SPP Southwest Power Pool

# Impact Study for Generation Interconnection Request GEN–2005–016

***SPP Tariff Studies (#GEN-2005-016)***

**November, 2006**

## Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Black & Veatch conducted the following Impact Study to satisfy the Impact Study Agreement executed by the requesting customer and SPP for SPP Generation Interconnection request Gen-2005-016. 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.

<u>Interconnection Facilities</u>

The Impact Study determined that a 34.5kV, 30Mvar capacitor bank is required to be installed in the Customer 345/34.5kV substation for reactive compensation of the Customer transformer, wind turbines, and wind turbine collector circuits.

The Impact Study determined that the wind farm will be compliant with FERC Order #661A LVRT provisions with the Gamesa G87 wind turbines without the addition of an SVC or STATCOM.

The Facilities needed for this request are summarized below. These costs will be finalized in a Facility Study if the requesting Customer executes the Facility Study Agreement.

**<u>Table 1: Direct Assignment Facilities</u>**

| Facility | ESTIMATED COST (2006 DOLLARS) |
|---|---|
| Customer – 345-34.5 kV Substation facilities. | * |
| Customer – 345kV line between Customer substation and new WERE 345kV switching station. | * |
| Customer - Right-of-Way for Customer Substation & Line. | * |
| Customer – 34.5kV, 30Mvar capacitor bank for reactive compensation of the wind farm | * |
| Customer – 345kV interconnection metering in WERE switching station installed by WERE. | 250,000 |
| | |
| **Total** | ***** |

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

**<u>Table 2: Required Interconnection Network Upgrade Facilities</u>**

| Facility | ESTIMATED COST (2006 DOLLARS) |
|---|---|
| WERE - Add 3-breaker ring 345kV switching station in Rose Hill – Neosho 345kV line. | $3,545,000 |
| WERE – 345kV turning structures. | 400,000 |
| | |
| | |
| **Total** | **$3,945,000** |

# IMPACT STUDY FOR SPP GENERATION

# QUEUE POSITION GEN-2005-016

**SOUTHWEST POWER POOL (SPP)**

**October 27, 2006**

**By**

BLACK & VEATCH

# Table of Contents

# EXECUTIVE SUMMARY

A transient stability study has been performed for Southwest Power Pool (SPP) Interconnection Queue Position Gen-2005-016 as part of the System Impact Study. The Interconnection Queue Position Gen-2005-016 is a wind farm of 150 MW capacity proposed to be located within the service territory of Westar Energy. The wind farm would be interconnected into a new ring bus substation on the Latham-Neosho 345 kV line.

Transient Stability studies were conducted with the full output of 150 MW (100%). The wind farm was considered to contain Gamesa G87 2.0 MW turbines in the study with the standard under voltage protection package.

The 2009 summer peak and 2006 light winter peak flow cases together with the SPP MDWG 2005 stability model were used as the base cases 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 PSS/E models supplied 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 30 MVAR capacitors at the 34.5 kV collector bus would be needed.

Transient Stability studies were conducted with the Gen-2005-016 output at 150 MW (100%) for two scenarios, i.e., (i) summer peak load and (ii) winter peak load. Twenty two (22) contingencies were considered for each of the scenarios.

The study has not indicated any angular or voltage instability problem for the contingencies analyzed in both the scenarios. The study has also indicated that this generation interconnection request complies with FERC Order #661A Low Voltage Ride Through (LVRT) provsions.

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-2005-016.

The Interconnection Queue Position Gen-2005-016 is a wind farm of 150 MW capacity proposed to be located within the service territory of Westar Energy. The wind farm would be interconnected into a new ring bus substation on the Latham-Neosho 345 kV. The system one line diagram of the area near the Queue Position Gen-2005-016 is shown in below.

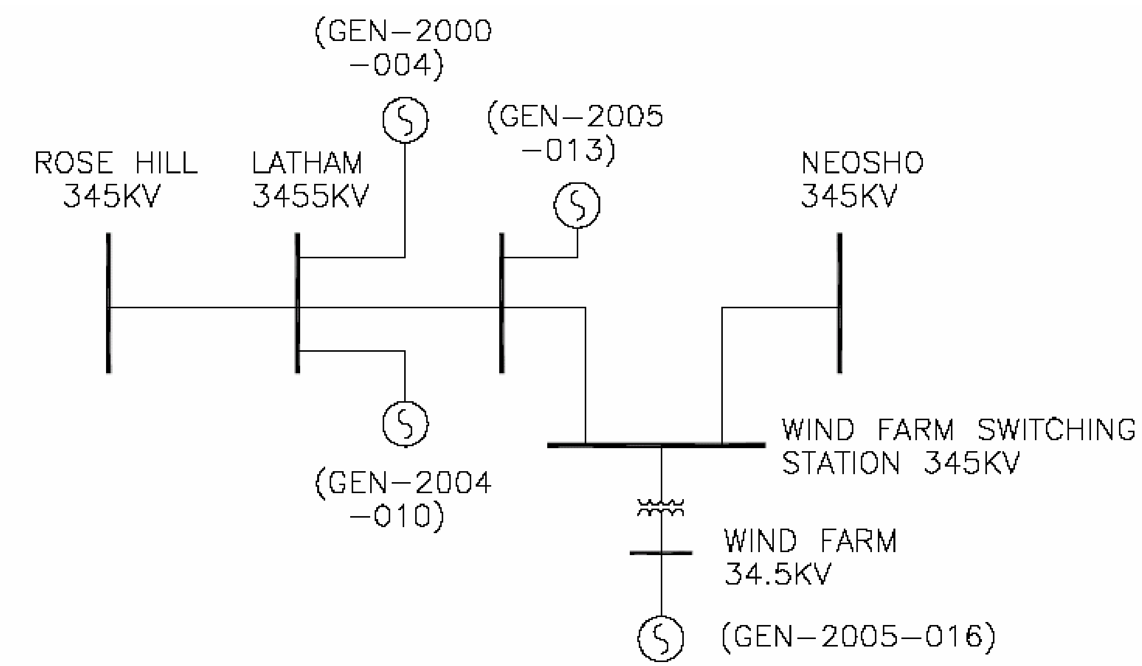


Figure 1 : System One Line Diagram near GEN-2005-016

Transient Stability studies were conducted with the full output of 150 MW (100%). The wind farm was considered to contain Gamesa G87 2.0 MW turbines in the study with the manufacturer's standard package.

## 2. STABILITY STUDY CRITERIA

The 2009 summer peak and 2006 winter peak load flow cases together with the SPP MDWG 2005 stability model were used as the base cases 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-2005-016 output at 150 MW (100%) for two scenarios, i.e., (i) 2009 summer peak load and (ii) 2006 winter peak load.

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

| Fault Number | Fault Definition |
|---|---|
| FLT13PH | Three phase fault at mid-point on the Rose Hill – Latham Switching Station 345 kv line. |
| FLT21PH | Single phase fault at mid-point on the Rose Hill – Latham Switching Station 345 kv line. |
| FLT33PH | Three phase fault on the Wind Farm Switching Station – Neosho 345 kv line, near Neosho. |
| FLT41PH | Single phase fault on the Wind Farm Switching Station – Neosho 345 kv line, near Neosho. |
| FLT53PH | Three phase fault at midpoint on the Neosho – Morgan 345 kv line. |
| FLT61PH | Single phase fault at midpoint on the Neosho – Morgan 345 kv line. |
| FLT73PH | Three phase fault on the Rose Hill – Wolf Creek 345 kv line, near Wolf Creek. |
| FLT81PH | Single phase fault on the Rose Hill – Wolf Creek |

| | |
|---|---|
| | 345 kv line, near Wolf Creek. |
| FLT93PH | Three phase fault on the Rose Hill – Benton 345 kv line, near Benton. |
| FLT101PH | Single phase fault on the Rose Hill – Benton 345 kv line, near Benton. |
| FLT113PH | Three phase fault on the Benton – Wichita 345 kv line, near Wichita. |
| FLT121PH | Single phase fault on the Benton – Wichita 345 kv line, near Wichita. |
| FLT133PH | Three phase fault on the Benton – Midian 138 kv line, near Midian. |
| FLT141PH | Single phase fault on the Benton – Midian 138 kv line, near Midian. |
| FLT153PH | Three phase fault on the Midian - Butler 138 kv line, near Butler. |
| FLT161PH | Single phase fault on the Midian - Butler 138 kv line, near Butler. |
| FLT173PH | Three phase fault on the Rose Hill - Weaver 138 kv line, near Weaver. |
| FLT181PH | Three phase fault on the Rose Hill - Weaver 138 kv line, near Weaver. |
| FLT193PH | Three phase fault on the Wind Farm Switching Station to Neosho 345 kv line at the POI to bring down the voltage to 0.15 p.u. (FERC 661A fault). |
| FLT201PH | Three phase fault on the Wind Farm Switching Station to Gen-2005-013 345 kv line at the POI to bring down the voltage to 0.15 p.u. (FERC 661A fault). |
| FLT213PH | Three phase fault on the Wind Farm Switching Station to Neosho 345 kv line at the POI to bring down the voltage to 0.0 p.u. (FERC 661A fault). |
| FLT221PH | Three phase fault on the Wind Farm Switching Station to Gen-2005-013 345 kv line at the POI to bring down the voltage to 0.0 p.u. (FERC 661A fault). |

Table 1: Study Cases

In all of the simulations, the fault duration was considered to be 5 cycles. A single shot line re-close was considered in all of the above cases with a wait time of 300 cycles for 500 kV lines and 25 cycles for 138 kV lines. However, 60 cycles wait time was used for Wichita-Benton and Rose Hill-Benton 500 kV lines.

# 4. SIMULATION MODEL

The customer requested to use Gamesa Wind turbines for the System Impact Study. The Gamesa turbines are a three phase induction generator. The following are the main electrical parameters of the Gamesa G87 2.0 MW wind turbine.

Rated Power : 2.0 MW
Voltage : 690 V ac
Rated Power Factor : 1.0

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-2005-016 modeled.

Table 2 provides the number of Gamesa G87 2.0 MW wind generators modeled as equivalents at each collector buses of the wind farm.

| **Collector Bus** | **No. of generators aggregated** |
|---|---|
| Gen-1 | 15 |
| Gen-2 | 15 |
| Gen-3 | 15 |
| Gen-4 | 15 |
| Gen-5 | 15 |

Table 2 : Equivalent Generators with Gamesa Turbines

The following transmission line parameters were used in the model for the overhead and underground lines within the Wind Farm and also between the Wind Farm and the Switching Station:

Line resistance : 0.045 ohms per 1000 ft for 1750 kcmil 34.5 kV cable
0.047 ohms per 1000 ft for 500 kcmil 34.5 kV cable
0.114 ohms per 1000 ft for 4/0 AWG 34.5 kV cable
0.168 ohms per 1000 ft for 2/0 AWG 34.5 kV cable
0.223 ohms per 1000 ft for 1/0 AWG 34.5 kV line

Line reactance : 0.064 ohms per 1000 ft for 750 kcmil 34.5 kV cable
0.07 ohms per 1000 ft for 500 kcmil 34.5 kV cable
0.088 ohms per 1000 ft for 4/0 AWG 34.5 kV cable
0.095 ohms per 1000 ft for 2/0 AWG 34.5 kV cable

0.097 ohms per mile for 1/0 AWG 34.5 kV line

Line capacitance: 0.087 µF per 1000 ft for 750 kcmil 34.5 kV cable
0.072 µF per 1000 ft for 500 kcmil 34.5 kV cable
0.053 µF per 1000 ft for 4/0 AWG 34.5 kV cable
0.048 µF per 1000 ft for 2/0 AWG 34.5 kV cable
0.043 µF per 1000 ft for 1/0 AWG 34.5 kV cable

The Customer provided the wind turbine feeder conductor types, lengths and impedance values.

The Customer also provided the substation transformer impedance value and was 9% at 95 MVA.

Prior queued projects Gen-2002-004 of 150 MW, Gen-2004-010 of 300 MW and Gen-2005-013 of 201 MW were also included in the model. Under voltage protections associated with these prior-queued projects were not modeled in this study, in order to study the effect of these prior queued projects on Gen-2005-016.

A power flow analysis was conducted to estimate the amount of additional shunt capacitors that would be needed at the wind farm collector buses so as to have zero reactive power exchange between wind farm and the grid. It was found that about 30 MVAR capacitors at 34.5 kV collector buses would be needed.

Gen-2005-016 was modeled using the Gamesa wind turbine model provided by the Customer. The model included the shaft dynamics and the pitch control. The Gamesa turbine generator data used in the study is as noted in Table 3.

Figure 2 also shows the 100% base case power flow for the project Gen-2005-016.

| Description | Value |
|---|---|
| Stator resistance, Ra | 0.0102 pu |
| Stator inductance, La | 0.1428 pu |
| Mutual inductance, Lm_D | 7.2114 pu |
| Mutual inductance, Lm_Y | 6.9453 pu |
| Rotor resistance | 0.0101 pu |
| Rotor inductance | 0.175 pu |

Table 3 : Gamesa 2.0 MW Wind Turbine Generator Parameters

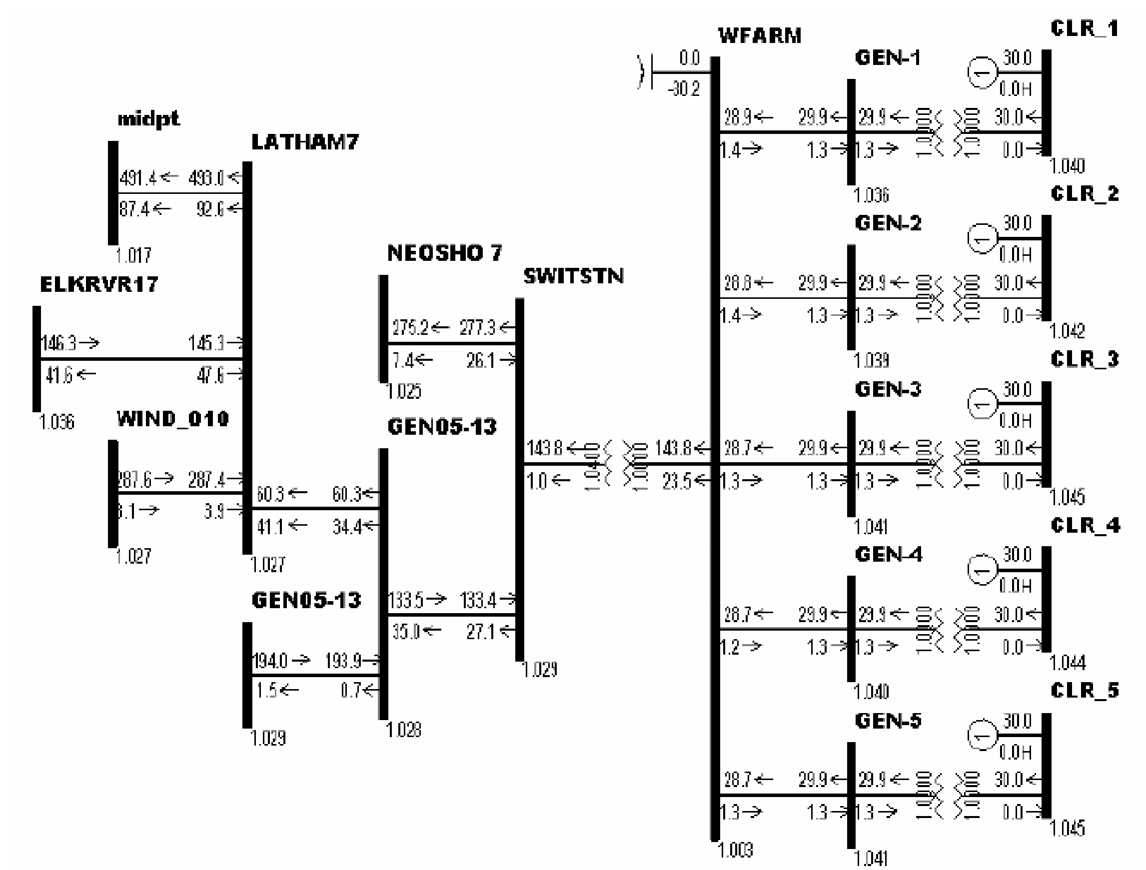


Figure 2 : Gen-2005-016 Power Flow Model

## 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. The turbine control models supplied by the Customer were used with their default values.
3. From the wind turbine data sheets the protection settings were used as and are shown in Table 4.
4. The generation in the SPP control area was scaled down to accommodate the new generation as indicated in Table 5.

| Protective Function | Protection Setting | Time Delay |
|---|---|---|
| Over Frequency | 62.0 Hz | 0 seconds |
| Under Frequency | 57.0 Hz | 0 seconds |
| Under Voltage | 15% | 0.04 seconds |
| Under Voltage | 30% | 0.625 seconds |
| Under Voltage | 45% | 1.1 seconds |
| Under Voltage | 60% | 1.575 seconds |
| Under Voltage | 75% | 2.05 seconds |
| Under Voltage | 90% | 2.55 seconds |
| Over Voltage | 110% | 0.06 second |

Table 4 : Protective Functions and Settings for Gamesa G87-2.0 MW Turbines

| Scenario | Generation within SPP | |
|---|---|---|
| | Summer | Winter |
| Without the Wind Farms | 38,861 MW | 26,435 MW |
| Gen-2005-016 at 100% output with the prior queued projects | 38,771 MW | 26,285 MW |

Table 5 : SPP Dispatches

# 6. SIMULATION RESULTS

Initial simulation was carried out for 20 seconds 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 with the standard protection package for Gen-2005-016.

| Fault Number | Summer Peak Load Level | Winter Peak Load Level |
|---|---|---|
| FLT13PH | -- | -- |
| FLT21PH | -- | -- |
| FLT33PH | -- | -- |
| FLT41PH | -- | -- |
| FLT53PH | -- | -- |

| | | |
|---|---|---|
| FLT61PH | -- | -- |
| FLT73PH | -- | -- |
| FLT81PH | -- | -- |
| FLT93PH | -- | -- |
| FLT101PH | -- | -- |
| FLT113PH | -- | -- |
| FLT121PH | -- | -- |
| FLT133PH | -- | -- |
| FLT141PH | -- | -- |
| FLT153PH | -- | -- |
| FLT161PH | -- | -- |
| FLT173PH | -- | -- |
| FLT181PH | -- | -- |
| FLT193PH | -- | -- |
| FLT203PH | -- | -- |
| FLT213PH | -- | -- |
| FLT223PH | -- | -- |

UV : 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 6 : Stability Study Results Summary

The Gen-2005-016 generators were found to stay connected to the grid for all the scenarios that were studied. Figure 3 and 4 show the system response for the case FLT193PH and FLT213PH respectively. These two cases are part of FERC 661A fault types.

FERC issued Order #661A in December 2005. In Order #661A, in the Low Voltage Ride Through provisions, FERC ordered that wind farms are required to stay on line for three phase faults at the point of interconnection. Wind farms that have an Interconnection agreement signed before December 31, 2006 will fall under the transitional requirements of having to withstand a fault at the point of interconnection that draws the voltage down to 0.15 p.u. After this date, wind farms that sign an Interconnection Agreement will be required to stay on line for faults that draw the voltage down to 0.0 p.u. Faults FLT193PH and FLT203PH are faults that simulate on Order #661A for IA signed prior to December 31, 2006. Faults FLT213 and FLT223PH are faults that simulate on Order #661A for IA signed after December 31, 2006.

The simulation results of both summer and winter load cases indicated that there was no stability problem associated with the project GEN-2005-016 and all the synchronous generators' rotor angles settled down to steady state values.

# 7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position Gen-2005-016 with its output at 150 MW consisting of Gamesa 2.0 MW wind turbines. The study was conducted for two different power flow scenarios, i.e., one for summer peak load and the other for winter peak load. The study has not indicated any angular or voltage instability problem for the contingencies analyzed in both the scenarios. The study has also indicated that Gen-2005-016 will comply with FERC Order #661A.

**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-2005-016 for FLT193PH

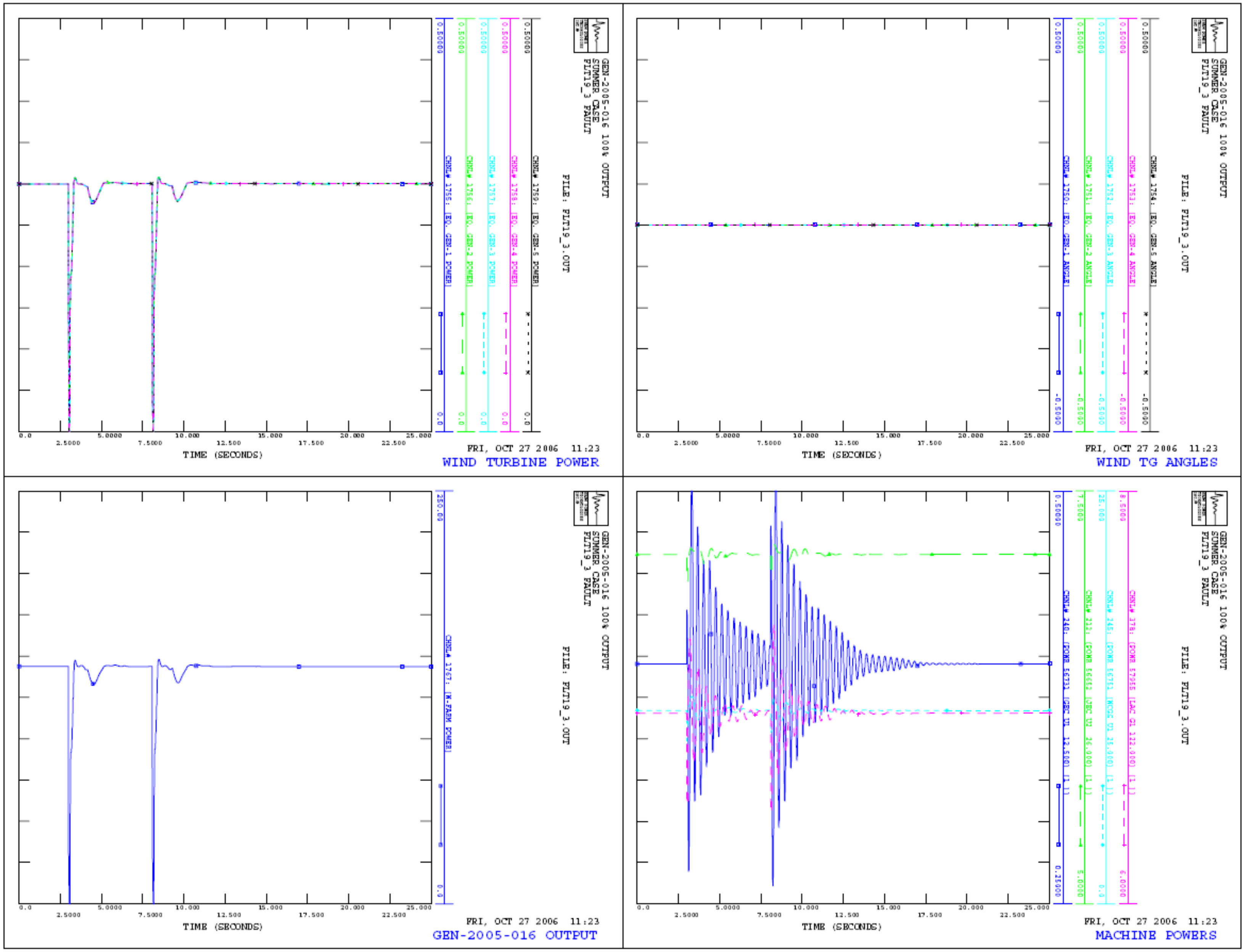

Figure 3 : System Responses with 100% output of Gen-2005-016 for FLT193PH (Cont'd)

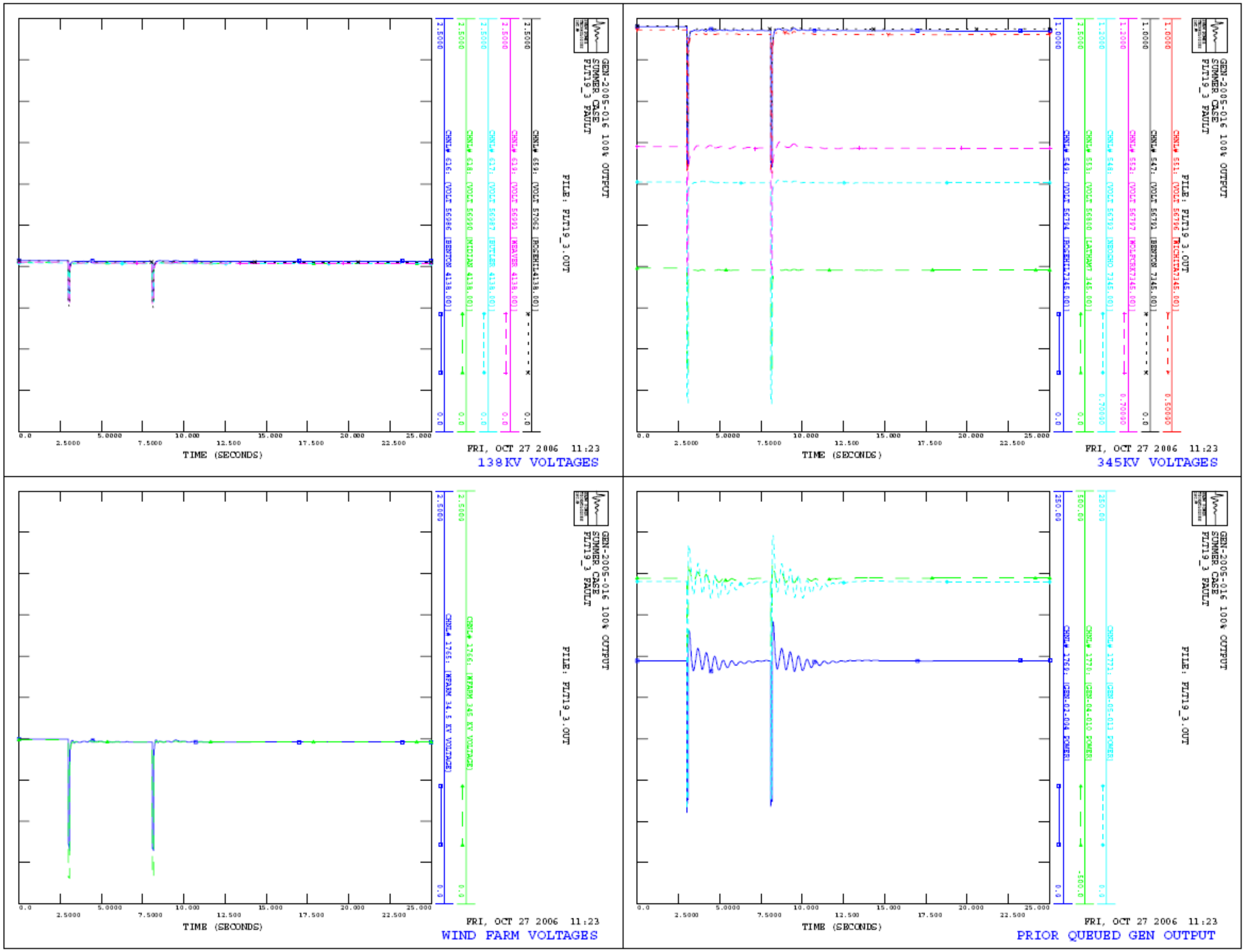

Figure 4 : System Responses with 100% output of Gen-2005-016 for FLT203PH

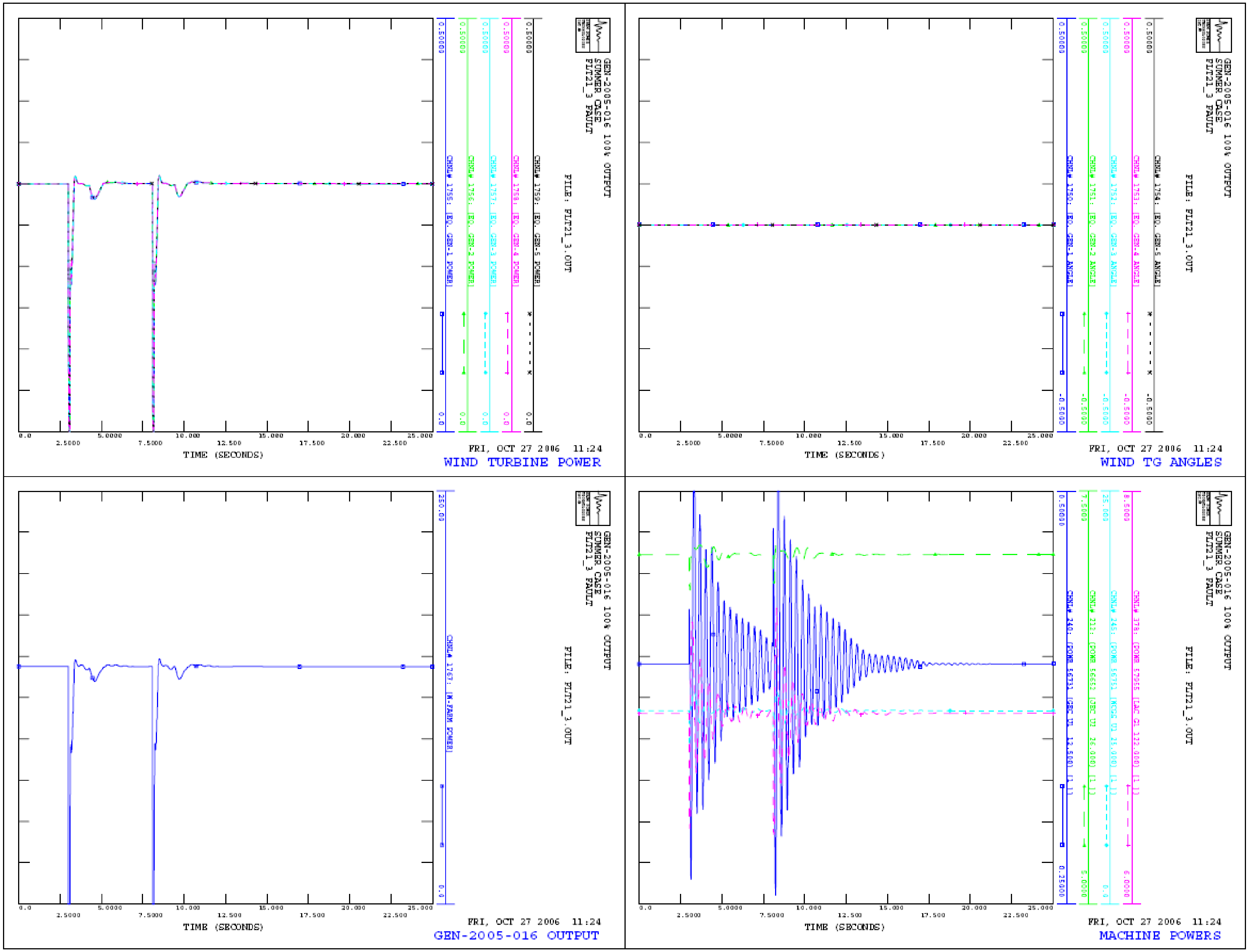

Figure 4 : System Responses with 100% output of Gen-2005-016 for FLT203PH (Cont'd)