Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2003–020

2nd Restudy

SPP Coordinated Planning
(#GEN-2003-020)

April 2006

1 Summary

ABB Inc. Electric Systems Consulting (ABB) performed the following Study at the request of the Southwest Power Pool (SPP) for Generation Interconnection request GEN-2003-020. 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, ABB 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.

The study history of this Generation Interconnection Request is as follows

- Feasibility Study – Completed March 20, 2004
- Impact Study (study GE turbines) – Completed December, 2004
- Facility Study – Completed May, 2005
- Impact Re-Study (study Mitsubishi turbines) – Completed February, 2006
- Impact 2nd Re-Study (study Mitsubishi turbines) – Completed April, 2006

Due to issues with the Mitsubishi dynamic model, the first Re-Study using Mitsubishi turbines did not produce results that were felt to be reasonable by SPP or ABB. After further consultation with the Customer, Mitsubishi, PTI, and ABB, this 2nd re-study was conducted using version 6 of the PTI Mitsubishi model and tweaking certain parameters within the model as described in the ABB report.

The results of this study show that for the substation configuration given by the Customer, 160MW cannot be installed at the location of this GI request using Mitsubishi wind turbines. Unacceptable power oscillations are observed for certain faults on the order of 40MW for the entire wind farm. The addition of an SVC did not alleviate the power oscillation problems that were observed.

The largest wind farm that can be installed at the location for the given substation configuration was determined to be 120MW. The wind farm stays on-line for close in faults and power oscillations dampen out in an acceptable manner for this output. Unlike the first re-study, an SVC is not required for this request at the 120 MW output level.

As detailed in the Study, Customer will be required to install two 34.5kV capacitor banks on the low side of the substation transformers for power factor correction of the Mitsubishi turbines. For the 120 MW output level, these capacitor banks are to be sized at 20 MVAR apiece.

FERC Order #661A was issued in December, 2005, in which the Customer will be required to comply with the transitional provisions of the low voltage ride through standard. In the transitional provisions, the wind turbines shall be able to withstand a fault that produces 0.15 pu voltage at the point of interconnection for 9 cycles. Faults FLT_11_3PH and FLT_19_3PH simulated the Order #661A Faults. The wind farm stayed on line for these faults with acceptable oscillation damping. Therefore, this request, at the 120 MW output level, is compliant with Order #661A.

The Customer has previously executed an Interconnection Agreement (IA) for the GI request in October, 2005. That IA was based on the use of GE turbines. If the Customer wishes to now build the wind farm with Mitsubishi turbines, a revised IA will need to be executed containing the changes that this Study has identified. The changes will include the following.

- The maximum power output for the IA will be reduced from 160MW to 120MW
- Mitsubishi turbines will be installed (instead of GE)
- The Customer shall install two (2) 34.5 kV, 20 MVAR capacitor banks in their substation for reactive power losses by the Mitsubishi turbines.

The revised IA will also need to address revisions to the schedule. The Interconnection Customer and the Transmission Owner will need to negotiate the revised milestone schedule. The revised IA will also need to address the addition of the Customer installed two (2) 34.5kV, 20 MVAR capacitor banks noted above.

ABB

POWER SYSTEMS DIVISION
GRID SYSTEMS - CONSULTING

SYSTEM IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2003-020 (MITSUBISHI WTGs)

REPORT NO.: 2006-11266-R1
Issued: April 27, 2006

ABB Inc.
Power Systems Division
Grid Systems - Consulting
940 Main Campus Drive
Raleigh, NC 27606

Legal Notice

ABB Inc – Grid Systems – Consulting Technical Report

SOUTHWEST POWER POOL	No. 2006-11266-R1	
GEN-2003-020 GENERATION INTERCONNECTION STUDY	April 27, 2006	Pages 24

Author(s): **Amit Kekare**

Reviewed by: **William Quaintance**

Approved by: **Willie Wong**

Summary

The main objective of this study is to assess the impact on local stability of interconnecting the proposed GEN-2003-020 wind farm located in Carson County, Texas. This proposed wind farm (GEN-2003-020) would be interconnected to the existing Carson county substation (Xcel Energy). System Impact Study for this wind farm was previously performed by ABB by using GE 1.5MW and Mitsubishi 1.0MW wind turbines (See Report: 2004-10963-R1 and 2006-11209-2R1.0). As the Mitsubishi wind turbine model in PSS/E was updated for better performance the study is repeated here with the updated model (Mitsubishi Ver6.0).

At the request of SPP, initial efforts were taken to determine the maximum size of the plant that can be interconnected at the proposed POI, with and without additional dynamic var support. The results indicated that maximum 120MW of plant can be interconnected at the proposed POI without any additional var support. And maximum 130MW plant can be interconnected with 10Mvar SVC (5Mvar at each 34.5kV collector bus system). SPP has determined that the 120MW windfarm with no SVC is the final acceptable design.

A comprehensive range of faults defined by SPP has been run in the study.

Following conclusions are reached from the study:

- Undamped power oscillations occur at the requested power level of 160 MW. The plant size must be reduced to 120 MW to achieve acceptable damping.
- Overall, the post-fault recoveries show stable system performance for GEN-2003-020 with Mitsubishi wind turbine generators (120MW plant size).
- To achieve unity power factor at the POI, a total of 40 Mvar of 34.5 kV capacitors are required at the substation.

In summary it can be concluded that interconnecting the proposed wind farm, GEN-2003-020, at a level of 120 MW with Mitsubishi WTGs will not adversely affect the stability of the system.

A full description of the study, and results, are given in this report.

The results of this study are based on available data and assumptions made at the time this study was conducted. The results included in this report may not apply if any of the data and/or assumptions made in developing the study models change.

Rev No.	**Revision Description**	**Date**	**Authored by**	**Reviewed by**	**Approved by**
R1	**Added Capacitor Requirements**	**4/27/06**	**WHQ**		
DISTRIBUTION: Southwest Power Pool					

Table of Contents

2 Introduction

Southwest Power Pool (SPP) commissioned ABB Inc., to perform the Impact Study for a Generation Interconnection request – GEN-2003-020 (160MW). The main objective of this study was to assess the impact of interconnecting the proposed windfarm (GEN-2003-020) on the stability of the system. The proposed windfarm would be interconnected at the Carson county substation (SPS d/b/a/ Xcel Energy). The System Impact Study for this windfarm was previously performed by ABB by using GE-DFIG and Mitsubishi wind turbine generators (See Reports: 2004-10963-R1 and 2006-11209-2R1.0). As the Mitsubishi wind turbine model in PSS/E was updated for better performance the study is repeated here with the updated model (Mitsubishi Ver6.0).

The faults simulated for the stability analysis were those defined in the SPP document "*Scope of Interconnection Impact Study for GEN-2003-020*".

Section 2 describes the efforts of base case development.

Section 3 describes the faults simulated.

Section 4 describes the analysis to find the maximum allowed plant size.

Section 5 describes the simulation of all fault cases.

Section 6 describes the conclusions of the study.

3 Base Case Development

SPP provided two (Fall Peak 2004 and Summer Peak 2009) loadflow cases (file names: '04fa_GEN-2003-020_basecase.sav' and '09sp_GEN-2003-020_basecase.sav) as input to the study. The proposed wind farm (GEN-2003-020) was added to the base cases. The plant was redispatched against the generation as per "526 SPS Dispatch Info 040414.xls" provided by SPP.

At the request of SPP, the prior-queued generation (GEN-2002-009) was replaced with Suzlon WTGs by using *'redo_2002-009.idv'* provided by SPP.

For the final windfarm equivalent model connected into the SPP system model, the two substation transformers were modeled explicitly. Connected to each substation transformer are equivalent feeder impedance, an equivalent generator step-up transformer, and an equivalent generator. See the PSS/E one-line diagram Figure 3-1, which shows the final acceptable plant size of 120 MW discussed in Section 4. The equivalent collector bus system impedance for the proposed windfarm is unusually high (8.9 % and 3.9 % on plant base), which can cause problems for conventional induction generators like the Mitsubishi. The details of the windfarm modeling are used from the previous study with Mitsubishi model.

Per an email from Xcel Energy, via SPP, the Carson – Hutchinson 115 kV line impedance was changed to the following values to represent an upgrade from 4/0 to 795 conductor:

$Z = 0.0175 + j\ 0.01095$ per unit

$B = 0.0151$ per unit

Capacitors

The Mitsubishi wind turbines come with capacitors connected to their 600 volt terminals to achieve a net power factor of 0.986 leading (absorbing reactive power) at the generator terminals. SPP requires a 1.0 power factor at the Point of Interconnection. To achieve this, a total of 40 Mvar of shunt capacitors are needed at the 34.5 kV substation for the 120 MW wind farm.

Dynamic Data

Snapshot files corresponding to the Fall Peak 2004 and Summer Peak 2009 loadflow cases were provided by SPP for the study ("04fa_GEN-2003-020_basecase.snp" and "09sp_GEN-2003-020_basecase.snp").

The Mitsubishi dynamic data for the proposed GEN-2003-020 plant is added to create the snapshot for GEN-2003-020 case. The power flow parameters used for this model were based on available information and the default parameters embedded in the setup files for the Mitsubishi Wind model. The stability model parameters were based on default data provided with the Mitsubishi Wind model. This model incorporates the standard ride-through capability that allows wind turbine generator operation below 60% terminal voltage for up to 150ms.

A windfarm layout and substation diagram provided by SPP is included in Appendix A for reference. The power flow and stability model representation is included in Appendix B.

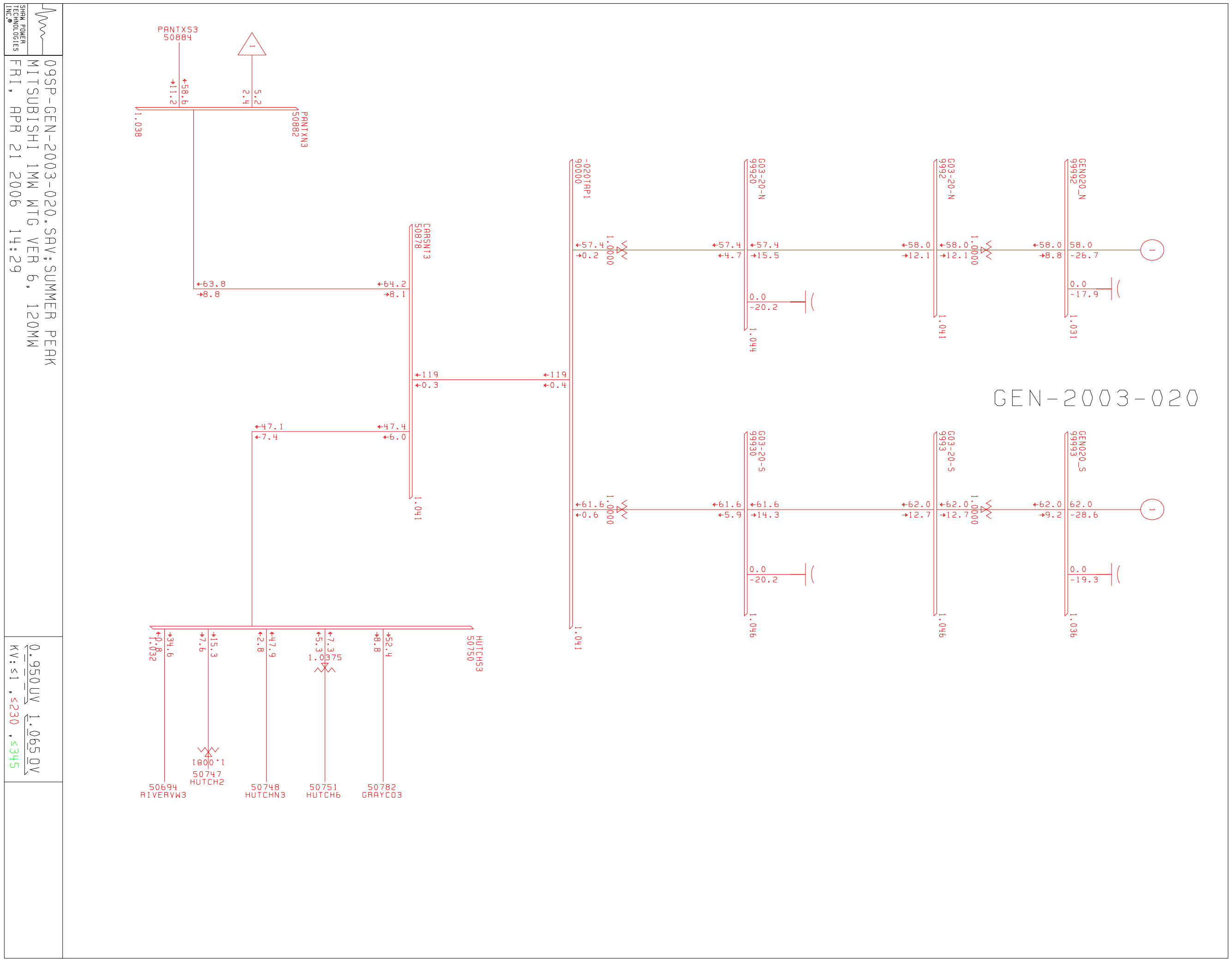

Figure 3-1: One-line diagram for GEN-2003-020 with Mitsubishi WTGs (at 120MW)

4 Fault Cases

The fault scenarios considered for the local stability assessment are listed in Table 4-1. The sequence impedance used to model the SLG faults were estimated by ABB.

Table 4-1: List of Disturbances simulated for Local Stability Analysis

FAULT	FAULT DESCRIPTION
FLT_1_3PH	3 Phase Fault on the Nichols (50915) to Grapevine (50827), 230kV line (at mid-line) After 5cy, Trip the Nichols (50915)-Grapevine (50827) 230kV line After 20cy, and then re-close the Nichols-Grapevine 230kV line into the fault After 5cy, trip the Nichols-Grapevine 230kV line and remove fault
FLT_2_1PH	SLG fault same as FLT_1_3PH
FLT_3_3PH	3 Phase Fault at Elk City 230kV bus (54123) After 5cy, trip Grapevine (50827) -Elk City (54123) 230kV line After 20cy, and then re-close the Elk City-Grapevine 230kV line into the fault After 5cy, trip the Elk City-Grapevine 230kV line and remove fault
FLT_4_1PH	SLG fault same as FLT_3_3PH
FLT_5_3PH	3 Phase Fault at Kirby bus 115kV (50932) After 5cy, trip the following lines Kirby (50932)-Conway (50928) Conway (50928)-Yarnell (50926) Yarnell (50926)-Nichols (50914) After 20cy, reclose the Kirby-Conway-Yarnell-Nichols lines into the fault After 5cy, trip Kirby-Conway-Yarnell-Nichols lines and clear the fault
FLT_6_1PH	SLG fault same as FLT_5_3PH
FLT_7_3PH	3 Phase Fault on Potter co. (50888)-Finney (50858) 345kV line (at mid-line) After 3.5cy, Trip Potter Co -Finney 345kV line and clear the fault
FLT_8_1PH	SLG fault at Potter Co (50888)-Finney (50858) 345kV line After 3.5cy, Trip Potter Co -Finney 345kV line After 32cy, reclose the Potter co- Finney 345kV line into the fault After 2cy, trip the Potter Co-Finney 345kV line and clear the fault
FLT_9_3PH	3Phase Fault at Hutchinson Co. Interchange (50750) After 5cy, trip Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV After 20Cy, reclose the Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV into the fault After 5cy, trip Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV and clear the fault
FLT_10_1PH	SLG fault same as FLT_9_3PH
FLT_11_3PH	3 Phase fault at Carson Bus (50878) After 5cy, trip Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 20cy, reclose the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 5cy, trip the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line and clear the fault
FLT_12_1PH	SLG fault same as FLT_11_3PH
FLT_13_3PH	3 Phase fault at Pantex N (50882) After 5cy, trip Carson (50878)- Pantex N (50882) 115kV line After 20cy, reclose the Carson-Pantex N 115kV line into the fault After 5cy, trip the Carson-Pantex N 115kV line and clear the fault
FLT_14_1PH	SLG fault same as FLT_13_3PH

FLT_15_3PH	3 Phase fault at HighLt3 (50880) After 5cy, Trip HighLt3-Pantex N (50884) 115kV line After 20cy, reclose the HighLt3-Pantex N 115kV line into the fault After 5cy, trip the HighLt3-Pantex N 115kV line and clear the fault
FLT_16_1PH	SLG fault same as FLT_15_3PH
FLT_17_3PH	3 Phase fault at Nichols (50915) After 5 cy, trip Nichols (50915)-Harrington (50907) 230kV line After 20cy, reclose the Nichols-Harrington 230kV line into the fault After 5cy, trip the Nichols-Harrington 230kV line and clear the fault
FLT_18_1PH	SLG fault same as FLT_17_3PH
FLT_19_3PH	3 Phase fault at Carson Bus (50878) After 5cy, trip Carson (50878)- Pantex N (50882) 115kV line After 20cy, reclose the Carson-Pantex N 115kV line into the fault After 5cy, trip the Carson-Pantex N 115kV line and clear the fault

5 Maximum Plant Size

Per the Low Voltage Ride through (LVRT) requirement of the Federal Energy Regulatory Commission (FERC) standard for Interconnection of Wind generating plants[1], the windfarm should stay on-line following a three phase fault causing a voltage as low as 0.15 p.u. at the Point of Interconnection (POI).

The results of the previous study (See Report: 2006-11209-2R1.0) indicated that the proposed windfarm (interconnection request for 160MW) would need an unreasonable size of SVC in order to meet the FERC Low Voltage Ride through (LVRT) criteria. At SPP's request, preliminary simulations were performed to find the maximum size of the proposed windfarm which can meet the FERC LVRT criteria with and without additional dynamic VAR support.

For this purpose only, the following two (2) faults at the POI were simulated for different plant sizes:

FLT_11_3PH	3 Phase fault at Carson Bus (50878) [0.00 + j-14062.5p.u.] After 5cy, trip Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 20cy, reclose the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 5cy, trip the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line and clear the fault
FLT_19_3PH	3 Phase fault at Carson Bus (50878) [0.00 + j-14062.5p.u.] After 5cy, trip Carson (50878)- Pantex N (50882) 115kV line After 20cy, reclose the Carson-Pantex N 115kV line into the fault After 5cy, trip the Carson-Pantex N 115kV line and clear the fault

5.1 Maximum Plant Size without dynamic VAR support

The above-mentioned two (2) faults were simulated for various plant sizes. The results indicated that a maximum of 120MW of generation can be interconnected at the proposed POI while meeting FERC LVRT criteria.

Figure 5-1 shows the plot for GEN-2003-020 parameters with 120MW plant size. A 130 MW plant would trip for these faults, violating the FERC criteria.

[1] The recently released FERC Order 661a has a transition period for LVRT from 0.15pu to zero voltage.

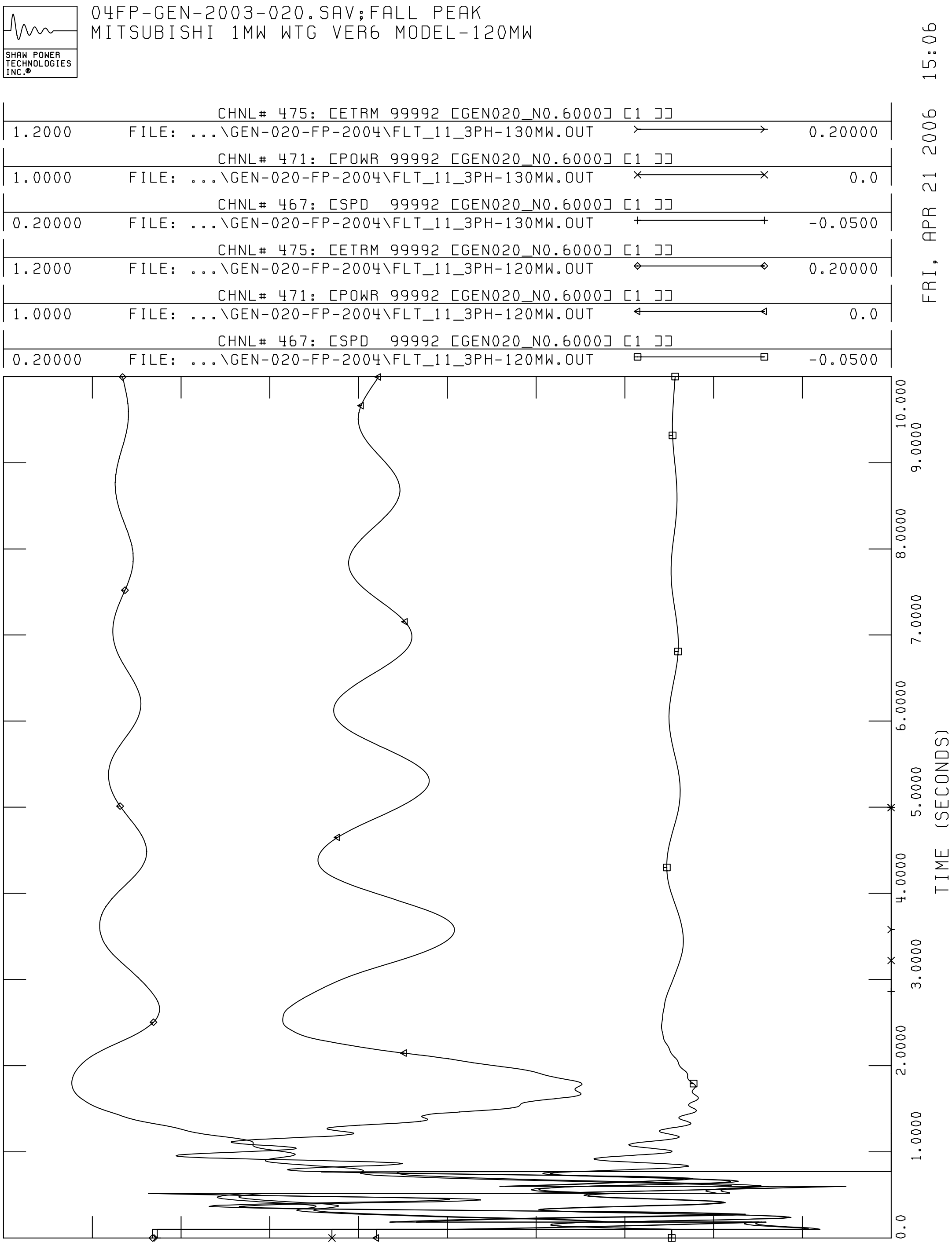

Figure 5-1: GEN-2003-020 parameters for FLT_11_3PH at 120MW and 130MW

5.2 Maximum Plant Size with dynamic VAR support

The original generation interconnection request by the windfarm developer is for 160MW. So the two (2) faults were simulated with 160MW plant size and 50Mvar SVC[2] (25Mvar SVC at each 34.5kV collector bus). The results indicated that the proposed windfarm would remain on-line at 160MW with 50MVAR SVC. However, poorly damped transient oscillations were observed in the electric power (P_{ELEC}) of the Mitsubishi WTGs (see Figure 5-2). The damping ratio for P_{ELEC} of Mitsubishi WTGs (GEN-2003-020) was calculated to be 0.000532 by using Prony Analysis. Currently SPP does not have any damping criteria, so the results were compared against Mid-Continental Power Pool (MAPP) damping criteria[3]. The oscillations in P_{ELEC} do not meet the required minimum damping ratio of 0.0081633.

As mentioned previously, at the time of study, the Mitsubishi WTG model in PSS/E was under development. So with consultation with Siemens – PTI, the two faults at the POI were repeated with following two changes in the Mitsubishi WTG model:

- Gain of the speed branch control (Kn) for MPTCH4 changed to 0.0 instead of 0.2 and,
- Integral time constant (Tn) for MPTCH4 was changed to 2.0 instead of 1.0

These changes did not resolve the poorly damped oscillations in the P_{ELEC} of Mitsubishi WTGs. In fact, slowing the pitch control resulted in turbine tripping on undervoltage in some cases.

---

[2] Per SPP's request, 50MVAr SVC is considered as a maximum reasonable size for 160MW windfarm, if needed.
[3] MAPP members Reliability Criteria and Study Procedures Manual Section 1.3.

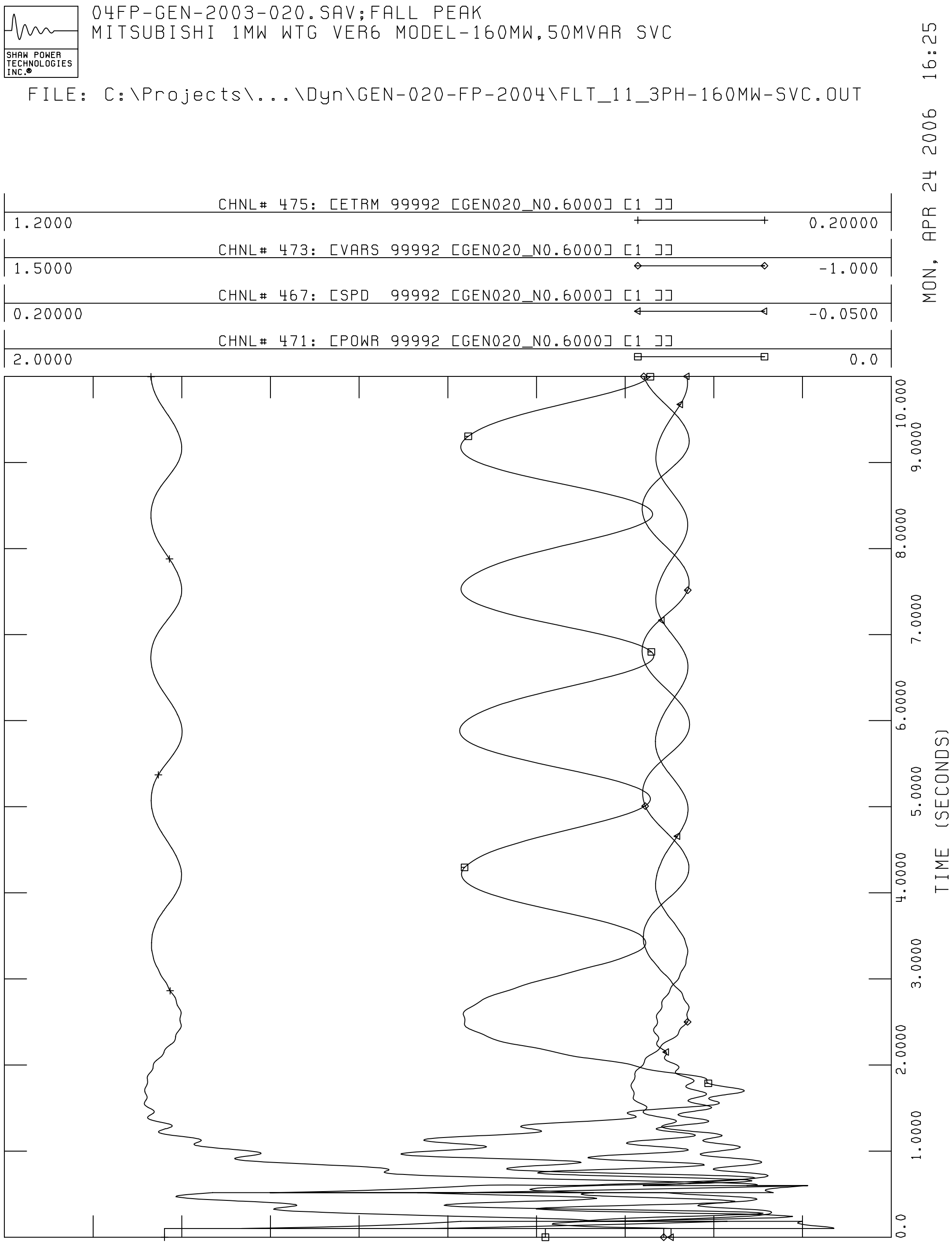

Figure 5-2: Oscillations in P_{ELEC} for GEN-2003-020 at 160MW output

In consultation with SPP, the next step was taken to determine the maximum plant size with additional dynamic var support and acceptable damping. The results indicated that a 130MW windfarm with 50Mvar SVC would meet the damping criteria (see Figure 5-3). Further the SVC size was adjusted to determine if it could be smaller. The results of simulation indicated that 130MW with 10Mvar SVC (5Mvar at each 34.5kV collector bus) would meet both FERC LVRT and MAPP damping criteria (see Figure 5-4), although marginally. The damping ratio for the 130 MW wind farm with 10Mvar SVC is 0.010865, compared to the required minimum of 0.0081633. SPP has determined that this level of damping is not sufficient, so the 120MW windfarm with no SVC is the final acceptable design.

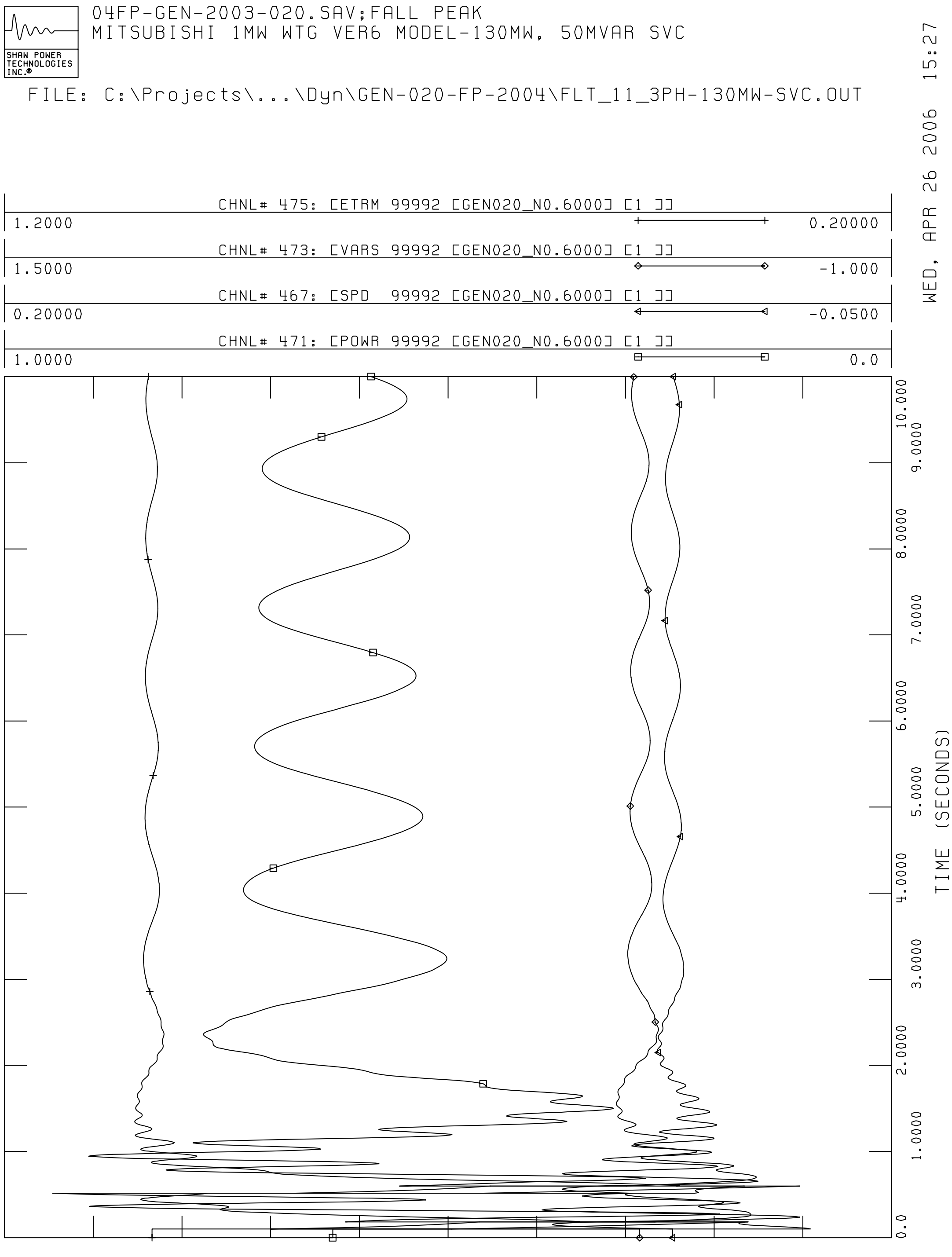

Figure 5-3: GEN-2003-020 parameters for 130MW with 50Mvar SVC

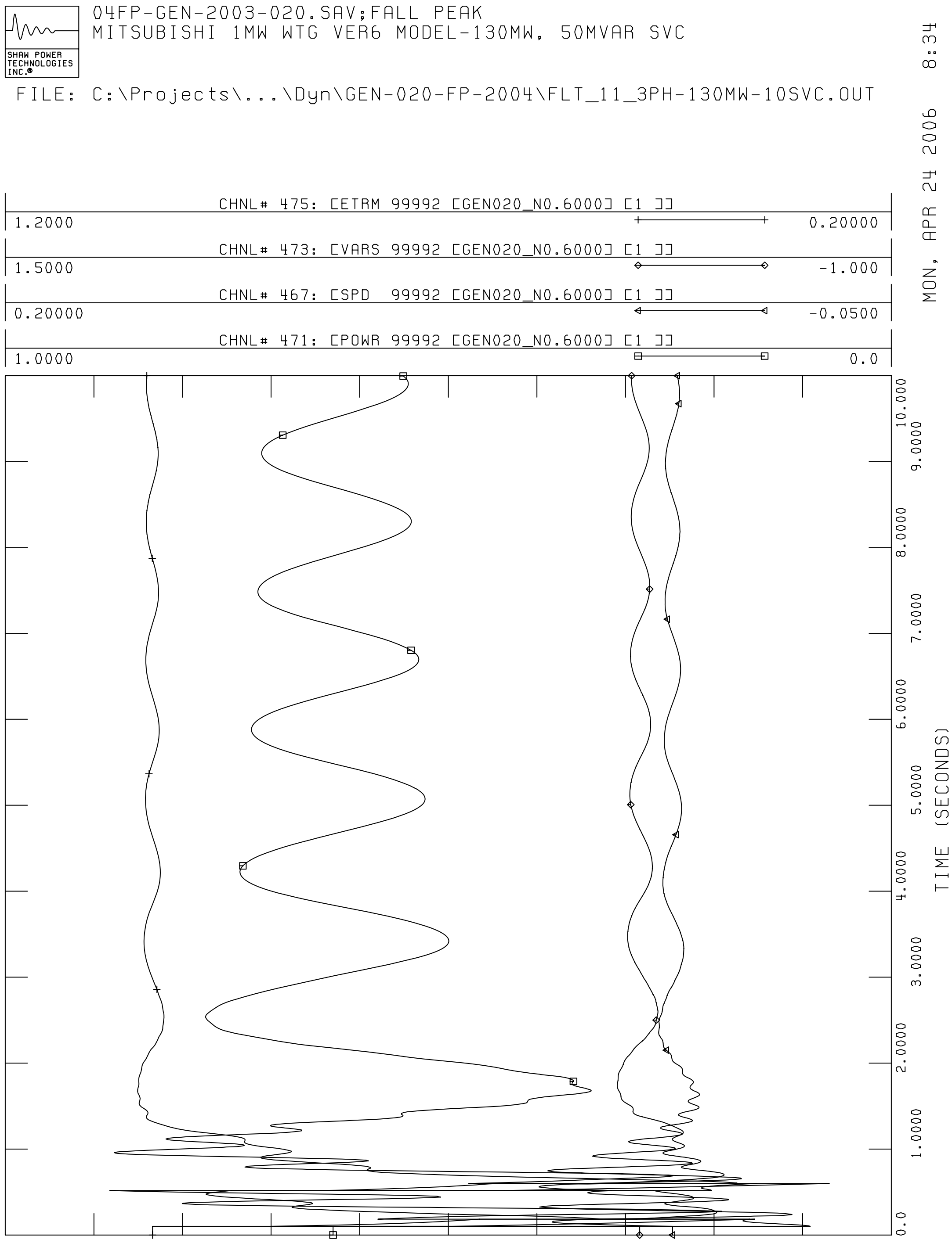

Figure 5-4: GEN-2003-020 parameters for 130MW with 10Mvar SVC

6 Study Results

Table 4-1 and Table 4-2 summarize the results for local stability simulations for Fall Peak 2004 and Summer Peak 2009 using the Mitsubishi Wind Turbine Generators for the proposed wind farm. The wind farm was modeled at 120 MW with no SVC.

All faults were run for 10 seconds.

The detailed simulation plots for all the faults are included in Appendix C.

No stability criteria violations were observed following all the simulated faults. The proposed windfarm remains on-line for all the simulated faults. Some local area windfarms were tripped following a few faults (FLT_7_3PH, FLT_9_3PH and FLT_17_3PH), in both cases (with and without proposed windfarm).

Table 4-1: Results for Stability Analysis GEN-2003-020 (Fall Peak 2009)

FAULT	FAULT DESCRIPTION	WITH GEN-2003-020
FLT_1_3PH	3 Phase Fault on the Nichols (50915) to Grapevine (50827), 230kV line (at mid-line) After 5cy, Trip the Nichols (50915)-Grapevine (50827) 230kV line After 20cy, and then re-close the Nichols-Grapevine 230kV line into the fault After 5cy, trip the Nichols-Grapevine 230kV line and remove fault	Stable
FLT_2_1PH	SLG fault same as FLT_1_3PH	Stable
FLT_3_3PH	3 Phase Fault at Elk City 230kV bus (54123) After 5cy, trip Grapevine (50827) -Elk City (54123) 230kV line After 20cy, and then re-close the Elk City-Grapevine 230kV line into the fault After 5cy, trip the Elk City-Grapevine 230kV line and remove fault	Stable
FLT_4_1PH	SLG fault same as FLT_3_3PH	Stable
FLT_5_3PH	3 Phase Fault at Kirby bus 115kV (50932) After 5cy, trip the following lines Kirby (50932)-Conway (50928) Conway (50928)-Yarnell (50926) Yarnell (50926)-Nichols (50914) After 20cy, reclose the Kirby-Conway-Yarnell-Nichols lines into the fault After 5cy, trip Kirby-Conway-Yarnell-Nichols lines and clear the fault	Stable
FLT_6_1PH	SLG fault same as FLT_5_3PH	Stable
FLT_7_3PH	3 Phase Fault on Potter co. (50888)-Finney (50858) 345kV line (at mid-line) After 3.5cy, Trip Potter Co -Finney 345kV line and clear the fault	local area W. Farms tripped due to undervoltage Stable
FLT_8_1PH	SLG fault at Potter Co (50888)-Finney (50858) 345kV line After 3.5cy, Trip Potter Co -Finney 345kV line After 32cy, reclose the Potter co- Finney 345kV line into the fault After 2cy, trip the Potter Co-Finney 345kV line and clear the fault	Stable
FLT_9_3PH	3Phase Fault at Hutchinson Co. Interchange (50750) After 5cy, trip Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV After 20Cy, reclose the Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV into the fault After 5cy, trip Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV and clear the fault	local area W. Farms tripped due to undervoltage Stable
FLT_10_1PH	SLG fault same as FLT_9_3PH	Stable

FAULT	FAULT DESCRIPTION	WITH GEN-2003-020
FLT_11_3PH	3 Phase fault at Carson Bus (50878) After 5cy, trip Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 20cy, reclose the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 5cy, trip the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line and clear the fault	Stable
FLT_12_1PH	SLG fault same as FLT_11_3PH	Stable
FLT_13_3PH	3 Phase fault at Pantex N (50882) After 5cy, trip Carson (50878)- Pantex N (50882) 115kV line After 20cy, reclose the Carson-Pantex N 115kV line into the fault After 5cy, trip the Carson-Pantex N 115kV line and clear the fault	Stable
FLT_14_1PH	SLG fault same as FLT_13_3PH	Stable
FLT_15_3PH	3 Phase fault at HighLt3 (50880) After 5cy, Trip HighLt3-Pantex N (50884) 115kV line After 20cy, reclose the HighLt3-Pantex N 115kV line into the fault After 5cy, trip the HighLt3-Pantex N 115kV line and clear the fault	Stable
FLT_16_1PH	SLG fault same as FLT_15_3PH	Stable
FLT_17_3PH	3 Phase fault at Nichols (50915) After 5 cy, trip Nichols (50915)-Harrington (50907) 230kV line After 20cy, reclose the Nichols-Harrington 230kV line into the fault After 5cy, trip the Nichols-Harrington 230kV line and clear the fault	local area W. Farms tripped due to undervoltage Stable
FLT_18_1PH	SLG fault same as FLT_17_3PH	Stable
FLT_19_3PH	3 Phase fault at Carson Bus (50878) After 5cy, trip Carson (50878)- Pantex N (50882) 115kV line After 20cy, reclose the Carson-Pantex N 115kV line into the fault After 5cy, trip the Carson-Pantex N 115kV line and clear the fault	Stable

Note: - The GEN-2002-006 and GEN-2003-013 are the two local windfarms tripped due to undervoltages.

Table 4-2: Results for Stability Analysis GEN-2003-020 (Summer Peak 2004)

FAULT	FAULT DESCRIPTION	WITH GEN-2003-020
FLT_1_3PH	3 Phase Fault on the Nichols (50915) to Grapevine (50827), 230kV line (at mid-line) After 5cy, Trip the Nichols (50915)-Grapevine (50827) 230kV line After 20cy, and then re-close the Nichols-Grapevine 230kV line into the fault After 5cy, trip the Nichols-Grapevine 230kV line and remove fault	Stable
FLT_2_1PH	SLG fault same as FLT_1_3PH	Stable
FLT_3_3PH	3 Phase Fault at Elk City 230kV bus (54123) After 5cy, trip Grapevine (50827) -Elk City (54123) 230kV line After 20cy, and then re-close the Elk City-Grapevine 230kV line into the fault After 5cy, trip the Elk City-Grapevine 230kV line and remove fault	Stable
FLT_4_1PH	SLG fault same as FLT_3_3PH	Stable
FLT_5_3PH	3 Phase Fault at Kirby bus 115kV (50932) After 5cy, trip the following lines Kirby (50932)-Conway (50928) Conway (50928)-Yarnell (50926) Yarnell (50926)-Nichols (50914) After 20cy, reclose the Kirby-Conway-Yarnell-Nichols lines into the fault After 5cy, trip Kirby-Conway-Yarnell-Nichols lines and clear the fault	Stable
FLT_6_1PH	SLG fault same as FLT_5_3PH	Stable
FLT_7_3PH	3 Phase Fault on Potter co. (50888)-Finney (50858) 345kV line (at mid-line) After 3.5cy, Trip Potter Co -Finney 345kV line and clear the fault	local area W. Farms tripped due to undervoltage Stable
FLT_8_1PH	SLG fault at Potter Co (50888)-Finney (50858) 345kV line After 3.5cy, Trip Potter Co -Finney 345kV line After 32cy, reclose the Potter co- Finney 345kV line into the fault After 2cy, trip the Potter Co-Finney 345kV line and clear the fault	Stable
FLT_9_3PH	3Phase Fault at Hutchinson Co. Interchange (50750) After 5cy, trip Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV After 20Cy, reclose the Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV into the fault After 5cy, trip Hutchinson Co. Interchange (50750)-Riverview Interchange (50694) 115kV and clear the fault	Stable
FLT_10_1PH	SLG fault same as FLT_9_3PH	Stable
FLT_11_3PH	3 Phase fault at Carson Bus (50878) After 5cy, trip Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 20cy, reclose the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line After 5cy, trip the Hutchinson Co. Interchange (50750)-Carson (50878) 115kV line and clear the fault	Stable
FLT_12_1PH	SLG fault same as FLT_11_3PH	Stable
FLT_13_3PH	3 Phase fault at Pantex N (50882) After 5cy, trip Carson (50878)- Pantex N (50882) 115kV line After 20cy, reclose the Carson-Pantex N 115kV line into the fault After 5cy, trip the Carson-Pantex N 115kV line and clear the fault	Stable
FLT_14_1PH	SLG fault same as FLT_13_3PH	Stable

FAULT	FAULT DESCRIPTION	WITH GEN-2003-020
FLT_15_3PH	3 Phase fault at HighLt3 (50880) After 5cy, Trip HighLt3-Pantex N (50884) 115kV line After 20cy, reclose the HighLt3-Pantex N 115kV line into the fault After 5cy, trip the HighLt3-Pantex N 115kV line and clear the fault	Stable
FLT_16_1PH	SLG fault same as FLT_15_3PH	Stable
FLT_17_3PH	3 Phase fault at Nichols (50915) After 5 cy, trip Nichols (50915)-Harrington (50907) 230kV line After 20cy, reclose the Nichols-Harrington 230kV line into the fault After 5cy, trip the Nichols-Harrington 230kV line and clear the fault	Stable
FLT_18_1PH	SLG fault same as FLT_17_3PH	Stable
FLT_19_3PH	3 Phase fault at Carson Bus (50878) After 5cy, trip Carson (50878)- Pantex N (50882) 115kV line After 20cy, reclose the Carson-Pantex N 115kV line into the fault After 5cy, trip the Carson-Pantex N 115kV line and clear the fault	Stable

Note: - The GEN-2002-006 and GEN-2003-013 are the two local windfarms tripped due to undervoltages.

7 Conclusions

A comprehensive range of fault cases has been simulated for stability analysis.

The following conclusions are reached from the studies:

- Undamped power oscillations occur at the requested power level of 160 MW. The plant size must be reduced to 120 MW to achieve acceptable damping.
- Overall, the post-fault recoveries show stable system performance for GEN-2003-020 with Mitsubishi wind turbine generators (120MW plant size).
- To achieve unity power factor at the POI, a total of 40 Mvar of 34.5 kV capacitors are required at the substation.

In summary it can be concluded that interconnecting the proposed wind farm, GEN-2003-020, at 120 MW with Mitsubishi WTGs will not adversely affect the stability of the system.

The results of this study are based on available data and assumptions made at the time this study was conducted. The results included in this report may not apply if any of the data and/or assumptions made in developing the study models change.