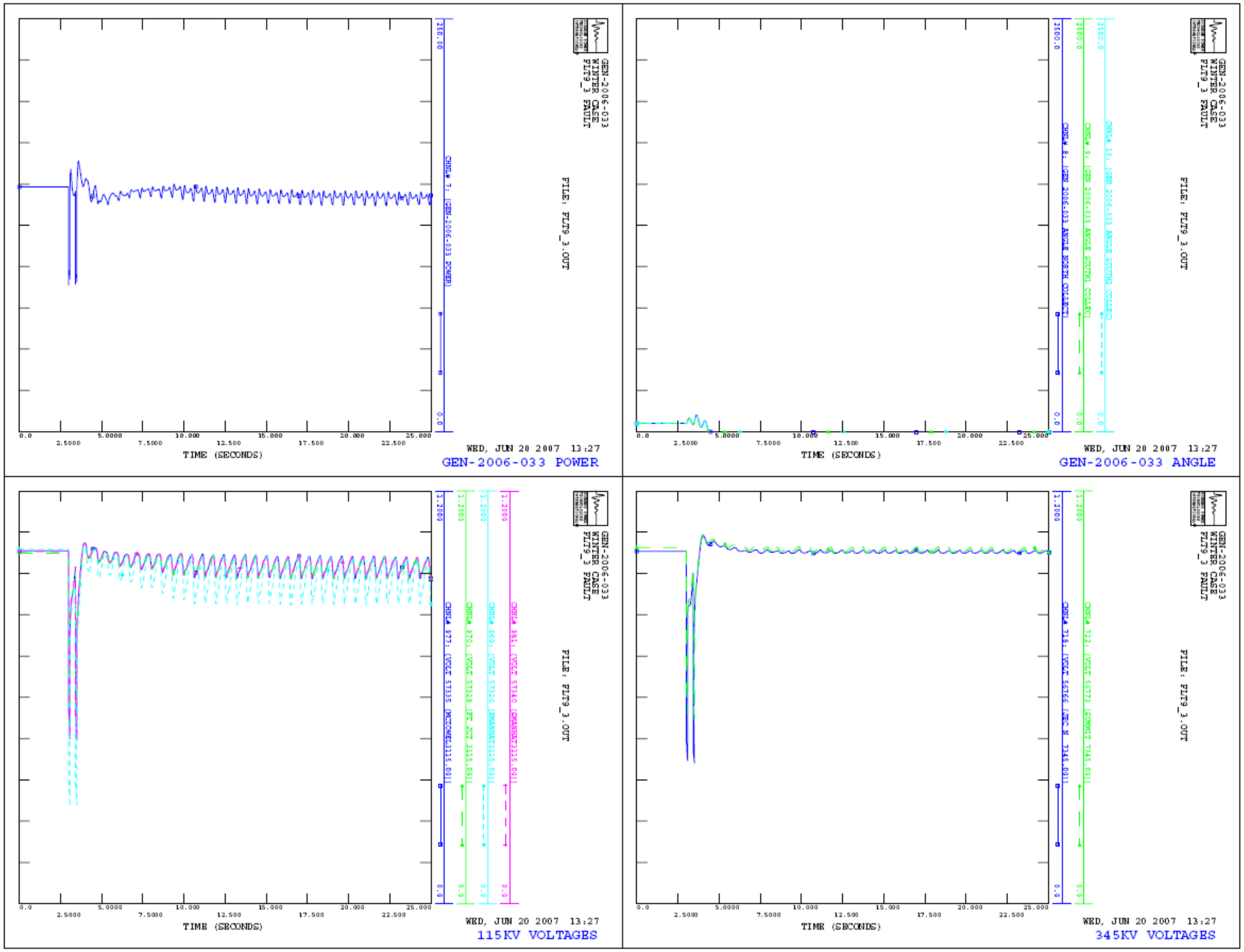

Figure 4: System Responses with 100% output of GEN-2006-033 for FLT9-3PH (Cont..)

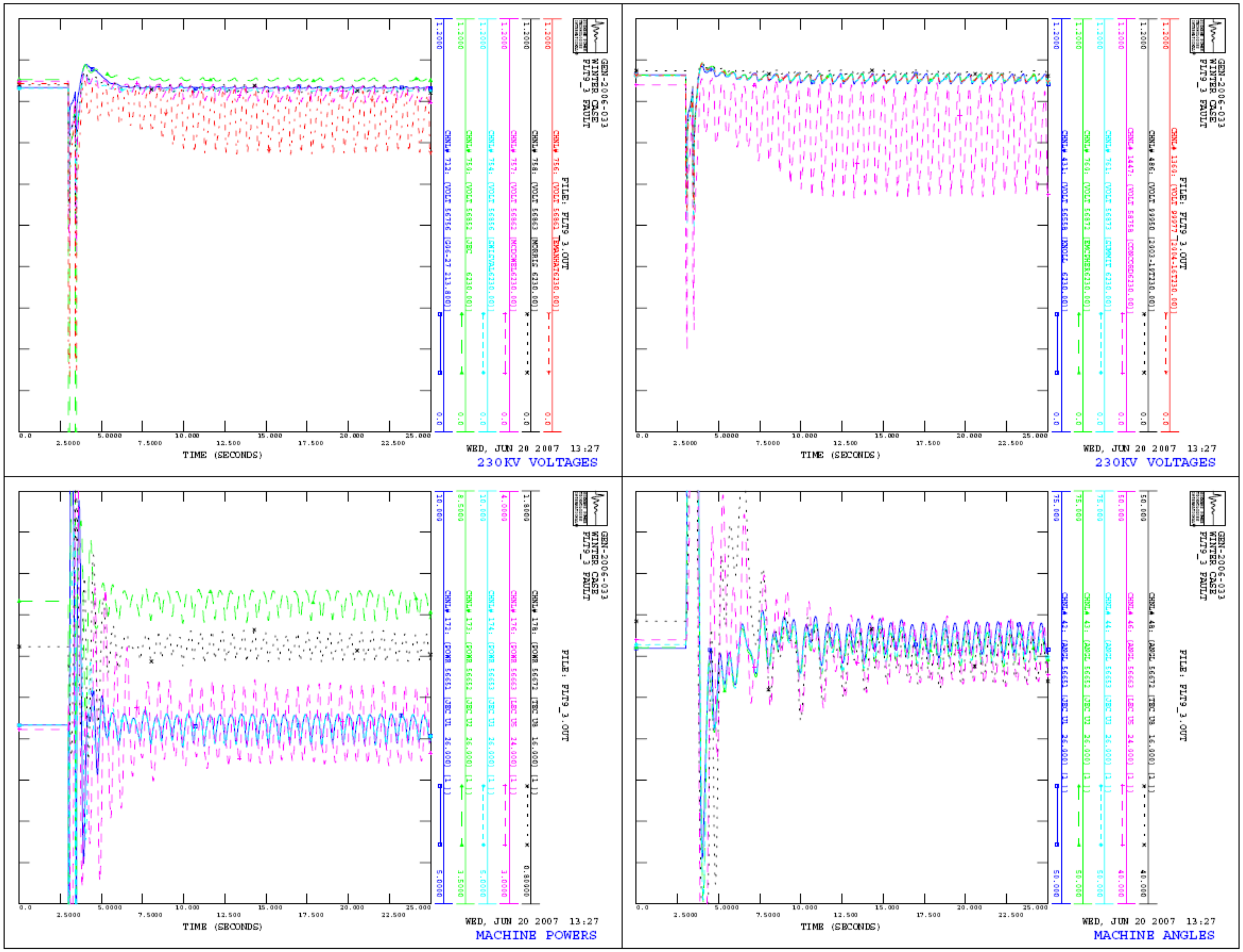

Figure 4 : System Responses with 100% output of GEN-2006-033 for FLT9-3PH (Cont..)