Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2005–022

SPP Coordinated Planning
(#GEN-2005-022)

July 2006

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 by the requesting customer and SPP for SPP Generation Interconnection request Gen-2005-022. 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.

POWER SYSTEMS DIVISION
GRID SYSTEMS - CONSULTING

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2005-022

FINAL REPORT

REPORT NO.: 2006-11326-R1.0
Issued: July 27, 2006
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ABB Inc – Grid Systems - Consulting

Technical Report

Southwest Power Pool	**No.** 2006-11326-R0	
Impact Study for Generation Interconnection request GEN-2005-022	July 27, 2006	# Pages 24

Author(s):	**Reviewed by:**	**Approved by:**
Amit Kekare	Bill Quaintance	Willie Wong

Executive Summary

Southwest Power Pool (SPP) has commissioned ABB Inc., to perform a Generation Interconnection Impact study for a simple cycle gas turbine power plant in Caddo County, Oklahoma with 168MW Summer Peak and 177MW Winter Peak output. This Combustion Turbine project will be interconnected into the existing Southwestern Power substation in the control area of American Electric Power West (AEPW). This plant will comprise two combustion turbine-generators. The interconnection study includes the stability analysis. The feasibility (power flow) study was not performed as a part of this study.

The objective of this study is to evaluate the impact on system stability after connecting the GEN-2005-022 to the interconnection point and its effect on the nearby transmission system and generating stations. The study is performed on two system scenarios: 2007 Winter Peak and the 2011 Summer Peak, provided by SPP.

The SPP system would be stable following all the simulated faults with the proposed GEN-2005-022 project in-service. Based on the results of stability analysis it can be concluded that the proposed GEN-2005-022 project does not adversely impact the stability of the SPP system.

The results of this analysis are based on available data and assumptions made at the time of conducting this study. If any of the data and/or assumptions made in developing the study model change, the results provided in this report may not apply.

Rev No.	Revision Description	Date	Authored by	Reviewed by	Approved by
0	Draft Report	07/27/06	Amit Kekare	Bill Quaintance	Willie Wong
1	Final Report	07/78/06	Amit Kekare	Bill Quaintance	Willie Wong
DISTRIBUTION: Charles Hendrix – Southwest Power Pool					

TABLE OF CONTENT

1 INTRODUCTION

Southwest Power Pool (SPP) has commissioned ABB inc., to perform a Generation Interconnection Impact study for a simple cycle gas turbine in Caddo County, Oklahoma with 168MW Summer Peak and 177MW Winter Peak output. This Combustion Turbine project will be interconnected into the existing Southwestern Power substation in the control area of American Electric Power West (AEPW). This plant will comprise two combustion turbine-generators. The interconnection study includes stability analysis. The feasibility (power flow) study was not performed as a part of this study.

The objective of the impact study is to evaluate the impact on system stability after connecting the GEN-2005-022 to the interconnection point and its effect on the nearby transmission system and generating stations. The study is performed on two system scenarios: 2007 Winter Peak and the 2011 Summer Peak, provided by SPP. Figure 1-1 shows the Point of interconnection for the GEN-2005-022. Figure 1-2 shows the schematic diagram for the interconnection of GEN-2005-022.

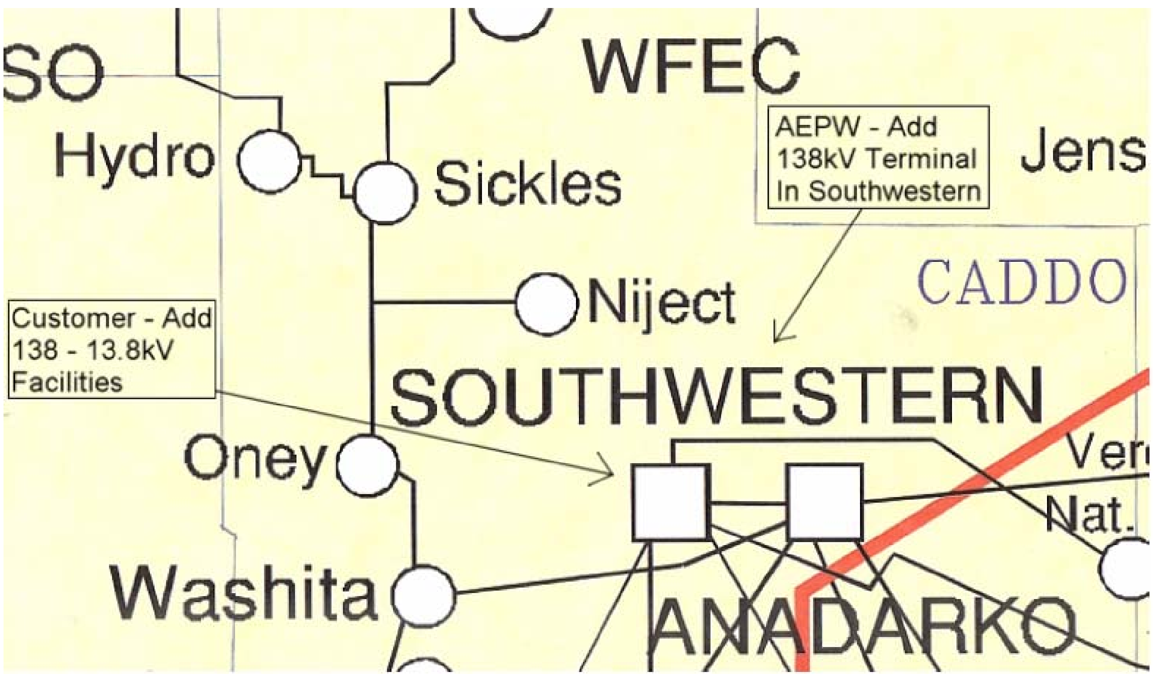

Figure 1-1: GEN-2005-022 Point of Interconnection

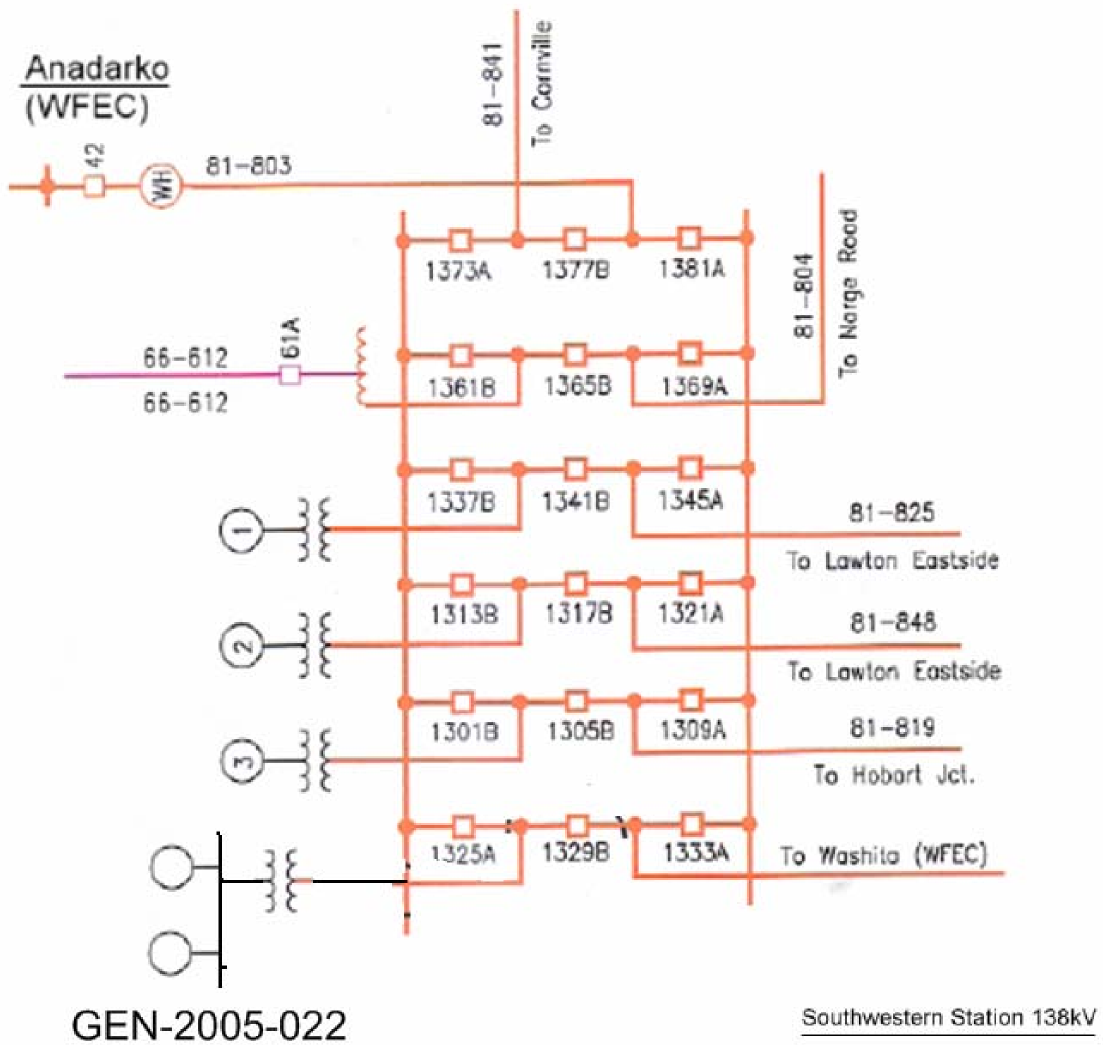

Figure 1-2: Schematic diagram for the interconnection of GEN-2005-022

2 STABILITY ANALYSIS

In this study, ABB investigated the stability of the system for the faults in the vicinity of the proposed plant as defined by SPP. The faults involve three-phase and single-phase faults cleared by primary protection, re-closing with the fault still on, and then permanently clearing the fault with primary protection.

2.1 STABILITY ANALYSIS METHODOLOGY

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 differences of the angular positions of synchronous machine rotors become constant following an aperiodic system disturbance."

Stability analysis was performed using Siemens-PTI's PSS/E dynamics program V29. Disturbances such as three-phase and single-phase line faults were simulated for the specified durations, including re-closing, and the synchronous machine rotor angles were monitored to make sure they maintained synchronism following the fault removal.

Single-phase line faults were simulated with the standard method of applying fault impedance to the positive sequence network to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the fault location of approximately 60% of pre-fault voltage, which is a typical value.

2.2 STUDY MODEL DEVELOPMENT

The study model consists of power flow cases and dynamics databases, developed as follows.

Power Flow Case

SPP provided two (2) Pre-project PSS/E power flow cases called "*gen05-22_11sp_base.sav*" representing the Summer Peak conditions of the SPP system for the year 2011 and the "*gen05-22_07wp_base.sav*" representing the Winter Peak conditions of the SPP system for the year 2007.

The proposed GEN-2005-022 project is comprised of two combustion turbine-generators. The two units will be connected to 138kV Southwest station by a 13.8/138kV step-up transformer. The proposed project was added to the Pre-project cases and the generation was dispatched against the T.P.S units at Tulsa (in AEPW). See Table 2-1 for details. Two Powerflow cases with GEN-2005-022 were established:

SP011-GEN-2005-022.SAV
WP07-GEN-2005-022.SAV

Figure 2-1 and Figure 2-2 shows the Powerflow diagram for the local area of Southwest station with GEN-2005-022 in-service (Summer Peak 2011 and Winter Peak 2007 system conditions).

Table 2-1: GEN-2005-022 project details

System condition	MW	Location	Point of Interconnection	Sink
Summer Peak	168	Caddo Co., OK	Southwest Substation 138kV	T.P.S Units at Tulsa (AEPW)
Winter Peak	177	Caddo Co., OK	Southwest Substation 138kV	T.P.S Units at Tulsa (AEPW)

<u>Stability Database</u>

SPP provided the stability database in the form of a PSS/E dynamic dyr data file "*gen05-22_11sp_base.dyr*" to model the Summer Peak stability dynamics database for 2011 and "*gen05-22_07wp_base.dyr*" to model the Winter Peak stability dynamics database for the year 2007. Along with the above-mentioned files, idev and batch files were also provided to compile and link user-written models. The provided files required the use of PSS/E version 29.

The stability data for GEN-2005-022 was appended to the Pre-GEN-2005-022 snapshot. The Powerflow and stability model representation for GEN-2005-022 are included in Appendix A.

Table 2-2 lists the disturbances simulated for stability analysis. All transmission lines were assumed to have re-closing enabled. All the faults were simulated for 10seconds.

Table 2-2: List of Faults for Stability Analysis

FAULT	FAULT DESCRIPTION
FLT_1_3PH	a. Apply Fault at Southwest Station (54140). b. Clear Fault after 3.5 cycles by removing the line from Southwest Station to Washita c. Wait 360 cycles, and then re-close the line in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_2_1PH	SLG fault same as FLT_1_3PH
FLT_3_3PH	a. Apply fault at the Hobart Jct bus (54126). b. Clear fault after 3.5 cycles by removing the line from Hobert Jct to Southwest Station c. Wait 8 cycles, and then re-close the line in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_4_1PH	SLG fault same as FLT_3_3PH
FLT_5_3PH	a. Apply fault at the Southwester Station bus (54140). b. Clear fault after 3.5 cycles by removing the line from Southwest Station to Anadarko c. Wait 30 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_6_1PH	SLG same as FLT_5_3PH
FLT_7_3PH	a. Apply fault at Norge Road (54146). b. Clear fault after 3.5 cycles by removing the line from Southwest Station to Norge Rd. c. Wait 8 cycles, and then re-close lines in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_8_1PH	SLG same as FLT_7_3PH

FAULT	FAULT DESCRIPTION
FLT_9_3PH	a. Apply fault at the Fletcher tap (54086). b. Clear fault after 3.5 cycles by removing the line from Fletcher Tap to Southwest Station c. Wait 8 cycles, and then re-close the line in (b) and remove fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_10_1PH	SLG same as FLT_9_3PH
FLT_11_3PH	a. Apply fault at the Southwestern bus (54140). b. Clear fault after 3.5 cycles by removing line from Southwest Station to Elgin Jct c. Wait 300 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_12_1PH	SLG same as FLT_11_3PH
FLT_13_3PH	a. Apply fault at the Cornville (54112). b. Clear fault after 3.5 cycles by removing line from Cornville to Southwest Station c. Wait 8 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_14_1PH	SLG same as FLT_13PH
FLT_15_3PH	a. Apply fault at the Anadarko bus (55814). b. Clear fault after 5 cycles by removing the line from Anadarko to Washita. c. Wait 20 cycles, and then re-close the line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_16_1PH	SLG same as FLT_15_3PH
FLT_17_3PH	a. Apply fault at the Southwest station (54140) b. Clear fault after 3.5 cycles by removing line from Southwest Station to Cornville c. Wait 8 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_18_3PH	a. Apply fault at the Southwest station (54140) b. Clear fault after 3.5 cycles by removing the line from Southwest Station to Fletcher Tap c. Wait 8 cycles, and then re-close the line in (b) and remove fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_19_3PH	a. Apply fault at the Southwest Station (54140). b. Clear fault after 3.5 cycles by removing the line from southwest Station to Hobert Jct c. Wait 8 cycles, and then re-close the line in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.
FLT_20_3PH	a. Apply fault at the Southwest Station (54140). b. Clear fault after 3.5 cycles by removing the line from Southwest Station to Norge road c. Wait 8 cycles, and then re-close lines in (b) into the fault. d. Leave fault on for 3.5 cycles, then trip the line in (b) and remove fault.

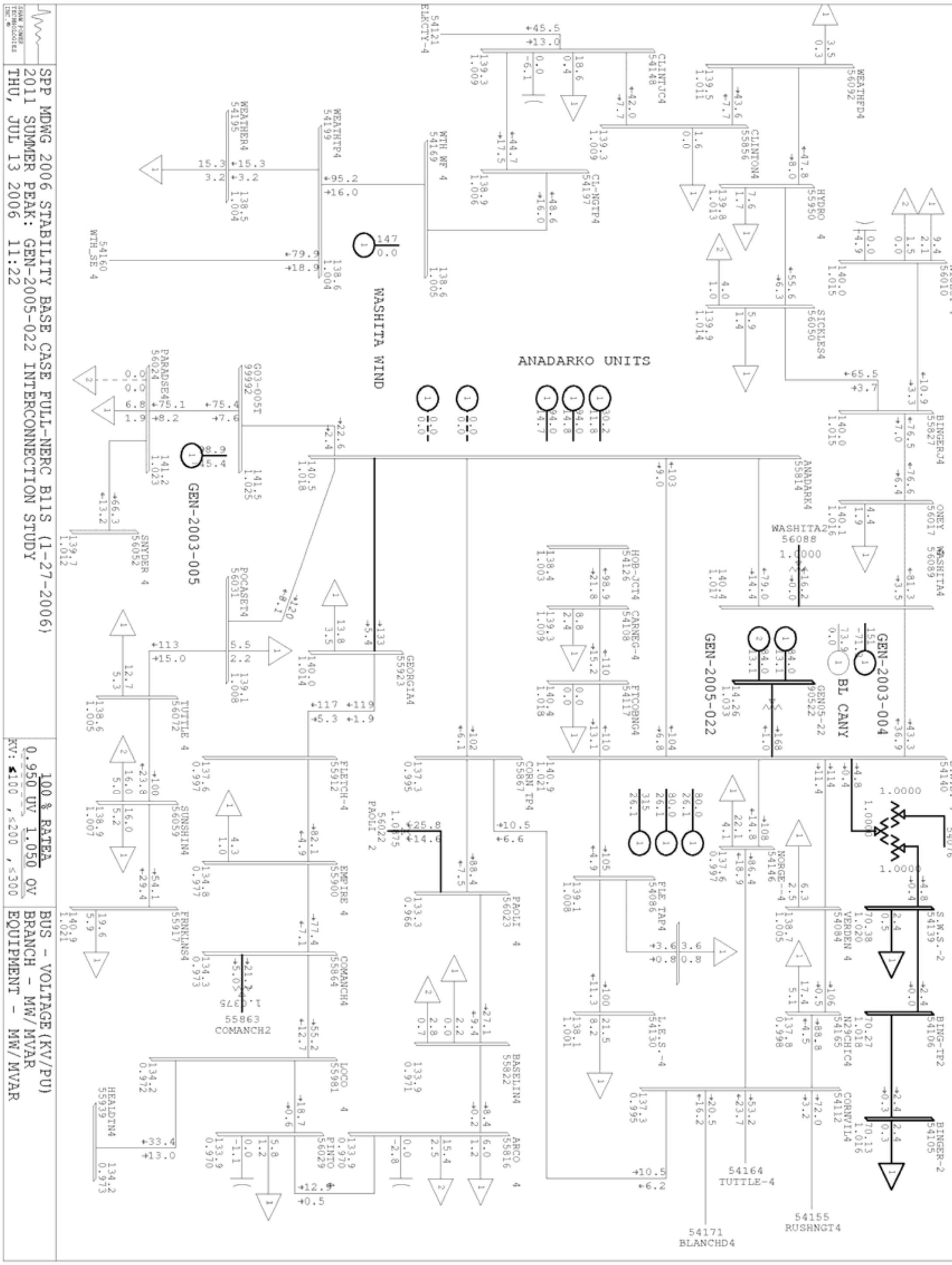

Figure 2-1: Powerflow diagram for GEN-2005-022 (Summer Peak 2011)

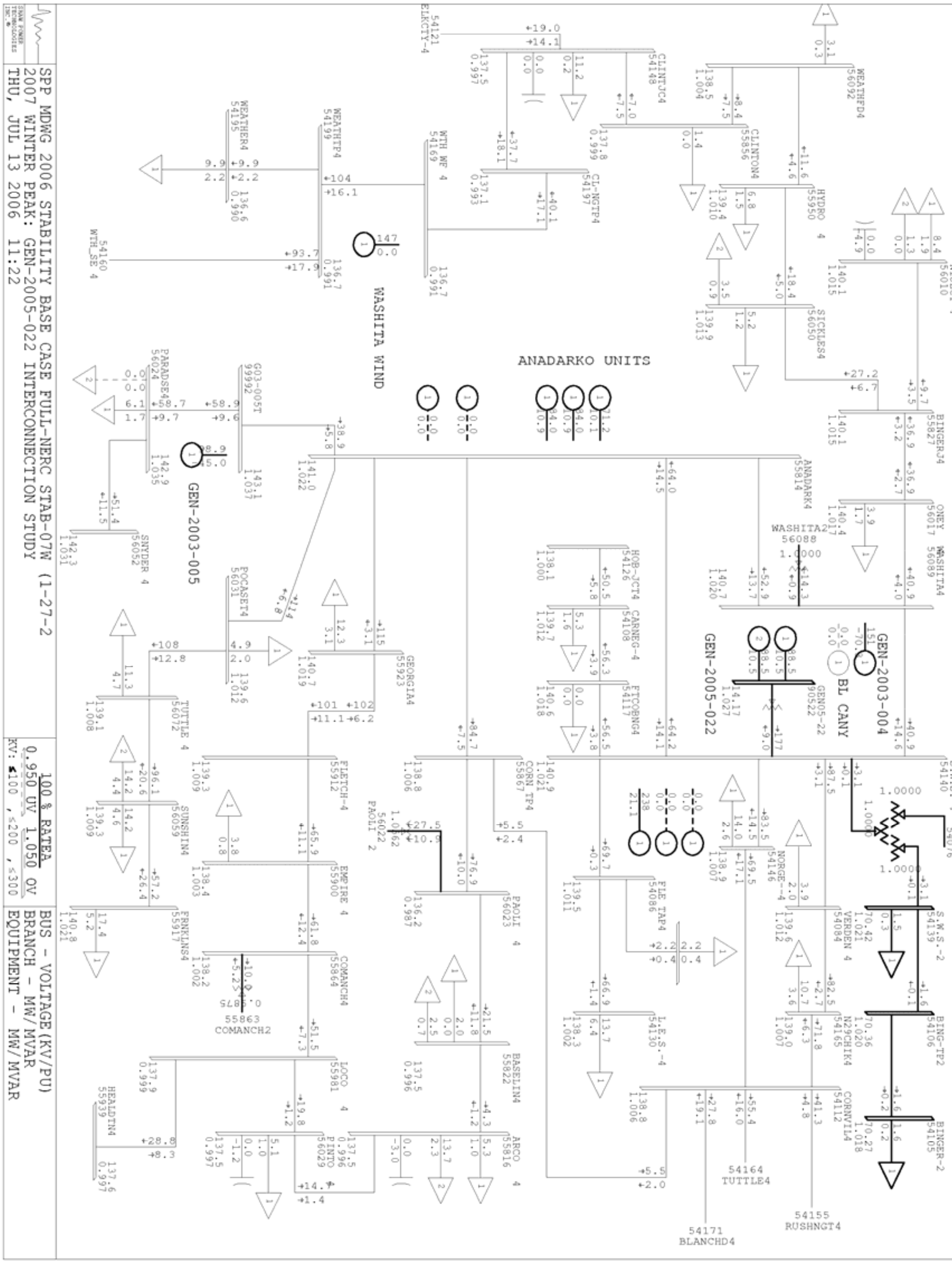

Figure 2-2: Powerflow diagram for GEN-2005-022 (Winter Peak 2007)

2.3 STUDY RESULTS

The results for all the disturbances simulated are summarized in Table 2-3.

The plots for all the simulated faults are included in Appendix B.

The results of the simulation indicate that the SPP system would be stable following all the simulated faults in both, Summer Peak and Winter Peak, system conditions**.**

The Blue canyon Windfarm (73.9MW) was tripped due to undervoltage following '*FLT_15_3PH*' in Summer Peak 2011 system conditions. The same fault was repeated on the case *without* GEN-2005-022. The Blue canyon windfarm tripped due to undervoltage in the Pre-GEN-2002-022 case following '*FLT_15_3PH*'.

GEN-2005-022 Exciter Response

The exciter response of GEN-2005-022 was unrealistically slow (see Figure 2-3). The power system stabilizer (PSS) response does not seem to be correct, and the PSS probably needs to be tuned. Hence, '*FLT_20_3PH*' was repeated by disabling the PSS (see Figure 2-4). Even after disabling the PSS the response of the exciter was not fast enough. On further investigation it was found that the response ratio of the exciter is 0.60. For the modern excitation systems this ratio should be higher than 1.00. Brushless exciters need a lot of forcing capability because they have to deal with the time constant of the exciter in addition to that of the generator. The forcing capability is limited by Va_{max}= 7.21. To exercise the maximum Vr_{max} = 29.08 value, Kb should be much higher than 1.00. Hence, Kb was set to 5.00 (~29.08/7.21). To keep the same overall gain, Ka was reduced by a factor of 5 to 200. '*FLT_20_3PH*' was repeated with adjusted Ka and Kb values and PSS disabled, resulting in a much faster and more realistic exciter response. (see Figure 2-5). The response ratio for the exciter with Kb=5.00 was 4.25. The exciter parameters of GEN-2005-022 should be revalidated before interconnection for its proper response.

Table 2-3: Results for Stability Analysis

FAULT	Summer Peak 2011	Winter Peak 2007
FLT_1_3PH	STABLE	STABLE
FLT_2_1PH	STABLE	STABLE
FLT_3_3PH	STABLE	STABLE
FLT_4_1PH	STABLE	STABLE
FLT_5_3PH	STABLE	STABLE
FLT_6_1PH	STABLE	STABLE
FLT_7_3PH	STABLE	STABLE
FLT_8_1PH	STABLE	STABLE
FLT_9_3PH	STABLE	STABLE
FLT_10_1PH	STABLE	STABLE
FLT_11_3PH	STABLE	STABLE
FLT_12_1PH	STABLE	STABLE
FLT_13_3PH	STABLE	STABLE
FLT_14_1PH	STABLE	STABLE
FLT_15_3PH	STABLE**	STABLE
FLT_16_1PH	STABLE	STABLE
FLT_17_3PH	STABLE	STABLE
FLT_18_3PH	STABLE	STABLE
FLT_19_3PH	STABLE	STABLE
FLT_20_3PH	STABLE	STABLE

Note:-
**Blue Canyon Windfarm was tripped due to undervoltage in Summer Peak 2011 case, both with and without GEN-2005-022.

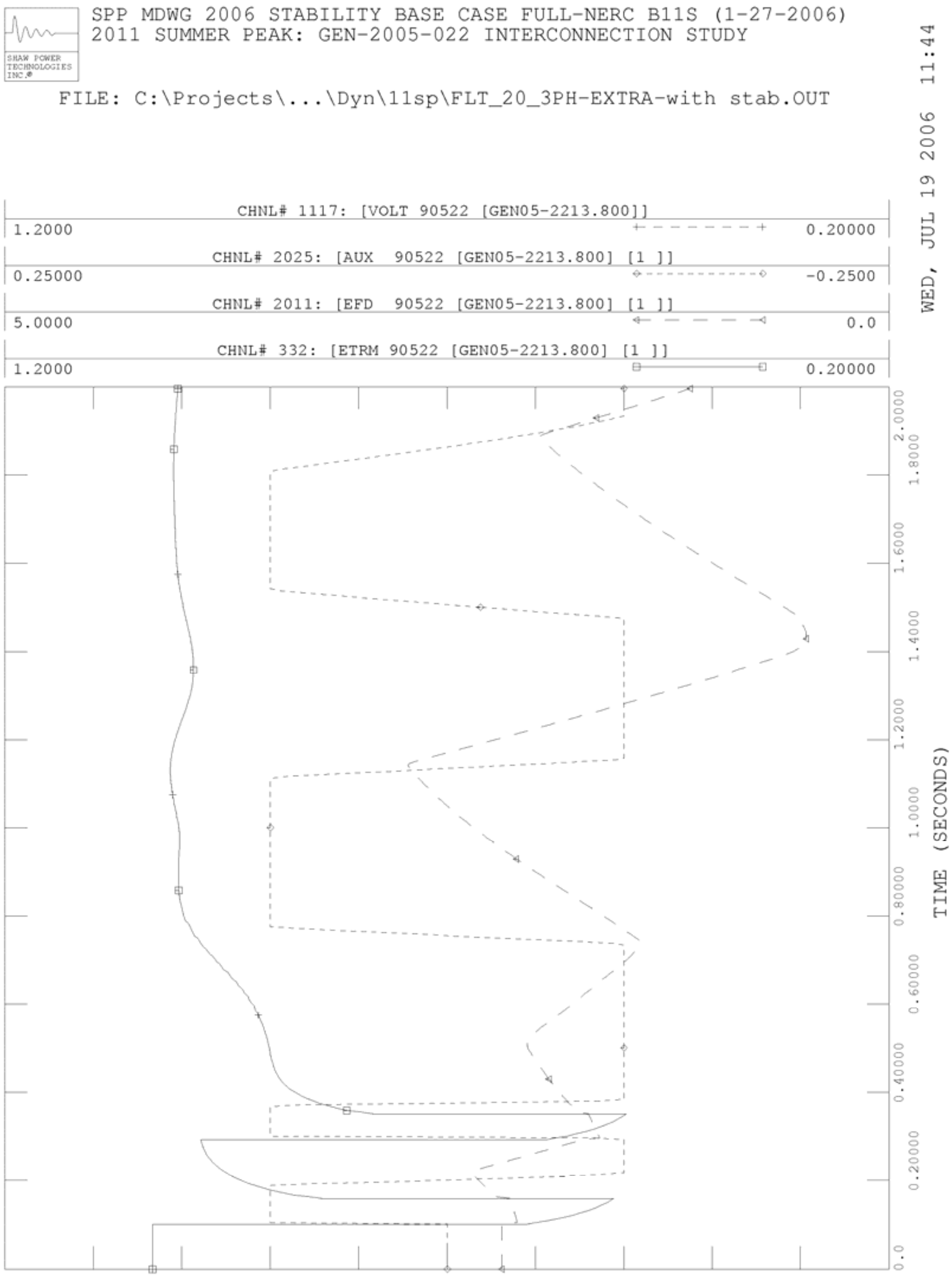

Figure 2-3: GEN-2005-022 exciter response with PSS

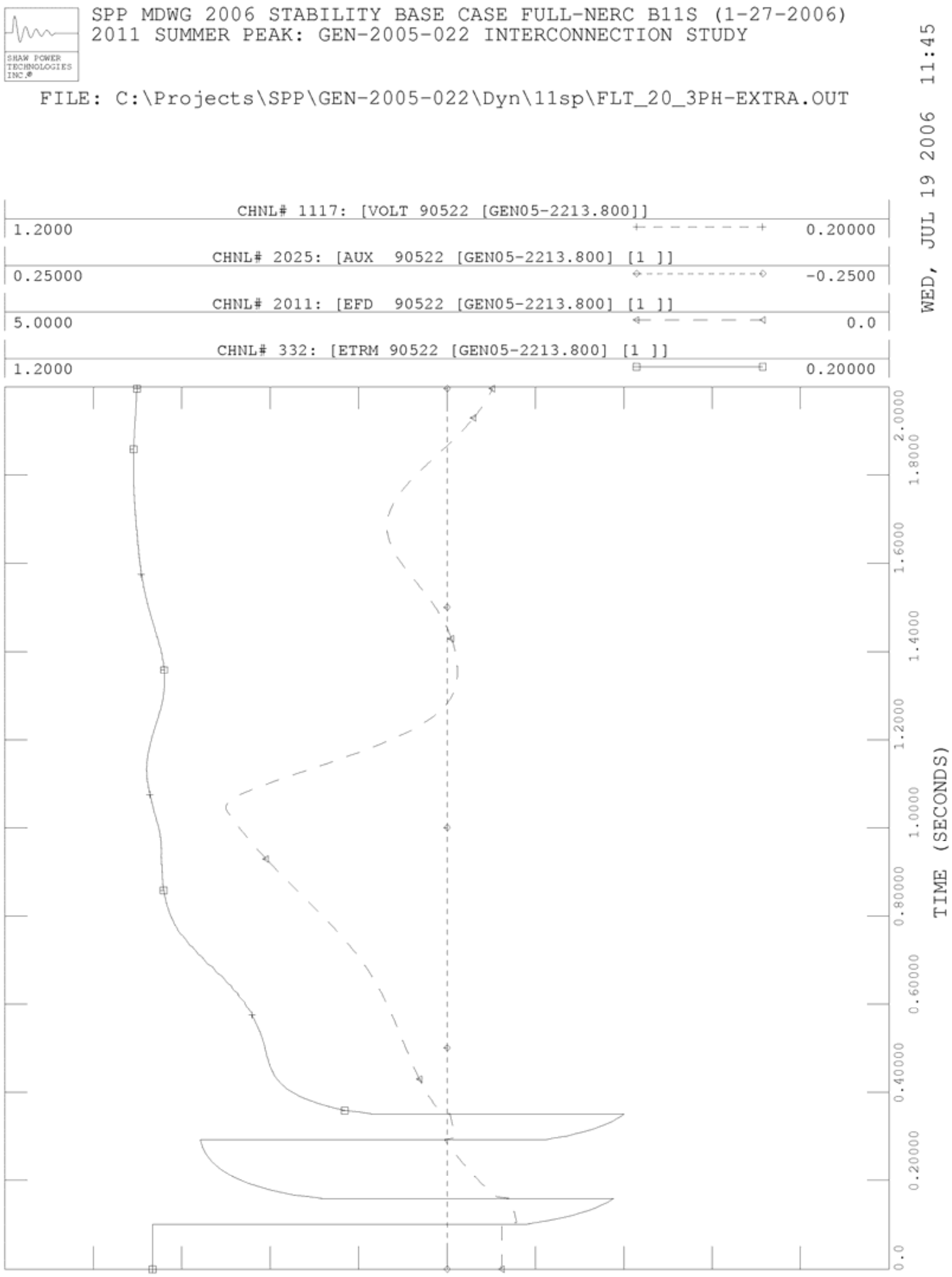

Figure 2-4: GEN-2005-022 exciter response without PSS

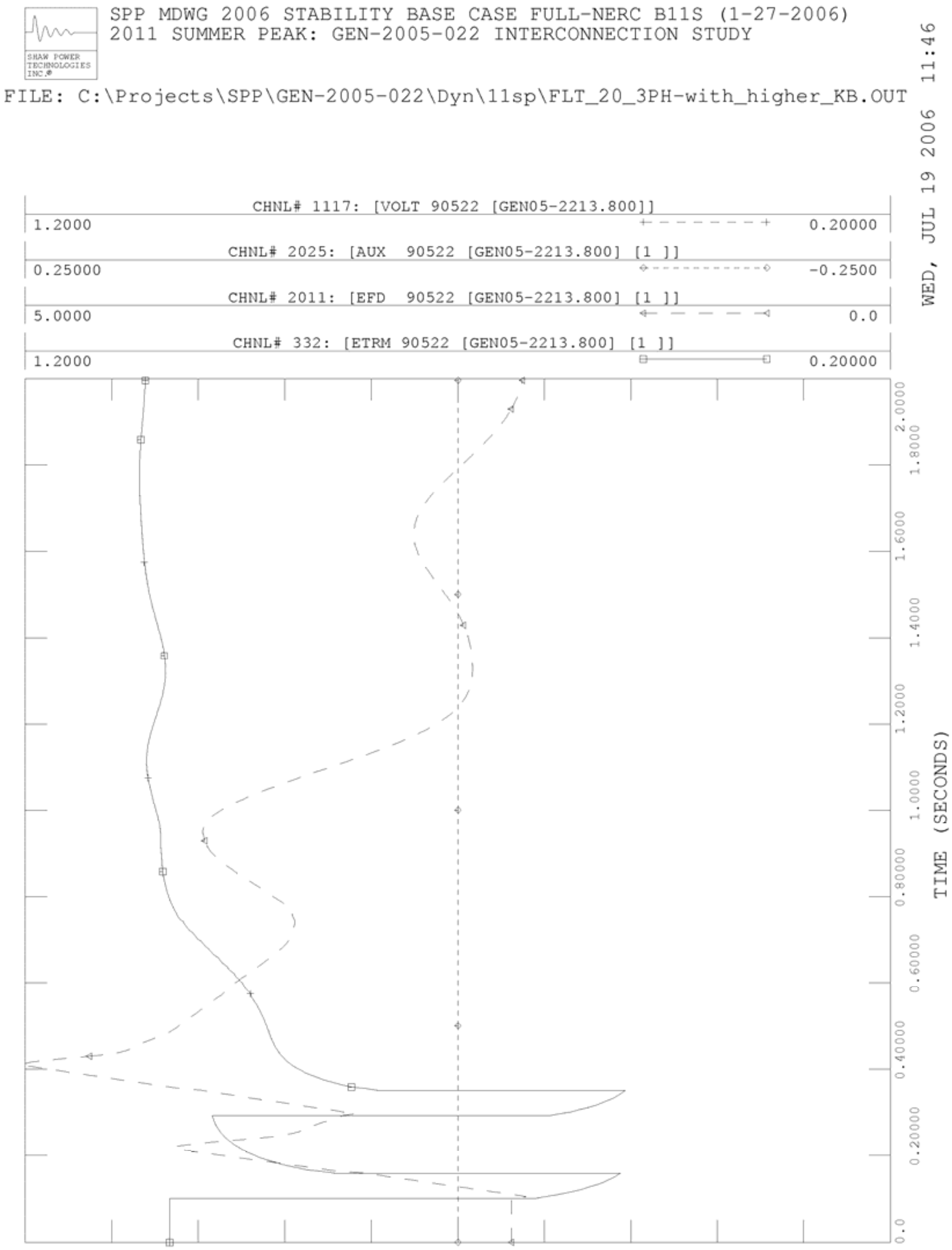

Figure 2-5: GEN-2005-022 exciter response without PSS and Kb =5.00 for exciter

3 CONCLUSIONS

The objective of this study is to evaluate the impact on system stability after connecting the GEN-2005-022 to the interconnection point and its effect on the nearby transmission system and generating stations. The study is performed on two system scenarios: 2007 Winter Peak and the 2011 Summer Peak, provided by SPP.

The SPP system would be stable following all the simulated faults with the proposed GEN-2005-022 project in-service. Based on the results of stability analysis it can be concluded that the proposed GEN-2005-022 project does not adversely impact the stability of the SPP system.

The results of this analysis are based on available data and assumptions made at the time of conducting this study. If any of the data and/or assumptions made in developing the study model change, the results provided in this report may not apply.

Appendix A - LOADFLOW AND DYNAMIC DATA FOR GEN-2005-022

A.1 POWERFLOW DATA

```
0,   100.00          / PSS/E-29.5    FRI, JUL 14 2006   9:29
SPP MDWG 2006 STABILITY BASE CASE FULL-NERC B11S (1-27-2006)
2011 SUMMER PEAK: GEN-2005-022 INTERCONNECTION STUDY
90522,'GEN05-22',  13.8000,2,     0.000,     0.000, 520, 204,1.03324,   5.2164,   1
0 / END OF BUS DATA, BEGIN LOAD DATA
0 / END OF LOAD DATA, BEGIN GENERATOR DATA
90522,'1 ',    84.000,    13.060,    32.000,   -30.000,1.02100,54140,   101.800,
0.00000,   0.15000,   0.00000,   0.00000,1.00000,1,  100.0,    86.530,     0.000,
1,1.0000
90522,'2 ',    84.000,    13.060,    32.000,   -30.000,1.02100,54140,   101.800,
0.00000,   0.15000,   0.00000,   0.00000,1.00000,1,  100.0,    86.530,     0.000,
1,1.0000
0 / END OF GENERATOR DATA, BEGIN BRANCH DATA
0 / END OF BRANCH DATA, BEGIN TRANSFORMER DATA
90522,54140,    0,'1 ',1,2,1,   0.00000,   0.00000,2,'GEN05-02',1,   1,1.0000
   0.00000,   0.12000,  120.00
1.00000,   0.000,   0.000,  200.00,  200.00,    0.00, 0,     0, 1.50000, 0.50000,
1.50000, 0.50000,  33, 0, 0.00000, 0.00000
1.00000,   0.000
0 / END OF TRANSFORMER DATA, BEGIN AREA DATA
 520,53715, -1311.000,     1.000,'AEPW    '
0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA
0 / END OF VSC DC LINE DATA, BEGIN SWITCHED SHUNT DATA
0 / END OF SWITCHED SHUNT DATA, BEGIN IMPEDANCE CORRECTION DATA
0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-TERMINAL DC DATA
0 / END OF MULTI-TERMINAL DC DATA, BEGIN MULTI-SECTION LINE DATA
0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA
 204,'WESTERN '
0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA
0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA
   1,'1       '
0 / END OF OWNER DATA, BEGIN FACTS DEVICE DATA
0 / END OF FACTS DEVICE DATA
```

A.2 DYNAMICS DATA

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      FRI, JUL 14 2006   9:32
 SPP MDWG 2006 STABILITY BASE CASE FULL-NERC B11S (1-27-2006)
 2011 SUMMER PEAK: ⌐ 2005 SOUTHWEST POWER POOL, INC.; RED DYN

 PLANT MODELS

 REPORT FOR ALL MODELS                         BUS 90522 [GEN05-2213.800] MODELS


 ** GENROU **   BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S
             90522     GEN05-22 13.800 1  145956-145969  55654-55659

             MBASE     Z S O R C E         X T R A N       GENTAP
             101.8  0.00000+J 0.15000  0.00000+J 0.00000  1.00000

  T'D0 T''D0  T'Q0 T''Q0     H   DAMP   XD     XQ     X'D    X'Q   X''D    XL
 12.80 0.050  3.90 0.050   5.60  0.00 1.9800 1.8100 0.2080 0.3000 0.1500 0.1000

                                 S(1.0)  S(1.2)
                                 0.1100  0.5100


 ** PSS2A **    BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S     V A R S      I C
O N S
             90522     GEN05-22 13.800 1  145984-146000  55666-55681   10356-10359
6497-6502

                    IC1 REMBUS1      IC2 REMBUS2       M       N
                      1       0        3       0       5       1

      TW1      TW2      T6       TW3      TW4      T7       KS2      KS3
     2.000    2.000    0.000    2.000    0.000    2.000    0.178    1.000

      T8       T9       KS1      T1       T2       T3       T4       VSTMAX   VSTMIN
     0.500    0.100   15.000    0.250    0.040    0.250    0.040    0.100   -0.100


 ** EXAC2 **    BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S
             90522     GEN05-22 13.800 1  146018-146040  55698-55702

    TR       TB       TC       KA       TA      VAMAX    VAMIN      KB     VRMAX    VRMIN
   0.010    1.000    1.000  1000.0    0.010    7.210   -7.210     1.0     29.1    -29.1

      TE       KL       KH       KF       TF       KC       KD       KE       VLR
     1.300    4.000    0.000    0.049    1.000    0.100    0.770    1.000    9.368

                          E1       S(E1)      E2      S(E2)
                        3.0440    0.0080    4.0580    0.0140


 ** GAST2A **   BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S     V A R S
             90522     GEN05-22 13.800 1  146064-146094  55708-55720   10364-10367

    W     X      Y      Z      ETD     TCD     TRATE     T     MAX    MIN    ECR    K3
  25.00 0.000 0.050  1.00  0.040  0.200   80.00  0.12  1.20  -0.10  0.010 0.770

    A     B      C     TF      KF      K5      K4      T3      T4      TT     T5
   1.00  0.05  1.00  0.40  0.000  0.200  0.800  15.00  2.500  917.0  3.30

                   AF1     BF1    AF2     BF2     CF2     TR      K6      TC
                  700.0  550.0 -0.300  1.300  0.500 1006.0  0.230 1010.0


 ** GENROU **   BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S
             90522     GEN05-22 13.800 2  145970-145983  55660-55665
```

```
            MBASE      Z S O R C E          X T R A N       GENTAP
            101.8  0.00000+J 0.15000  0.00000+J 0.00000  1.00000

  T'D0 T''D0  T'Q0 T''Q0     H   DAMP   XD     XQ     X'D    X'Q   X''D    XL
 12.80 0.050  3.90 0.050   5.60  0.00 1.9800 1.8100 0.2080 0.3000 0.1500 0.1000

                               S(1.0)  S(1.2)
                               0.1100  0.5100


 ** PSS2A **   BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S     V A R S       I C
O N S
            90522     GEN05-22 13.800 2  146001-146017  55682-55697   10360-10363
6503-6508

                   IC1 REMBUS1     IC2 REMBUS2       M       N
                     1       0       3       0       5       1

      TW1      TW2      T6       TW3      TW4      T7       KS2      KS3
     2.000    2.000    0.000    2.000    0.000    2.000    0.178    1.000

      T8       T9       KS1      T1       T2       T3       T4      VSTMAX   VSTMIN
     0.500    0.100    15.000   0.250    0.040    0.250    0.040    0.100   -0.100


 ** EXAC2 **   BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S
            90522     GEN05-22 13.800 2  146041-146063  55703-55707

    TR      TB      TC      KA      TA     VAMAX   VAMIN     KB    VRMAX   VRMIN
  0.010   1.000   1.000  1000.0   0.010   7.210  -7.210     1.0    29.1   -29.1

       TE      KL      KH      KF      TF      KC      KD      KE      VLR
     1.300   4.000   0.000   0.049   1.000   0.100   0.770   1.000   9.368

                          E1      S(E1)     E2      S(E2)
                        3.0440   0.0080   4.0580   0.0140


 ** GAST2A **  BUS X-- NAME --X BASEKV MC    C O N S     S T A T E S     V A R S
            90522     GEN05-22 13.800 2  146095-146125  55721-55733   10368-10371

    W      X      Y      Z      ETD     TCD     TRATE     T     MAX     MIN    ECR    K3
  25.00 0.000 0.050  1.00   0.040   0.200   80.00   0.12   1.20   -0.10  0.010 0.770

    A      B      C      TF     KF      K5      K4       T3      T4      TT      T5
   1.00   0.05   1.00   0.40   0.000   0.200   0.800   15.00   2.500   917.0   3.30

                   AF1     BF1     AF2     BF2     CF2     TR      K6      TC
                  700.0   550.0 -0.300   1.300   0.500 1006.0   0.230  1010.0
```

Appendix B - SIMULATION PLOTS FOR STABILITY ANALYSIS