SPP Southwest Power Pool

System Impact Study for Generation Interconnection Request

GEN-2003-013

(REVISED AUGUST 26, 2005)

SPP Tariff Studies
(#GEN-2003-013-2A)

August, 2005

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Appendices

1. *Interconnection Guidelines For Transmission Interconnected Producer-Owned Generation Greater Than 20 MW Version 2.0*, p. 24, Retrieved 02/11/2004 from http://www.xcelenergy.com/docs/corpcomm/TransmissionInterconnectionGuidelines.pdf

Executive Summary

This study addendum has been conducted in response to the Facility Study conducted by XCEL Energy (Facility Study) in June, 2005 and the Overvoltage Analysis Study conducted by Shawnee Power Consulting (EMTP study) in June, 2005. These studies recommended placing non-switchable line reactors at the Interconnection substation feeding the Customer generating facility. This addendum will study the line reactors' effect on voltage and power oscillation of the wind farm under certain fault simulations.

<OMITTED TEXT> (Customer) has requested a System Impact Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnection of up to a 198 MW wind powered generation facility in Stevens County, Kansas to the transmission system of Southwestern Public Service Company (SPS/Xcel Energy). The wind powered generation facility will be comprised of 132 individual 1.5MW GE 1.5sL wind turbines. The requested in-service date for the 198MW facility was September 30, 2004. However, this date was considered non-feasible considering the long order and lead times for equipment and construction. The revised in-service date is December 1, 2005.

The wind powered generation facility will interconnect approximately 7 miles northeast of Hugoton, Kansas, and 2 miles east of US Highway 56. The generation facility will interconnect to the Potter to Finney 345kV line circuit J3 via a new 345kV substation. The substation configuration is discussed in the Facility Study.

The Facility Study has required that this project install a non-switchable 50MVAR line reactor at the new switching station, or two non-switchable 27MVAR line reactors if the construction of a higher queued Generator Interconnection Request on the 345kV transmission circuit is also built (Request GEN 2002-008).

There were no adverse impacts to the SPS/Xcel Energy transmission system identified through the power flow and single contingency studies, provided the generation facility satisfies the power factor requirements of SPS/Xcel Energy. The Customer must provide any capacitors or other devices needed to achieve this power factor performance level.[1] The GE turbines utilized for this facility have the capability of achieving this power factor requirement. However, it should be noted that the requirement is at the Point of Interconnection and not at the turbines. Losses between the facility and the Point of Interconnection may require additional compensation depending on final siting and equipment configuration. For purposes of this study, the customer 345/34.5kV transformer substation is assumed adjacent to the 345kV substation on the Potter to Finney line. If during the operation of the facility, the power factor requirements are not met, a capacitor bank shall be required to be installed.

Using the machine models for the turbines proposed by the requestor and other information publicly available, the stability studies indicate that the SPS/Xcel Energy system will remain stable for all simulated faults when the 198MW wind powered generation facility is connected to the transmission system. The GE turbines were able to ride-through all fault simulations that were specified by SPS/Xcel Energy.

The total estimated cost of required network upgrades on the SPS/Xcel Energy system for this interconnection is $6.6 million. The Facility Study should be referenced for details of the interconnection facility and costs.

1. *Interconnection Guidelines For Transmission Interconnected Producer-Owned Generation Greater Than 20 MW Version 2.0*, p. 24, Retrieved 02/11/2004 from http://www.xcelenergy.com/docs/corpcomm/TransmissionInterconnectionGuidelines.pdf

1.0 Introduction

This study addendum has been conducted to further analyze the effects of the line reactors that are proposed to be installed at the interconnection point of this proposed generating facility. The line reactors were proposed in the Facility Study performed by Xcel Energy on June 21, 2005. The Facility Study references the Overvoltage Study conducted by Shawnee Consultants on June 3, 2005 (EMTP Study). This study addendum will only address the stability aspects of the generation request due to the addition of the proposed line reactors.

<OMITTED TEXT> (Customer) has requested a System Impact Study under the Southwest Power Pool Open Access Transmission Tariff (OATT) for interconnecting up to a 198 MW wind powered generation facility in Stevens County, Kansas to the transmission system of Southwestern Public Service Company (SPS/Xcel Energy). The wind powered generation facility will be comprised of 132 individual 1.5MW GE 1.5s wind turbines. The requested in-service date for the 198MW facility was September 30, 2004. However, this date was considered non-feasible considering the long order and lead times for equipment and construction. The revised in-service date is December 1, 2005.

The wind powered generation facility will interconnect approximately 7 miles northeast of Hugoton, Kansas, and 2 miles east of US Highway 56. The generation facility will interconnect to the Potter to Finney 345kV line circuit J3 via a new 345kV substation.

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, and 2002–009), which have higher queue priority than this request, were modeled in this case.

However, due to special considerations on the J3 345kV line circuit, this study addendum did address the possibility of customer GEN-2002-008 might drop out of the interconnection queue, and this study looked at fault simulations with and without GEN-2002-008.

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 GE 1.5s wind turbines. The nameplate rating of each turbine is 1.5MW (1500kW) with a machine base of 1667kVA. The turbine output voltage is 575V. The GE turbines utilize a doubly fed induction-generator with a wound rotor and slip rings. The generator synchronous speed is 1200 rpm, and a variable frequency power converter tied to the generator rotor allows the generator to operate at speeds ranging from 800 rpm to 1600 rpm. Nominal speed at 1.5MW power output is 1440 rpm and the maximum allowable non-operating rotational speed is 1680 rpm. The power converter allows the generator to produce power at a power factor of 0.9 lagging to 0.95 leading. The power factor is settable at each WTG or by the Plant SCADA system.

This power converter capability allows the turbines to have a significantly stronger voltage ride-through capability than other turbine models.

GE has provided optional equipment configurations that consist of enhanced low voltage ride through capability and improved power electronics that will improve efficiency and grid response to power fluctuations. This study was performed using the latest GE Standard Voltage and Frequency Settings with Fault Ride Through modeling stability package available from Shaw PTI (rev. 3.0).

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 Stevens County, Kansas on the existing Potter to Finney 345kV line circuit J3. The new substation would be configured to accept a terminal from an adjacent 345/34.5kV transformer substation that serves the wind powered generation facility.

The 345kV circuit J3 is approximately 220 miles long and connects southwest Kansas to the Amarillo, Texas area. There are no other substations along the line between these two points. However, there is a previously queued request in the SPP Interconnection queue that has requested interconnection to this same circuit J3. This request is a 240MW wind farm located on circuit J3 near the point where the transmission line crosses the Texas-Oklahoma state border. This study has analyzed the project with and without the previously queued project, GEN-2002-008. The location of the GEN-2002-008 plant interconnection substation is between the GEN-2003-013 requested point of interconnection and the Potter substation.

The estimated Network Upgrade costs associated with this interconnection are ***$6,636,765***. The Facility study should be consulted for details.

4.0 Analysis

4.1 Powerflow Analysis

The powerflow analysis was not re-conducted for the August, 2005 study addendum.

A powerflow analysis was conducted for the facility using modified versions of the 2004 Fall Peak and 2009 Summer Peak models. The output of the Customer's facility was offset in each model by a reduction in output of existing online SWPS generation. The in-service date of the facility is proposed to be December 2005. At the time the study was initiated, the next available stability model for simulation was the 2009 Summer Peak. During this initial analysis, a 2004 Fall Peak model was made available and was used to simulate a light load condition with the wind farms operating at full output.

The analysis of the customer's project shows that the proposed location can handle the entire 198MW of output under steady state and single contingency (n-1) conditions without system upgrades in all seasons out to the end of SPP's planning horizon. The powerflow analysis does not study transient disturbances and their effects on the system.

There are several other proposed wind generation additions in the general area of the Customer's facility. It was assumed in the analysis that not all of these other projects were in service. Those previously queued projects that have advanced to nearly complete phases were included in this System Impact study.

4.1.1 Powerflow Analysis Methodology

The Southwest Power Pool (SPP) criteria states that: The transmission system of the SPP region shall be planned and constructed so that the contingencies as set forth in the Criteria will meet the applicable *NERC Planning Standards* for System Adequacy and Security – Transmission System Table I hereafter referred to as NERC Table I) and its applicable standards and measurements.

Using the created models and the ACCC function of PSS\E, single contingencies in the SWPS control area were applied and the resulting scenarios analyzed. This satisfies the 'more probable' contingency testing criteria mandated by NERC and the SPP criteria.

4.2 Stability Analysis

The Stability Analysis was re-conducted for the August, 2005 study addendum for the following scenarios

- A 50MVAR non-switchable line reactor is proposed on the 345kV line from Customer Interconnection substation to Potter County substation located at the Customer station (if GEN-2002-008 customer does **not** sign their IA).
- A 27MVAR non-switchable line reactor is proposed on the 345kV line from Customer interconnection substation to Finney Substation located at the Customer substation; And an additional 27MVAR non-switchable line reactor is proposed on the line from GEN-2002-008 Customer to Potter County Substation located at the GEN-2002-008 Customer substation (if GEN-2002-008 customer does sign their IA).

The following fault simulations were used to analyze the effects on various transmission system facilities and the wind farm.

The faults that were defined by XCEL/SPS and are as follows:

1. Fault on the GEN-2002-013 (90001) – Finney Switch Station (50858) 345kV line, near Finney.

   FLT_1_3_PH - 3-phase Fault
   a. Apply fault at the Finney bus (50858).
   b. Clear fault after 3 cycles by removing the line from 90001 to 50858.
   c. Wait 30 cycles, and then re-close the line in (b) into the fault.
   d. Leave fault on for 3 cycles, then trip the line in (b), remove the 50MVAR reactor at Finney and remove fault.

2. Fault on the GEN-2002-013 (90001) – Finney Switch Station (50858) 345kV line, near Finney ***(utilizing single pole tripping***).

   FLT_2_1_PH - 1-phase Fault
   a. Apply fault at the Finney bus (50858).
   b. Clear fault after 3 cycles by tripping one phase on the line from 90001 to 50858.
   c. Wait 20 cycles, and then re-close the phase in (b) into the fault.
   d. Leave fault on for 3 cycles, then trip the line in (b), remove the 50MVAR reactor at Finney and remove fault.

3. Fault on the GEN-2002-008 (66661) – Potter County (50888) 345kV line, near Potter County.

   FLT_3_3_PH - 3-phase Fault
   a. Apply fault at the Potter County bus (50888).
   b. Clear fault after 3 cycles by removing the line from 50888 to 66661.
   c. Wait 20 cycles, and then re-close line in (b) into the fault.
   d. Leave fault on for 3 cycles, then trip line in (b) remove the 75MVAR reactor at Potter and remove fault.

4. Fault on the GEN-2002-008 (66661) – Potter County (50888) 345kV line, near Potter County ***(utilizing single pole tripping***).

FLT_4_1_PH - 1-phase Fault

a. Apply fault at the Potter bus (50888).
b. Clear fault after 3 cycles by tripping one phase on the line from 66661 to 50888.
c. Wait 20 cycles, and then re-close the phase in (b) into the fault.
d. Leave fault on for 3 cycles, then trip the line in (b) remove the 75MVAR reactor at Potter and remove fault.

5. Fault on the GEN-2002-008 (66661) – GEN-2003-013 (90001) 345kV line; at the midpoint of the line

FLT_5_3_PH - 1-phase Fault

a. Apply fault at the midpoint of the line (99996).
b. Clear fault after 3 cycles by tripping the line from 66661 to 90001.
c. Wait 30 cycles, and then re-close the line in (b) into the fault.
d. Leave fault on for 3 cycles, then trip the line in (b) trip the reactors at 2002-008 and 2003-013 and remove fault.

(In the scenario that GEN-2002-008 does not execute IA; the line was tripped and reclosed from GEN-2003-013 to Potter and the reactors at Potter (75MVAR) and GEN-2003-013 (50MVAR) were tripped.

6. Fault on the GEN-2002-008 (66661) – GEN-2003-013 (90001) 345kV line, at the midpoint of the line ***(utilizing single pole tripping***).

FLT_6_1_PH - 1-phase Fault

a. Apply fault at the midpoint of the line (99996).
b. Clear fault after 3 cycles by tripping one phase on the line from 66661 to 90001.
c. Wait 20 cycles, and then re-close the phase in (b) into the fault.
d. Leave fault on for 3 cycles, then trip the line in (b) trip the reactors and remove fault.

(In the scenario that GEN-2002-008 does not execute IA; the line was tripped and reclosed from GEN-2003-013 to Potter and the reactors at Potter (75MVAR) and GEN-2003-013 (50MVAR) were tripped.

7. Fault on the Grapevine (50827) – Elk City (54153) 230 kV line, near Grapevine.

FLT_7_3_PH - 3-phase Fault

a. Apply fault at the Grapevine bus (50827).
b. Clear Fault after 5 cycles by removing line from 50827 – 54153.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

8. Fault on the Grapevine (50827) – Elk City (54153) 230 kV line, near Grapevine.

FLT_8_1_PH - 1-phase Fault

a. Apply fault at the Grapevine bus (50827).
b. Clear Fault after 5 cycles by removing line from 50827 – 54153.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

9. Fault on the Potter County (50887) – Plant X (51419) 230kV line, near Plant X.

FLT_9_3_PH - 3-phase Fault

a. Apply fault at the Plant X bus (51419).
b. Clear Fault after 5 cycles by removing line from 50887 – 51419.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

10. Fault on the Potter County (50887) – Plant X (51419) 230kV line, near Plant X.

FLT_10_1_PH - 1-phase Fault

a. Apply fault at the Plant X bus (51419).
b. Clear Fault after 5 cycles by removing line from 50887 – 51419.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

11. Fault on the Pringle Interchange (50652) – Blackhawk (50718) 115kV line, near Blackhawk.

FLT_11_3_PH - 3-phase Fault

a. Apply fault at the Blackhawk bus (50718).
b. Clear Fault after 5 cycles by removing line from 50652 – 50718.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

12. Fault on the Pringle Interchange (50652) – Blackhawk (50718) 115kV line, near Blackhawk.

FLT_12_1_PH - 1-phase Fault

a. Apply fault at the Blackhawk bus (50718).
b. Clear Fault after 5 cycles by removing line from 50652 – 50718.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

13. Fault on the Wolfforth Interchange (51762) – Terry County (51830) 115kV line, near Terry County.

FLT_13_3_PH - 3-phase Fault

a. Apply fault at the Terry County bus (51830).
b. Clear Fault after 5 cycles by removing line from 51762 – 51830.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

14. Fault on the Wolfforth Interchange (51762) – Terry County (51830) 115kV line, near Terry County.

FLT_14_1_PH - 1-phase Fault

a. Apply fault at the Terry County bus (51830).
b. Clear Fault after 5 cycles by removing line from 51762 – 51830.
c. Wait 20 cycles, and then re-close line in (b) into the fault.
d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

The above cases were run for the following conditions (Voltage control was enabled on the GE machines for all scenarios):

<u>2010 Summer Peak (Max loading conditions)</u>

- Wind farm at 198MW and GEN-2002-008@240MW; 27MVAR fixed line reactors at each wind farm substation. (Appendix 1)
- Wind farm output at 198MW and no GEN-2002-008; 50MVAR fixed line reactor at the GEN-2003-013 interconnection substation. (Appendix 2)

4.2.1 Equivalent Modeling of the Wind Powered Generation Facility

The rated output of the generation facility is 198MW, comprised of 132 GE 1.5s wind turbines. The base voltage of the GE turbine is 575 V, and a generator step up transformer (GSU) of 1.75MVA connects each unit to the high side of 34.5kV. The rated power output of each turbine is 1.5MW 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 substation will consist of two (2) 100MVA, 345kV/34.5kV transformers connected in parallel. From the preliminary one-lines received from the customer, on the 34.5kV side of each transformer, 6 feeder circuits will extend into the generating facility. Each feeder will connect to a collection substation that will in turn consist of 3 collection circuits. Each collection circuit will consist of 7 or 8 turbines each. Each turbine then has its own pad-mounted transformer rated 575V/34.5kV and 1.75MVA. Figure 1 represents the facility and surrounding system that was studied for the scenario assuming that customer GEN-2002-008 does execute their IA. Figure 2 represents the facility and surrounding system assuming the GEN-2002-008 does not sign their IA.

The actual parameters (R, X and B) of the 34.5kV collector circuits are calculated based on the data provided by the customer and assumptions of typical conductor characteristics. This information is useful in estimating the impedance of the collection and feeder systems. The cable impedance characteristic table is as follows:

Cable Impedance Characteristic Table				
Cardinal	1000 ACSR	RAC=0.0186 Ohm/1000'	XL=0.0737 Ohm/1000'	XC=0.0168 Mohm-1000'
MV-105	1/0 Cu Shielded	RAC=0.1060 Ohm/1000'	XL=0.0500 Ohm/1000'	XC=0.0483 Mohm-1000'

4.2.2 Machine Dynamics Data

The GE 1.5s wind turbine generators utilize a doubly fed induction-generator with a wound rotor and slip rings. The generator synchronous speed is 1200 rpm, and a variable frequency power converter tied to the generator rotor allows the generator to operate at speeds ranging from 800 rpm to 1600 rpm. Nominal speed at 1.5MW power output is 1440 rpm and the maximum allowable non-operating rotational speed is 1680 rpm. The power converter allows the generator to produce power at a power factor of 0.9 lagging to 0.95 leading. The power factor is settable at each WTG or by the Plant SCADA system.

Shaw Power Technologies Inc. (PTI) has produced a GE 1.5s turbine model package for use on their PSS/E simulation software. This package was obtained from PTI and was used exclusively in modeling this wind farm. The GE stability model package used was released by Siemens PTI in July, 2005.

The PTI 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), whether the turbines will be set to a specific voltage or power factor setpoint, 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). Improved default protection schemes are a part of the improved GE wind turbine model package from PTI. These protection schemes represent the Standard Voltage and Frequency Settings with Fault Ride Through capability of the GE machines.

4.2.3 Turbine Protection Schemes

The GE turbines utilize an undervoltage/overvoltage protection scheme and an underfrequency/overfrequency 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 below:

Voltage	Time Limit
1.3000pu +	1.2 cycles (0.02s)
1.1500pu -- 1.299pu	6 cycles (0.1s)
1.1499pu – 1.1000pu	60 cycles (1.0s)
1.0999pu – 0.8501pu	Continuous Operation
0.8500pu -- 0.7501pu	600 cycles (10.0s)
0.7500pu – 0.7001pu	60 cycles (1.0s)
0.7000pu – 0.3001pu	6 cycles (0.1s)
0.3000pu – 0.0000pu	1.2 cycles (0.02s)

Table 1: GE 1.5s Turbine Voltage Protection

The frequency protection scheme is outlined in Table 2 below:

Frequency	Time Limit
62.5000Hz +	1.2 cycles (0.02s)
62.4999Hz -- 61.500Hz	1800 cycles (30.0s)
61.4999Hz -- 57.5001Hz	Continuous Operation
57.5000Hz – 56.5001Hz	600 cycles (10.0s)
56.5000Hz – 0.0000Hz	1.2 cycles (0.02s)

Table 2: GE 1.5s Turbine Frequency Protection

4.3 Stability Results

The GEN-2003-013 wind farm appears to remain stable for all faults applied. In the previous study, the wind farm tripped off for 3-phase faults close to the wind farm (FLT_1_3PH and FLT_5_3PH) due to low voltage. Slight in the PTI stability models and SPP network models show that the generator busses do not drop below the instantaneous trip point for these faults. In the earlier study the generator busses dip below the 0.3 pu instantaneous trip; in this study the generator busses dip to around 0.33 pu.

Faults closer to the wind farm were not analyzed for this request but would probably result in the instantaneous tripping of the wind farm.

The wind farm and the surrounding transmission system appear to remain stable for all faults applied and for all scenarios analyzed. This is in contrast to results previously documented for this request. Previously, the single-phase fault at Finney (FLT_2_1PH) would cause a voltage and power oscillation at both wind farms on this line, which would translate out to the rest of the SPS transmission system. This voltage and power oscillation was caused by a combination of the controls on the Vestas wind turbines and the hampered controls of the GE wind turbines due to modeling deficiencies.

This study was created using the latest models available from PTI for the GE wind turbines. The models for this study were built using the Southwest Power Pool 2005 series models for the 2010 summer peak using PSS/E version 29. Previous studies were performed using older PTI models in PSS/E version 28.

This study was run by modeling the reactors at Finney, Potter County, GEN2002-008 interconnection point, and GEN2003-013 interconnection point as non-switchable. All reactors remained in service for all simulations unless called on to trip during a line trip. The system performed satisfactorily for all simulations using this configuration.

It was also found during the course of the study that the proposed capacitor banks at the GEN-2002-008 collector substations were not modeled as being able to be switched in during the fault analysis. GEN-2002-008 has proposed to place a 3x10MVAR switched capacitor bank at each of its 3 collection substations. The settings on these capacitor banks should be closely scrutinized. The pickup times should be staggered, as a close fault may cause each collector substation to experience a very low voltage almost simultaneously. This would cause the 3 capacitor banks to switch in simultaneously causing a sudden large voltage rise that may cause the turbines to either trip offline or trip their power factor correction capacitors.

Adding a switched capacitor bank at the GEN-2003-013 site would also be beneficial as to allow the GE turbines some reactive reserve margin in which to operate. If the GE machines are at the maximum limits of their reactive capability, they will be unable to regulate any voltage or power deviations that may occur. It is impossible to determine what size of capacitor bank may be required for all situations or wind farm generating levels. However, the interconnection guidelines of SPS/Xcel Energy require that induction generator installations must provide reactive compensation such that the power factor at the point of interconnection is between 0.95 leading to 0.95 lagging. To execute an Interconnection Agreement, the Customer will be required to meet this power factor. For this 198MW wind farm, that reactive requirement is 65MVAR. The GE machines are capable of providing up to 65MVAR (0.95 leading) and absorbing 96MVAR (0.90 lagging) of reactive power. However, there are transformer and collection system losses that must be taken into account. If the required power factor is not maintained during operation, a capacitor bank shall be required.

It may be required to convert the existing fixed line reactors at Potter and Finney into switched reactors with supervisory control that can be placed in-service if both wind farms are at minimum output or the voltage profile along the line requires the shunt. It is possible the line reactors at Potter and Finney will not be required at the wind farm interconnection substations (both GEN-2002-008 and GEN-2003-013) when the wind farms were operating. As the wind turbines would inherently draw VARS from the system, the reactors would simply be an additional reactive sink and place a greater burden on the wind farms to provide for their own voltage support. According to the EMTP study, non-switchable line reactors are required on the 345kV lines leaving the interconnection substations when attempts are made to close the lines.

5.0 <u>Conclusion</u>

No stability concerns presently exist for the GEN-2003-013 wind farm as proposed and studied. Whether or not the higher queued wind farm request (GEN-2002-008) executes an IA or not, the required non-switchable line reactors for overvoltage do not impair system stability. Due to the close electrical proximity of this wind farm to a previously studied, higher queued wind farm (GEN-2002-008), close coordination between both wind farm developers and equipment manufacturers will be required to ensure that the equipment is being modeled correctly and controls are adjusted correctly.

Additional facilities analyzed for this study addendum include –

- 50 MVAR non-switchable line reactor if Gen-2002-008 does Not sign their IA
- 27 MVAR non-switchable line reactor located at Gen-2002-008 and Gen-2003-013 if Gen-2002-008 does sign their IA

The Network Upgrade cost of interconnecting the Customer project approximately $6.6 million. The Facility Study should be consulted for details.

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. The models do contain all the firm transmission service included by the transmission owners in their model updates for SPP's planning models.

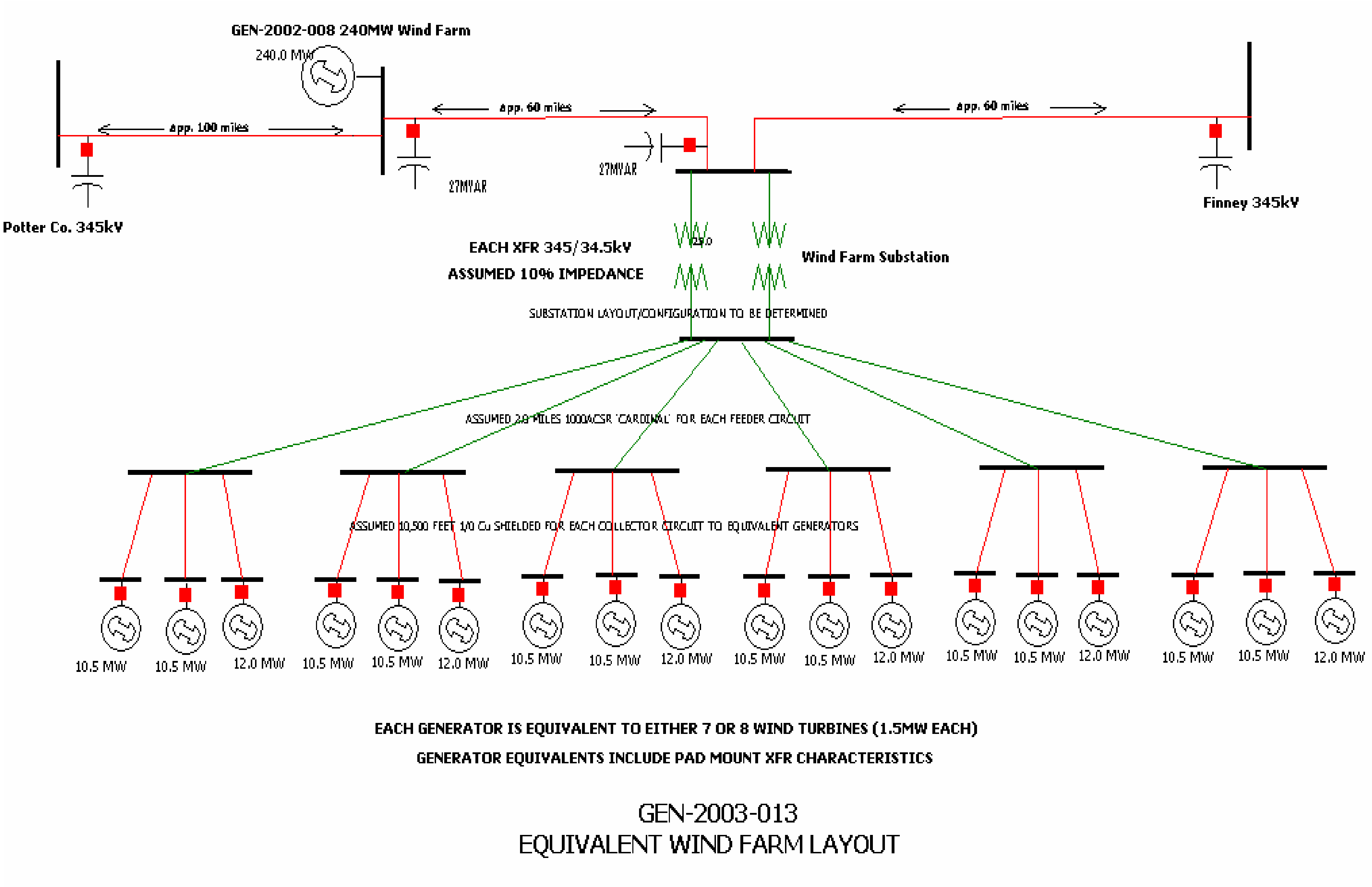


Figure 1. – Layout Assuming GEN-2002-008 Executes I.A.

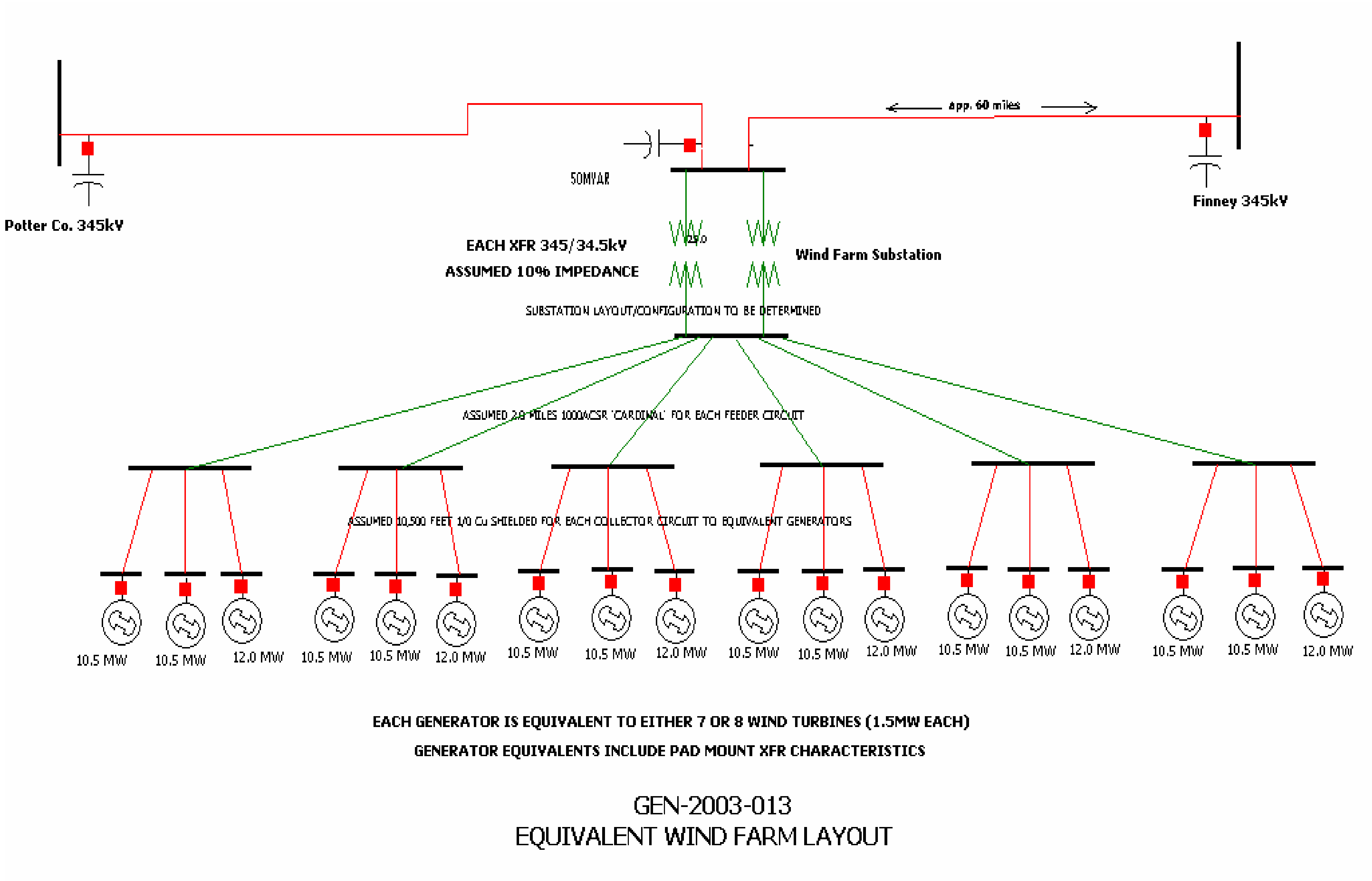


Figure 2. – Layout Assuming GEN-2002-008 Does Not Execute I.A.

Appendix 1

Plots of Fault Simulations

Plots of Wind Farm generators voltage response during faults
Plots of various SPS/Xcel Energy generator angle response during faults

Scenario:

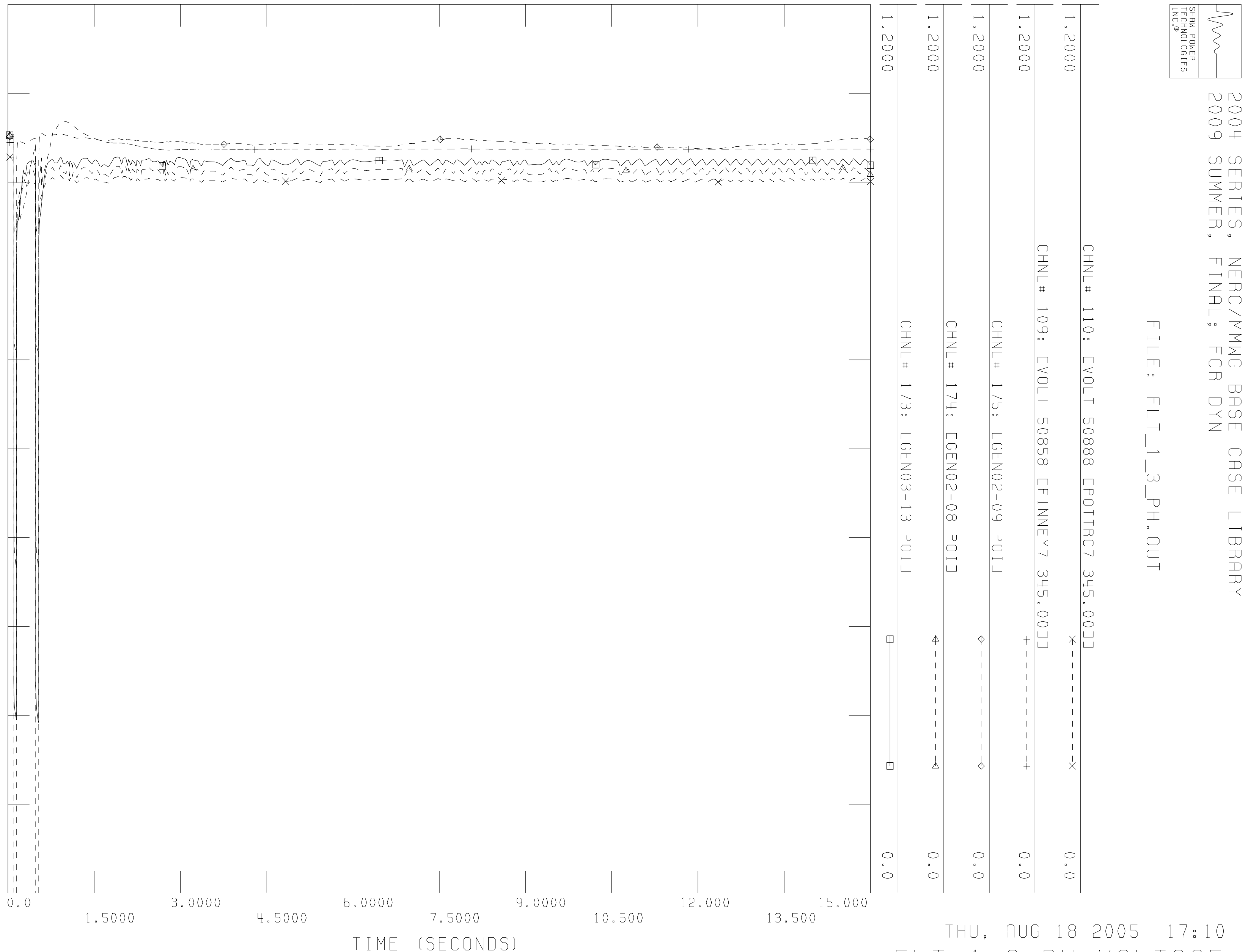
2010 Summer Peak with Wind Farm at 198MW output and Voltage Control enabled

Adjacent GEN-2002-008 wind farm at 240MW output

345kV line between the two wind farms has a non-switchable 27MVAR line reactor at each end

- **Plot #1 –** System Voltage for contingency FLT_1_3_PH
- **Plot #2 –** System Voltage for contingency FLT_3_3_PH
- **Plot #3 -** System Voltage for contingency FLT_5_3_PH

Voltage and Angle Plots for All Contingencies can be provided on request.



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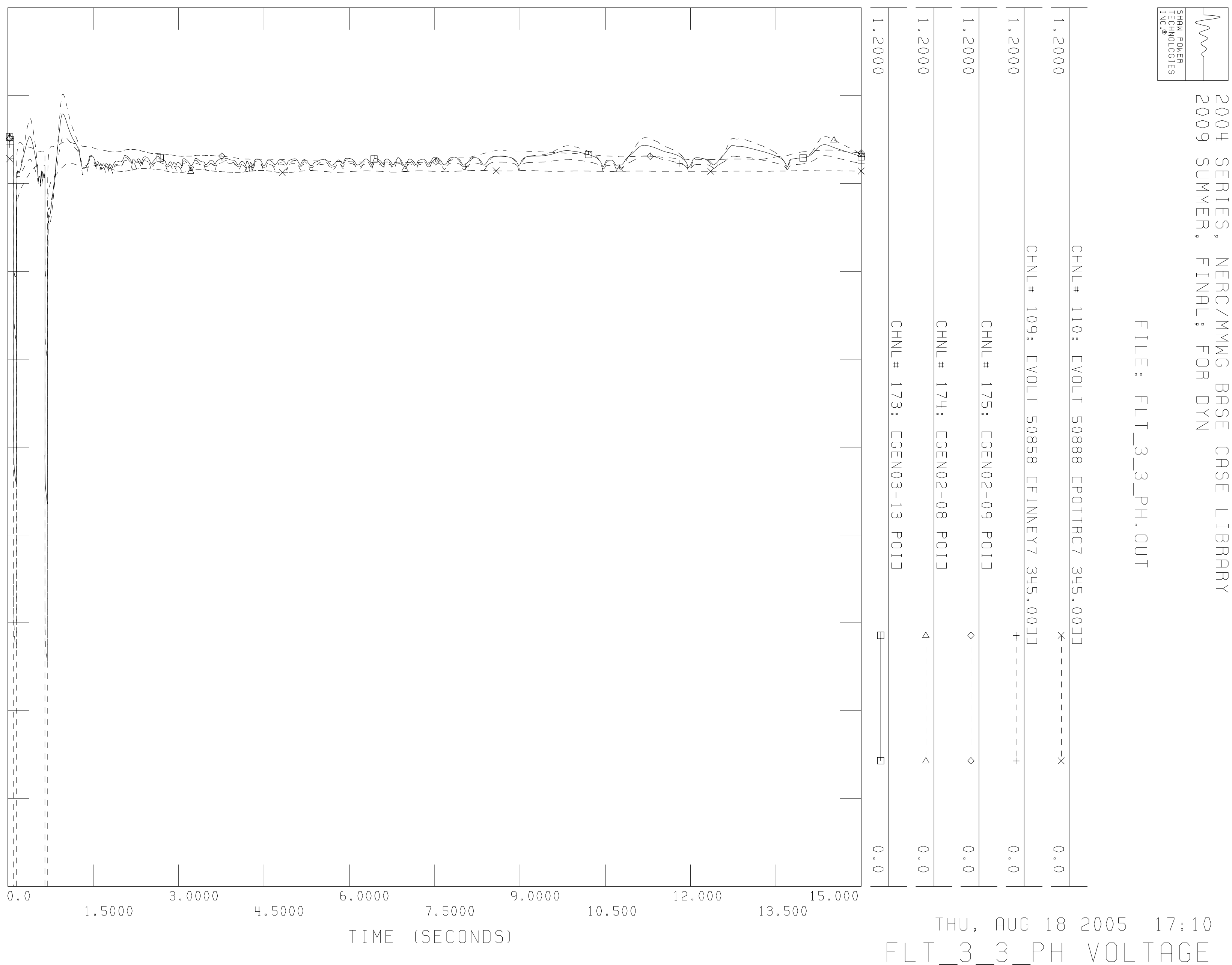
FLT_1_3_PH VOLTAGE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2009 SUMMER, FINAL; FOR DYN
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SHAW POWER TECHNOLOGIES INC.®
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CHNL# 109: [VOLT 50858 [FINNEY7 345.00]]
CHNL# 175: [GEN02-09 POI]
CHNL# 174: [GEN02-08 POI]
CHNL# 173: [GEN03-13 POI]
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0.0
1.5000
3.0000
4.5000
6.0000
7.5000
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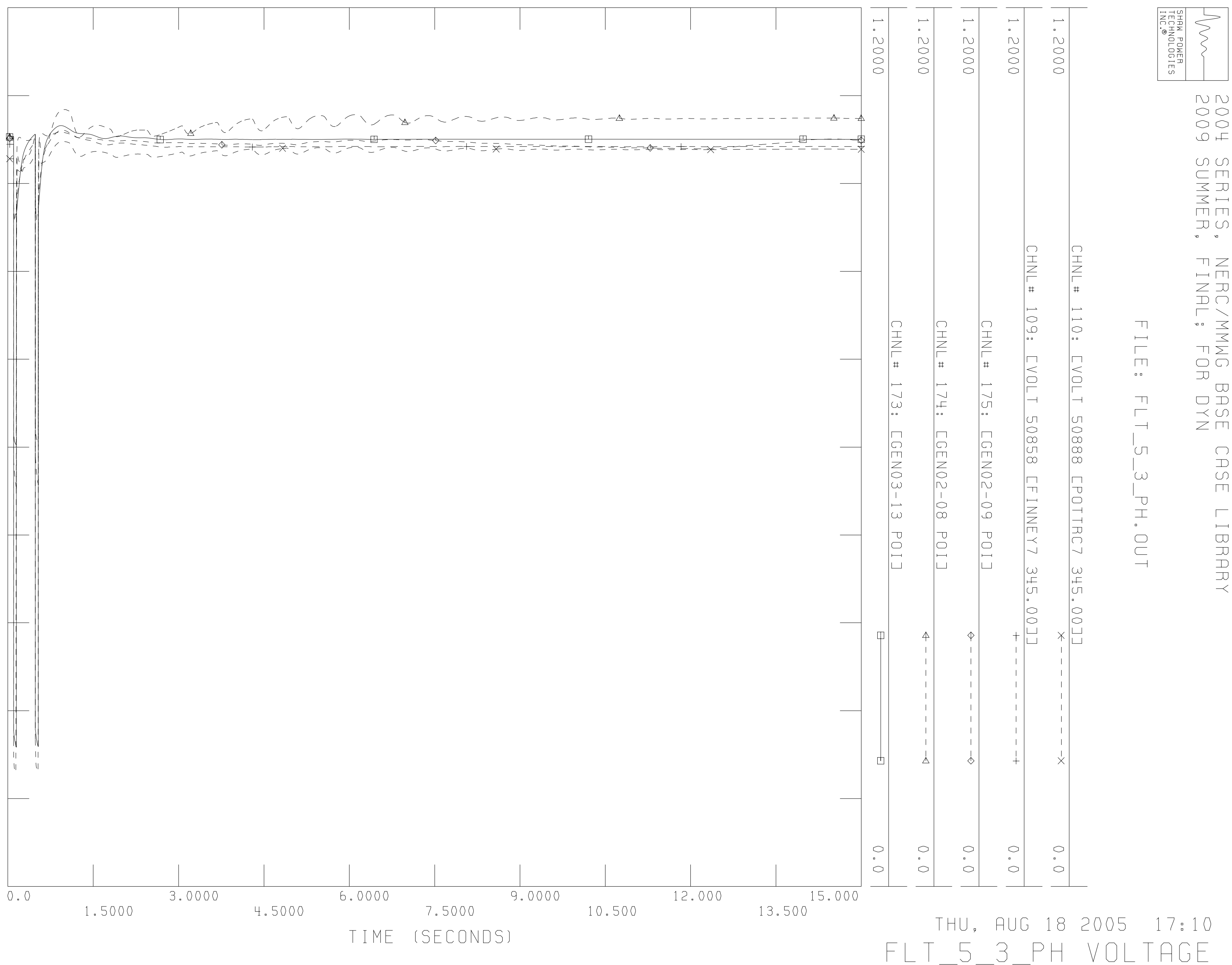
TIME (SECONDS)
THU, AUG 18 2005 17:10
FLT_3_3_PH VOLTAGE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CHNL# 174: [GEN02-08 POI]
CHNL# 173: [GEN03-13 POI]
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SHAW POWER TECHNOLOGIES INC.®
0.0
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TIME (SECONDS)
THU, AUG 18 2005 17:10
FLT_5_3_PH VOLTAGE

Appendix 2

Plots of Fault Simulations

Plots of Wind Farm generators voltage response during faults
Plots of various SPS/Xcel Energy generator angle response during faults

Scenario:

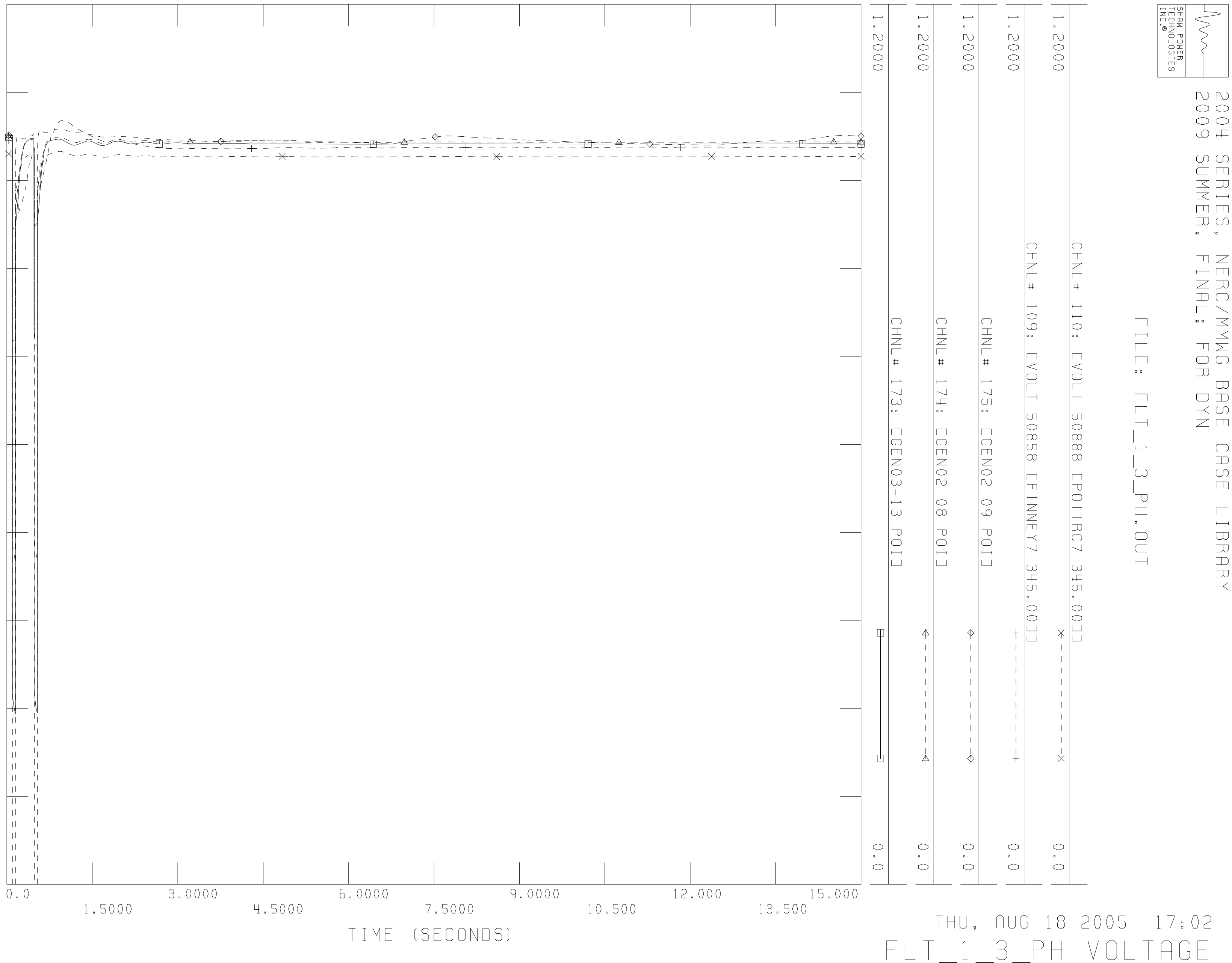
2010 Summer Peak with Wind Farm at 198MW output and Voltage Control enabled

(No GEN-2002-008 wind farm)

345kV line between GEN-2003-013 and Potter has a 50MVAR non-switchable reactor on Customer end and existing 75MVAR non-switchable reactor at Potter

- **Plot #1 –** System Voltage for contingency FLT_1_3_PH
- **Plot #2 –** System Voltage for contingency FLT_5_3_PH
- **Plot #3 -** System Voltage for contingency FLT_7_3_PH

Voltage and Angle Plots for All Contingencies can be provided on request.



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0.0
1.5000
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7.5000
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TIME (SECONDS)
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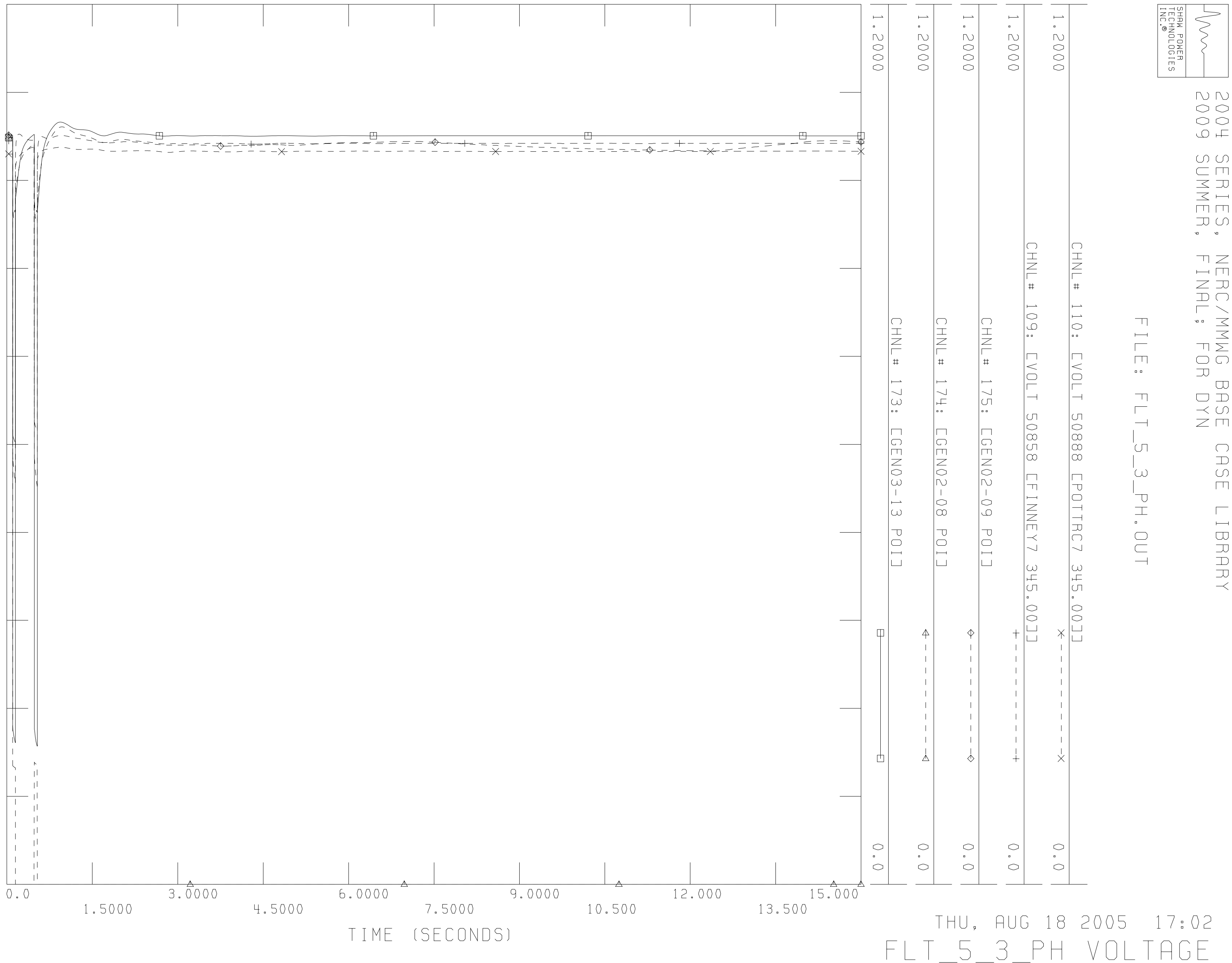
FLT_1_3_PH VOLTAGE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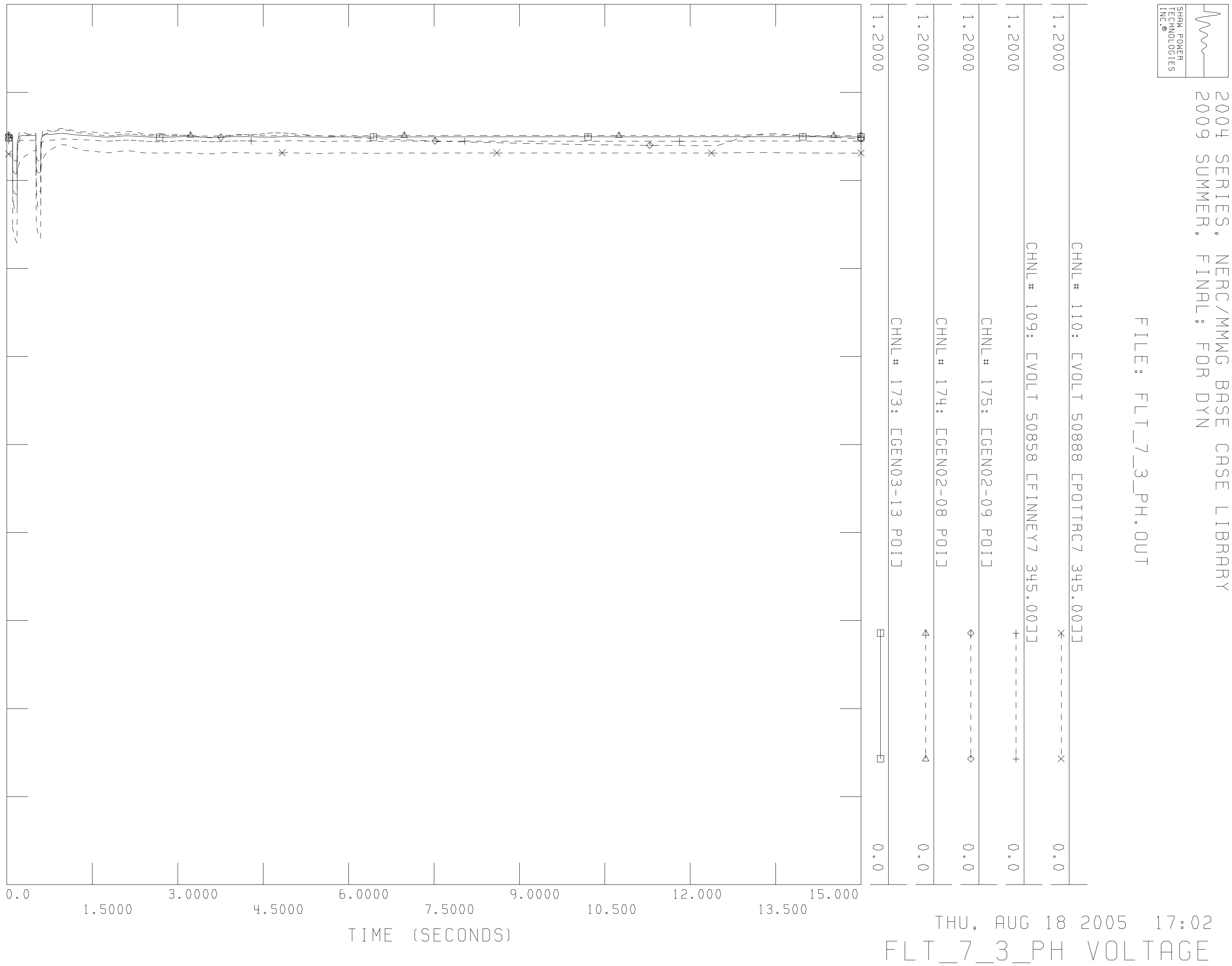
TIME (SECONDS)
THU, AUG 18 2005 17:02
FLT_5_3_PH VOLTAGE
SHAW POWER TECHNOLOGIES INC.®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CHNL# 174: [GEN02-08 POI]
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TIME (SECONDS)
THU, AUG 18 2005 17:02
FLT_7_3_PH VOLTAGE