Impact Study for Generation Interconnection Request GEN–2006–043

SPP Tariff Studies
(#GEN-2006-043)

March 2009

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-2006-043. 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. The Impact Study for GEN-2006-043 was originally studied with GE 1.5 MW wind turbines. This restudy analyzed the use of Siemens 2.3 MW wind turbines.

Power Factor Requirements

To maintain a unity power factor during normal operation, the Impact Study determined that a total of 32 Mvars of 34.5kV capacitor banks are required for the operation of GEN-2006-043. This capacitor bank(s) should be staged so that excessive voltage variations are not experienced on the AEPW transmission system.

To meet the low voltage requirements of FERC Order #661A, the Impact Study determined that the Interconnection Customer will be required to install a 34.5kV, +/- 20 MVA STATCOM device. The size of these devices or possibly even the need for the devices may change depending upon a number of factors, including whether prior queued interconnection requests in the local area withdraw or whether new transmission lines are built in the area of the interconnection request as a result of transmission service request studies. Interconnection Customer and the manufacturer of this device will need to coordinate with SPP during the design of such device to ascertain it will meet FERC Order #661A requirements.

Interconnection Facilities

The requirements for interconnection of the 99 MW consist of constructing a new 230 kV line terminal on the Elk City – Grapevine 230 kV line owned by AEPW. Depending upon the status of the prior queued projects in the area, the Interconnection Customer's cost responsibility could vary. Please se the Facility Study for GEN-2006-043 for further details.

IMPACT STUDY FOR SPP GENERATION QUEUE POSITION GEN-2006-043

SOUTHWEST POWER POOL (SPP)
March 10, 2009

Final Report

By

BLACK & VEATCH

Table of Contents

EXECUTIVE SUMMARY

A transient stability study was performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2006-043 as part of the System Impact Study. The Interconnection Queue Position GEN-2006-043 is a wind farm of 99 MW capacity proposed to be connected to a new substation to be built along the Elk City – Grapevine 230 kV line. The line is owned by American Electric Power (AEP).

Transient Stability studies were conducted with the full output of 99 MW (100%). The wind farm was considered to contain Siemens 2.3 MW turbines.

The 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 Siemens wind turbine models provided by the customer.

Transient Stability studies were conducted with the GEN-2006-043 output at 99 MW (100%) for two scenarios, i.e., (i) summer peak load and (ii) winter peak load. Sixteen (16) contingencies were considered for each of the scenarios.

The study has indicated that a STATCOM of 20 MVAR would be required under dynamic conditions, in order to keep the system stable for faults involving the Wind Farm – Elk City line. This requirement is in addition to 36 MVAR of shunt capacitors that would be needed under steady conditions to keep the 230 kV collector bus voltage to unity.

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 AEP transmission facilities.

1. INTRODUCTION

This report discusses the results of a transient stability study performed for Southwest Power Pool (SPP) Interconnection Queue Position GEN-2006-043.

The Interconnection Queue Position GEN-2006-043 is a wind farm of 99 MW capacity proposed to be connected to a new substation to be built along the Elk City – Grapevine 230 kV line. The line is owned by American Electric Power (AEP). The system one line diagram of the area near the Queue Position GEN-2006-043 is shown below.

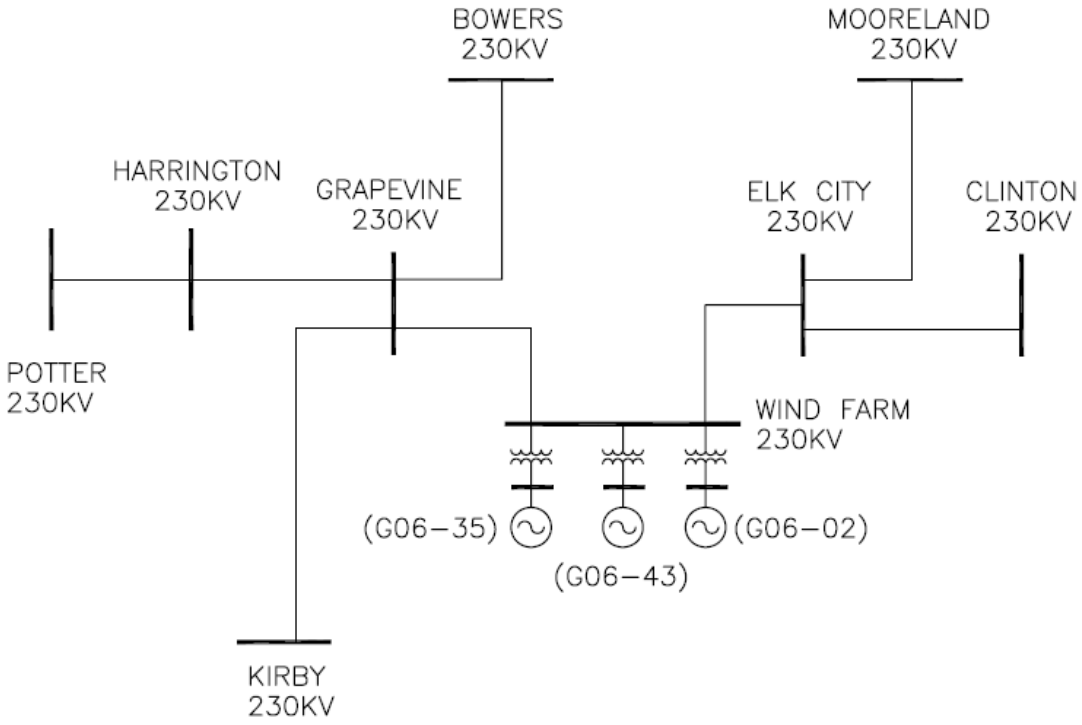

Figure 1: System One Line Diagram near GEN-2006-043

Transient Stability studies were conducted with the full output of 99 MW (100%). The wind farm was considered to contain Siemens -2.3 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-2006-043 output at 99 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 the wind farm (Gen-2006-043) to Stateline 230 kV line, near the wind farm.
FLT21PH	Single phase fault on the wind farm (Gen-2006-043) to Stateline 230 kV line, near the wind farm.
FLT33PH	Three phase fault on the wind farm (Gen-2006-043) to Elk City 230 kV line, near the wind farm.
FLT41PH	Single phase fault on the wind farm (Gen-2006-043) to Elk City 230 kV line, near the wind farm.
FLT53PH	Three phase fault on Clinton Jct- Elk City 138 kV line, near Clinton Jct, with one shot reclosing after 20 cycles.
FLT61PH	Single phase fault on Clinton Jct- Elk City 138 kV line, near Clinton Jct, with one shot reclosing after 20 cycles.
FLT73PH	Three phase fault on the G02-05 Sub - Morewood 138 kV line, near Morewood, with one shot reclosing after

	20 cycles.
FLT81PH	Single phase fault on the G02-05 Sub - Morewood 138 kV line, near Morewood, with one shot reclosing after 20 cycles.
FLT93PH	Three phase fault on the Hobart Jct- Elk City 138 kV line, near Elk City, with one shot reclosing after 20 cycles.
FLT101PH	Single phase fault on the Hobart Jct- Elk City 138 kV line, near Elk City, with one shot reclosing after 20 cycles.
FLT113PH	Three phase fault on Grapevine - Nichols 230 kV line, near Grapevine, with one shot reclosing after 20 cycles.
FLT121PH	Single phase fault on Grapevine - Nichols 230 kV line, near Grapevine, with one shot reclosing after 20 cycles.
FLT133PH	Three phase fault on the Grapevine 230/115 kV autotransformer on the 230 kV bus.
FLT141PH	Single phase fault on the Grapevine 230/115 kV autotransformer on the 230 kV bus.
FLT153PH	Three phase fault on the Conway – Yarnell – Nichols 115 kV line, near Nochols, with one shot reclosing after 20 cycles.
FLT161PH	Single phase fault on the Conway – Yarnell – Nichols 115 kV line, near Nochols, 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.

4. SIMULATION MODEL

The customer requested to use Siemens SWT-2.3 MW wind turbine for the System Impact Study. The Siemens SWT-2.3 wind turbine generator consists of an induction generator and an ac/dc/ac converter. The following are the main electrical parameters of the Siemens SWT-2.3 wind turbine.

Rated Power : 2.3 MW
Operating Nominal Voltage : 690V
Operating Power Factor : 0.9 Lead to 0.9 Lag. (as per the Catalog)

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-2006-043 modeled.

Table 2 provides the number of Siemens 2.3 MW wind generators modeled as equivalents at each collector buses of the wind farm.

Collector Bus	No. of generators aggregated
1-7	7
8-11	4
12-16	5
17-20	4
21-22	2
23-26	4
27-32	6
33-35	3
36-39	4
40-43	4

Table 2: Equivalent Generators with Siemens SWT-2.3 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)
4/0	0.107	0.049
500kcmil	0.047	0.042
1000 kcmil	0.025	0.04

Table 3: Cable impedance per 1000 feet

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

The base case power flow diagram for the project GEN-2006-043 is shown in Figure 2.

The prior queued projects Gen-2006-002 (150 MW) and Gen-2006-035 (225 MW) 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 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	62.4 Hz	0.1 seconds
Under Frequency	57.0 Hz	10 seconds
Under Voltage	90%	3.000
Under Voltage	50%	1.735
Under Voltage	15%	0.650
Over Voltage	110%	1.0 second
Over Voltage	120%	0.2 seconds

Table 4: Standard protective functions and settings for Siemens 2.3 MW Turbines

Scenario	Generation within SPP	
	Summer	Winter
Without the Wind Farms	41536	28802
GEN-2006-043 at 100% output with the prior queued projects	41671	28937

Table 5: Generation in SPP Area

6. SIMULATION RESULTS

Initial power flow studies were carried out to determine the amount of shunt capacitors that would be needed at the 34.5 kV collector bus, in order to keep the voltage at the 230 kV bus at 1.0 per unit for the contingencies listed in Table 1. It was found that 36 MVAR shunt capacitors would be required.

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

Table 6 provides the summary of the stability studies for GEN-2006-043.

System instability was encountered for faults involving Gen-2006-043 to Elk City 115 kV line (FLT33PH and FLT41PH). Gen-2006-043 generators were found to stay connected for other contingencies.

Fault Number	Summer Peak Load Case	Winter Peak Load Case
FLT13PH	- -	- -
FLT21PH	- -	- -
FLT33PH	S	S

FLT41PH	S	S
FLT53PH	- -	- -
FLT61PH	- -	- -
FLT73PH	- -	- -
FLT81PH	- -	- -
FLT93PH	- -	- -
FLT101PH	- -	- -
FLT113PH	- -	- -
FLT121PH	- -	- -
FLT133PH	- -	- -
FLT141PH	- -	- -
FLT153PH	- -	- -
FLT161PH	- -	- -

UV : GEN-2006-043 Tripped due to low voltage
OV : GEN-2006-043 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

The system responses corresponding to FLT33PH are shown in Figure 3.

In order to solve the system instability issue, a STATCOM device was considered at the 34.5 kV collector bus. It was found that 20 MVAR STATCOM would be required for stable operation.

The system responses corresponding to FLT33PH with the proposed STATCOM are shown in Figure 4.

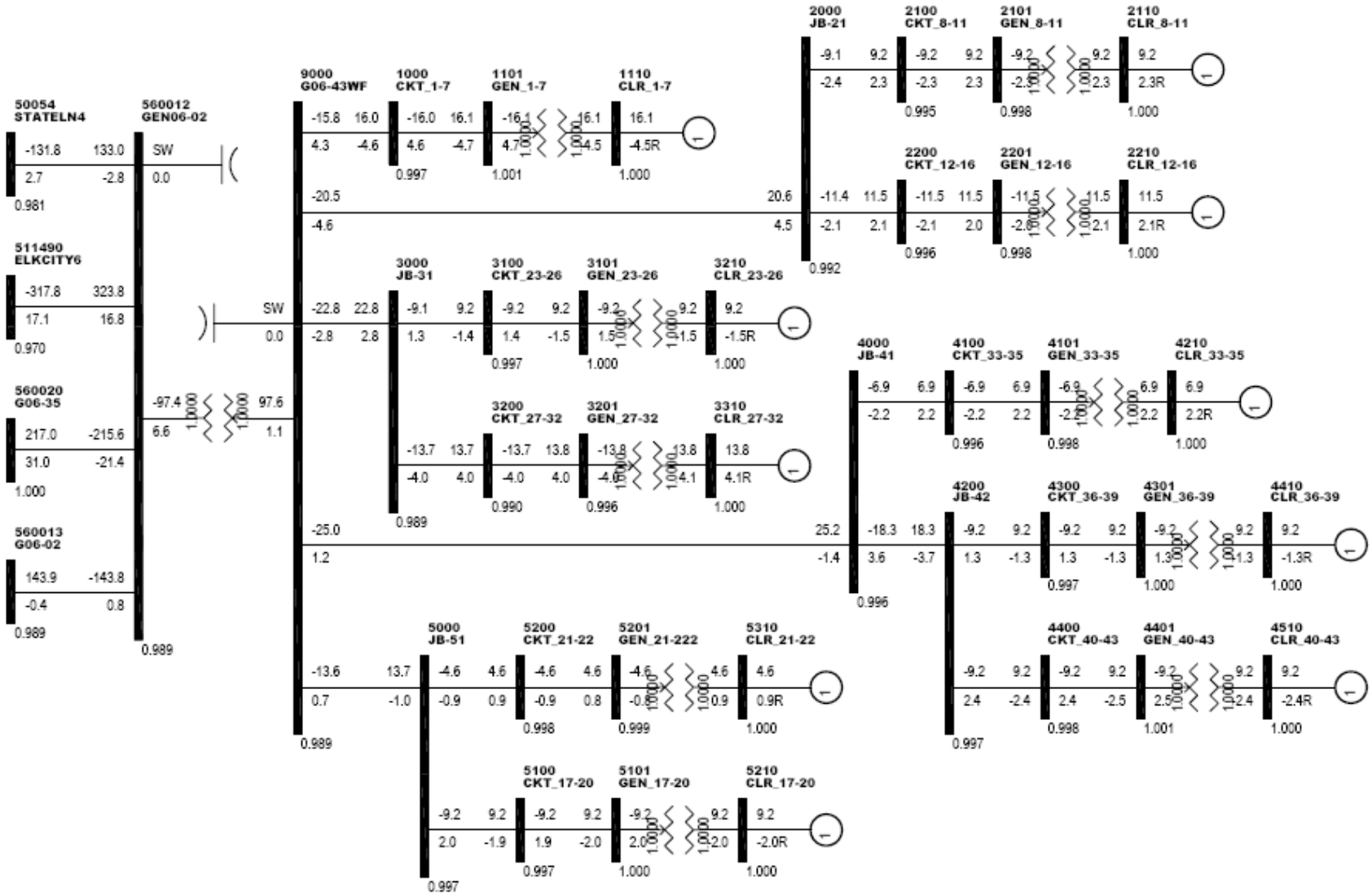

Figure 2: 100% Power Flow Base Case for GEN-2006-043

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position GEN-2006-043 consisting of Siemens 2.3 MW wind turbines, for an aggregate output of 99 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 indicated that a STATCOM of 20 MVAR would be required under dynamic conditions, in order to keep the system stable for faults involving the wind farm – Elk City line. This requirement is in addition to 36 MVAR of shunt capacitors that would be needed under steady conditions to keep the 230 kV collector bus voltage to unity.

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 AEP 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 AEP 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-2006-043 for FLT33PH

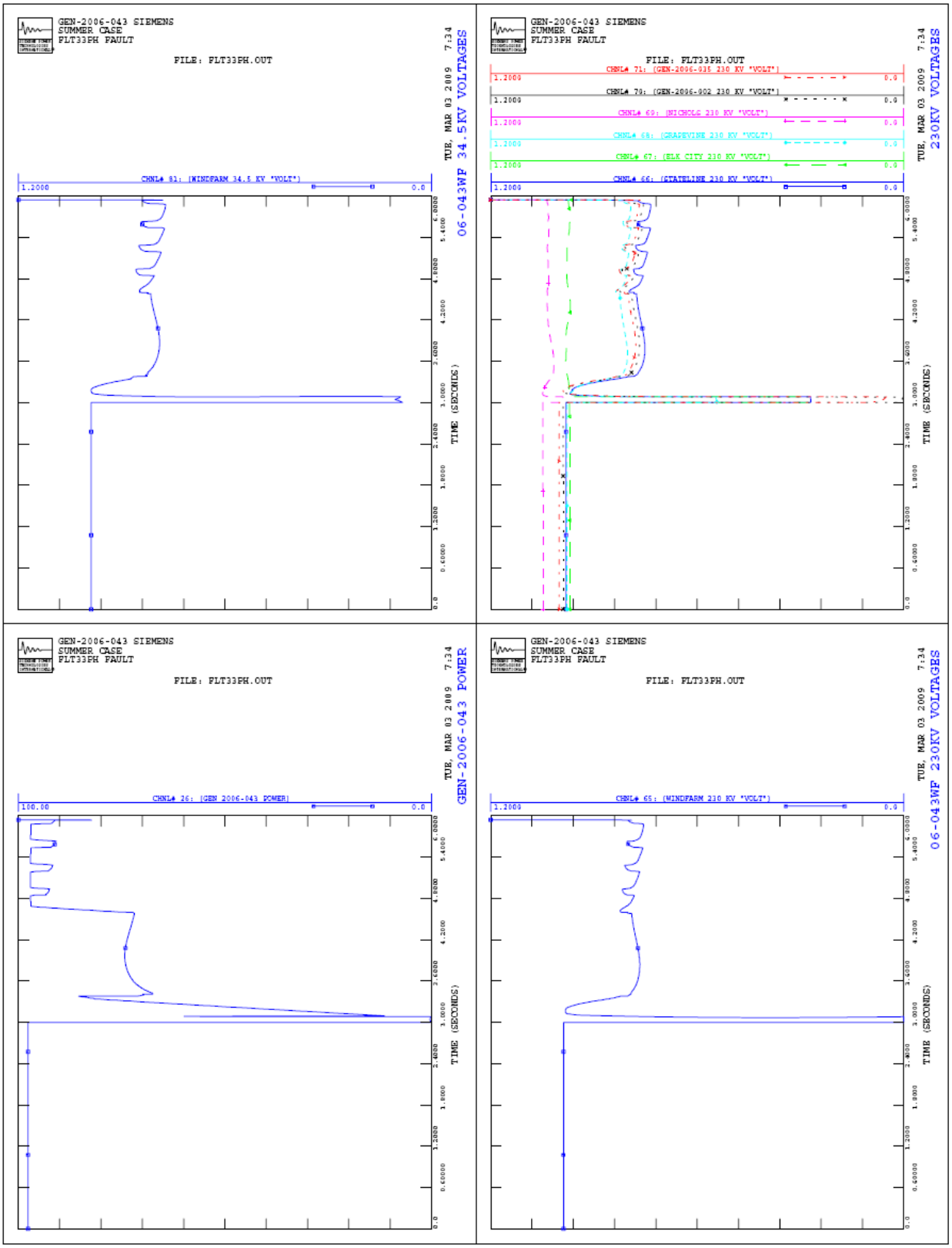

Figure 3 : System Responses with 100% output of GEN-2006-043 for FLT33PH (Cont'd)

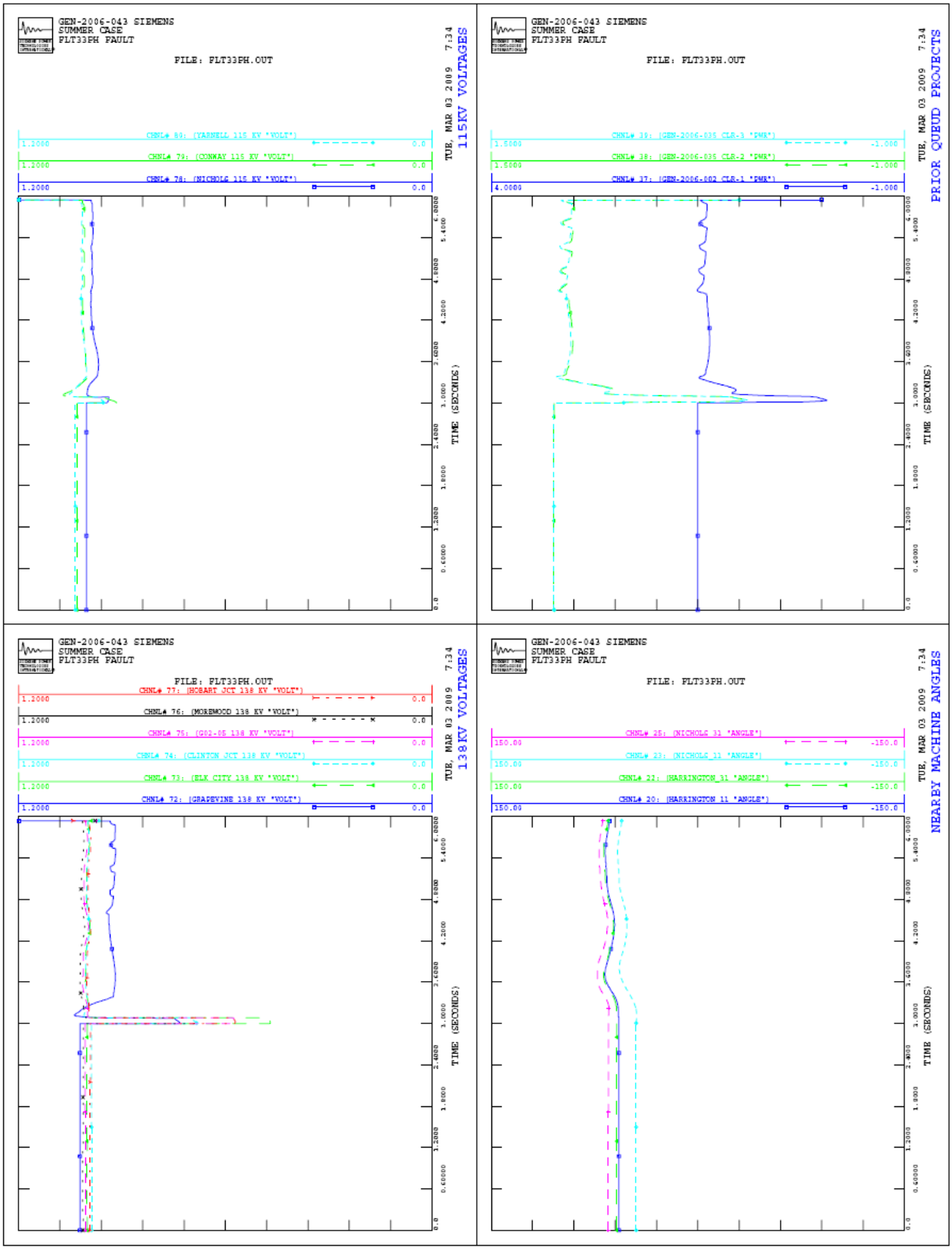

Figure 4 : System Responses with GEN-2006-043 for FLT33PH with STATCOM

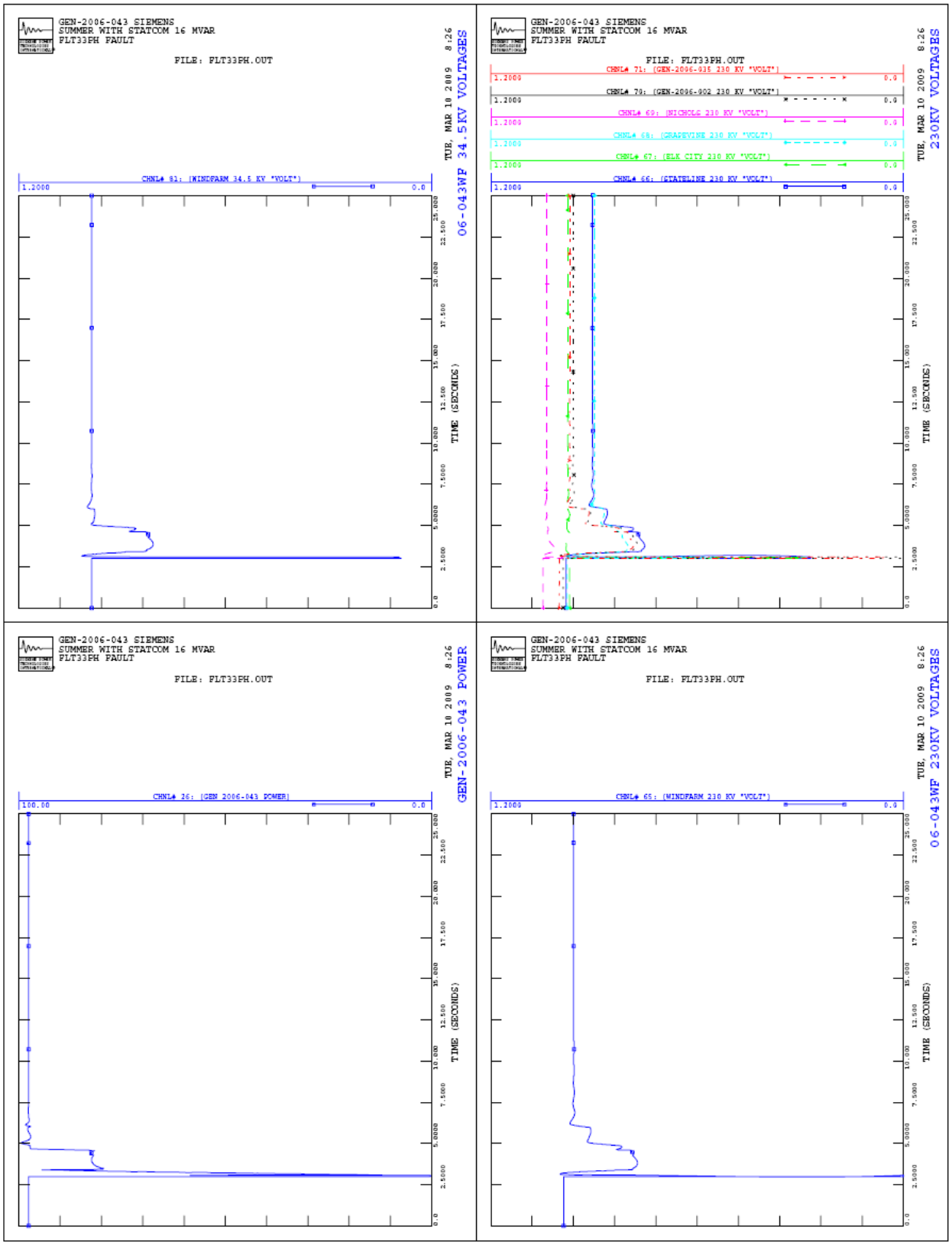

Figure 4 : Svstem Responses with GEN-2006-043 for FLT33PH with STATCOM (Cont'd)