Southwest Power Pool

Impact Study For Generation Interconnection Request GEN-2005-002

SPP Tariff Studies

(#GEN-2005-002)

September, 2005

Executive Summary

<OMITTED TEXT> (Customer) has requested a System Impact Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnection of up to an 80 MW wind powered generation facility in Hutchinson County, Texas to the transmission system of Southwestern Public Service Company (SPS/Xcel Energy). The wind powered generation facility will be comprised of 40 individual 2.0MW Gamesa G87 wind turbines. The requested in-service date for the 80MW facility is September 1, 2006.

The generation facility will interconnect to the Riverview-Pringle 115kV line circuit via a new 115kV substation. The interconnection facilities are estimated at $2,590,000, which does not include the cost of the customer substation or the 115kV line leading from the interconnection switching substation to the Customer substation. The cost of the necessary facilities will be further refined in a Facility study if requested by the Customer. The Customer substation will be required to have a minimum of (2) 15.3 MVAR capacitor banks to maintain required power factor at the wind farm facility and for transmission support needed to export power from the interconnection point.

Three seasonal base cases were used in the study to analyze the stability impacts of the proposed generation facility. The cases studied were the 2006 winter peak, 2007 fall case, and the 2009 summer peak case. Each case was modified to include prior queued projects that are discussed in the body of the report. The Gamesa G87 wind turbines were modeled using information provided by the manufacturer. Seventeen contingencies were simulated.

Stability Study results show that the system is stable for all simulated contingencies studied. The wind farm stays on-line for the contingencies studied except for the contingency of losing a Nichols-Harrington 230kV tie line.

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

1.0 Introduction

<OMITTED TEXT> (Customer) has requested a System Impact Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnecting up to an 80 MW wind powered generation facility in Hutchinson County, Texas to the transmission system of Southwestern Public Service Company (SPS/Xcel Energy). The wind powered generation facility studied was comprised of 40 individual 2.0MW Gamesa G87 wind turbines. The requested in-service date for the 80MW facility is September 1, 2006. The wind powered generation facility will interconnect to the existing SPS Riverview-Pringle 115kV line.

2.0 Purpose

The purpose of the Interconnection System Impact Study is to evaluate the impact of the proposed interconnection on the reliability of the Transmission System. The Impact Study considers the Base Case as well as all Generating Facilities (and with respect to (iii) below, any identified Network Upgrades associated with such higher queued interconnection) that, on the date the Interconnection System Impact Study is commenced: (i) are directly interconnected to the Transmission System; (ii) are interconnected to Affected Systems and may have an impact on the Interconnection Request; (iii) have a pending higher queued Interconnection Request to interconnect to the Transmission System; and (iv) have no Queue Position but have executed an LGIA or requested that an unexecuted LGIA be filed with FERC.

There are several previously queued projects ahead of this request in the SPP Generation Interconnection queue. It was assumed for purposes of this study that not all of those projects would be in-service if this project is built. Any changes to this assumption, i.e. one or more of the previously queued projects not included in the study signing an interconnection agreement, may require a re-study of this request at the expense of the customer. Other wind farms modeled in the case (GEN-2002-006, 2002-008, GEN-2002-009, GEN2003-013, GEN-2003-020, and GEN-2004-003), which have higher queue priority than this request, were modeled in this case.

Nothing in this System Impact Study constitutes a request for transmission service or confers upon the Interconnection Customer any right to receive transmission service.

3.0 Facilities

3.1 Generating Facility

The generating facility was studied with the assumption that it would be using the Gamesa G87 2MW wind turbines. The nameplate rating of each turbine is 2000kW with a machine base of 2030kVA. The turbine output voltage is 690V. The Gamesa turbines utilize a doubly fed induction-generator. The generator synchronous speed is 1800 rpm, and a variable frequency power converter tied to the generator rotor allows the generator to operate at speeds ranging from 1020 rpm to 2340 rpm. Nominal speed at 2.0MW power output is 2015 rpm. The power converter allows the generator to produce power at a power factor of 0.95

lagging (producing vars) to 0.9 leading (absorbing vars). The power factor is settable at each WTG or by the Plant SCADA system.

3.2 Interconnection Facility

The Customer has proposed an interconnection facility, which would connect to the SPS/Xcel Energy transmission system via a new substation located in Hutchinson County, Texas on the existing Riverview to Pringle 115kV circuit. The new substation would be configured to accept a terminal from an adjacent 115/34.5kV transformer substation that serves the wind powered generation facility.

As noted in the Feasibility Study for this generation interconnection request, a minimum of two (2) 15.3 MVAR switchable capacitor banks are required at the Customer substation as necessary for reactive compensation for the wind farm and for exporting power from the interconnection point. Stability analysis reveals that the reactive compensation does not need to be dynamic (SVC).

The total cost for adding a new 115kV switching station, the required interconnection facility is estimated at $2,590,490. This cost does not include building the 115kV line from the Customer substation to the new substation on the Riverview-Pringle 115kV line. The costs for all interconnection facilities can be further refined by a Facility study, if the customer chooses to have a Facility study conducted. Figure 1 shows a one-line of the interconnection and generating facilities.

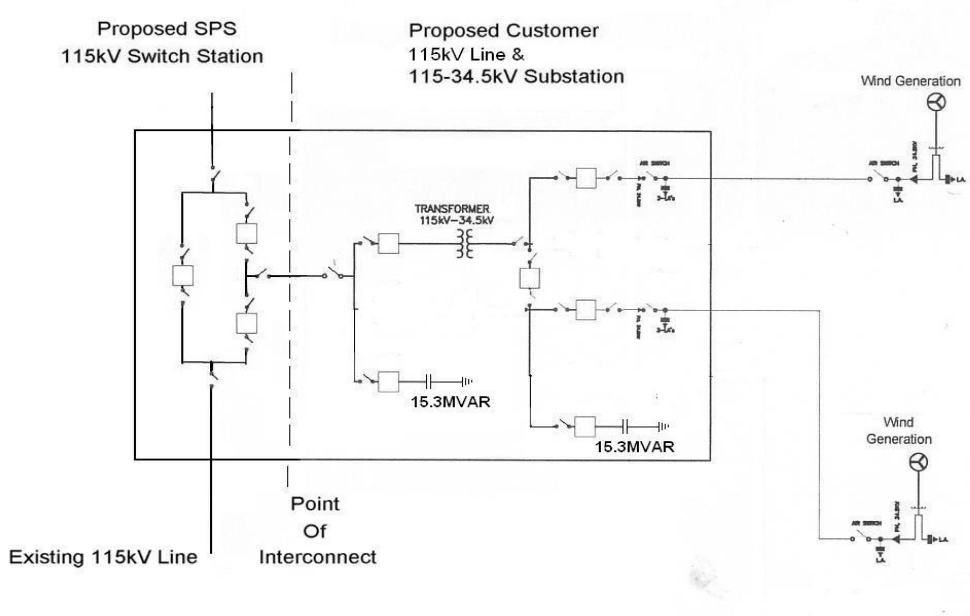


Figure 1. One-Line of the Interconnection and Generating Facilities

4.0 Stability Analysis

4.1 Objective

The objective of the stability study is to determine the impact on system stability of connecting the proposed GEN-2005-002 wind farm to SPP's 115 kV transmission system.

4.2 Equivalent Modeling of the Wind Generating Facility

The rated output of the generation facility is 80MW, comprised of (40) Gamesa G87 wind turbines. The base voltage of the Gamesa turbine is 690 V, and a generator step up transformer (GSU) of 2100kVA connects each unit to the high side of 34.5kV. The rated power output of each turbine is 2.0 MW while the actual power output depends on the wind.

In performing a system impact study, the wind farm generation from the study customer and previously queued customers is dispatched into the SPP footprint.

The generating facility 115/34.5 substation will consist of (1) 115/34.5kV transformer assumed to be 8% on a 50MVA OA Base with a top rating of 83MVA. From the preliminary one-lines received from the customer, on the 34.5kV side of the transformer, 2 feeder circuits will extend from the Customer's 115/34.5kV substation. One feeder will collect output from turbines north of the substation and the second will collect output from turbines south of the substation. The north feeder will consist of approximately 22 turbines and the south will consist of approximately 18 turbines. Each turbine then has its own pad-mounted transformer rated 690V/34.5kV and 2.1MVA.

4.3 Modeling of the Wind Turbines in the Power Flow

In order to simplify the model of the wind farm while capturing the effect of the different impedances of cables (due to change of the conductor size and length), the wind turbines connected to the same 34.5kV feeder end points were aggregated into one equivalent unit. An equivalent impedance of that feeder is represented in the load flow database by taking the equivalent series impedances of the different feeders connecting the wind turbines. Using this approach, the wind farm was modeled with equivalent units as shown in Figure 1. The number of individual wind turbines that are aggregated at each bus is shown.

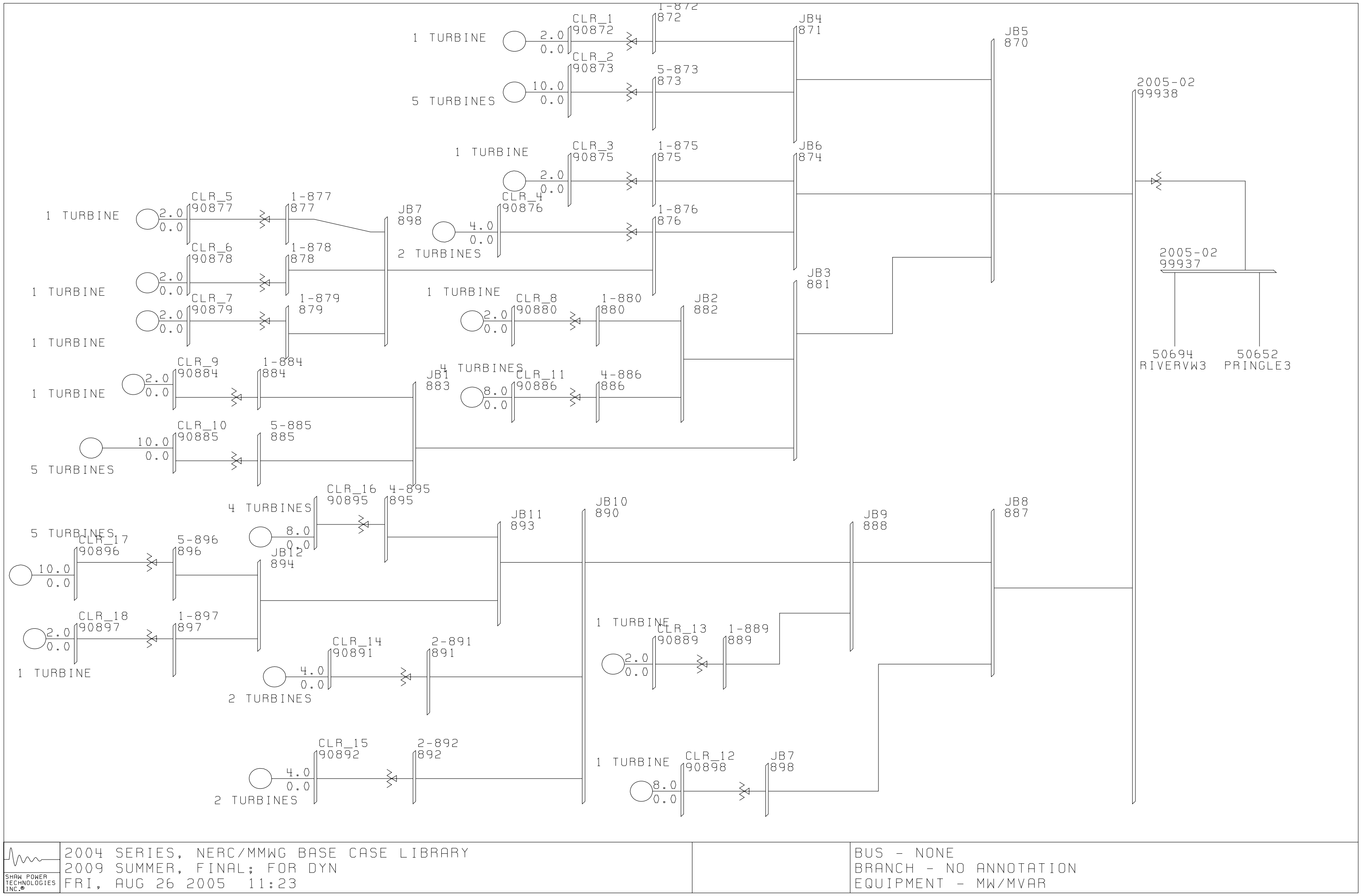


Figure 2. _One-Line Drawing of the GEN-2005-002 Facility

4.4 Modeling of the Wind Turbines for the Stability Simulation

4.4.1 Machine Dynamics Data

The Gamesa G87 wind turbine generators utilize a doubly fed induction-generator. The nameplate rating of each turbine is 2000kW with a machine base of 2030kVA. The turbine output voltage is 690V. The generator synchronous speed is 1800 rpm, and a variable frequency power converter tied to the generator rotor allows the generator to operate at speeds ranging from 1020 rpm to 2340 rpm. Nominal speed at 2.0MW power output is 2015 rpm. The power converter allows the generator to produce power at a power factor of 0.95 lagging (producing vars) to 0.9 leading (absorbing vars). The power factor is settable at each WTG or by the Plant SCADA system.

The wind turbine manufacturer provided a wind turbine model package for use on PTI's PSS/E simulation software. This package was used exclusively in modeling this wind farm. The model package used is version 5.3.

The Gamesa model package consists of an IPLAN program that creates the dynamic stability data for the wind farm based on inputs from the user. The user is able to choose how the wind farm is dispatched (via a wind speed data set or dispatched directly), at what power factor the turbines will operate at, and the protection schemes for the turbines (both frequency and voltage).

The wind farm was dispatched directly by the program to the level specified (100% rated power). For this study, it was assumed the turbines would operate at 1.0 unity power factor. Default protection schemes were used for the turbines

4.4.2 Turbine Protection Schemes

The Gamesa turbines have an under-voltage/over-voltage protection scheme and an under-frequency/over-frequency protection scheme. The various protection schemes are designed to protect the wind turbines in the case of system disturbances that can cause damage to the mechanical systems or power electronics on board the turbine. Generally, the protection schemes will disconnect the generator from the electric grid if the sampled frequency or voltage is outside of a specified band for a specified amount of time.

The voltage protection scheme is outlined in Table 1 on the next page:

Voltage	Time Limit
1.1pu +	3.6 cycles (0.06s)
0.90pu-1.1pu	Continuous Operation
0.75pu – 0.90pu	2.55 seconds
0.60pu – 0.75pu	2.05 seconds
0.45pu – 0.60pu	1.575 seconds
0.30pu – 0.45 pu	1.1 seconds
0.15pu - 0.30pu	0.625 seconds
< 0.15pu	2.4 cycles (0.04s)

Table 1: Gamesa Turbine Voltage Protection

The frequency protection scheme is outlined in Table 2 below:

Frequency	Time Limit
57-62 HZ	Continuous Operation
Below 57Hz	3 cycles (0.05 s)
Above 62 Hz	3 cycles (0.05 s)

Table 2: Gamesa Turbine Frequency Protection

4.5 Contingencies Simulated

Seventeen (17) contingencies were considered for the transient stability simulations which included three phase faults, as well as single phase line faults, at the locations defined by SPP. Single-phase line faults were simulated by applying a fault impedance to the positive sequence network at the fault location 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 specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice. The exception to this practice was simulation of the SLG on the Potter-Finney 345kV line in which the apparent impedence was taken from the study commissioned by SPS which defined the impedence using single pole tripping.

The faults that were defined and simulated are as follows:

1. **FLT_1_3_PH –** 3 phase fault on the Nichols-Grapevine 230kV line
    a. Apply fault at the midpoint of the Nichols-Grapevine 230kV line
    a. Clear fault after 5 cycles by removing the line from service.
    b. Wait 20 cycles, and then re-close the line into the fault.
    c. Leave fault on for 5 cycles, then trip and lock out the line.

2. **FLT_2_1_PH -** SLG fault same as FLT_1_3_PH

3. **FLT_3_3_PH –** 3 phase fault on the Elk City-Grapevine 230kV line
    a. Apply fault at the Elk City 230kV bus
    b. Clear fault after 5 cycles by tripping the Elk City-Grapevine 230kV line
    c. Wait 20 cycles, then reclose the line into the fault
    d. Leave fault on for 5 cycles, then trip and lock out the line

4. **FLT_4_1_PH** – SLG fault same as FLT_3_3_PH

5. **FLT_5_3_PH –** 3 phase fault on the Kirby-Conway-Yarnell-Nichols 115kV line
    a. Apply fault at the Kirby 115kV bus
    b. Clear fault after 5 cycles by tripping the line sections from Kirby-Nichols
    c. Wait 20 cycles, and then re-close line sections into the fault.
    d. Leave fault on for 5 cycles, then trip the line sections and lock out.

6. **FLT_6_1_PH -** SLG fault same as FLT_5_3_PH

7. **FLT_7_3_PH** – 3 phase fault on the Potter-Finney 345kV line
    a. Apply fault at the midpoint of the line between GEN-2002-008 and GEN-2003-013
    b. Clear fault after 3 cycles by tripping the GEN-2002-008-GEN-2003-013 345kV line and associated line reactors
    c. Wait 20 cycles then reclose the line sections and reactors into the fault
    d. Leave fault on for 3 cycles, then trip the line sections and line reactors out.

8. **FLT_8_1_PH** - SLG Fault on the Potter-Finney 345kV line (utilizing single pole tripping)
    a. Apply single phase at the midpoint of the line between GEN-2002-008 and GEN-2003-013
    b. After 3 cycles, trip one phase of the line
    c. Wait 20 cycles and reclose the single phase back into the line
    d. After 3 cycles, disconnect the line and lock out

9. **FLT_9_3_PH** - 3 Phase fault on the Riverview-Hutchinson 115kV line
    a. Apply fault on the Riverview 115kV bus
    b. Clear fault after 5 cycles by tripping the Riverview-Hutchinson 115kV line
    c. Wait 20 cycles and then reclose the line into the fault
    d. After 5 cycles, clear fault by tripping the line and lock out.

10. **FLT_10_1_PH** - SLG fault the same as FLT_9_3_PH

11. **FLT_11_3_PH** - 3 Phase fault on the Pringle-Harrington 230kV line
    a. Apply fault at Pringle 230kV bus
    b. Clear fault after 5 cycles by tripping the Pringle-Harrington 230kV line
    c. Wait 20 cycles and then reclose the line into the fault
    d. After 5 cycles, clear fault by tripping the line and lock out.

12. **FLT_12_1_PH** - SLG fault same as FLT_11_3_PH

13. **FLT_13_3_PH** - 3 Phase Bus Fault on the Pringle 115kV bus
    a. Apply bus fault at Pringle 115kV bus
    b. Clear fault after 5 cycles by tripping the Pringle 230/115kV autotransformer

14. **FLT_14_3_PH** - 3 Phase fault on the Pringle-Blackhawk 115kV line
    a. Apply fault at Pringle 115kV bus
    b. Clear fault after 5 cycles by tripping the Pringle-Blackhawk 115kV line
    c. Wait 20 cycles and then reclose the line into the fault
    d. After 5 cycles, clear fault by tripping the line and lock out.

15. **FLT_15_1_PH** - SLG fault the same as FLT_14_3_PH

16. **FLT_16_3_PH** - 3 Phase fault on the Nichols-Harrington 230kV line
    a. Apply fault at Nichols 230kV bus
    b. Clear fault after 5 cycles by tripping one Nichols-Harrington line
    c. Wait 20 cycles and then reclose the line into the fault
    d. After 5 cycles, clear fault by tripping the line and lock

17. **FLT_17_1_PH** - SLG phase fault the same as FLT_16_3_PH

4.6 Further Model Preparation

The above cases were run for the following conditions (Power Factor control at unity power factor was enabled on the Gamesa machines for all scenarios):

- 2009 Summer Peak Loading (All Previous Queued Projects included)
- 2006 Winter Peak Loading (All Previous Queued Projects included)
- 2007 Fall Loading (GEN-2002-009, GEN-2003-020, GEN-2004-003 are the only previously queued projects included in the fall case)

The previously queued projects which were added to the stability base case are summarized in Table 3.

Study Plant	Total MW
GEN-2002-006	150
GEN-2002-008	240
GEN-2002-009	80
GEN-2003-013	198
GEN-2003-020	160
GEN-2004-003	240

Table 3 – Summary of Prior Queued Projects

4.7 Stability Results

Results for all the disturbances simulated are summarized in Table 4. The results indicate that the system and all generators are stable following for most of the faults simulated. The only exception was contingency #16 in which a portion of the wind farms turbines tripped on over-voltage following a 3 phase fault close in on the Nichols 230kV bus.

FAULT	FAULT DEFINITION	2006 WP	2007 Fall	2009 SP
FLT_1_3_PH	3 PHASE FAULT AT THE MIDPOINT OF THE NICHOLS-GRAVEPINE 230KV LINE	STABLE	STABLE	STABLE
FLT_2_1_PH	SLG same as FLT_1_3_PH	STABLE	STABLE	STABLE
FLT_3_3_PH	3 PHASE FAULT AT ON THE ELK CITY-GRAPEVINE 230KV LINE NEAR ELK CITY	STABLE	STABLE	STABLE
FLT_4_1_PH	SLG same as FLT_3_3_PH	STABLE	STABLE	STABLE
FLT_5_3_PH	3 PHASE FAULT AT ON THE CONWAY-KIRBY-YARNELL-NICHOLS 115KV LINE NEAR KIRBY	STABLE	STABLE	STABLE
FLT_6_1_PH	SLG same as FLT_5_3_PH	STABLE	STABLE	STABLE
FLT_7_3_PH	3 PHASE FAULT AT ON POTTER-FINNEY 345KV LINE NEAR THE MIDPOINT OF THE LINE BETWEEN GEN-2002-008 AND GEN-2003-013	STABLE	STABLE	STABLE
FLT_8_1_PH	SLG same as FLT_7_3_PH	STABLE	STABLE	STABLE
FLT_9_3_PH	3 PHASE FAULT AT ON THE RIVERVIEW-HUTCHINSON 115KV LINE NEAR RIVERVIEW	STABLE	STABLE	STABLE
FLT_10_1_PH	SLG same as FLT_9_3_PH	STABLE	STABLE	STABLE
FLT_11_3_PH	3 PHASE FAULT AT ON THE PRINGLE-HARRINGTON 230KV LINE NEAR PRINGLE	STABLE	STABLE	STABLE
FLT_12_1_PH	SLG same as FLT_11_3_PH	STABLE	STABLE	STABLE
FLT_13_3_PH	3 PHASE FAULT AT ON THE PRINGLE 115KV SUBSTATION BUS	STABLE	STABLE	STABLE
FLT_14_3_PH	3 PHASE FAULT AT ON THE PRINGLE-BLACKHAWK 115KV LINE NEAR PRINGLE	STABLE	STABLE	STABLE
FLT_15_1_PH	SLG same as FLT_14_3_PH	STABLE	STABLE	STABLE
FLT_16_3_PH	3 PHASE FAULT ON THE NICHOLS-HARRINGTON 230KV LINE NEAR NICHOLS	Partial Wind Farm Trip from Overvoltage	Partial Wind Farm Trip from Overvoltage	STABLE
FLT_17_1_PH	SLG same as FLT_16_3_PH	STABLE	STABLE	STABLE

Table 4. SUMMARY OF FAULT SIMULATION RESULTS

5.0 Conclusion

No stability concerns presently exist for the GEN-2005-002 wind farm as proposed and studied.

The Network Upgrade cost of interconnecting the Customer project approximately $2,590,000. The interconnection facilities needed will be addressed by a Facility Study if requested by the Customer. This figure does not address the cost of the Customer substation, the (2) 15.3 MVAR capacitor banks to be installed in the Customer substation, or the transmission line between the Customer substation and the SPS/Excel switching substation located on the Riverview-Pringle 115kV line.

The 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. It should be noted that the models used for simulation do not contain all SPP transmission service.

APPENDIX A.

SELECTED STABILITY PLOTS

All Plots available upon request

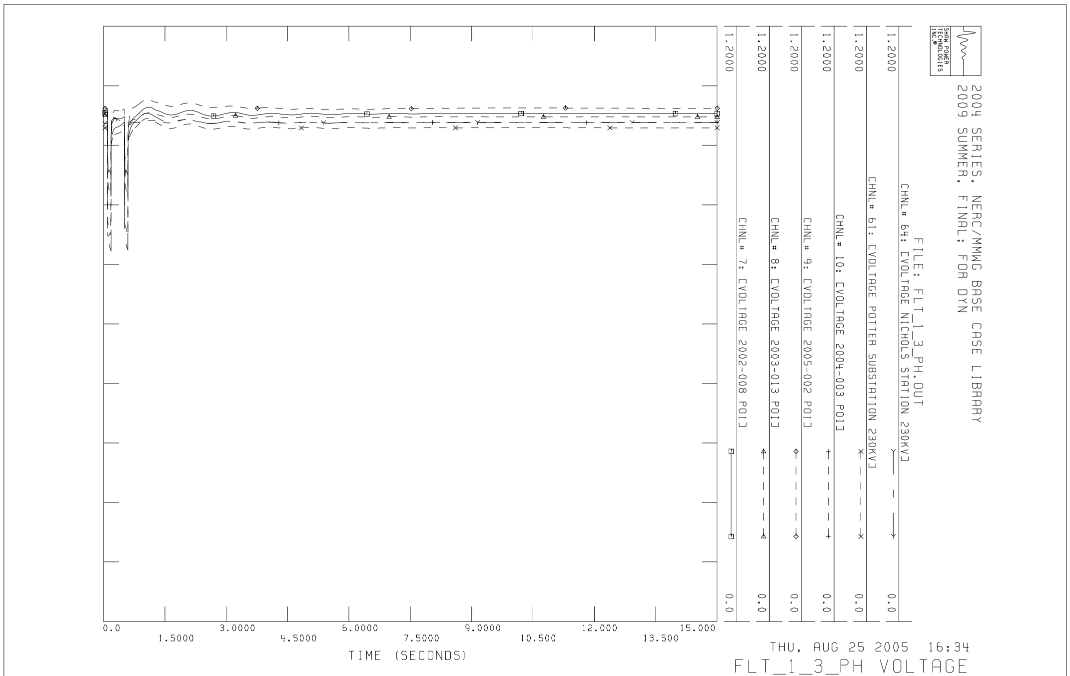
Page A1 – 2009 SP - Contingency FLT_1_3_PH
2009 SP - Contingency FLT_2_1_PH

Page A2 – 2009 SP - Contingency FLT_7_3_PH
2009 SP - Contingency FLT_8_1_PH

Page A3 – 2006 WP - Contingency FLT_3_3_PH
2006 WP - Contingency FLT_4_1_PH

Page A4 – 2006 WP - Contingency FLT_15_3_PH
2006 WP - Contingency FLT_16_1_PH

Page A5 – 2007 FA - Contingency FLT_15_3_PH
2007 FA - Contingency FLT_16_1_PH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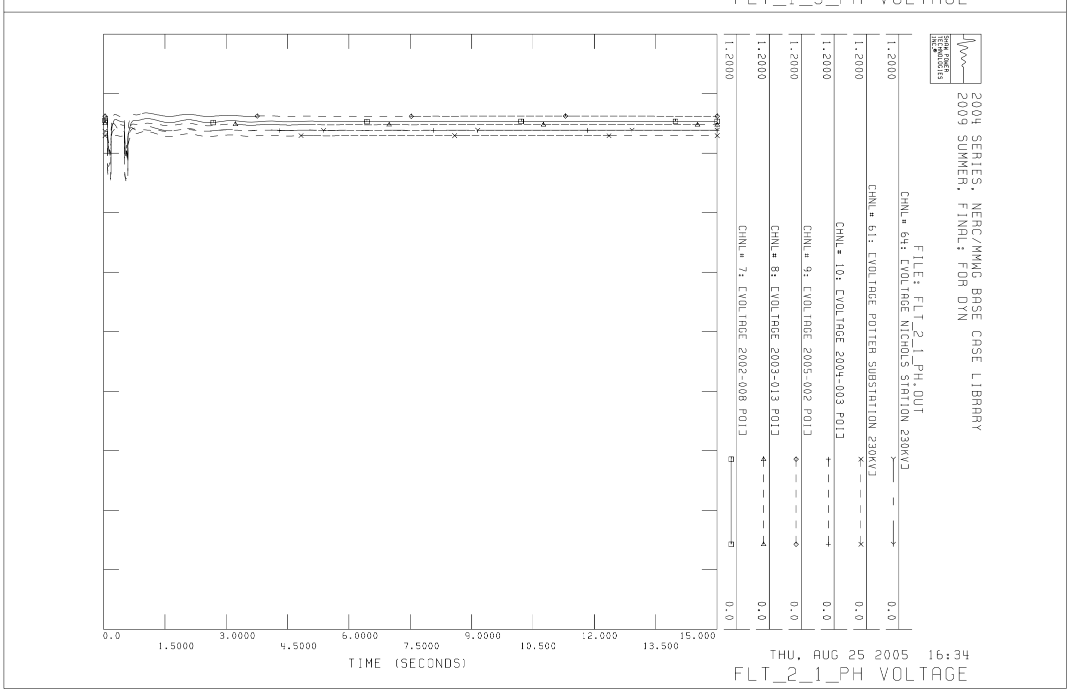
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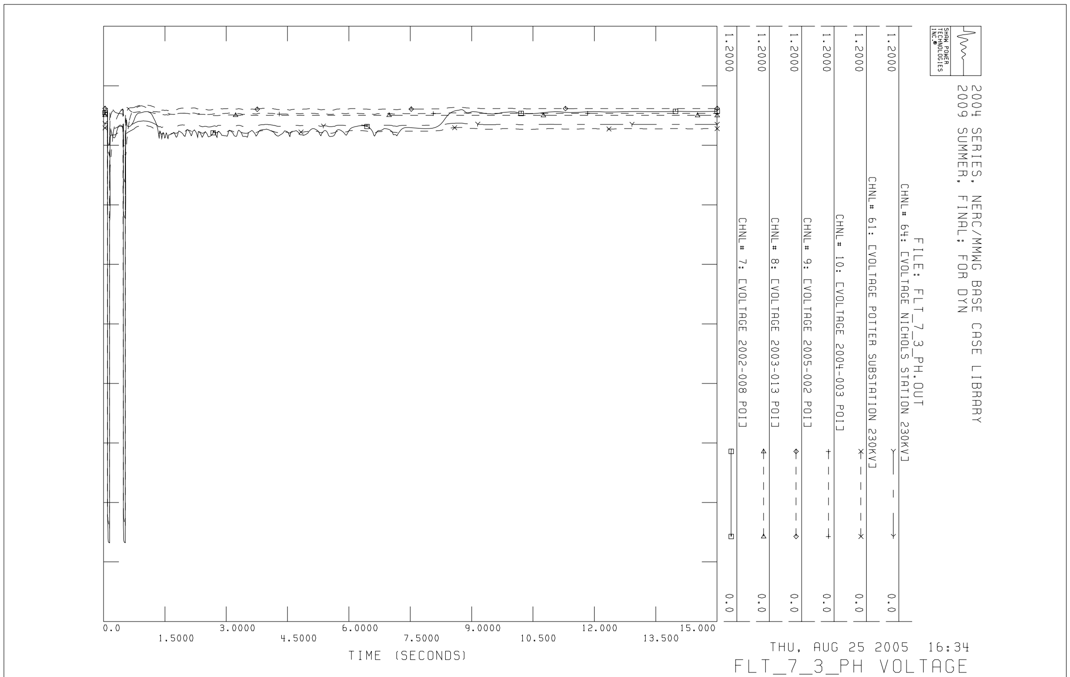
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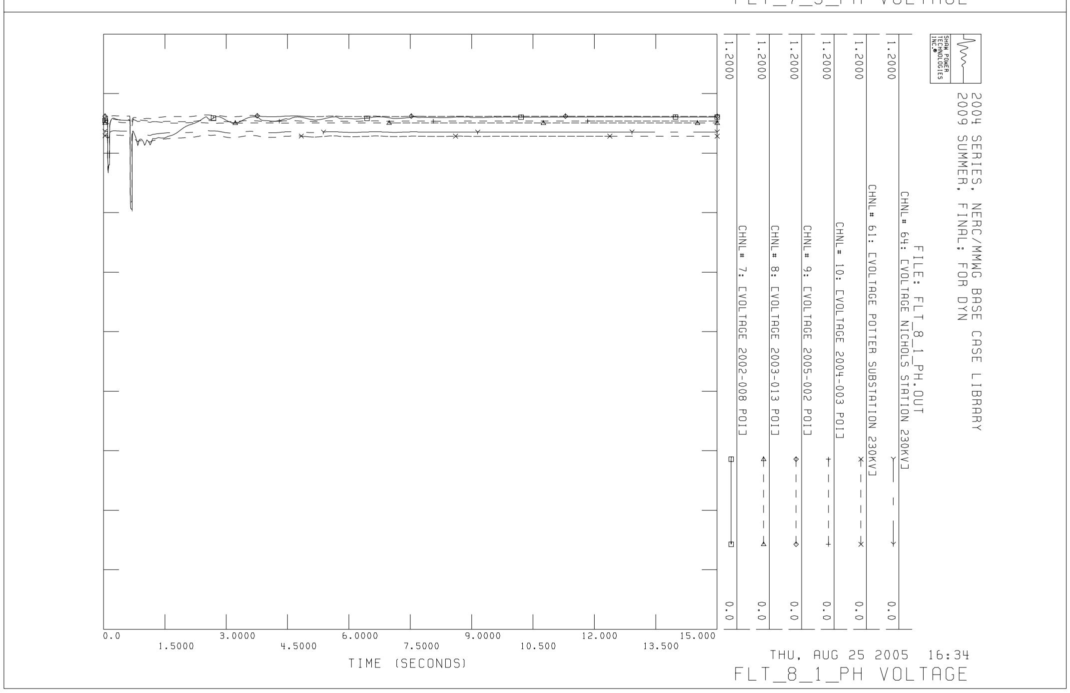
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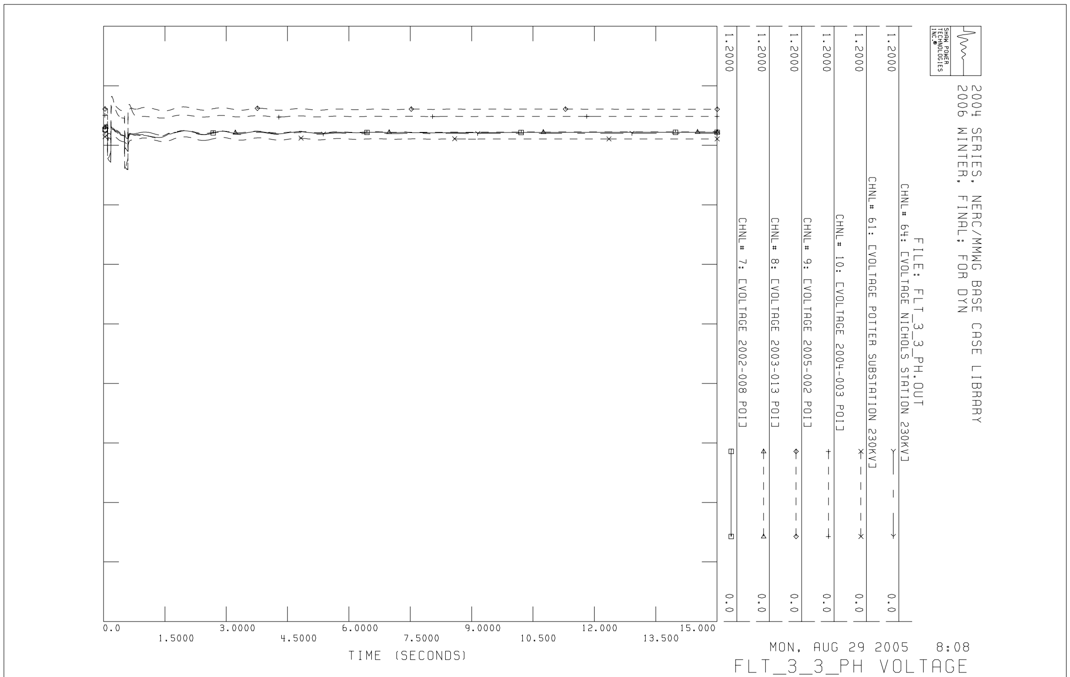

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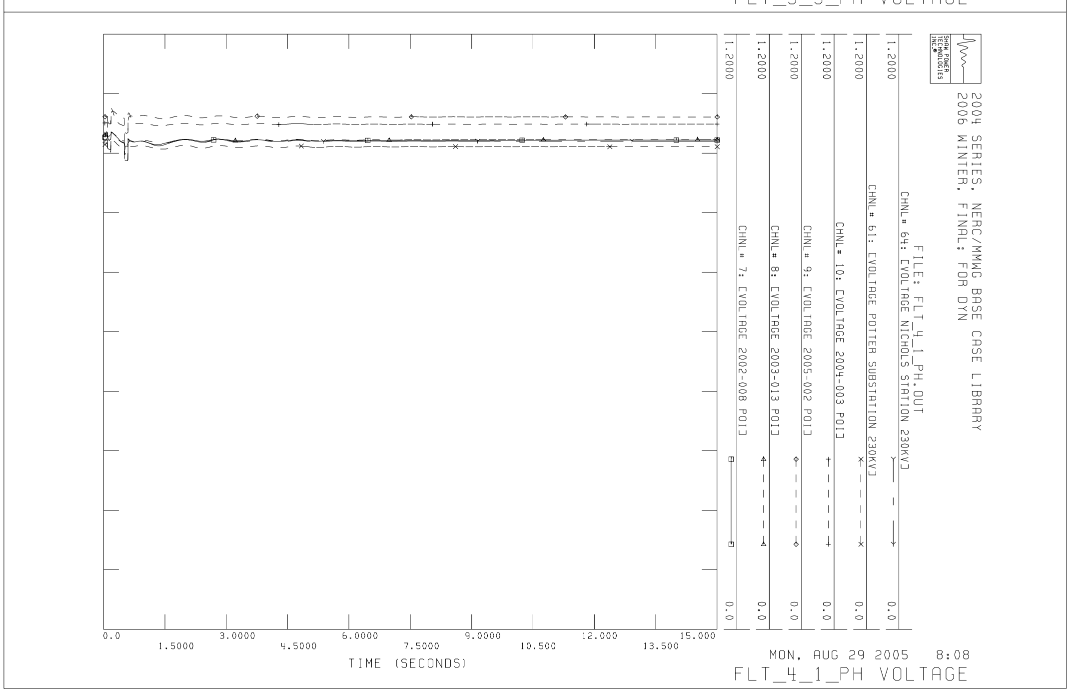

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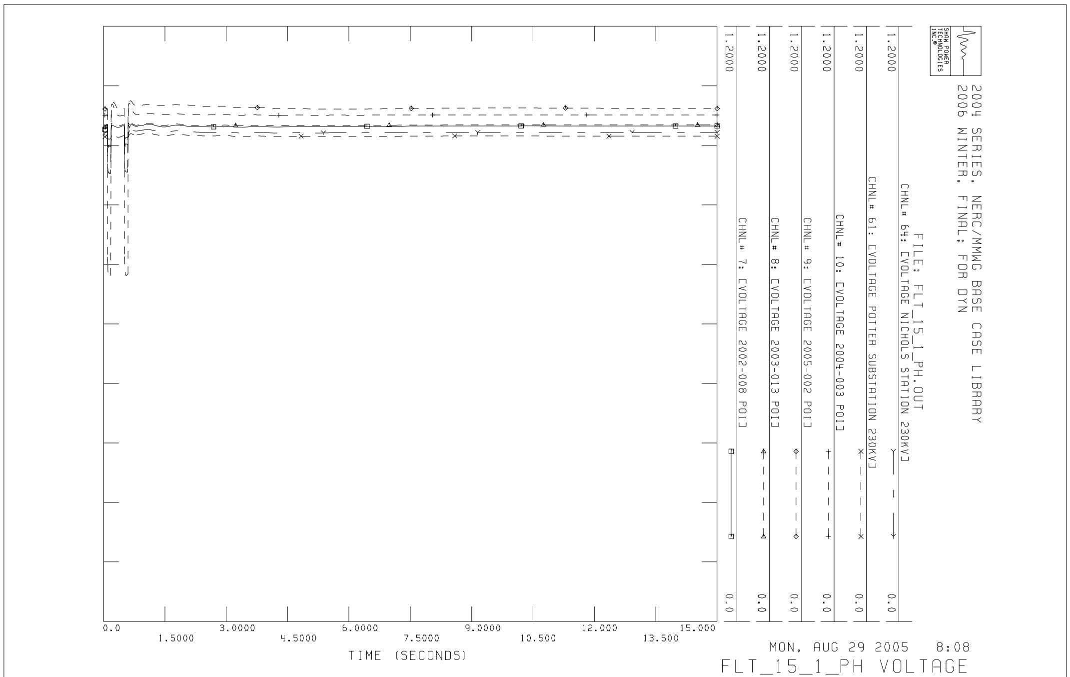
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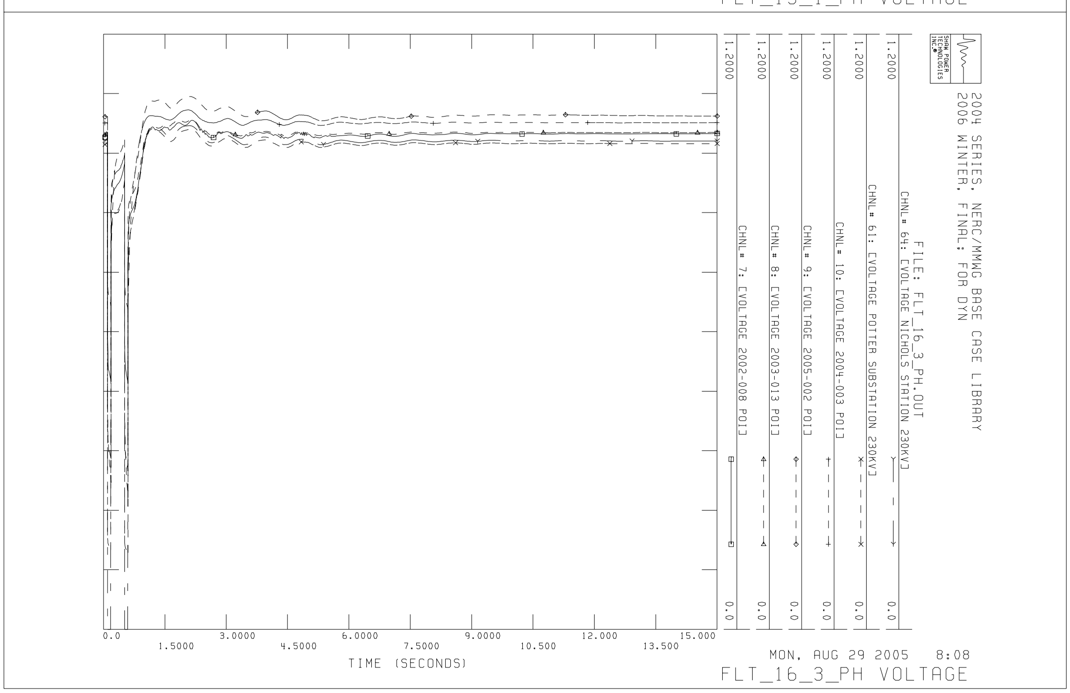
2004 SERIES, NERC/MMWG BASE CASE LIBRARY
2006 WINTER, FINAL; FOR DYN
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CHNL# 61: [VOLTAGE POTTER SUBSTATION 230KV]
CHNL# 10: [VOLTAGE 2004-003 POI]
CHNL# 9: [VOLTAGE 2005-002 POI]
CHNL# 8: [VOLTAGE 2003-013 POI]
CHNL# 7: [VOLTAGE 2002-008 POI]
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0.0
1.5000
3.0000
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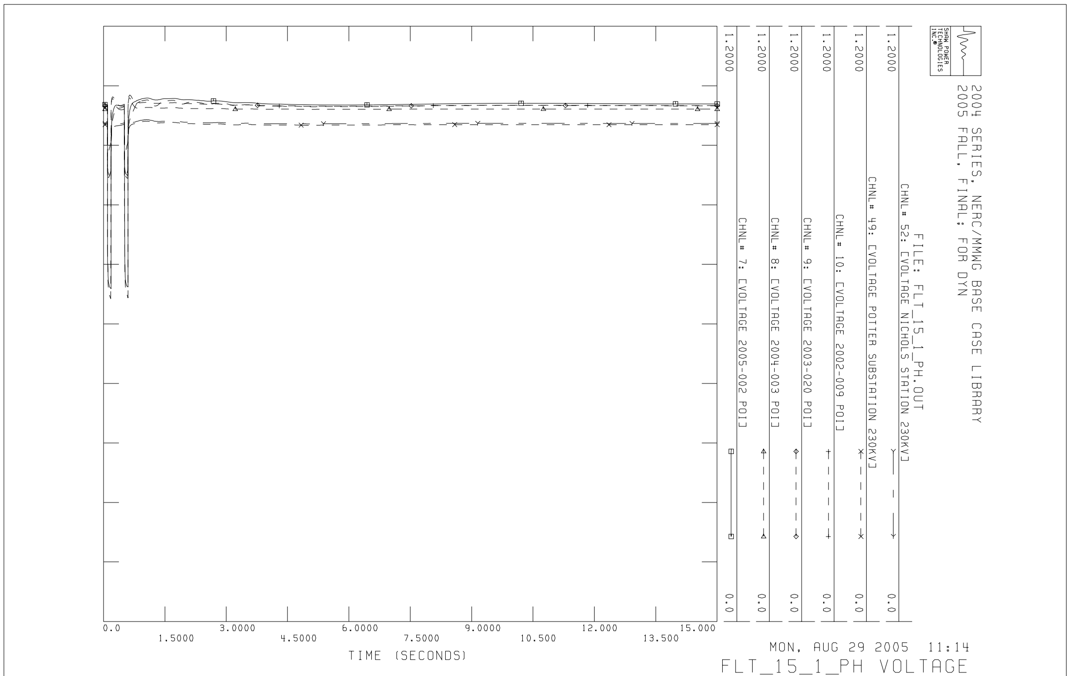
FLT_16_3_PH VOLTAGE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2005 FALL, FINAL; FOR DYN
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CHNL# 49: [VOLTAGE POTTER SUBSTATION 230KV]
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CHNL# 9: [VOLTAGE 2003-020 POI]
CHNL# 8: [VOLTAGE 2004-003 POI]
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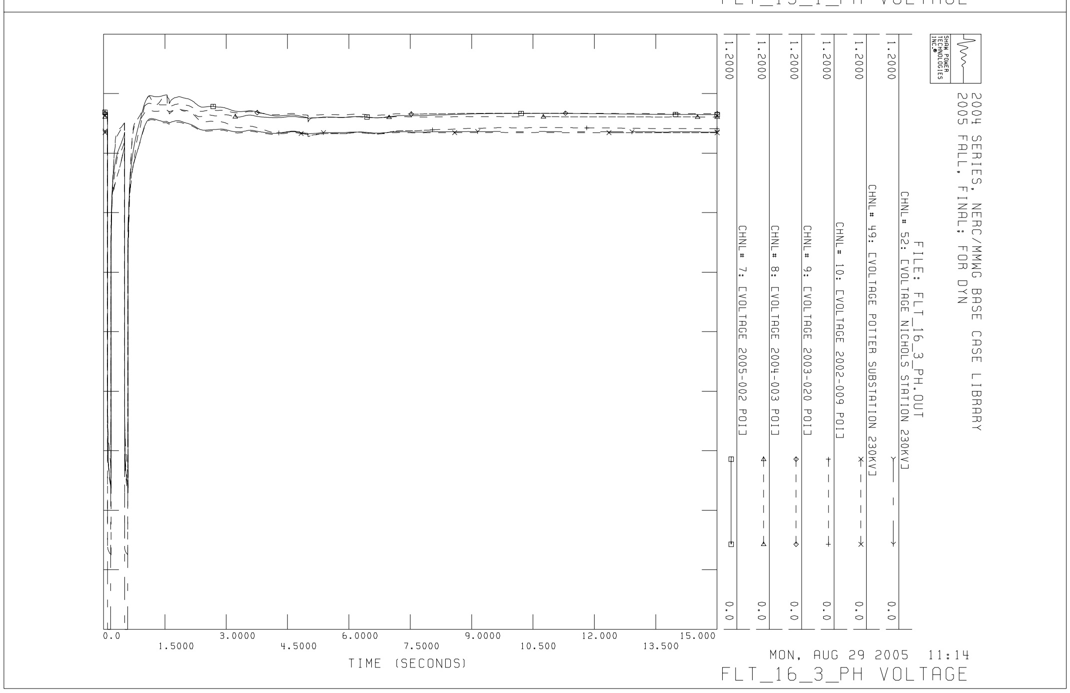
MON, AUG 29 2005 11:14
FLT_15_1_PH VOLTAGE


2004 SERIES, NERC/MMWG BASE CASE LIBRARY
2005 FALL, FINAL; FOR DYN
FILE: FLT_16_3_PH.OUT
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CHNL# 49: [VOLTAGE POTTER SUBSTATION 230KV]
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CHNL# 9: [VOLTAGE 2003-020 POI]
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MON, AUG 29 2005 11:14
FLT_16_3_PH VOLTAGE