SPP Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2004–003

Restudy

SPP Tariff Studies
(#GEN-2004-003)

June 2006

Summary

Black & Veatch performed the following Study at the request of the Southwest Power Pool (SPP) for Generation Interconnection request GEN-2004-003. 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.

Pursuant to the tariff, Black & Veatch was asked to perform a detailed Impact re-Study of the generation interconnection request to satisfy the Impact re-Study Agreement executed by the requesting customer and SPP. The purpose of the re-Study was to determine the impacts of a new turbine manufacturer that the Customer planned to use. The Customer has asked for the re-Study to examine Mitsubishi turbines.

<u>FERC Order #661A Compliance</u>
FERC Order #661A was issued in December, 2005, in which the Customer is required to comply with the transitional provisions of the low voltage ride through (LVRT) standard. In the transitional provisions, the wind turbines shall be able to withstand (remain on-line for) a fault that produces 0.15 pu voltage at the point of interconnection for 5-9 cycles.

In previous impact studies conducted and consulted out by SPP, it has been observed that Mitsubishi turbines are vulnerable to the new requirements in FERC Order #661A LVRT provisions. This is particularly true in remote parts of the transmission system coupled with wind farm layouts that contain long runs of overhead line for collector circuits. This vulnerability was observed in this request since both of these conditions applied.

In the study, Black & Veatch made the determination that for the 240MW of Mitsubishi turbines to stay on line for Fault FLT13PH (a three phase fault at the point of interconnection followed by tripping of the line from the POI switching station to Nichols 115kV, followed by a reclose and subsequent lockout) that in addition to the 70MVAR of capacitor banks, a 200 MVA STATCOM device is required to be installed at the Customer's 34.5kV bus in their substation.

Therefore, for the proposed wind farm and substation configuration supplied to SPP by the Customer, the following requirements are required. These facilities will need to be include into an Interconnection Agreement between the Customer, SPP, and Xcel Energy. The requirements are

- 115kV, 10 MVAR capacitor bank at the Customer's 115kV bus in the Customer substation

- 34.5kV, 60 MVAR staged capacitor banks (or multiple banks) at the Customer's 34.5kV bus in the Customer substation.

- 34.5kV, +200MVA STATCOM device located at the Customer's 34.5kV bus in the Customer's substation.

At the request of SPP, Black & Veatch conducted a secondary analysis for this request in which the consultant was asked to determine the maximum amount of wind generation that could be installed without the means of a STATCOM device and comply with Order #661A.

Black & Veatch worked with the proposed layout provided by the Customer and determined that a total of 68 MW of wind turbines could be installed with no STATCOM device necessary. However, this 68MW total is conditional upon the following parameters.

- 15MVAR of 34.5kV capacitors are necessary in the Customer substation
- The Customer proposed 60/80/100 MVA transformer with Z=9% cannot be reduced in size.
- The 68MW of wind turbines that can be installed are the following
  - Wind Turbine String 'A' (16 MW)
  - Wind Turbine String 'B' (15 MW)
  - Wind Turbine String 'C' (37 MW)

Additional SPP Analysis

Upon receiving the Black &Veatch report and study files, SPP conducted some additional analysis to determine other solutions to the LVRT issue. Highlights of this analysis are as follows.

Wind Farm Only Analysis - After several iterations of working within the framework of the wind farm layout provided by the Customer, an alternate arrangement for the wind farm was determined below.

- 113 MW Wind Farm – (1) 40 MVA STATCOM required with 32MVAR of 34.5kV capacitors. The following turbine and collector configuration will be required.
  - Include the 68 turbines (68MW) mentioned above.
  - Include Turbine String 'D' (45 MW).
    - The circuit from the substation to Jct. Box 'D' will be required to be triple circuit 954 ACSR MCM instead of the proposed double circuit.
  - The Customer proposed 60/80/100 MVA transformers with Z=9% can not be reduced in size. A total of two are necessary.
  - It is thought that Wind Turbine Strings 'E', 'F', & 'G' need to be served by a new 115/34.5kV substation as these junction boxes are 3.5 miles, 4.5 miles, and 5.5 miles from the Customer substation.

The power output of the wind farm at 113MW with the 40MVA STATCOM during Fault FLT13PH is shown in Figure 1. After 15 seconds, the wind farm output is still at 113MW, showing an acceptable response to the fault.

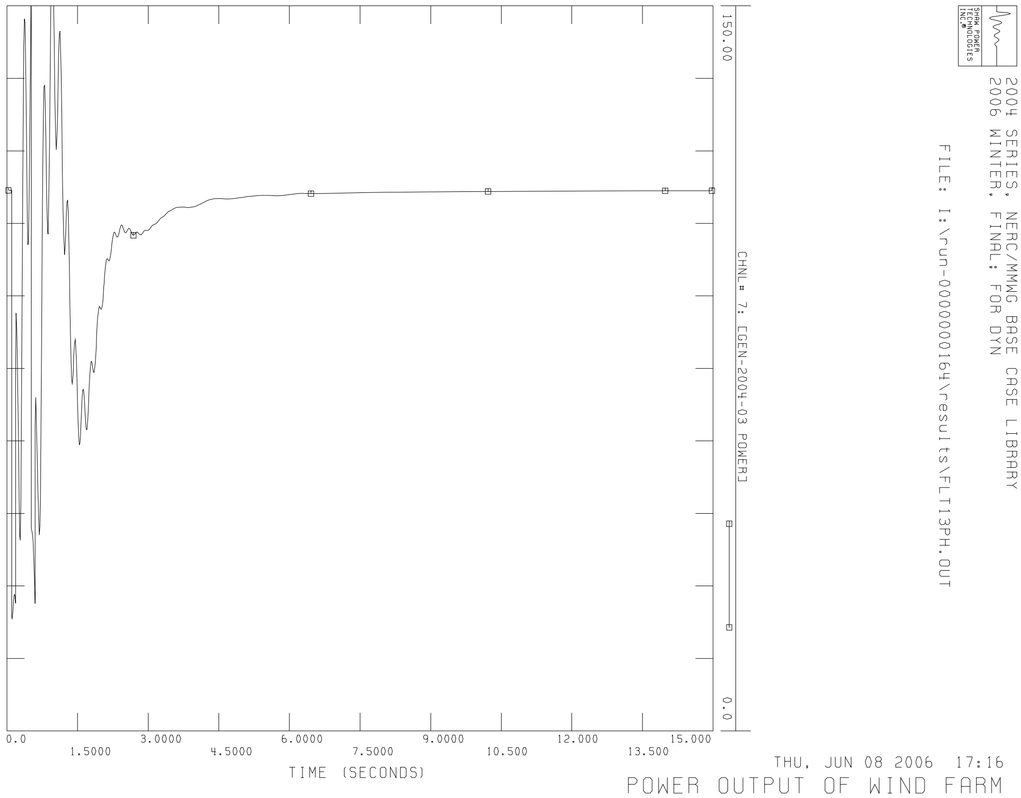

Figure 1. Power Output of 113MW Wind Farm with 40 MVA STATCOM

The power output of the wind farm at 113MW with the 35MVA STATCOM during Fault FLT13PH is shown in Figure 2. As can be seen, the wind farm output drops to 15MW, indicating most of the turbines have tripped off line, an unacceptable response to the fault as it does not comply with Order #661A.

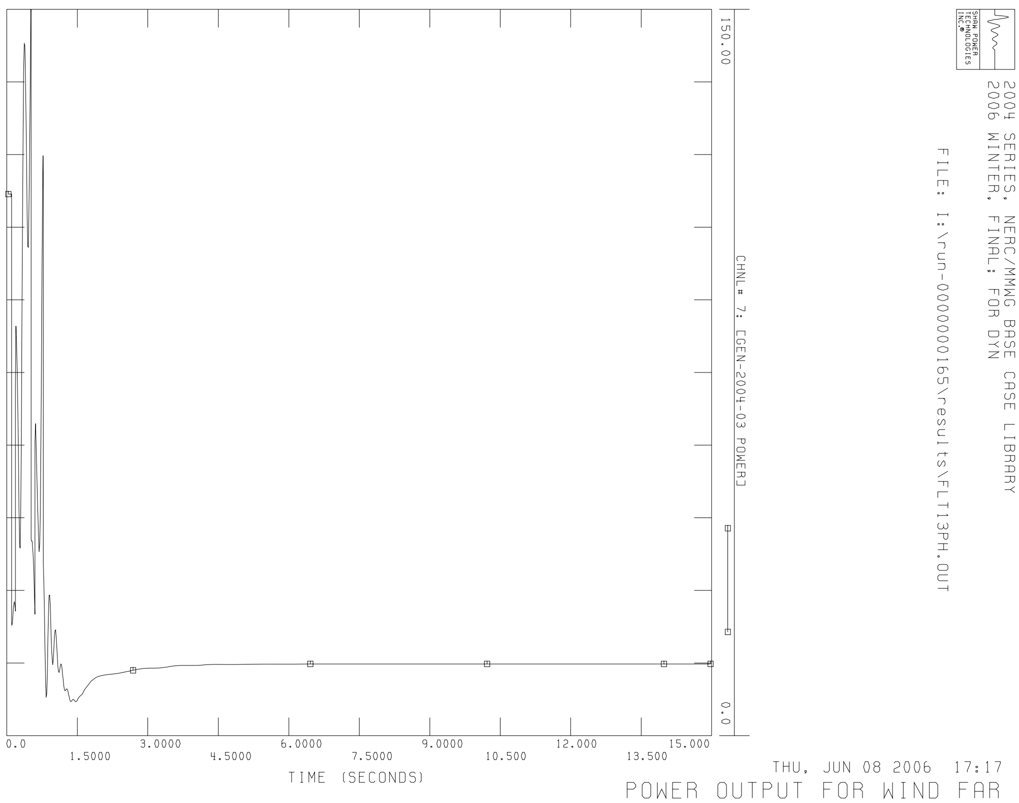

Figure 2. Power Output of 113MW Wind Farm with 35 MVA STATCOM

<u>Transmission Reinforcement Analysis</u> – Due to the weak system condition observed during the outage of the line from the Wind Farm to Nichols, SPP modeled a new 115kV transmission line from the Wind Farm to new station on the Nichols-Hutchison 115kV line. The details of this configuration are as follows

- 174MW Wind Farm, no STATCOM device required
    - Construction of a new line from the Wind Farm to a new station on the Nichols-Hutchinson 115kV line (approximately 10 miles) buit to 795 MCM ACSR. A new terminal would be necessary at the Wind Farm switching station.
    - This analysis determined that Turbine strings ‘A’-‘F’ (with the exception of turbines F1-F9, and F26-F41) could be installed for a total of 174 MW
    - Three (3) 60/80/100 MVA transformers are required
    - All wind farm collector circuit upgrades mentioned above are still required plus the addition of adding an additional circuit to serve Turbine String ‘F’.
    - It may still be possible to get to 240MW with the addition of a STATCOM device and further changes in collector circuit conductor and cable size. This device was not sized at this time.

- o If this option is chosen, a Facility Study must be undertaken to determine the optimal place to interconnect into the Nichols-Hutchinson line. A new impact study will need to be conducted upon that configuration.

The power output of the wind farm at 174MW with this configuration during Fault FLT13PH is shown in Figure 3. After 15 seconds, the wind farm output is still at 174 MW, showing an acceptable response to the fault.

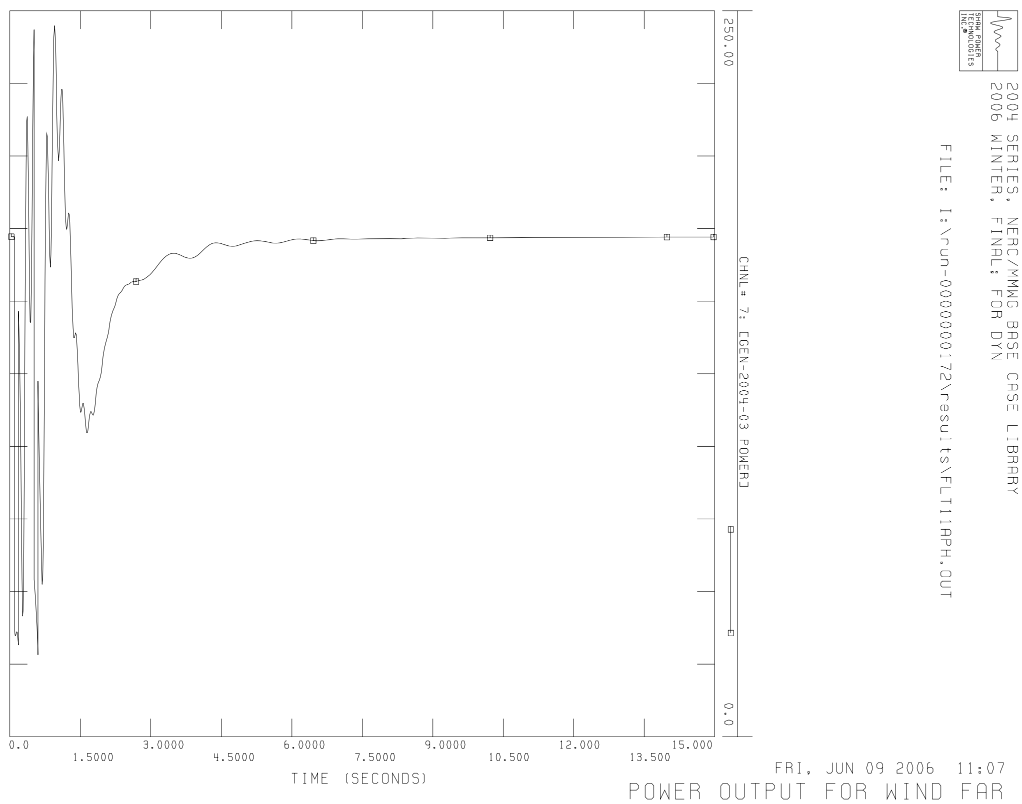

Figure 3. Power Output of 174 MW Wind Farm with new line and no STATCOM

Disclaimer

This analysis was conducted upon the wind farm layout provided by the Customer. The Customer has other options in which the impedence of collector circuits may be lowered including the changing from overhead conductor to underground cable and using oversized underground cable in place of the proposed underground cable. It is beyond the scope of SPP to optimize the Customer's wind farm layout. The possibility may also exist of installing multiple statcom devices at the Junction Boxes of the collector circuits. This will place the reactive power where it is needed most, at the location of the turbines. This option could substantially lower the reactive requirements of the STATCOM.

If the Customer wishes to change the wind farm and substation layout, a new impact study will need to be conducted.

Customer Input Necessary

SPP will need input from the Customer upon how they wish to proceed. The Customer will have the option of going with the following options

- 68MW option, no STATCOM or transmission reinforcement necessary.
- 113MW option, 40MVA STATCOM and wind farm collector upgrades necessary.
- 174MW option, new 115kV line necessary, no STATCOM necessary
- 240MW option, no transmission, 200MVA STATCOM necessary.
- Customer submits new wind farm layout for a restudy.

It is not recommended for Customer to pick the 240MW with no transmission option, as transmission capacity is not available to accommodate this output.

SPP will supply the Customer with a Facility Study Agreement to be executed by the Customer for the option of building the new 115kV line.

Nothing in this study should be construed as a guarantee of transmission service. If the customer wishes to sell power from the facility, a separate request for transmission service shall be requested on Southwest Power Pool's OASIS by the Customer.

IMPACT STUDY FOR SPP GENERATION

QUEUE POSITION GEN-2004-003

SOUTHWEST POWER POOL (SPP)

June 20, 2006

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-2004-003 as part of the System Impact Study. The Interconnection Queue Position Gen-2004-003 is a wind farm of 240 MW capacity proposed to be located within the service territory of Xcel Energy. The wind farm would be interconnected into a new ring bus substation on the Nichols-Kirby 115 kV line near the existing Conway district substation.

Transient Stability studies were conducted with the full output of 240 MW (100%). The wind farm was considered to contain Mitsubishi MWT-1000 (1.0 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 2004 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 60 MVAR capacitors at the 34.5 kV collector bus and about 10 MVAR at the 115 kV switching station would be needed in the summer peak load case.

Transient Stability studies were conducted with the Gen-2004-003 output at 240 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. However, the study has indicated that Gen-2004-003 generators would be disconnected for certain faults near the wind farm by the under voltage protection scheme. This generation interconnection request is required to comply with FERC Order #661A Low Voltage Ride Through (LVRT) provisions. Therefore, under voltage tripping is not allowed for faults that draw the voltage down to 0.15 p.u. at the point of interconnection.

To comply to Order #661A LVRT provisions, a static synchronous compensator (STATCOM) of 200 MVA was found to be required at the 34.5 kV collector bus in order to enable this 240 MW wind farm stay connected to the grid during the grid faults.

Alternatively, a wind farm capacity of 68 MW, with 68 Mitsubishi 1.0 MW turbines, was found not to require any dynamic VAR compensation.

Based on the study results the Customer shall discuss with Mitsubishi, the turbine manufacturer, to enable the Mitsubishi 1.0 MW turbines to ride through low voltages during grid faults either by providing a dynamic VAR compensator or by reducing the overall wind farm output.

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-2004-003.

The Interconnection Queue Position Gen-2004-003 is a wind farm of 240 MW capacity proposed to be located within the service territory of Xcel Energy. The wind farm would be interconnected into a new ring bus substation on the Nichols-Kirby 115 kV line near the existing Conway district substation. The system one line diagram of the area near the Queue Position Gen-2004-003 is shown in below.

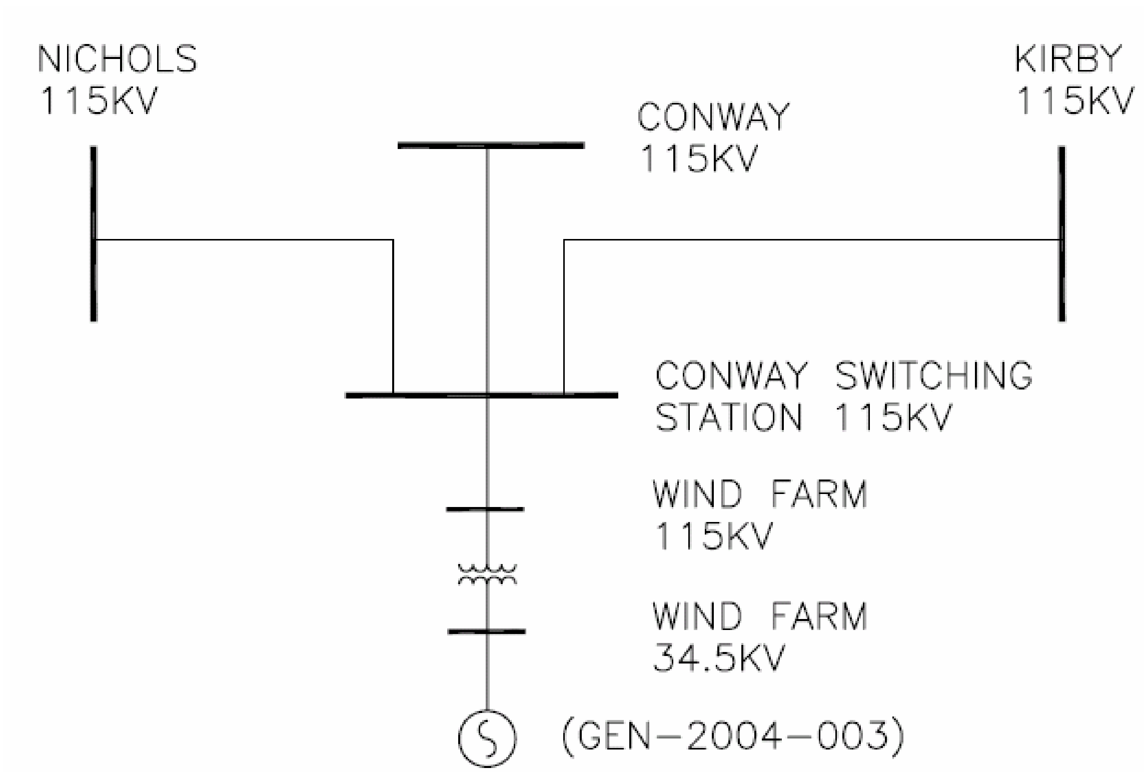

Figure 1 : System One Line Diagram near GEN-2004-003

Transient Stability studies were conducted with the full output of 240 MW (100%). The wind farm was considered to contain Mitsubishi MWT-1000, 1 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 2004 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-2004-003 output at 240 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	3-phase fault on Nichols – Wind Farm 115 kV line, closer to the Wind Farm. The voltage at the point of interconnection (POI) is reduced to 0.15 p.u.
FLT21PH	1-phase fault on Nichols – Wind Farm 115 kV line, closer to the Wind Farm.
FLT33PH	3-phase fault on Kirby – Wind Farm 115 kV line, closer to the Wind Farm. The voltage at the point of interconnection (POI) is reduced to 0.15 p.u.
FLT41PH	1-phase fault on Kirby – Wind Farm 115 kV line, closer to the Wind Farm.
FLT53PH	3-phase fault on Kirby – Grapevine 115 kV line, closer to Grapevine.
FLT61PH	1-phase fault on Kirby – Grapevine 115 kV line, closer to Grapevine.

FLT73PH	3-phase fault on Grapevine – Bowers 115 kV line, closer to Bowers.
FLT81PH	1-phase fault on Grapevine – Bowers 115 kV line, closer to Bowers.
FLT93PH	3-phase fault on Kirby – McLelln3 115 kV line, closer to McLelln3.
FLT101PH	1-phase fault on Kirby – McLelln3 115 kV line, closer to McLelln3.
FLT113PH	3-phase fault on McLelln3 – McLean Rural 115 kV line, closer to McLean Rural.
FLT121PH	1-phase fault on McLelln3 – McLean Rural 115 kV line, closer to McLean Rural.
FLT133PH	3-phase fault on Grapevine – Elk City 230 kV line, closer to Elk City.
FLT141PH	1-phase fault on Grapevine – Elk City 230 kV line, closer to Elk City.
FLT153PH	3-phase fault at the middle of Nichols – Grapevine 230 kV line.
FLT161PH	1-phase fault at the middle of Nichols – Grapevine 230 kV line.
FLT173PH	3-phase fault on Nichols – Hutchinson County Interchange 230 kV line, closer to Hutchinson County Interchange.
FLT181PH	1-phase fault on Nichols – Hutchinson County Interchange 230 kV line, closer to Hutchinson County Interchange.
FLT193PH	3-phase fault on Nichols – Whitaker 115 kV line, closer to Whitaker.
FLT201PH	1-phase fault on Nichols – Whitaker 115 kV line, closer to Whitaker.
FLT213PH	3-phase fault on Whitaker – East Plant Interchange 115 kV line, closer to East Plant Interchange.
FLT221PH	1-phase fault on Whitaker – East Plant Interchange 115 kV line, closer to East Plant Interchange.

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 20 cycles.

4. SIMULATION MODEL

The customer requested to use Mitsubishi Wind turbines for the System Impact Study. The Mitsubishi turbines are a three phase induction generator. The following are the main electrical parameters of the Mitsubishi MWT-1000 wind turbine.

Rated Power : 1,000 kW
Apparent Power : 1,110 kVA
Maximum Reactive Power Output : 0 kVAR
Maximum Reactive Power Consumption : 463 kVAR
Shunt Capacitor at Generator Terminal : 290 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-2004-003 modeled.

Table 2 provides the number of Mitsubishi 1.0 MW wind generators modeled as equivalents at each collector buses of the wind farm.

Collector Bus	**No. of generators aggregated**
A16	16
B15-1	15
C14	14
C15	7
C22	16
D10	10
D11	3
D14	16
D30	16
E10	10
E11	3
E14	16
E30	16
F1	9
F10	16
F26	16
G1	9
G10	16
G26	16

Table 2 : Equivalent Generators with Mitsubishi 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 : 0.028 ohms per 1000 ft for 1000 kcmil 34.5 kV cable
0.047 ohms per 1000 ft for 500 kcmil 34.5 kV cable
0.107 ohms per 1000 ft for 4/0 AWG 34.5 kV cable
0.212 ohms per 1000 ft for 1/0 AWG 34.5 kV cable
0.109 ohms per mile for 954 ACSR 34.5 kV line
0.13 ohms per mile for 795 ACSR 34.5 kV line
0.212 ohms per mile for 477 ACSR 115 kV line

Line reactance : 0.037 ohms per 1000 ft for 1000 kcmil 34.5 kV cable
0.042 ohms per 1000 ft for 500 kcmil 34.5 kV cable
0.049 ohms per 1000 ft for 4/0 AWG 34.5 kV cable
0.055 ohms per 1000 ft for 1/0 AWG 34.5 kV cable
0.395 ohms per mile for 954 ACSR 34.5 kV line
0.408 ohms per mile for 795 ACSR 34.5 kV line
0.43 ohms per mile for 477 ACSR 115 kV line

Line capacitance: 0.9 nF per 1000 ft for 1000 kcmil 34.5 kV cable
0.69 nF per 1000 ft for 500 kcmil 34.5 kV cable
0.52 nF per 1000 ft for 4/0 AWG 34.5 kV cable
0.45 nF 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 60 MVA.

A prior queued project, Gen-2002-022 of 240 MW was also included in the model.

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 60 MVAR capacitors at 34.5 kV collector buses and about 10 MVAR capacitors at 115 kV switching station would be needed in the summer peak load case. These additional capacitors were included in the study.

Gen-2004-003 was modeled using the Mitsubishi wind turbine model provided by the Customer. The model included the shaft dynamics and the pitch control. The Mitsubishi 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-2004-003.

Description	Value
Synchronous reactance, X	0.37 pu
Transient reactance, X’	0.18 pu
Leakage reactance, XL	0.111 pu
Transient time constant, T’	0.81 sec
Drive train inertia	8.31 sec
Shaft damping	1.0 pu
Shaft stiffness	2.98 pu
Generator rotor inertia	0.37 sec
Number of generator pole pairs	2
Gear box ratio	92.05

Table 3 : Mitsubishi 1.0 MW Wind Turbine Generator Parameters

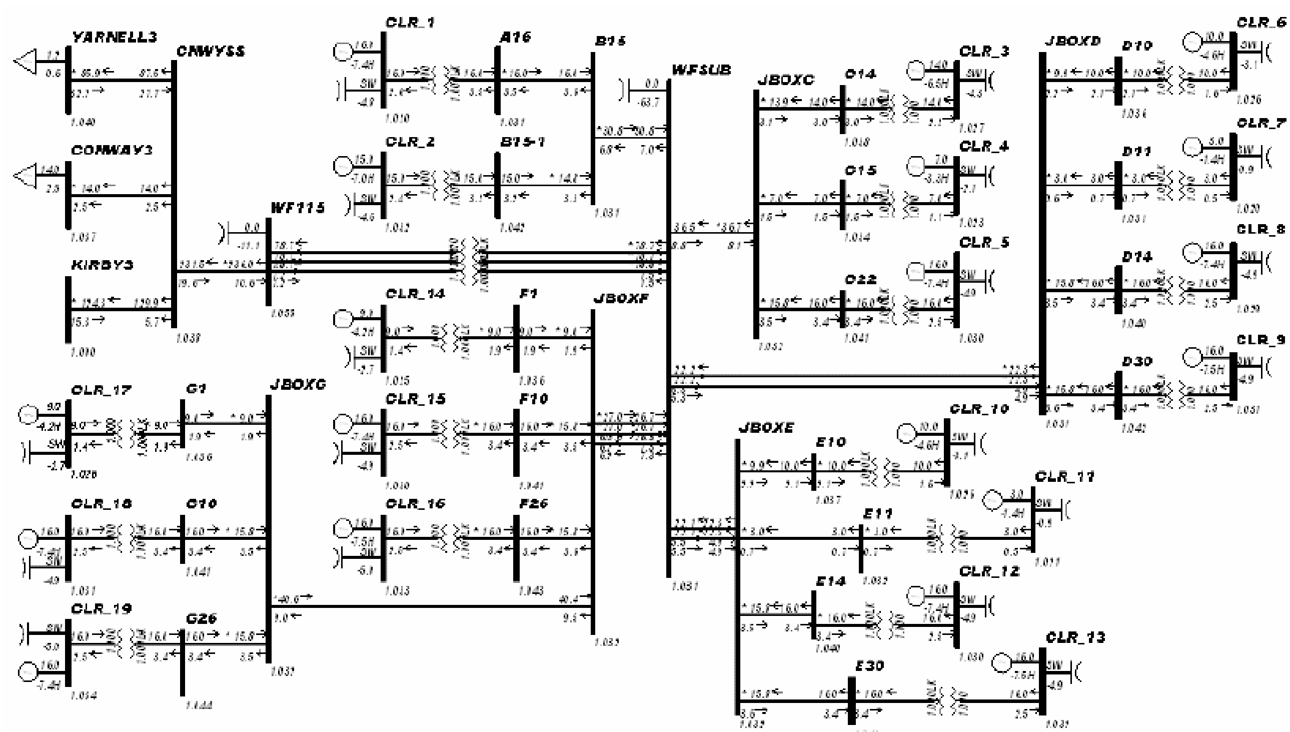

Figure 2 : Gen-2004-003 Power Flow Model

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 loads in the SPP control area were scaled up to accommodate the new generation as indicated in Table 5.

Protective Function	**Protection Setting**	**Time Delay**
Over Frequency	61.0 Hz	0.5 seconds
Under Frequency	59.0 Hz	0.1 seconds
Under Voltage	60%	0.15 seconds
Under Voltage	70%	0.25 seconds
Under Voltage	85%	0.5 second
Over Voltage	120%	0.02 second

Table 4 : Protective Functions and Settings for Mitsubishi 1.0 MW Turbines

Scenario	**Control Area**	**Load**	
		Summer	**Winter**
Without the Wind Farm (Base Case)	SPS	5034 MW	3384 MW
	AEP	10280 MW	6965 MW
	OGE	5928 MW	3896 MW
	KCPL	3884 MW	2313 MW
Gen-2004-003 at 100% output with the prior queued projects	SPS	5074 MW	3424 MW
	AEP	10380 MW	7065 MW
	OGE	5978 MW	3946 MW
	KCPL	3934 MW	2363 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-2004-003.

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

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

Gen-2004-003 generators were found to be tripped for the following faults:

- FLT13PH and FLT21PH : Fault on Nichols – Wind Farm 115 kV line, closer to the Wind Farm.
- FLT33PH and FLT41PH : Fault on Kirby – Wind Farm 115 kV line, closer to the Wind Farm
- FLT53PH : 3-phase fault on Kirby – Grapevine 115 kV line, closer to Grapevine.
- FLT93PH : 3-phase fault on Kirby – McLelln3 115 kV line, closer to McLelln3.
- FLT153PH : 3-phase fault at the middle of Nichols – Grapevine 230 kV line.
- FLT193PH : 3-phase fault on Nichols – Whitaker 115 kV line, closer to Whitaker.
- FLT213PH : 3-phase fault on Whitaker – East Plant Interchange 115 kV line, closer to East Plant Interchange.

The Gen-2004-003 generators were found to stay connected to the grid for the remaining contingencies. The voltages at the wind generator terminals were found to be lower than the permissible 0.6 p.u for more than 0.15 seconds for the above contingencies and hence the generators were found to be tripped by the under voltage relays as illustrated in Figure 3 for FLT13PH case.

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 FLT13PH and FLT33PH are faults that simulate on Order #661A LVRT fault.

Simulations were carried out to verify whether the wind farm could be made to remain connected to the grid during the grid faults with the help of some kind of dynamic VAR compensator system. The following options were considered in the study:

- A static VAR compensator (SVC) at the 34.5 kV collector bus
- A static synchronous compensator (STATCOM) at the 34.5 kV collector bus

An SVC is similar to a shunt capacitor and provides very little reactive power support during very low voltages, however would be very beneficial during the voltage recovery period following the fault removal. It was found that employing an SVC at the collector buses of Gen-2004-003 did not prevent the wind turbine generators being tripped due to under voltage.

Alternatively, a static synchronous compensator (STATCOM) was considered at the 34.5 kV collector bus and was found that a STATCOM of 200 MVA would be required in order to enable the Gen-2004-003 wind farm stay connected to the grid during the grid faults. Figure 4 shows the system response with 200 MVA STATCOM at the 34.5 kV collector bus for FLT13PH case.

Studies were also conducted to identify a lower wind farm capacity for which no external dynamic VAR support would be necessary during the grid faults. It was found that if the Gen-2004-003 wind farm's capacity is reduced to 68 MW, then the wind farm would stay connected to the grid without the assistance of any dynamic VAR compensation. Shunt capacitors of 15 MVAR would be required at the 34.5 kV collector buses in order to have zero reactive power transfer between the wind farm and the grid, if the wind farm capacity is 68 MW.

The simulation results of both peak and light load cases indicated that there was no stability problem associated with the project GEN-2004-003 and all the synchronous generators' rotor angles settled down to steady state values.

It was also noted that the prior queued project Gen-2002-022 was found to stay connected in all the cases studied.

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position Gen-2004-003 with its output at 240 MW consisting of Mitsubishi 1.0 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.

However, the study has indicated that Gen-2004-003 generators would be disconnected for certain faults near the wind farm by the wind turbine generator under voltage protection scheme. As this request must comply with FERC Order #661A, under voltage tripping is not allowed.

A static synchronous compensator (STATCOM) of 200 MVA was found to be required at the 34.5 kV collector bus in order to enable this 240 MW wind farm stay connected during the grid faults.

Alternatively, a wind farm capacity of 68 MW, with 68 Mitsubishi 1.0 MW turbines, was found not to require any dynamic VAR compensation.

Based on the study results the Customer shall discuss with Mitsubishi, the turbine manufacturer, to enable the Mitsubishi 1.0 MW turbines to ride through low voltages during grid faults either by providing a dynamic VAR compensator or by reducing the overall wind farm output.

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-2004-003

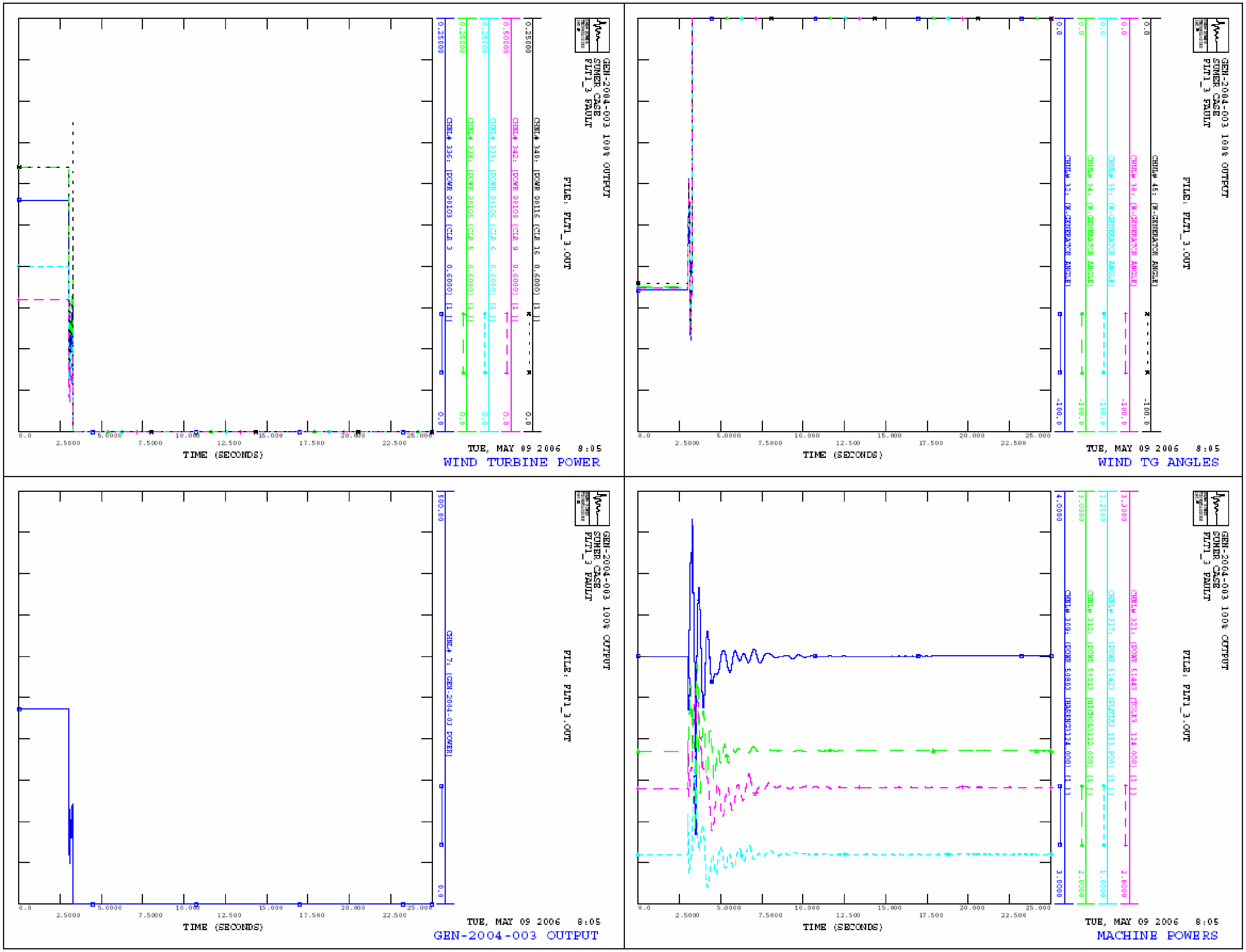

Figure 3 : System Responses with 100% output of Gen-2004-003 (Cont'd)

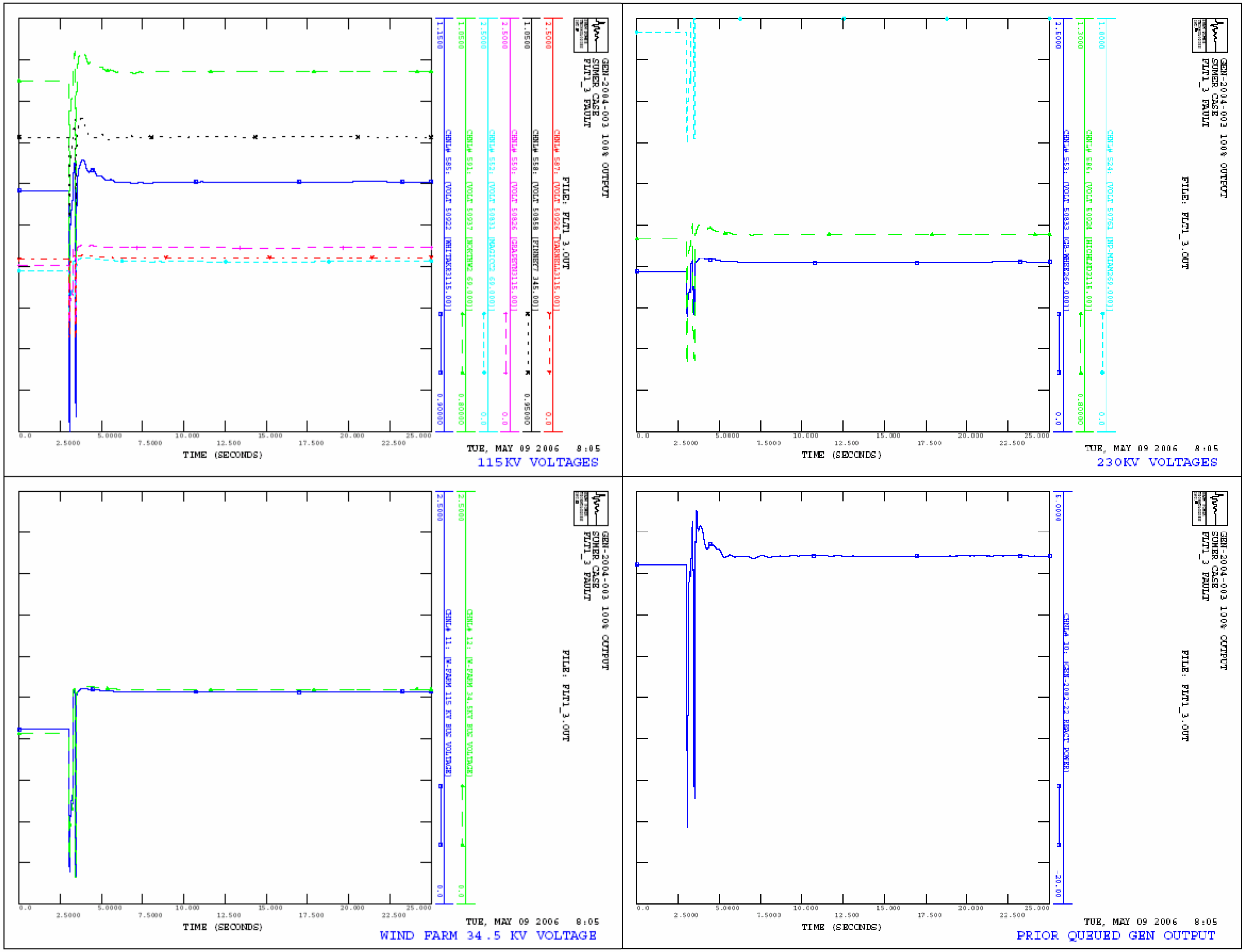

Figure 4 : System Responses with a 200 MVA STATCOM and 100% output

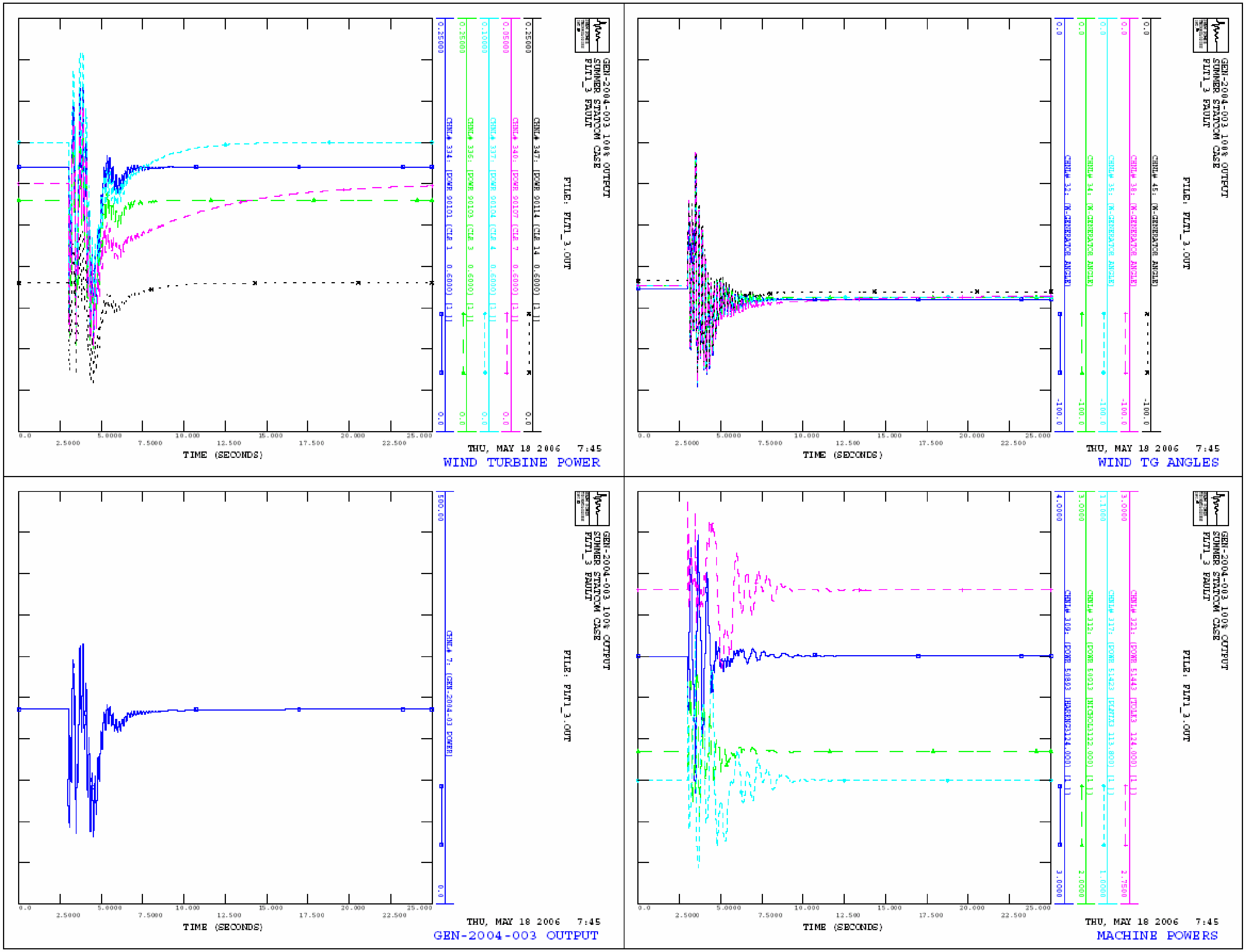

Figure 4 : System Responses with a 200 MVA STATCOM and 100% output (Cont'd)