Southwest Power Pool

System Impact Study for Generation Interconnection Request

GEN-2003-013

(REVISED JUNE 25, 2004)

SPP Tariff Studies
(#GEN-2003-013)

June 2004

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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 has been conducted to further analyze the effect of improved wind turbine modeling and its effect on a voltage and power oscillation of this 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 will be finalized during the Facility Study if the customer elects to proceed.

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 Producer 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.

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 12 of 14 distinct fault simulations that were specified by SPS/Xcel Energy. Three-phase faults close to the wind farm cause the voltage to drop below the instantaneous trip setting of the turbines. Investigation of adding an SVC at the wind farm site to prevent the voltage from reaching the instantaneous trip point was unsuccessful.

It may be required that line reactors be placed on the lines leaving the interconnection substation such that if the wind farm is not operating, the voltage does not get too high on the 345kV line. It was estimated for purposes of this study that the line reactors would be sized at 25MVAR each.

Short circuit analysis for this wind powered generation facility will be performed by SPS/Xcel Energy as part of the Facility Study if the customer elects to proceed. This will require that SPS/Xcel Energy perform an EMTP study during the Facility Study.

The total estimated cost of required network upgrades on the SPS/Xcel Energy system for this interconnection is $3.9 million. The cost includes only construction of the 345kV substation tapping the Potter to Finney line. This cost does not include any costs associated with customer facilities including the customer 345/34.5kV substation, any line connecting the customer substation and the new 345kV substation or associated right-of-way, or the proposes line reactors mentioned above.

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1.0 Introduction

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<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. The substation configuration will be finalized during the Facility Study if the customer elects to proceed.

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 will consider 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 also 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, -008, and –009), 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 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 "LVRT (Low Voltage Ride Through" option and the latest GE 1.5s wind turbine 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. It was assumed for this study that this previously queued project, GEN-2002-008, was in-service for all scenarios. This places the GEN-2002-008 plant interconnection substation on the line between the GEN-2003-013 requested point of interconnection and the Potter substation.

The estimated Network Upgrade costs associated with this interconnection are as follows:

Network Upgrades Required:

- 345kV substation (tentatively proposed as a 3-breaker ring bus) ***$3,837,900***
- Line Reactor(s) required at the 345kV substation* ***$1,898,914***
  *Note: The need for and final sizing for any line reactors will be determined by an EMTP study conducted by SPS/Xcel Energy as part of the Facility Study.
- Breaker replacement or adjustment* ***[No Estimate Determined]***
  *Note: The need for and final sizing of any breaker adjustment or replacement will be determined by the Short Circuit study to be conducted by SPS/Xcel Energy as part of the Facility Study.
- Total Network Upgrade cost: ***$5,736,814***

The estimated Direct Assignment costs associated with this interconnection are as follows:

Direct Assignment Facilities:
- Line connecting 345kV substation with customer 34.5kV substation (est. 1000') ***$974,183***
- Right-of-way for above line ***$85,000***

These Direct Assignment costs are estimates only and depend entirely up on final siting of the customer substation and the length/ownership of the line connecting it to the 345kV substation.

4.0 Analysis

4.1 Powerflow Analysis

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

The faults that were performed were defined by 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 5 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 5 cycles, then trip the line in (b), remove the 50MVAR reactor at bus 50858 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 5 cycles by tripping one phase on the line from 90001 to 50858.
   c. Wait 30 cycles, and then re-close the phase in (b) into the fault.
   d. Leave fault on for 5 cycles, then trip the line in (b), remove the 50MVAR reactor at bus 50858 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 5 cycles by removing the line from 50888 to 66661.
   c. Wait 30 cycles, and then re-close line in (b) into the fault.
   d. Leave fault on for 5 cycles, then trip line in (b) 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 5 cycles by tripping one phase on the line from 66661 to 50888.
   c. Wait 30 cycles, and then re-close the phase in (b) into the fault.
   d. Leave fault on for 5 cycles, then trip the line in (b) 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 5 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 5 cycles, then trip the line in (b) and remove fault.

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 5 cycles by tripping one phase on the line from 66661 to 90001.
   c. Wait 30 cycles, and then re-close the phase in (b) into the fault.
   d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

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):

2009 Summer Peak (Max loading conditions)
System base case with Wind farm idled (0MW) and GEN-2002-008@240MW (Appendix 1)
Wind farm output at 198MW and GEN-2002-008@240MW (Appendix 2)
Wind farm output at 198MW and GEN-2002-008 idled (0MW) (Appendix 3)
Wind farm output at 99 MW and GEN-2002-008@240MW (Appendix 4)

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, existing on-line generation in the local control area is displaced by the addition of the generator in order to preserve control area interchange schedules in the model. Adjustment of the control area dispatch is performed with input from the Transmission Owner to accurately model unit commitments and availability.

The generating facility substation will consist of three (3) 42MVA 115kV/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. Please see the one-line drawing (Figure 1) attached to this document.

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 version 1.5 released by Shaw PTI.

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 and 50% rated power). It was also assumed that all turbines located in the farm were in-service (50% rated power means that all 100 turbines were generating at 50% rated power). Improved default protection schemes are a part of the new, improved GE wind turbine model package from Shaw PTI. These protection schemes represent the Low Voltage Ride Through (LVRT) 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 Representing LVRT Package

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. However, for 3-phase faults close to the wind farm (FLT_1_3PH and FLT_5_3PH) the wind farm trips offline due to low voltage. The voltage at the generator buses in each fault approaches 0.25pu, which is below the instantaneous trip setting of the wind turbines. Single-phase faults at these locations (FLT_2_1PH and FLT_6_1PH) do not trip the turbines. In an investigative measure aimed at trying to prevent the wind farm from tripping, an SVC was added at the 34.5kV bus with up to 170MVAR of capacitive reactive support capability. This SVC was tuned to allow very fast operation in order to help the voltage at the wind farm recover from the fault very quickly. However, the voltage at the wind farm would still reach a level below the GE instantaneous trip setting and cause the wind turbines to trip offline. Further study with the SVC was abandoned.

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. Further discussion of this topic will occur in section 4.3.1.

4.3.1 Differences in results of stability analysis from previous study (3/24/03 version)

Previously, this generation interconnection request was found to cause voltage instability at both the GEN-2003-013 wind farm and the GEN-2002-008 wind farm for the single-phase fault at Finney. This fault simulation consisted of grounding one phase of the 345kV line by applying a fault at the Finney 345kV bus at time=0.1 seconds. Tripping on this 345kV line consists of single-pole tripping which allows only the affected phase to be tripped initially during the first clearing. This tripping scheme is an attempt to keep the phase angle difference between Southwest Kansas and North Texas from becoming too large. The tripped phase has automatic reclosing that connects the line back into the fault. Second clearing of the fault removes all 3 phases from service.

In the previous study, during the fault simulation the GEN-2002-008 wind farm rotor protection system would engage and as the fault cleared, the GEN-2002-008 power factor correction capacitors would trip due to a slight overvoltage as the voltage recovered. This would cause a reactive power deficiency that forced the Vestas wind turbine controls to “hunt” for a new operating point. This hunting caused a voltage and power oscillation that was transmitted to the rest of the transmission system. This was further aggravated by the addition of the GEN-2003-013 wind farm with its active var control device. The aggravation was the greatest when the GE turbines were set to regulate the voltage to a specific setpoint.

Several factors were present in the model that made this reactive power deficiency worse. It was proposed during the feasibility study phase of GEN-2002-008 that line reactors may be required at the interconnection substation to alleviate voltage rise on the long 345kV line. These reactors were estimated at 25MVAR on each line leaving the GEN-2002-008 substation. However, it was found during this study that those line reactors may not be necessary when the wind farm is operating. It was also found that during the stability analysis of the GEN-2002-008 wind farm and the previous analysis of the GEN-2003-013 wind farm that those line reactors were incorrectly modeled as bus shunts. These bus shunts were left in-service during and after the fault, contributing significantly to the reactive deficiency in the area and driving voltages down further than necessary. A similar situation was found with the line reactors at both Potter County and Finney. An important point is that in the situation where both wind farms are either offline or generating at reduced output levels, the voltage on the 345kV line can approach rather high levels due to the high charging current present on this line. These line reactors would be required in this operating condition.

In addition, two proposed 345kV lines were removed from service in the re-analysis of GEN-2003-013. These two 345kV lines are no longer proposed so they were removed from the case.

Since the initial stability analysis was performed for GEN-2003-013, Shaw PTI has updated the GE wind turbine stability model to better represent the voltage regulation abilities of the power converter onboard each turbine. Updating the GE model significantly contributed to improved simulation results.

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. For this 198MW wind farm, that reactive requirement is $\pm$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. Results of an EMTP study and final design layout information will be required to determine the need for additional capacitors at GEN-2003-013.

Upon further discussion with SPS/Xcel Energy, 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 was also assumed that line reactors were not 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. Line reactors may be required on the 345kV lines leaving the interconnection substations when attempts are made to close the lines. However, these line reactors may need to be removed under certain operating conditions. Voltage setpoints and the voltage profile along the line should be closely scrutinized and final sizing of the capacitor bank(s) and possibly line reactor(s) will be completed during the Facility Study phase if the customer elects to proceed.

At this time, it does not appear necessary that the reactive support requirements for GEN-2003-013 should be dynamic.

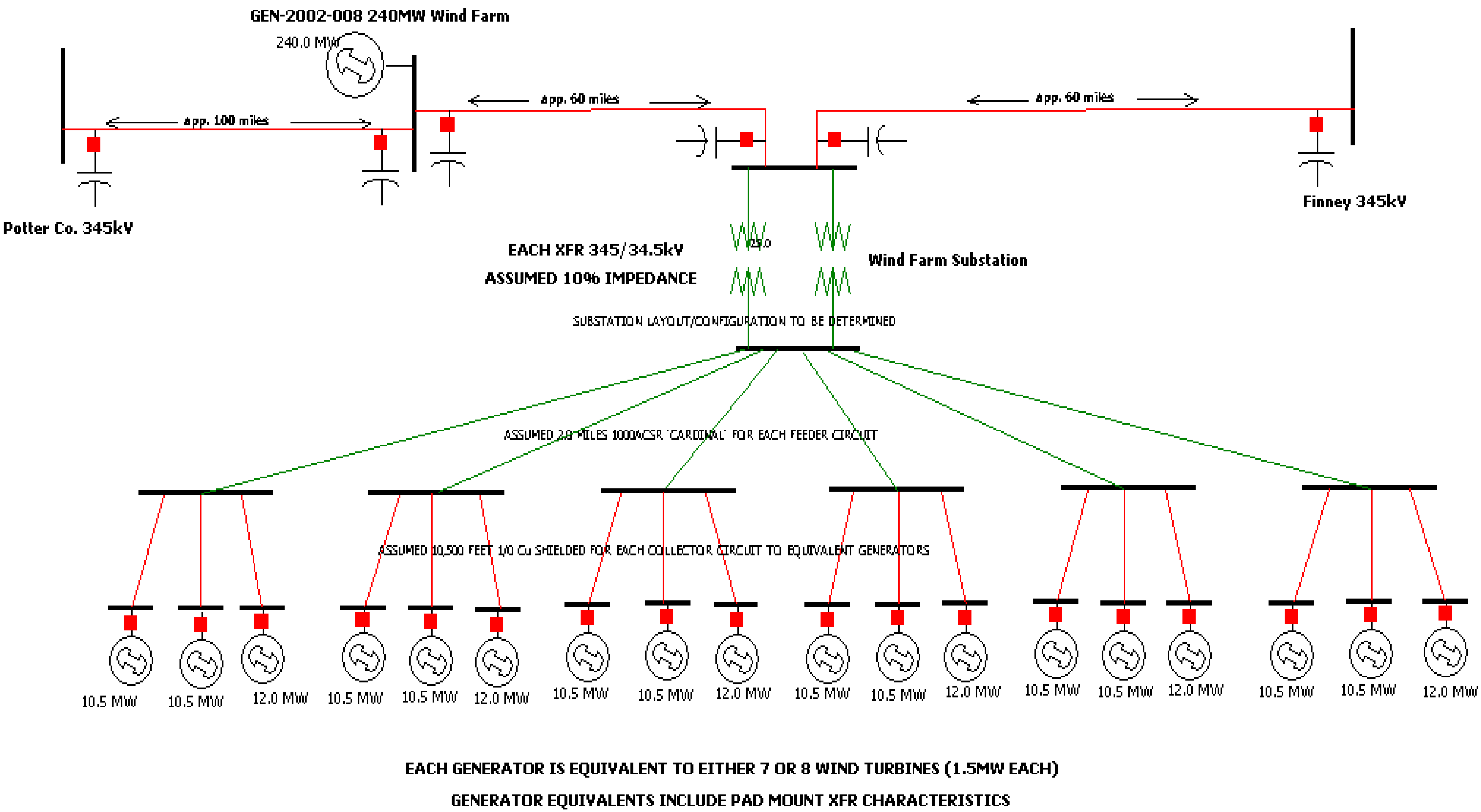
5.0 Conclusion

No stability concerns presently exist for the GEN-2003-013 wind farm as proposed and studied. 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.

At this time, there are no recommendations for further transmission facilities that would be required for interconnection. However, breaker duty ratings and line charging compensation will be investigated as part of the Facility Study if the customer elects to proceed. Additional facilities may be required in addition to those already estimated.

The minimum Network Upgrade cost of interconnecting the Customer project is $3.9 million, which is the cost of the interconnection substation. However, as stated earlier, additional facilities may be required depending upon the outcome of the Facility Study.

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.



GEN-2003-013
EQUIVALENT WIND FARM LAYOUT

Figure 1

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:
2009 Summer Peak with Wind Farm at 0MW output and Voltage Control enabled

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

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED

FILE: FLT_1_3_PH.OUT

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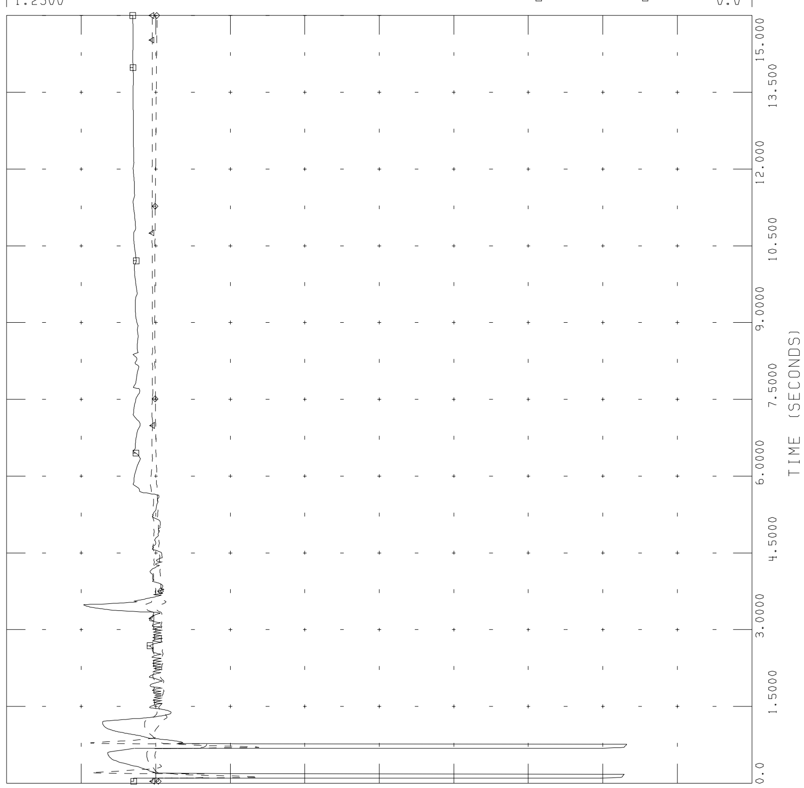
FLT_1_3_PH VOLTAGE

CHNL# 45: [VOLTAGE 2002-006 WIND FARM] 1.2500 – 0.0
CHNL# 43: [VOLTAGE HARRINGTON STATION 230KV] 1.2500 – 0.0
CHNL# 2: [VOLTAGE 2003-013 POI] 1.2500 – 0.0



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED

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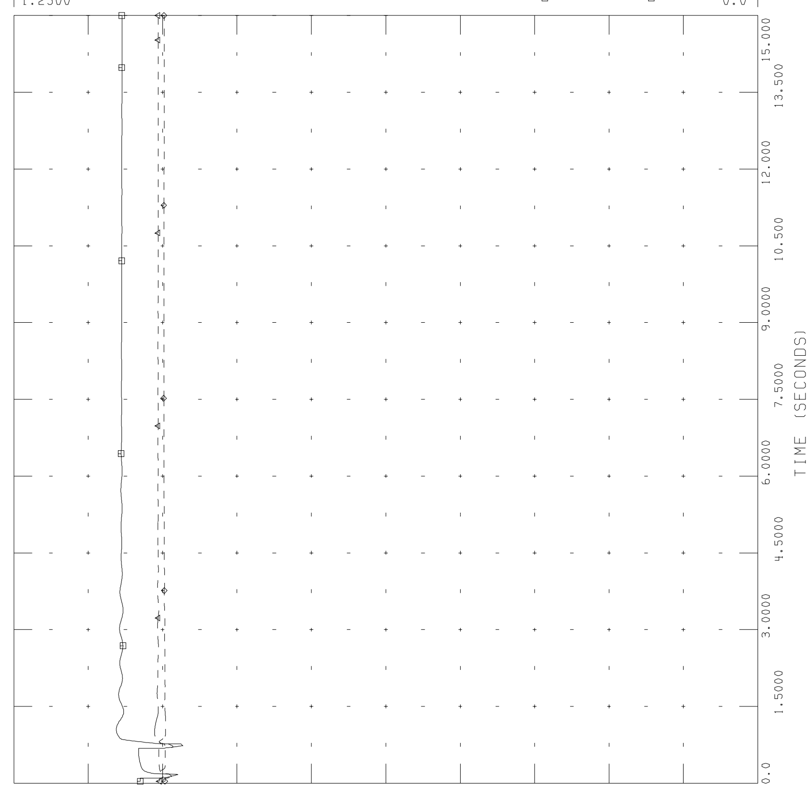

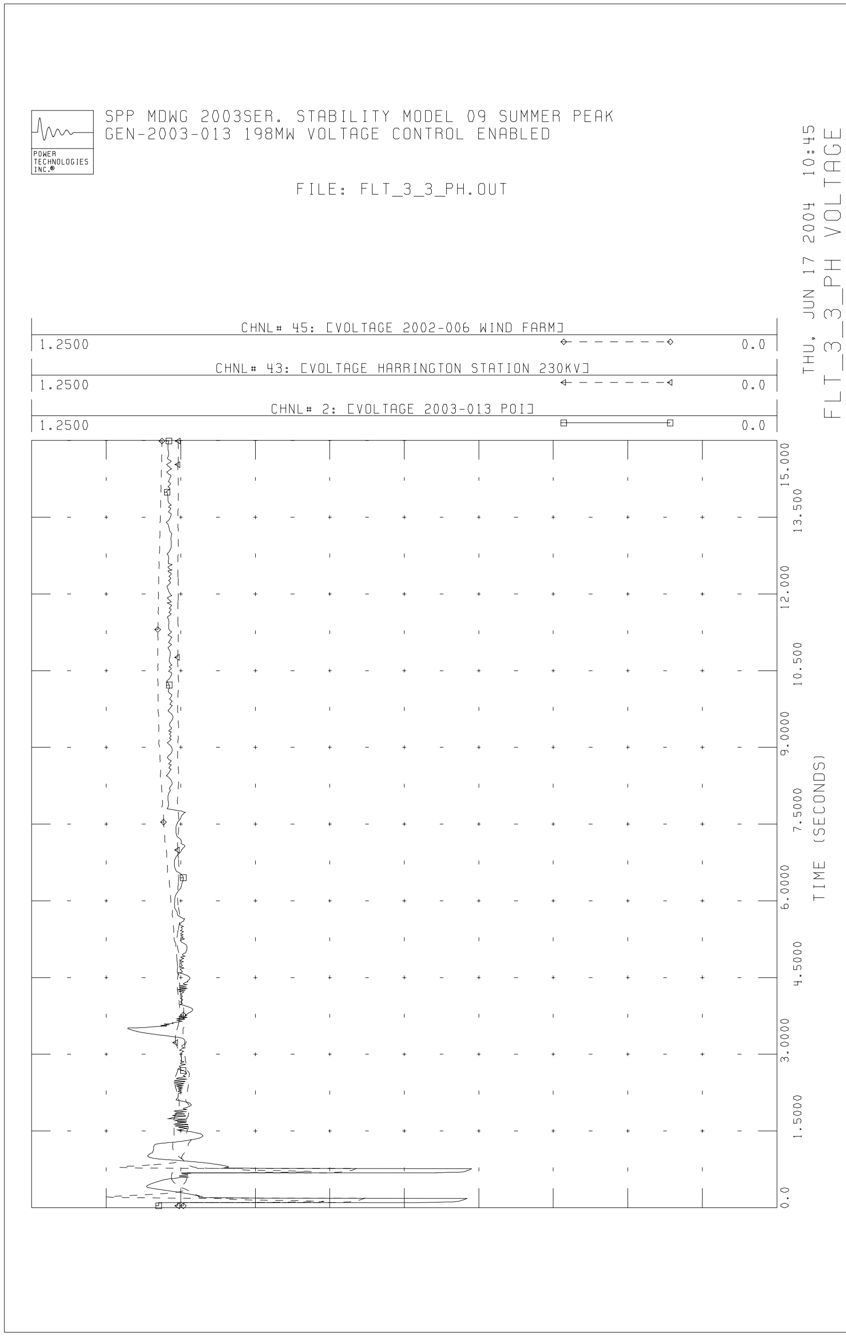

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1.5000
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4.5000
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7.5000
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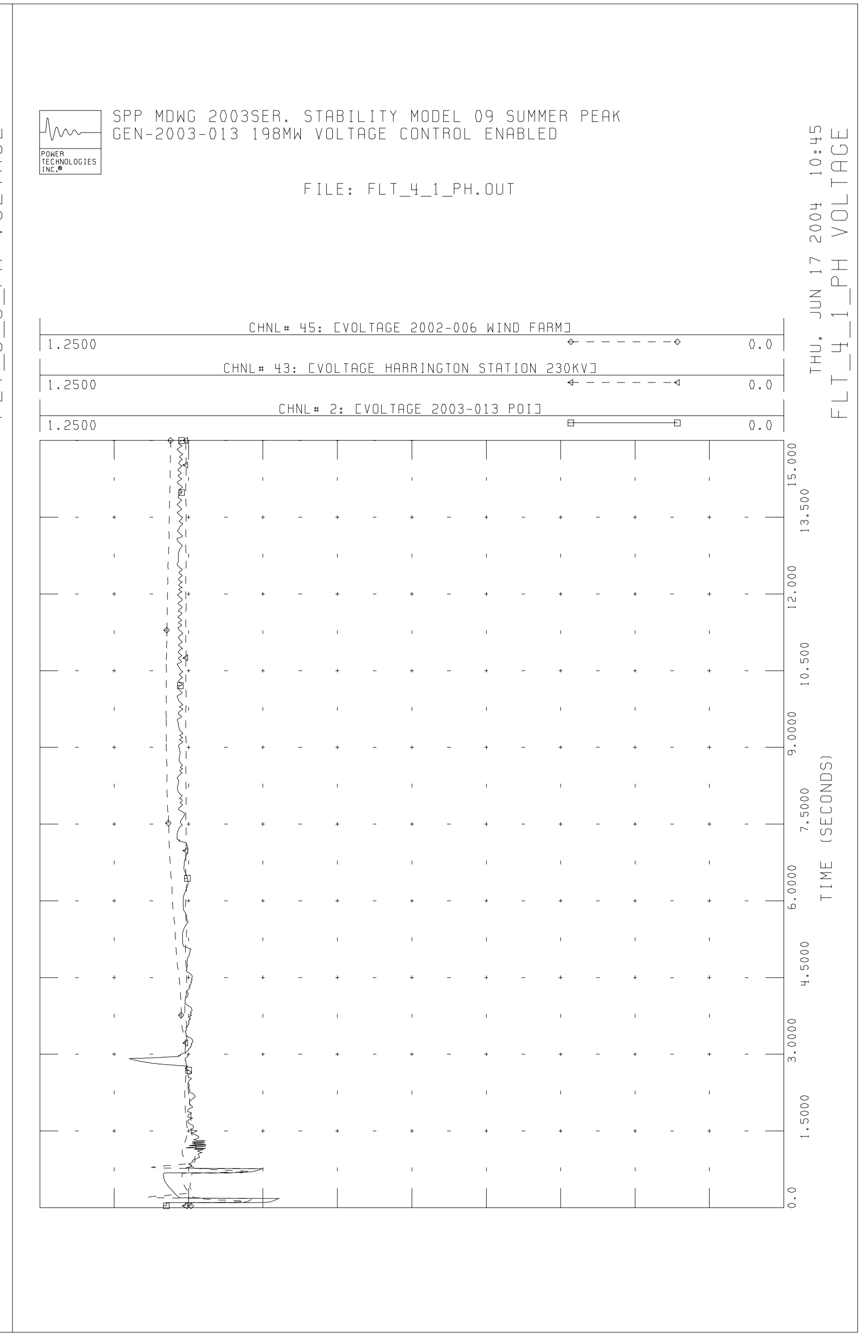

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
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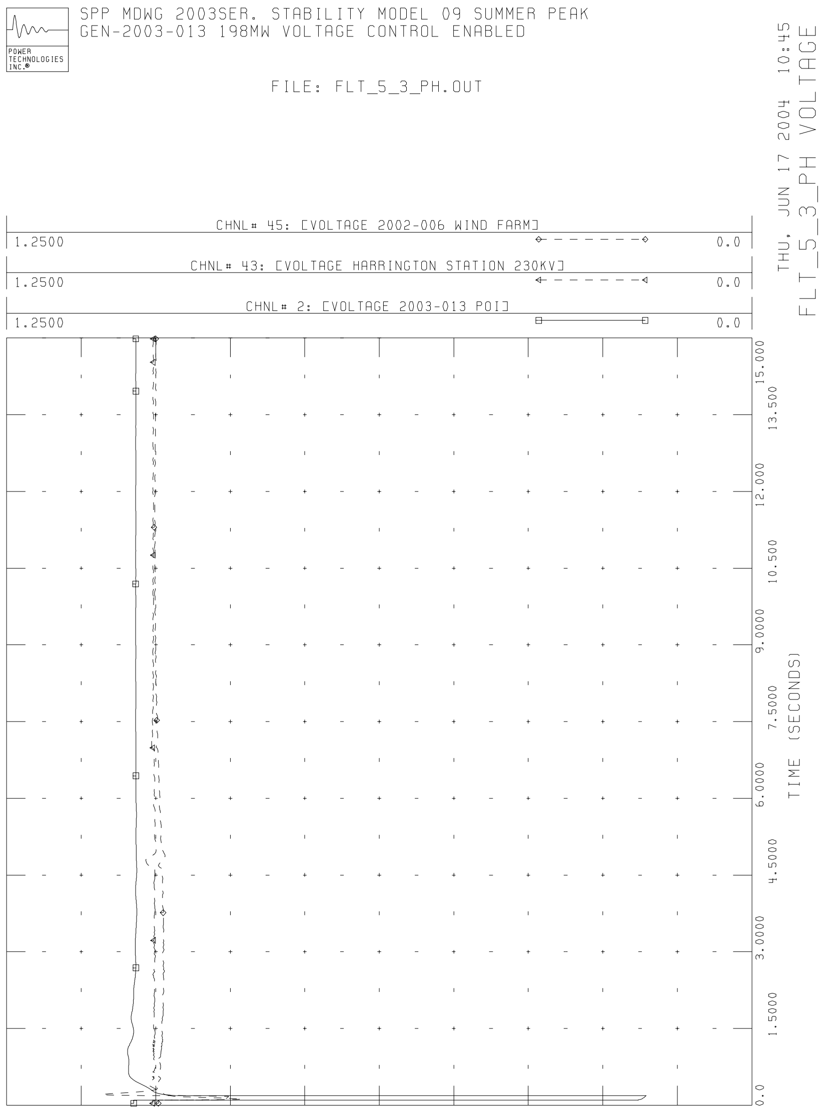
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CHNL# 2: [VOLTAGE 2003-013 POI]
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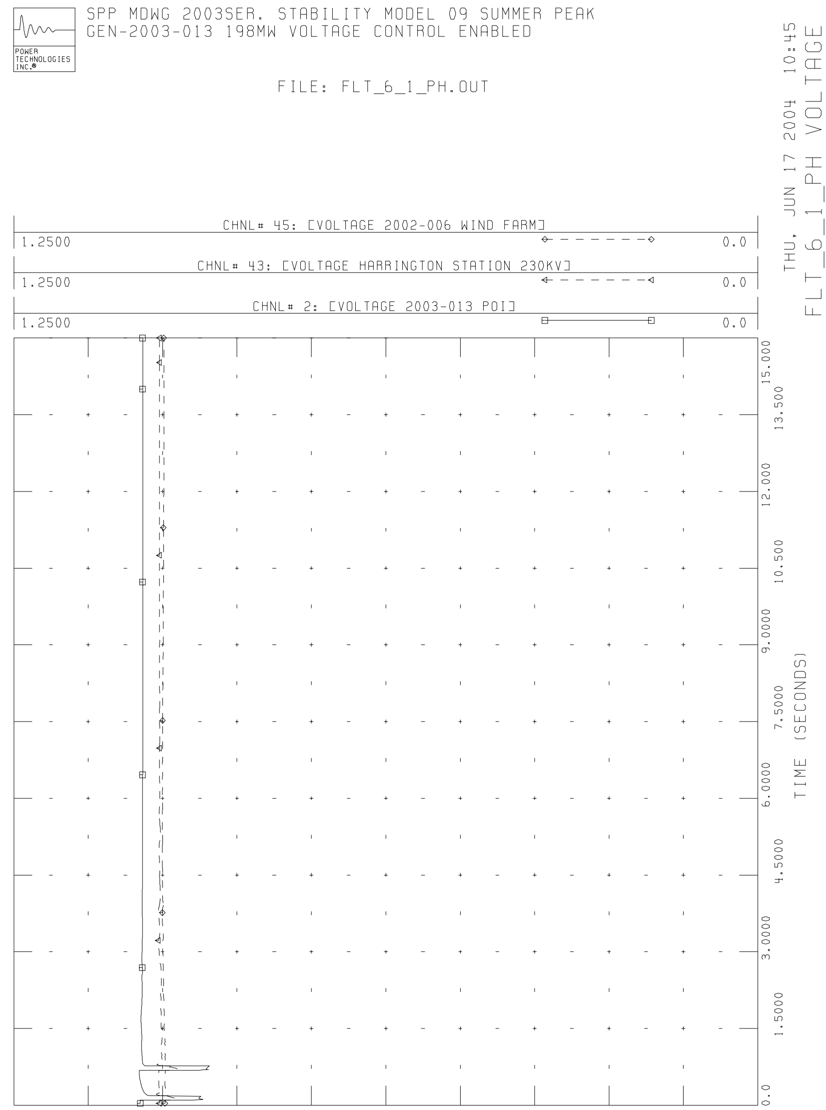
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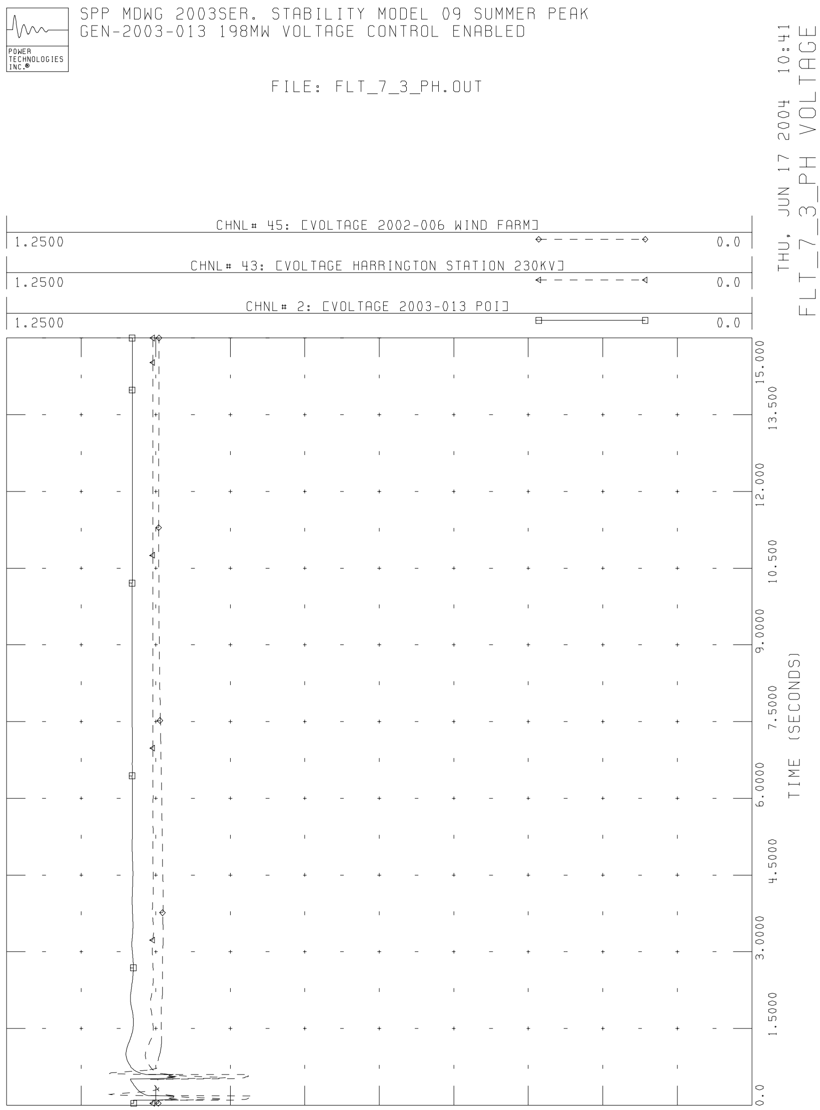
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CHNL# 2: [VOLTAGE 2003-013 POI]
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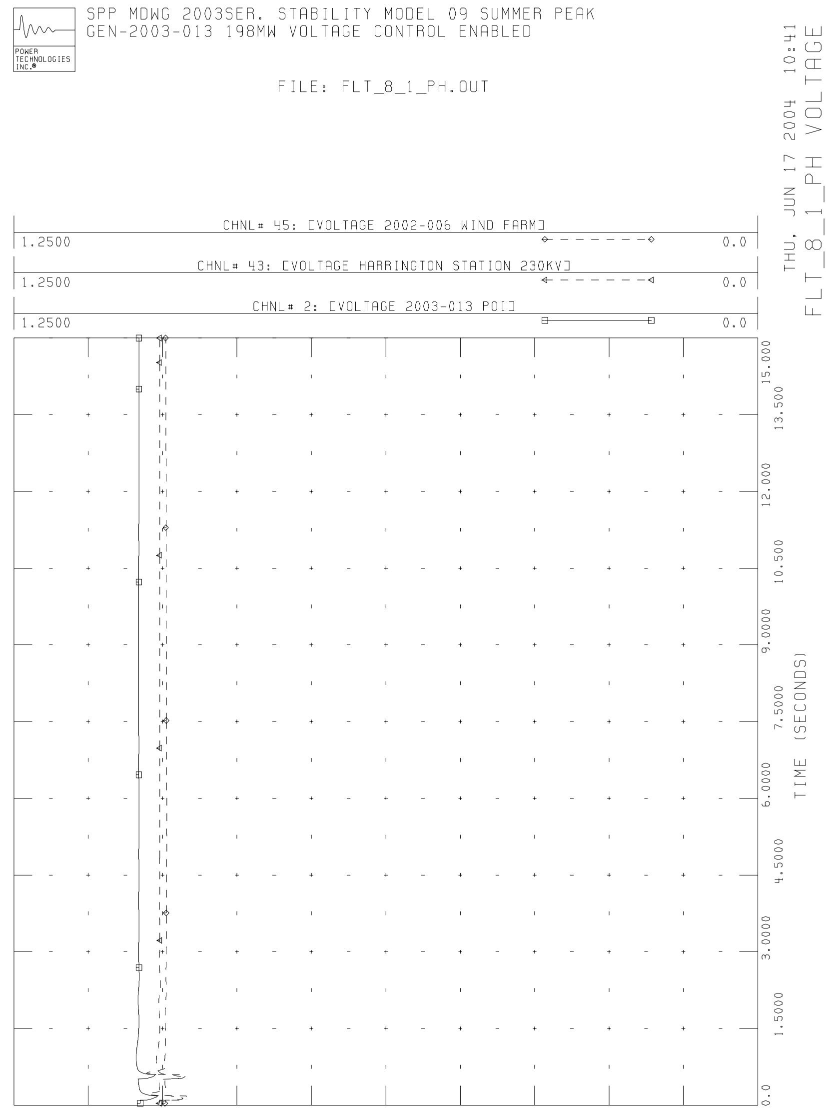
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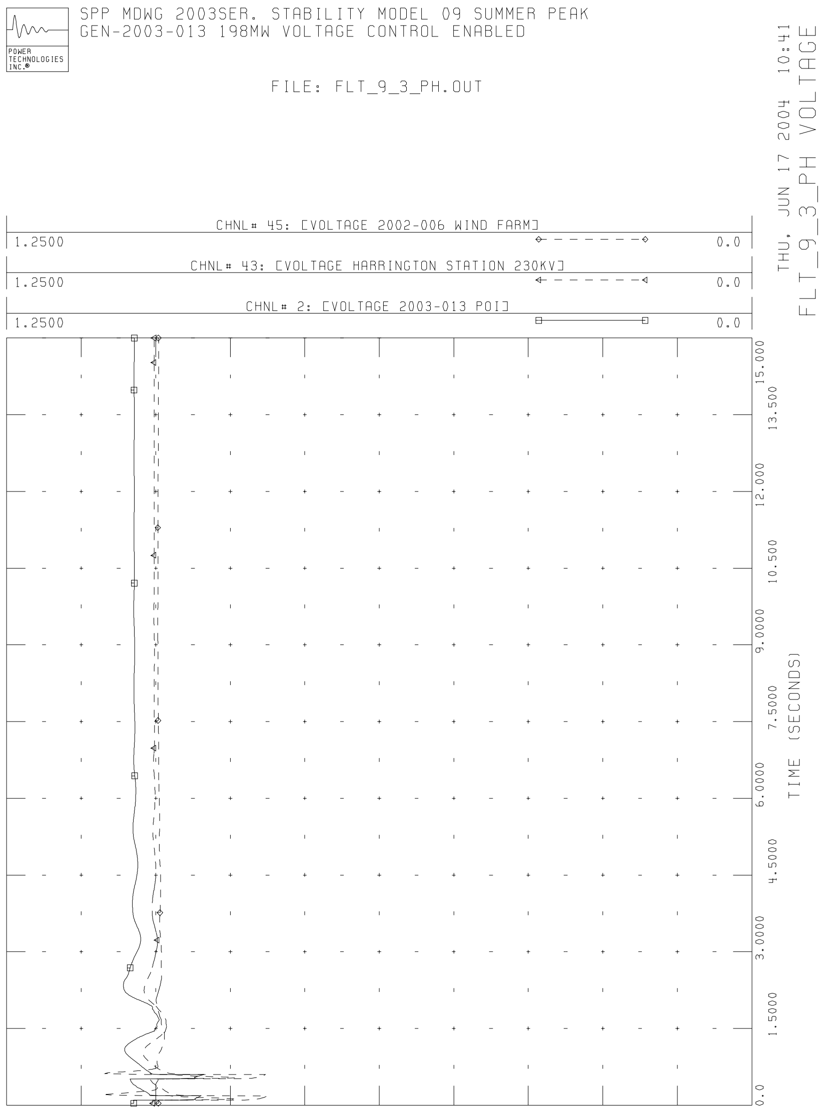

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CHNL# 2: [VOLTAGE 2003-013 POI]
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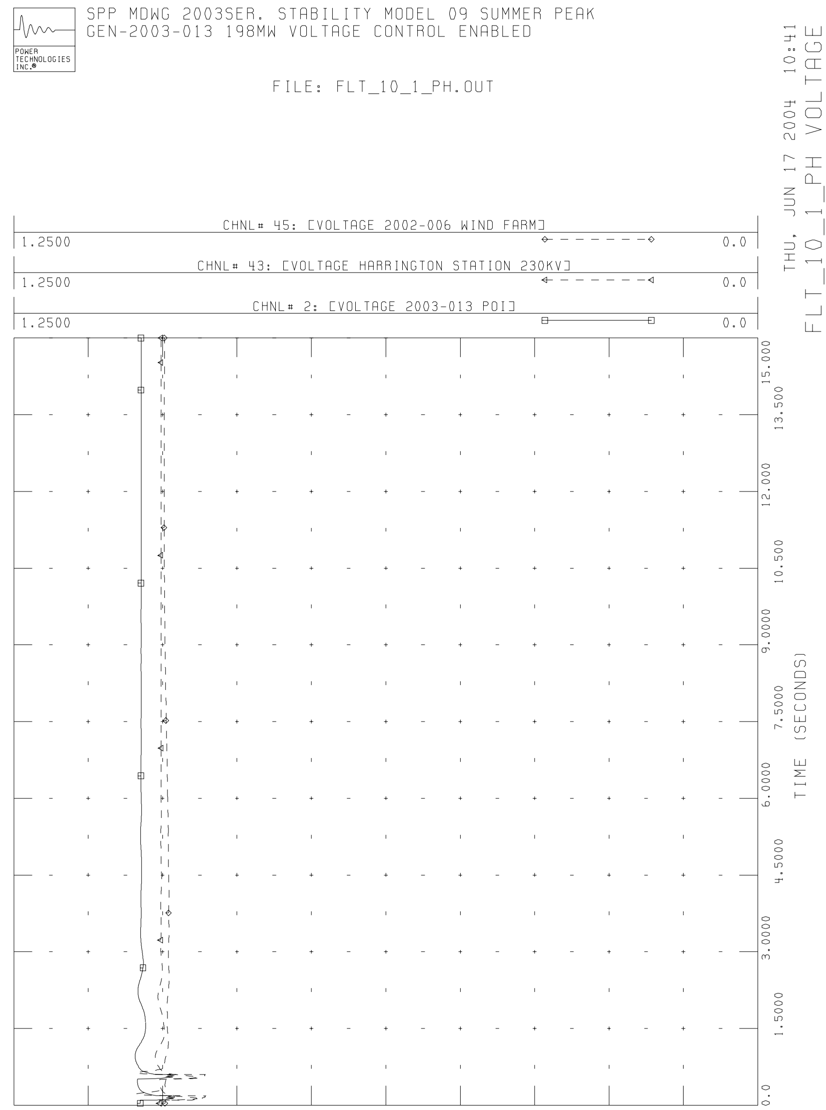

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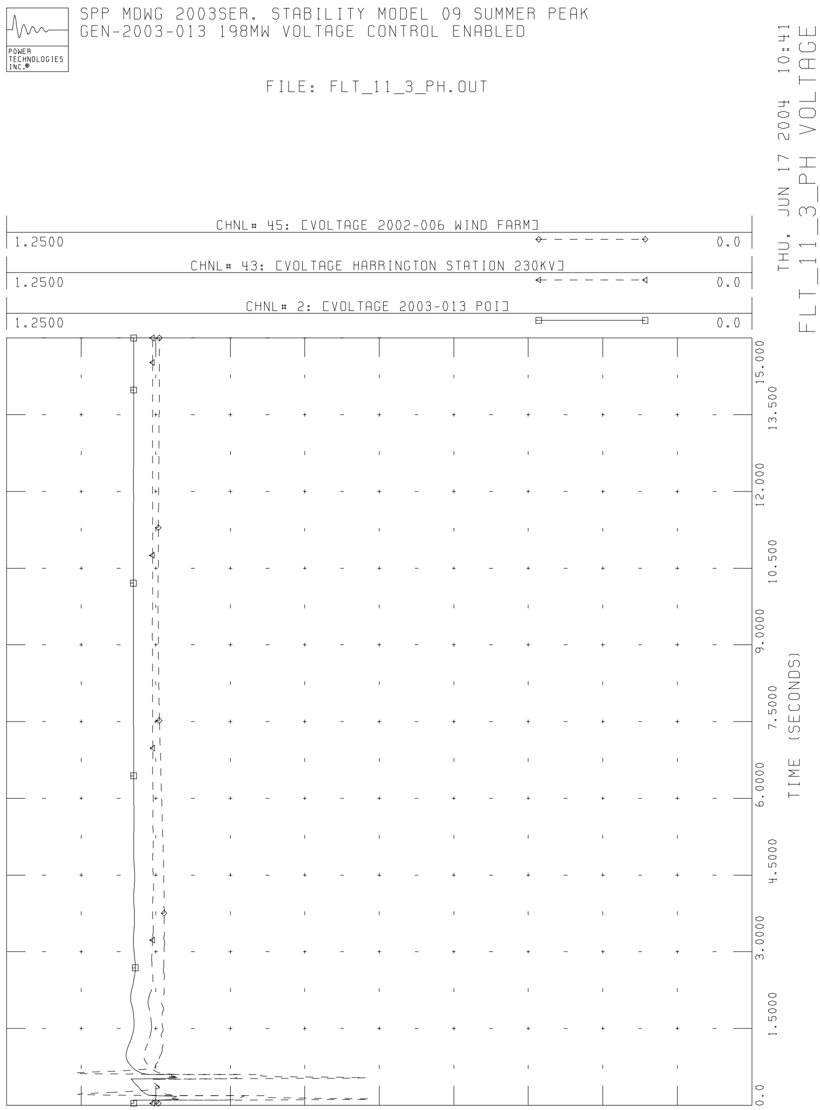
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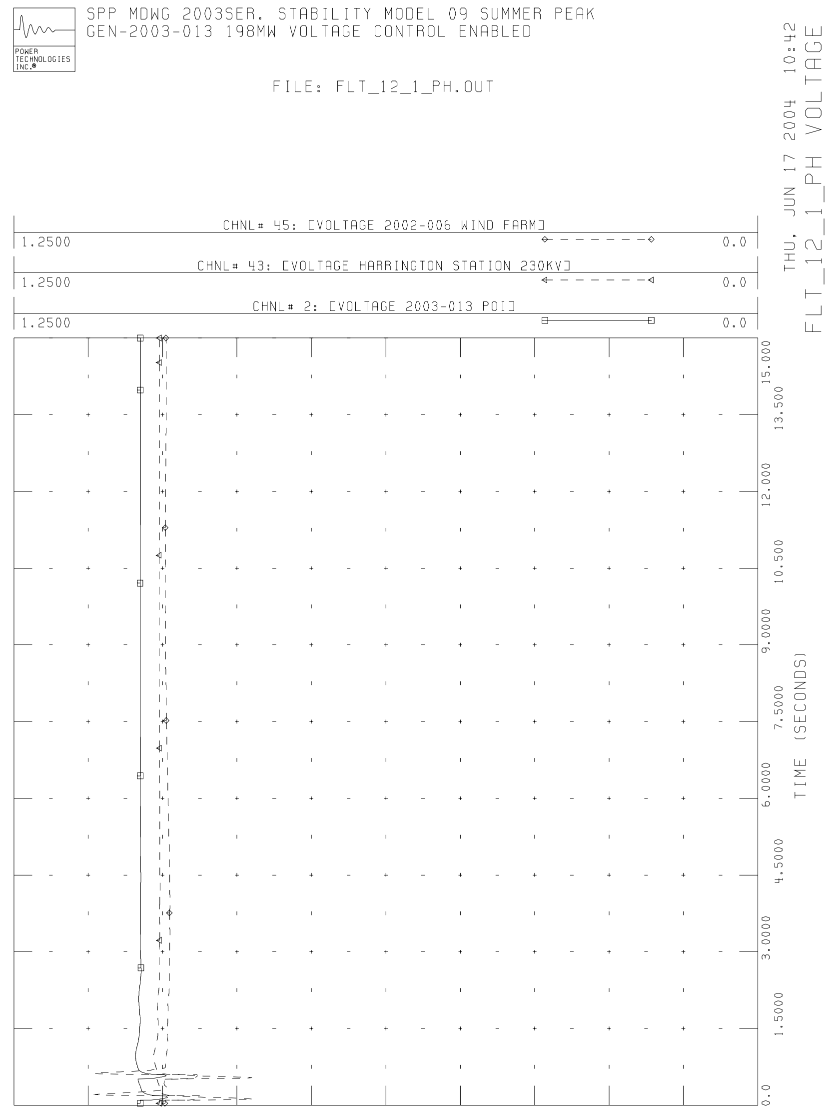
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CHNL# 2: [VOLTAGE 2003-013 POI]
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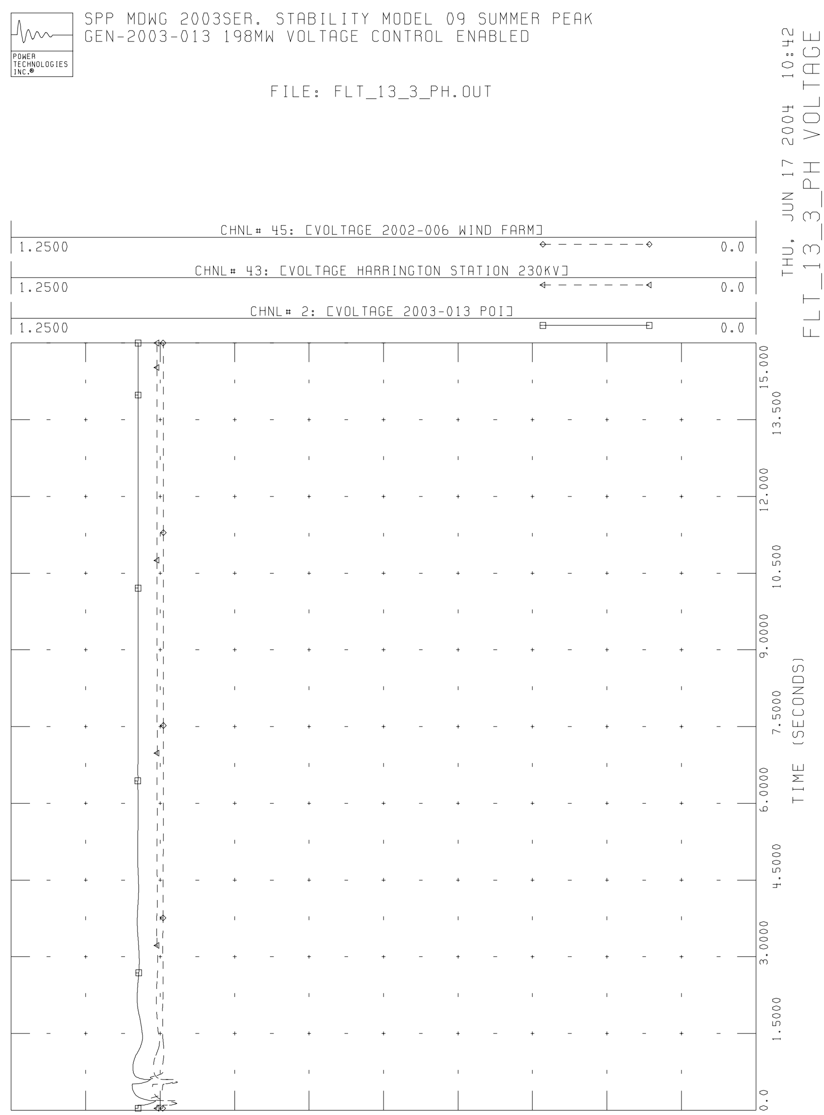
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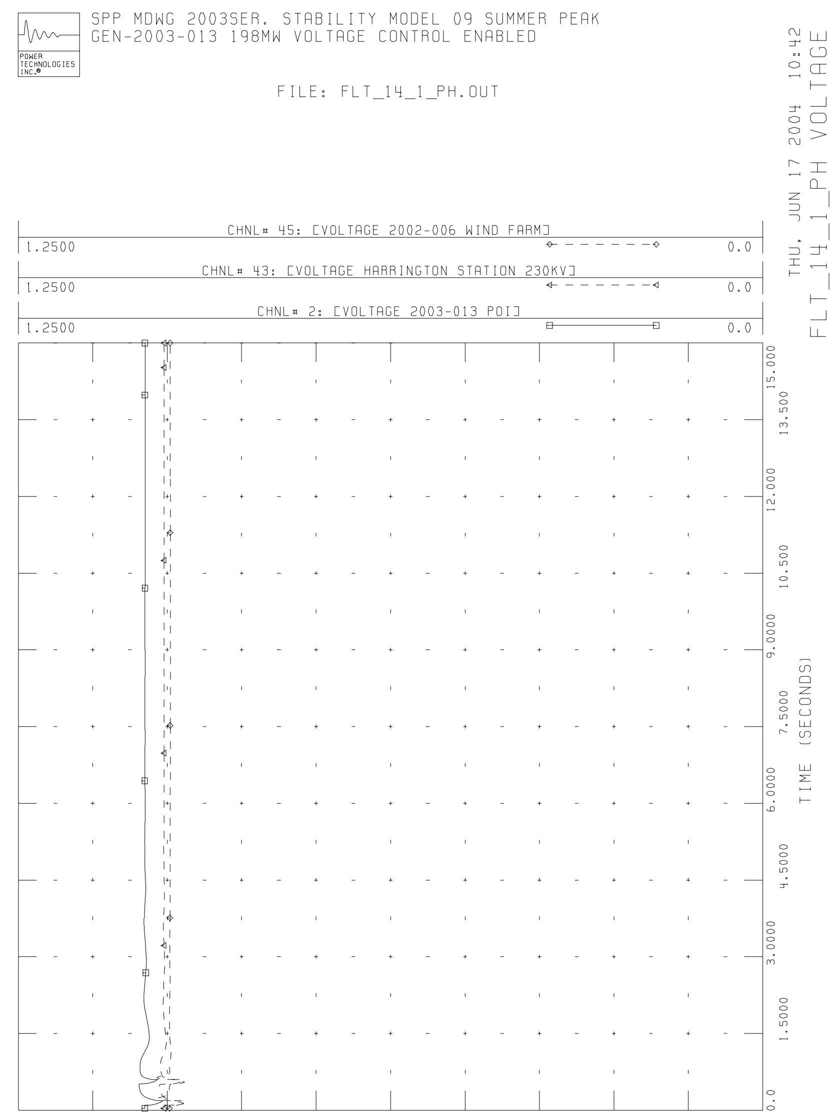
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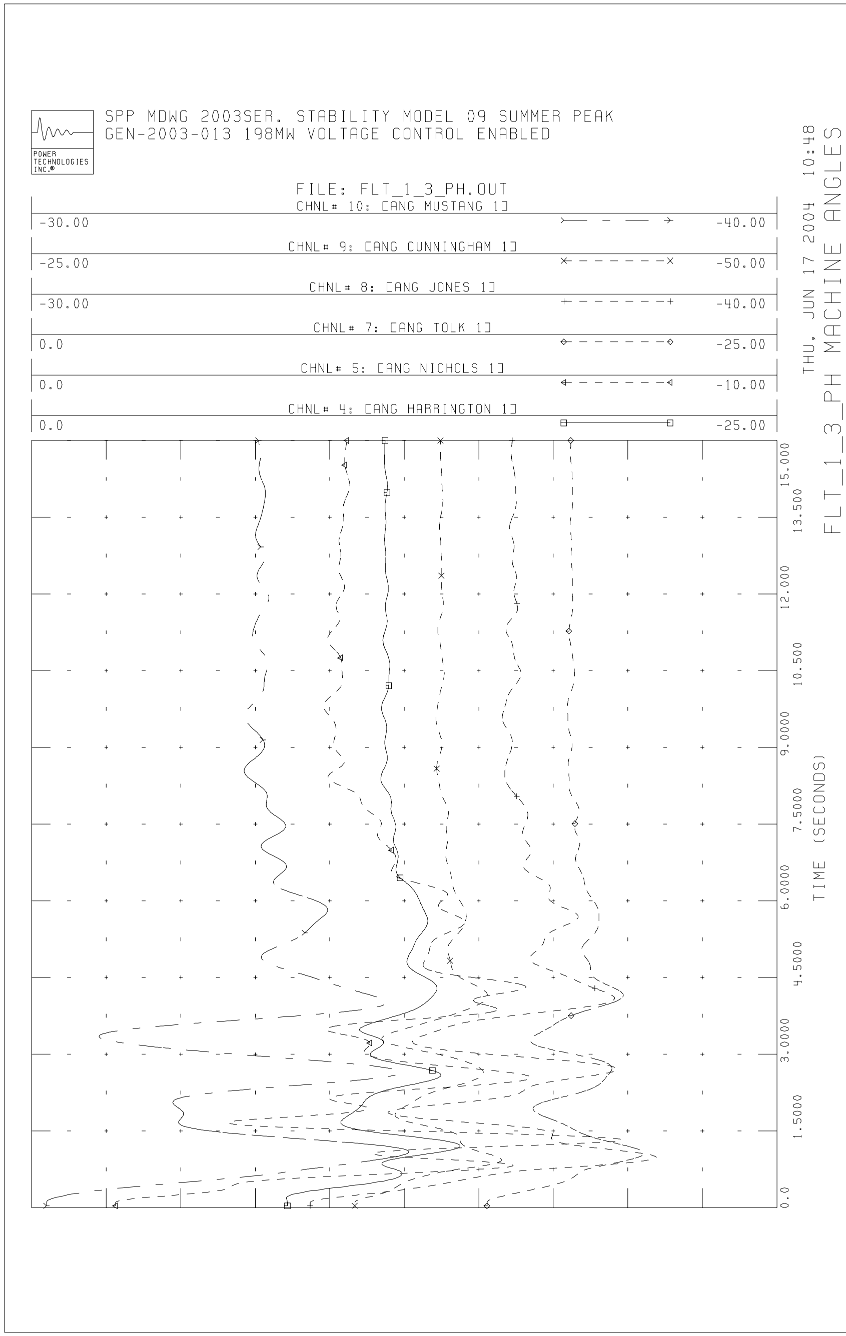

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-40.00
CHNL# 7: [ANG TOLK 1]
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-25.00
CHNL# 5: [ANG NICHOLS 1]
0.0
-10.00
CHNL# 4: [ANG HARRINGTON 1]
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0.0
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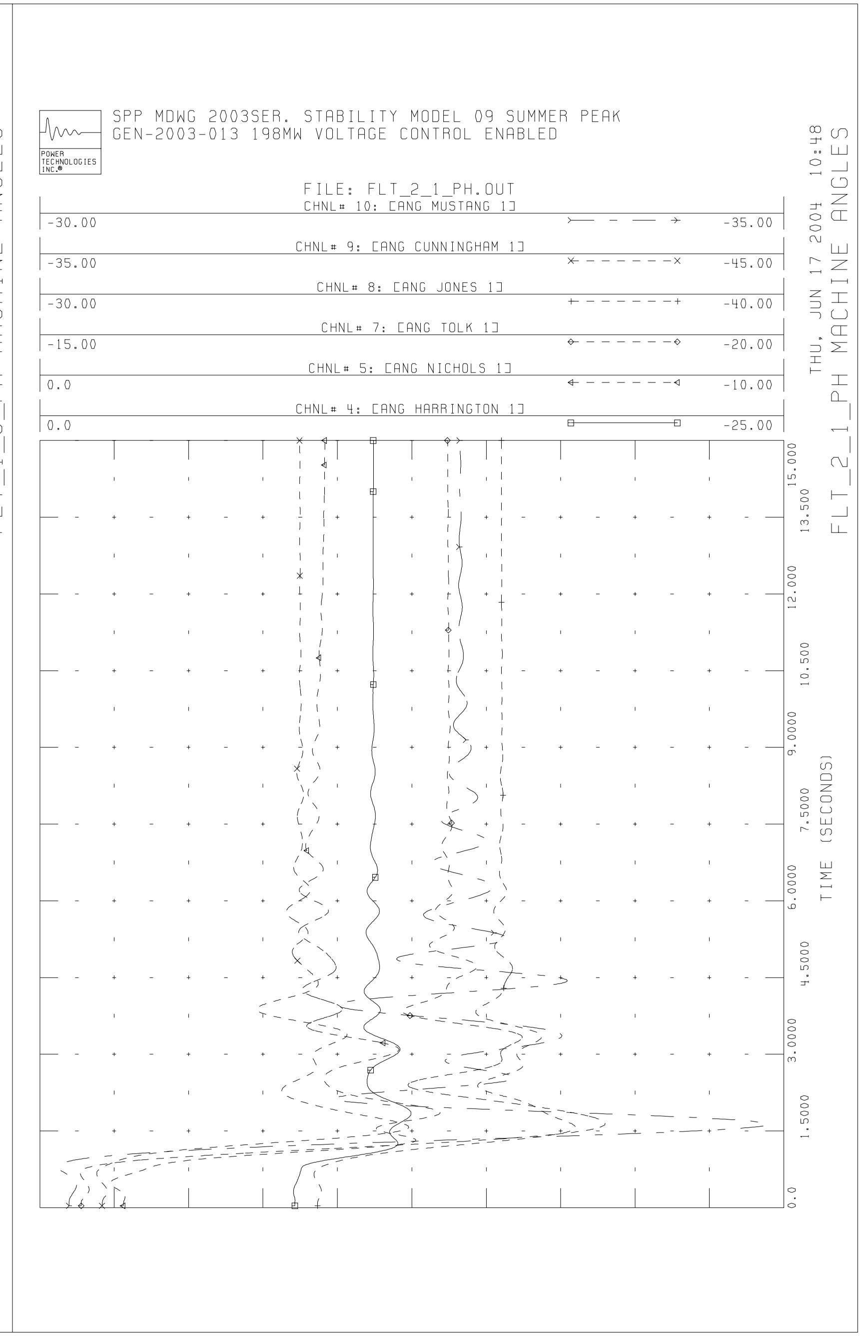

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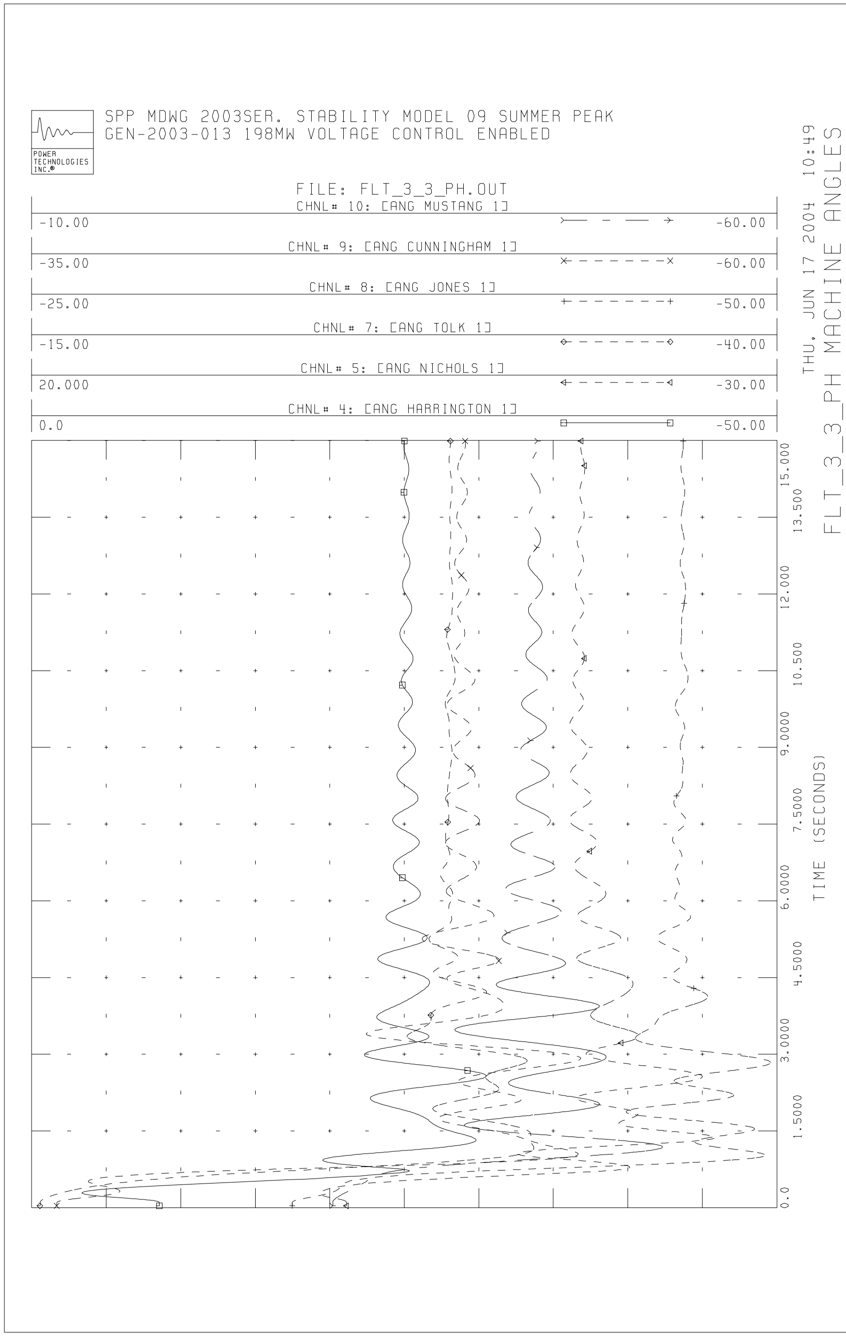
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CHNL# 4: [ANG HARRINGTON 1] 0.0 -50.00
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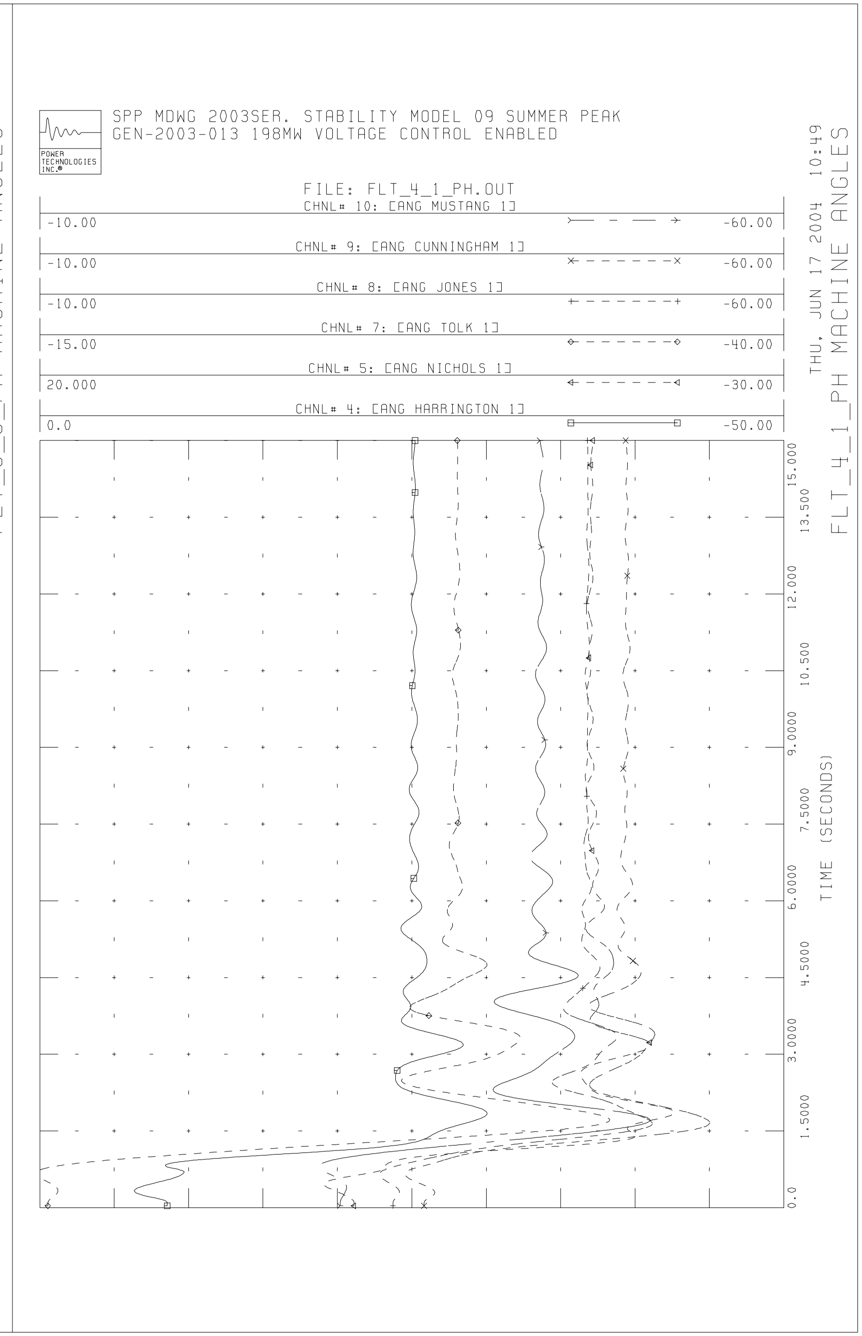
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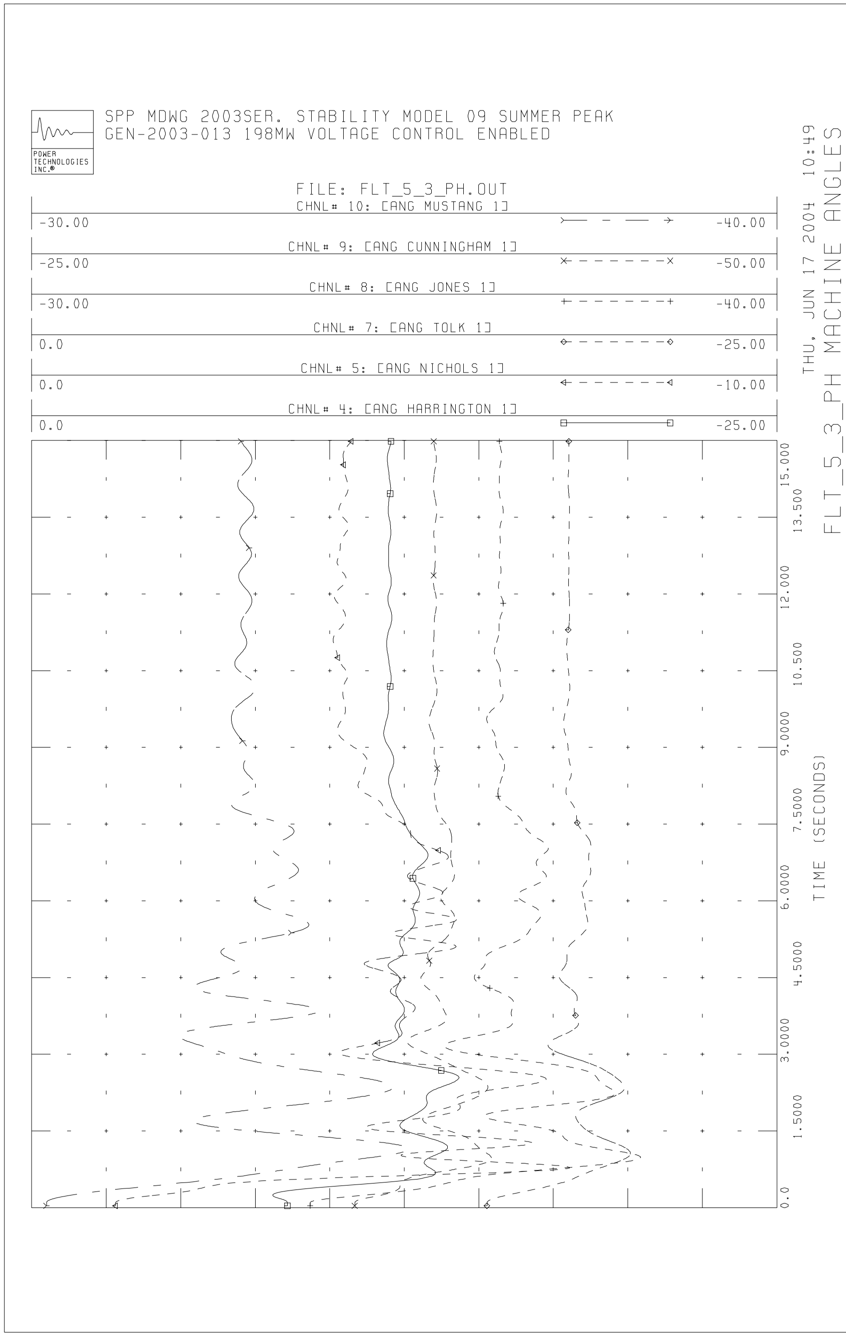
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CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
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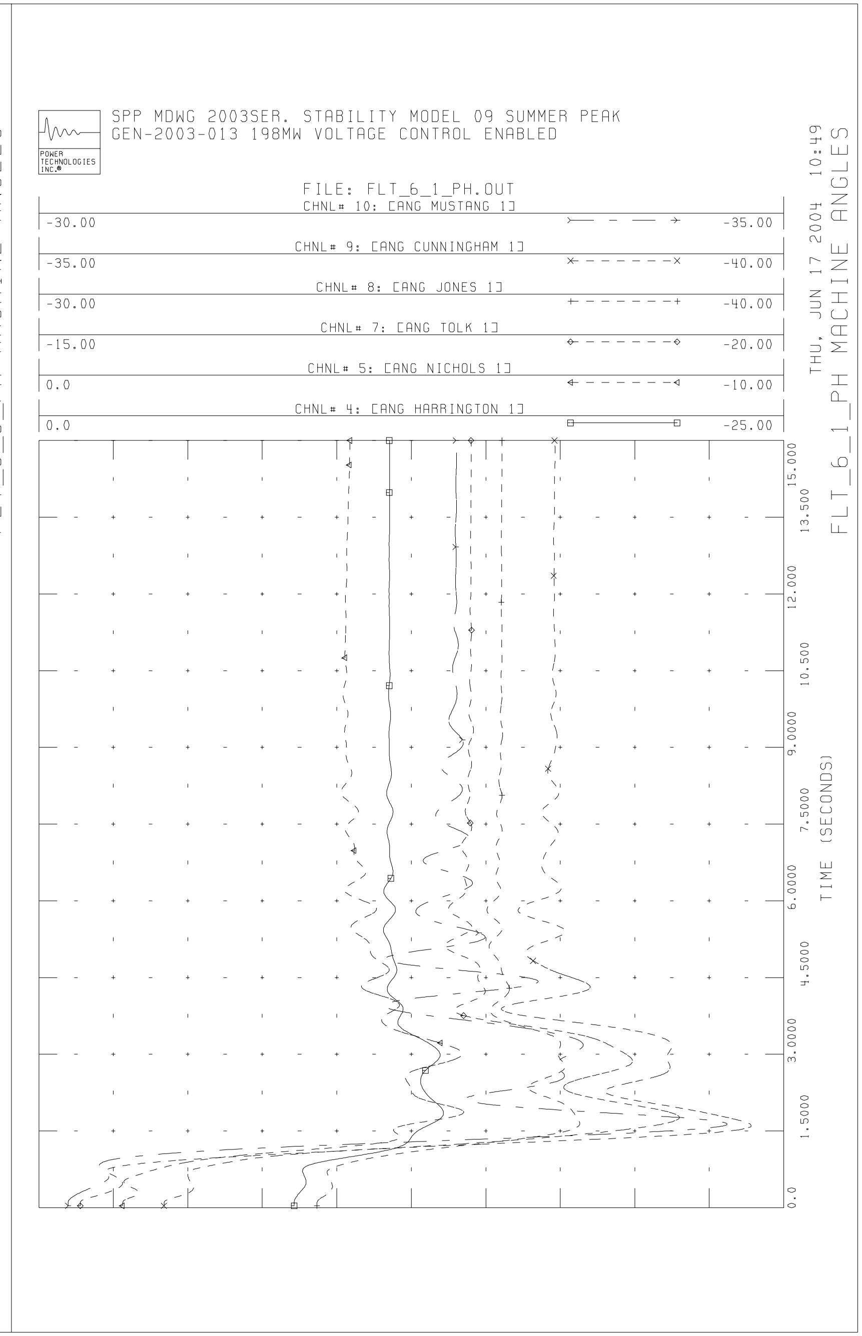
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CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
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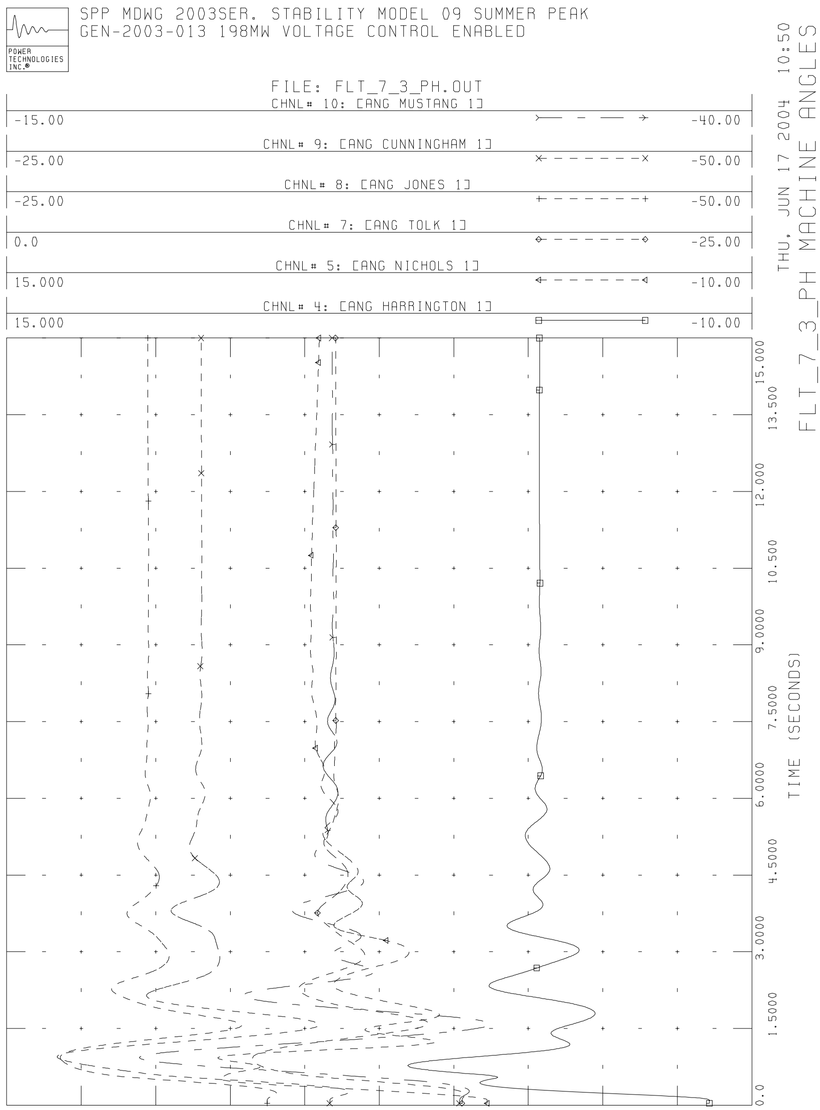
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CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 15.000 -10.00
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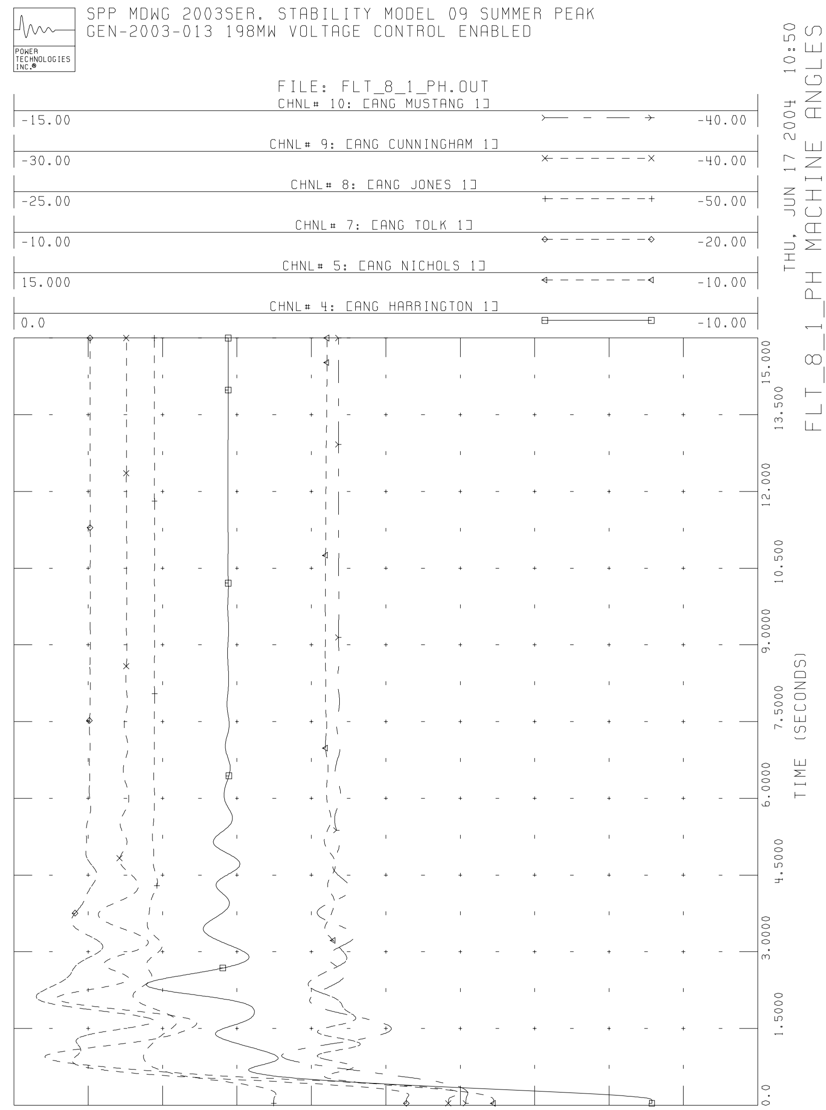
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CHNL# 4: [ANG HARRINGTON 1] 0.0 -10.00
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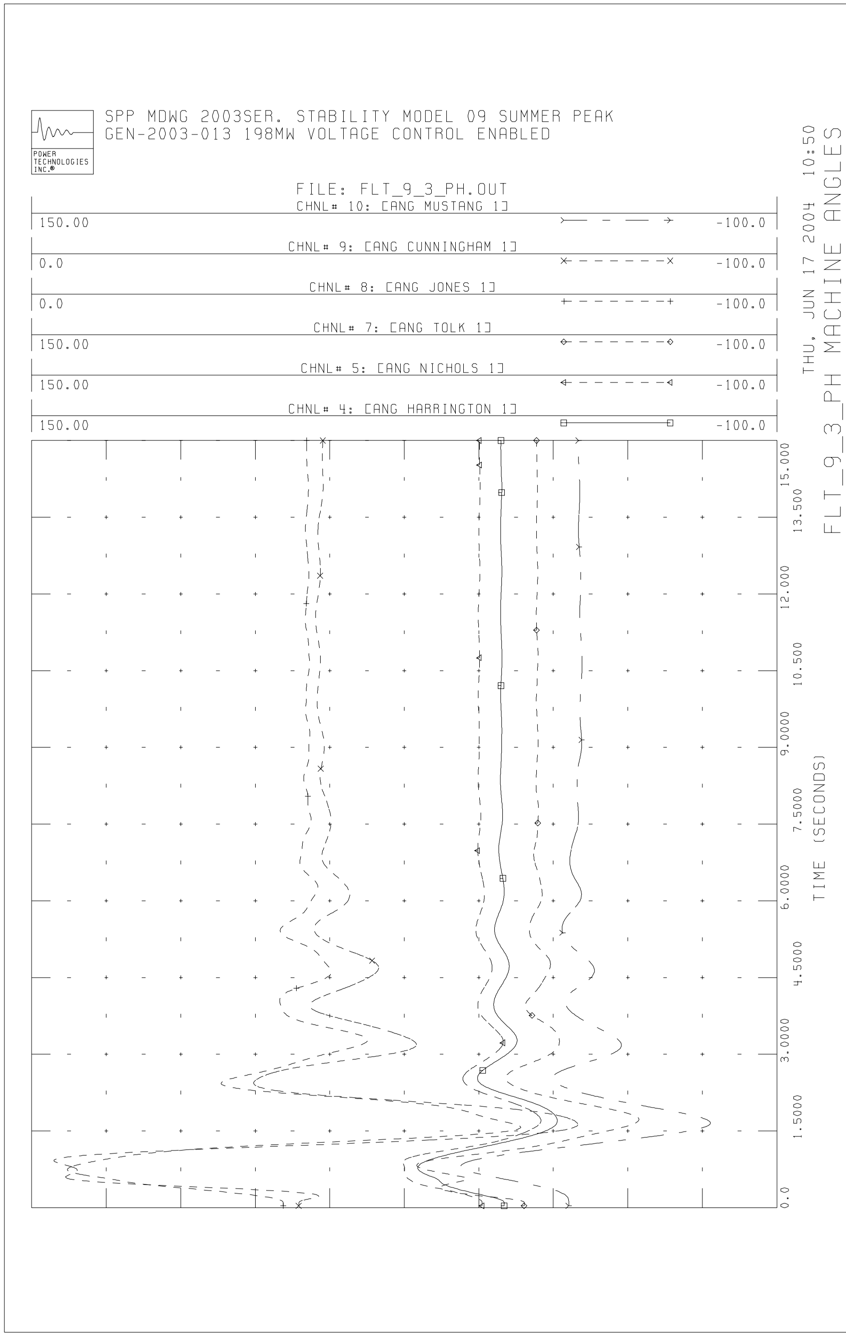
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CHNL# 4: [ANG HARRINGTON 1] 150.00 -100.0
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1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 10:50
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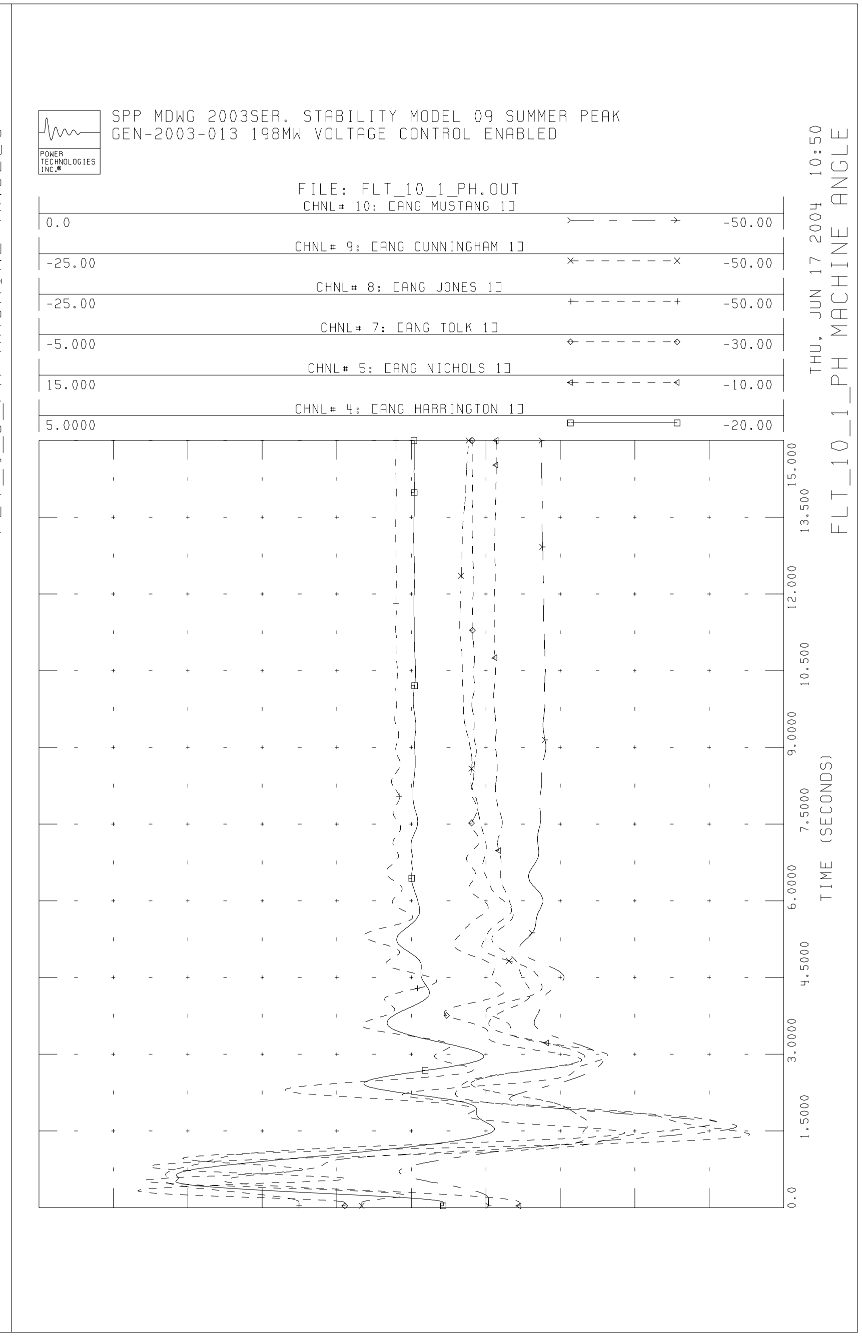
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_10_1_PH.OUT
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CHNL# 8: [ANG JONES 1] -25.00 -50.00
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CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 5.0000 -20.00
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3.0000
4.5000
6.0000
7.5000
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THU, JUN 17 2004 10:50
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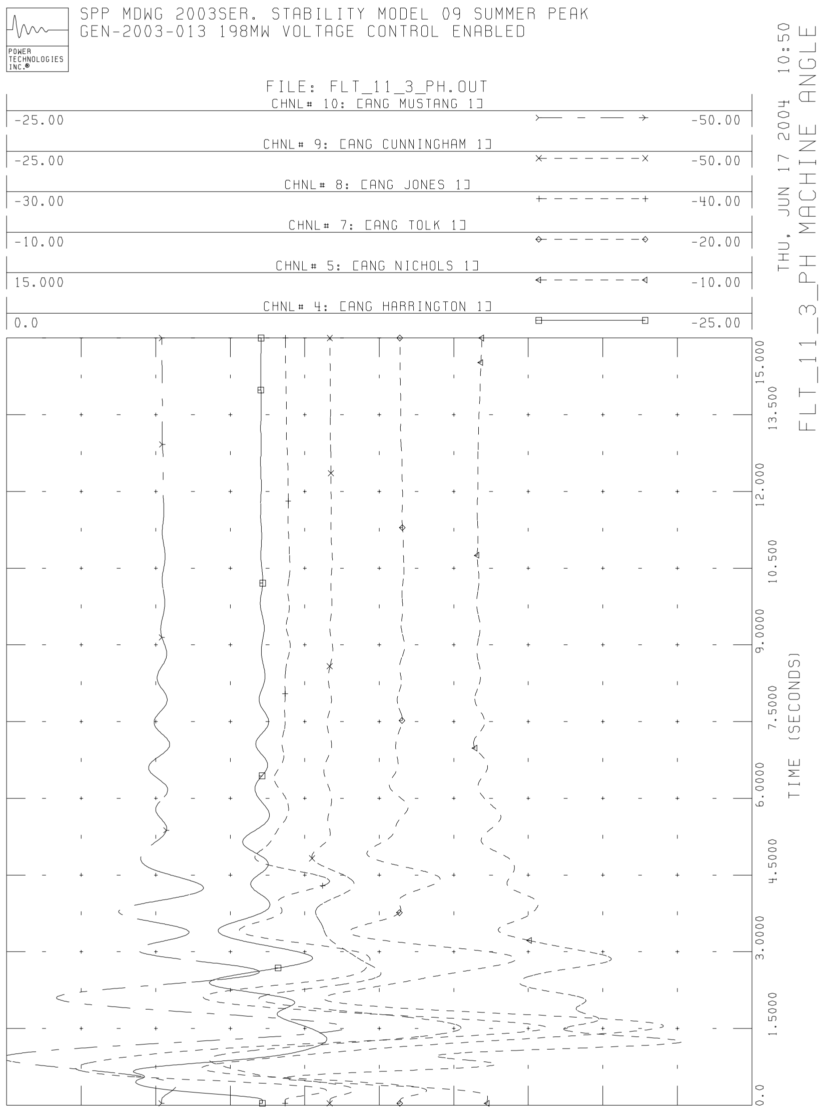
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 8: [ANG JONES 1] -30.00 -40.00
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CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
THU, JUN 17 2004 10:50
FLT_11_3_PH MACHINE ANGLE
TIME (SECONDS)
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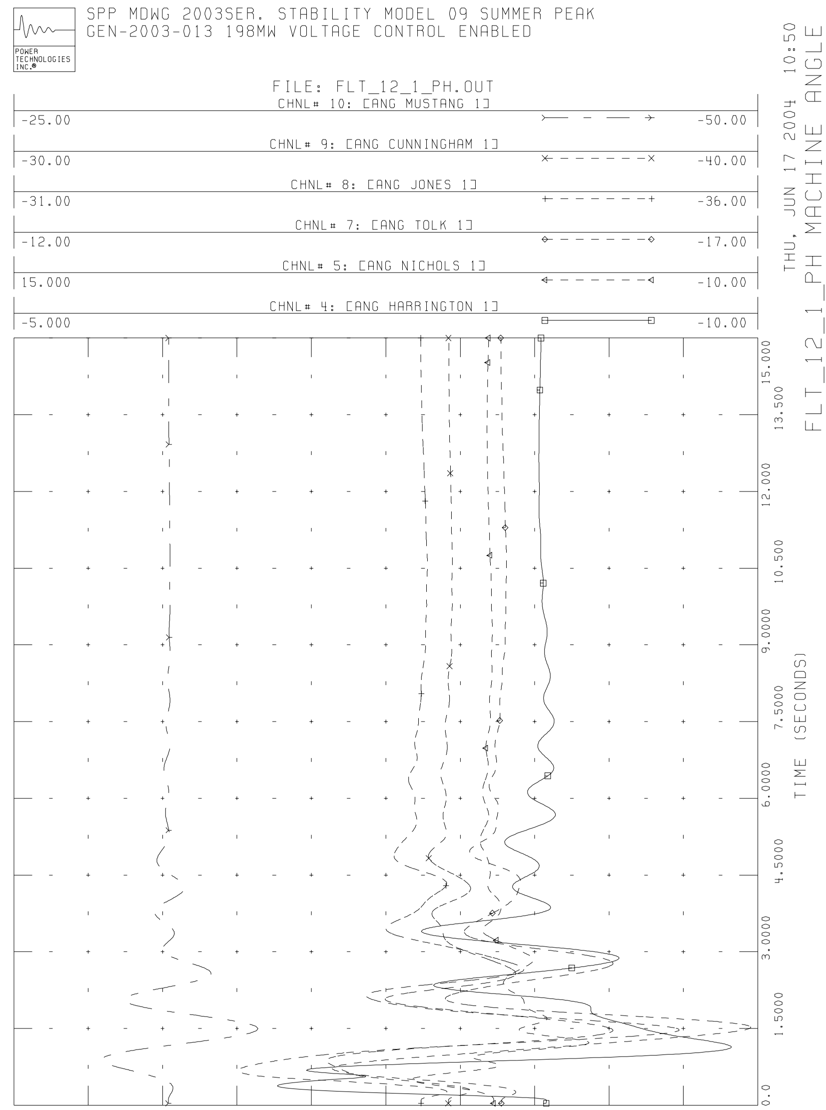
15.000


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
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CHNL# 8: [ANG JONES 1] -31.00 -36.00
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THU, JUN 17 2004 10:50
FLT_12_1_PH MACHINE ANGLE
TIME (SECONDS)
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6.0000
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9.0000
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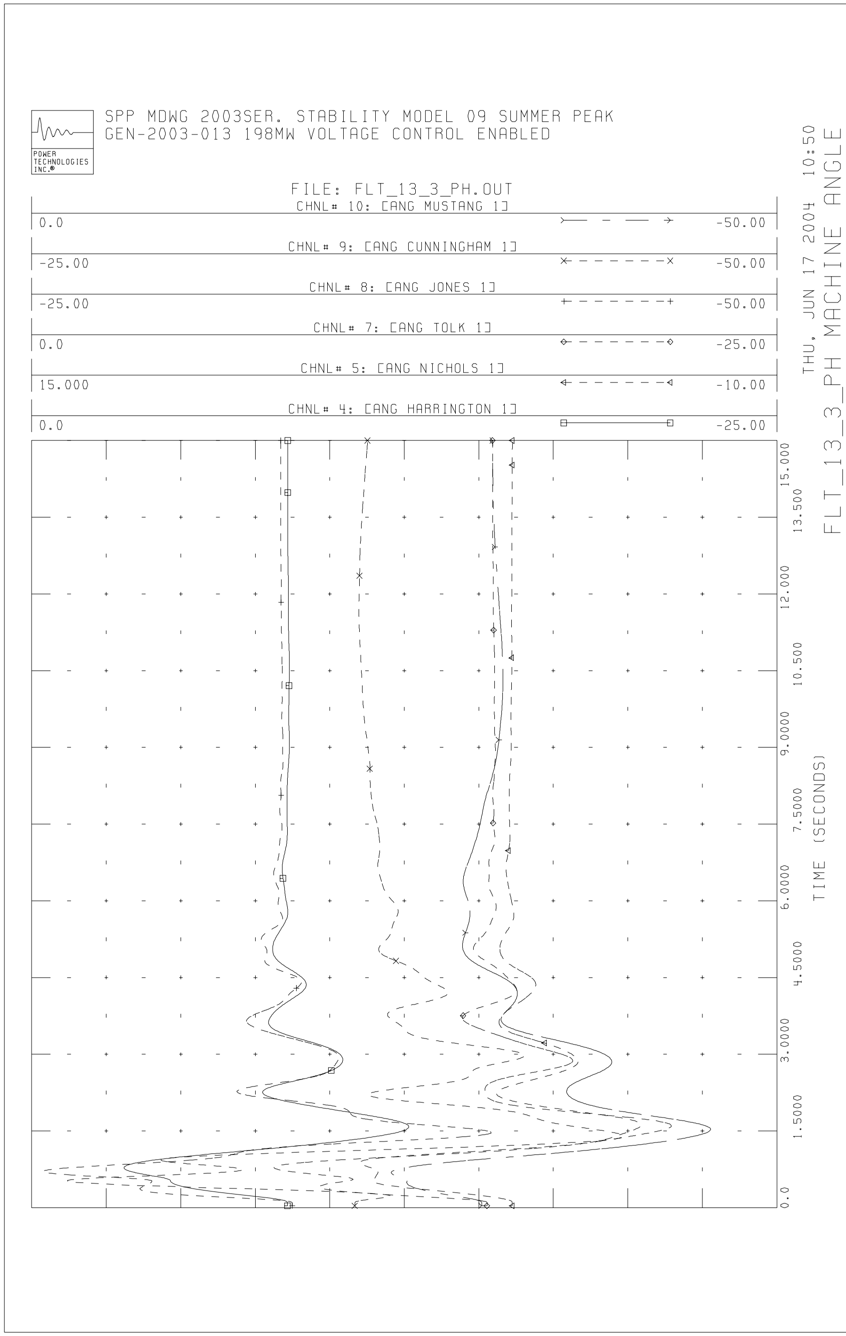
15.000


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 9: [ANG CUNNINGHAM 1]
-25.00
-50.00
CHNL# 8: [ANG JONES 1]
-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
0.0
-25.00
CHNL# 5: [ANG NICHOLS 1]
15.000
-10.00
CHNL# 4: [ANG HARRINGTON 1]
0.0
-25.00
THU, JUN 17 2004 10:50
FLT_13_3_PH MACHINE ANGLE
TIME (SECONDS)
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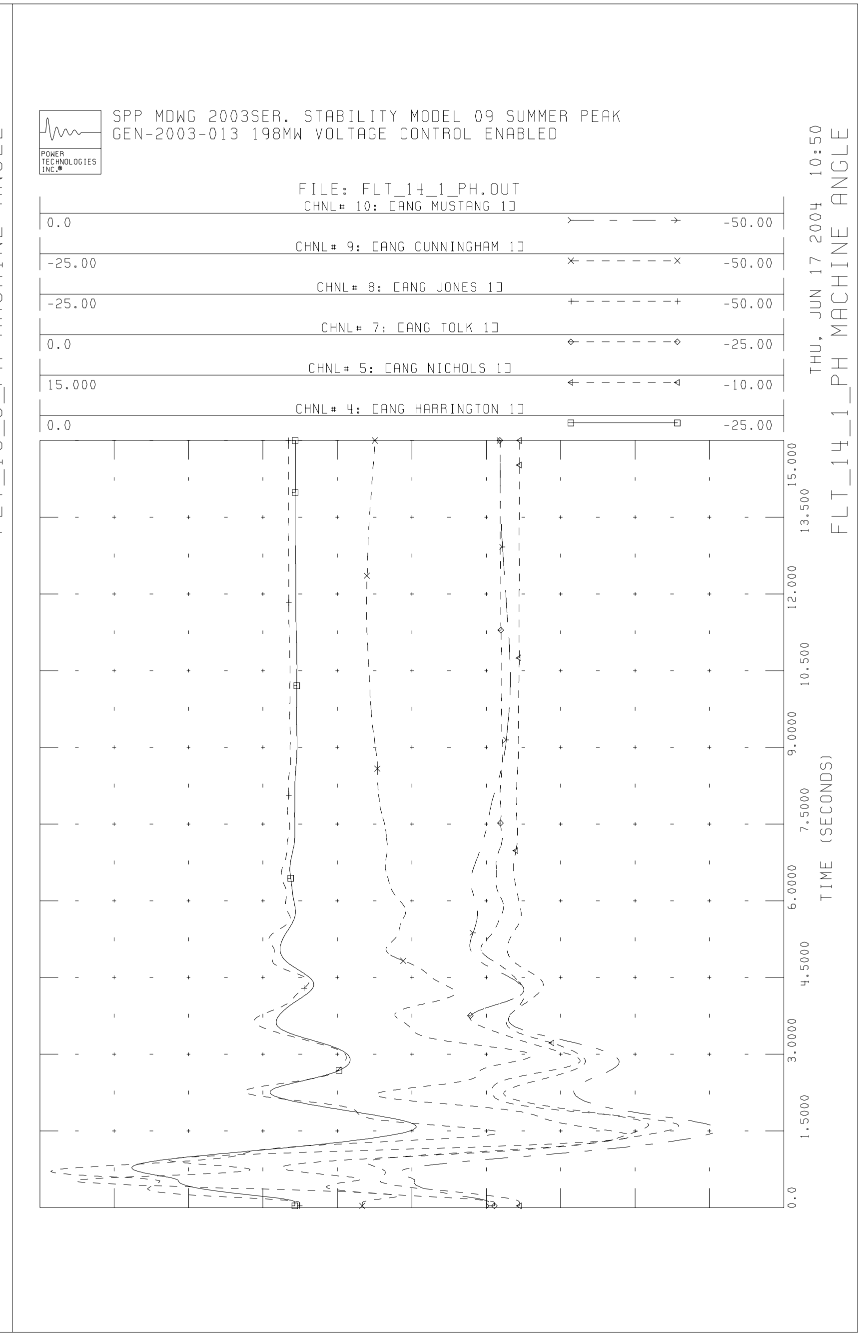
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 9: [ANG CUNNINGHAM 1]
-25.00
-50.00
CHNL# 8: [ANG JONES 1]
-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
0.0
-25.00
CHNL# 5: [ANG NICHOLS 1]
15.000
-10.00
CHNL# 4: [ANG HARRINGTON 1]
0.0
-25.00
THU, JUN 17 2004 10:50
FLT_14_1_PH MACHINE ANGLE
TIME (SECONDS)
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000

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

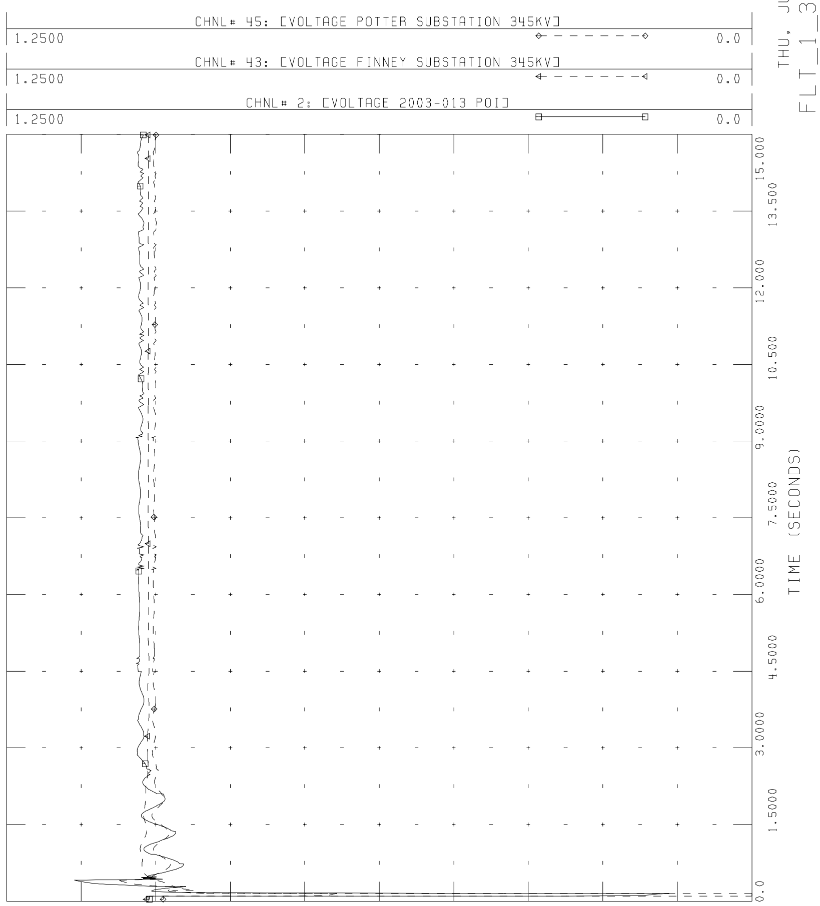
Scenario:
2009 Summer Peak with Wind Farm at 198MW output and Voltage Control enabled
Adjacent GEN-2002-008 wind farm at 240MW output

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED

FILE: FLT_1_3_PH.OUT

THU, JUN 17 2004 9:17

FLT_1_3_PH VOLTAGE

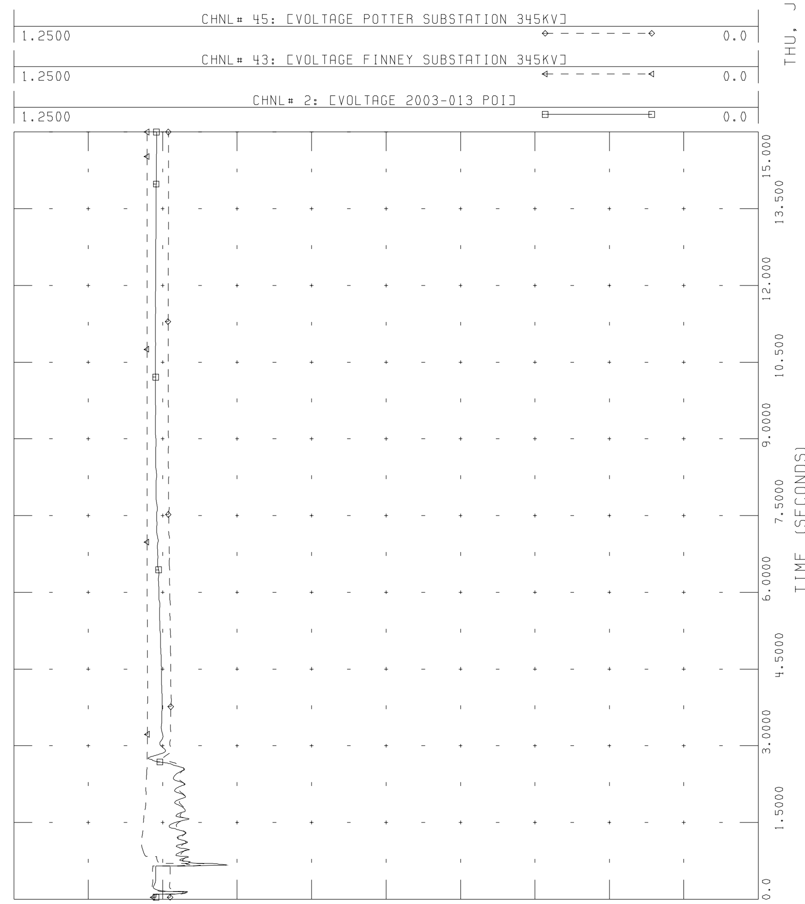


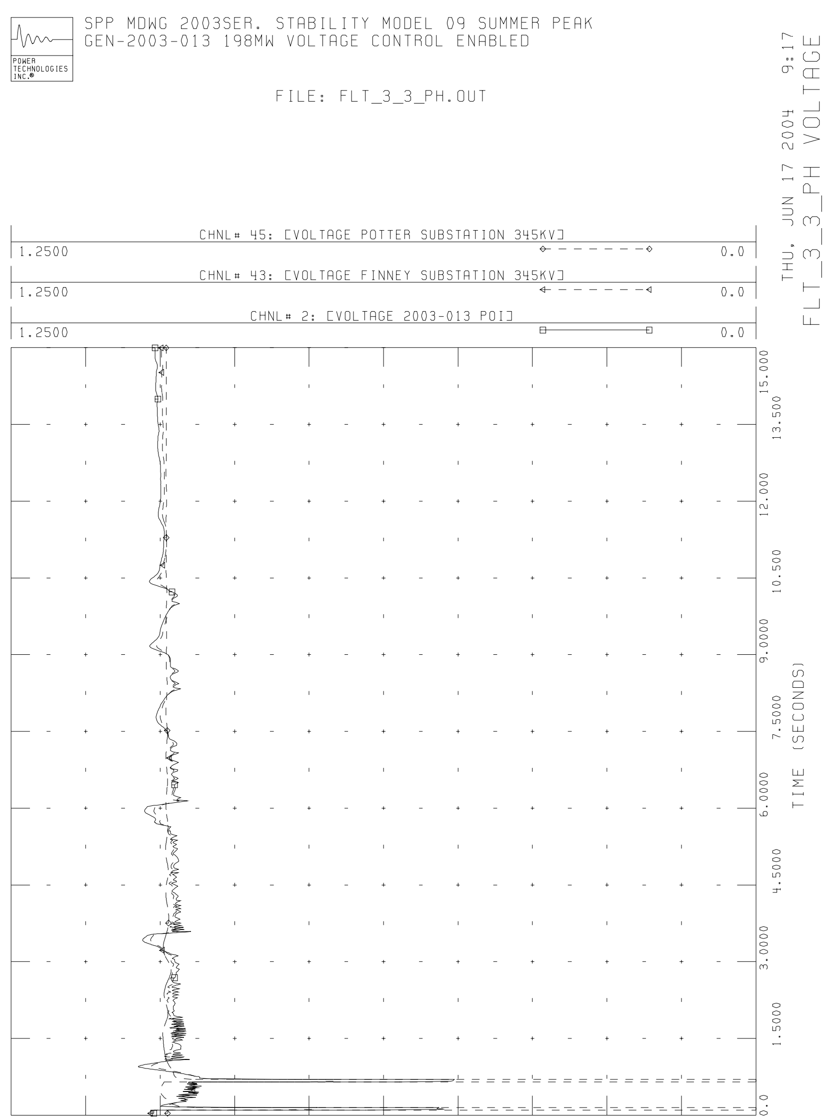
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED

FILE: FLT_2_1_PH.OUT

THU, JUN 17 2004 9:17

FLT_2_1_PH VOLTAGE





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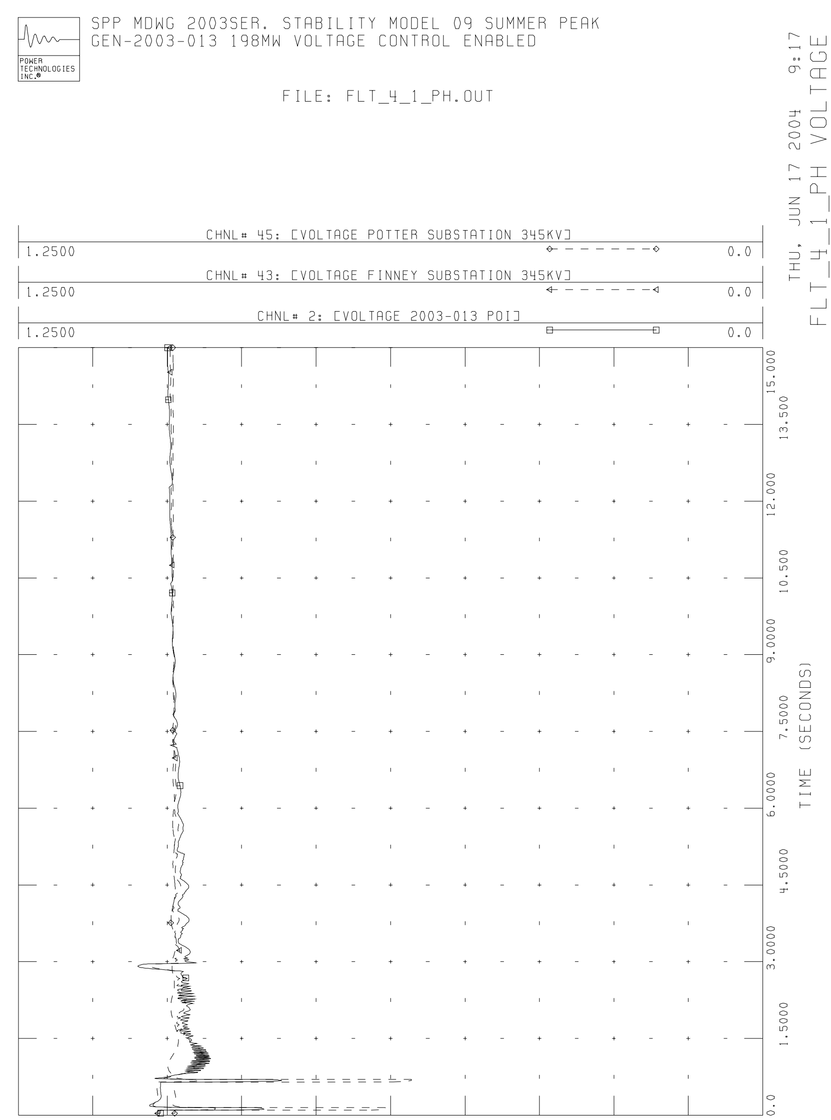
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_3_3_PH.OUT
THU, JUN 17 2004 9:17
FLT_3_3_PH VOLTAGE
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500 0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500 0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500 0.0
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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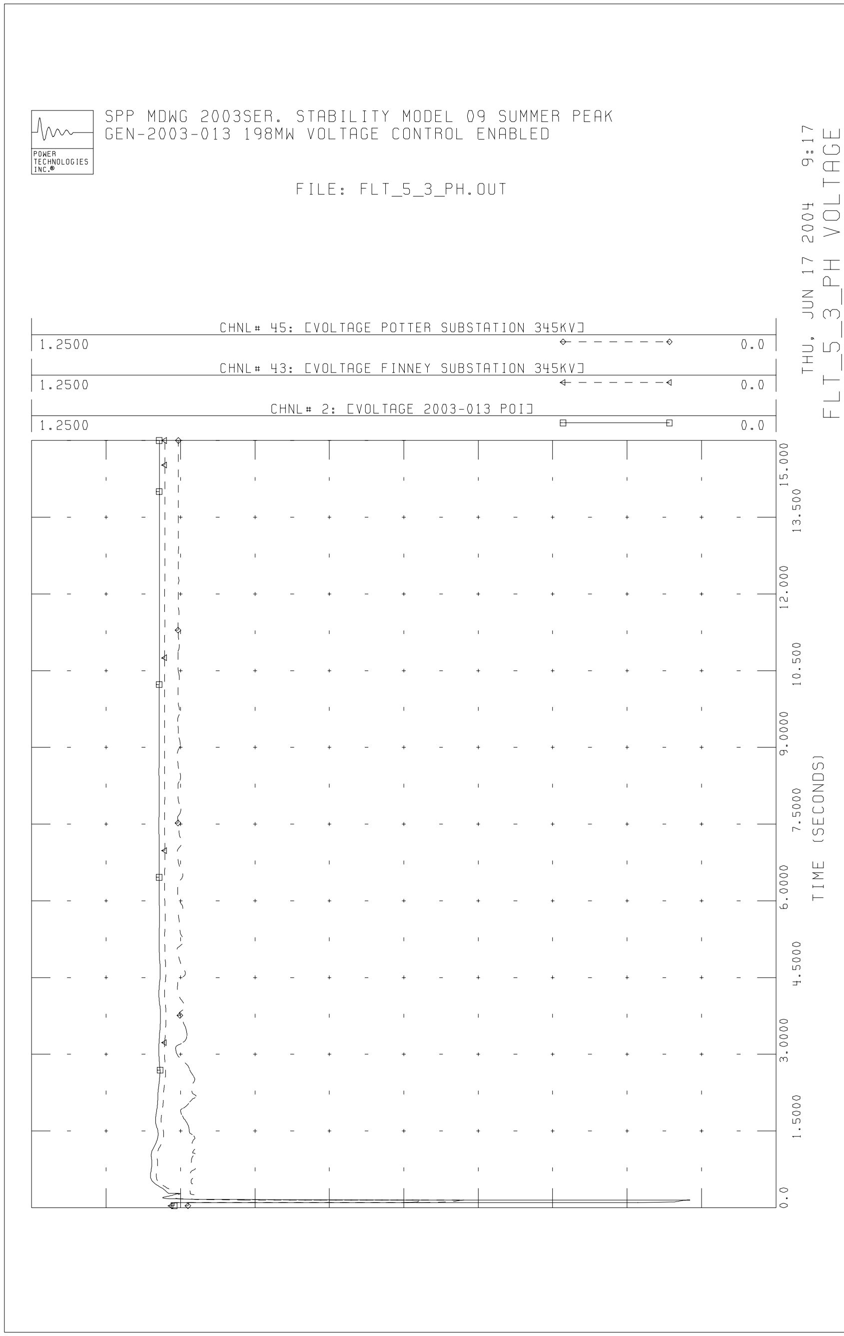
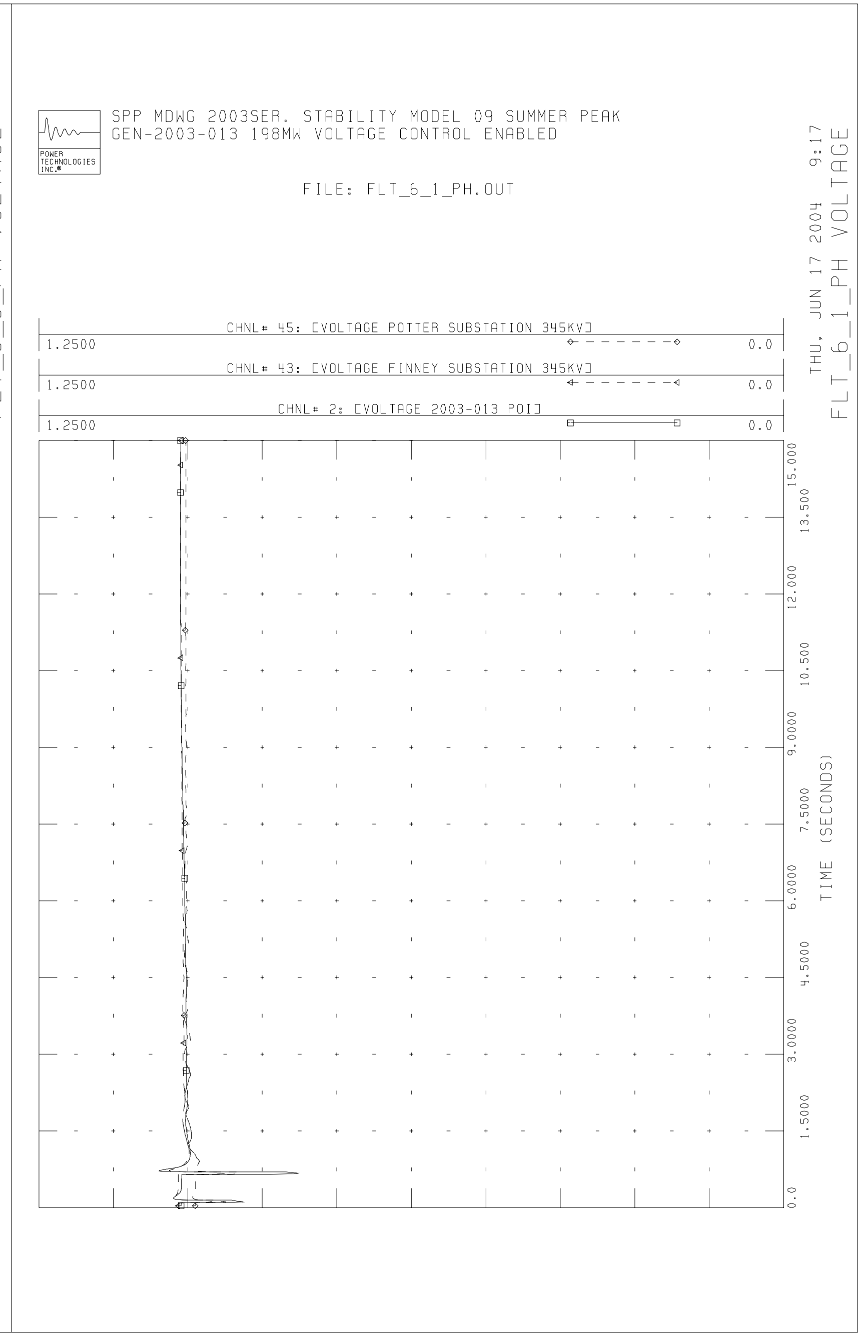
FLT_4_1_PH VOLTAGE
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500 0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500 0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500 0.0
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)



POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_5_3_PH.OUT
THU, JUN 17 2004 9:17
FLT_5_3_PH VOLTAGE
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)



POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_6_1_PH.OUT
THU, JUN 17 2004 9:17
FLT_6_1_PH VOLTAGE
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1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
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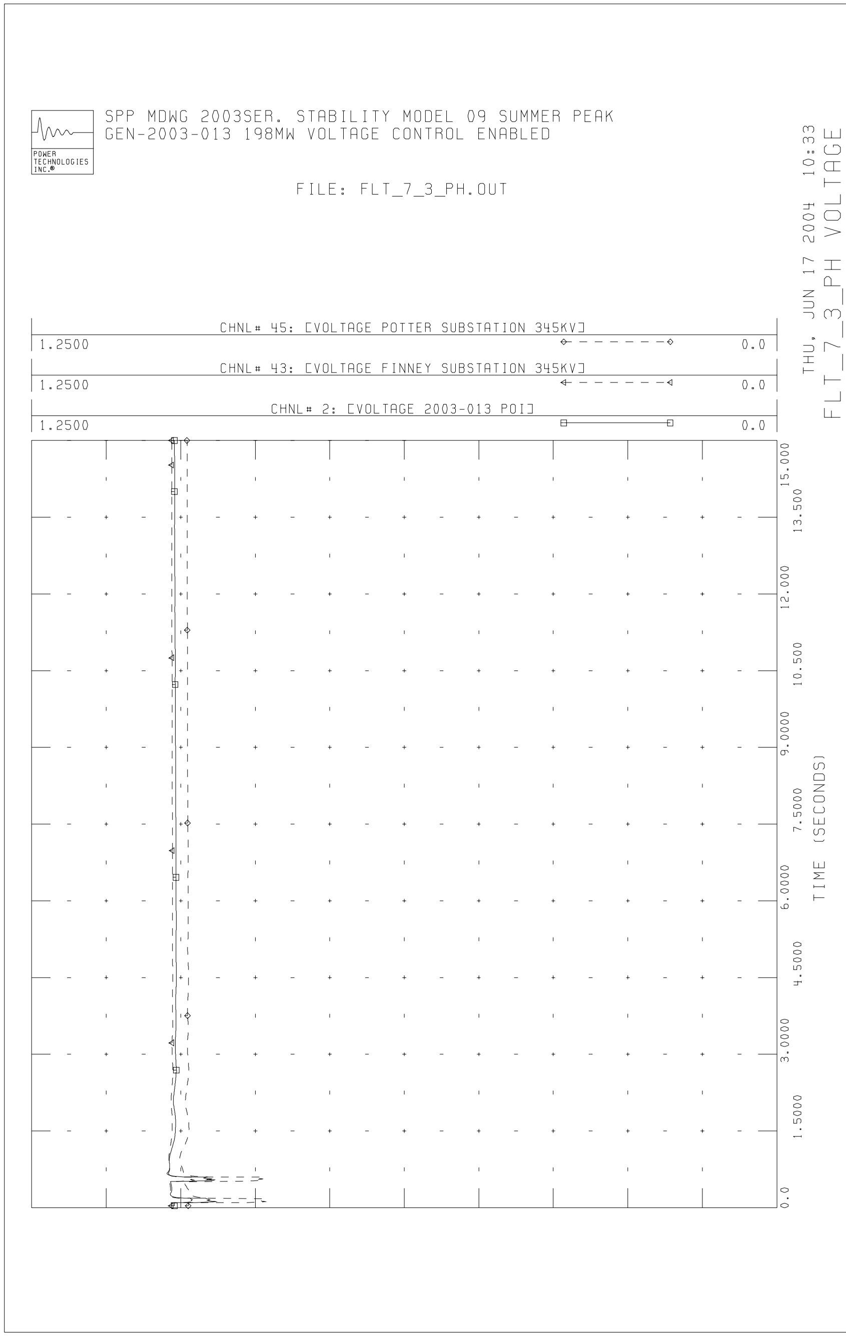
12.000
13.500
15.000
TIME (SECONDS)


POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_7_3_PH.OUT
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CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
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0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
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12.000
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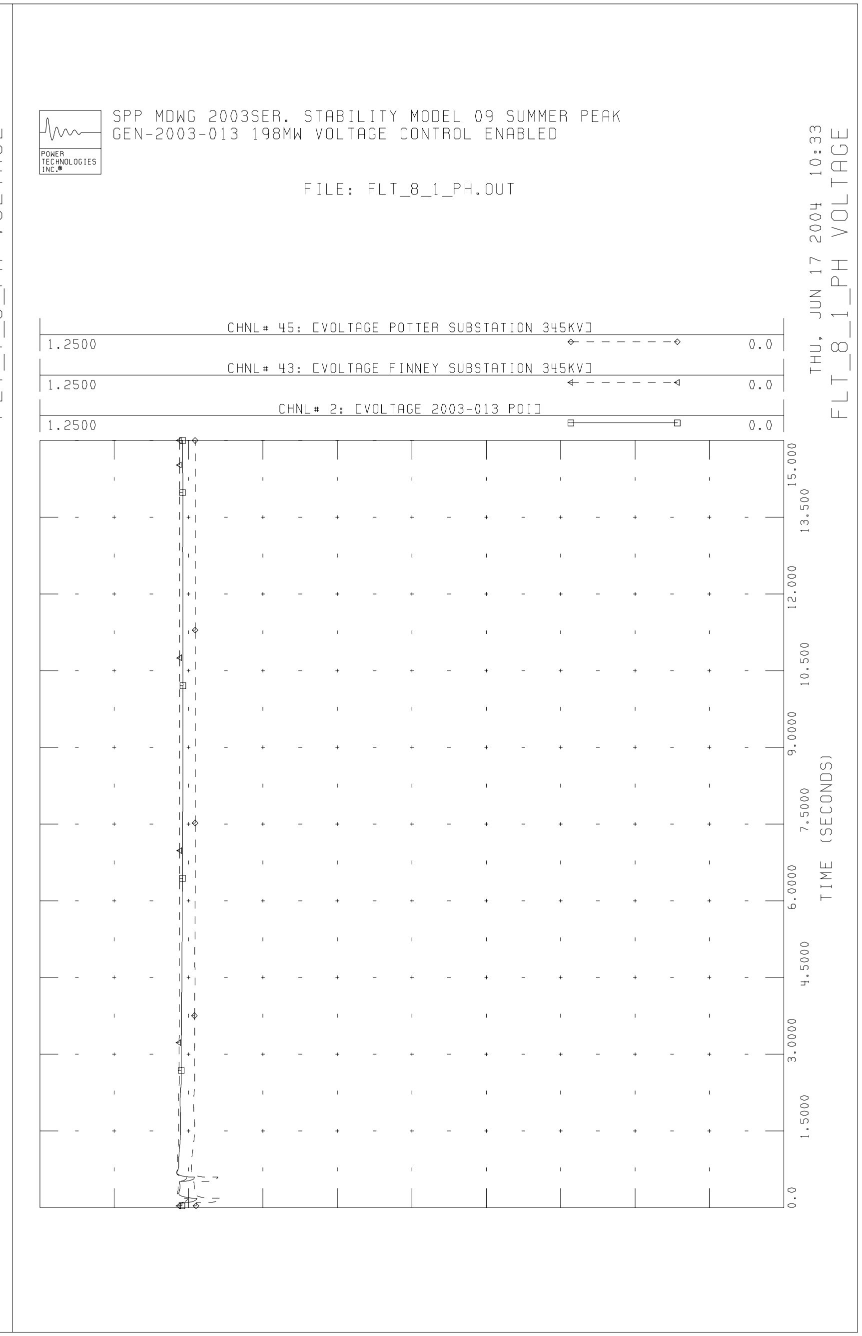
TIME (SECONDS)
THU, JUN 17 2004 10:33
FLT_7_3_PH VOLTAGE


POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_8_1_PH.OUT
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CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
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12.000
13.500
15.000
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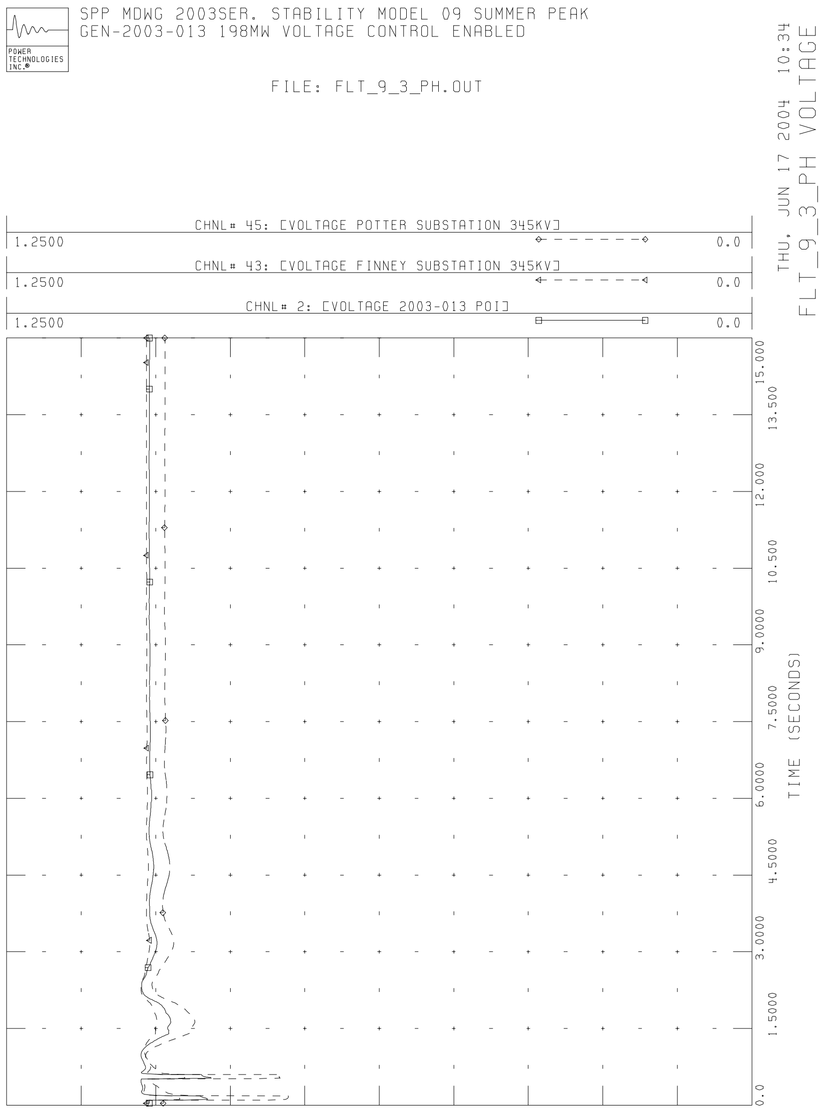
THU, JUN 17 2004 10:33
FLT_8_1_PH VOLTAGE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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
TIME (SECONDS)
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4.5000
6.0000
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9.0000
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12.000
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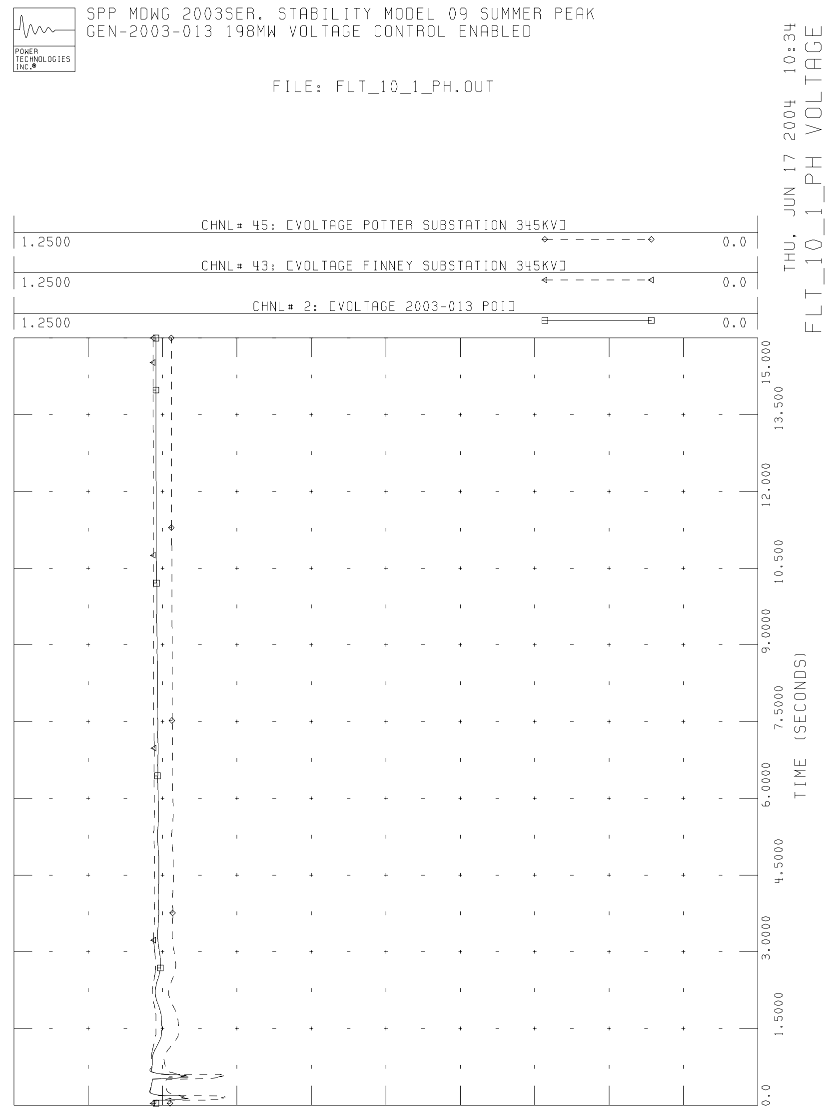
15.000


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
TIME (SECONDS)
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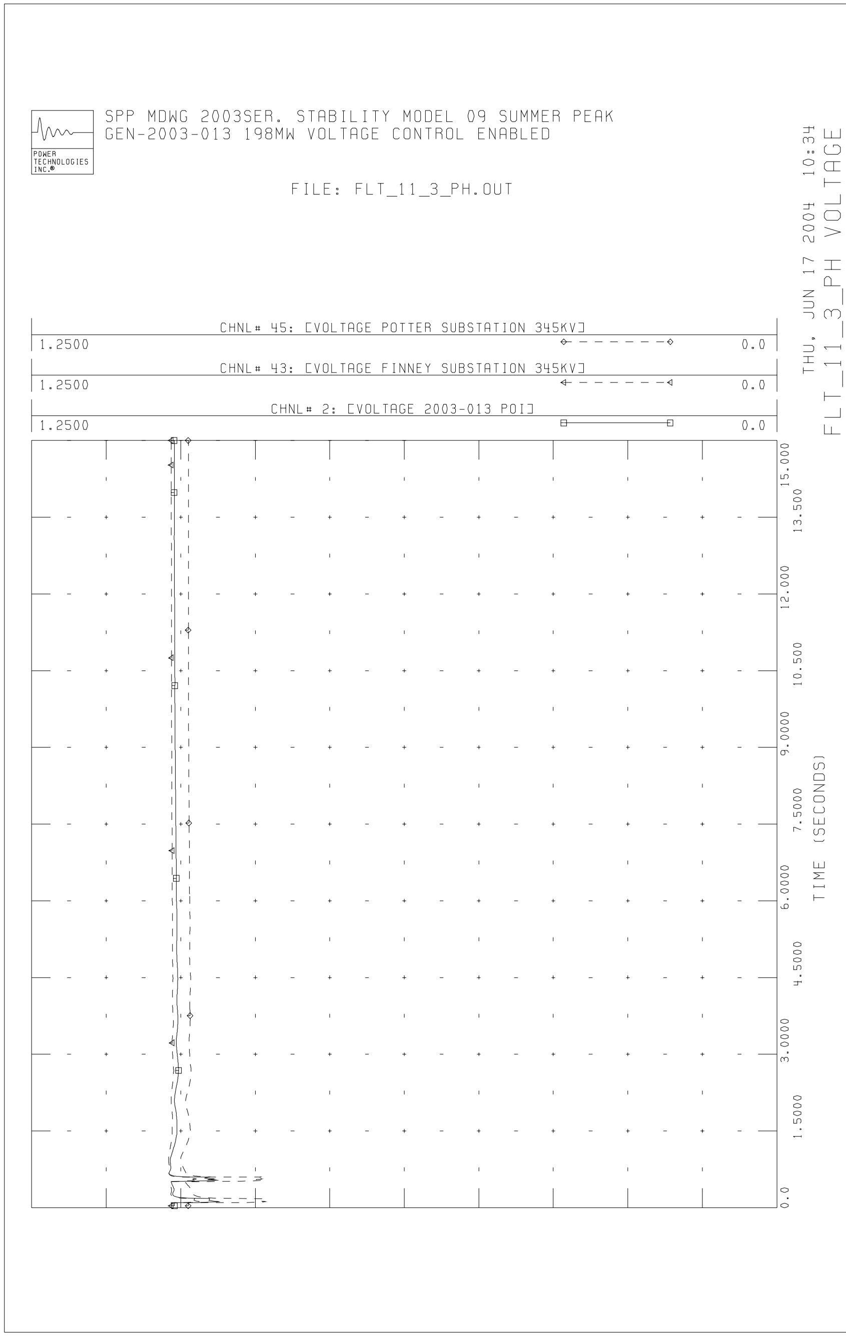

POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
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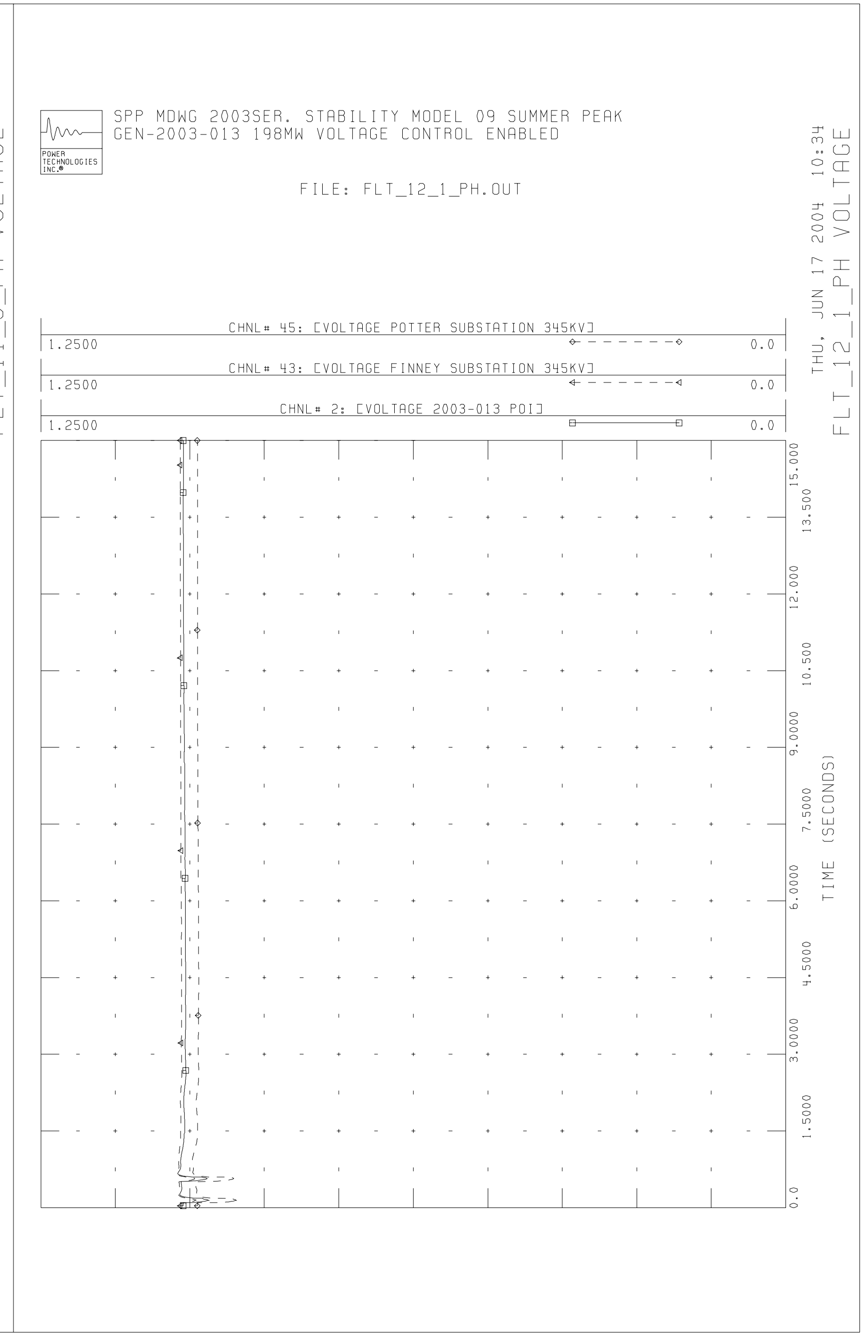

POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
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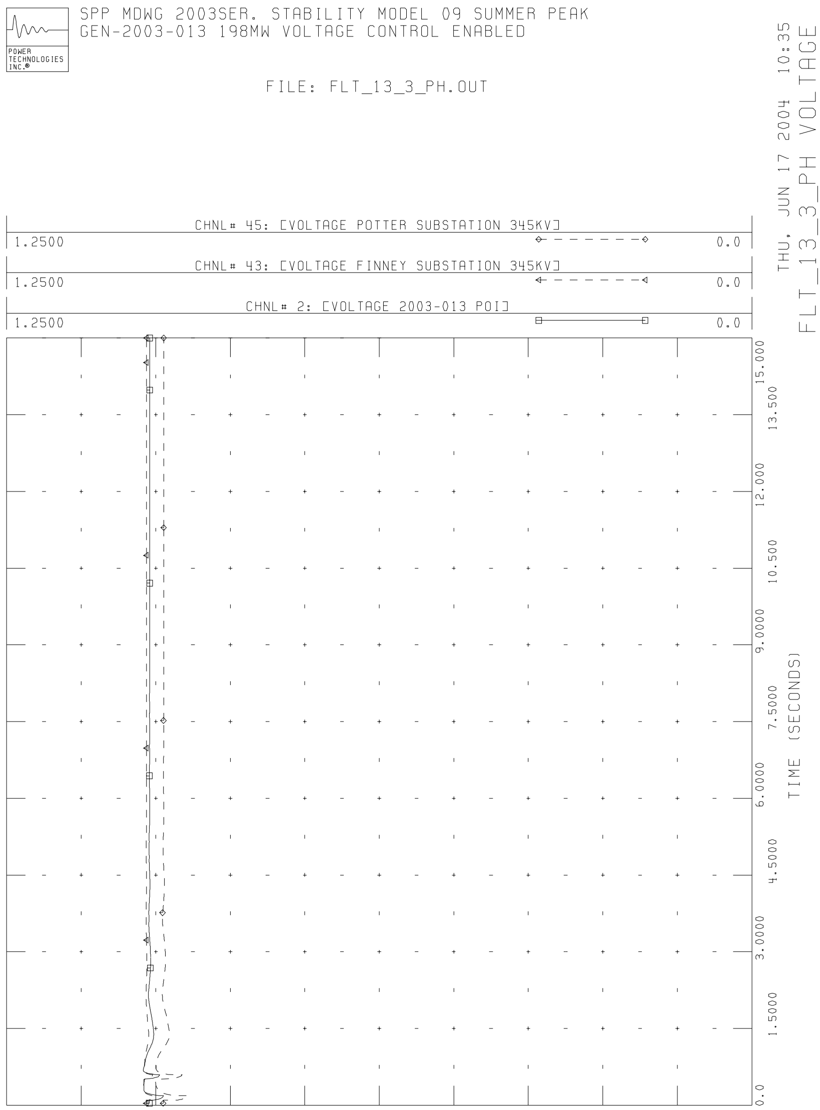
TIME (SECONDS)


POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
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THU, JUN 17 2004 10:35
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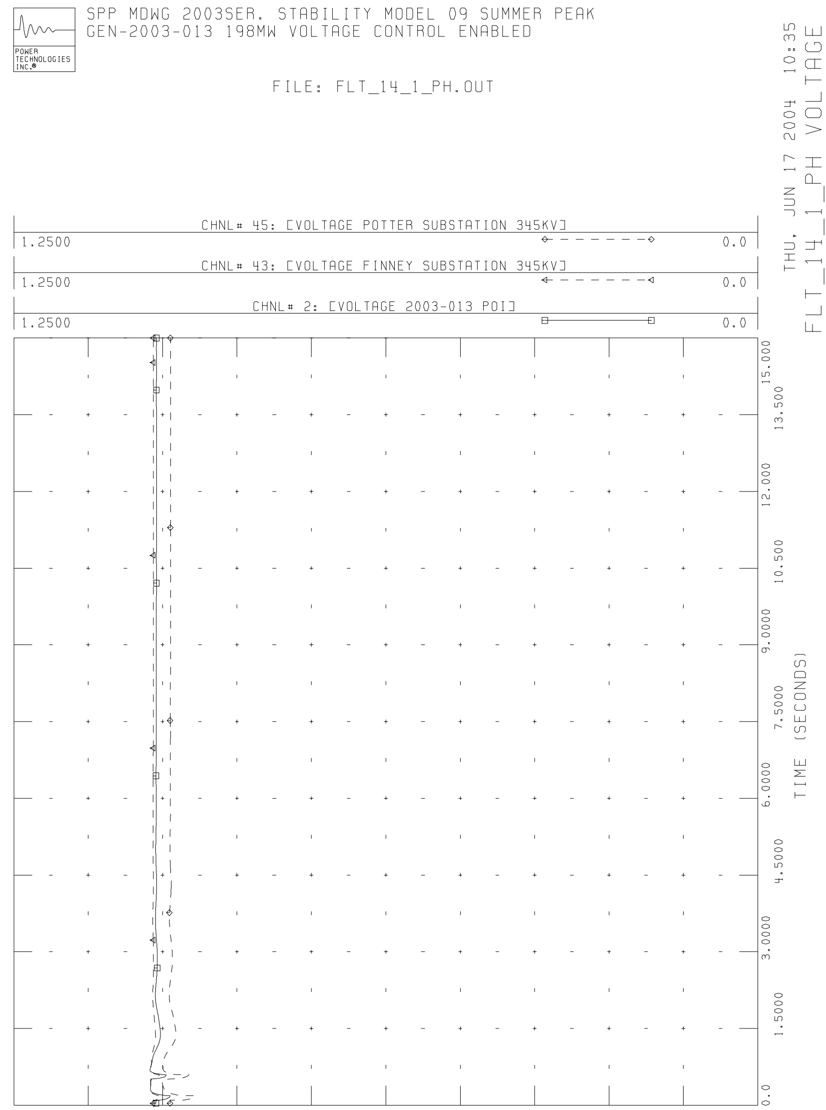
POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_14_1_PH.OUT
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CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
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7.5000
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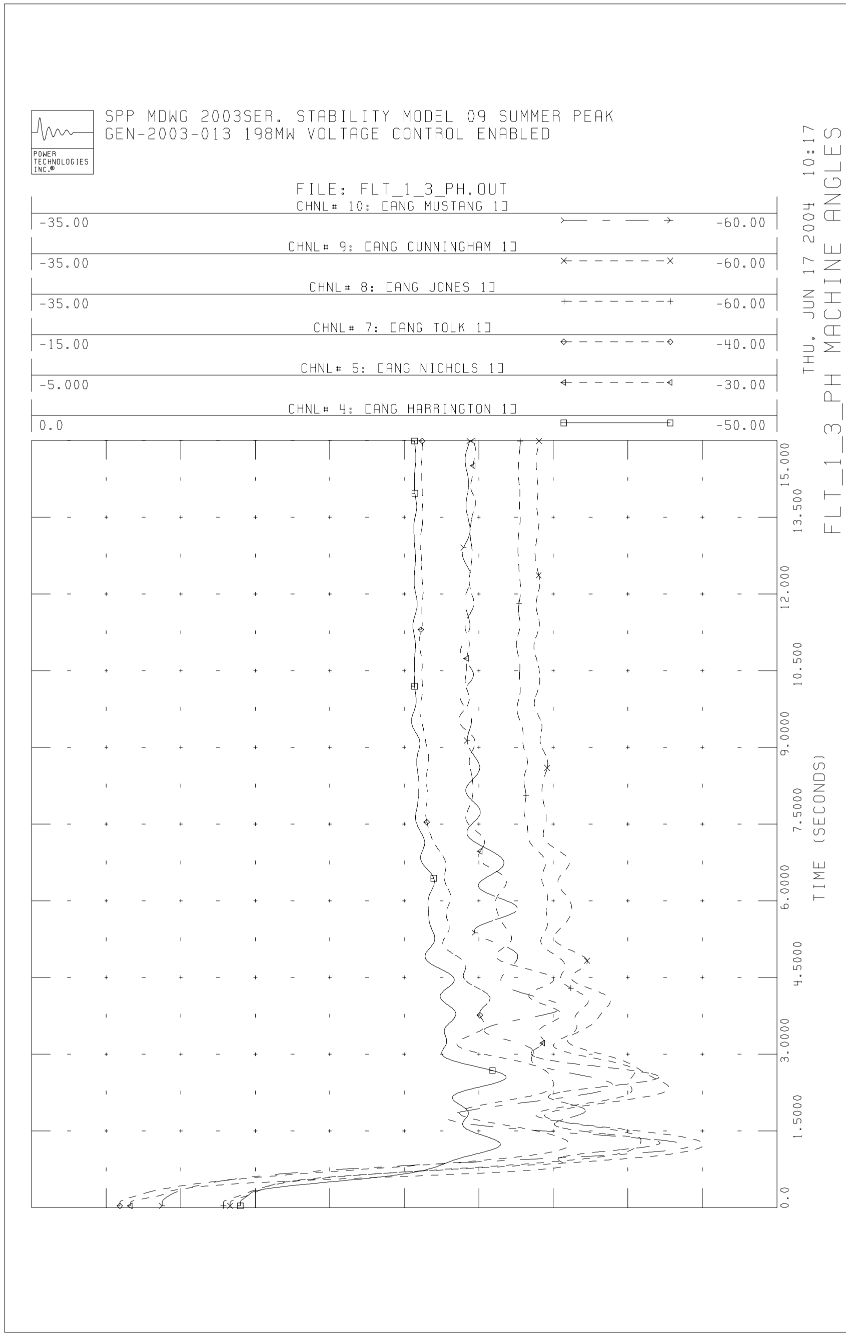
TIME (SECONDS)
THU, JUN 17 2004 10:35
FLT_14_1_PH VOLTAGE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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_1_3_PH.OUT
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CHNL# 9: [ANG CUNNINGHAM 1] -35.00 -60.00
CHNL# 8: [ANG JONES 1] -35.00 -60.00
CHNL# 7: [ANG TOLK 1] -15.00 -40.00
CHNL# 5: [ANG NICHOLS 1] -5.000 -30.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -50.00
THU, JUN 17 2004 10:17
FLT_1_3_PH MACHINE ANGLES
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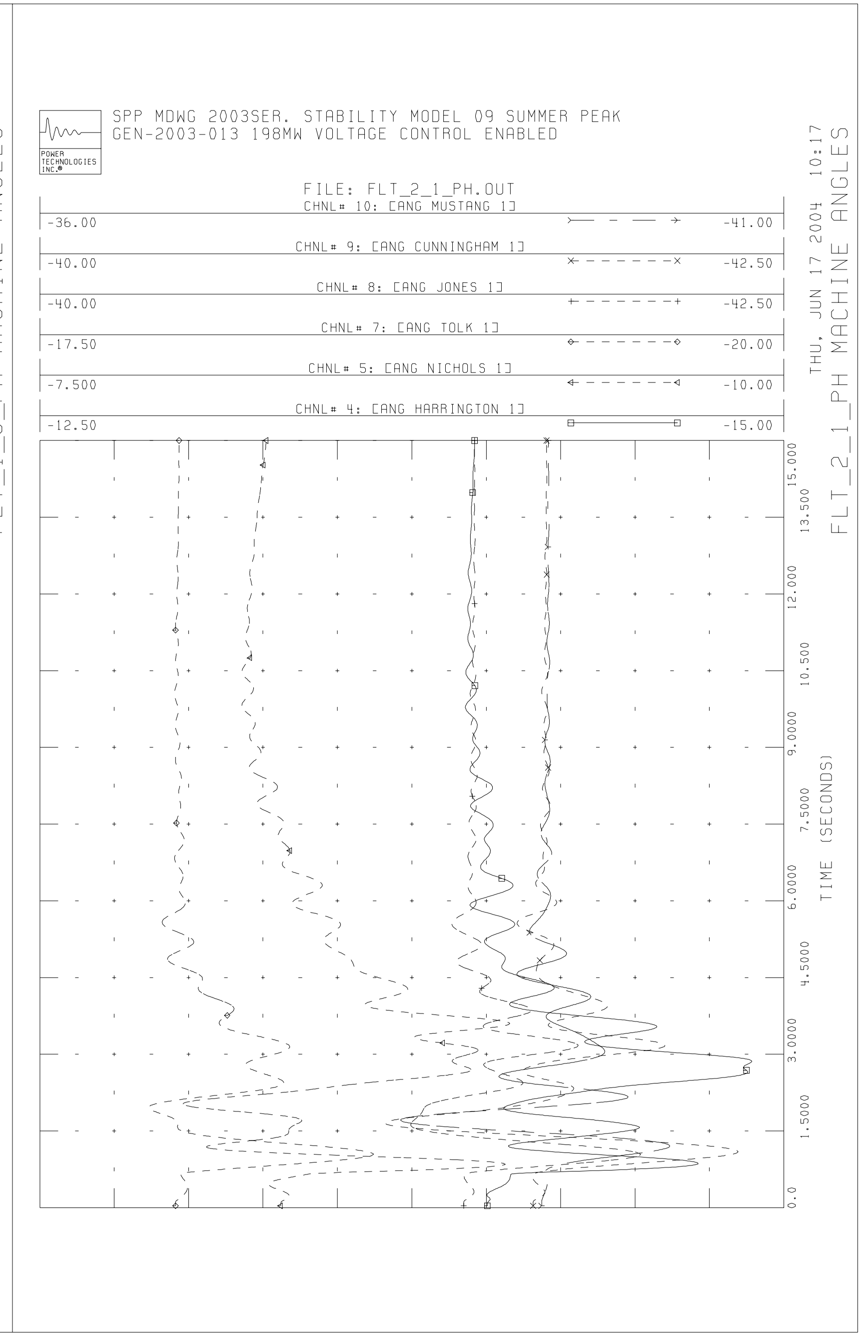
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_2_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -36.00 -41.00
CHNL# 9: [ANG CUNNINGHAM 1] -40.00 -42.50
CHNL# 8: [ANG JONES 1] -40.00 -42.50
CHNL# 7: [ANG TOLK 1] -17.50 -20.00
CHNL# 5: [ANG NICHOLS 1] -7.500 -10.00
CHNL# 4: [ANG HARRINGTON 1] -12.50 -15.00
THU, JUN 17 2004 10:17
FLT_2_1_PH MACHINE ANGLES
TIME (SECONDS)
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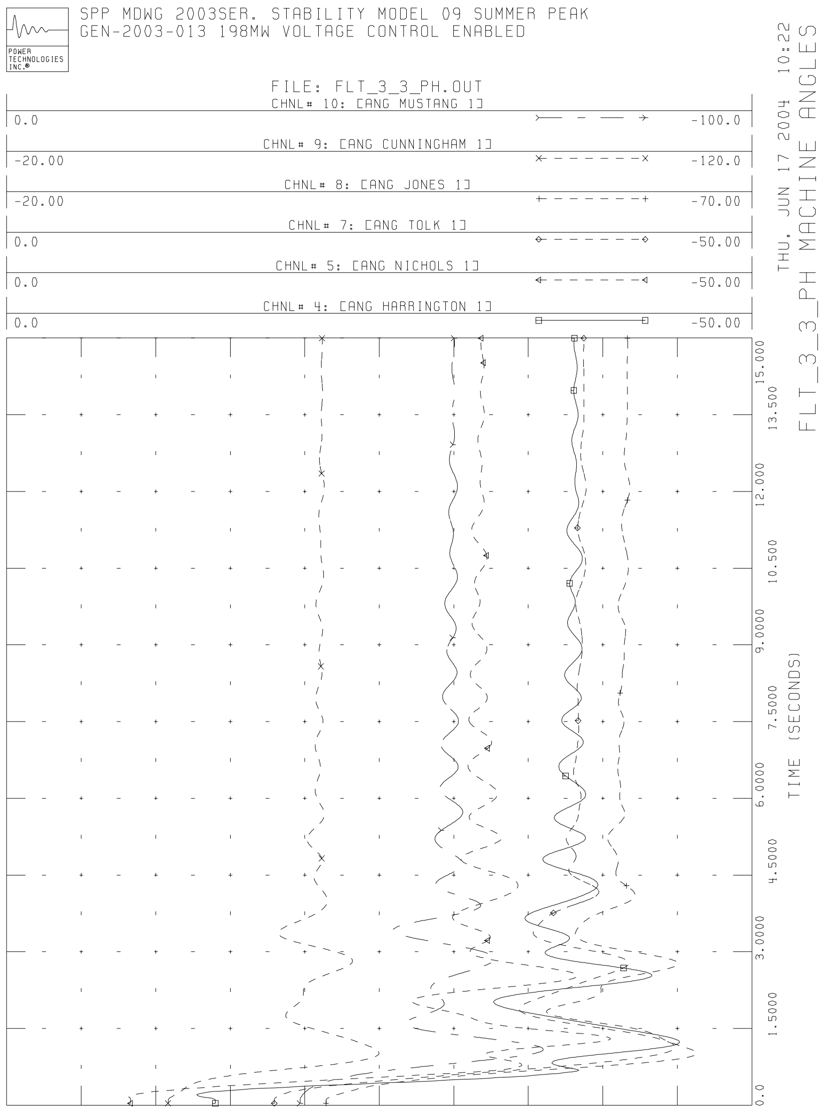

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_3_3_PH.OUT
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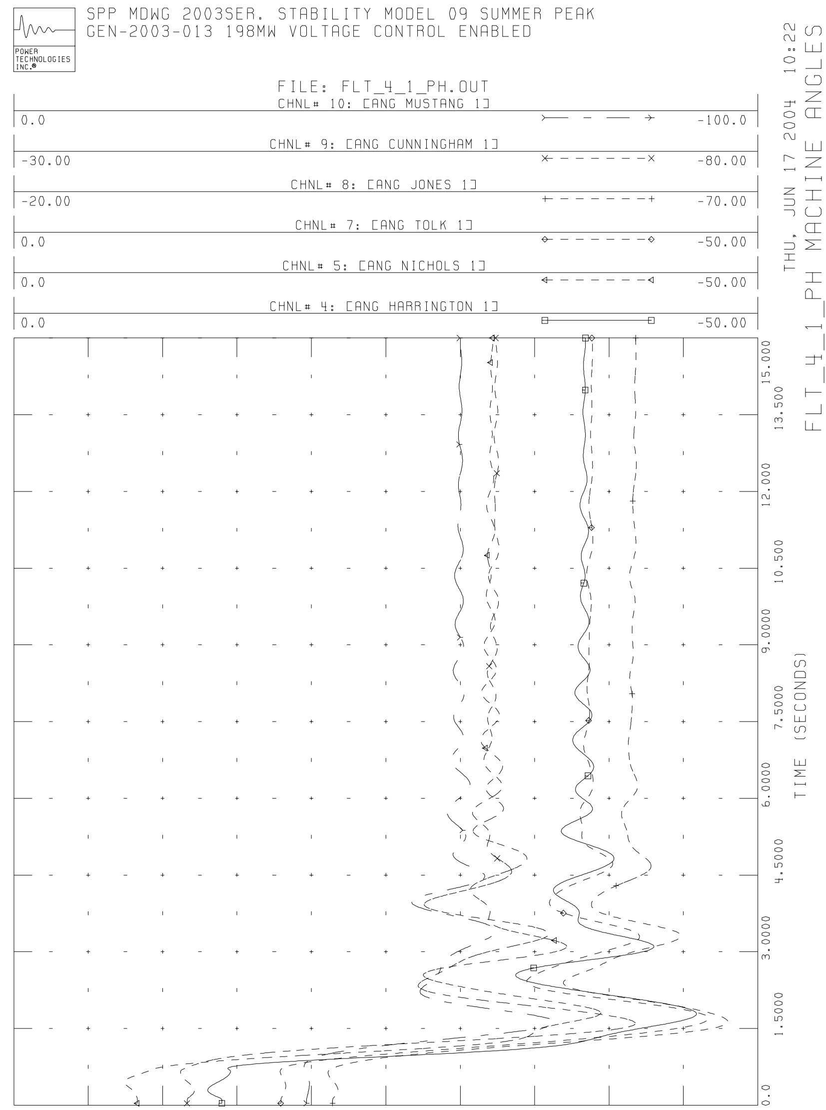
CHNL# 9: [ANG CUNNINGHAM 1] -20.00 -120.0
CHNL# 8: [ANG JONES 1] -20.00 -70.00
CHNL# 7: [ANG TOLK 1] 0.0 -50.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -50.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -50.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 10:22
FLT_3_3_PH MACHINE ANGLES



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_4_1_PH.OUT
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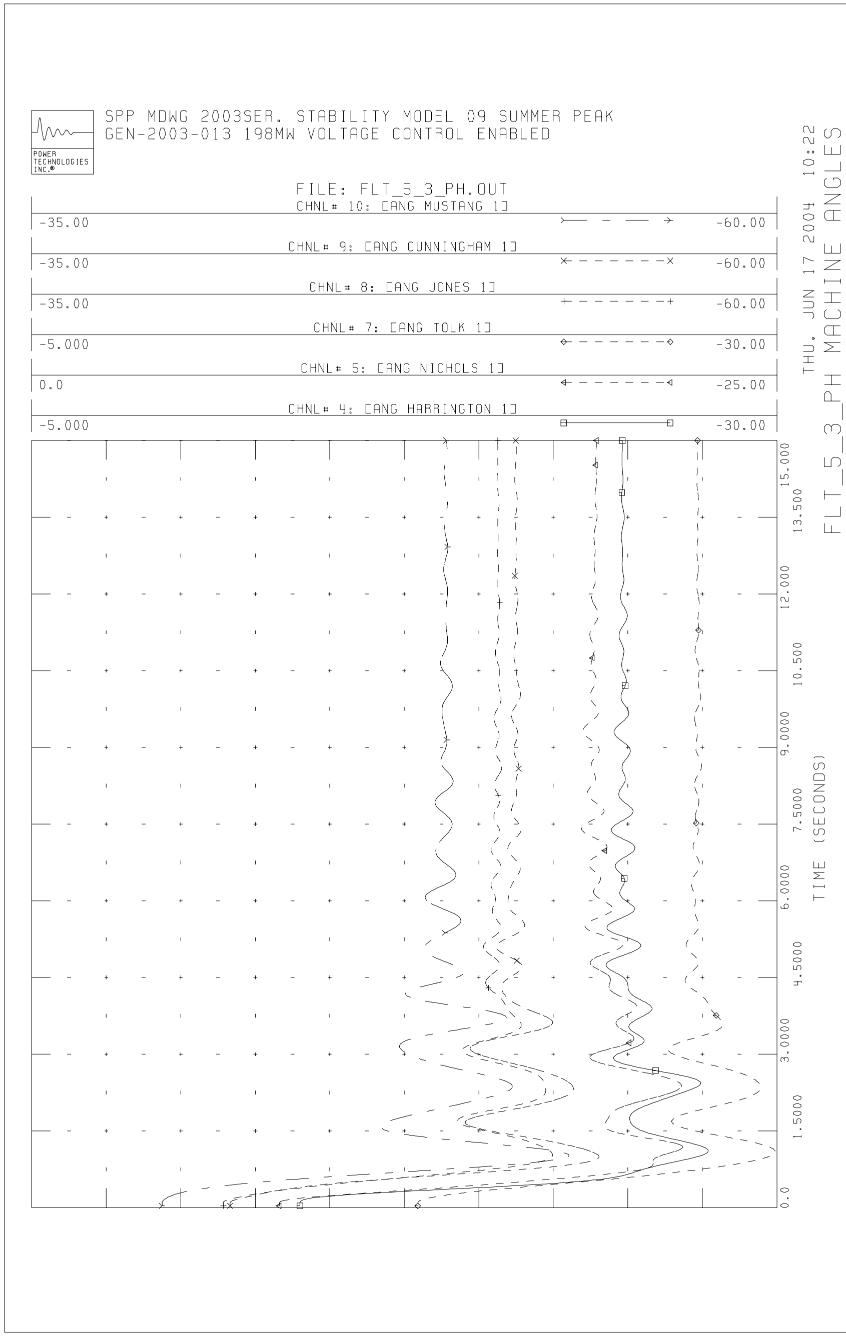
CHNL# 9: [ANG CUNNINGHAM 1] -30.00 -80.00
CHNL# 8: [ANG JONES 1] -20.00 -70.00
CHNL# 7: [ANG TOLK 1] 0.0 -50.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -50.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -50.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 10:22
FLT_4_1_PH MACHINE ANGLES



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 9: [ANG CUNNINGHAM 1] -35.00 -60.00
CHNL# 8: [ANG JONES 1] -35.00 -60.00
CHNL# 7: [ANG TOLK 1] -5.000 -30.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] -5.000 -30.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
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THU, JUN 17 2004 10:22
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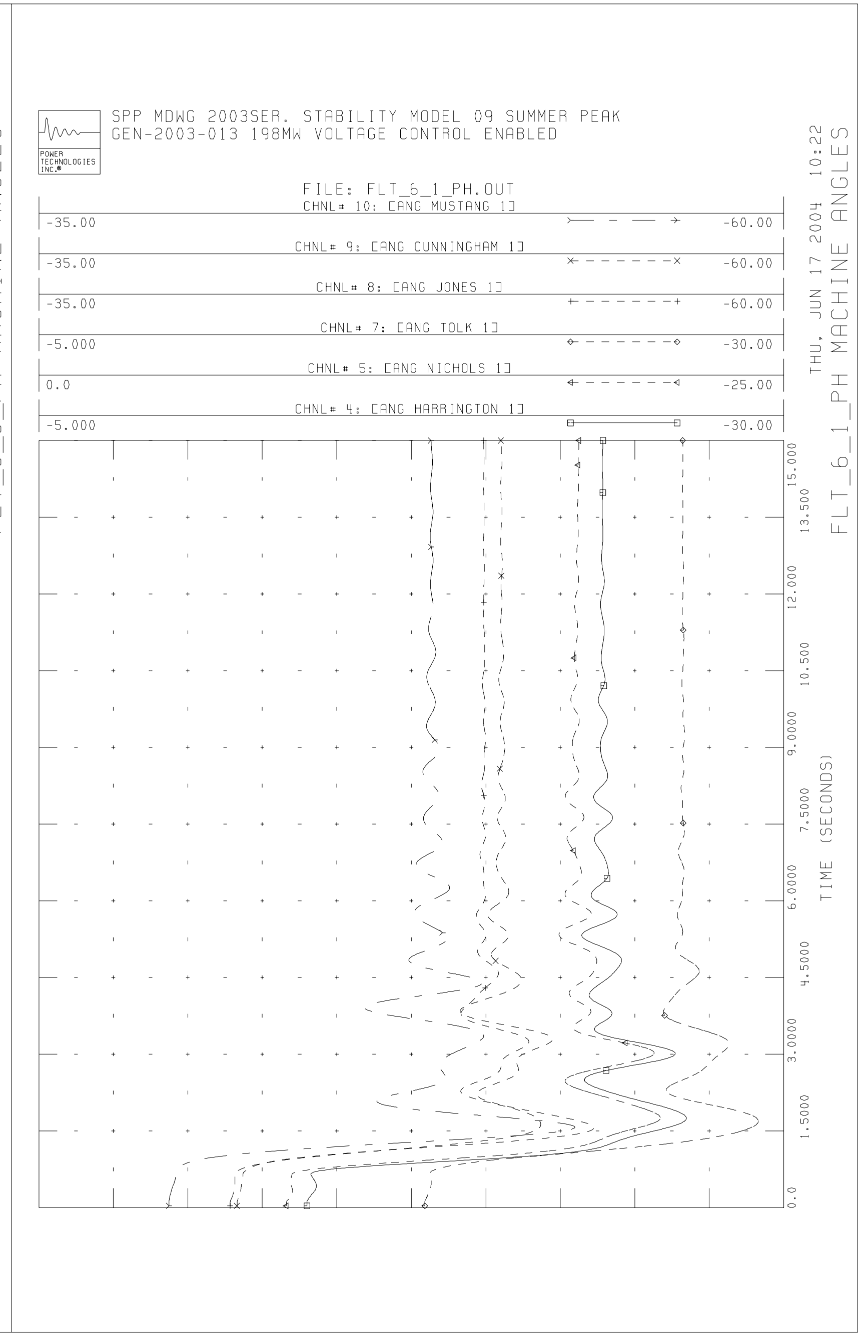

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 7: [ANG TOLK 1] -5.000 -30.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] -5.000 -30.00
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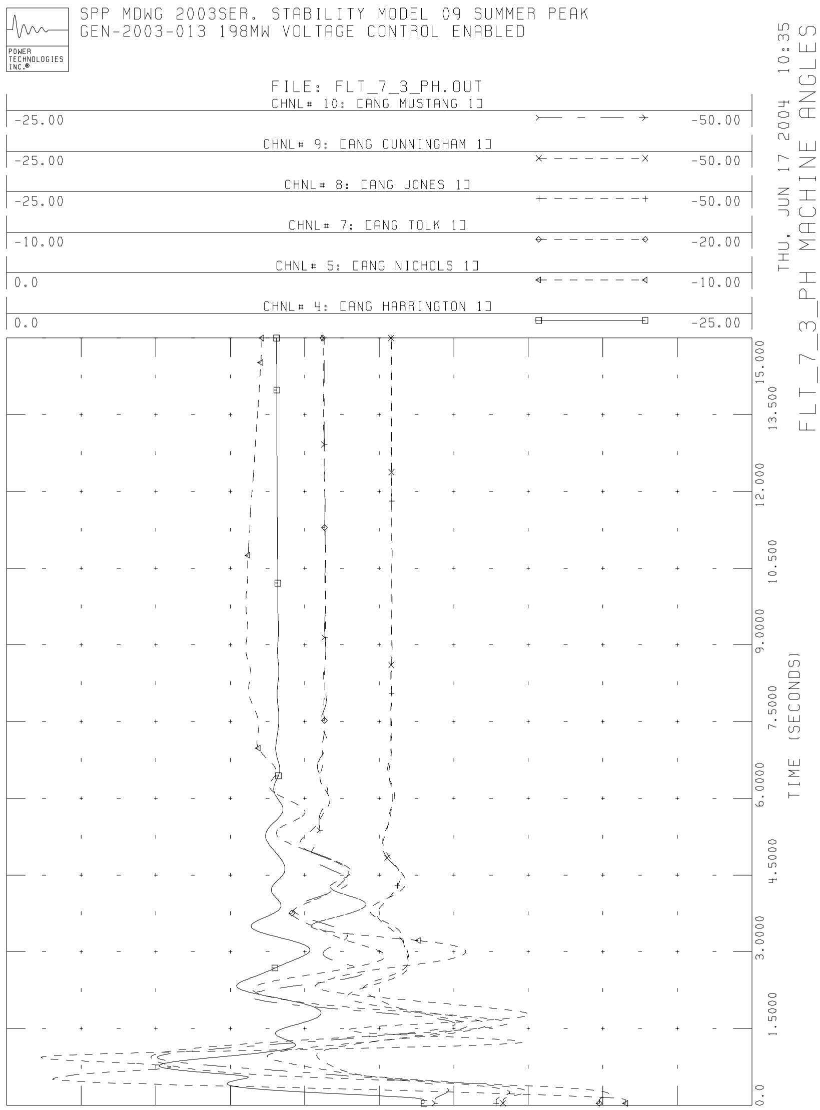
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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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-50.00
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-25.00
-50.00
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-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
-10.00
-20.00
CHNL# 5: [ANG NICHOLS 1]
0.0
-10.00
CHNL# 4: [ANG HARRINGTON 1]
0.0
-25.00
THU, JUN 17 2004 10:35
FLT_7_3_PH MACHINE ANGLES
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4.5000
6.0000
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12.000
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15.000
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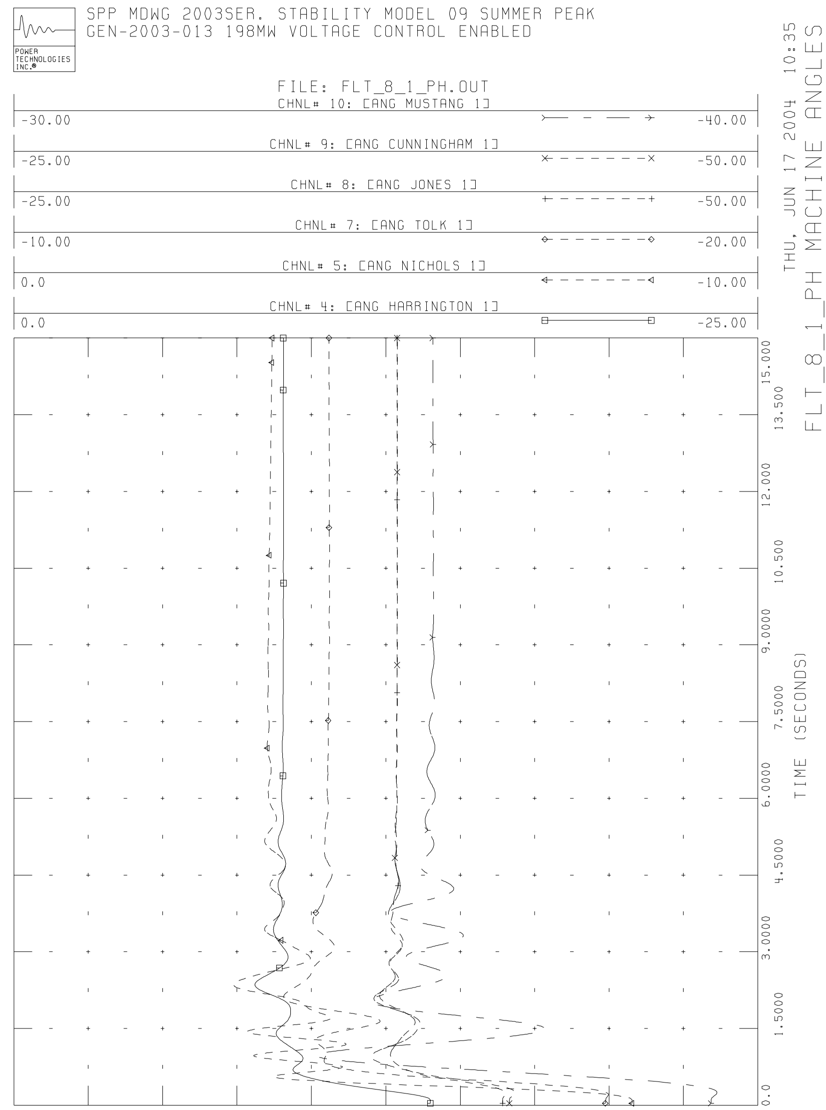
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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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-50.00
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-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
-10.00
-20.00
CHNL# 5: [ANG NICHOLS 1]
0.0
-10.00
CHNL# 4: [ANG HARRINGTON 1]
0.0
-25.00
THU, JUN 17 2004 10:35
FLT_8_1_PH MACHINE ANGLES
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4.5000
6.0000
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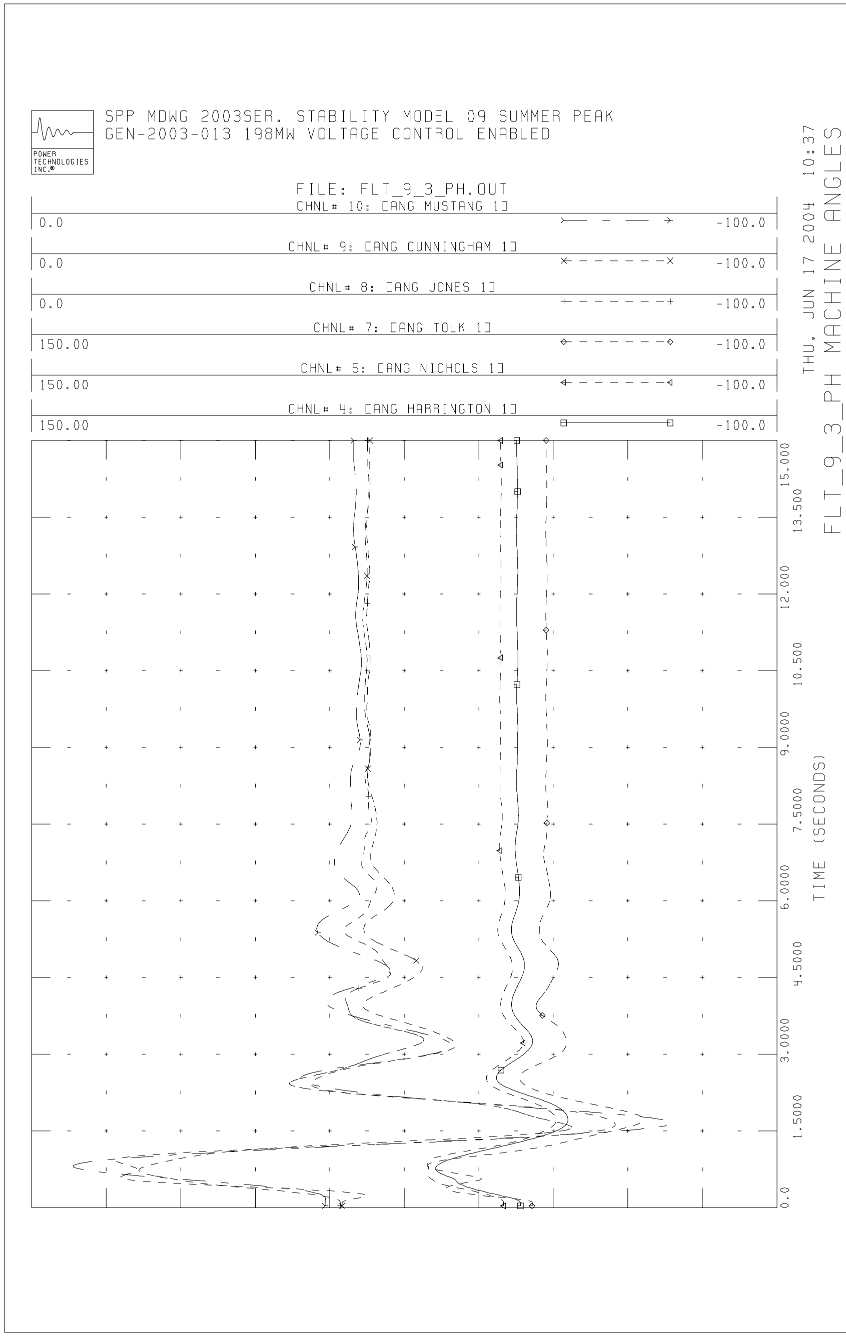
TIME (SECONDS)


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 9: [ANG CUNNINGHAM 1] 0.0 -100.0
CHNL# 8: [ANG JONES 1] 0.0 -100.0
CHNL# 7: [ANG TOLK 1] 150.00 -100.0
CHNL# 5: [ANG NICHOLS 1] 150.00 -100.0
CHNL# 4: [ANG HARRINGTON 1] 150.00 -100.0
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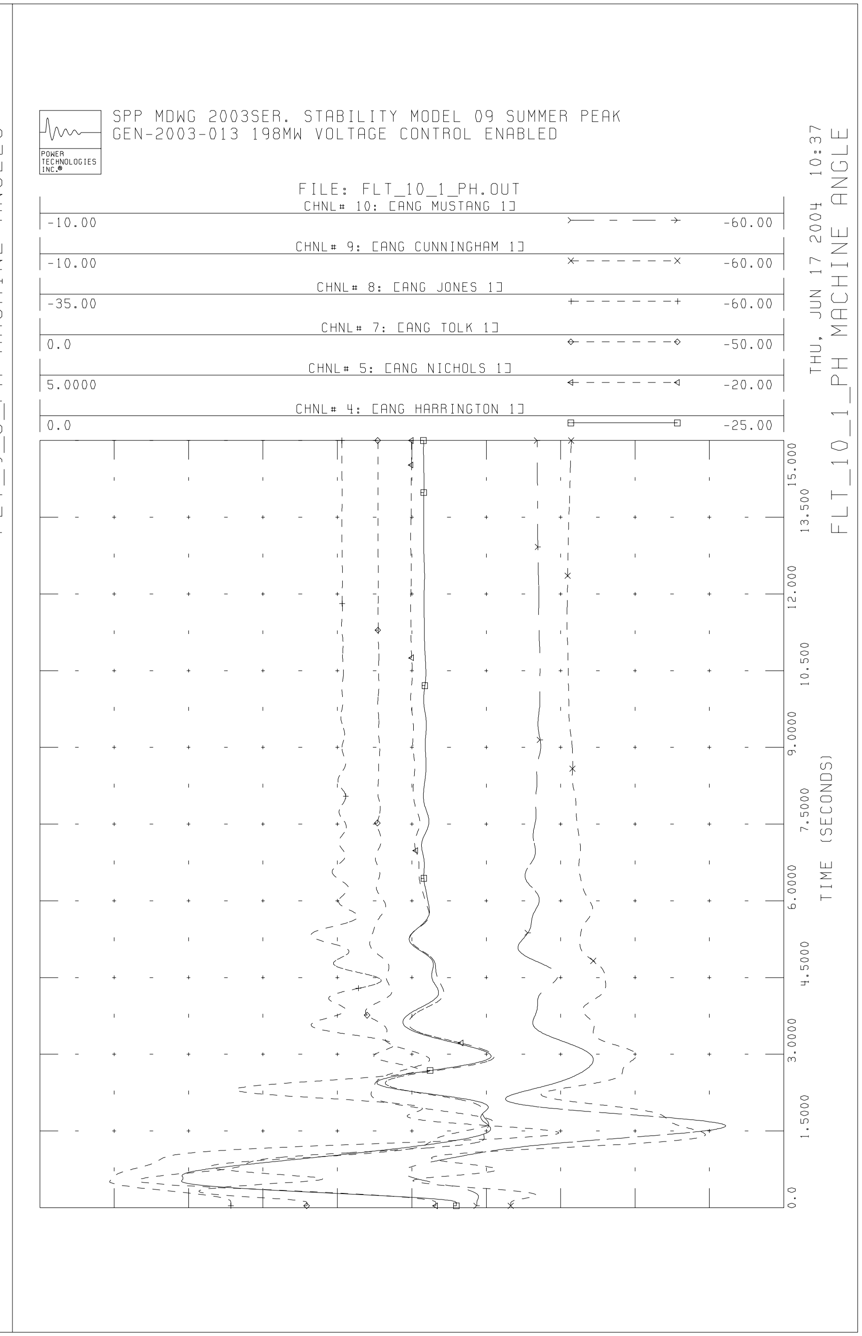
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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 8: [ANG JONES 1] -35.00 -60.00
CHNL# 7: [ANG TOLK 1] 0.0 -50.00
CHNL# 5: [ANG NICHOLS 1] 5.0000 -20.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
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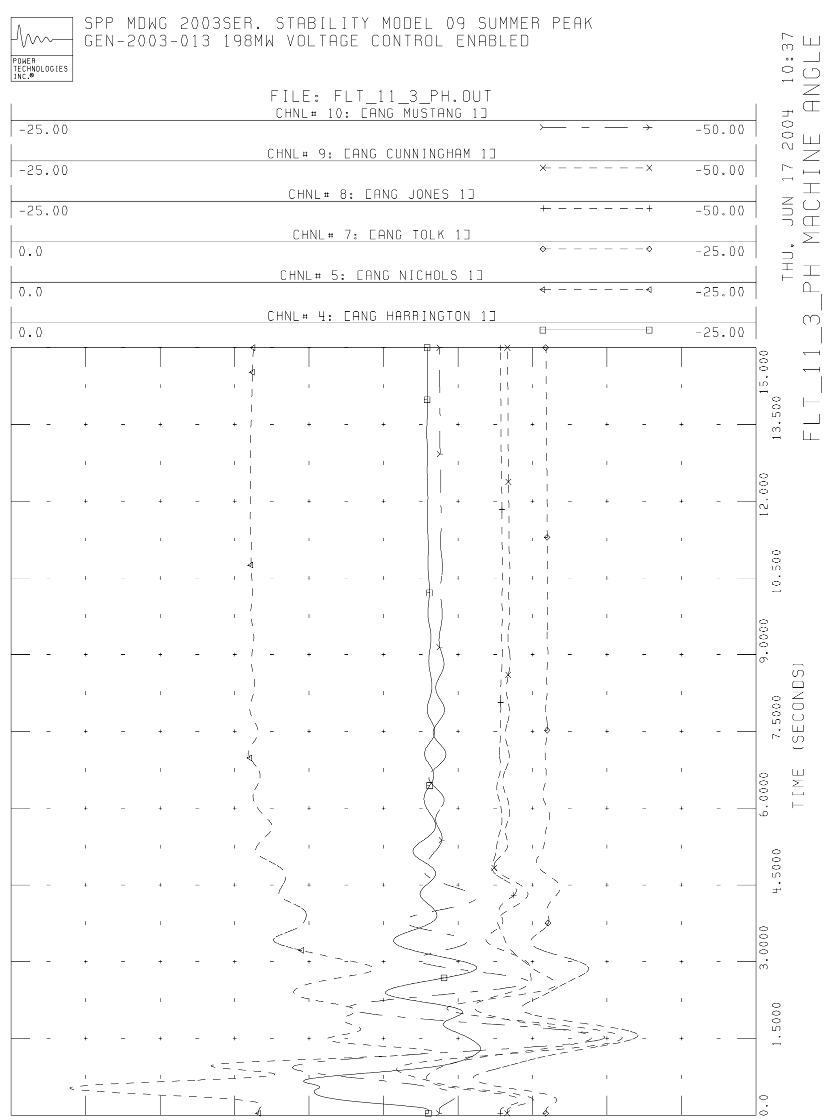
FLT_10_1_PH MACHINE ANGLE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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
THU, JUN 17 2004 10:37
FLT_11_3_PH MACHINE ANGLE
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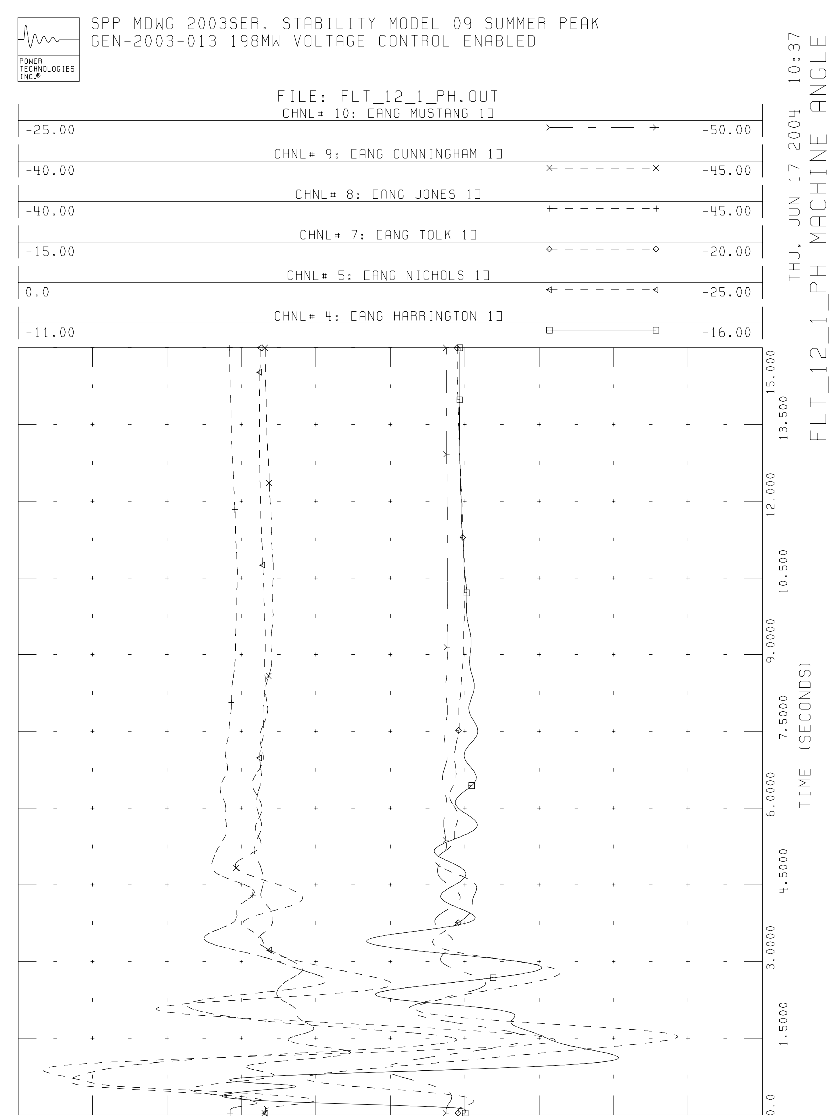
TIME (SECONDS)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POWER TECHNOLOGIES INC.
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CHNL# 9: [ANG CUNNINGHAM 1] -40.00 -45.00
CHNL# 8: [ANG JONES 1] -40.00 -45.00
CHNL# 7: [ANG TOLK 1] -15.00 -20.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] -11.00 -16.00
THU, JUN 17 2004 10:37
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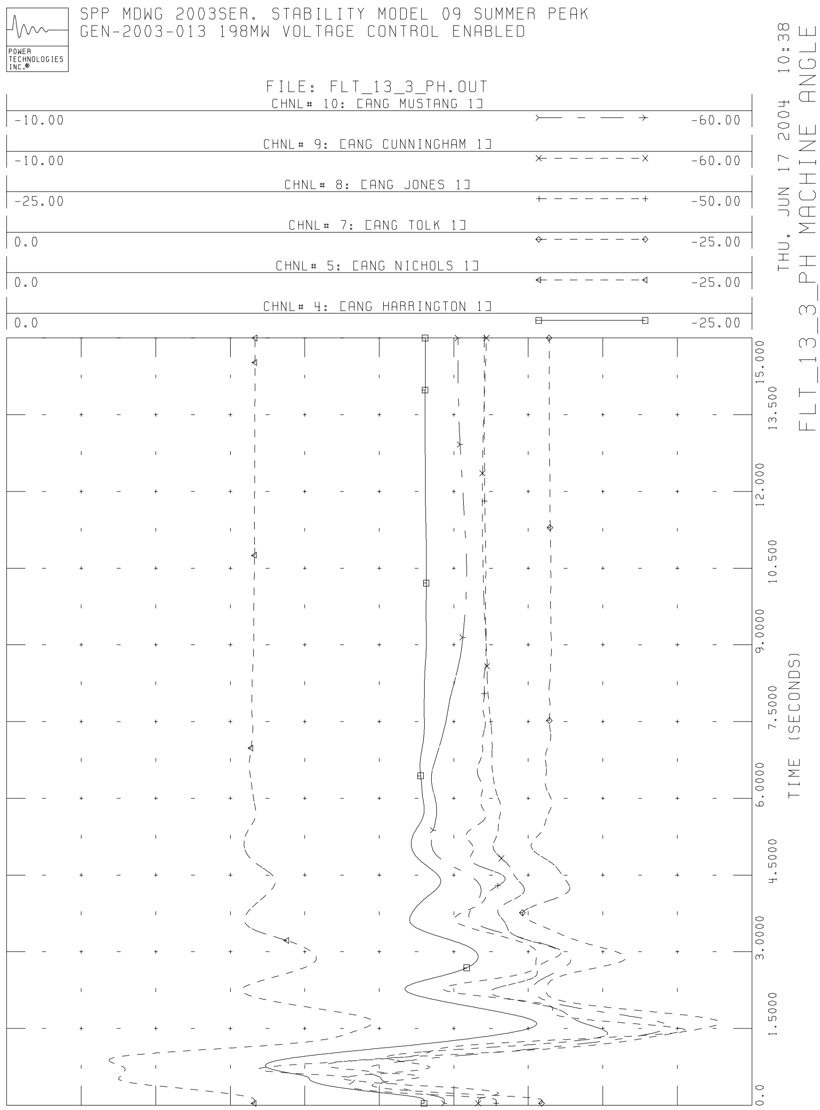
TIME (SECONDS)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SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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CHNL# 9: [ANG CUNNINGHAM 1] -10.00 -60.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
THU, JUN 17 2004 10:38
FLT_13_3_PH MACHINE ANGLE
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6.0000
7.5000
9.0000
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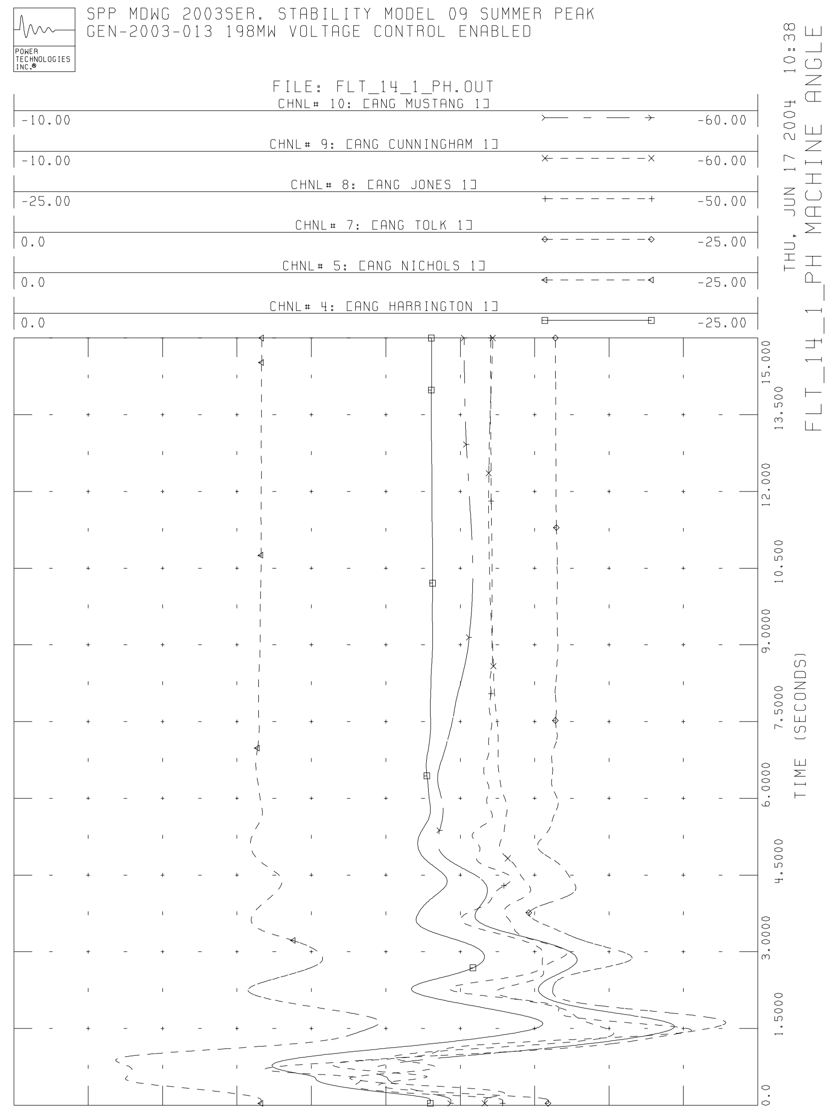
12.000
13.500
15.000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SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
THU, JUN 17 2004 10:38
FLT_14_1_PH MACHINE ANGLE
TIME (SECONDS)
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1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000

Appendix 3

Plots of Fault Simulations

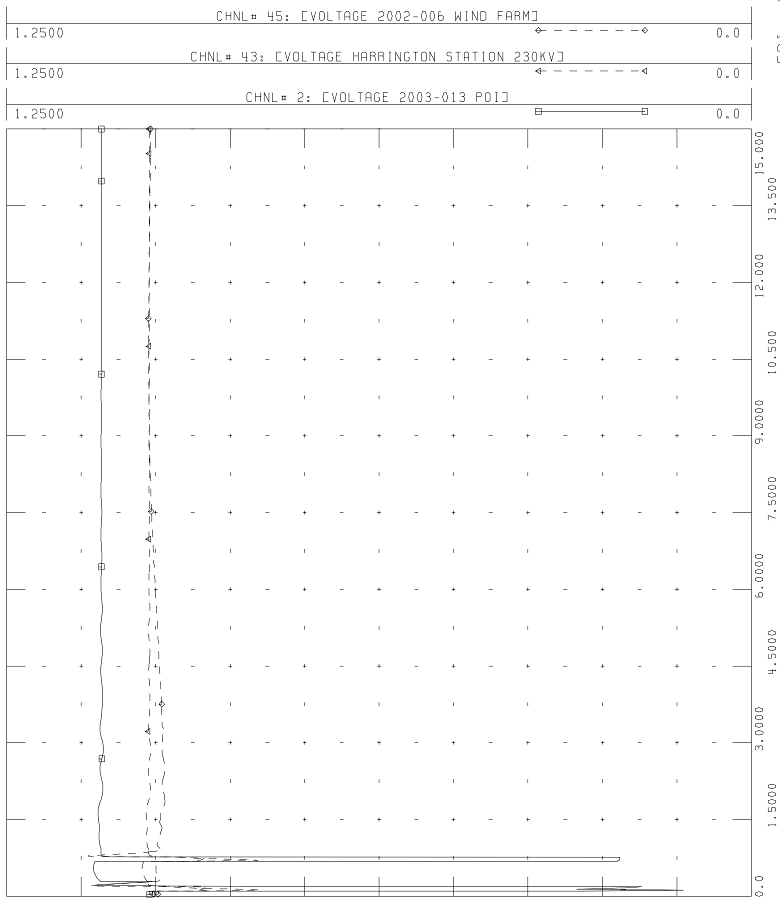
Plots of Wind Farm generators voltage response during faults
Plots of various SPS/Xcel Energy generator angle response during faults

Scenario:
2009 Summer Peak with Wind Farm at 198MW output and Voltage Control enabled
Adjacent GEN-2002-008 wind farm at 0MW output

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED

FILE: FLT_1_3_PH.OUT

FRI, JUN 18 2004 15:53
FLT_1_3_PH VOLTAGE



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED

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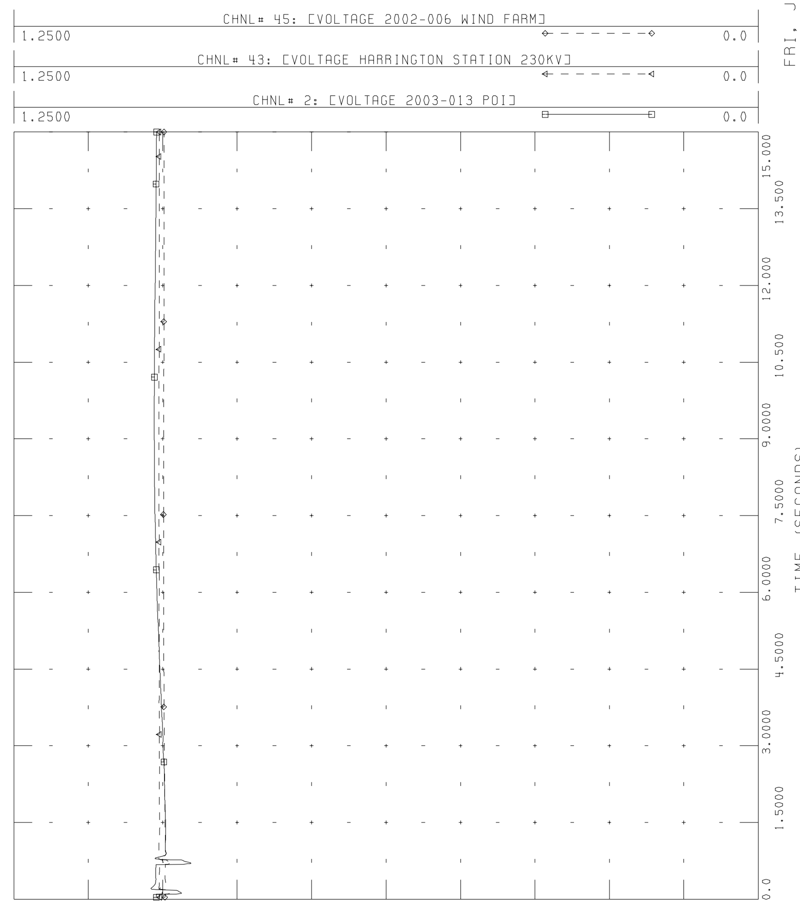
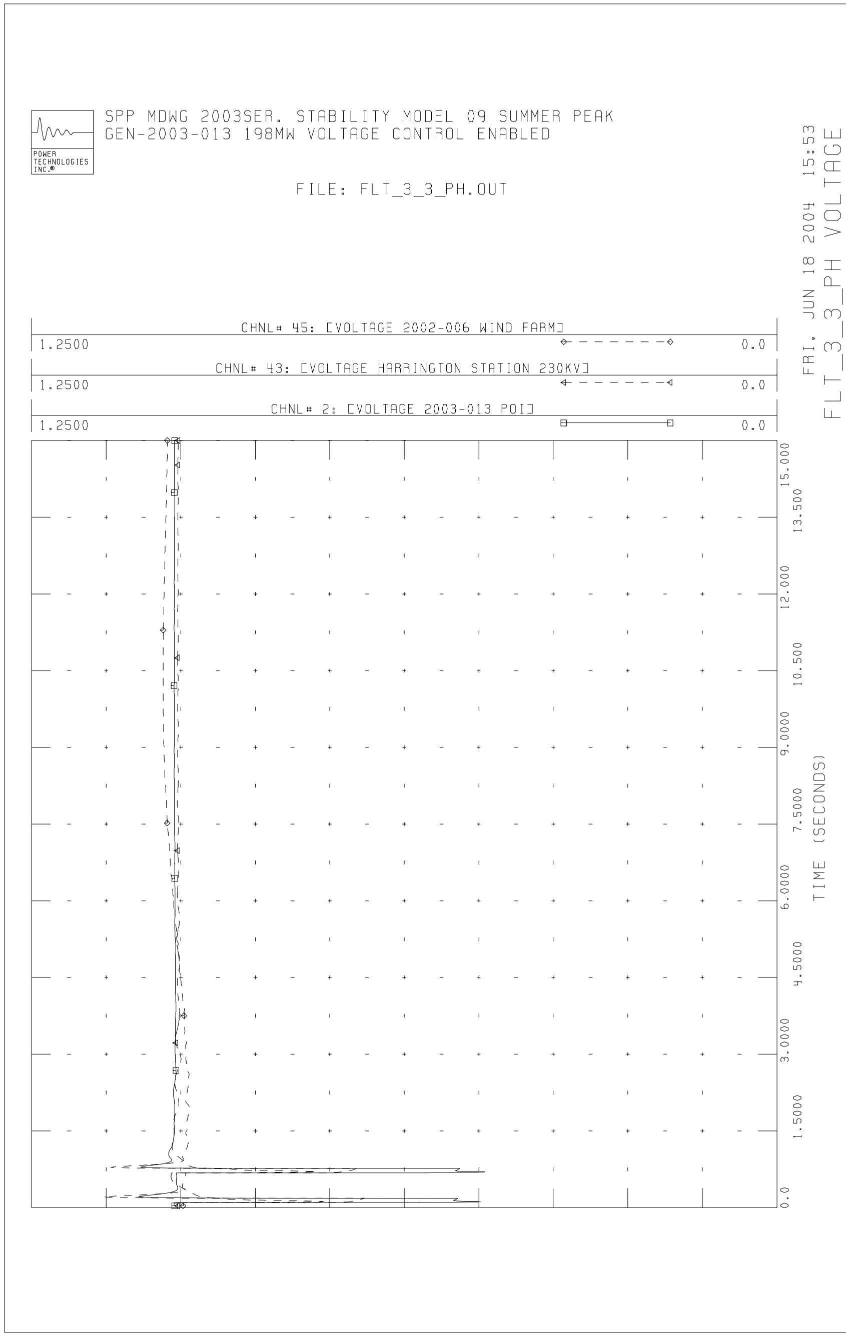
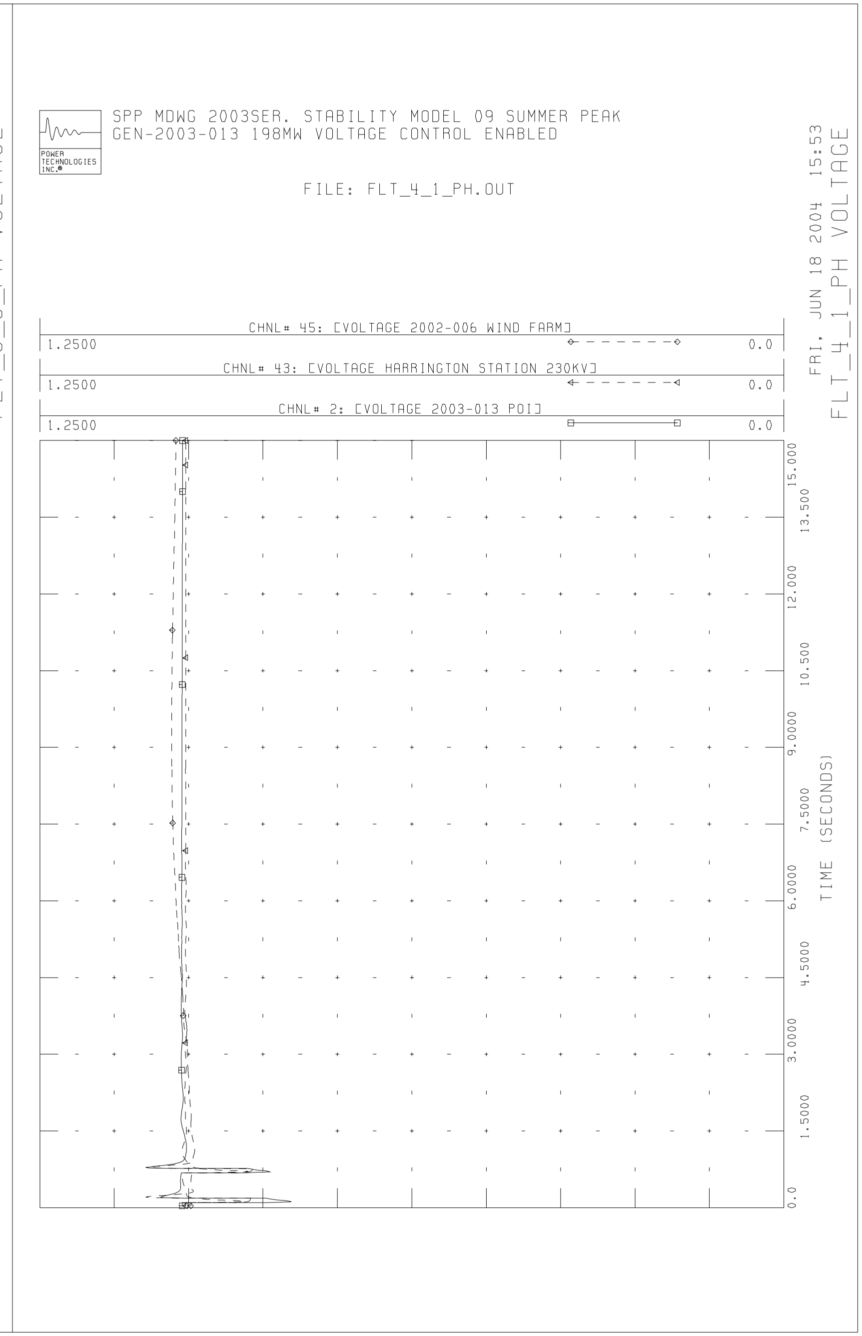




POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_3_3_PH.OUT
CHNL# 45: [VOLTAGE 2002-006 WIND FARM]
1.2500
0.0
CHNL# 43: [VOLTAGE HARRINGTON STATION 230KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:53
FLT_3_3_PH VOLTAGE



POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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0.0
CHNL# 43: [VOLTAGE HARRINGTON STATION 230KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
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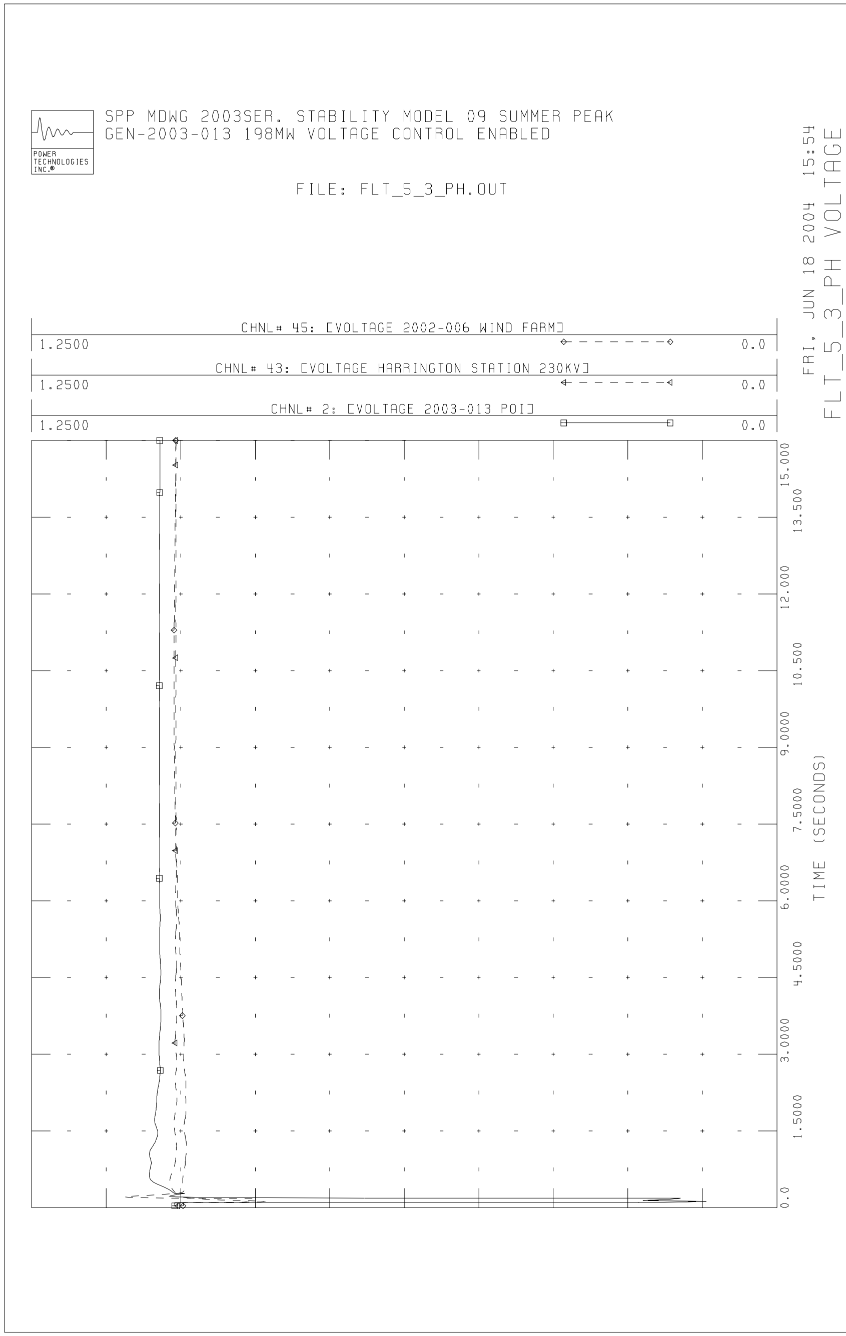
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:53
FLT_4_1_PH VOLTAGE



POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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0.0
CHNL# 43: [VOLTAGE HARRINGTON STATION 230KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
FRI, JUN 18 2004 15:54
FLT_5_3_PH VOLTAGE
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7.5000
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12.000
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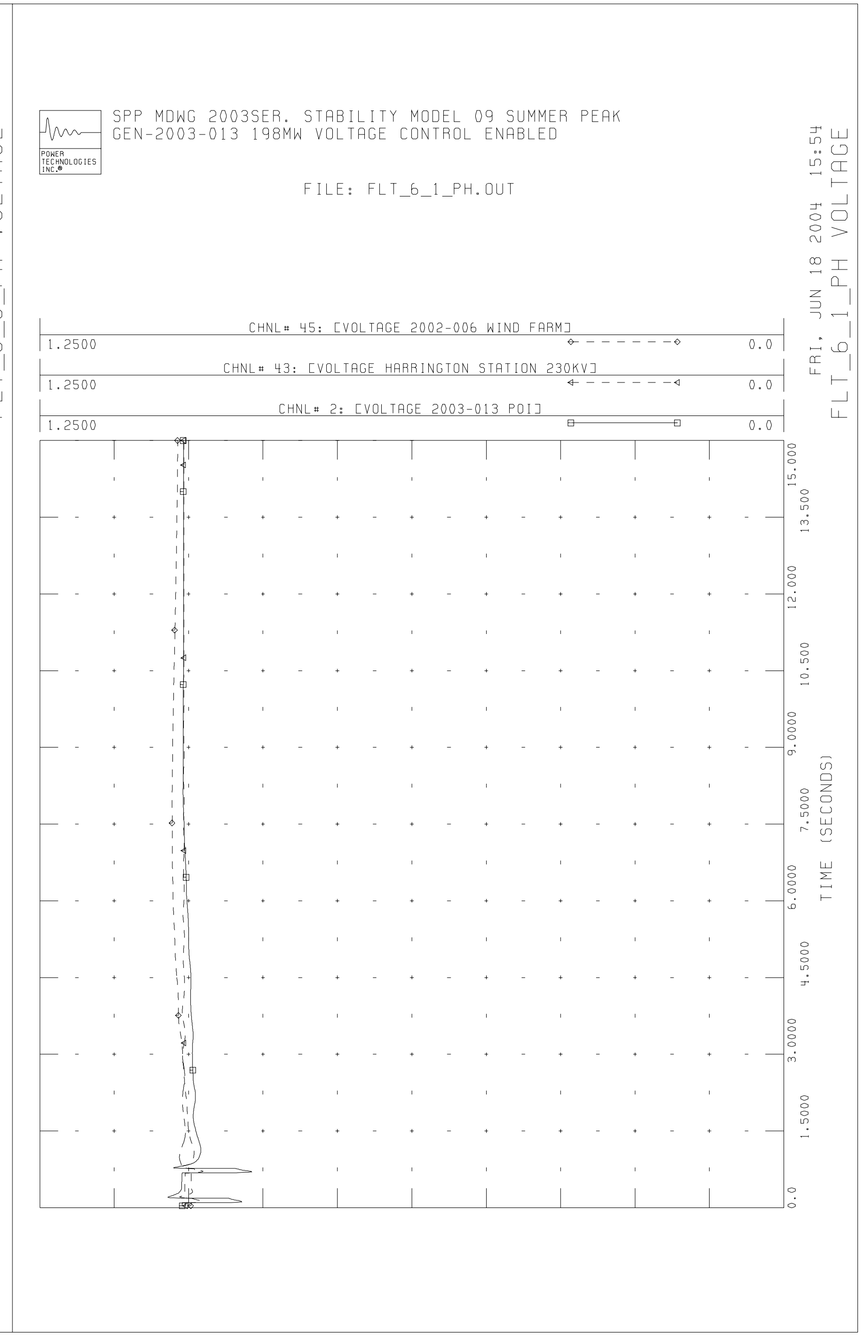
TIME (SECONDS)



POWER TECHNOLOGIES INC.
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CHNL# 43: [VOLTAGE HARRINGTON STATION 230KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
FRI, JUN 18 2004 15:54
FLT_6_1_PH VOLTAGE
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4.5000
6.0000
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12.000
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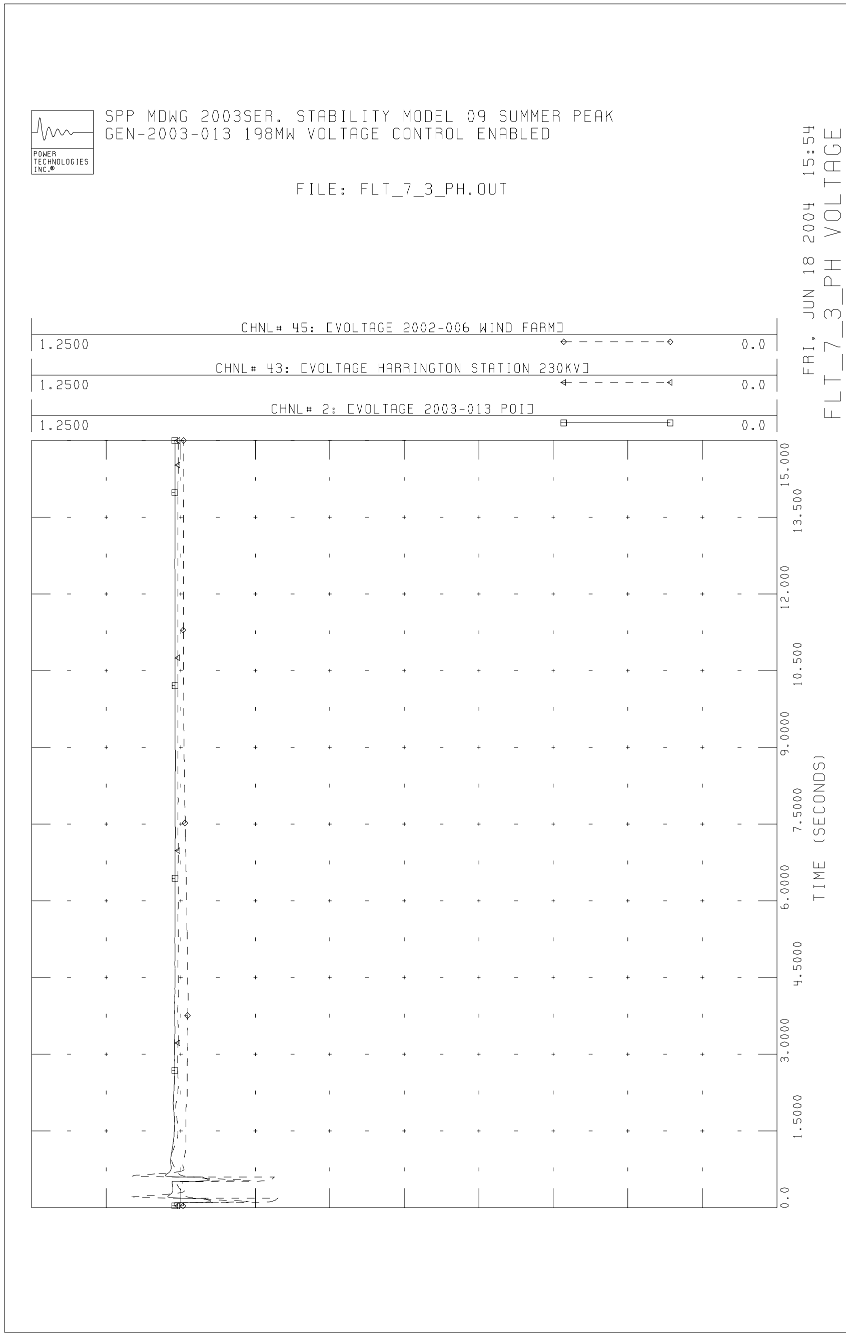
TIME (SECONDS)



POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
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CHNL# 2: [VOLTAGE 2003-013 POI]
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FRI, JUN 18 2004 15:54
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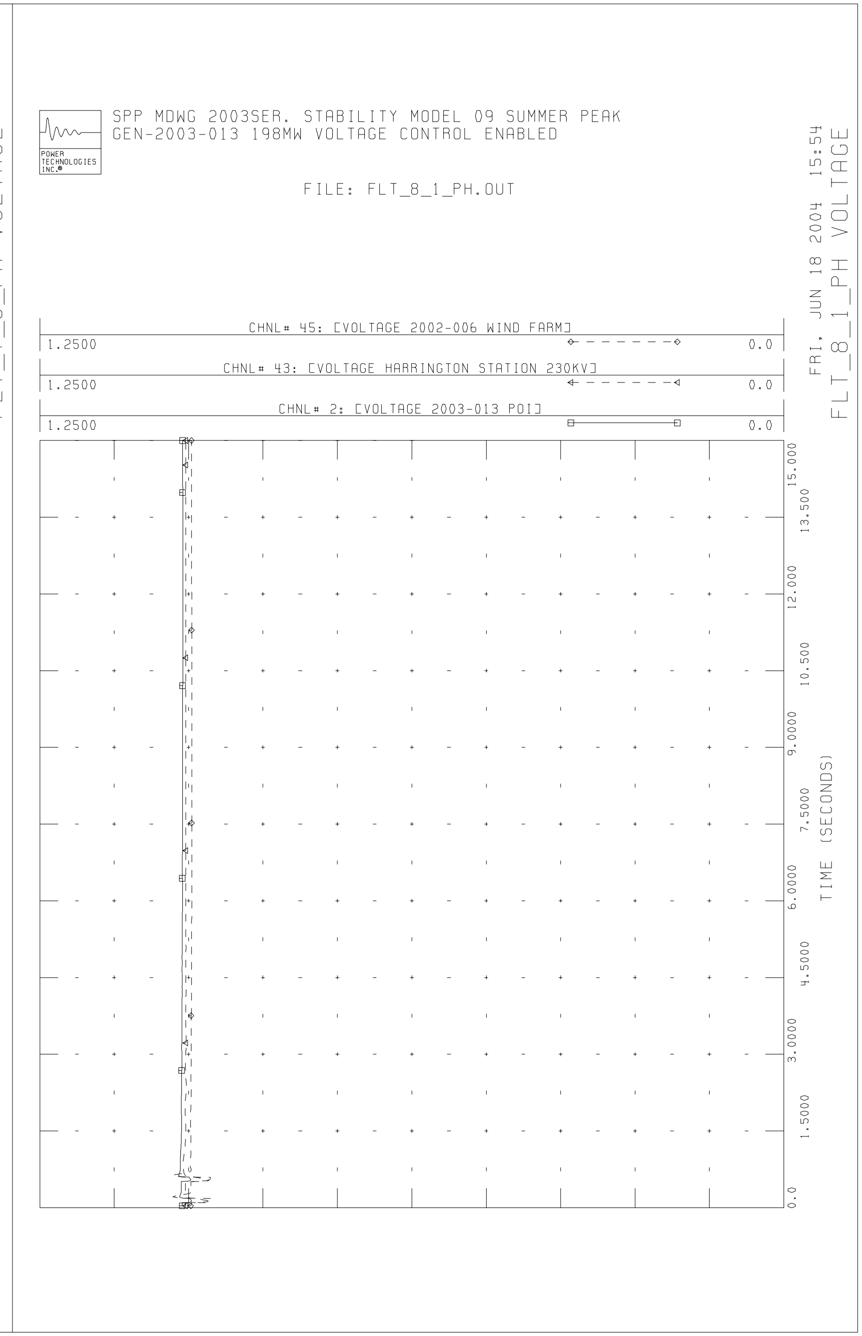

POWER TECHNOLOGIES INC.
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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
FRI, JUN 18 2004 15:54
FLT_8_1_PH VOLTAGE
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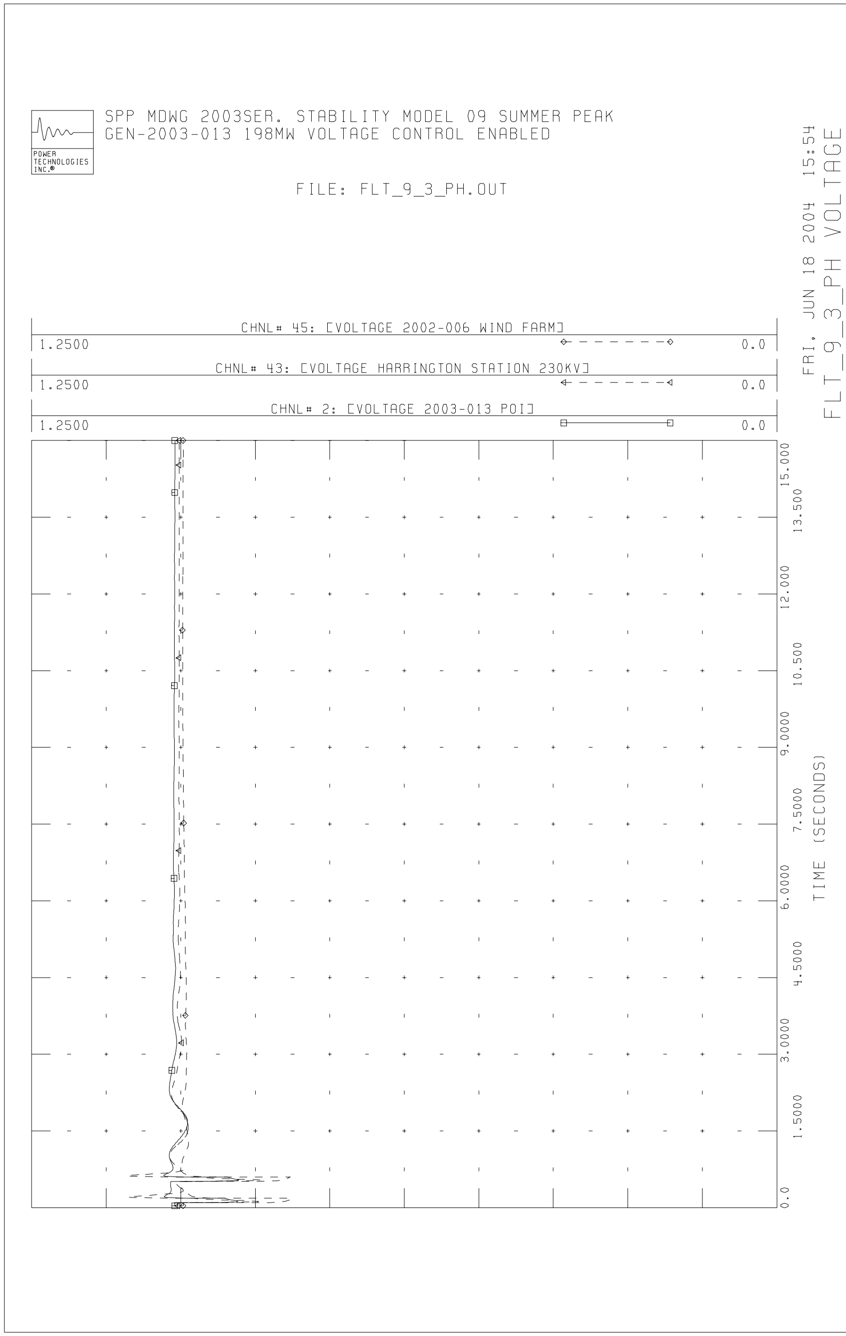

POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
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CHNL# 43: [VOLTAGE HARRINGTON STATION 230KV]
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0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
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0.0
1.5000
3.0000
4.5000
6.0000
7.5000
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TIME (SECONDS)
FRI, JUN 18 2004 15:54
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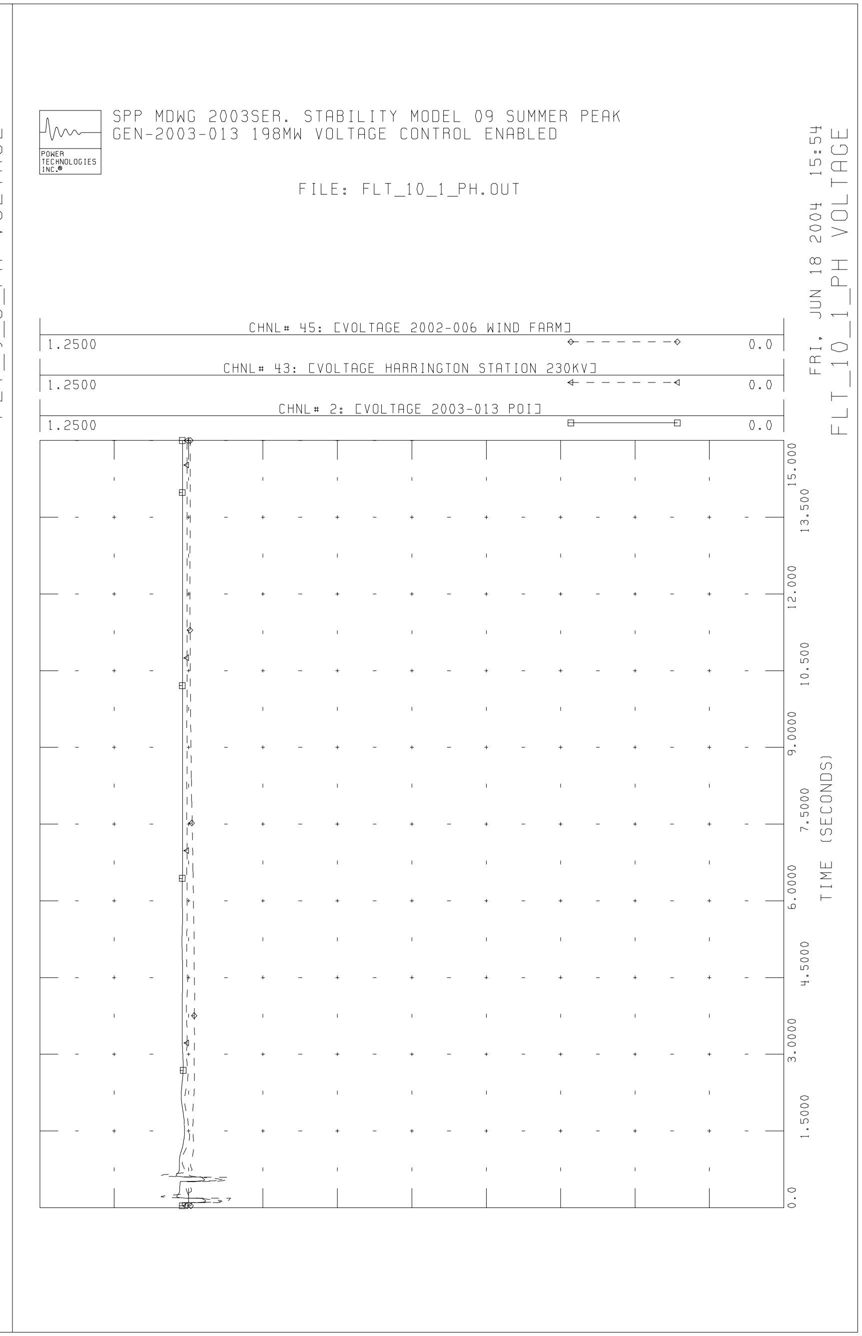

POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
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0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
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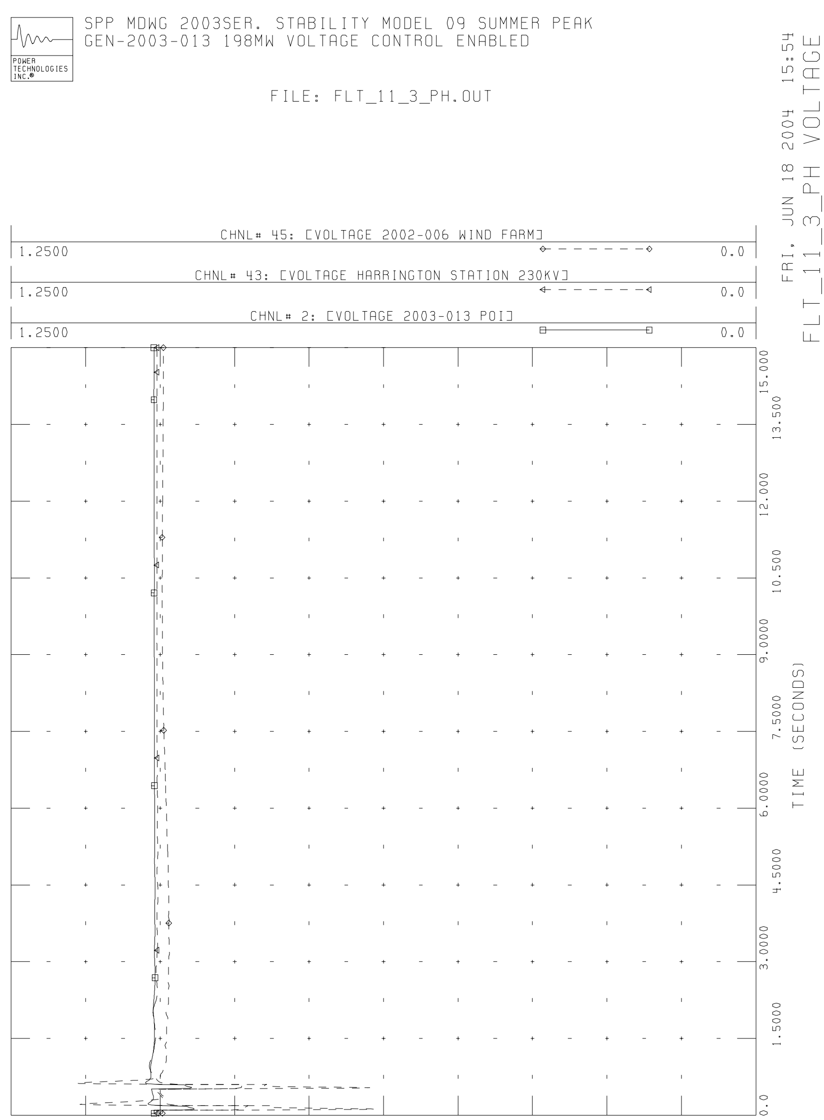
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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
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0.0
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4.5000
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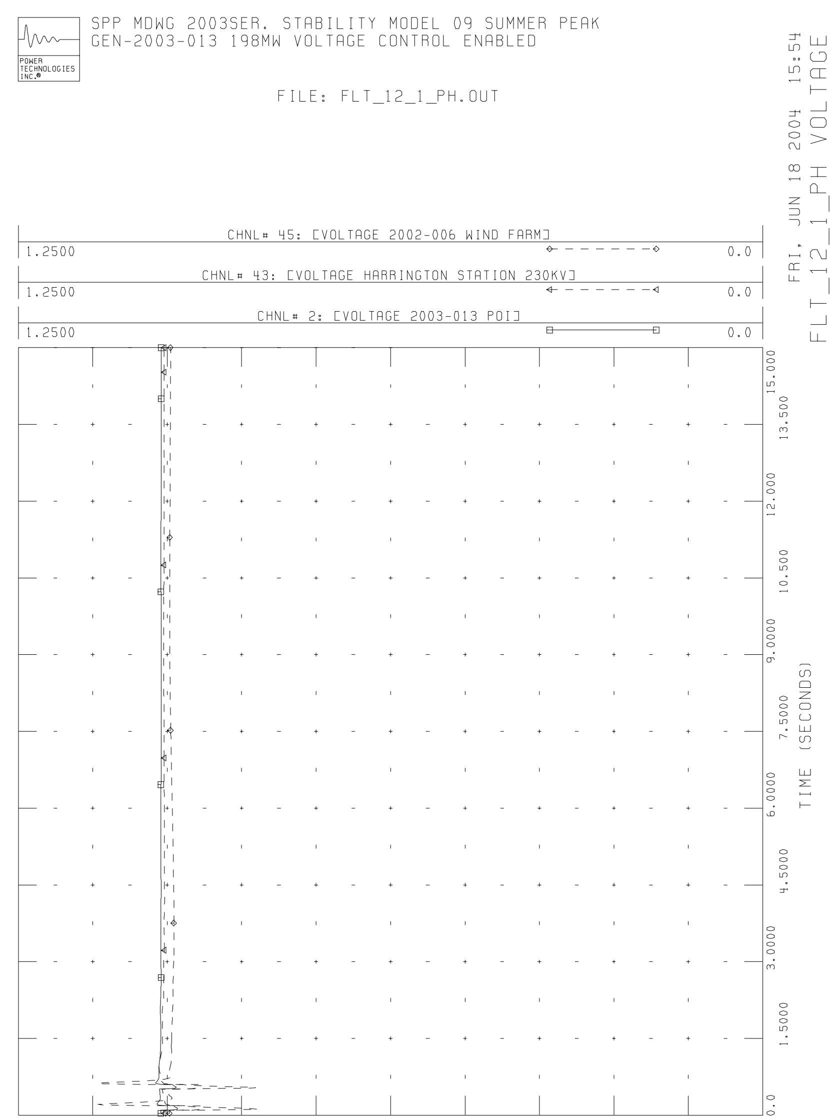
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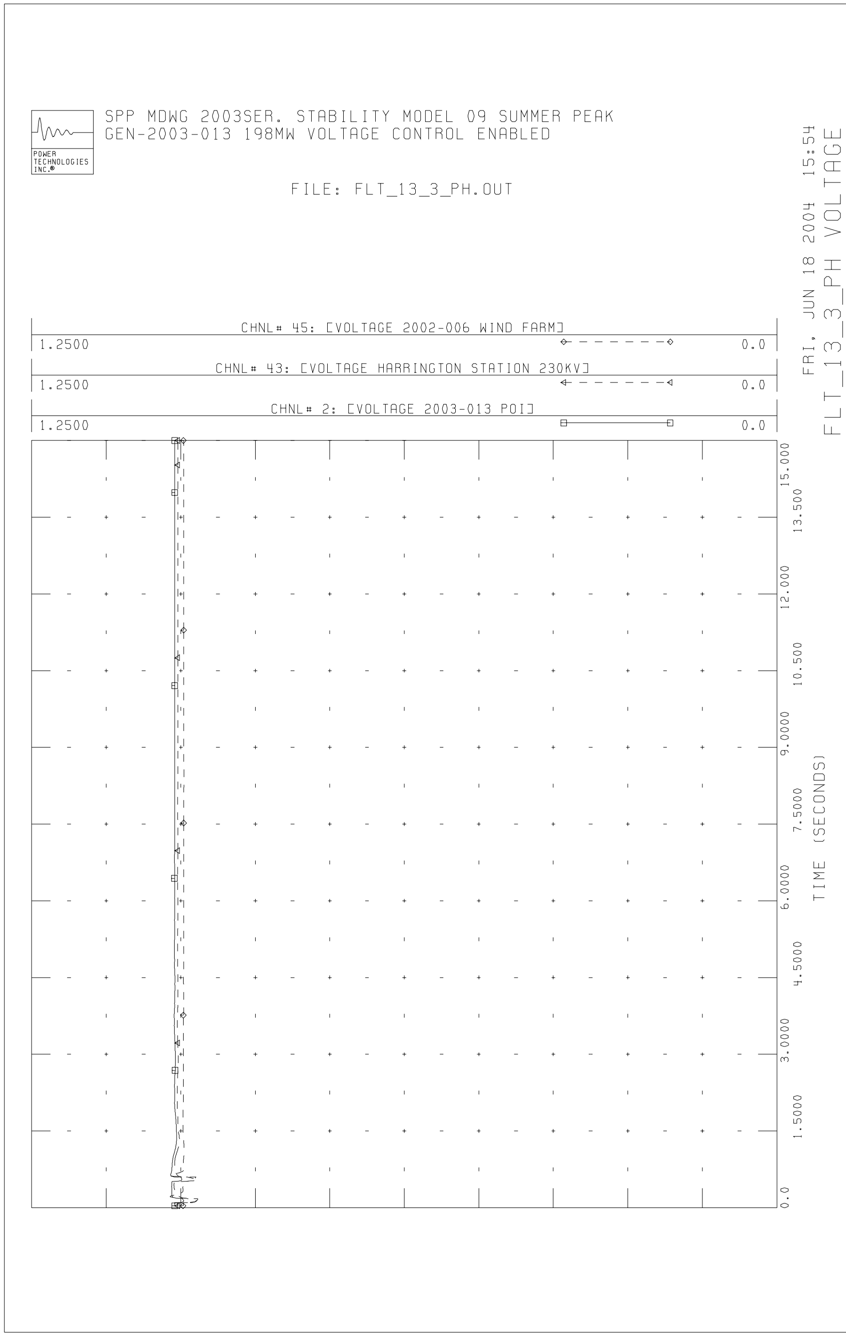
POWER TECHNOLOGIES INC.
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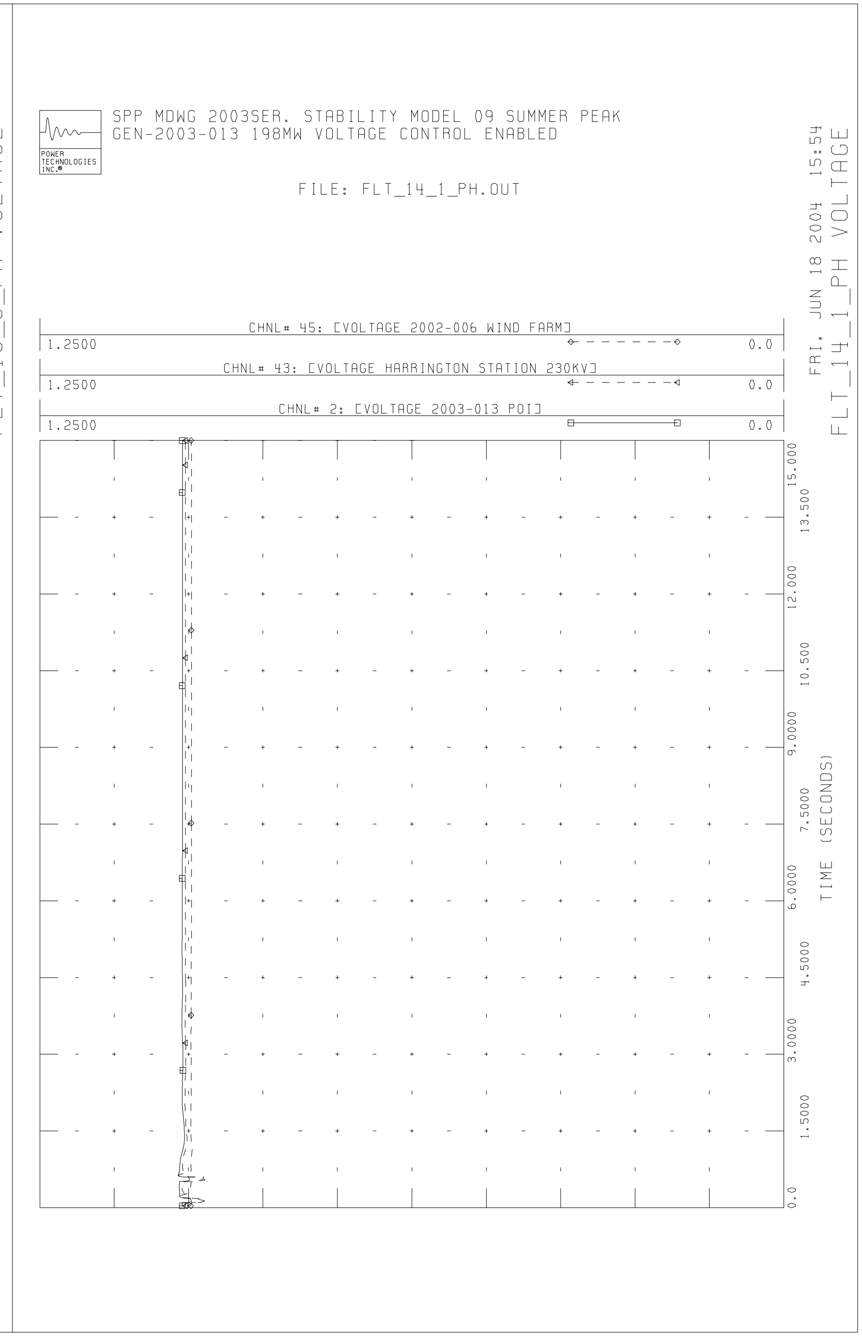
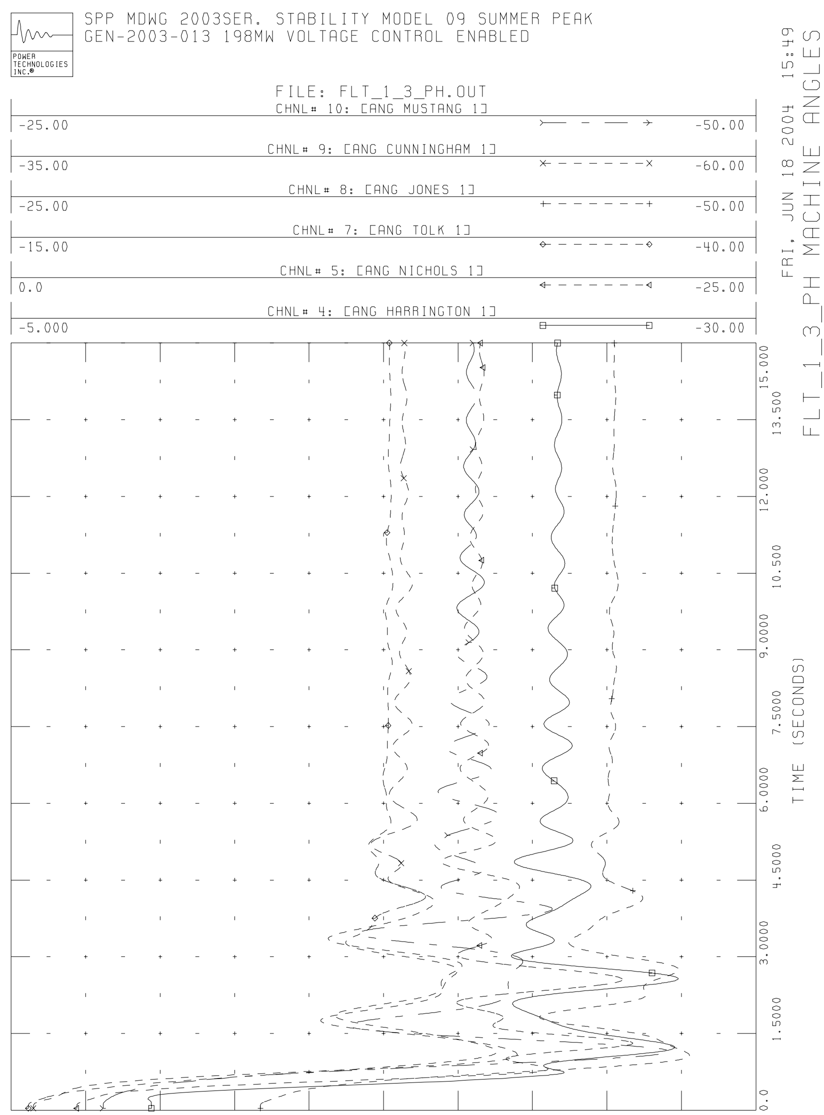

POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_14_1_PH.OUT
CHNL# 45: [VOLTAGE 2002-006 WIND FARM]
1.2500
0.0
CHNL# 43: [VOLTAGE HARRINGTON STATION 230KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:54
FLT_14_1_PH VOLTAGE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_1_3_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -25.00 -50.00
CHNL# 9: [ANG CUNNINGHAM 1] -35.00 -60.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] -15.00 -40.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] -5.000 -30.00
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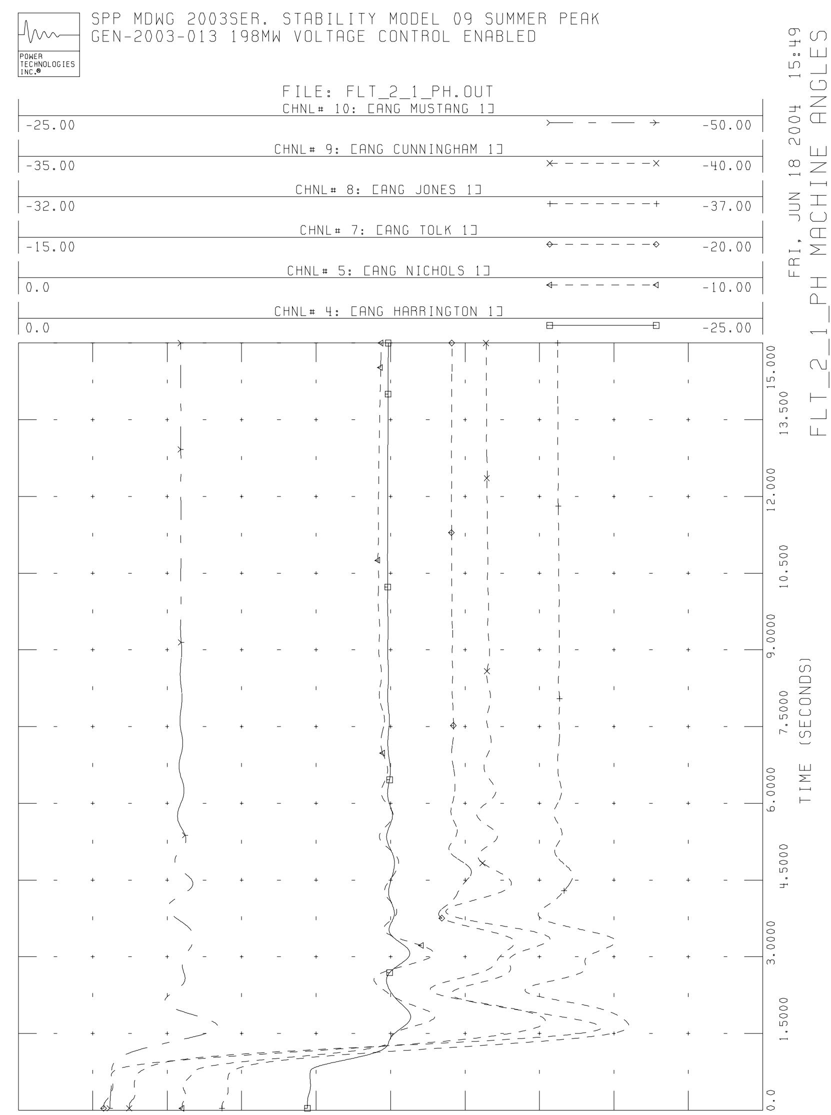
TIME (SECONDS)
FRI, JUN 18 2004 15:49
FLT_1_3_PH MACHINE ANGLES


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_2_1_PH.OUT
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CHNL# 9: [ANG CUNNINGHAM 1] -35.00 -40.00
CHNL# 8: [ANG JONES 1] -32.00 -37.00
CHNL# 7: [ANG TOLK 1] -15.00 -20.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
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TIME (SECONDS)
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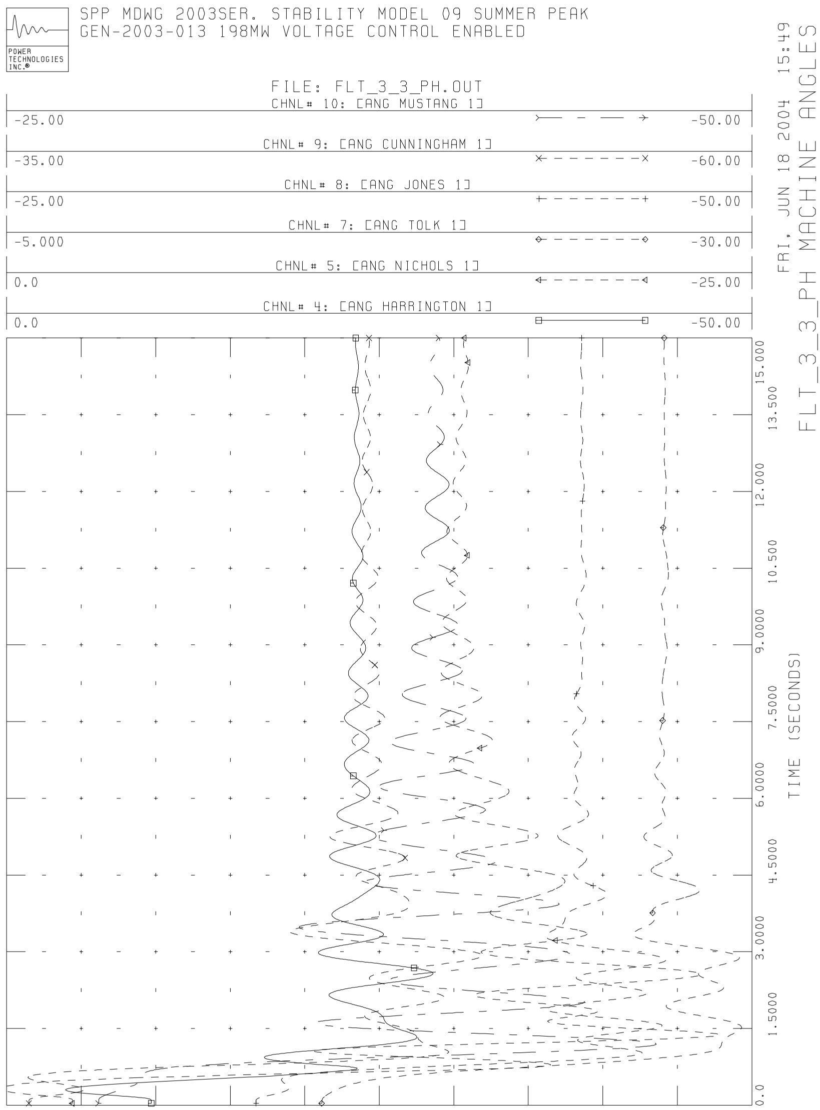
FLT_2_1_PH MACHINE ANGLES


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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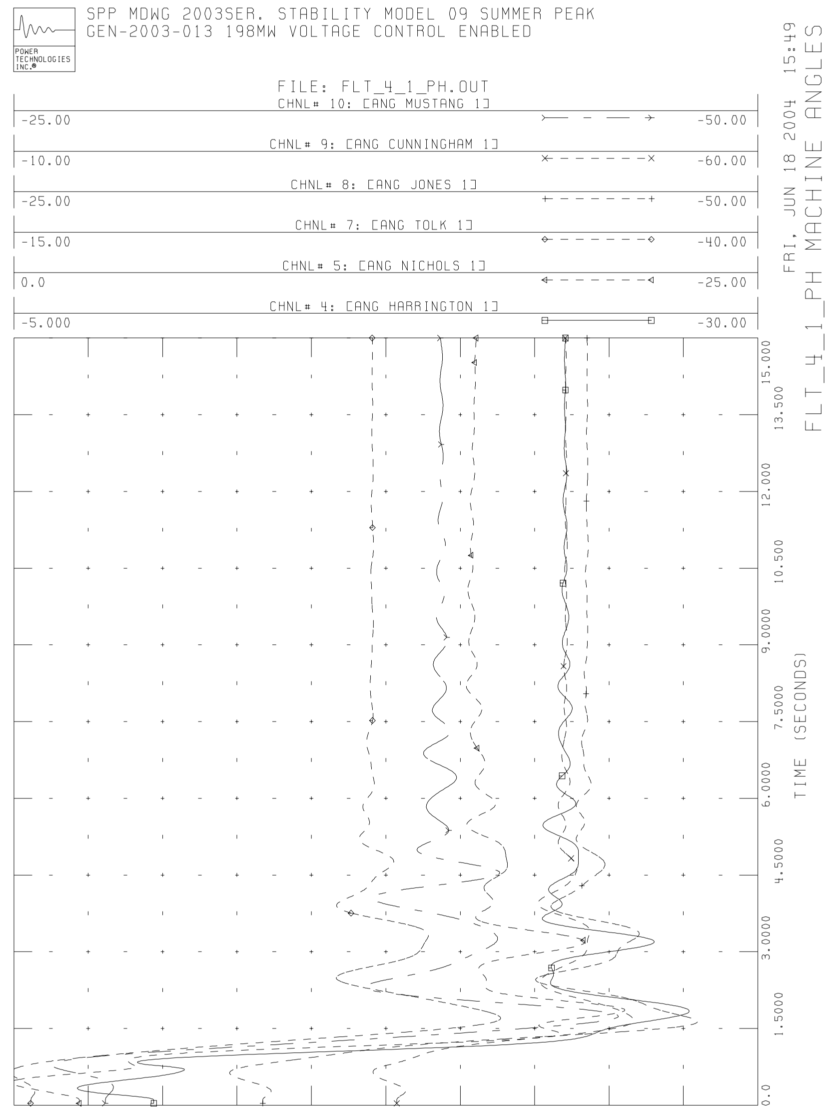
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] -5.000 -30.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -50.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:49
FLT_3_3_PH MACHINE ANGLES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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
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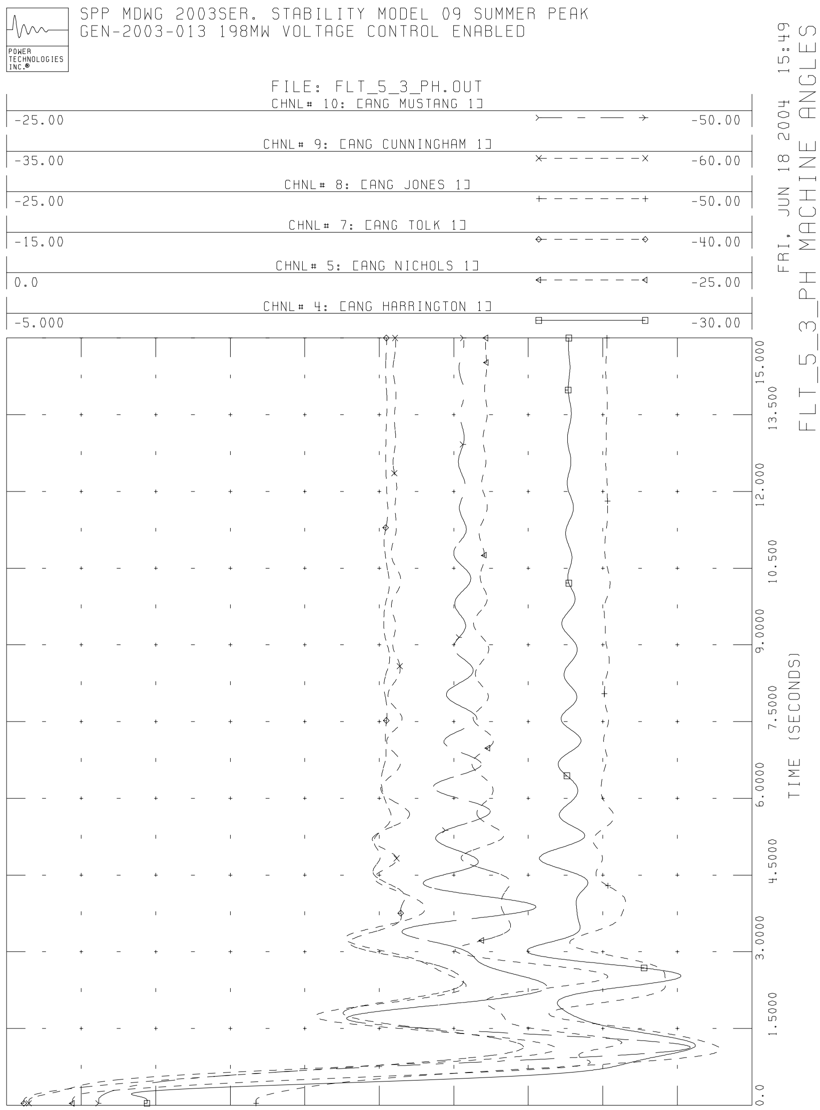
CHNL# 7: [ANG TOLK 1] -15.00 -40.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] -5.000 -30.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:49
FLT_4_1_PH MACHINE ANGLES


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_5_3_PH.OUT
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-50.00
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-35.00
-60.00
CHNL# 8: [ANG JONES 1]
-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
-15.00
-40.00
CHNL# 5: [ANG NICHOLS 1]
0.0
-25.00
CHNL# 4: [ANG HARRINGTON 1]
-5.000
-30.00
FRI, JUN 18 2004 15:49
FLT_5_3_PH MACHINE ANGLES
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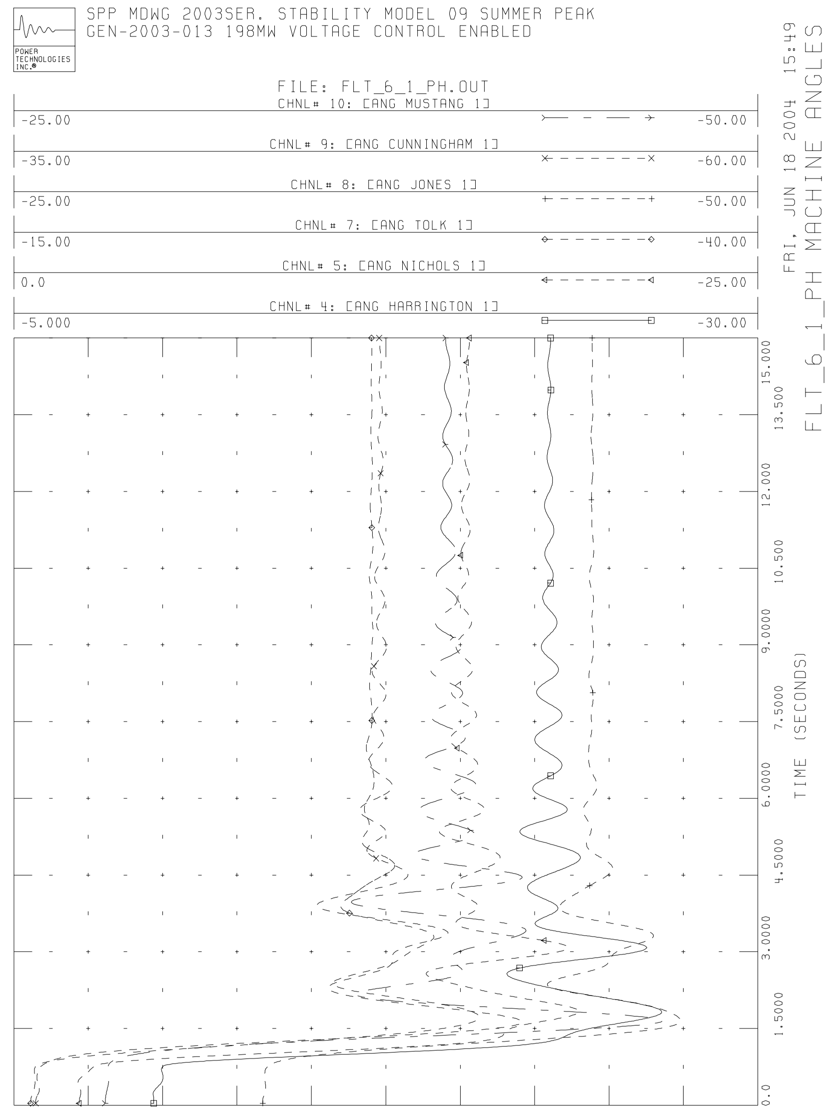
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_6_1_PH.OUT
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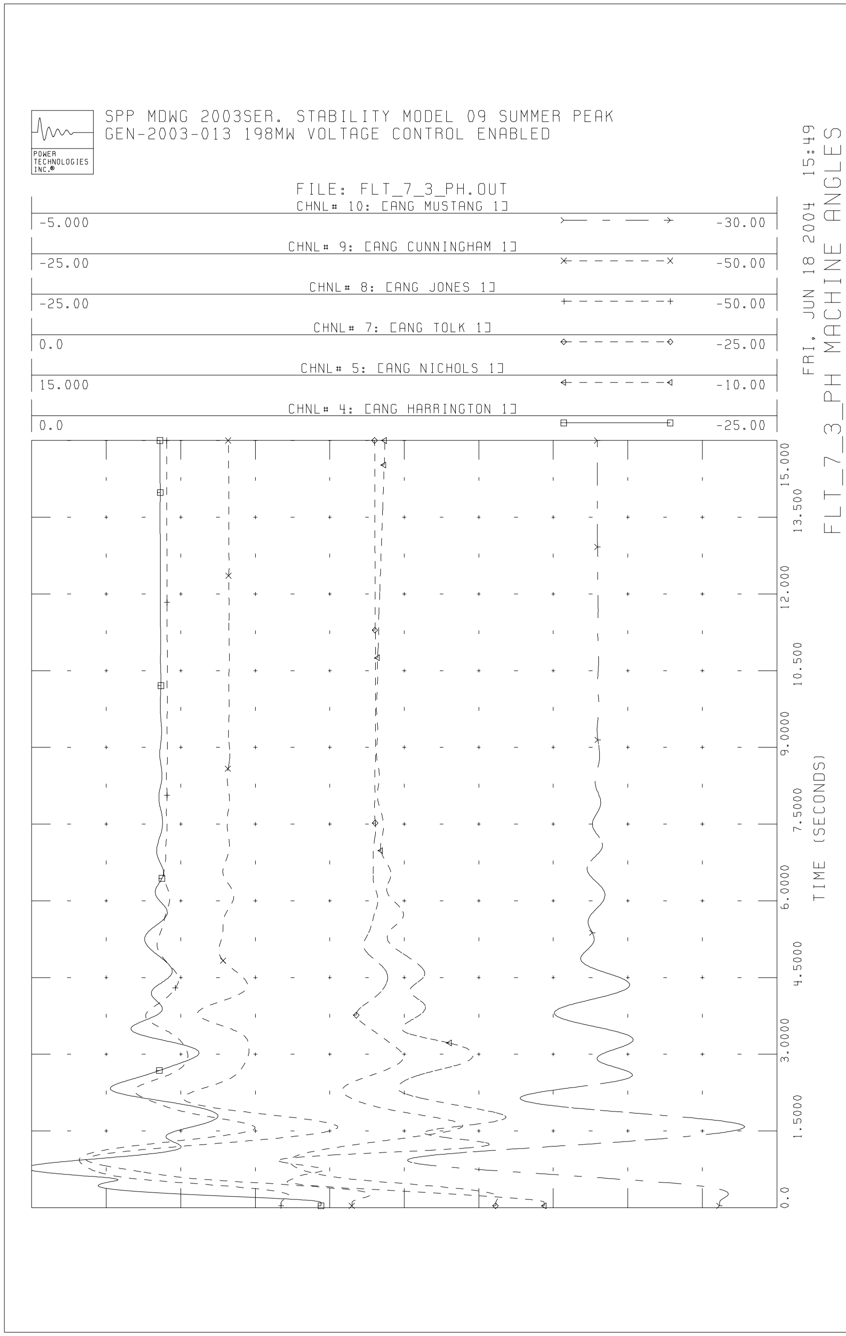
-25.00
-50.00
CHNL# 9: [ANG CUNNINGHAM 1]
-35.00
-60.00
CHNL# 8: [ANG JONES 1]
-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
-15.00
-40.00
CHNL# 5: [ANG NICHOLS 1]
0.0
-25.00
CHNL# 4: [ANG HARRINGTON 1]
-5.000
-30.00
FRI, JUN 18 2004 15:49
FLT_6_1_PH MACHINE ANGLES
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_7_3_PH.OUT
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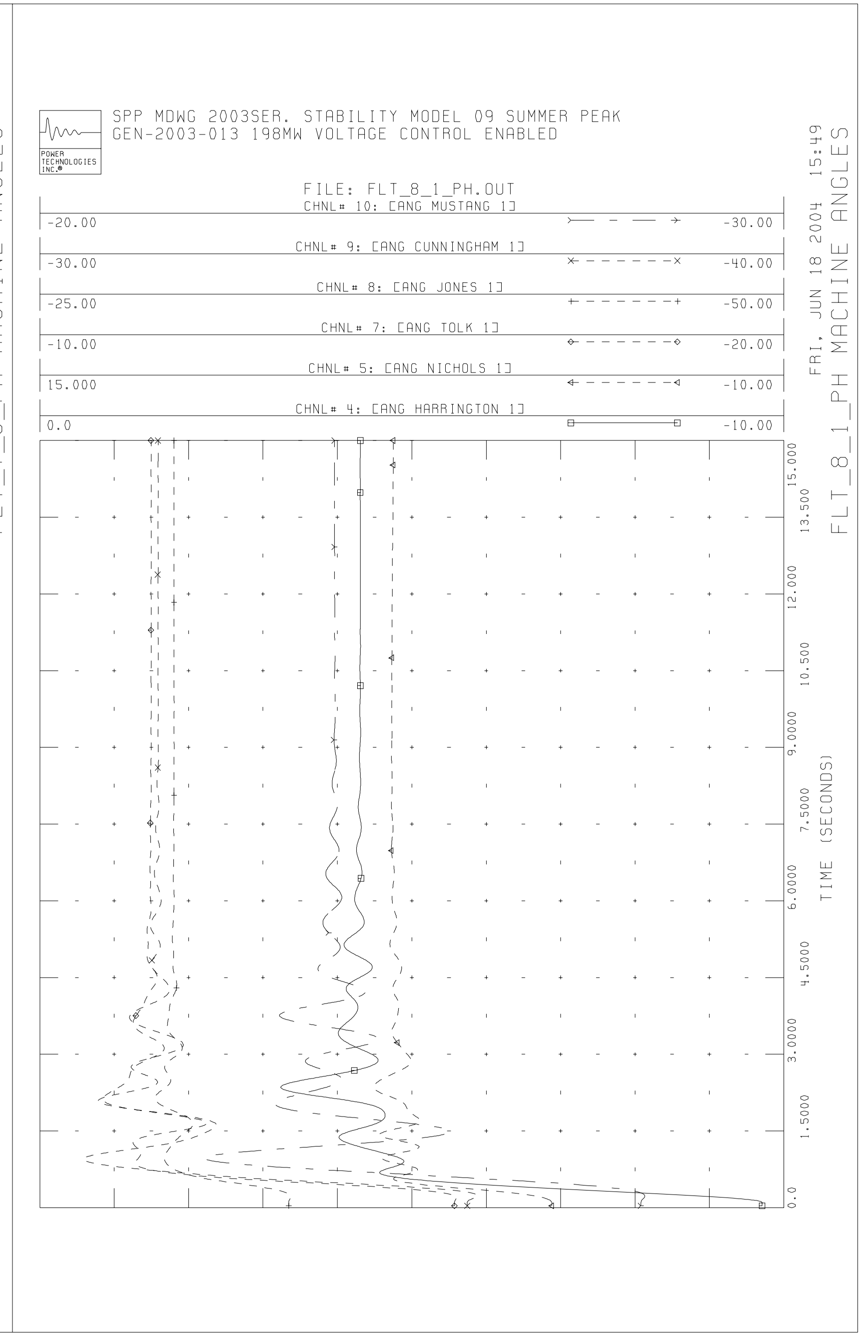
-5.000
-30.00
CHNL# 9: [ANG CUNNINGHAM 1]
-25.00
-50.00
CHNL# 8: [ANG JONES 1]
-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
0.0
-25.00
CHNL# 5: [ANG NICHOLS 1]
15.000
-10.00
CHNL# 4: [ANG HARRINGTON 1]
0.0
-25.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:49
FLT_7_3_PH MACHINE ANGLES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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_8_1_PH.OUT
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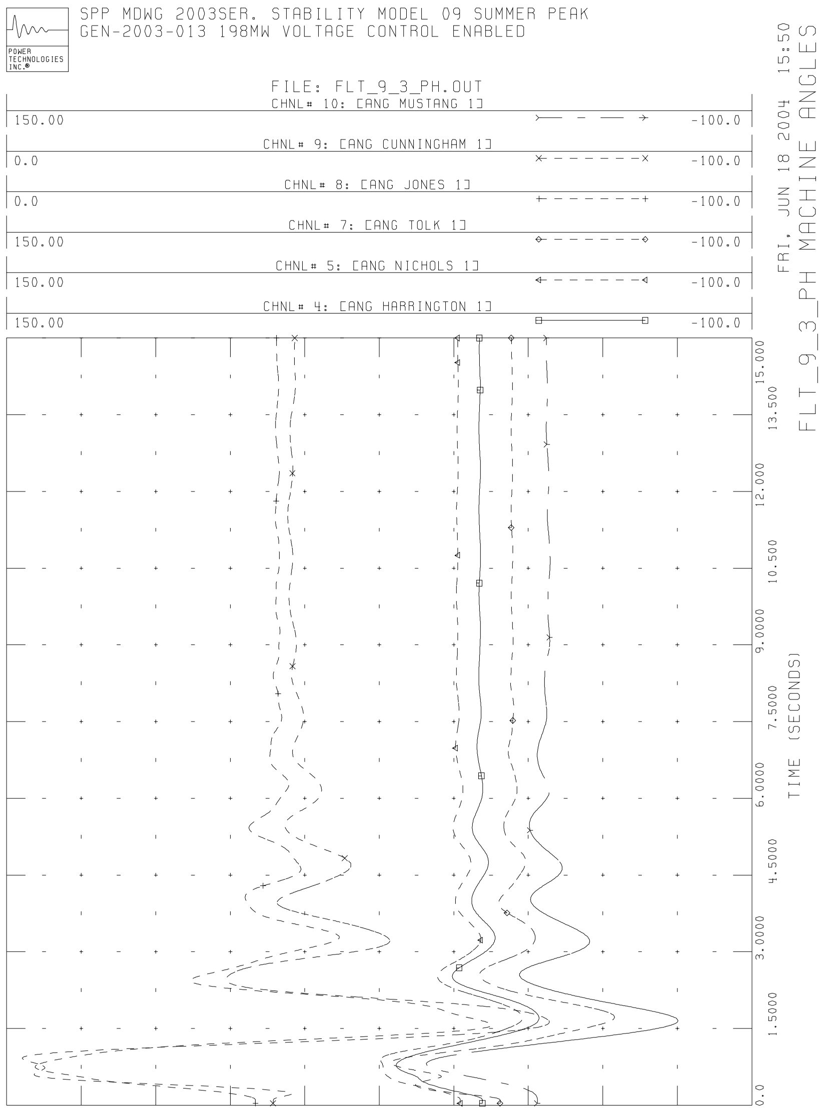
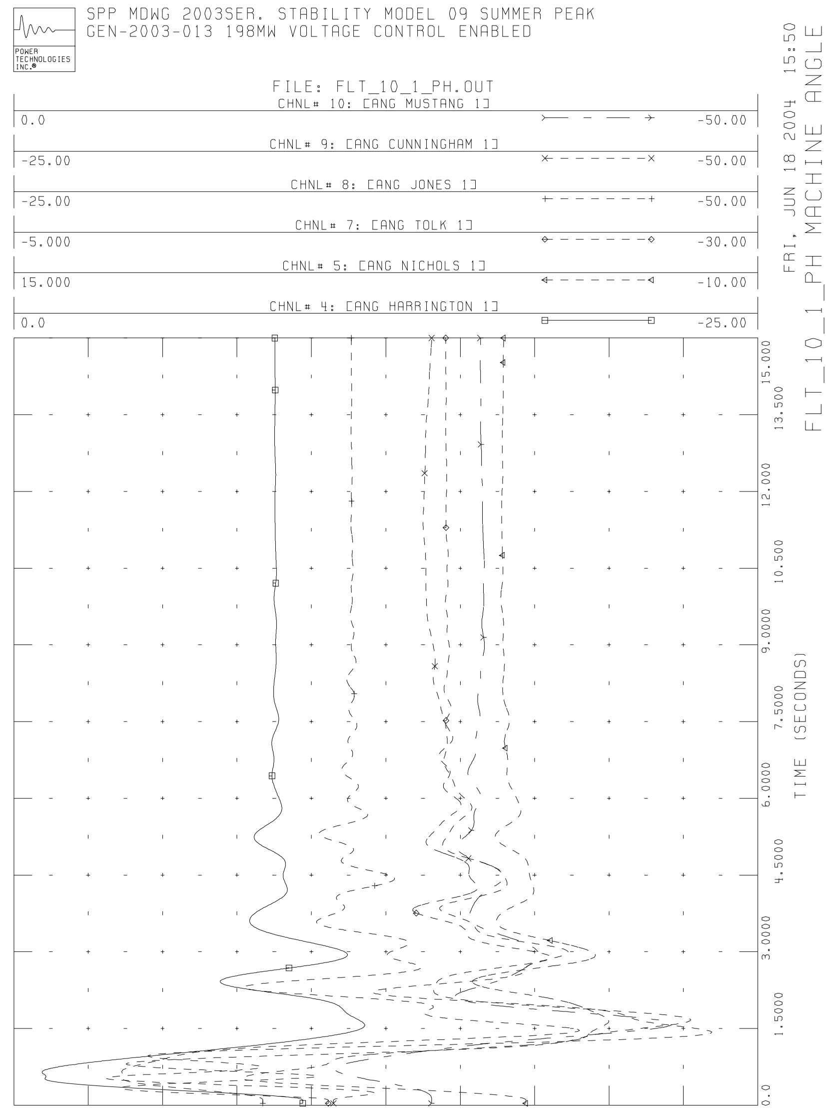
-20.00
-30.00
CHNL# 9: [ANG CUNNINGHAM 1]
-30.00
-40.00
CHNL# 8: [ANG JONES 1]
-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
-10.00
-20.00
CHNL# 5: [ANG NICHOLS 1]
15.000
-10.00
CHNL# 4: [ANG HARRINGTON 1]
0.0
-10.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:49
FLT_8_1_PH MACHINE ANGLES



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_9_3_PH.OUT
CHNL# 10: [ANG MUSTANG 1]
150.00
-100.0
CHNL# 9: [ANG CUNNINGHAM 1]
0.0
-100.0
CHNL# 8: [ANG JONES 1]
0.0
-100.0
CHNL# 7: [ANG TOLK 1]
150.00
-100.0
CHNL# 5: [ANG NICHOLS 1]
150.00
-100.0
CHNL# 4: [ANG HARRINGTON 1]
150.00
-100.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:50
FLT_9_3_PH MACHINE ANGLES



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_10_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1]
0.0
-50.00
CHNL# 9: [ANG CUNNINGHAM 1]
-25.00
-50.00
CHNL# 8: [ANG JONES 1]
-25.00
-50.00
CHNL# 7: [ANG TOLK 1]
-5.000
-30.00
CHNL# 5: [ANG NICHOLS 1]
15.000
-10.00
CHNL# 4: [ANG HARRINGTON 1]
0.0
-25.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
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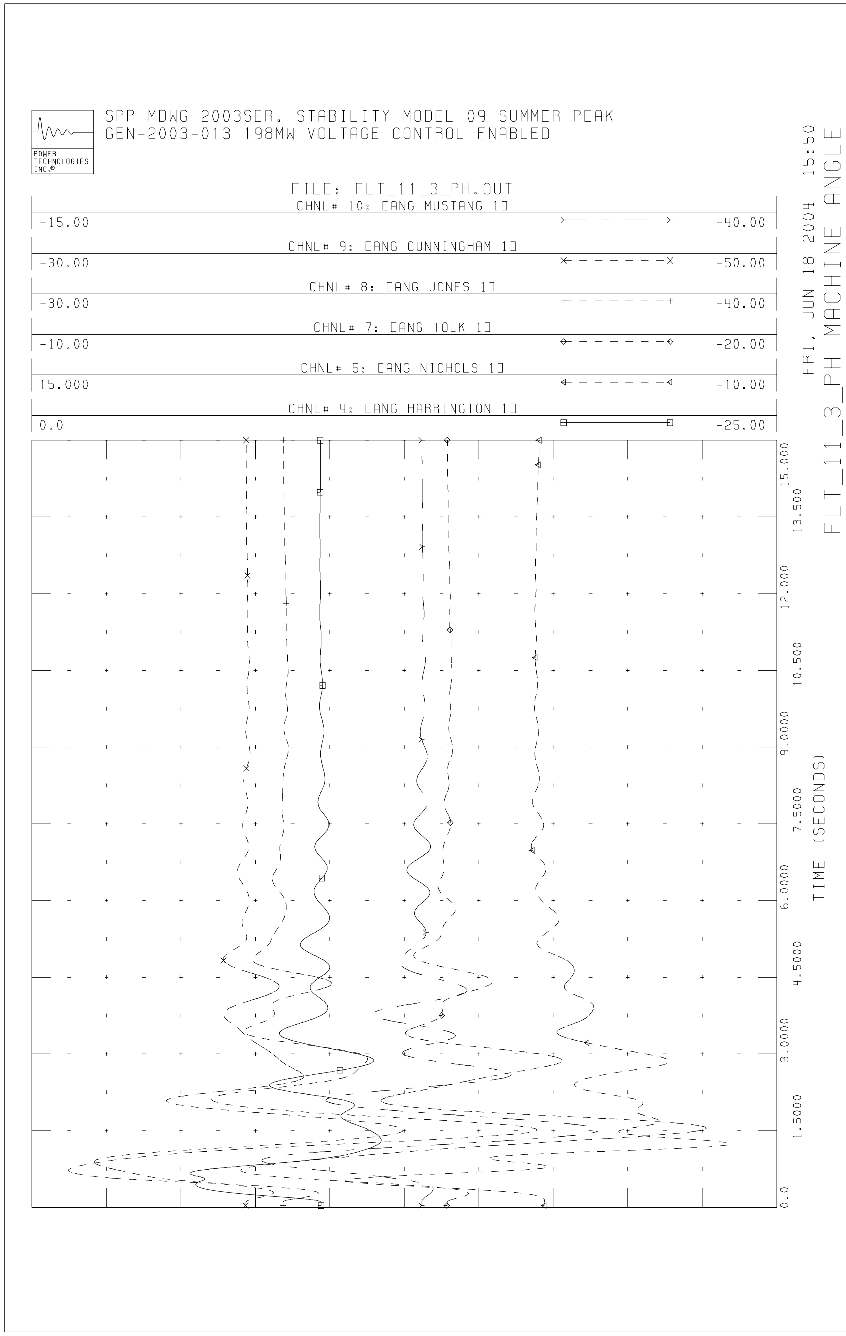
FRI, JUN 18 2004 15:50
FLT_10_1_PH MACHINE ANGLE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_11_3_PH.OUT
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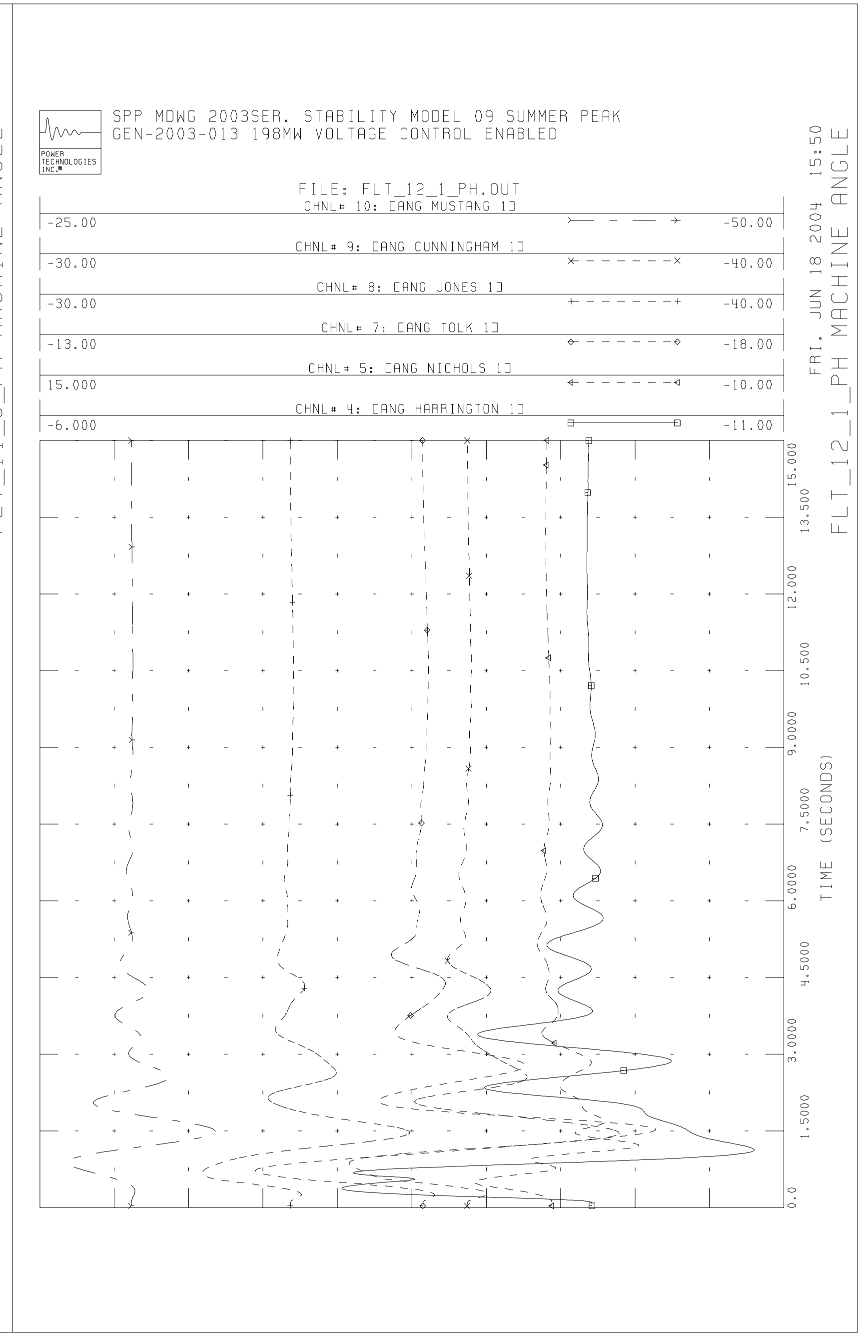
CHNL# 9: [ANG CUNNINGHAM 1] -30.00 -50.00
CHNL# 8: [ANG JONES 1] -30.00 -40.00
CHNL# 7: [ANG TOLK 1] -10.00 -20.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:50
FLT_11_3_PH MACHINE ANGLE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GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_12_1_PH.OUT
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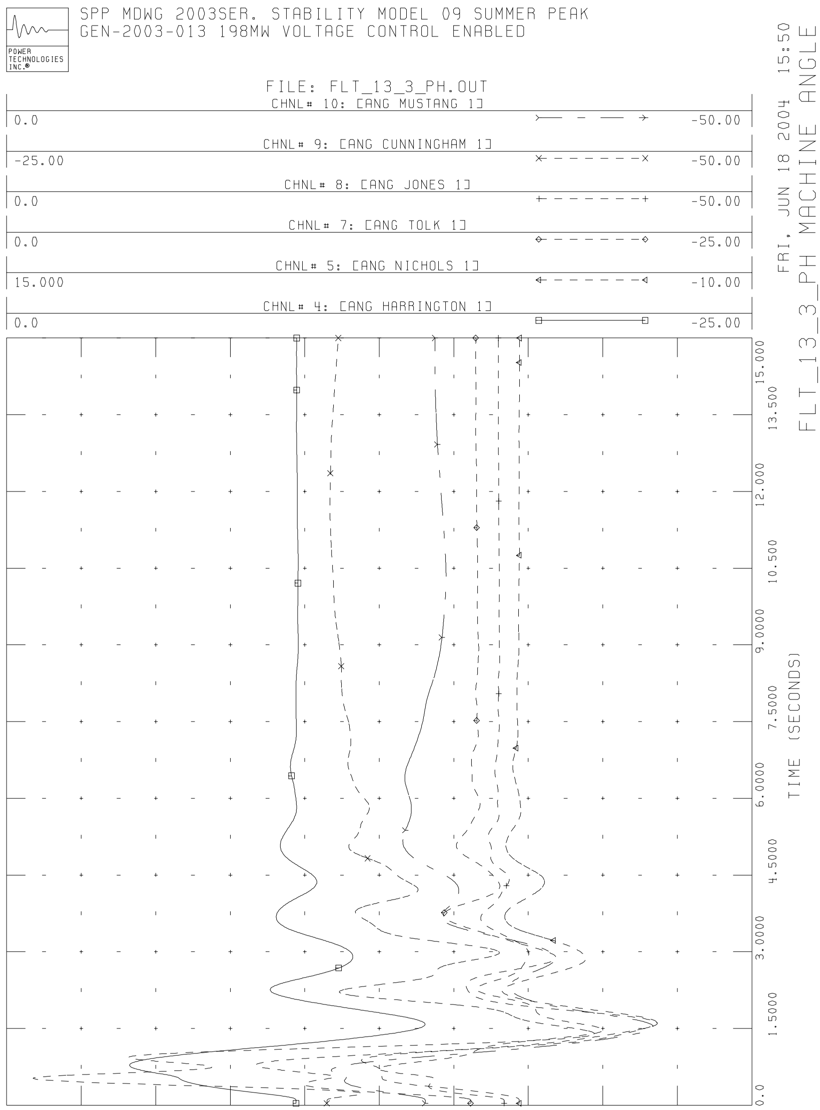
CHNL# 9: [ANG CUNNINGHAM 1] -30.00 -40.00
CHNL# 8: [ANG JONES 1] -30.00 -40.00
CHNL# 7: [ANG TOLK 1] -13.00 -18.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] -6.000 -11.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:50
FLT_12_1_PH MACHINE ANGLE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_13_3_PH.OUT
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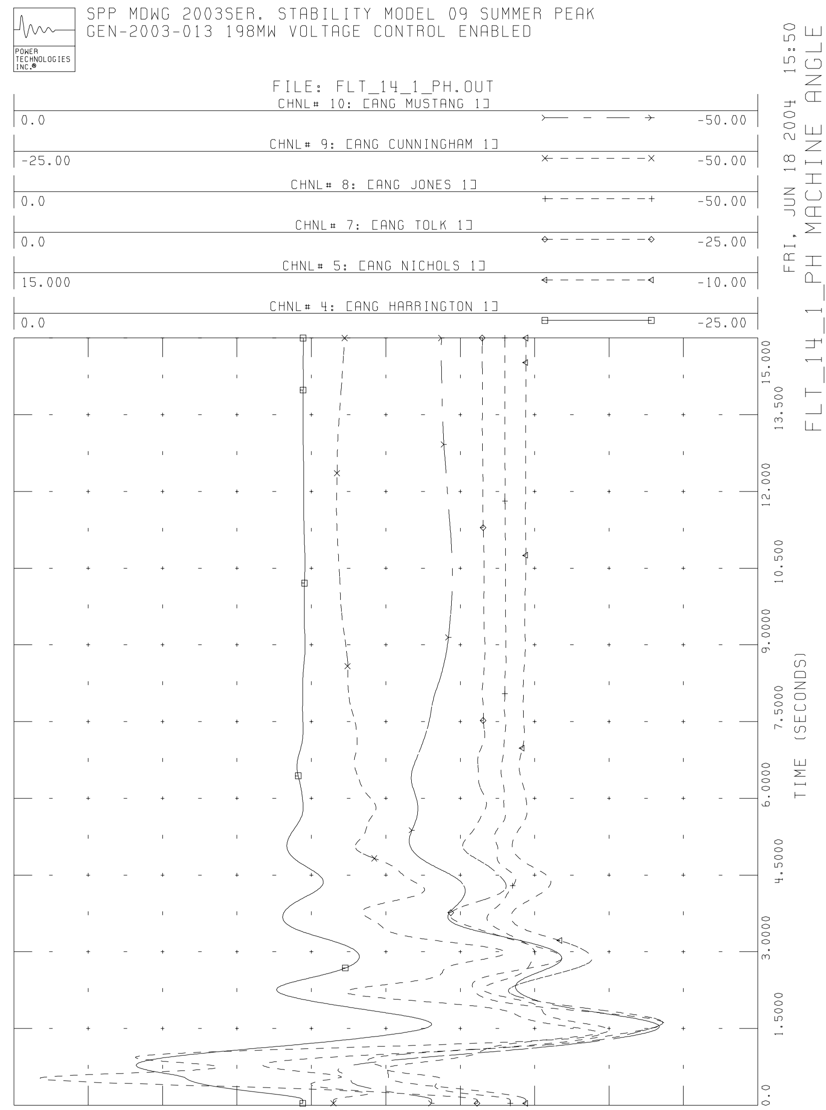
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] 0.0 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:50
FLT_13_3_PH MACHINE ANGLE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_14_1_PH.OUT
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CHNL# 8: [ANG JONES 1] 0.0 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
FRI, JUN 18 2004 15:50
FLT_14_1_PH MACHINE ANGLE

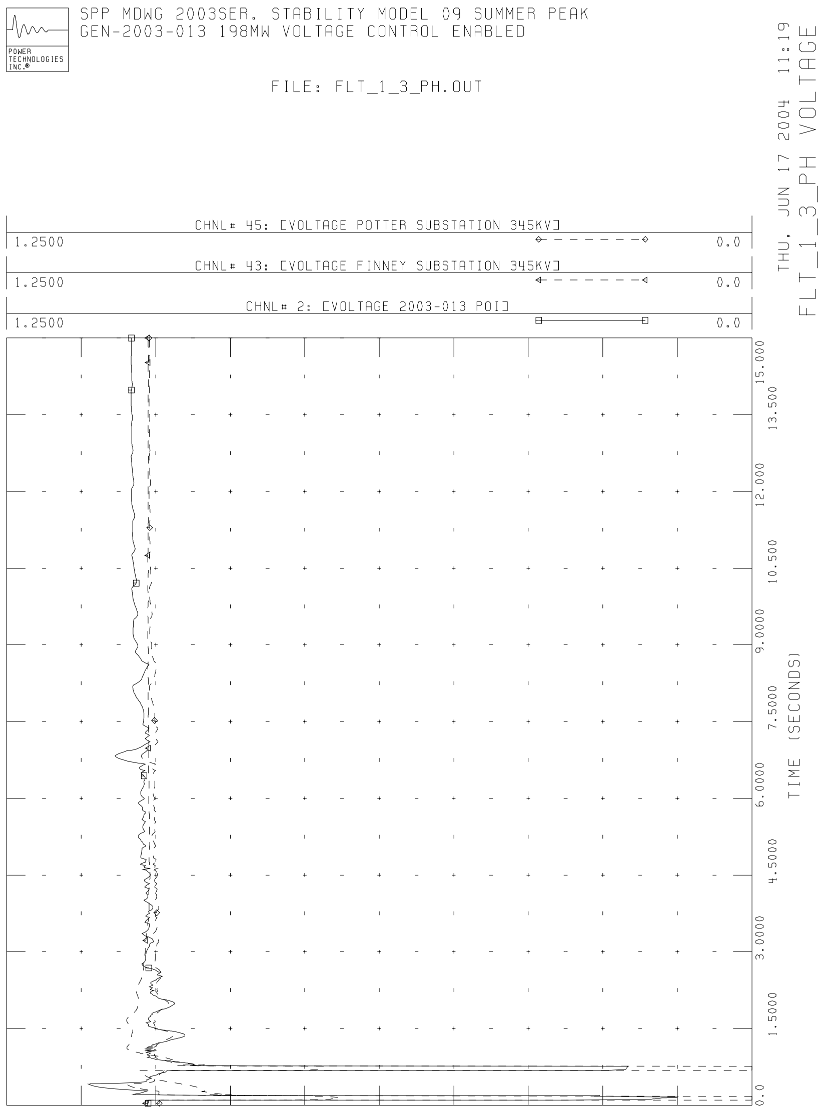
Appendix 4

Plots of Fault Simulations

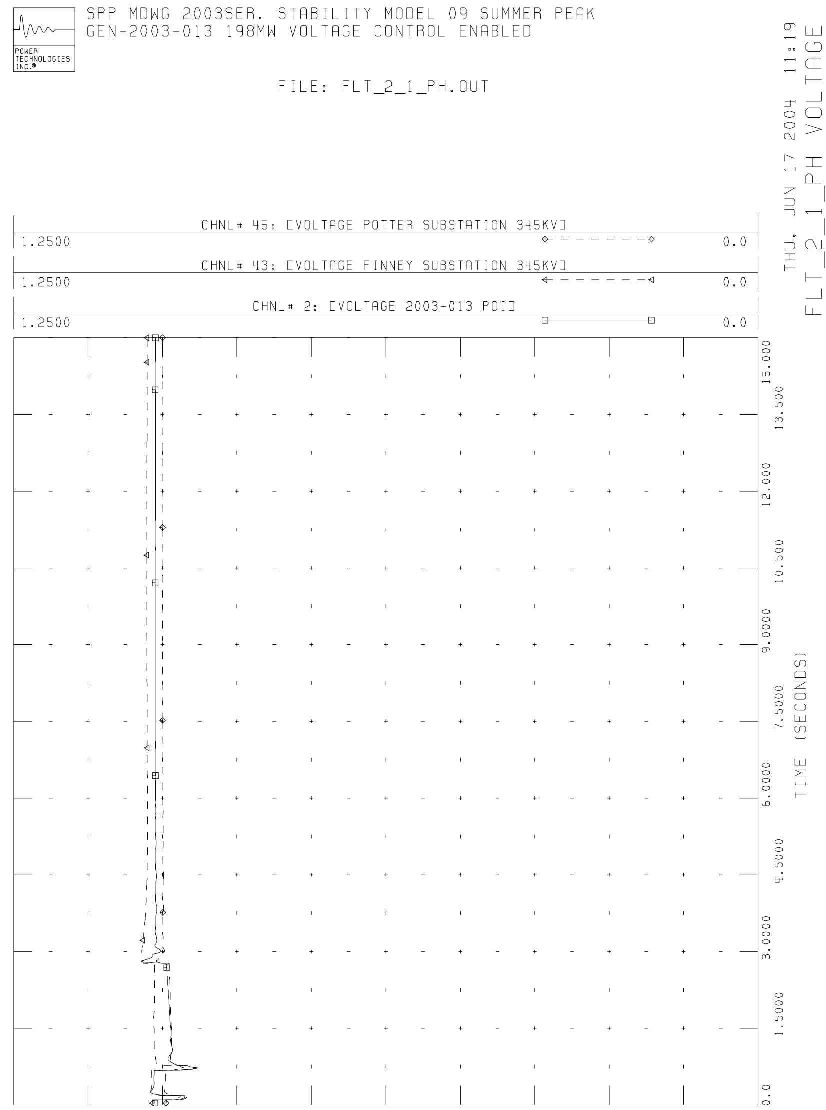
Plots of Wind Farm generators voltage response during faults
Plots of various SPS/Xcel Energy generator angle response during faults

Scenario:
2009 Summer Peak with Wind Farm at 99MW output and Voltage Control enabled

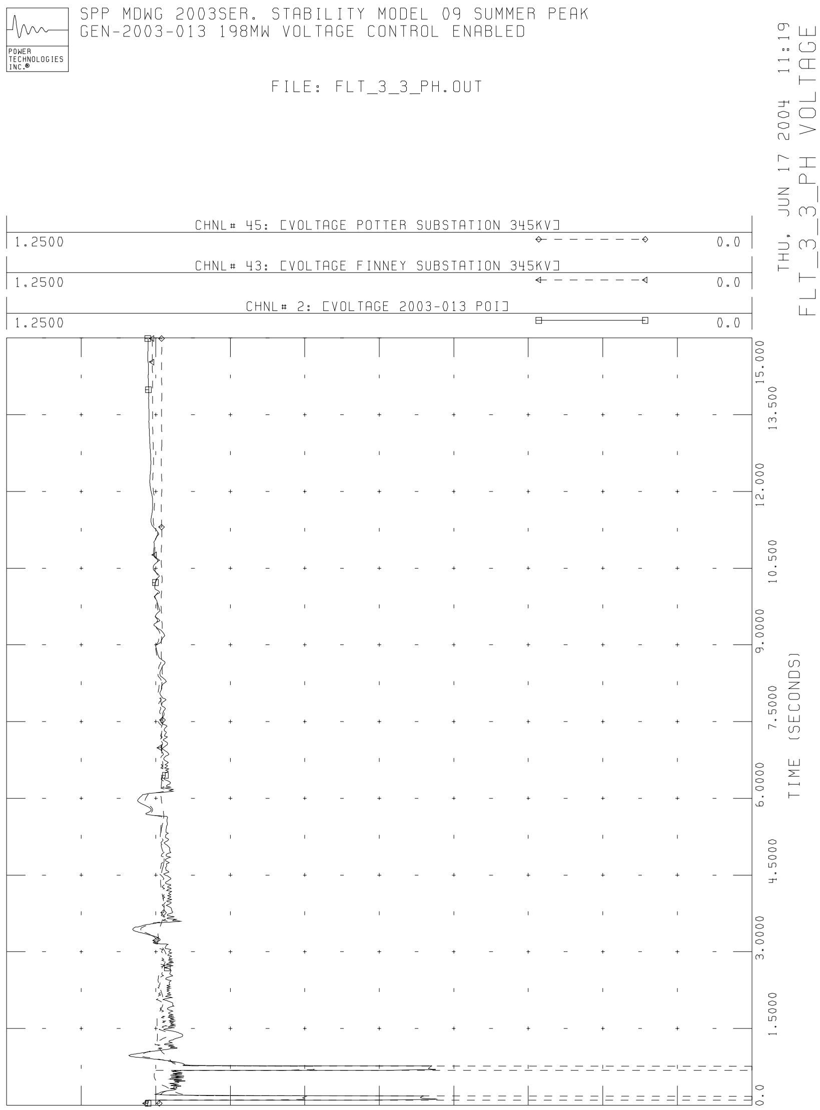
Adjacent GEN-2002-008 wind farm at 0MW output



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_1_3_PH.OUT
THU, JUN 17 2004 11:19
FLT_1_3_PH VOLTAGE
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_2_1_PH.OUT
THU, JUN 17 2004 11:19
FLT_2_1_PH VOLTAGE
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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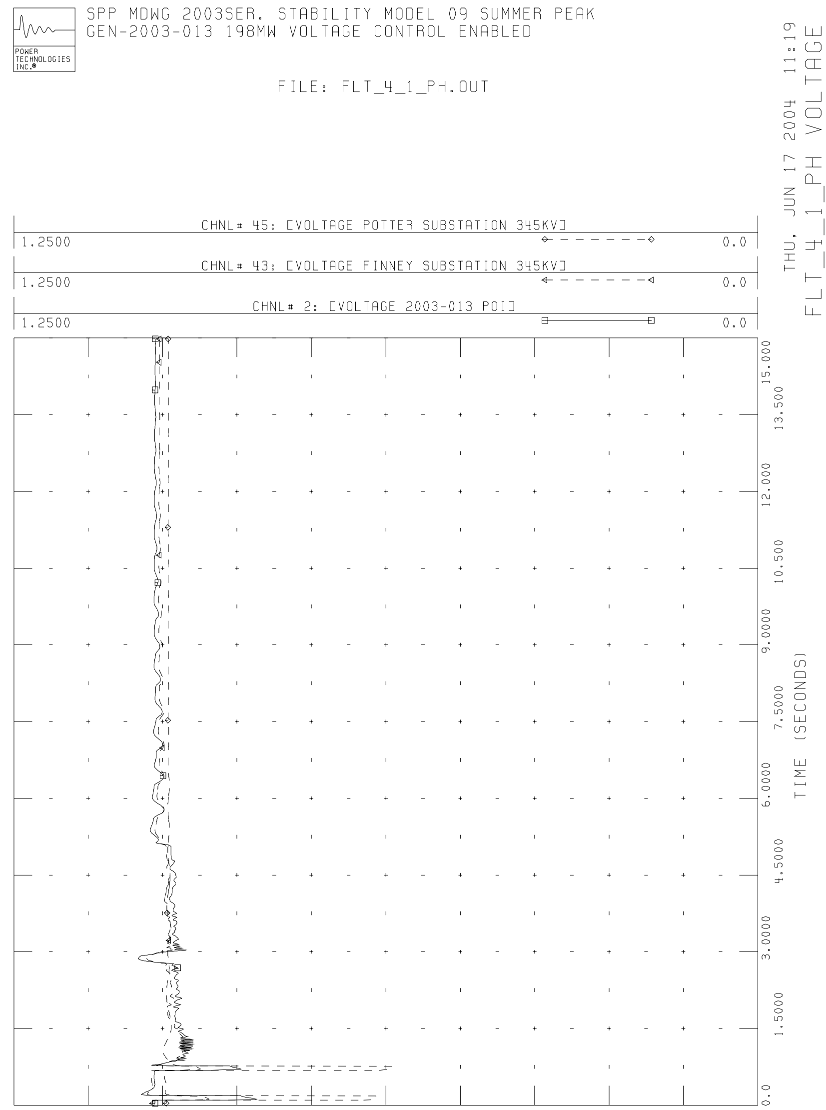
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:19
FLT_3_3_PH VOLTAGE



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
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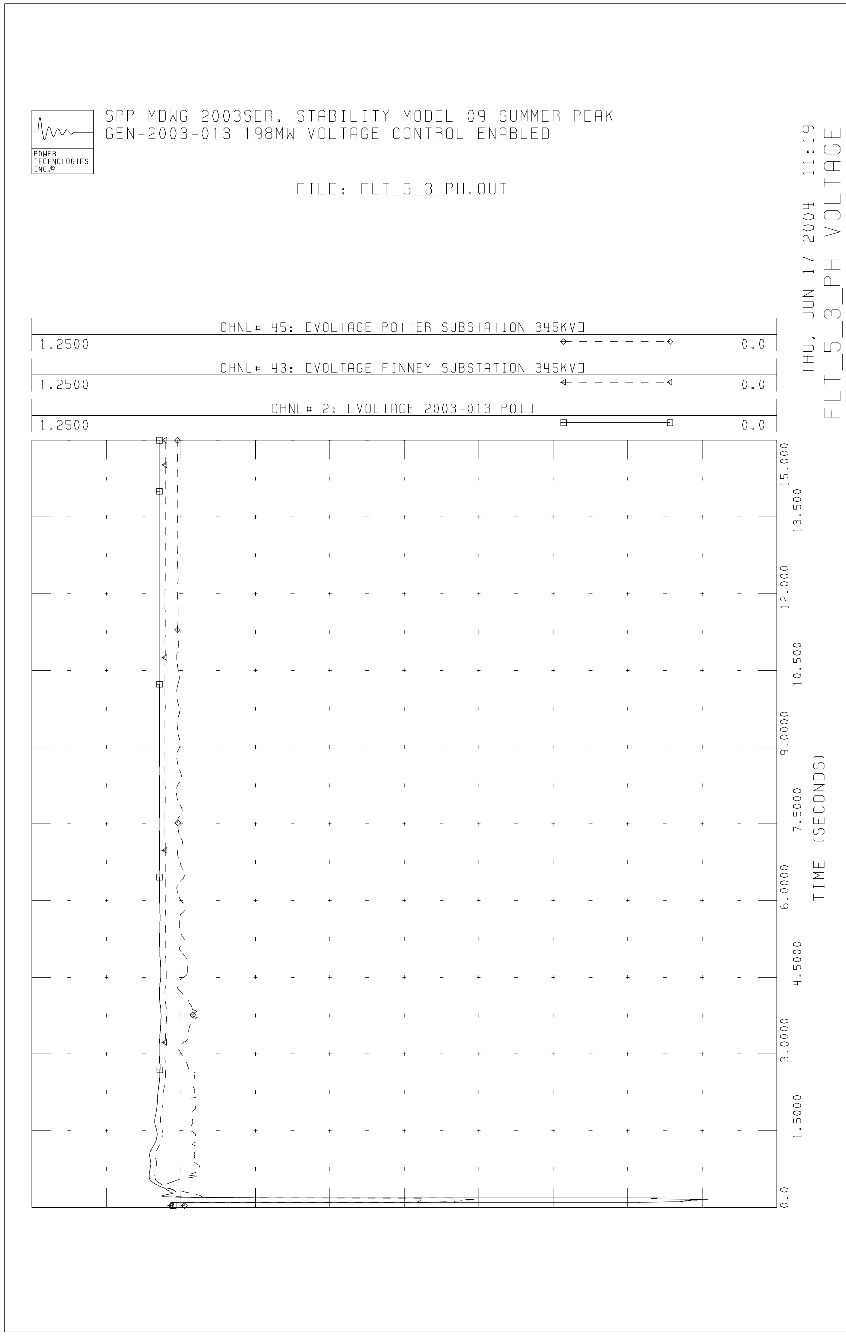
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:19
FLT_4_1_PH VOLTAGE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_5_3_PH.OUT
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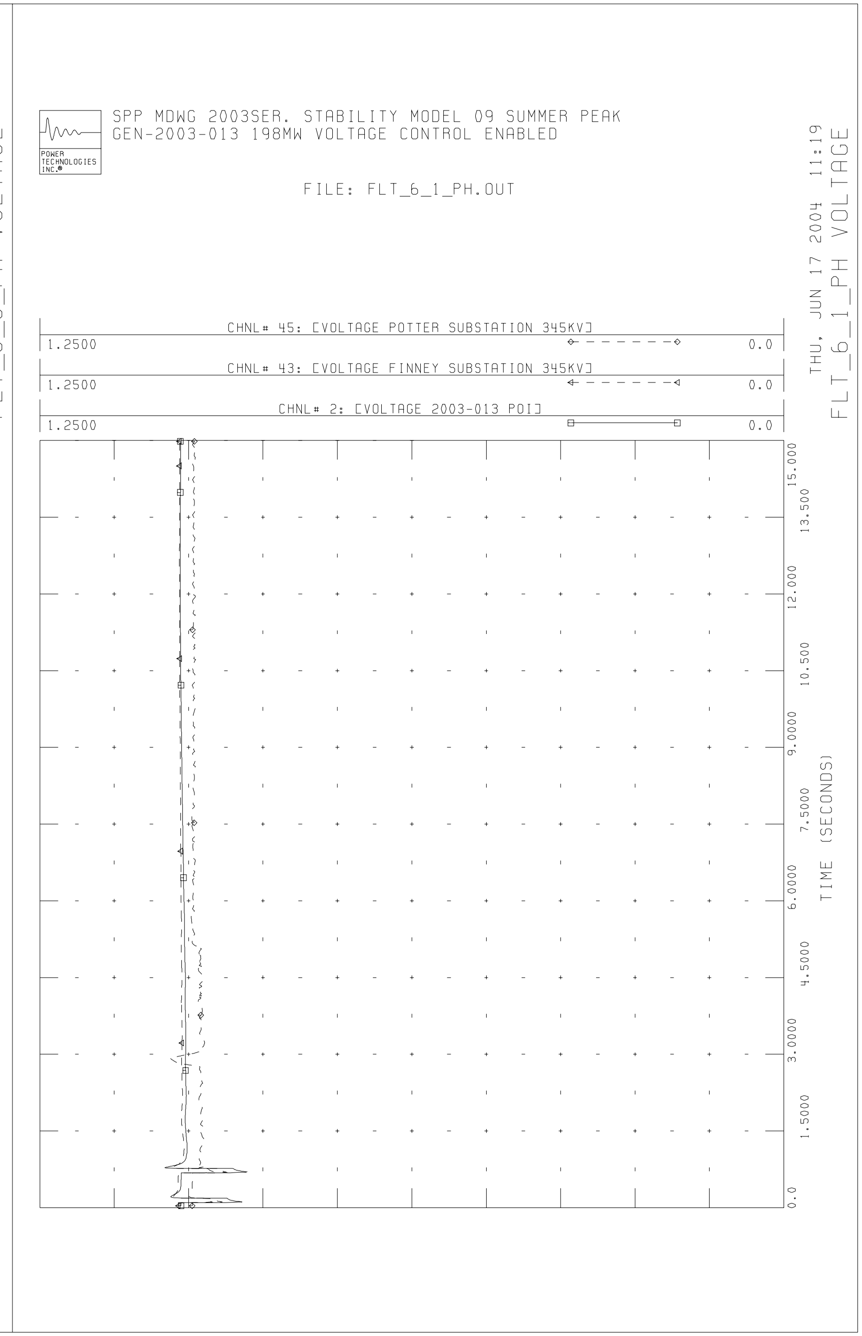
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:19
FLT_5_3_PH VOLTAGE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_6_1_PH.OUT
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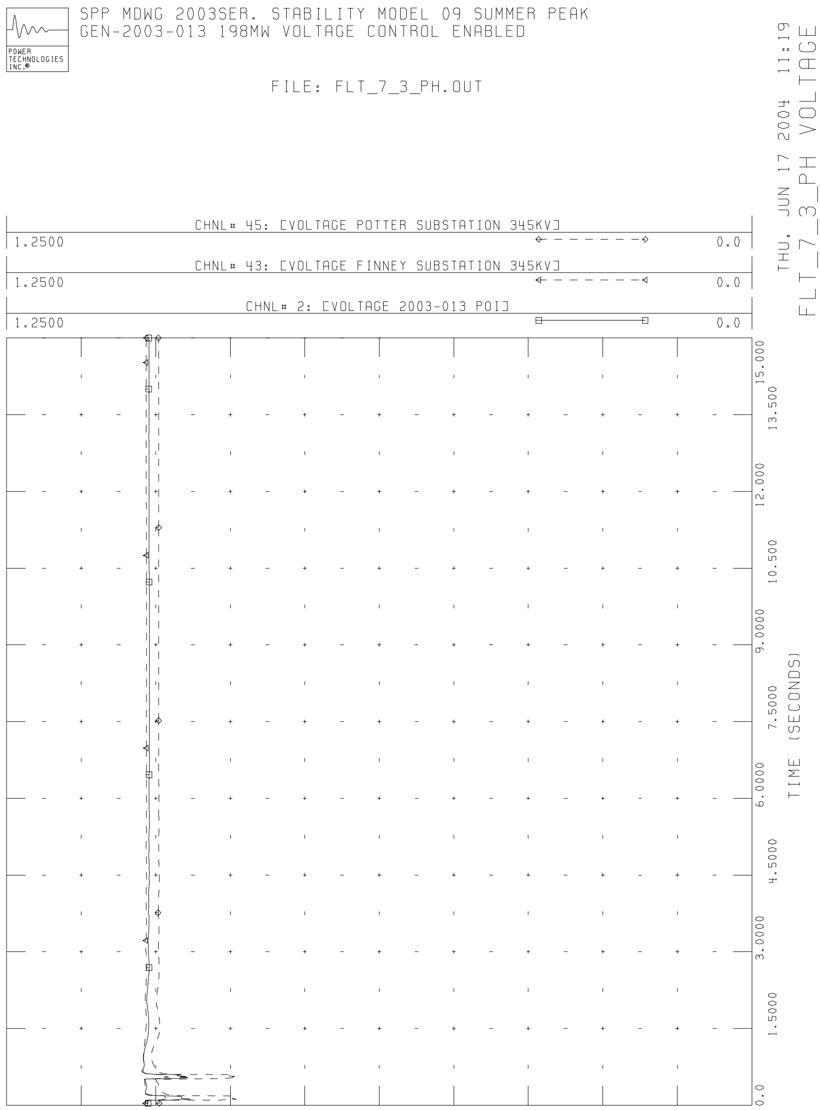
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:19
FLT_6_1_PH VOLTAGE



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_7_3_PH.OUT
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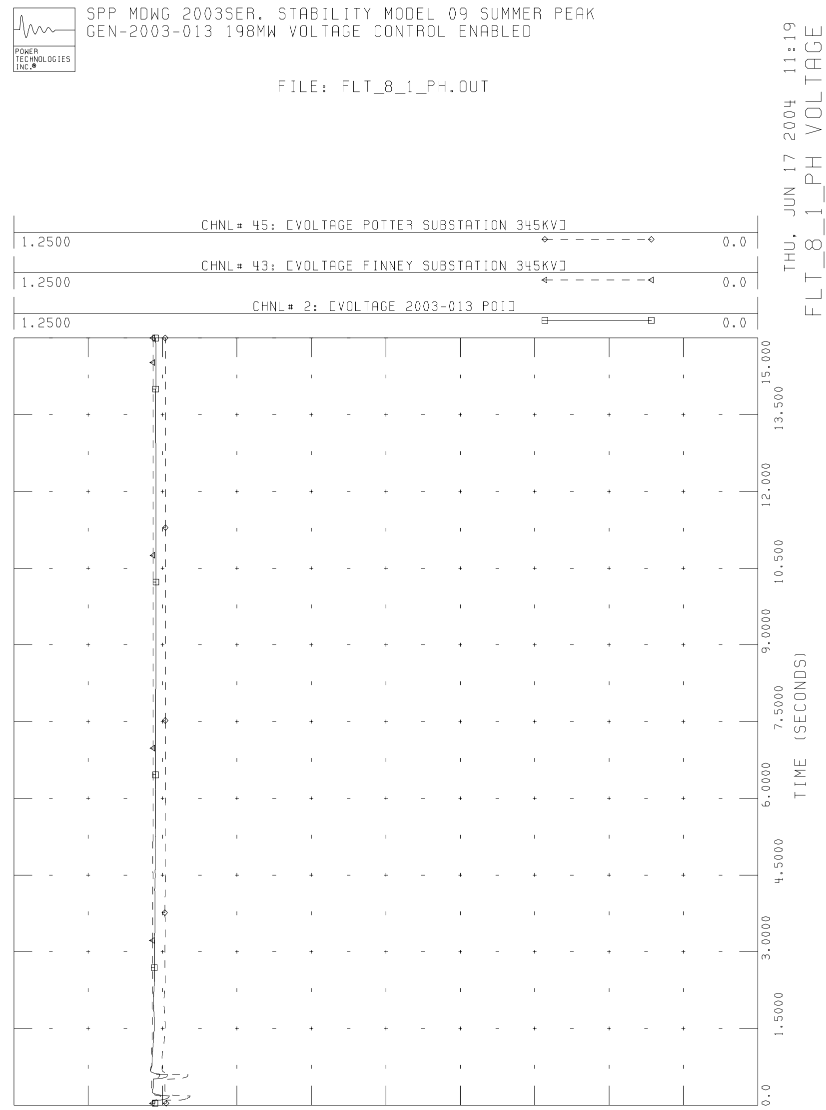
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
THU, JUN 17 2004 11:19
FLT_7_3_PH VOLTAGE
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_8_1_PH.OUT
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
THU, JUN 17 2004 11:19
FLT_8_1_PH VOLTAGE
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4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
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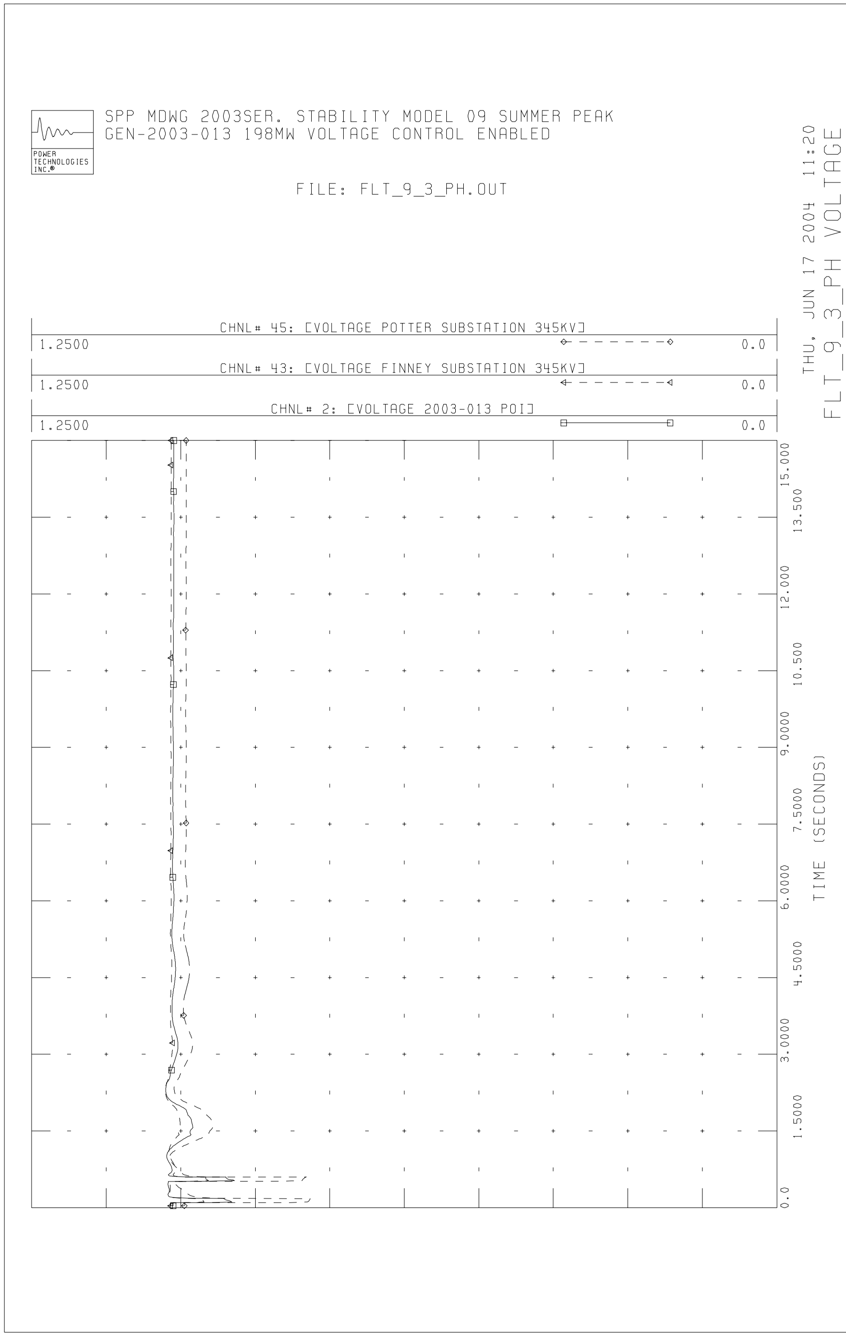
TIME (SECONDS)


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_9_3_PH.OUT
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
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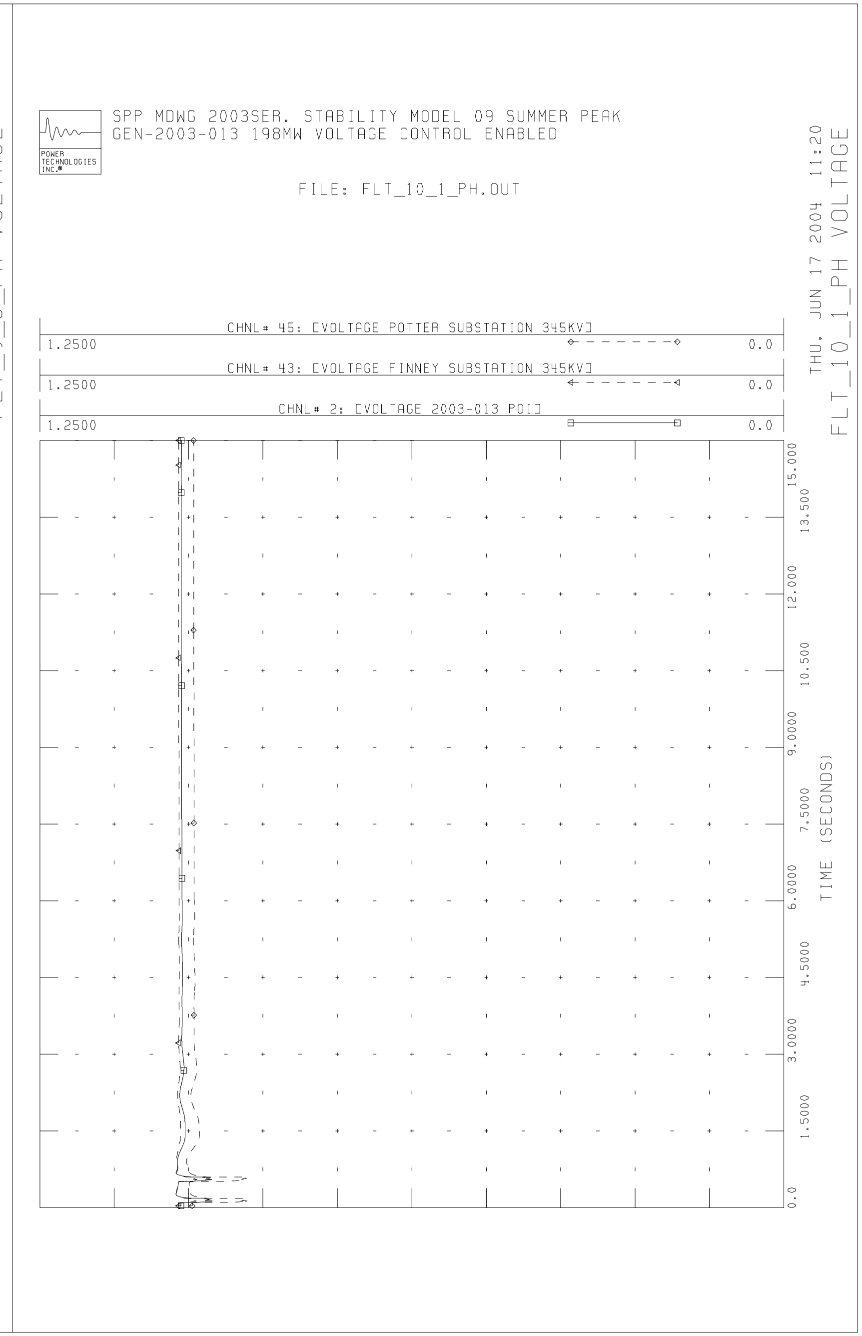
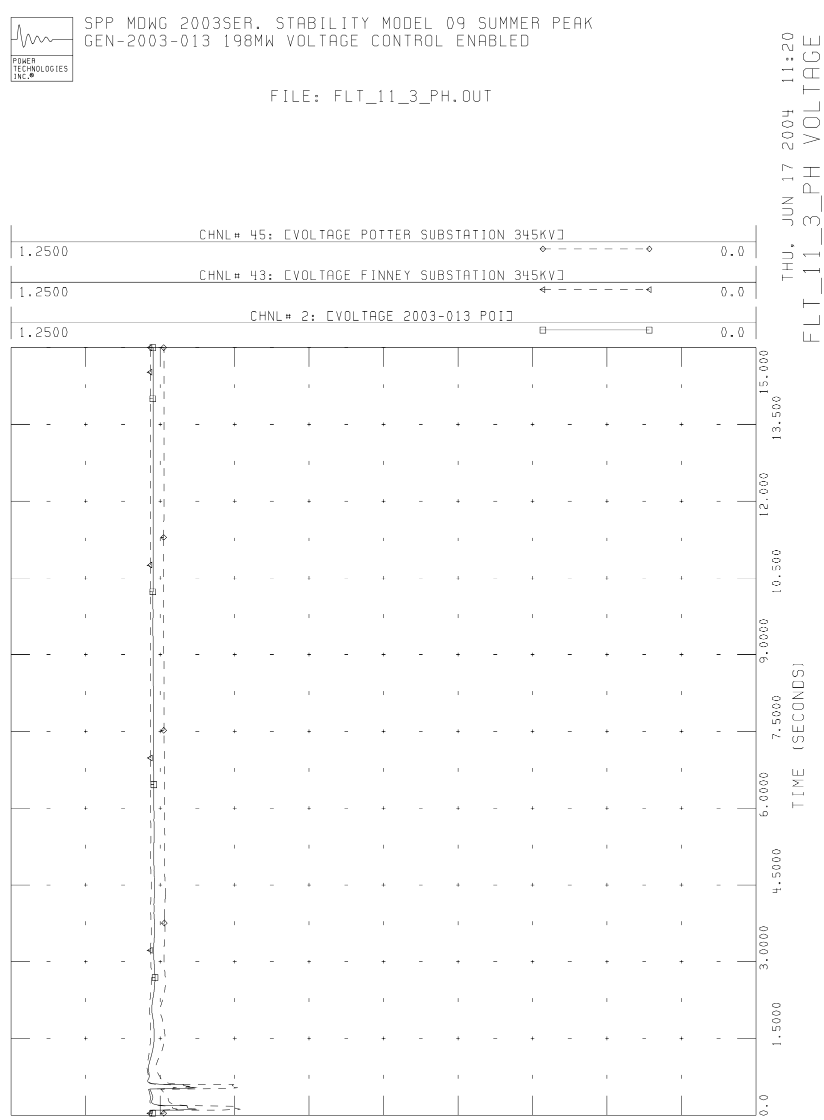
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:20
FLT_9_3_PH VOLTAGE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_10_1_PH.OUT
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:20
FLT_10_1_PH VOLTAGE



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_11_3_PH.OUT
POWER TECHNOLOGIES INC.
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
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CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
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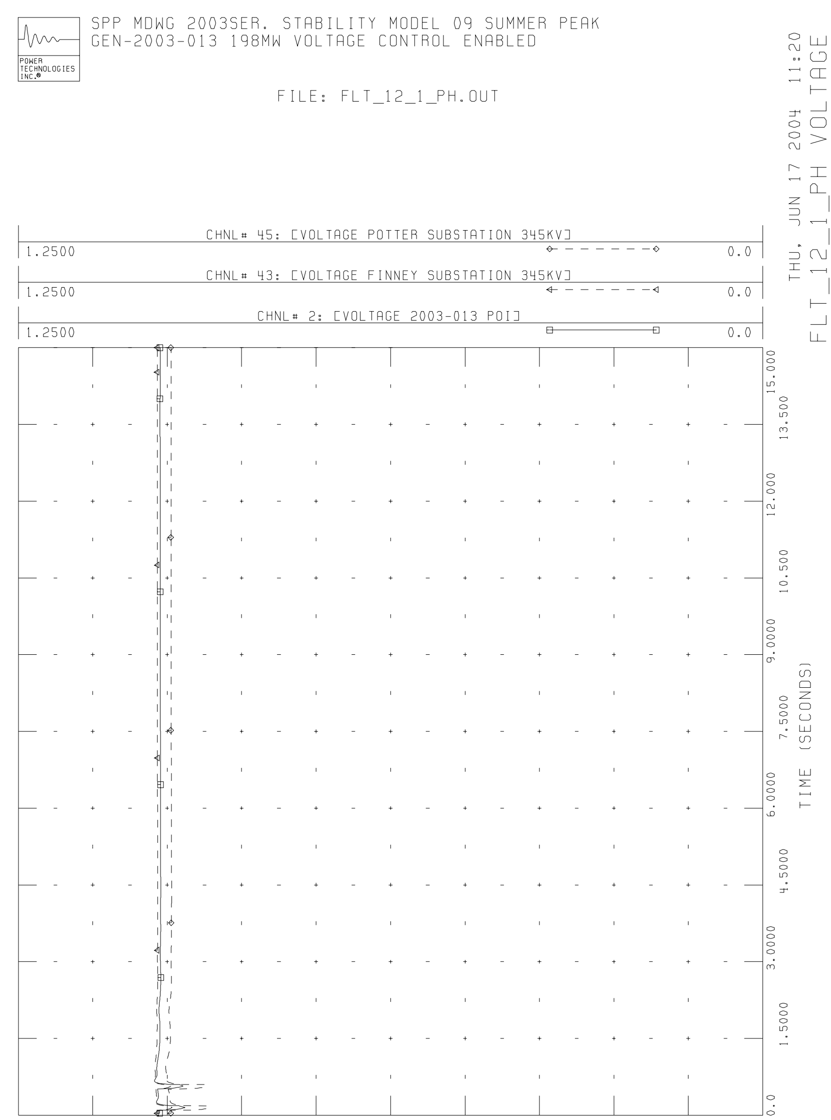
TIME (SECONDS)
THU, JUN 17 2004 11:20
FLT_11_3_PH VOLTAGE



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_12_1_PH.OUT
POWER TECHNOLOGIES INC.
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
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CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
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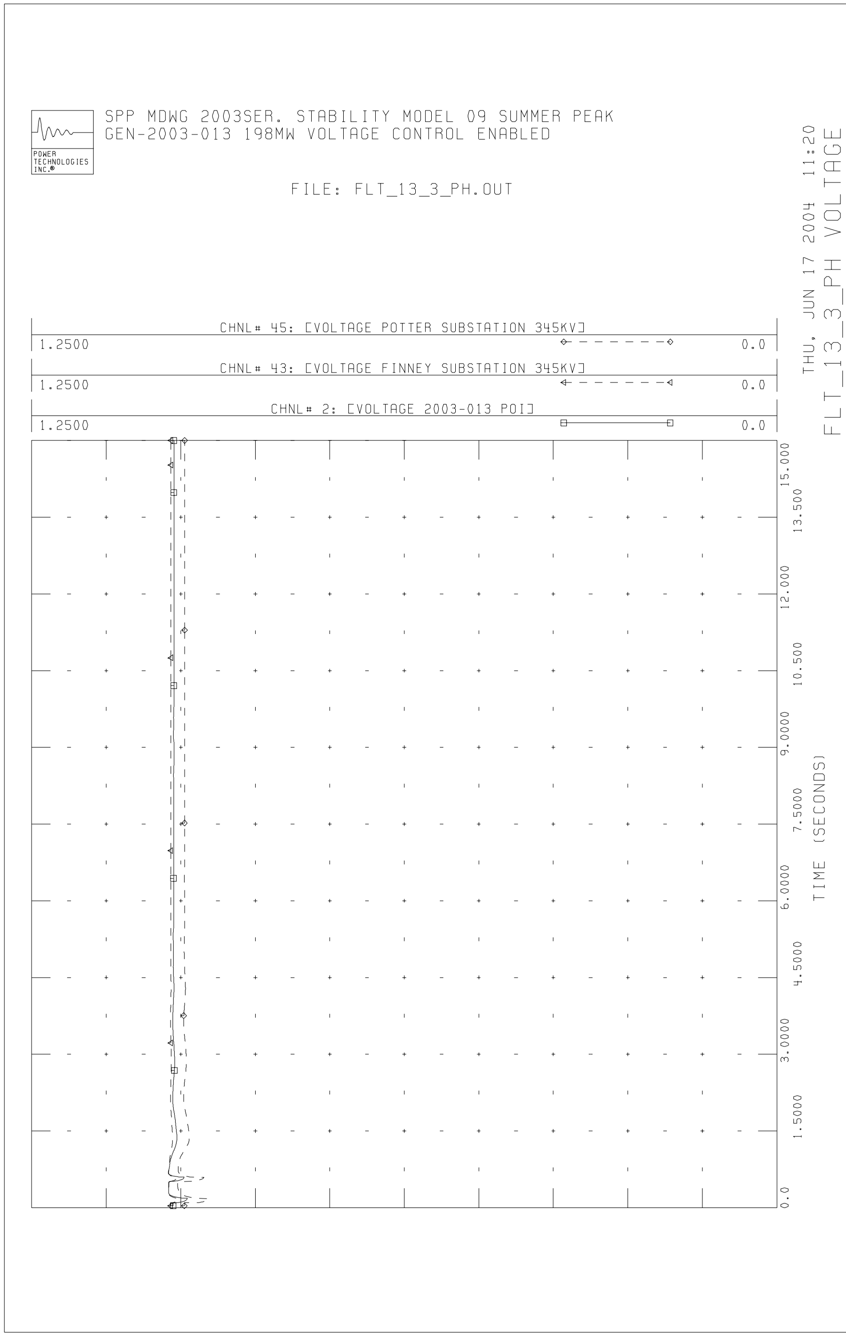
TIME (SECONDS)
THU, JUN 17 2004 11:20
FLT_12_1_PH VOLTAGE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_13_3_PH.OUT
THU, JUN 17 2004 11:20
FLT_13_3_PH VOLTAGE
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
0.0
CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
TIME (SECONDS)
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4.5000
6.0000
7.5000
9.0000
10.500
12.000
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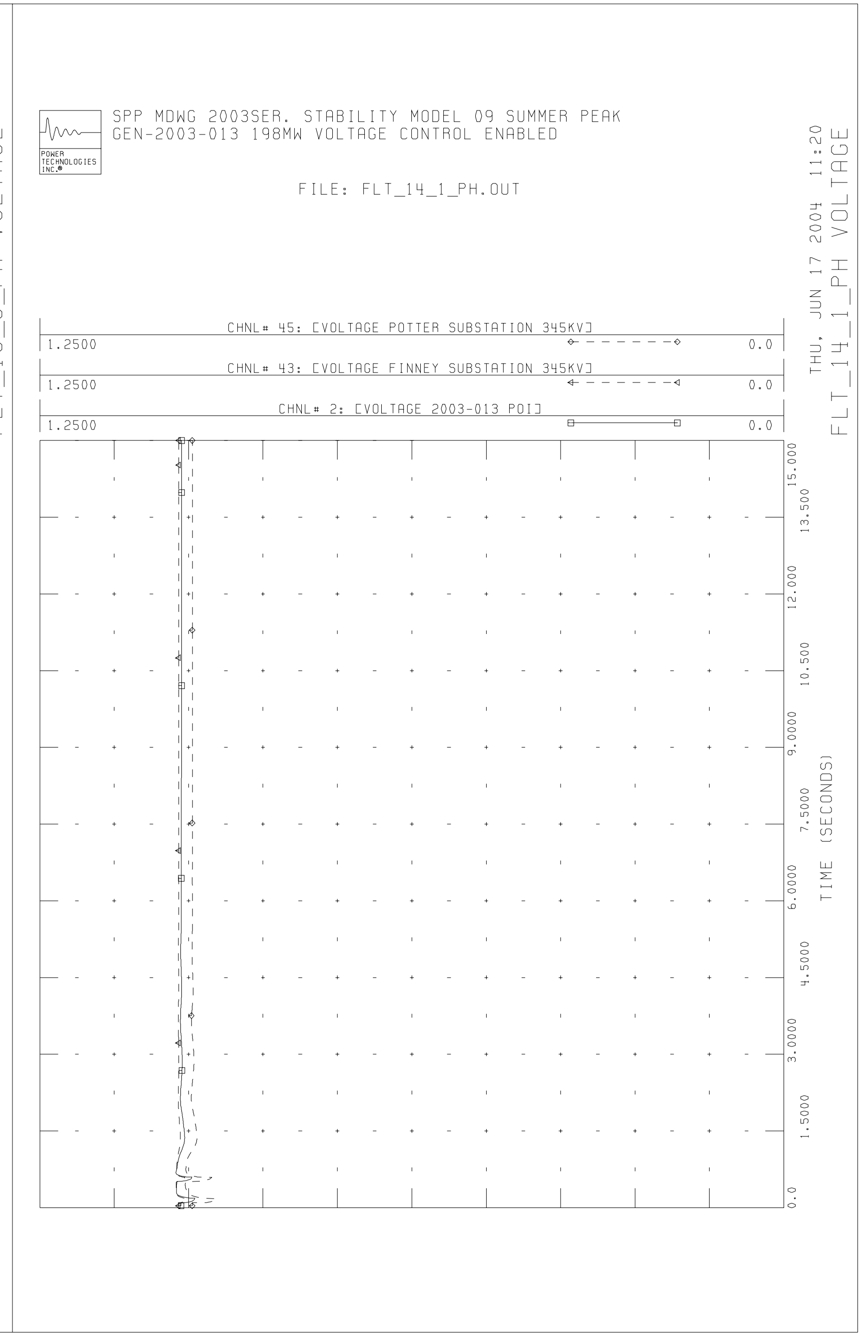
15.000


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_14_1_PH.OUT
THU, JUN 17 2004 11:20
FLT_14_1_PH VOLTAGE
CHNL# 45: [VOLTAGE POTTER SUBSTATION 345KV]
1.2500
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CHNL# 43: [VOLTAGE FINNEY SUBSTATION 345KV]
1.2500
0.0
CHNL# 2: [VOLTAGE 2003-013 POI]
1.2500
0.0
TIME (SECONDS)
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1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
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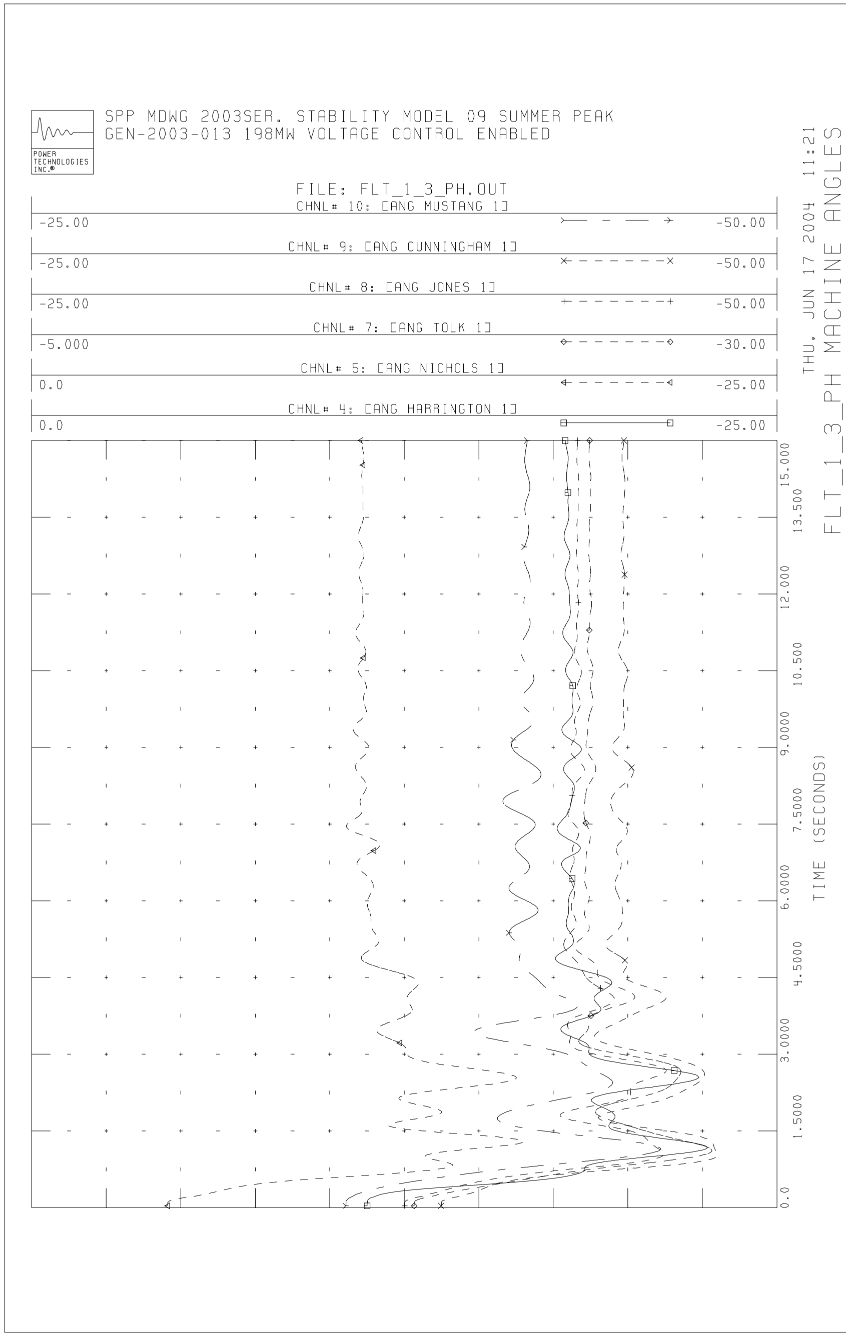
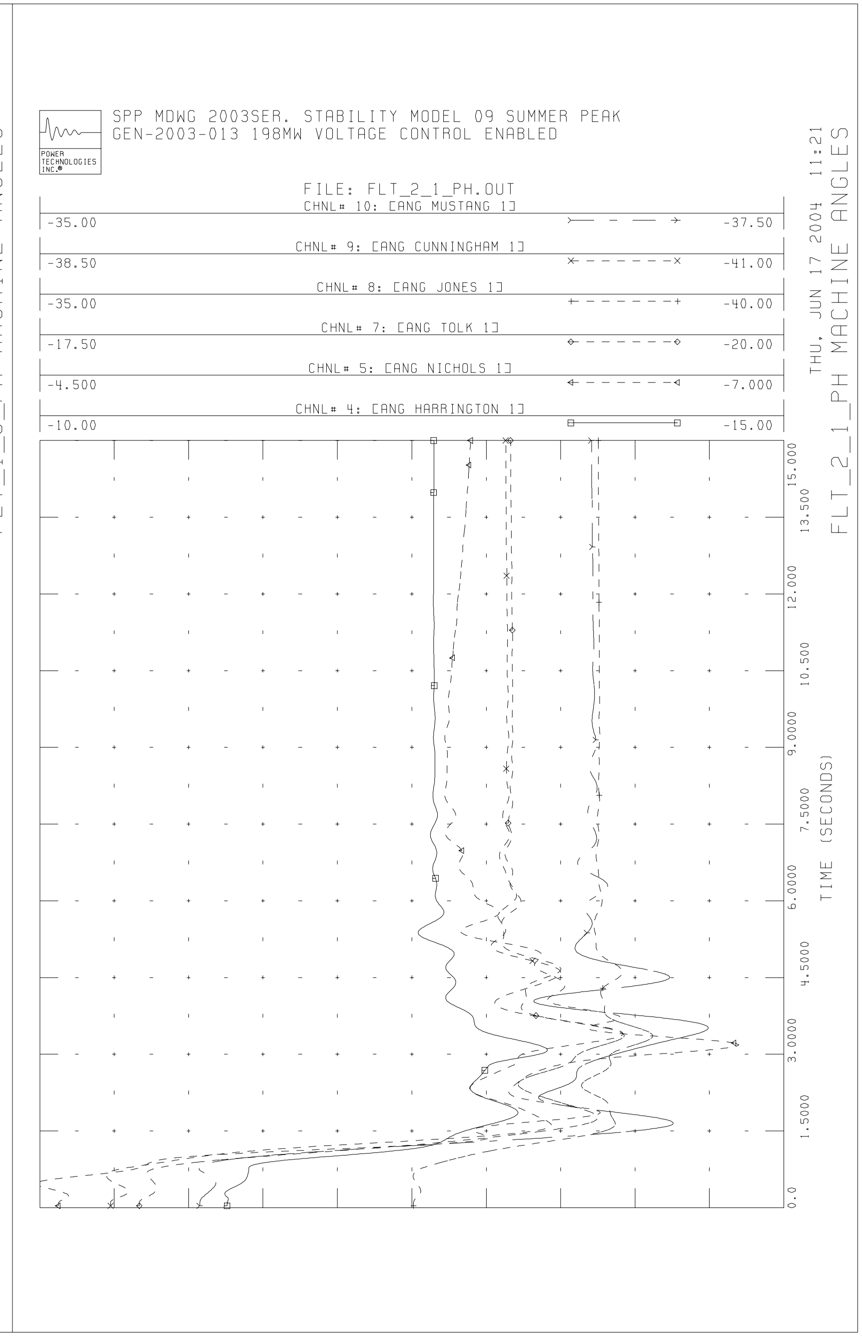
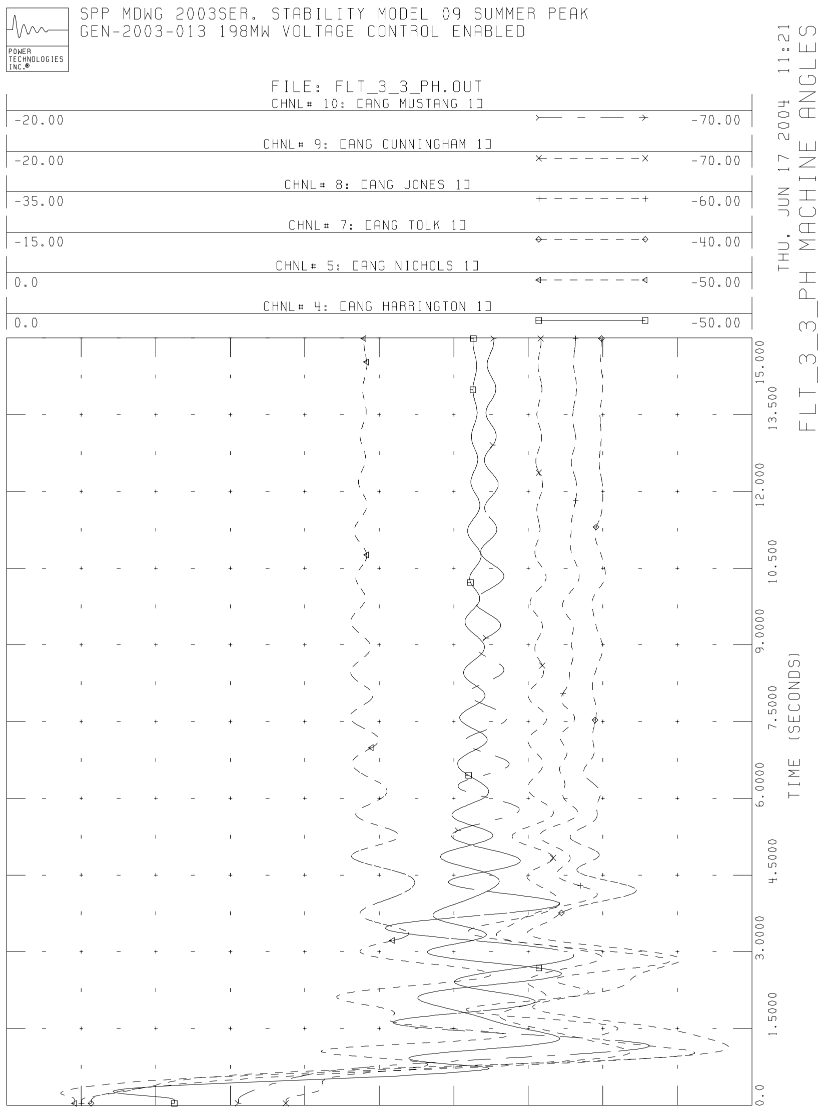
12.000
13.500
15.000



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_1_3_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -25.00 -50.00
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] -5.000 -30.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_1_3_PH MACHINE ANGLES



SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_2_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -35.00 -37.50
CHNL# 9: [ANG CUNNINGHAM 1] -38.50 -41.00
CHNL# 8: [ANG JONES 1] -35.00 -40.00
CHNL# 7: [ANG TOLK 1] -17.50 -20.00
CHNL# 5: [ANG NICHOLS 1] -4.500 -7.000
CHNL# 4: [ANG HARRINGTON 1] -10.00 -15.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_2_1_PH MACHINE ANGLES


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_3_3_PH.OUT
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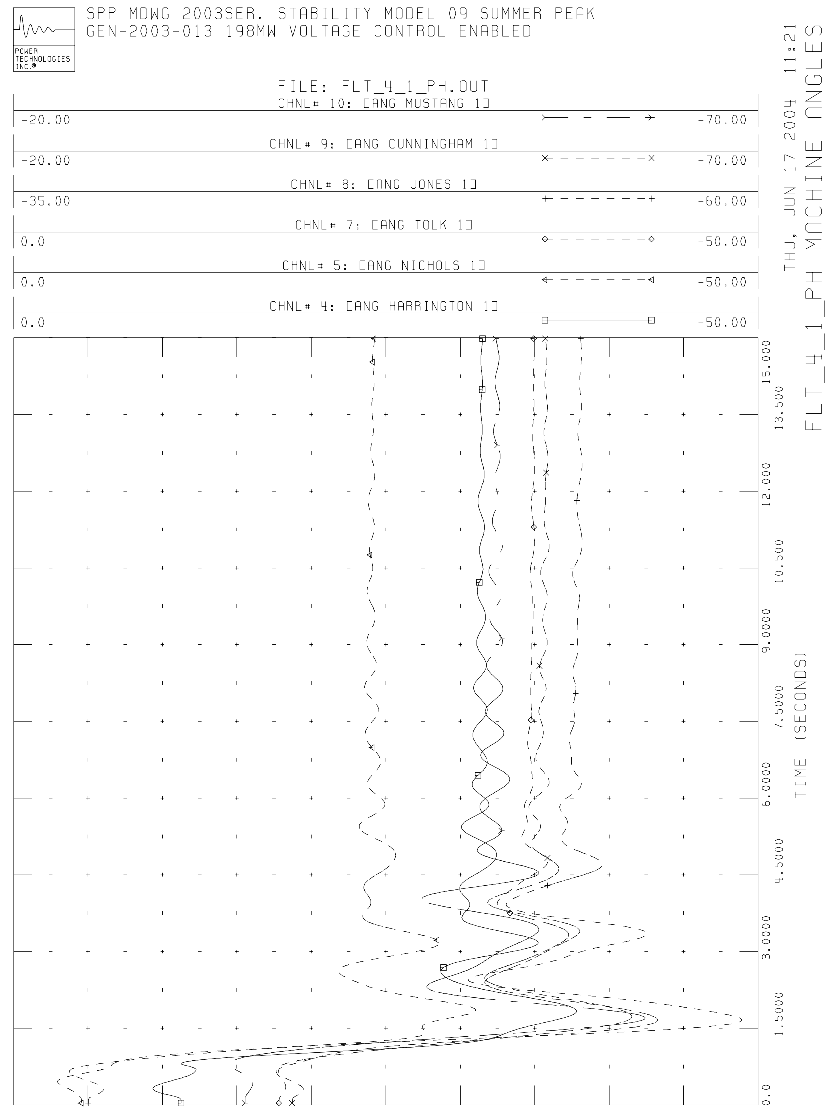
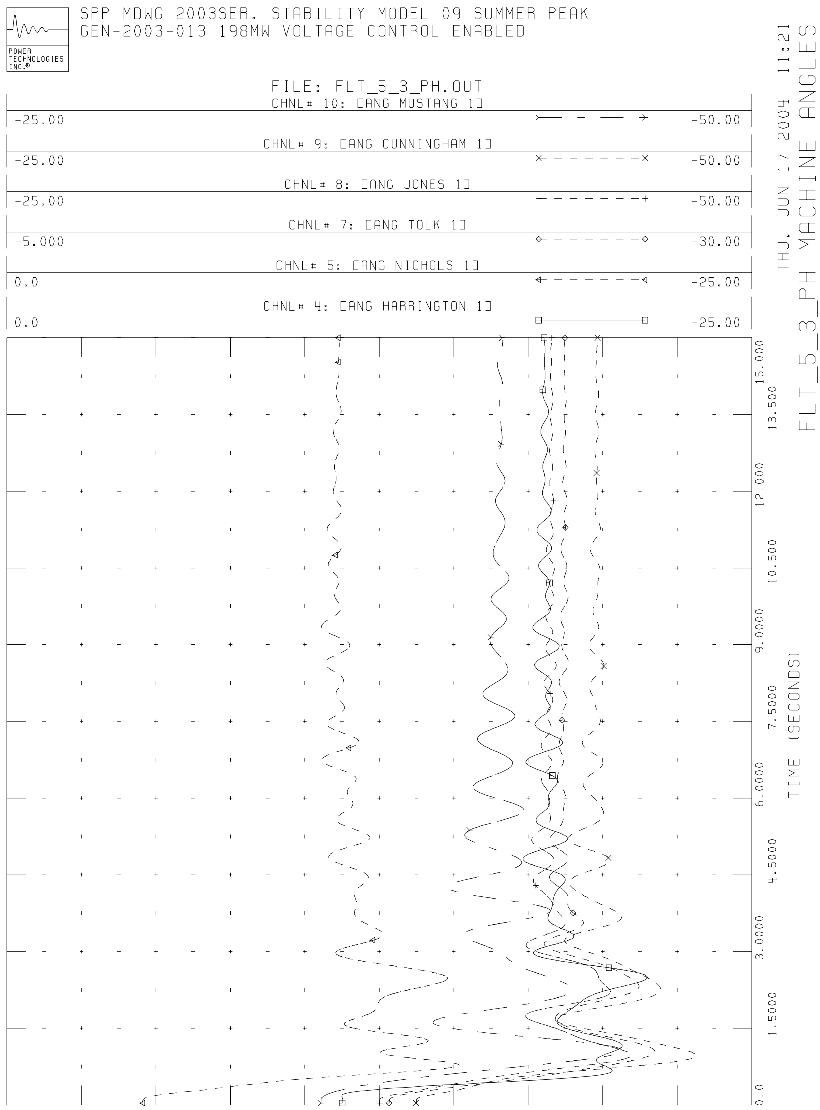
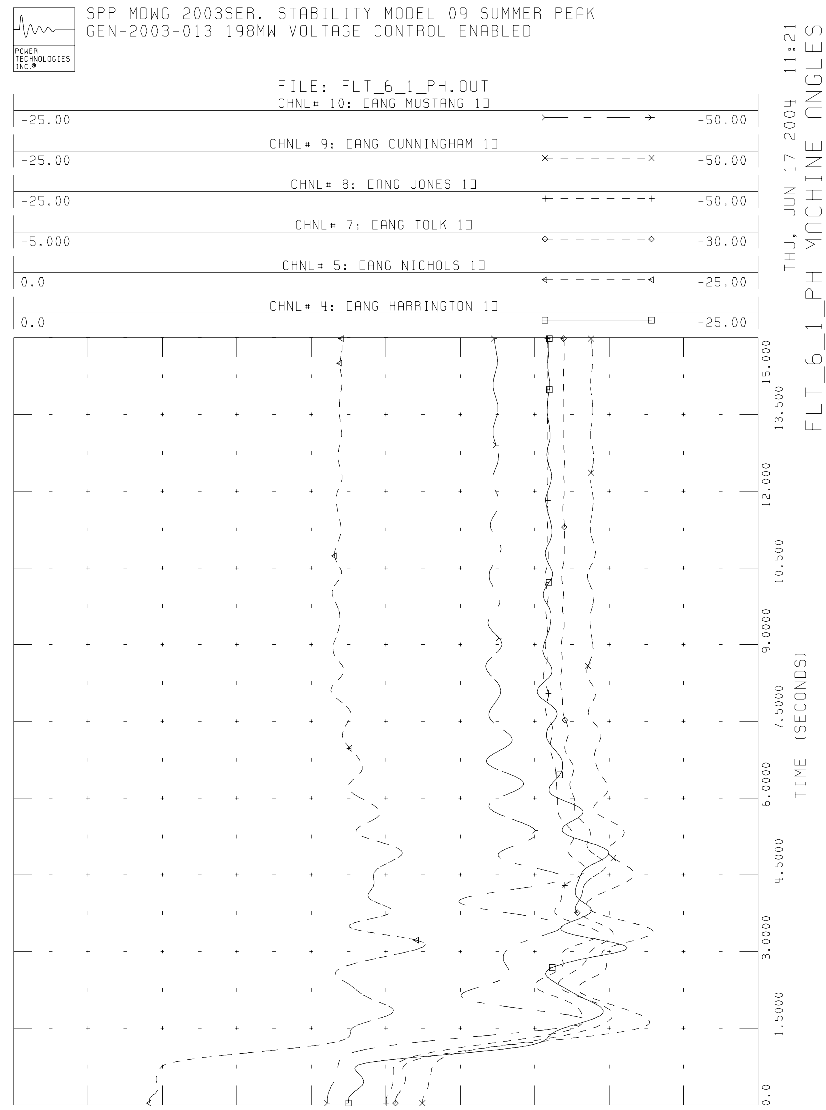
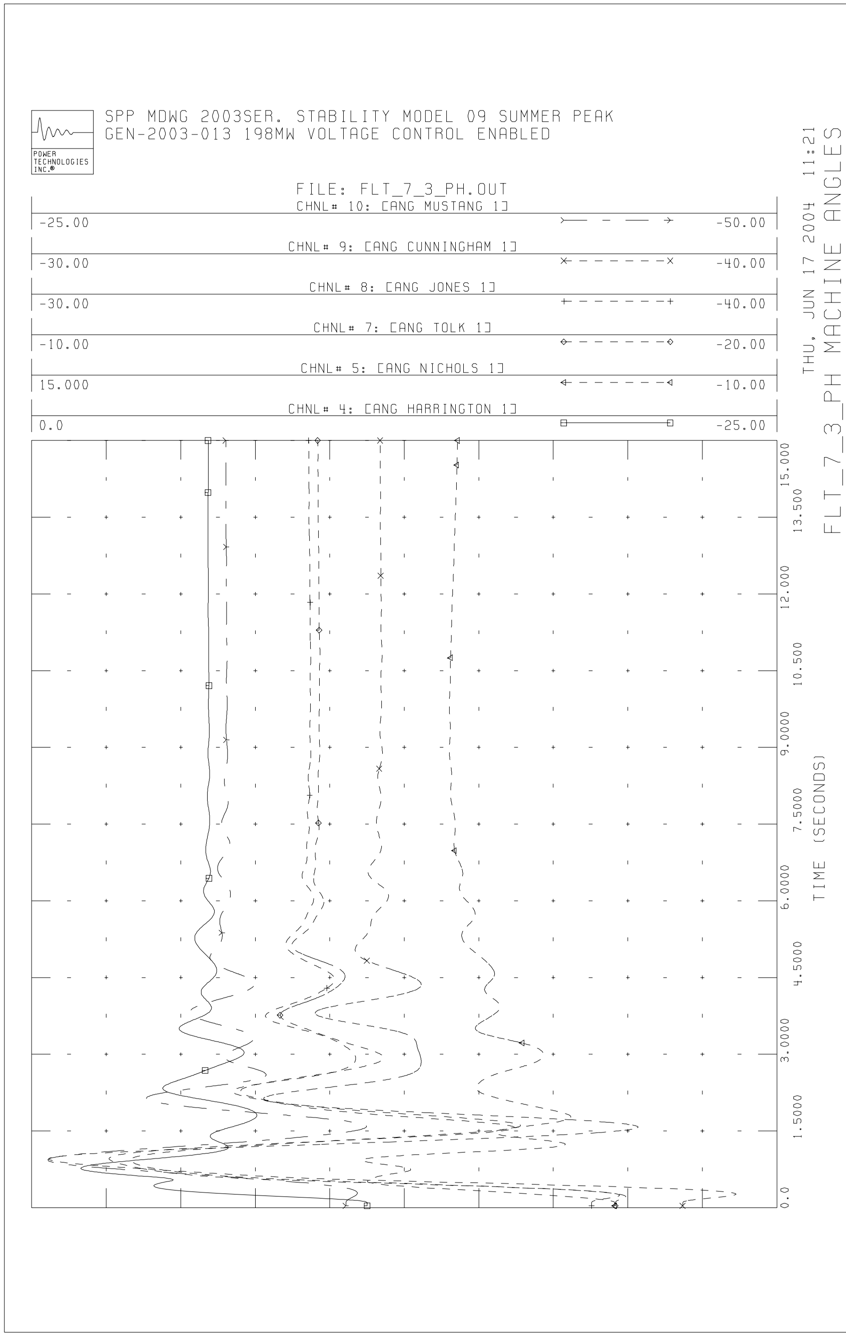
CHNL# 9: [ANG CUNNINGHAM 1] -20.00 -70.00
CHNL# 8: [ANG JONES 1] -35.00 -60.00
CHNL# 7: [ANG TOLK 1] -15.00 -40.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -50.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -50.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_3_3_PH MACHINE ANGLES

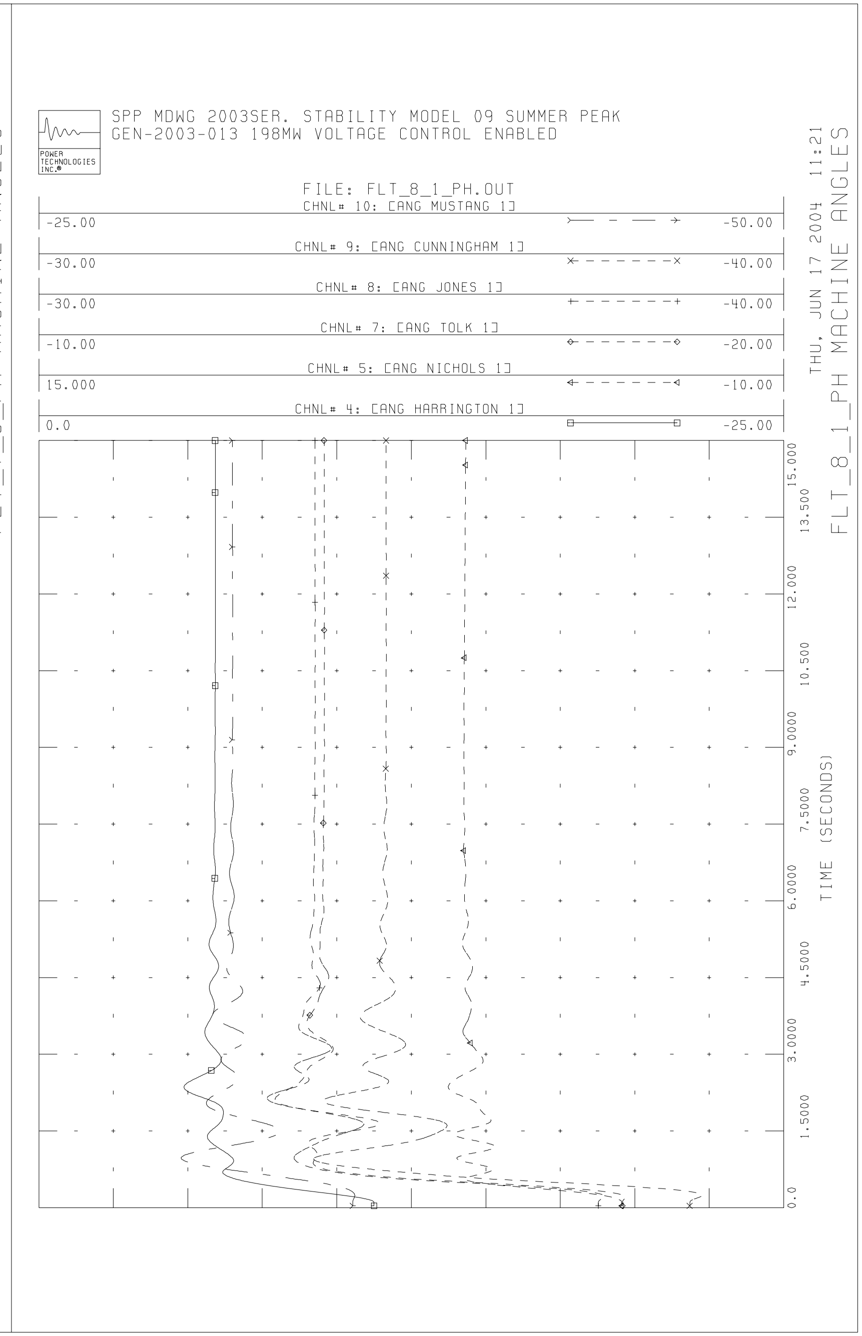

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_4_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -20.00 -70.00
CHNL# 9: [ANG CUNNINGHAM 1] -20.00 -70.00
CHNL# 8: [ANG JONES 1] -35.00 -60.00
CHNL# 7: [ANG TOLK 1] 0.0 -50.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -50.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -50.00
0.0
1.5000
3.0000
4.5000
6.0000
7.5000
9.0000
10.500
12.000
13.500
15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_4_1_PH MACHINE ANGLES


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_5_3_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -25.00 -50.00
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] -5.000 -30.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_5_3_PH MACHINE ANGLES

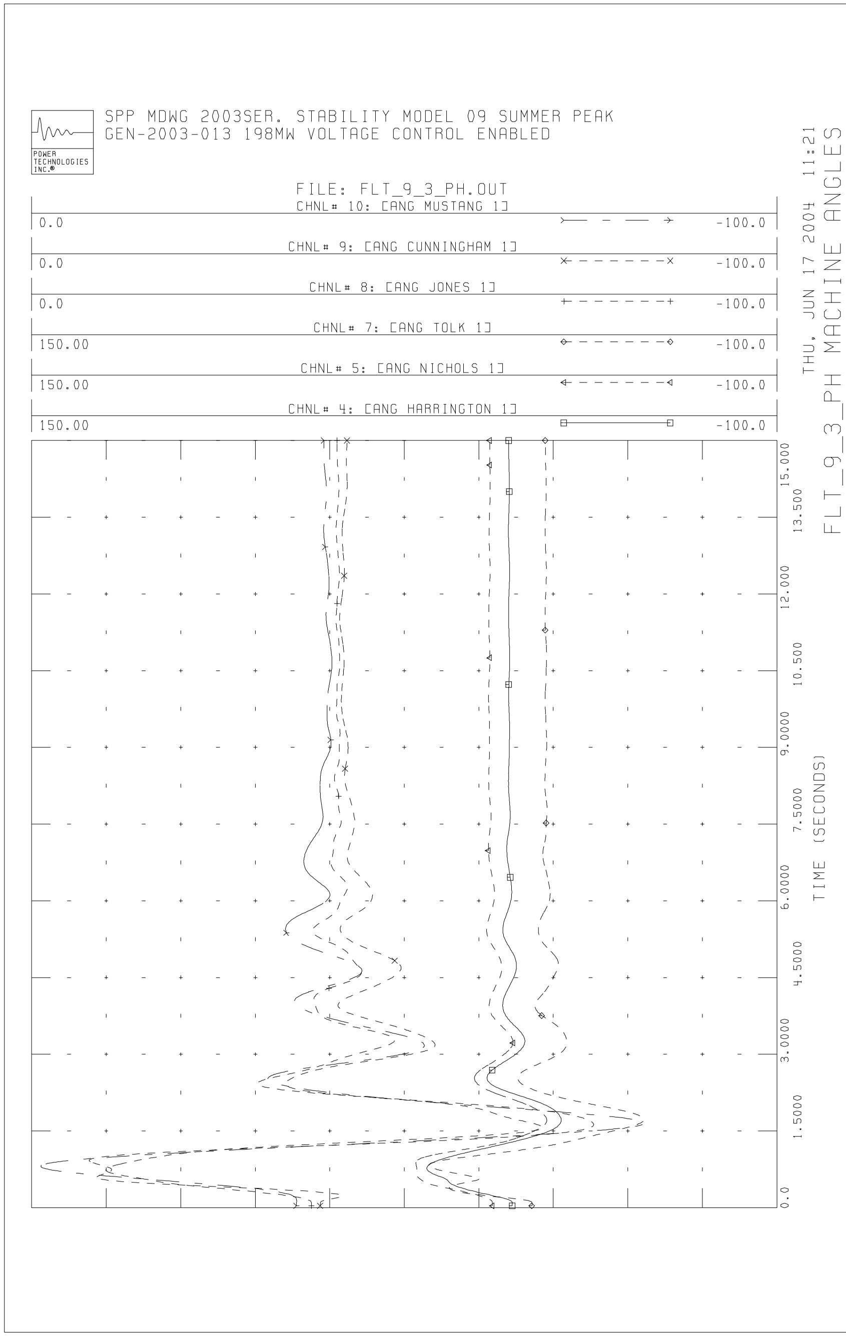

SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_6_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -25.00 -50.00
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] -5.000 -30.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -25.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_6_1_PH MACHINE ANGLES



POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_7_3_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -25.00 -50.00
CHNL# 9: [ANG CUNNINGHAM 1] -30.00 -40.00
CHNL# 8: [ANG JONES 1] -30.00 -40.00
CHNL# 7: [ANG TOLK 1] -10.00 -20.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_7_3_PH MACHINE ANGLES



POWER TECHNOLOGIES INC.
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
FILE: FLT_8_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -25.00 -50.00
CHNL# 9: [ANG CUNNINGHAM 1] -30.00 -40.00
CHNL# 8: [ANG JONES 1] -30.00 -40.00
CHNL# 7: [ANG TOLK 1] -10.00 -20.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_8_1_PH MACHINE ANGLES


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_9_3_PH.OUT
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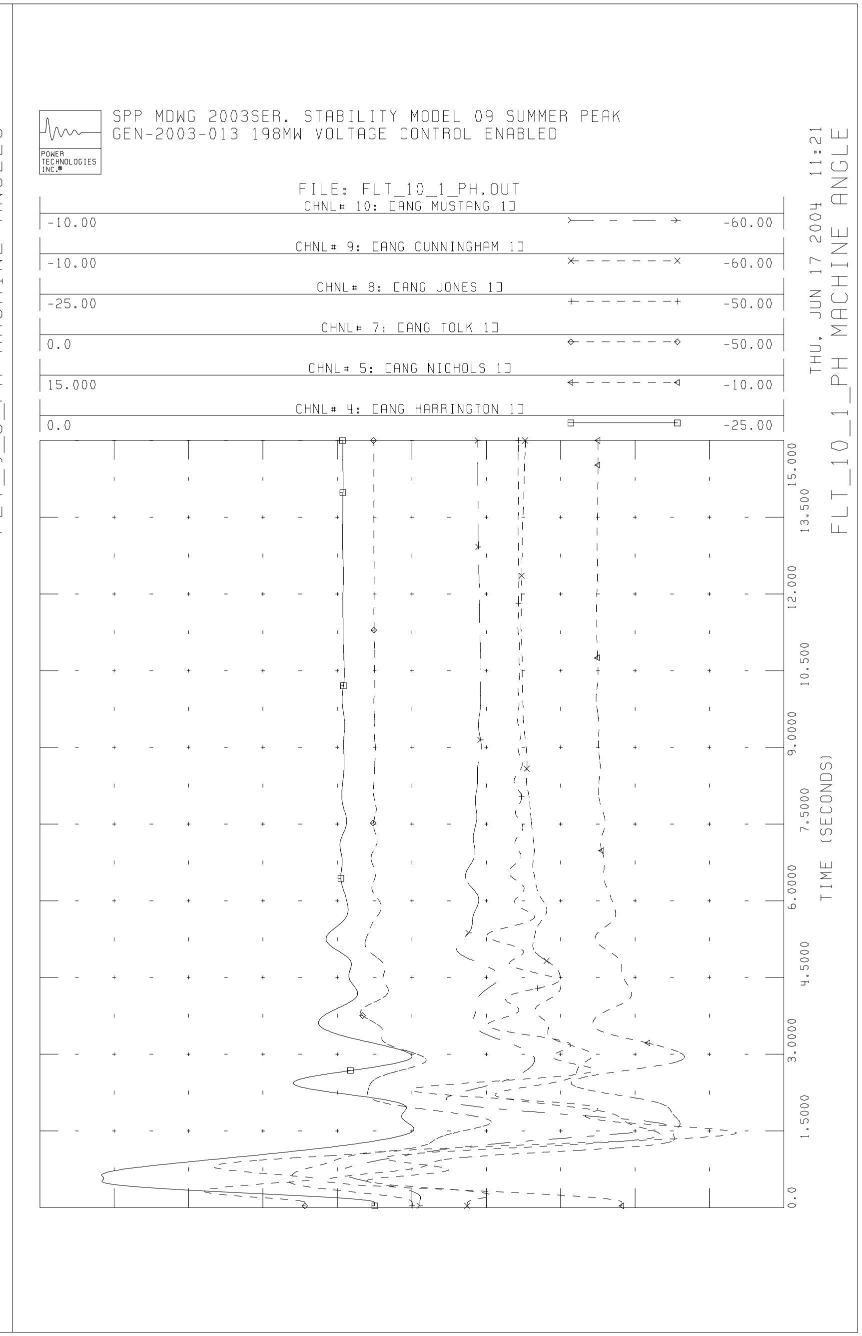
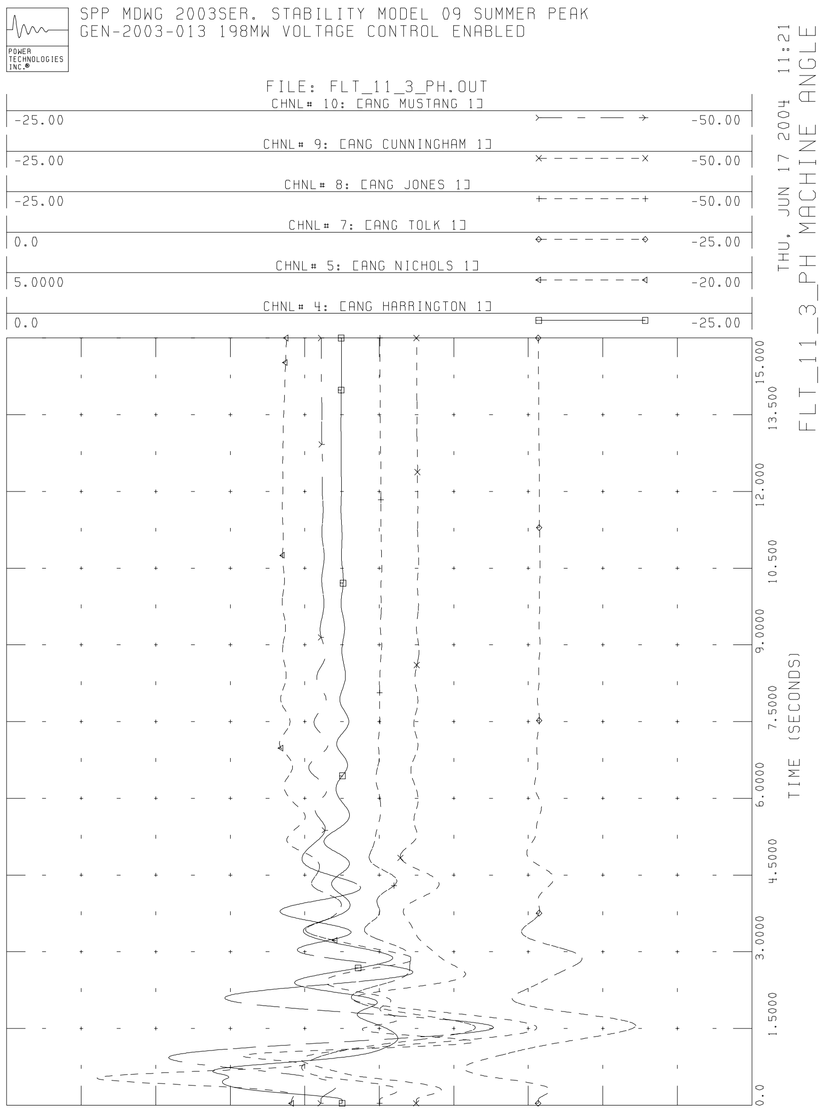
CHNL# 9: [ANG CUNNINGHAM 1] 0.0 -100.0
CHNL# 8: [ANG JONES 1] 0.0 -100.0
CHNL# 7: [ANG TOLK 1] 150.00 -100.0
CHNL# 5: [ANG NICHOLS 1] 150.00 -100.0
CHNL# 4: [ANG HARRINGTON 1] 150.00 -100.0
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_9_3_PH MACHINE ANGLES


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_10_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -10.00 -60.00
CHNL# 9: [ANG CUNNINGHAM 1] -10.00 -60.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -50.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 11:21
FLT_10_1_PH MACHINE ANGLE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_11_3_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -25.00 -50.00
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 5.0000 -20.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
THU, JUN 17 2004 11:21
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TIME (SECONDS)
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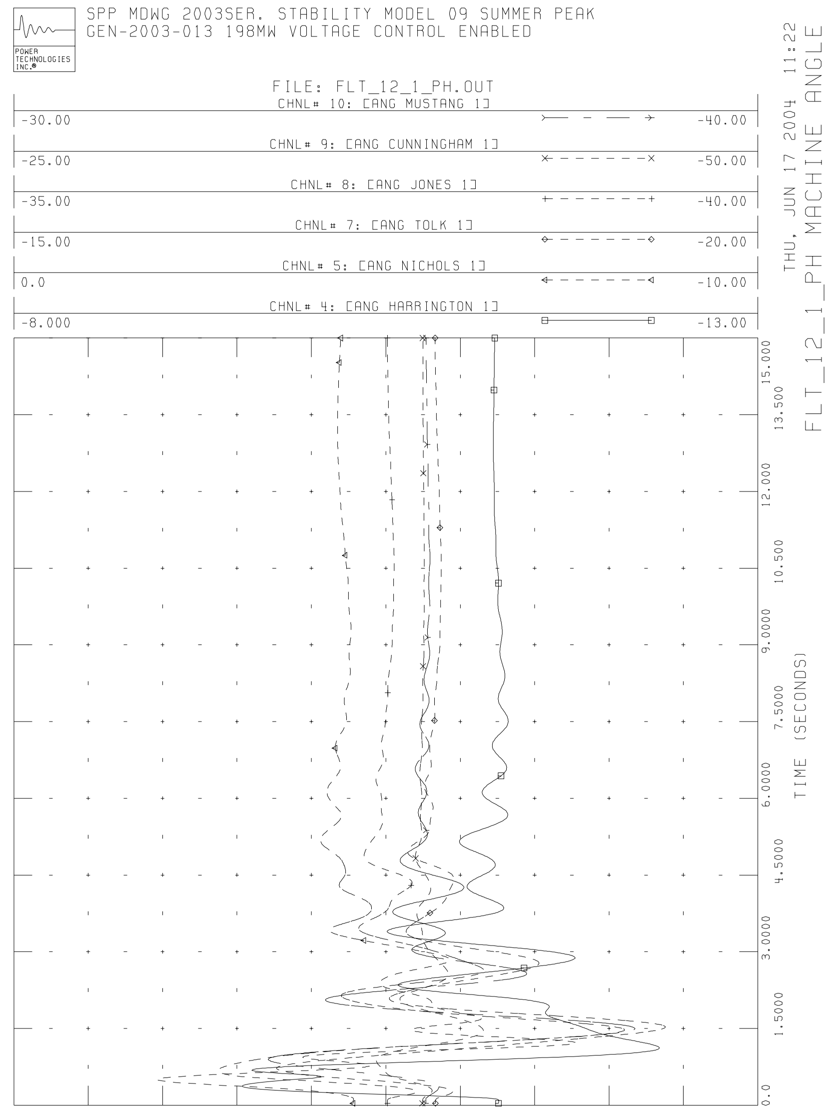
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_12_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -30.00 -40.00
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] -35.00 -40.00
CHNL# 7: [ANG TOLK 1] -15.00 -20.00
CHNL# 5: [ANG NICHOLS 1] 0.0 -10.00
CHNL# 4: [ANG HARRINGTON 1] -8.000 -13.00
THU, JUN 17 2004 11:22
FLT_12_1_PH MACHINE ANGLE
TIME (SECONDS)
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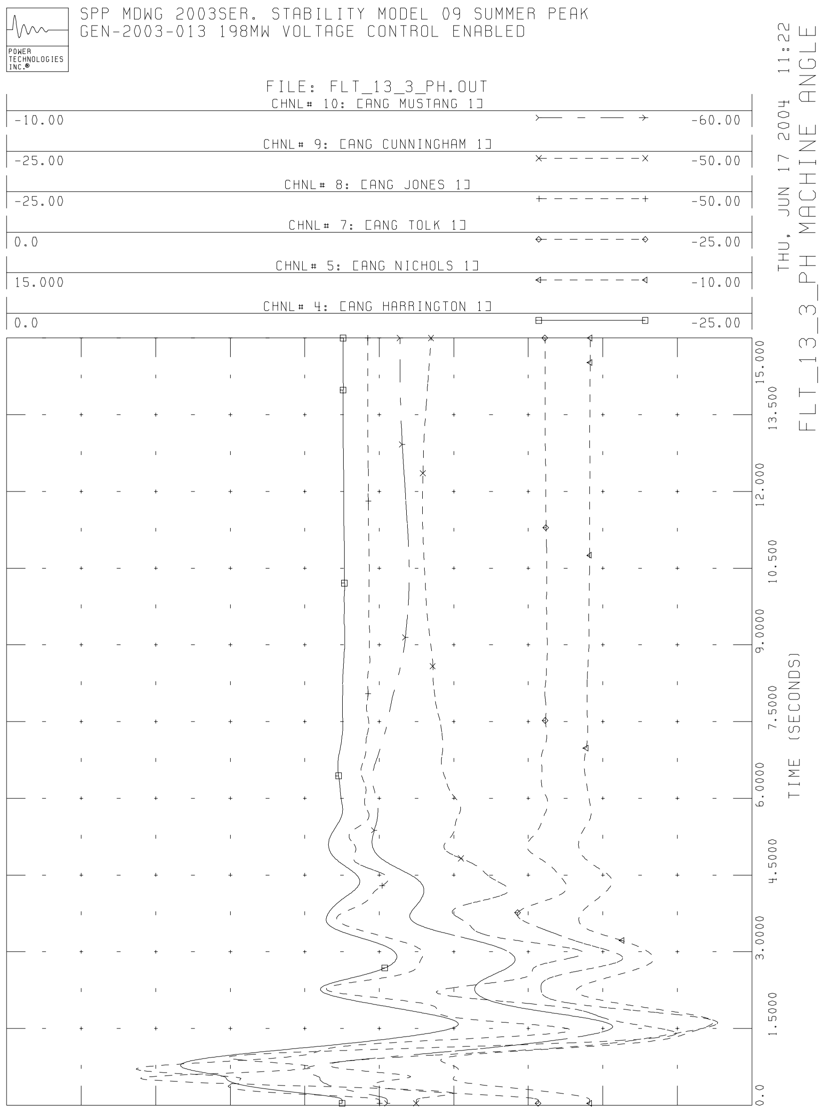
SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_13_3_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -10.00 -60.00
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
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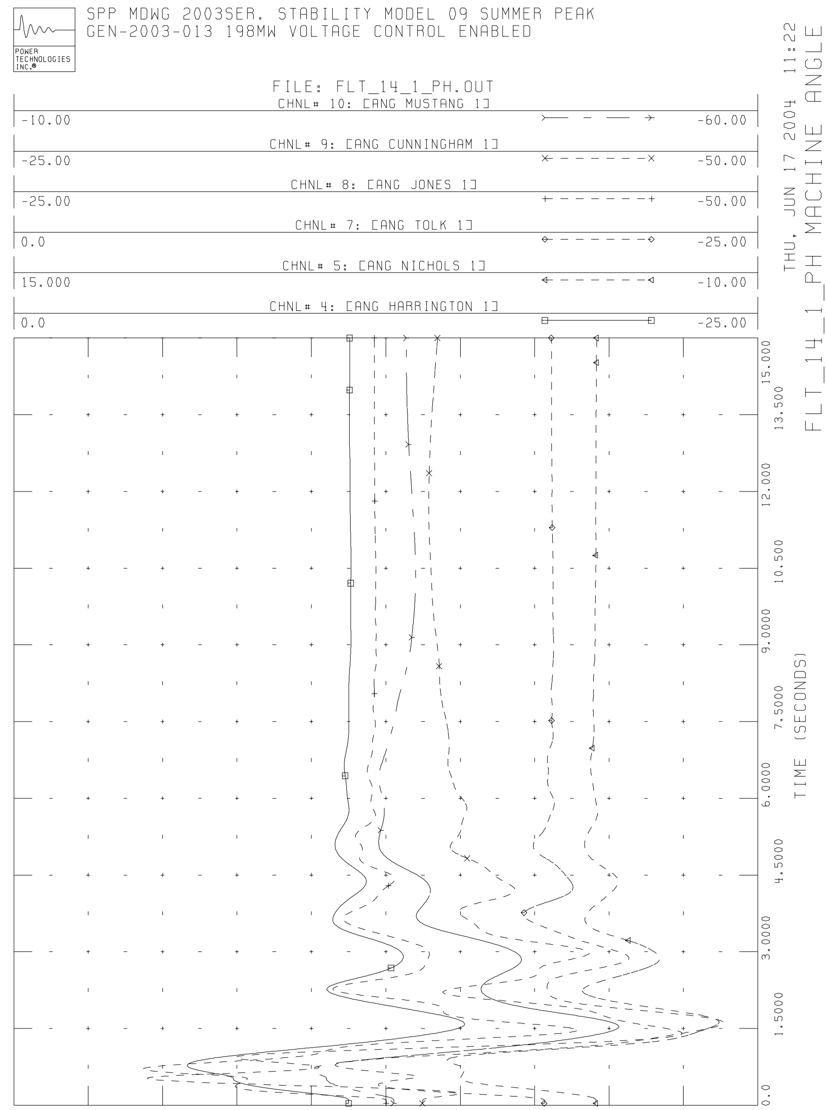
TIME (SECONDS)
THU, JUN 17 2004 11:22
FLT_13_3_PH MACHINE ANGLE


SPP MDWG 2003SER. STABILITY MODEL 09 SUMMER PEAK
GEN-2003-013 198MW VOLTAGE CONTROL ENABLED
POWER TECHNOLOGIES INC.
FILE: FLT_14_1_PH.OUT
CHNL# 10: [ANG MUSTANG 1] -10.00 -60.00
CHNL# 9: [ANG CUNNINGHAM 1] -25.00 -50.00
CHNL# 8: [ANG JONES 1] -25.00 -50.00
CHNL# 7: [ANG TOLK 1] 0.0 -25.00
CHNL# 5: [ANG NICHOLS 1] 15.000 -10.00
CHNL# 4: [ANG HARRINGTON 1] 0.0 -25.00
0.0 1.5000 3.0000 4.5000 6.0000 7.5000 9.0000 10.500 12.000 13.500 15.000
TIME (SECONDS)
THU, JUN 17 2004 11:22
FLT_14_1_PH MACHINE ANGLE