Southwest Power Pool

Impact Study for Generation Interconnection Request GEN – 2003– 020

SPP Coordinated Planning
(#GEN-2003-020)

December 2004

Executive Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP) ABB Inc. Electric Systems Consulting (ABB) performed the following Impact Study to satisfy the Impact Study Agreement executed for SPP Generation Interconnection request Gen-2003-020. The request for interconnection was placed with SPP in accordance with SPP's Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system.

Powerflow Analysis

The Customer should review the Executive Summary of the Gen-2003-020 Feasibility Study. The Powerflow analysis indicated that for the powerflow cases studied, the maximum interconnection that can flow on the Carson Co. to Hutchinson line is 99 MVA. The Feasibility Study suggested as an alternative to rebuilding the Carson to Hutchison line, the use of a special protection scheme. After further review based on reliability issues, SPP and the Transmission Owner are not willing to consider a special protection scheme in this case since the DOE Pantex facility cannot be put in jeopardy in case the special protection scheme does not operate correctly. The Transmission Owner and Southwest Power Pool are in agreement that the interconnection of 160 MW will require upgrading the Carson Co to Hutchinson line to include the interconnection flow into the emergency summer rating.

Cost Estimate

The estimated cost to upgrade the Carson Co. to Hutchinson line is as follows:

Right of way	$ 422,000 (additional right of way required
Carson – Hutchison line upgrade	$ 3,500,000 (assuming wood H-frame, 795 MCM)
Line Subtotal estimated cost	$3,922,000

The feasibility study included a substation diagram using 5 breakers and noted "Final substation design to be determined." Based on the latest analysis of the existing Carson Co. substation, the interconnection of the Wind farm will require a new seven breaker, breaker and one-half substation at Carson County to facilitate the interconnection of the Gen-2003-020 wind farm. The estimated cost to build the new seven breaker, breaker and one-half substation is estimated below and includes a bay for two 14.4Mvar (28.8 Mvar total) capacitor banks: See Figure 1.

Substation estimated cost	$4,168,822
Total estimated interconnection cost	$8,090,822

Conclusion

The minimum cost of interconnecting the Customer project is estimated at $ 8,090,822. Since the GE doubly-fed induction generators themselves provide all of the reactive power needed to achieve unity power factor at the 115 kV interconnection point, there may not be a need for any capacitor banks at the substation. Final customer designs and specifications will determine if additional reactive support is required. The Transmission Owner will review the estimated cost in greater detail during the Facility Study if the Customer signs a Facility Study Agreement.

As noted in the attached impact study, interconnecting the proposed wind farm, GEN-2003-020, will not adversely affect the stability of the system.

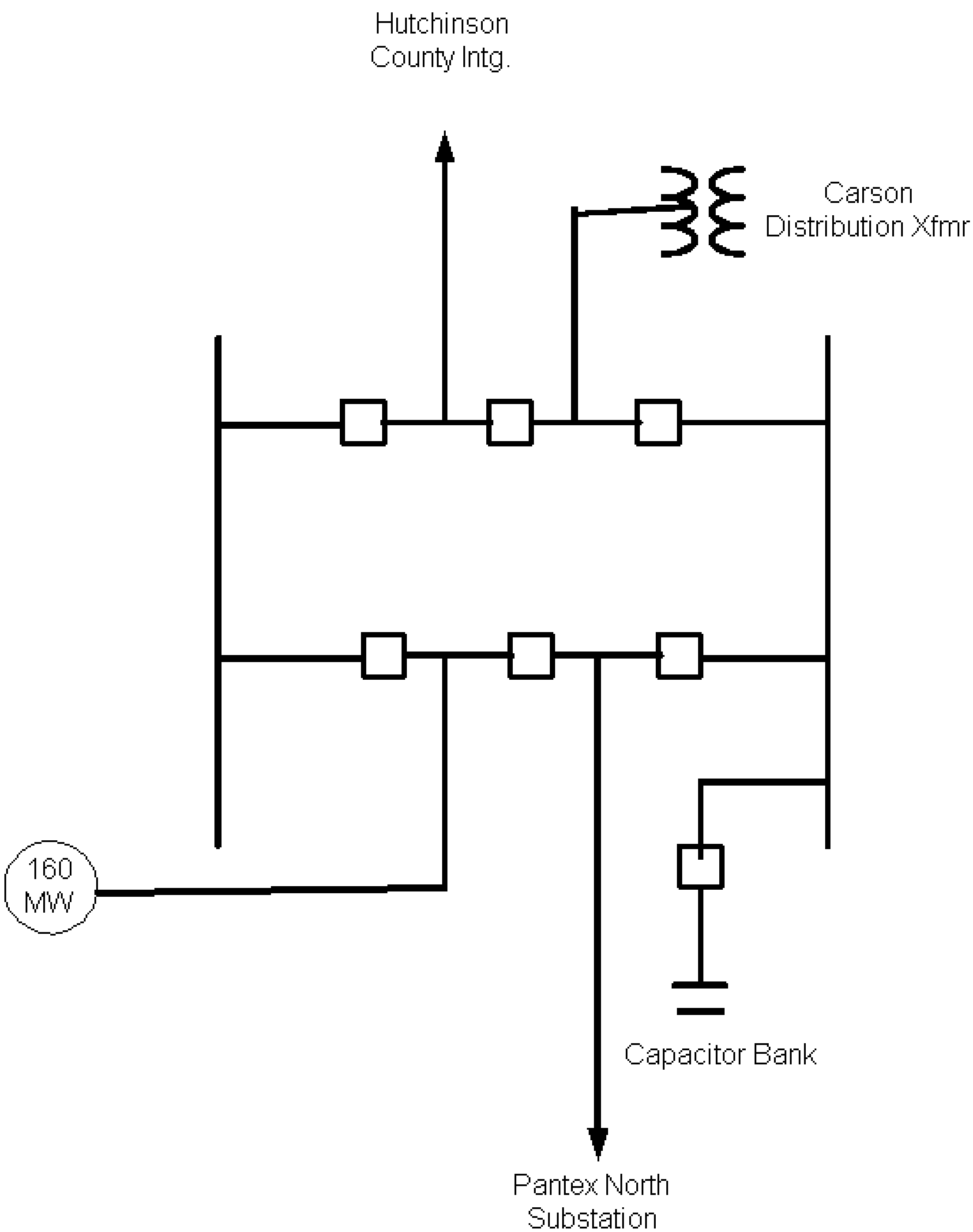
These interconnection costs do not include any cost that may be associated with short circuit studies. The short circuit costs will be determined during the Facility Study if the Customer signs a Facility Study Agreement.

These costs do not include any costs associated with the deliverability of the energy to final customers. These costs are determined by separate studies if the Customer requests transmission service through Southwest Power Pool's OASIS.

The construction milestone schedule associated with the line upgrade and substation rebuild is difficult to estimate at this time. The current estimate is 24 months assuming no difficulties with the CCN required by the state of Texas. If there are delays with the CCN, the schedule could be increased by 12 months. The milestone schedule will be further negotiated during the Interconnection Agreement for the project after completion of the Facility study.

The Impact Study performed by ABB is attached.

Figure 1: Proposed Interconnection



System Impact Study for Generation Interconnection Request GEN-2003-020

Issued: December 15, 2004

Prepared for Southwest Power Pool, Little Rock, AR

Report Number: 2004-10963-1

SUBMITTED BY:

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Legal Notice

GEN-2003-020 Interconnection Study	No. 2004-10963-1		
Prepared for Southwest Power Pool	**Dept.** ESC	Date 12/15/2004	Pages 23

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Executive 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), and will have a nominal rating of 160MW. On request of SPP and the wind farm developer, the proposed wind farm is been studied by using GE wind turbine generators.

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

The following conclusions are reached from the studies:

- Overall, the post-fault recoveries show stable system performance for GEN-2003-020 with GE wind turbine generators.

- Due to undervoltage protection, the proposed wind farm (GEN-2003-020) and a few other wind farms in the local area tripped following the faults near the proposed wind farm. The faults were repeated with delayed undervoltage trip-settings (i.e. better undervoltage ride-through) for the respective wind farms. With wind farms online following the fault, no stability violations were observed. Thus, stability is maintained whether or not the plants trip.

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

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

Rev. #	Revision	Date	Author	Reviewed	Approved
DISTRIBUTION Southwest Power Pool					

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1 INTRODUCTION

The main objective of this study is to assess the impact of interconnecting the proposed GEN-2003-020 wind farm on stability of the system. This proposed wind farm (GEN-2003-020) would be interconnected to the existing Carson county substation (SPS d/b/a/ Xcel Energy), and will have a nominal rating of 160MW. On request of SPP and the wind farm developer, the proposed wind farm is assumed to use GE wind turbine generators.

Proper modeling of the wind farm is always a consideration for wind farm studies. Care has been taken in preparation of the equivalent model for the wind farm, and the assumptions in developing this model are presented in the report.

The cases run for the study were those defined in the SPP document "Scope of Interconnection Impact Study for GEN-2003-020".

A description of the model, assumptions, and case results are given in the report.

2 GEN-2003-020 with GE Wind Turbines

2.1 CASE DEVELOPMENT

2.1.1 Power Flow Case Development

SPP provided two (Fall Peak 2004 and Summer Peak 2009) loadflow base 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.

2.1.2 Wind Farm Power Flow Model

The preliminary plant layout was given in two drawings that are included in Appendix A and labeled Diagram E1 and Diagram E2. There are two substation transformers, with 79.5 MW (53 turbines) on each transformer. The two substation transformers were modeled explicitly in PSS/E. Connected to each substation transformer are an equivalent feeder impedance, an equivalent generator step-up transformer, and an equivalent 79.5 MW generator. See the PSS/E one-line diagram in Figure 1.1.

Ultimately, 106 1.5MW GE wind turbine generators are modeled as two single-equivalent generators, 79.5MW each, for developing the case with GE wind turbines.

The IPLAN program ("GE15WIND9.IRF") provided with the PTI GE Wind model was used to model the GSU transformer (with impedance 0.0077+j0.0579 p.u. on transformer base).

2.1.3 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 GE 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 PTI GE Wind model. The stability model parameters were based on default data provided with the PTI GE Wind model. This model incorporates the standard ride-through capability that allows wind turbine generator operation below 70% terminal voltage for up to 100ms and instantaneous tripping (~20ms) for terminal voltages below 30%. The wind farm was modeled assuming generator terminal voltage control.

The GE doubly-fed induction generators themselves provide all of the reactive power needed to achieve unity power factor at the 115 kV interconnection point. With the data supplied currently by the customer, the use of the GE generators will require no direct assignment installation of capacitor banks for the wind farm. Design or specification changes may alter this requirement.

The power flow and stability model representation is included in Appendix B.

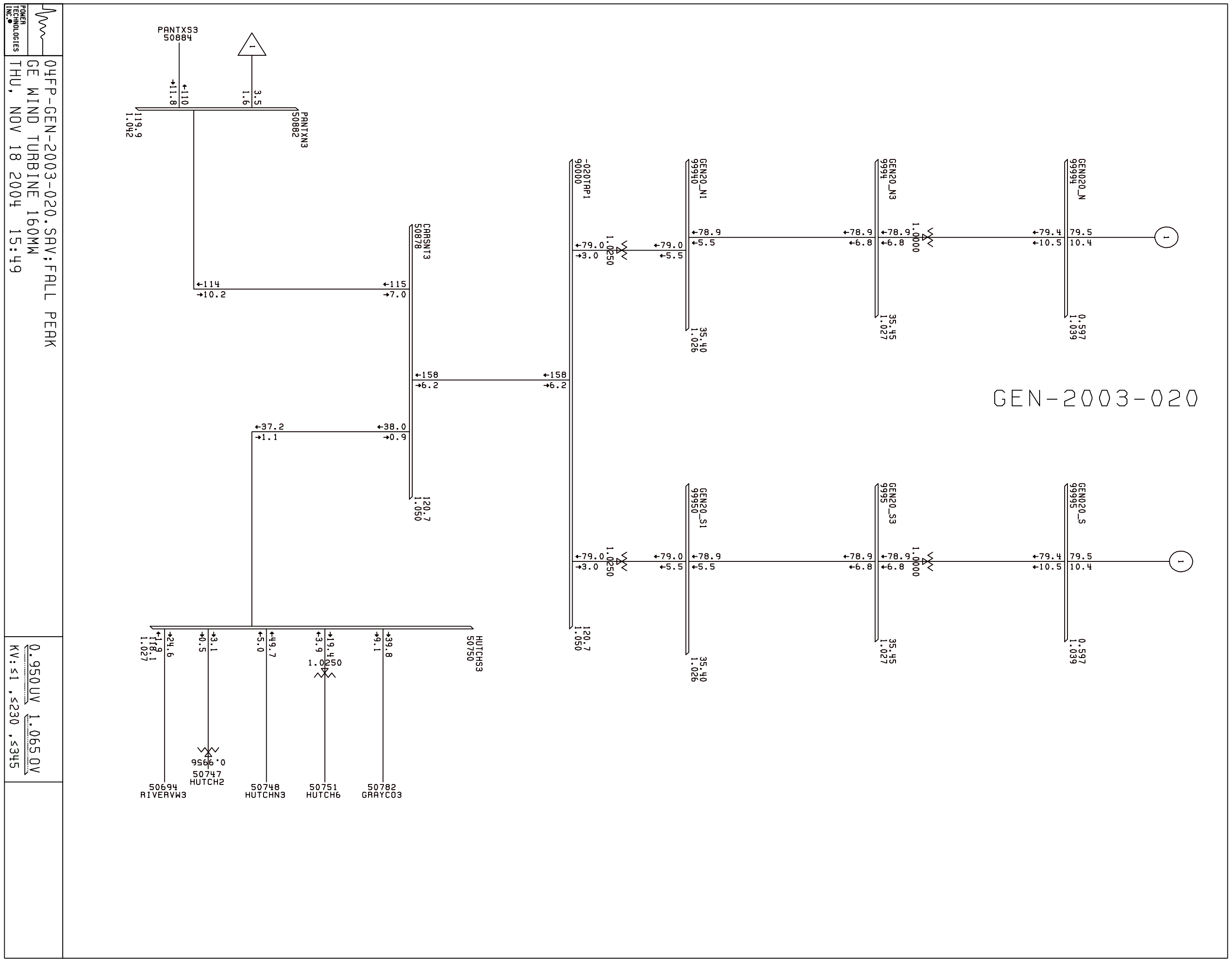

Figure 1.1 PSS/E One-line Diagram for GEN-2003-020

2.2 STABILITY SIMULATIONS

The fault scenarios considered for the local stability assessment are listed in Table 2.2. The sequence impedance used to model the SLG faults were estimated by ABB.

Table 2.2 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

2.3 STABILITY RESULTS

Table 2.3 summarizes the results for local stability simulations for Fall Peak 2004 and Summer Peak 2009 using the GE Wind Turbine model for the proposed wind farm.

All faults were run for 10 seconds.

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

With the standard under-voltage ride-through capability (see section 2.1.3), the GEN-2003-020 wind farm and a few other local area wind farms tripped due to undervoltage. The faults for which the wind farms tripped due to undervoltage were repeated with the delayed undervoltage trip settings for those wind farms (named with extension "-nt" to the fault ID). With wind farms staying online following the fault, no stability criteria violations were observed.

In summary, local stability assessment indicates that the GEN-2003-020 plant with GE Wind Turbine Generators does not adversely affect the stability of the system.

2.3.1 Vestas Turbine Shaft Oscillations

Simulation plots showed poorly damped oscillations in the speeds of local area wind farms (at #Gen-2002-008 and #Gen-2002-009) for all the faults. Figure 2.1 shows the speeds of the local area wind farm generators for fault 'FAULT_3_3PH'. This oscillation does not show up in the electrical power of the generators, and as such it is a purely mechanical mode of oscillation not affecting the electrical system. The default value for shaft damping in PSS/E Vestas TSHAFT model is 1.0 pu. We consider this to be unrealistically low and not an accurate representation of the actual wind turbine design.

To illustrate that the above oscillations are indeed attributable to the damping constant in the stability models of the local area wind farms, the shaft damping for the local area wind farms (at #Gen-2002-008 and #Gen-2002-009) was increased from 1.0 pu to 2.0 pu. Fault 'FAULT_3_3PH' was repeated. As shown in Figure 2.1, the oscillations in the local area wind farms are well damped with a higher shaft damping value.

Similar oscillations between the generator and turbine were seen in early versions of the PTI GE Wind model. The latest version has a higher damping value and does not show this issue. The Vestas model needs to be similarly updated.

2.3.2 Vestas Voltage Oscillations

The Vestas wind turbine controls in PSS/E include a feature that will move the variable rotor resistance to its maximum value if the voltage goes too low. This voltage setting is 0.9 p.u. by default. This has the effect of reducing the reactive power drawn by the induction generator, and thus increasing the voltage. However, for a weak system condition, the voltage may jump up significantly following the reduction in reactive power drawn by the machine. This large increase in voltage will then move the resistance back into variable mode. Thus, the machine reactive power and terminal voltage jump up and down at a high frequency, producing "scribbles" or noise in the plots.

Vestas engineers have indicated that the actual protection on the turbines is for over-current protection of the power electronics controlling the rotor resistance. When rotor current gets too high, the controls turn on the full rotor resistance. The PSS/E model is inaccurate because it senses terminal voltage instead of rotor current.

A few local area wind farms have been modeled by using PSS/E Vestas model. The "scribble" was observed in the local area wind farms during weaker system conditions. Figure 2.2 shows that the "scribble" in the electrical quantities can be removed with higher value of FLT_VOLT (i.e. fault voltage set point for the rotor current protection control). The "scribble" in the local area wind farm quantities is not attributable to the GEN-2003-020 wind farm.

Table 2.3 Local Stability simulation results (Fall Peak 2004 and Summer Peak 2009)

FAULT	FAULT DESCRIPTION	RESULTS	
		Fall Peak '04	Summer Peak '09
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	Stable
FLT_2_1PH	SLG fault same as FLT_1_3PH	Stable	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	Stable
FLT_4_1PH	SLG fault same as FLT_3_3PH	Stable	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	Stable
FLT_6_1PH	SLG fault same as FLT_5_3PH	Stable	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	GEN-2003-020 and local area W. Farms tripped due to undervoltage	GEN-2003-020 and local area W. Farms tripped due to undervoltage
FLT_7_3PH-nt	same as FLT_7_3PH, with delayed undervoltage trip settings for the wind farms	Stable	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	Stable

FAULT	FAULT DESCRIPTION	RESULTS	
		Fall Peak '04	Summer Peak '09
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	GEN-2003-020 and local area W. Farms tripped due to undervoltage	Stable
FLT_9_3PH-nt	same as FLT_9_3PH, with delayed undervoltage trip settings for the wind farms	Stable	Not tested
FLT_10_1PH	SLG fault same as FLT_9_3PH	Stable	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	GEN-2003-020 tripped due to undervoltage	GEN-2003-020 tripped due to undervoltage
FLT_11_3PH-nt	same as FLT_11_3PH, with delayed undervoltage trip settings for the wind farms	Stable	Stable
FLT_12_1PH	SLG fault same as FLT_11_3PH	Stable	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	GEN-2003-020 tripped due to undervoltage	GEN-2003-020 tripped due to undervoltage
FLT_13_3PH-nt	same as FLT_13_3PH, with delayed undervoltage trip settings for the wind farms	Stable	Stable
FLT_14_1PH	SLG fault same as FLT_13_3PH	Stable	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	GEN-2003-020 tripped due to undervoltage	GEN-2003-020 tripped due to undervoltage
FLT_15_3PH-nt	same as FLT_15_3PH, with delayed undervoltage trip settings for the wind farms	Stable	Stable
FLT_16_1PH	SLG fault same as FLT_15_3PH	Stable	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	GEN-2003-020 and local area W. Farms tripped due to undervoltage	GEN-2003-020 tripped due to undervoltage
FLT_17_3PH-nt	same as FLT_17_3PH, with delayed undervoltage trip settings for the wind farms	Stable	Stable
FLT_18_1PH	SLG fault same as FLT_17_3PH	Stable	Stable

FAULT	FAULT DESCRIPTION	RESULTS	
		Fall Peak '04	Summer Peak '09
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	GEN-2003-020 tripped due to undervoltage	GEN-2003-020 tripped due to undervoltage
FLT_19_3PH-nt	same as FLT_19_3PH, with delayed undervoltage trip settings for the wind farms	Stable	Stable

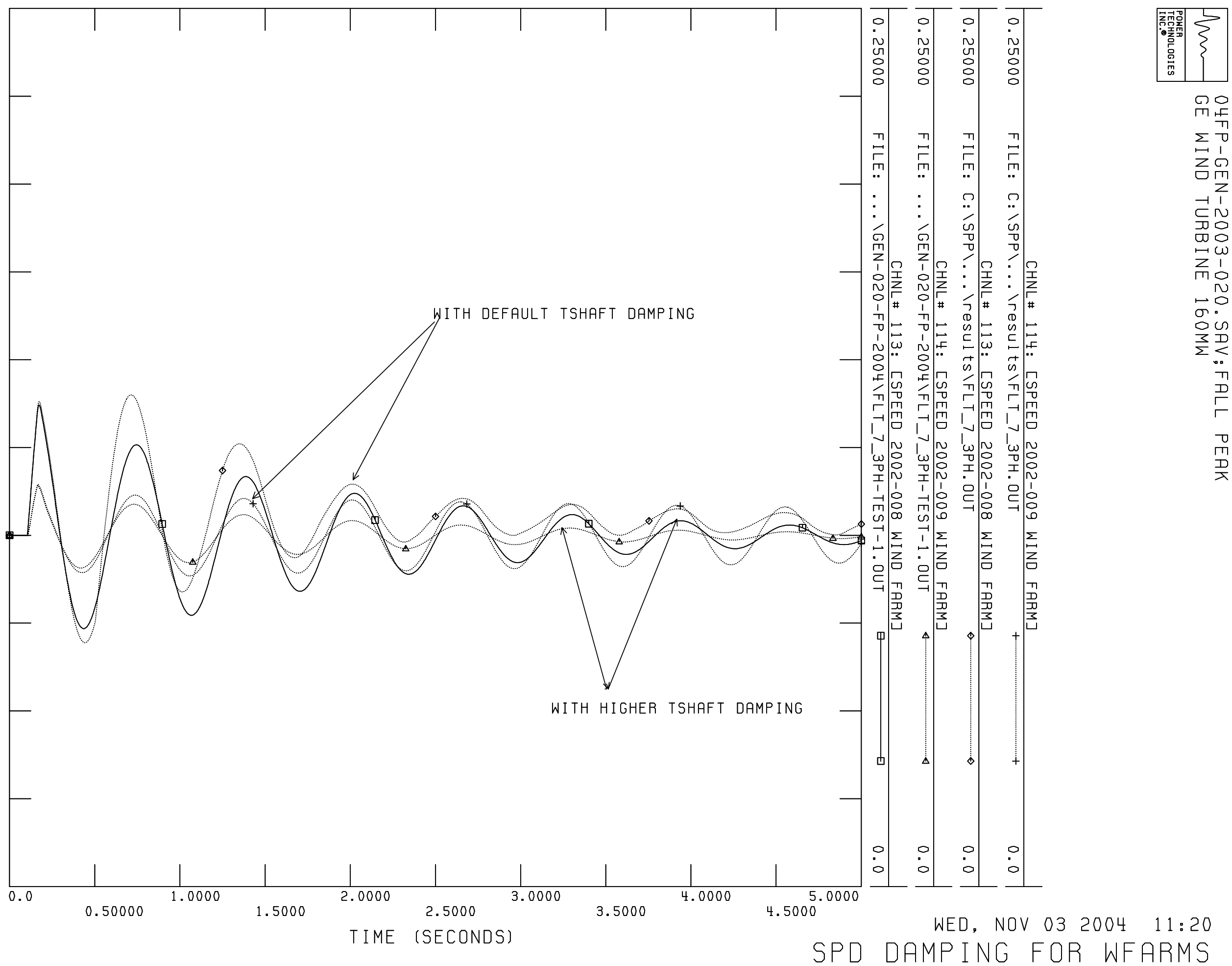

Figure 2.1 Generator Speed Oscillations in the Local Area Wind Farms, with shaft damping of 1.0 p.u. and 2.0 p.u.

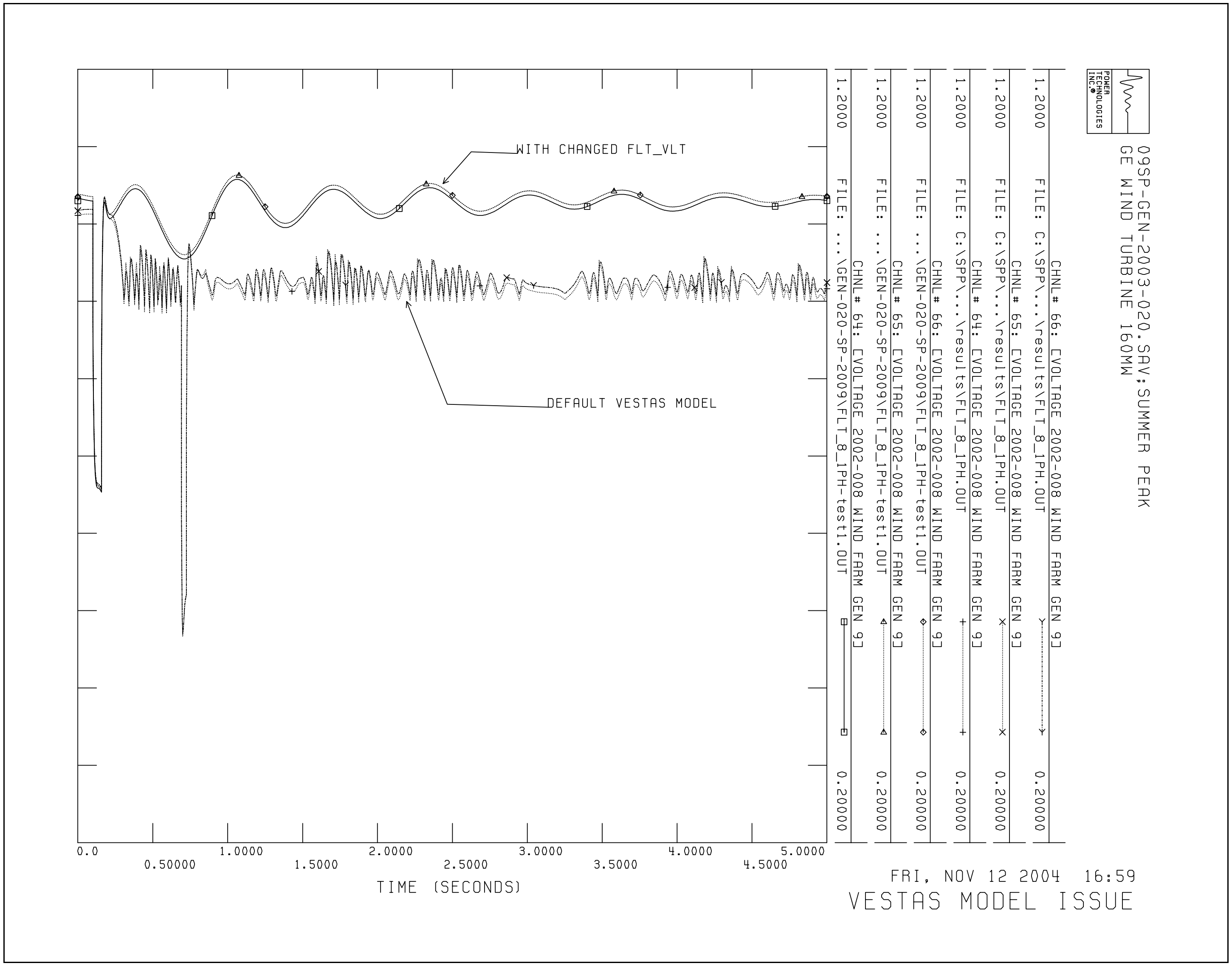

Figure 2.2 Comparison of the Vestas model parameters with Change in Fault voltage set point.

3 CONCLUSIONS

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

The following conclusions are reached from the studies:

- ❑ Overall, the post-fault recoveries show stable system performance for GEN-2003-020 with GE wind turbine generators.

- ❑ Due to undervoltage protection, the proposed wind farm (GEN-2003-020) and a few other wind farms in the local area tripped following the faults near the proposed wind farm. The faults were repeated with delayed undervoltage trip-settings (i.e. better undervoltage ride-through) for the respective wind farms. With wind farms online following the fault, no stability violations were observed. Thus, stability is maintained whether or not the plants trip.

- ❑ In summary it can be concluded that interconnecting the proposed wind farm, GEN-2003-020, will not adversely affect the stability of the system.

Appendices are not included in the SPP posting due to size constraints.

APPENDIX A - GEN-2003-020 WIND FARM MODEL DEVELOPMENT

APPENDIX B - LOAD FLOW AND STABILITY DATA FOR GEN-2003-020

APPENDIX C - SIMULATION PLOTS (GE WTG)