Impact Study for Generation Interconnection Request GEN – 2003 – 018

SPP Tariff Studies
(#GEN-2003-018)

December 2004

Executive Summary

Attached is a System Impact study performed for Southwest Power Pool (SPP) interconnection request Gen-2003-018. The interconnection request Gen-2003-018 is a wind farm of 298.5 MW capacity proposed to be located in Chaves County, New Mexico within the service territory of Southwestern Public Service Company (SPS). The proposed point of interconnection is in the existing Eddy County – Tolk 345 kV transmission line at a new switching station located about 55 miles east of Roswell in Lea County near Caprock. The requested in-service date is October 1, 2005.

Powerflow Analysis

A detailed powerflow analysis was performed in order to determine if any facilities in the surrounding transmission system are overloaded due to the addition of the generating facility. Modified versions of the 2004 series SPP powerflow models were used. The seasons evaluated were: 2005 winter peak, 2007 summer peak, 2007 winter peak, 2010 summer peak, and the 2010 winter peak. The models were modified to include all prior queued requests for interconnection and any network upgrades already assigned or committed.

The contingency analysis reveals that, due to the interconnection of the GEN-2003-018 generating facility, the Eddy County 230/115kV transformer becomes overloaded for the outage of Eddy County – Seven Rivers 230kV and the outage of the Seven Rivers 230/115kV transformer. Replacement of this transformer would cost approximately $3.1 million and require a lead-time of approximately 16-18 months. Other non-committed projects in the local area may alter the requirements for the Eddy County transformer replacement.

Analysis was also performed to determine the requirements for any line reactors at the 345kV switch station. During the feasibility study, it was initially determined that 30MVAR may be required (15MVAR on each line leaving the station) to help limit the line voltages at the switch station after a line energization event. However, further analysis determined that no line reactors were required to control the line voltage due to line energization events.

Stability Analysis

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Black and Veatch performed the stability analysis (found in the attached report) to satisfy the Impact Study Agreement executed by the requesting customer and SPP Generation Interconnection request Gen-2003-018.

The study has indicated that the Gen-2003-018 generators would be disconnected by the under voltage protection for three phase faults on the Wind Farm Switching Station – Tolk 345kV line. In the study, the wind turbine generators were found to be tripped even if the total generation was reduced to 50%. The Interconnection Customer shall consider this additional risk implication of wind farm outages that the wind turbine under voltage control scheme may cause to the wind farm.

The 34.5 kV, 138 kV and 345kV bus voltages at the Wind Farm were found to be about 20% higher than the nominal voltage following the tripping of wind turbine generators. This was due to the large amount of capacitors connected to the 34.5 kV buses. It is recommended that the 138/345kV transformer be disconnected automatically if all the wind turbine generators are tripped by their protection.

The impact study performed by Black & Veatch is attached.

IMPACT STUDY FOR SPP GENERATION

QUEUE POSITION GEN-2003-018

SOUTHWEST POWER POOL (SPP)

November 5, 2004

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-2003-018 as part of the System Impact Study. The Interconnection Queue Position Gen-2003-018 is a wind farm of 298.5 MW capacity proposed to be located in Chaves County, New Mexico within the service territory of Southwestern Public Service Company (SPS). The proposed point of interconnection is in the existing Eddy County – Tolk 345 kV transmission line at a new switching station located about 55 miles east of Roswell in Lea County near Caprock.

Transient Stability studies were conducted with the full output of 298.5 MW (100%). The wind farm was considered to contain GE 1.5 MW turbines in the study with the standard low voltage ride thru package.

The 2009 summer peak load flow case together with the SPP MDWG 2004 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 model available in PSS/E.

Transient Stability studies were conducted with the Gen-2003-018 output at 298.5 MW (100%) for two scenarios, i.e., (i) Black Water and Eddy dc ties exporting power from SPS to WECC and (ii) the dc ties importing power from WECC to SPS system. 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 options. However, the study has indicated that the Gen-2003-018 generators would be disconnected by the under voltage protection for three phase faults on the Wind Farm Switching Station – Tolk 345 kV line. The Interconnection Customer shall consider this additional risk implications of wind farm outages that the wind turbine under voltage control scheme may cause to the wind farm.

The 34.5 kV, 138 kV and 345 kV bus voltages at the Wind Farm were found to be about 20% higher than the nominal voltage following the tripping of wind turbine generators. This was due to the large amount of capacitors connected to the 34.5 kV buses. It is recommended that the 138/345 kV transformer be disconnected automatically if all the wind turbine generators are tripped by their protection.

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-2003-018.

The Interconnection Queue Position Gen-2003-018 is a wind farm of 298.5 MW capacity proposed to be located in Chaves County, New Mexico within the service territory of Southwestern Public Service Company (SPS). The proposed point of interconnection is in the existing Eddy County – Tolk 345 kV transmission line at a new switching station located about 55 miles east of Roswell in Lea County near Caprock. The system one line diagram of the area near the Queue Position Gen-2003-018 is shown in below.

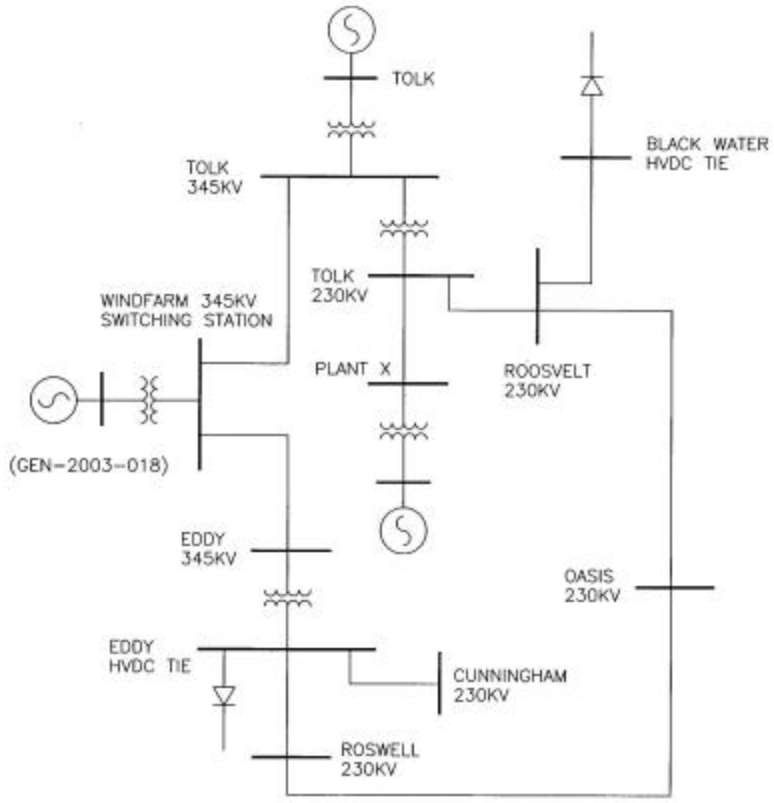

Figure 1 : System One Line Diagram near GEN-2003-018

Transient Stability studies were conducted with the full output of 298.5 MW (100%). The wind farm was considered to contain GE 1.5 MW turbines in the study with the standard low voltage ride thru package.

2. STABILITY STUDY CRITERIA

The 2009 summer peak load flow case together with the SPP MDWG 2004 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. In addition, the performance of the nearby back-to-back HVDC ties to WECC, Black Water and Eddy, were also monitored.

3. SIMULATION CASES

Transient Stability studies were conducted with the Gen-2003-018 output at 298.5 MW (100%) for two scenarios, i.e., (i) Black Water and Eddy dc ties exporting power from SPS to WECC and (ii) the dc ties importing power from WECC to SPS system.

Table 1 indicates the contingencies which were studied for each of the two (dc ties export and import) cases.

Fault Number	Fault Definition
FLT13PH	Three phase fault on Tolk – Gen-2003-018 switching station 345 kV line at mid point.
FLT21PH	Single phase fault on Tolk – Gen-2003-018 switching station 345 kV line at mid point.
FLT33PH	Three phase fault on Gen-2003-018 switching station – Eddy County 345 kV line, near Eddy County.
FLT41PH	Single phase fault on Gen-2003-018 switching station – Eddy County 345 kV line, near Eddy County.
FLT53PH	Three phase fault on Potter County – Finney 345 kV line at mid point.

FLT61PH	Single phase fault on Potter County – Finney 345 kV line at mid point.
FLT73PH	Three phase fault on Tucomari – O.K.U 345 kV line, near Tucomari.
FLT81PH	Single phase fault on Tucomari – O.K.U 345 kV line, near Tucomari.
FLT93PH	Three phase fault on Cunningham – Potash Junction 230 kV line, near Potash Junction.
FLT101PH	Single phase fault on Cunningham – Potash Junction 230 kV line, near Potash Junction.
FLT113PH	Three phase fault on Lea County – Midland 230 kV line, near Midland.
FLT121PH	Single phase fault on Lea County – Midland 230 kV line, near Midland.
FLT133PH	Three phase fault on Eddy County – Chaves County 230 kV line, near Chaves County.
FLT141PH	Single phase fault on Eddy County – Chaves County 230 kV line, near Chaves County.
FLT153PH	Three phase fault on Cunningham – Eddy County 230 kV line, near Eddy County.
FLT161PH	Single phase fault on Cunningham – Eddy County 230 kV line, near Eddy County.
FLT173PH	Three phase fault on Eddy County – Roswell Interchange 115 kV line at mid point.
FLT181PH	Single phase fault on Eddy County – Roswell Interchange 115 kV line at mid point.
FLT193PH	Three phase fault on Tolk – Roosvelt County 115 kV line, near Roosvelt County.
FLT201PH	Three phase fault on Tolk – Roosvelt County 115 kV line, near Roosvelt County.
FLT213PH	Three phase fault on Eddy County – Pecos Interchange 115 kV line, near Pecos Interchange.
FLT221PH	Single phase fault on Eddy County – Pecos Interchange 115 kV line, near Pecos Interchange.

Table 1: Study Cases

In all of the simulations, the fault duration was considered to be 5 cycles, except for FLT53PH and FLT61PH in which the fault duration was 3.5 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. For the scenario FLT53PH, reclosing was not considered and single pole tripping and reclosing was considered for FLT61PH.

4. SIMULATION MODEL

The customer requested to use GE Wind turbines 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.

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
M1	11
M2	10
M3	10
M4	11
M5	13
M6	10
M7	10
M8	11
T1	11
T2	11
T3	11
T4	10
T5	10
T6	10
T7	10
L1	10
L2	9
L3	11
L4	10

Table 2 : Equivalent Generators with GE 1.5 MW Turbines

The following transmission line parameters in percent (based on 100 MVA) were used in the model for the 138 kV overhead lines between the Wind Farm and the Switching Station:

Line resistance : 0.118 per mile for 336 ACSR
0.084 per mile for 477 ACSR
0.05 per mile for 795 ACSR

Line reactance : 0.506 per mile for 336 ACSR
0.402 per mile for 477 ACSR
0.303 per mile for 795 ACSR

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.

As per the Customer's one line diagram, 60 MVAR capacitor banks are connected at each of the three 34.5 kV buses, i.e., Top, Mid and Low buses. These 34.5 kV capacitors were modeled as 4x15 MVAR switchable shunts so as to keep the 34.5 kV buses at unity. In the base case, the amount of capacitors needed were: 60 MVAR at Top 34.5 kV bus, 60 MVAR at Mid 34.5 kV bus and 30 MVAR at Lower 34.5 kV bus. A 30 MVAR shunt reactor was considered to be present at the 345 kV switching station as per the earlier Feasibility Study.

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 GE data used in the study is as noted in Table 3.

The 100% base case power flow diagram for the project GEN-2003-018 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 3 : GE 1.5 MW Wind Turbine Generator Parameters

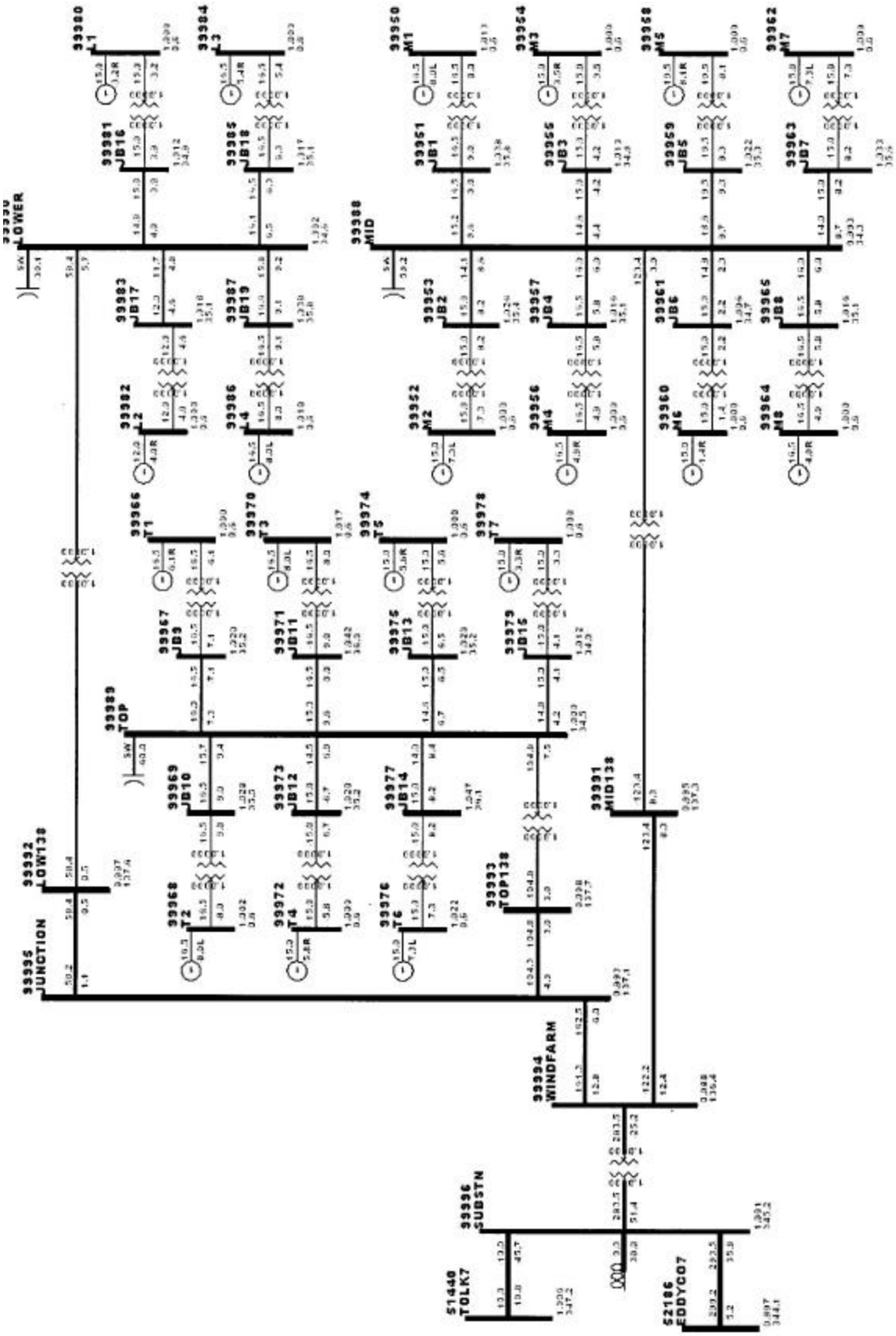

Figure 2 : Base Case Power Flow Diagrams for Phase II with GE 1.5 MW Turbines

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 4.
4. 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	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	30%	0.02 seconds
Under Voltage	70%	0.1 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 4 : Protective Functions and Settings for GE 1.5 MW Turbines

Scenario	Generation within SPP
Without the Wind Farm	38,850 MW
Gen-2003-018 at 100% output	39,149 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 GE 1.5 MW turbines for Gen-2003-018.

Fault Number	DC ties export power to WECC from SPS	DC ties import Power from WECC to SPS
FLT13PH	UV, DC	UV
FLT21PH	- -	- -
FLT33PH	DC	- -
FLT41PH	DC	- -
FLT53PH	- -	- -
FLT61PH	- -	- -
FLT73PH	- -	- -
FLT81PH	- -	- -
FLT93PH	- -	- -
FLT101PH	- -	- -
FLT113PH	- -	- -
FLT121PH	- -	- -
FLT133PH	DC	DC
FLT141PH	DC	DC
FLT153PH	- -	- -
FLT161PH	- -	- -
FLT173PH	- -	- -
FLT181PH	- -	- -
FLT193PH	- -	- -
FLT201PH	- -	- -
FLT213PH	- -	- -
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
DC : Black Water DC converter firing angle chatter

Table 6 : Stability Study Results Summary

The Gen-2003-018 generators were found to be tripped for the following fault:

- FLT13PH : Three phase fault on Wind Farm Switching Station - Tolk 345 kV line at midpoint.

The voltages at the wind generator terminals were found to be lower than the permissible 0.3 p.u for more than 0.02 seconds for the above contingency and hence the generators were found to be tripped by the under voltage relays as illustrated in Figure 3. The Gen-2003-018 generators were found to stay connected to the grid for the remaining contingencies.

Simulations were carried out by considering the Gen-2003-018 output as 150 MW (50%) and found that the wind generators were still found to be tripped for the scenario FLT13PH.

The simulation results also indicated that the Black Water HVDC Converter firing angle did not settle down to a steady state value following the fault isolation for the following scenarios:

- FLT13PH : Three phase fault on Gen-2003-018 Switching Station – Tolk 345 kV line at midpoint.
- FLT33PH : Three phase fault on Gen-2003-018 Switching Station – Eddy County 345 kV line near Eddy County.
- FLT41PH : Single line-to-ground fault on Gen-2003-018 Switching Station – Eddy County 345 kV line, near Eddy County.
- FLT133PH : Three phase fault on Eddy County – Chaves County 230 kV line, near Chaves County.
- FLT141PH : Single line-to-ground fault on Eddy County – Chaves County 230 kV line, near Chaves County.

In order to assess whether the HVDC converter firing angle chatter found in the above cases were caused by Gen-2003-018, simulations were also carried out for the base case, i.e., without Gen-2003-018. It was found that the HVDC converter responses were similar to the response of the system with GEN-20030018, as illustrated in Figure 4. Hence, it can be said that the converter firing angle chatter shown in Figure 3 was not caused by Gen-2003-018.

The simulation results of both cases (export and import) indicated that there was no stability problem associated with the project GEN-2003-018 and all the synchronous generators' rotor angles settled down to steady state values.

The bus voltages were found to recover to pre-fault values except when the Gen-2003-018 generators were tripped due to under voltage for FLT13PH fault. Following the tripping of wind generators, the 34.5 kV, 138 kV and 345 kV bus voltages at Gen-2003-

018 were found to rise up to 120% due to the large amount of capacitors connected to the 34.5 kV buses. It is recommended that the 138/345 kV transformer be tripped if all the wind generators are tripped by their protection. Figure 5 shows the Gen-2003-018 bus voltages in which the 138/345 kV transformer was disconnected 7 cycles after all the wind turbines were tripped by under voltage protection.

7. SUMMARY

A transient stability analysis was conducted for the SPP Interconnection Generation Queue Position Gen-2003-018 with its output at 298.5 MW consisting of GE 1.5 MW wind turbines. The study was conducted for two different power flow scenarios, i.e., one for Black Water and Eddy HVDC ties exporting power to WECC and the other for importing power from WECC. The study has not indicated any angular or voltage instability problem for the contingencies analyzed in both the scenarios.

The study has indicated that the Gen-2003-018 generators would be disconnected by the under voltage protection for three phase faults on the Wind Farm Switching Station – Tolk 345 kV line. In the study, the wind turbine generators were found to be tripped even if the total generation was reduced to 50%. The Interconnection Customer shall consider this additional risk implications of wind farm outages that the wind turbine under voltage control scheme may cause to the wind farm.

The 34.5 kV, 138 kV and 345 kV bus voltages at the Wind Farm were found to be about 20% higher than the nominal voltage following the tripping of wind turbine generators. This was due to the large amount of capacitors connected to the 34.5 kV buses. It is recommended that the 138/345 kV transformer be disconnected automatically if all the wind turbine generators are tripped by their protection.

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.

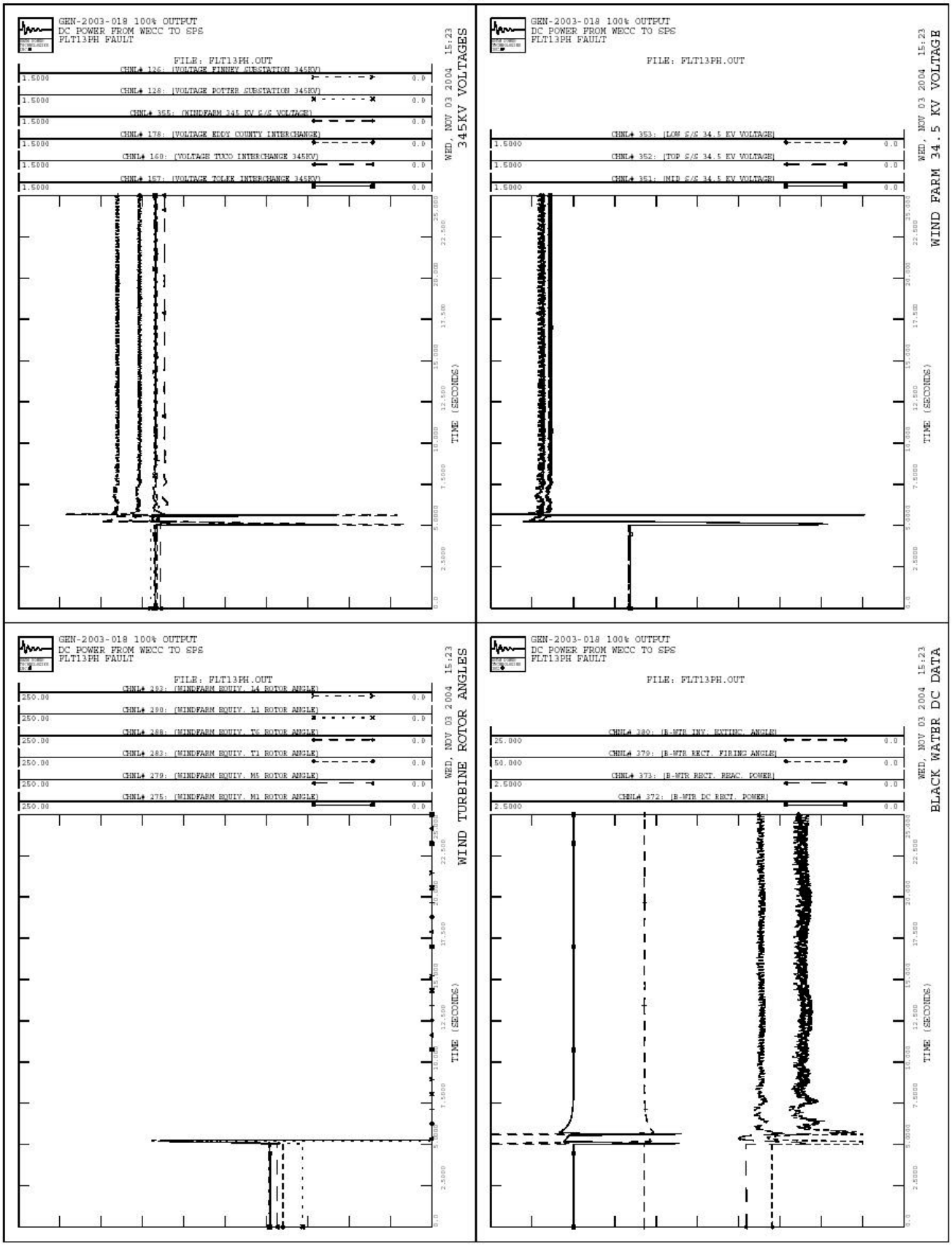

Figure 3 : System Responses with 100% output of Gen-2003-018

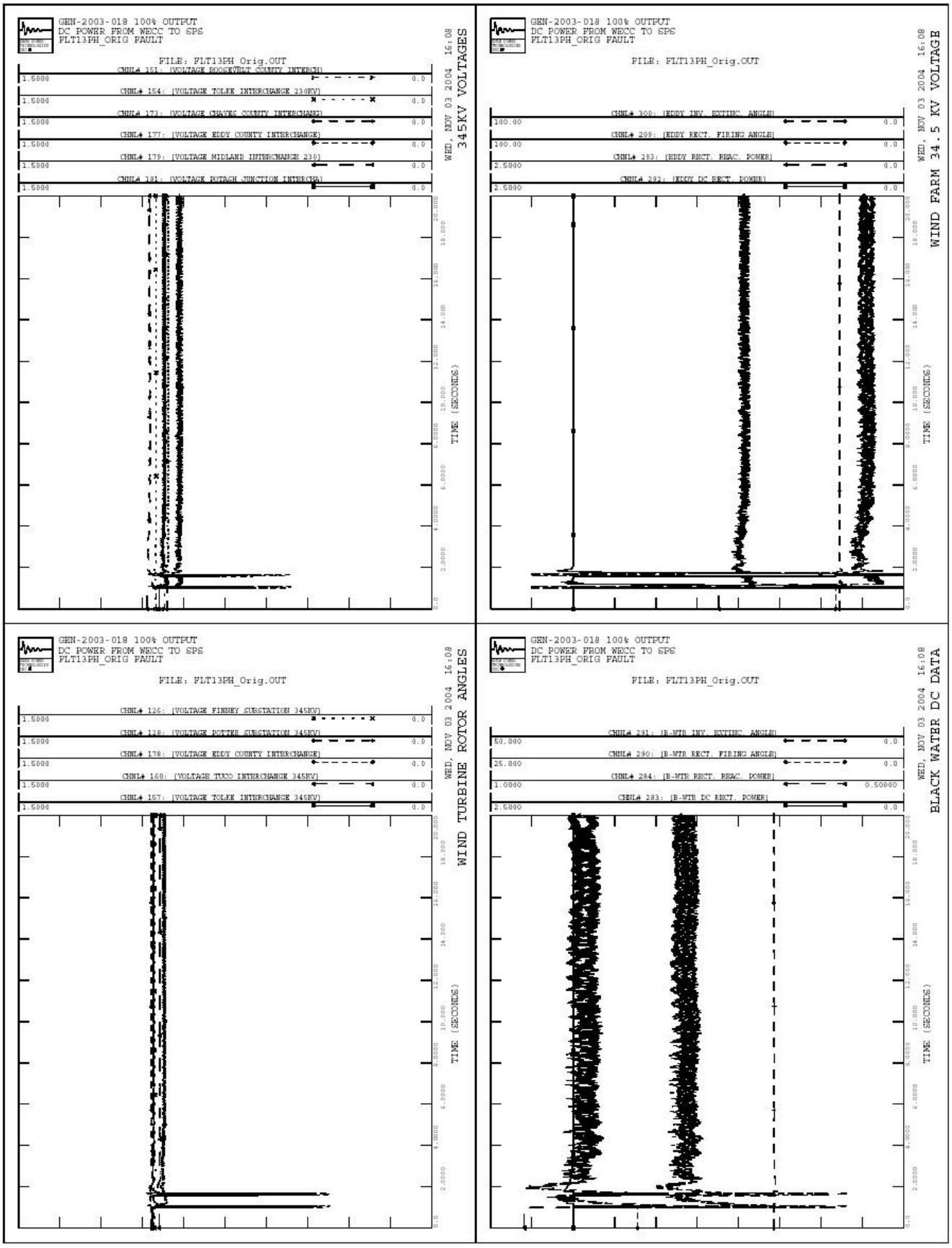

Figure 4 : System Response without Gen-2003-018

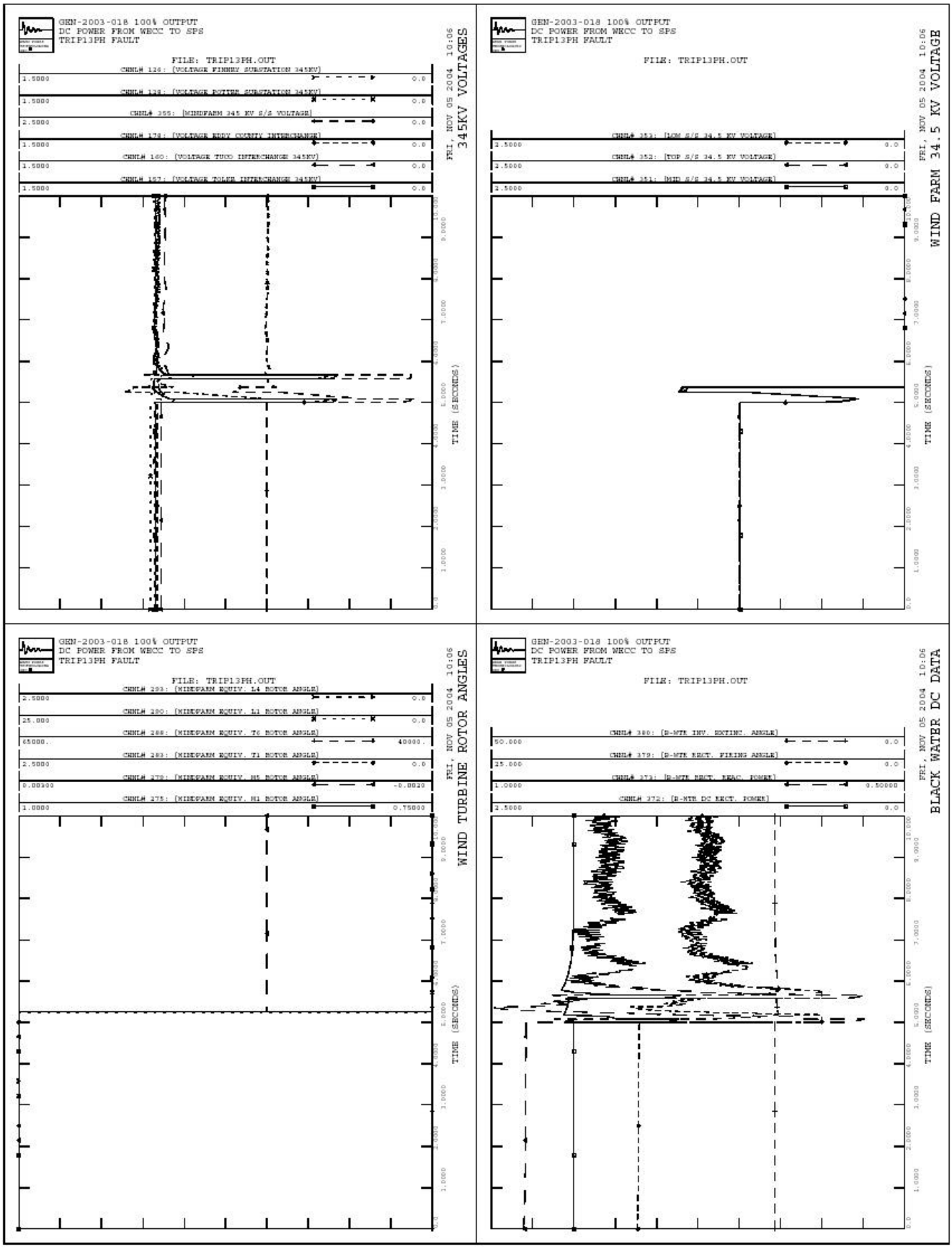

Figure 5 : System Responses with the 230/345 kv transformer trip logic