LAMAR BACK-TO-BACK DC LINK SYSTEM STUDIES (DRAFT)

Prepared for

Xcel Energy

By

Electranix Corporation
107 – 865 Waverley St.,
Winnipeg, MB, R3T 5P4
Canada

Manitoba HVDC Research Centre Inc.
244 Cree Crescent,
Winnipeg, MB, R3J 3W1
Canada

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Project Leader: Garth Irwin,
Phone: +1 204 953 1831
Fax: +1 204 953 1839
e-mail: gdi@electranix.com

Contributors:

Alan Wang	– Manitoba HVDC Research Centre
Dennis Woodford	– Electranix Corporation
Alfred Lee	– Teshmont Consultants
Saif Imran	– Teshmont Consultants

LAMAR Back-to-Back DC Link – Task 8 Final Report
Executive Summary (DRAFT for Review By Xcel Energy)

Garth Irwin
Electranix Corporation, Winnipeg, Manitoba, Canada
(204) 953-1831, gdi@electranix.com

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Introduction

Task 8 performs Loadflow and Dynamic Transient studies of the Lamar HVDC Back to Back system. This report summarizes results from 4 sets of studies:

1) Load-flow Studies of the HVDC System and Gobbler's Knob Wind Farm
2) Electro-Magnetic Transients Studies of the Gobbler's Knob Wind Farm (without the HVDC System operating)
3) Transient Stability Studies of the HVDC System
4) HVDC Electro-Magnetic Transients Studies

The original Task 8 specification was to perform loadflow and transient stability studies 1) and 3) above. Study 2) was requested by Xcel after concerns were raised about voltage regulation during the addition of the 160 MW wind farm (without the DC system). Study 4) above was essentially a repeat of Study 3), but using the PSCAD program (to more accurately represent the HVDC system and controls) and concentrating on the HVDC system and AC voltage regulation concerns near Lamar.

Load Flow Study Results (Wind Farm and HVDC System)

- The load flow studies indicate pre-existing undervoltage problems in the 115 kV system (near LAJUNTAW) if the BOONE 230/115 transformer is lost (this transformer's tap control regulates voltages in the 115 system during normal operation). The addition of the HVDC system slightly improves the situation (by providing reactive power through the 115 kV system from Lamar) but does not prevent the undervoltages for this contingency.
- DC Power Order reductions must be performed if the Lamar-Boone 230 line is tripped.
- When exporting the full 210 MW, undervoltages near the LAMAR 230 kV bus occur for many contingencies, unless an AC voltage control mode of the DC link is added.
- If an AC voltage control mode is added at the DC link, then full power can be imported or exported through all single contingencies.

EMT Wind Farm Results (Wind Farm Only)

- If the wind farm regulates reactive power so as to only perform power factor correction to .95 (as per the cancelled interconnection specification), voltage deviations would be outside of the valid range specified by the WSCC criteria.
- A continuous voltage regulating controller (such as an SVC or possibly if the wind farm used a doubly-wound induction generator) would have to be employed in order to regulate voltages within tolerance.

HVDC Transient Stability Results (HVDC System Only)

- The AC filters of the HVDC link must be tripped after a blocking operation (or power order reduction) to prevent long-duration overvoltages and overloading of the CTY LAM 25 MW machine.
- All electro-mechanical oscillations are damped (the emergency block of the HVDC system was the largest step-disturbance possible in the vicinity of the Lamar bus).
- These studies have been backed up with detailed electro-magnetic transients (PSCAD) models. This was done to properly represent the HVDC system operating in the system with a low short circuit ratio and to study voltage regulation with more accuracy.

HVDC PSCAD Results (HVDC System Only)

- All electro-mechanical oscillations in the studies performed were damped (using generic HVDC controls).
- The HVDC system showed an interaction with the 25 MW machine at CTY LAM, however the interactions were damped (using preliminary HVDC control models).
- Once the final HVDC control design is complete, a detailed study of the interactions between the HVDC system and nearby machines should be performed to see if a PSS damping controller is required (a provision for a PSS input is in the HVDC specification).
- The AC filters of the HVDC link must be tripped after a blocking operation (or power order reduction) to prevent long-duration overvoltages and overloading of the CTY LAM 25 MW machine.
- All voltages are within WSCC undervoltage criteria and meet the TOV criteria in the HVDC specification (as long as AC filters are tripped during blocking of the HVDC system or during power order reductions).

Conclusions

The addition of the Lamar HVDC Back to Back system (as per the design in the HVDC specification) will not have any adverse reactions on the WSCC system.

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Garth Irwin April 19, 2002
Electranix Corporation, Winnipeg, Manitoba, Canada
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Study 1) - Load-flow Studies

Load-flow studies were performed to ensure steady state voltages and power flows meet the NERC/WSCC Planning Standards. The studies also evaluated the effectiveness of an AC voltage control mode of the DC link added (at the cost of additional +50/-20 MVAR reactive power, which is representative of regulating reactive power that might be available in the DC design).

The first preliminary round of studies indicated numerous undervoltage problems in the 115 kV system near LAJUNTAW and BOONE (as well as additional problems). Further investigations revealed the original WSCC load flow files did not properly represent the tap changer capability of the BOONE 230/115 transformer.

A second round of studies (B Cases) was performed, repeating all cases, but with the BOONE 230/115 tap changer represented. Numerous undervoltages were reported (particularly during exporting power cases), demonstrating the poor voltage regulating characteristics of the Lamar 230 bus.

A third round of studies (C Cases) repeated all B) cases, but with an AC voltage control mode of the DC Link added (at the cost of additional 50 MVAR reactive power availability in the DC design). The AC voltage control mode of the DC link was included in the HVDC specification, so the following discussion relates to the C cases.

Load Flow Case List

Five base cases were analyzed, as summarized in Table 1:

Table 1 – Load Flow Case Descriptions

Base Case #	Back-to-Back (+ve from SPP to WSCC) (MW)	Wind Turbine (MW)	Change in WSCC Generation (MW)
1 (Orig Case)	0	0	0
2	210	0	-210
3	-210	0	210
4	50	160	-210
5	-210	160	50

Load Flow Data Modifications

A PSLF load flow data has been provided by XCEL Energy for this study (Case 05ha1sa.sav, received November 27, 2001). The following changes were made to the base system:

- The DC system has been represented as a generator (for load flow studies only).
- When the DC link is operated without AC voltage control, it is represented as a constant real power source (i.e. Q=0.0 since the reactive power consumed by the converters will be nearly balanced by switcheable AC filters)
- When the DC link is operated with an AC voltage control mode, it is represented as a generator that controls its terminal voltage to a set-point with reactive power limits of +50/-20 MVAR. (the voltage set-point is usually 1.04 pu – the bus volts is not set to 1.05 pu since the Ferranti effect can increase the bus volts above tolerance during contingencies or when a line is lightly loaded)
- A 40 mile line to the Gobbler's Knob wind farm was added for Cases 4 and 5
- The 160 MW wind farm (Cases 4 and 5) is modeled as a generator which controls the voltage at its terminals. Note that the wind farm would employ a switched shunt device which would switch in capacitor banks in discrete steps, but this is currently modeled using a continuous reactive power/voltage controller. This eliminates guess-work in the voltage set-points and bank-sizes of a switched shunt since the wind farm is at a preliminary stage. The continuous reactive power output of the SVC will approximate the switched shunt behavior.
- The switched shunt capacitor at Bus 70460 (Walsh 69 kV) was modified so its adjustment method is continuous (instead of discrete) to improve convergence qualities for many of the solved cases.
- The power imported/exported into/out of the WSCC system is handled by a proportionate reduction/increase of generation in zones 700 and 706.

Outage List
Each of the load flow cases listed in Table 1 is first run with all lines in service (the existing base case), but then single contingency outage cases are repeated with all lines (115 kV and above) and all devices shown in Appendix 1 out of service. This includes 13 lines, 5 transformers and 3 shunt reactors connected at these busses, each of which is removed from service.

Appendix 2 shows a table of each of the contingency cases run with the corresponding HVDC power, wind farm power and generation changes in the WSCC system. Note the power order reductions specified during contingency 2) (loss of LAMAR-BOONE 230 line).

The solved load flow for each of the base cases (with all devices in service) resulted in voltages at shunt reactor locations which were below the set-points of the switched shunt device, so contingency cases 19-21 (which remove the shunt reactors from service) are not required.

Contingency case 18 (removal of 115 kV line from BOONE 70060 to LAJUNTAW 70249) results in an islanded system in the LAJUNTAW system (i.e. there is no local generation to meet load requirements), so this contingency case is also not performed.

All cases were repeated with and without an AC voltage control mode in the HVDC link.

Load Flow Case List and Monitoring
As per the Study Plan, the power transferred through all devices in Zones 704 and 712 are monitored to ensure ratings are not exceeded, and the voltages at all busses in Zones 704 and 712 are monitored to ensure they are within specifications ($0.95 < Vpu < 1.05$).

Study 1) Load Flow Results
Load-flow study results indicate the following:

- The load flow studies indicate pre-existing undervoltage problems in the 115 kV system (near LAJUNTAW) if the BOONE 230/115 transformer is lost (this transformer's tap control regulates voltages in the 115 system during normal operation).
- When the DC link is added, no additional problems were observed while importing up to the full 210 MW.
- When exporting the full 210 MW, undervoltages near the LAMAR 230 kV bus occur for many contingencies, unless an AC voltage control mode of the DC link is added.
- If an AC voltage control mode is added at the DC link, then full power can be imported or exported through all single contingencies (note an anticipated power order reduction is required when the LAMAR-BOONE 230 line is lost).

- When the 160 MW wind farm is added, an AC voltage control mode of the DC link is still required to prevent undervoltages for the worst case during exporting a full 210 MW (net export of 50 MW from the WSCC system).

A total of 85 load flow cases have been considered: 5 different base cases * 17 cases each (base case plus 16 contingencies). The case list and monitoring is setup using the EPCL scripting facilities in PSLF. The PSLF output of voltages, transformer overloads and transmission line overloads is automatically processed into Excel spreadsheets for each of the 5 base cases and for each contingency case.

The results are shown in Appendix 3 (Case B - DC link without an AC voltage control mode) and in Appendix 4 (Case C - DC link has an AC voltage control mode with +50/-20 MVAR additional reactive power capacity).

1) The original base case (before the DC or wind farm is added) shows a few problems:
- Undervoltages at many 115 kV busses (near LAJUNTA) during contingency 7 (loss of BOONE 230/115 transformer) – typical voltages being around 0.91 pu . This transformer's tap control regulates voltages in the 115 system during normal operation, so when it is lost undervoltages occur. The 115 kV system is connected back to the grid through the LAMAR 230/115 transformer, but this connection is insufficient to maintain bus voltages.
- Minor overvoltages at LAMAR and COMANCHE 230 busses for contingencies 4 and 11 (worst overvoltage = 1.061 pu)
- Overloading of the LAJUNTAW 115/69 transformer occur for most contingencies (up to 1.043 pu)

2) When 210 MW is imported into the WSCC system via the DC (no wind farm), then:
- Similar conditions appear as in the pre-existing system (i.e. consistent undervoltages occur in 115 kV busses during the loss of the BOONE 230/115 transformer and overloading of the LAJUNTAW 115/69 transformer – worst case 1.034 pu)
- Note Cases B-2 and C-2 (contingency 2 - loss of LAMAR-BOONE 230 line) require a power order reduction to 100 MW to avoid overloading the LAMAR 230/115 transformer.
- For Case C-2 (when an AC voltage control mode is added to the DC link) contingency 2 (loss of LAMAR-BOONE 230 line), a slight overload of the LAMAR 230/115 transformer occurs (its 100 MVA rating is exceeded by the 100 MW DC power plus the small additional MVAR output for AC voltage control). If the emergency rating of this transformer is not sufficient, then the power order would have to be reduced (below 100 MW) so the DC MW+MVAR output will be less than 100 MVA.
- For Case C-2 (when an AC voltage control mode is added to the DC link) contingency 7 (loss of Boone 230/115 transformer), then the undervoltages in the 115 kV system are slightly improved, but still outside tolerance (despite controlling the LAMAR 230 kV bus to 1.04 pu). This shows that the tap changer

on the Boone 230/115 transformer is essential to control voltage in the 115 kV system .

3) When 210 MW is exported from the WSCC system via the DC (no wind farm), then:
- Without AC voltage control at the DC link terminals (Case B), it was observed;
  - severe undervoltages occur at the LAMAR 230 bus and nearby system for nearly all contingencies.
  - Note Case 5 did not solve (indicating severe undervoltages/overloads).
- With AC voltage control at the DC link terminals (Case C), then
  - most problems are solved, except for:
    - Minor undervoltages (.941 pu) during contingency 5 (loss of BOONE-COMANCHE 230 line). A detailed printout of the power flow and voltages at all critical busses is shown in Appendix 5. Note the DC link is exporting a full 210 MW and is generating 50 MVAR into the system. The minor undervoltage at LAMAR (.948) could be corrected if 52 MVAR (instead of 50 MVAR) capacity were available for the AC voltage controller. 64 MVARs would be required to control the Boone voltage to .95 pu.
    - Note: A DC power order reduction to 48 MW was required during contingency 2 (loss of LAMAR-BOONE 230 kV line) to maintain voltages and loadings within tolerance (based on a separate sensitivity study to determine the level of DC power order reduction necessary for adequate system operation).
- Similar conditions appear as in the pre-existing base case 1) above (i.e. consistent undervoltages occur in 115 kV busses during the loss of the BOONE 230/115 transformer and overloading of the LAJUNTAW 115/69 transformer)

4) This base case is similar to Case 2) above (in that a total of 210 MW is injected into the WSCC system) except now 160 MW comes from the wind farm (and 50 from the DC).
The results are nearly identical to 3) above, i.e. only the pre-existing problems occur (undervoltages during the loss of the BOONE 230/115 transformer and minor overloading of the LAJUNTAW 115/69 transformer for most cases). Note for contingency 2) (loss of LAMAR-BOONE 230 line) requires the power order to change from an import of 50 MW to an export of 60 MW so as to not overload the LAMAR 230/115 transformer.

5) This case has the wind farm operating at full capacity (160 MW) and a full export of 210 MW on the DC, resulting in a net draw of 50 MW from the WSCC system.
- If AC voltage control is not added at the DC link terminals (Case B), then
  - undervoltages occur at the LAMAR 230 bus and nearby system for contingency 2 (loss of LAMAR-BOONE 230 line). It is anticipated that a further power order reduction could be performed which would bring bus voltages within tolerance.
- If AC voltage control is added at the DC link terminals (Case C):

  - The system operates within tolerance for all contingencies without a power order reduction.
  - A minor overvoltage (1.052 pu) occurs during contingency 15 (loss of LAMAR-WILOW CK 115 line). This is due to the Ferranti effect (a lightly loaded line will have a higher voltage at its endpoint) and is easily solved if the set-point of the AC voltage control mode of the DC link is reduced slightly from its current set-point of 1.04 pu.
- The BOONE 230/115 transformer was slightly overloaded (.6% with AC voltage control and 2.3% without AC voltage control on the DC link) during contingency 2 (loss of LAMAR-BOONE 230 line).
- Similar conditions appear as in the base case 1) above (i.e. consistent undervoltages occur in 115 kV busses during the loss of the BOONE 230/115 transformer and overloading of the LAJUNTAW 115/69 transformer).

Study 1) Load Flow Discussion and Summary

Problems in the pre-existing system are evident:

- When the BOONE 230/115 transformer is lost (the loss of this tap-changer results in undervoltages in the 115 kV system near LAJUNTA).
- Minor overloading of the LAJUNTAW 115/69 kV transformer (around 5% overload), even in steady state with all devices in service (Case 1B – contingency 1).

The dominant critical contingency cases are:

1) Loss of the LAMAR-BOONE 230 kV line (contingency 2).
   This case necessitates a power order reduction in order to avoid overloading the LAMAR 230/115 transformer). The power order reductions required are:
   - Case 2 (Importing 210 MW from DC) – reduction to Importing of 100 MW from DC.
   - Case 3 (Exporting 210 MW to DC) – reduction to Exporting of 48 MW to DC (only possible if combined with AC voltage control mode of the DC link).
   - Case 4 (Importing 50 from DC + 160 MW from wind) – reversal to Exporting of 60 MW to DC.
   - Case 5 (Exporting 210 to DC + 160 from wind) – no reduction required.

   These levels of power order reductions (100 MW and 48 MW) are based on steady state load flow studies and cannot necessarily be applied in the final system without a detailed PSCAD transients study. The very low short circuit ratio when the Lamar Boone line trips can be challenging for HVDC system operation and the dynamic operation will likely determine the power order reduction levels (not the steady state criteria).

2) Loss of the BOONE 230/115 kV transformer (contingency 7).
   In nearly all cases this resulted in extensive undervoltages in the 115 kV system near LAJUNTA. The additional power imported from the DC link helps the

situation (via the 115 system connection at LAMAR), but is not sufficient to prevent the undervoltages (even if the AC voltage control mode of the DC link is used).

3) Loss of the BOONE-COMANCHE 230 Line (contingency 5).
If an AC voltage control mode is added at the DC link (with limits of +50/-20 MVAR), then this will hold the LAMAR 230 bus at .948 pu and the BOONE 230 Bus at .941 pu., which are slightly below tolerance.

   Subsequent studies showed 52 MVAR capacity instead of 50 MVAR (in addition to the 105 MVARs of AC filters) was sufficient to bring the Lamar 230 volts to .95 pu, but 64 MVARs would be required to bring the Boone 230 volts to .95 pu. A possible solution to fix the undervoltage at Boone during this contingency would be a slight increase in the exciter voltage reference settings at Comanche (this was not studied).

The benefit of adding an AC voltage control mode to the DC link is evident when exporting power out of the WSCC system.

- Without the AC voltage control mode of the DC link (refer to Case 3B), severe undervoltages exist near LAMAR 230 for nearly all contingencies.
- With +50/-20 MVAR reactive power limits in the AC voltage control mode of the DC link (refer to Case 3C) then operation is successful and within tolerances.

Study 2) - Gobbler's Knob Wind Farm Studies

Concerns about the interconnection specification for the Wind Farm (and the demise of Enron) were raised requiring additional studies to be performed (these were not part of the original Task 8 specification). These studies looked at the reactive power criteria as specified in the cancelled interconnection specification and the impact on system voltage regulation if the wind farm was added without the HVDC system in operation.

PSCAD electro-magnetic transients studies were performed using an induction generator in a stall regulated wind farm. The induction generator model was a minimally sized machine operating near its maximum ratings. Results indicate:

- If the wind farm regulates reactive power so as to only perform power factor correction to .95 pu (as per the cancelled interconnection specification), voltage deviations would be outside of the valid range specified by the WSCC criteria.
- A continuous voltage regulating device (such as an SVC or possibly if the wind farm used a doubly-wound induction generator) would have to be employed in order to regulate voltages within tolerance.

If the induction generator were over-rated, then the reactive power consumption would be less severe, but the .95 pu reactive power specification would still be problematic. The nearest active voltage regulating devices in this system are the Comanche generators and the CTY LAM machine on the 115 kV system (a small 25 MW machine). These devices are too far from where the wind-farm is to connect to be useful to regulate voltages effectively.

These results were generated using typical machine data (from an existing induction generator applied in a wind farm application) and applied to the AC system near Lamar. The .95 pu power factor correction specification may be suitable in some systems (which have better voltage regulation) but a pure power factor correction specification is not suitable in this application.

A double-wound induction generator (with Voltage Sourced Converter controls on the rotor circuit) was not investigated, but could be an alternative provided voltage regulation was performed to satisfy WSCC criteria. Based on the lack of concrete specifications for the wind farm, further studies looked at the HVDC system in isolation without the impact of the wind farm.

This underlines the need for detailed studies before a significant wind farm (such as this 160 MW application) is added to the system.

Study 3) - Stability Studies

Stability studies were performed to ensure electro-mechanical oscillations were damped during large disturbances of the HVDC system and that voltages were within WSCC criteria. PSLF stability data has been provided by XCEL Energy for this study (Case 05ha1sa.sav and 05ha1s1.dyd, received November 27, 2001).

The impact of the Gobbler's Knob wind farm and possible interactions with the HVDC system were not analyzed in this stage of the studies. Study 2) above indicated that the wind farm project was in a preliminary state and that a suitable design and interconnection specification was not finalized. The high degree of uncertainty in the design and specification would introduce too many variables and options to study the combined operation of the wind farm and HVDC system in sufficient detail.

The HVDC system was represented as a simple PQ load in the stability program due to limitations and complexities in stability HVDC models while operating under very low Short Circuit Ratios (as occurs when the Lamar – Boone 230 line is tripped). The PQ load values were stepped to lower levels to represent an HVDC power order reduction as required. This representation is considered valid because the worst case and the largest step disturbance (for the study the stability of electro-mechanical oscillations) occurs when the DC system is tripped out. For the study of ac voltage transients and interactions with nearby machines, the HVDC system was represented in detail in Study 4) below.

The closest machine to the Lamar system is a small 25 MW machine connected near the Willow Creek 115 bus (at CTY LAM). The possibility of a mechanical oscillation of this machine against the system past Boone (initiated by a disturbance near Lamar) was investigated.

The base cases investigated using the transient stability program were:

1) Original Base Case (before HVDC System was added)
2) DC System at full import capability (210 MW)
3) DC System at full export capability (-210 MW)

Disturbances investigated were:

- Case 1a (import and export) - Emergency Block of HVDC system without tripping of filters
- Case 1b (import and export) - Emergency Block of HVDC system and tripping of filters
- Case 2 (import and export) - Fault on Lamar-Boone 230 line, trip and HVDC power order reduction
- Case 3 (import and export) - Faults on Lamar-Willow Creek 115 line, trip
- Case 4 (import and export) - Faults on LajuntaT-Willow Creek 115 line, trip

Stability – Acceptance Criteria

The document entitled "NERC/WSCC Planning Standards" specifies allowable criteria and limits which must be met before new equipment can be added to the system. This portion of study considers stability criteria for N-1 single contingencies.

For each of the base cases, each contingency will be considered and specified bus voltages will be monitored to ensure they are within specifications. The voltage criteria specifies the time duration of voltage dips not to exceed 20% for 20 cycles. In addition, electro-mechanical oscillations must be damped over the 10 second duration of each simulation (reference Table W-1 and Figure W-1, pages 12-13 of NERC/WSCC Planning Standards).

In addition, TOV voltage specifications from the HVDC specifications (Figure 8.1 on Page 48) in the document entitled "Xcel Energy Services, Inc., Request for Proposal LB1003, 210 Megawatt Back-to-Back Dc Converter at Lamar, Co." (dated April 5, 2002) were followed. These provide for maximum allowable voltages as a function of time.

- TOV values must be controlled to no more than 1.3 times the max continuous operating voltage within 50 msec.
- TOV values must be controlled to no more than 1.2 times the max continuous operating voltage within 200 msec.
- TOV values must be controlled to within 1% of normal operation voltage within 2 sec.

Study 3) Transient Stability Results

Appendix 6.1-.6.3 contains PSLF simulation traces for each of the above cases. The cases were run for 10 seconds (as per the WSCC planning guide) to ensure all oscillations were damped within this period.

- Appendix 6.1 – Original Base Case (without DC)
- Appendix 6.2 – Importing 210 MW
- Appendix 6.3 – Exporting 210 MW

For each case run, time domain graphs of the following quantities are shown:

- Plot 1 - 230 kV voltages near Lamar and Boone
- Plot 2 - 115 kV voltages near Lamar and Boone
- Plot 5 - CTY LAM machine angle

In addition to the plots shown, real and reactive power through the transmission lines and transformers were monitored to ensure they are within ratings for the single contingencies studied (the final PQ levels were verified from loadflow studies performed in Study 1) above).

Electro-mechanical oscillations were damped for all cases.

Notes for Base Case 1) - Pre-existing system before the DC system was added:

- Case 3 (fault on Lamar-Willow Creek 115 kV line and trip) resulted in post-disturbance voltages above 1.05 pu at the Lamar 230 and 115 busses. The load flow studies in Study 1 above did not show an overvoltage for this contingency. The difference between the load flow and transient stability results is that tap changers and switched shunt devices are not operational during transient stability simulations. Therefore the overvoltages following this disturbance can only be reduced by operation of tap-changers or the switching of a reactor bank.

Notes Common to Base Cases 2 and 3) - HVDC Importing and Exporting 210 MW:

- Voltages for Cases 1a (block of DC without tripping filters) are above specification.
- Voltages for Cases 1b (block of DC with tripping of filters) are within tolerance, indicating that HVDC AC filters must be tripped after the DC is blocked.
- Damped oscillations are evident in the voltages near Lamar when the Lamar-Boone 230 kV line is tripped (Case 2i). The oscillations are at 2.5 Hz and are primarily due to the CTY LAM machine (in the 115 kV system near Willow Creek).
- Case 2i and 2e (fault on Lamar-Boone 230 kV line and trip) show dynamic voltage swings which are damped, but are above the TOV 2 second limit. The oscillations are at 2.5 Hz and are primarily due to the CTY LAM machine (near the 115 kV system at Willow Creek) and its response to a stepped PQ load change (this is how the HVDC power order reduction is performed in the stability program). More detailed studies were performed to study this using the PSCAD program (see Studies in 4 below). The PSCAD results (with the HVDC system now represented in detail) show the oscillation with a higher degree of damping and show the voltages to be within the TOV limits.

Notes for Base Case 2) – HVDC System Importing 210 MW:

- Case 3i (fault on Lamar-Willow Creek 115 kV line and trip) shows steady state voltages higher than 1.05. This is due to the representation of the DC system as a constant PQ load in the stability program. In this simple representation, the DC system continues to operate at the same PQ levels even after the line trips. In a more detailed model, the AC voltage control mode of the HVDC system would have reduced the voltage back down to the pre-fault levels (this was not represented in the stability program but is represented in the detailed PSCAD

models in Studies 4 below).

The representation of the HVDC system as a simple PQ load is valid when studying electro-mechanical oscillations and machine swings/stability (particularly since the worst case disturbance occurs when the HVDC system is suddenly blocked), but will not properly represent the dynamic voltage regulation in the Lamar system and is thus not suitable to look at HVDC interactions with nearby machines. To study these aspects, additional studies were performed using a generic but detailed HVDC system model in the PSCAD model as reported in Study 4) below.

Study 4) – HVDC Electro-Magnetic Transients Studies

PSCAD studies were performed to represent the HVDC system in more detail and look for possible voltage stability problems and electro-mechanical oscillations against the CTY LAM machine. The concern was that the Lamar system has a very low Short Circuit Ratio (particularly when the Lamar-Boone line is tripped) and that the transient stability representation of HVDC systems would not be accurate or even feasible. For this reason, the HVDC system and controls were represented in detail, as was the 25 MW generator/ST3A exciter/gas turbine at the CTY LAM bus (which feeds into the Willow Creek 115 kV system).

The PSCAD system diagram for the circuit and generic HVDC controls used in this study is shown in Appendix 7. The model used in the specification studies was used as a starting point. The system includes detailed line models of the 230 and 115 kV system in the circuits between Lamar and Boone, with loads and system equivalents as per the model used as per the specification model. Note that the system represented in this study will have a higher Short Circuit Ratio then that used in the specification (which was a worst case model), due mainly to the addition of the CTY LAM 25 MW machine.

The cases from Study 3) above were repeated (except now on PSCAD instead of a transient stability program). Results are shown in Appendix 8, with plots of AC 230 Volts, AC 115 Volts, CTY LAM machine angle and HVDC quantities.

Disturbances investigated were:

- Case 1a (import and export) - Emergency Block of HVDC system without tripping of filters
- Case 1b (import and export) - Emergency Block of HVDC system and tripping of filters
- Case 2 (import and export) - Fault on Lamar-Boone 230 line, line trip and HVDC power order reduction
- Case 3 (import and export) - Fault on Lamar-Willow Creek 115 line, trip
- Case 4 (import and export) - Fault on LajuntaT-Willow Creek 115 line, trip

Study 4) Results:

- All electro-mechanical oscillations in the studies performed were damped (using generic HVDC controls).

- The HVDC system showed an interaction with the 25 MW machine at CTY LAM. Early studies performed with a faster master power controller resulted in 2.5 Hz oscillations which were critically damped. In the studies shown in this report (using generic HVDC controls), a slow dc voltage signal into the Master Power Controller was sufficient to ensure oscillations against the 25 MW machine were damped.
- Once the final HVDC control design is complete, a detailed study of the interactions between the HVDC system and nearby machines should be performed to see if a PSS damping controller is required (a provision for a PSS input is in the HVDC specification).
- The AC filters of the HVDC link must be tripped after a blocking operation (or power order reduction) to prevent long-duration overvoltages and overloading of the CTY LAM machine.
- All voltages are within WSCC undervoltage criteria and meet the TOV criteria in the HVDC specification (as long as AC filters are tripped during blocking of the HVDC system or during power order reductions).

Task 8 Conclusions

1) HVDC Power Order reductions must be performed if the Lamar-Boone 230 kV line is tripped (this is provided for in the HVDC specification). The final levels of power transfer during this contingency will depend largely on the dynamic performance of the HVDC scheme selected while operating under very low short circuit ratios.
2) The AC filters of the HVDC system must be tripped if the DC link is blocked (this is provided for in the HVDC specification).
3) If an AC voltage control mode is added at the DC link, then full power can be imported or exported through all single contingencies (additional reactive power capability and an AC voltage control mode is provided for in the HVDC specification).
4) The HVDC system showed an interaction with the 25 MW machine at CTY LAM, however the interactions were damped (using preliminary HVDC control models).
5) Once the final HVDC control design is complete, a detailed study of the interactions between the HVDC system and nearby machines should be performed to see if a PSS damping controller is required (a provision for a PSS input is provided for in the HVDC specification).
6) The pre-existing system (before the HVDC system is added) can result in undervoltages in the 115 kV system near LAJUNTA if the BOONE 230/115 transformer is lost. The addition of the HVDC system slightly improves the situation (by providing reactive power through the 115 kV system from Lamar) but does not prevent the undervoltages for this contingency.
7) Study 2) results indicate that if the wind farm (without the DC link operating) regulates reactive power so as to only perform power factor correction to .95 pu (as per the cancelled interconnection specification), voltage deviations would be outside of the valid range specified by the WSCC criteria.
8) Study 2) results indicate that a continuous voltage regulating device (such as an SVC or possibly if the wind farm used a doubly-wound induction generator) would have to be employed in order to regulate voltages within tolerance.

The addition of the Lamar HVDC Back to Back system (as per the design in the HVDC specification) will not have any adverse reactions on the WSCC system.

Acknowledgements

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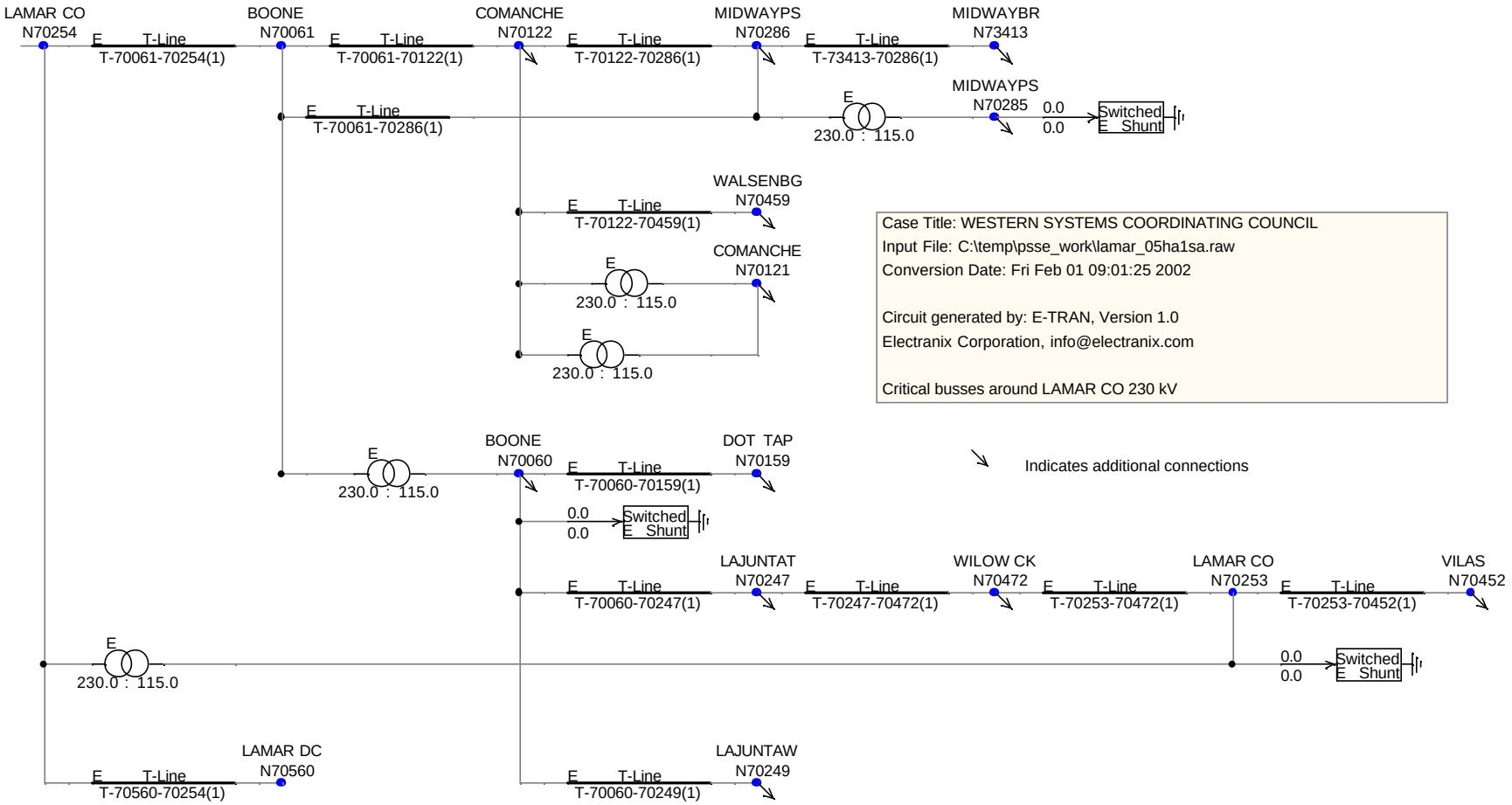


Appendix 1 - Load Flow Bus Specification

Case #	Outage	Bus #'s	1) Original			2) Import 210 MW			3) Export 210 MW			4) Import 50 + 160 Wind			5) Export 210 + 160 Wind		
			DC	Wind	? Gen	DC	Wind	? Gen	DC	Wind	? Gen	DC	Wind	? Gen	DC	Wind	? Gen
1	All Lines and Transformers In Service		0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
2	230 Line	70254-70061	0	0	0	100*	0	-210	-48*	0	210	-60*	160	-210	-210	160	50
3	230 Line	70254-70560	0	0	0	0#	0	-210	0#	0	210	0#	160	-210	0#	160	50
4	230/115 Transf	70254-70253	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
5	230 Line	70061-70122	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
6	230 Line	70061-70286	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
7	230/115 Transf	70061-70060	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
8	230 Line	70122-70286	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
9	230 Line	70122-70459	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
10	230/115 Transf	70122-70121	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
11	230 Line	70286-73413	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
12	230/115 Transf	70286-70285	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
13	115 Line	70247-70472	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
14	115 Line	70253-70452	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
15	115 Line	70253-70472	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
16	115 Line	70060-70159	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
17	115 Line	70060-70247	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
18	115 Line	70060-70249	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
19	115 Shunt React	70285	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
20	115 Shunt React	70253	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50
21	115 Shunt React	70060	0	0	0	210	0	-210	-210	0	210	50	160	-210	-210	160	50

Appendix 2 - Case Descriptions - DC, Wind Farm and Change in WSCC Generation (MW)

Notes: - * indicates a dc power order reduction

- # indicates a dc shutdown due to loss of connector line from LAMAR DC to LAMAR CO 230 bus

Appendix 3 – Load Flow Study Results
(Without AC Voltage Control Capability of HVDC Link)

Zones for the criteria check are: **Base Case 05ha1sa-1b - Original Load Flow**
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	1b_LF01	Base Case (all in service)	2	1b_LF02	Lamar Co 70254-Boone 70061 230 Line
3	1b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	1b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	1b_LF05	Boone 70061-Comanche 70122 230 Line	6	1b_LF06	Boone 70061-Midwayps 70286 230 Line
7	1b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	1b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	1b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	1b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	1b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	1b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	1b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	1b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	1b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	1b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	1b_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria															Violation	Actual	
bus	name	kV	zone	min volts	max volts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70122	COMANCHE	230.0	704	0.95	1.05											x							1	1.051	1.051
70549	APT MEM	115.0	712	0.95	1.05							x											1	0.928	0.928
70030	APT PARK	115.0	712	0.95	1.05							x											1	0.931	0.931
70031	APT TAP	115.0	712	0.95	1.05							x											1	0.937	0.937
70022	APT TAP2	115.0	712	0.95	1.05							x											1	0.926	0.926
70060	BOONE	115.0	712	0.95	1.05							x											1	0.910	0.910
70158	DOT	115.0	712	0.95	1.05							x											1	0.910	0.910
70159	DOT TAP	115.0	712	0.95	1.05							x											1	0.913	0.913
70247	LAJUNTAT	115.0	712	0.95	1.05							x											1	0.939	0.939
70249	LAJUNTAW	115.0	712	0.95	1.05							x											1	0.864	0.864
70254	LAMAR CO	230.0	712	0.95	1.05				x		x												2	1.051	1.061
70560	LAMAR DC	230.0	712	0.95	1.05				x		x												2	1.051	1.061

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-1b - Original Load Flow**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	1b_LF01	Base Case (all in service)	2	1b_LF02	Lamar Co 70254-Boone 70061 230 Line
3	1b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	1b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	1b_LF05	Boone 70061-Comanche 70122 230 Line	6	1b_LF06	Boone 70061-Midwayps 70286 230 Line
7	1b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	1b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	1b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	1b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	1b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	1b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	1b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	1b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	1b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	1b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	1b_LF17	Boone 70060-Lajuntat 70247 115 Line			

no transmission lines in the selected area(s) and with the selected voltage level(s) have overloads greater than the criteria

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-1b - Original Load Flow**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case n	Case Id	Case Description	Case n	Case Id	Case Description
1	1b_LF01	Base Case (all in service)	2	1b_LF02	Lamar Co 70254-Boone 70061 230 Line
3	1b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	1b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	1b_LF05	Boone 70061-Comanche 70122 230 Line	6	1b_LF06	Boone 70061-Midwayps 70286 230 Line
7	1b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	1b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	1b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	1b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	1b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	1b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	1b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	1b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	1b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	1b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	1b_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus						Base	Cases where loading exceeds criteria																	O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct		rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1		25.0 M																		16	1.043

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Multi-case Voltage Summary

Zones for the criteria check are: **Base Case 05ha1sa-2b - DC Power = 210 MW(Import)**
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	2b_LF01	Base Case (all in service)	2	2b_LF02a	Lamar Co 70254-Boone 70061 230 Line - PDC 100 MW
3	2b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	2b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	2b_LF05	Boone 70061-Comanche 70122 230 Line	6	2b_LF06	Boone 70061-Midwayps 70286 230 Line
7	2b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	2b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	2b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	2b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	2b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	2b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	2b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	2b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	2b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	2b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	2b_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria															Violation	Actual	
bus	name	kV	zone	min volts	max volts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70549	APT MEM	115.0	712	0.95	1.05							x											1	0.925	0.925
70030	APT PARK	115.0	712	0.95	1.05							x											1	0.928	0.928
70031	APT TAP	115.0	712	0.95	1.05							x											1	0.934	0.934
70022	APT TAP2	115.0	712	0.95	1.05							x											1	0.922	0.922
70060	BOONE	115.0	712	0.95	1.05							x											1	0.905	0.905
70158	DOT	115.0	712	0.95	1.05							x											1	0.906	0.906
70159	DOT TAP	115.0	712	0.95	1.05							x											1	0.908	0.908
70247	LAJUNTAT	115.0	712	0.95	1.05							x											1	0.925	0.925
70249	LAJUNTAW	115.0	712	0.95	1.05							x											1	0.859	0.859
70301	NTHRIDGE	115.0	712	0.95	1.05							x											1	0.949	0.949

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-2b - DC Power = 210 MW(Import)**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	2b_LF01	Base Case (all in service)	2	2b_LF02a	Lamar Co 70254-Boone 70061 230 Line - PDC 100 MW
3	2b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	2b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	2b_LF05	Boone 70061-Comanche 70122 230 Line	6	2b_LF06	Boone 70061-Midwayps 70286 230 Line
7	2b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	2b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	2b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	2b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	2b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	2b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	2b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	2b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	2b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	2b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	2b_LF17	Boone 70060-Lajuntat 70247 115 Line			

no transmission lines in the selected area(s) and with the selected voltage level(s) have overloads greater than the criteria

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-2b - DC Power = 210 MW(Import)**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case n	Case Id	Case Description	Case n	Case Id	Case Description
1	2b_LF01	Base Case (all in service)	2	2b_LF02a	Lamar Co 70254-Boone 70061 230 Line - PDC 100 MW
3	2b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	2b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	2b_LF05	Boone 70061-Comanche 70122 230 Line	6	2b_LF06	Boone 70061-Midwayps 70286 230 Line
7	2b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	2b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	2b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	2b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	2b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	2b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	2b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	2b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	2b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	2b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	2b_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus					Base	Cases where loading exceeds criteria															O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1	25.0 M																		16	1.034
70253	LAMAR CO	115.0	712	70254	LAMAR CO	230.0	712	1	100.0 M																		0	1.000

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Zones for the criteria check are: **Base Case 05ha1sa-3b - DC Power = -210 MW(Export)**
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	3b_LF01	Base Case (all in service)	2	3b_LF02_bx	Lamar Co 70254-Boone 70061 230 Line - PDC= -40 MW
3	3b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	3b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	3b_LF05	**Boone 70061-Comanche 70122 230 Line (not solved**	6	3b_LF06	Boone 70061-Midwayps 70286 230 Line
7	3b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	3b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	3b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	3b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	3b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	3b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	3b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	3b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	3b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	3b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	3b_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria															Violation	Actual	
bus	name	kV	zone	min volts	max volts	1	2	3	4	~~5~~	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70549	APT MEM	115.0	712	0.95	1.05					-		x											1	0.878	0.878
70030	APT PARK	115.0	712	0.95	1.05					-		x											1	0.883	0.883
70031	APT TAP	115.0	712	0.95	1.05					-		x											1	0.892	0.892
70022	APT TAP2	115.0	712	0.95	1.05					-		x											1	0.874	0.874
70060	BOONE	115.0	712	0.95	1.05					-		x											1	0.844	0.844
70158	DOT	115.0	712	0.95	1.05					-		x											1	0.847	0.847
70159	DOT TAP	115.0	712	0.95	1.05					-		x											1	0.850	0.850
70247	LAJUNTAT	115.0	712	0.95	1.05					-		x										x	2	0.865	0.886
70249	LAJUNTAW	115.0	712	0.95	1.05					-		x											1	0.792	0.792
70253	LAMAR CO	115.0	712	0.95	1.05		x			-	x	x						x	x	x		x	7	0.914	0.942
70254	LAMAR CO	230.0	712	0.95	1.05	x	x		x	-	x	x	x	x	x	x	x	x	x	x	x	x	15	0.890	0.947
70560	LAMAR DC	230.0	712	0.95	1.05	x	x		x	-	x	x	x	x	x	x	x	x	x	x	x	x	15	0.887	0.944
70301	NTHRIDGE	115.0	712	0.95	1.05					-		x											1	0.915	0.915
70452	VILAS	115.0	712	0.95	1.05					-												x	1	0.945	0.945
70472	WILOW CK	115.0	712	0.95	1.05		x			-		x						x				x	4	0.920	0.950

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-3b - DC Power = -210 MW(Export)**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case	Case Id	Case Description	Case n	Case Id	Case Description
1	3b_LF01	Base Case (all in service)	2	3b_LF02_bx	Lamar Co 70254-Boone 70061 230 Line - PDC=-40 MW
3	3b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	3b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	3b_LF05	Boone 70061-Comanche 70122 230 Line (not solved	6	3b_LF06	Boone 70061-Midwayps 70286 230 Line
7	3b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	3b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	3b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	3b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	3b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	3b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	3b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	3b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	3b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	3b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	3b_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus						Base	Cases where loading exceeds criteria																	O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	sect	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70301	NTHRIDGE	115.0	712	70285	MIDWAYPS	115.0	791	1	1	576.8 A																		1	1.020

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-3b - DC Power = -210 MW(Export)**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case n	Case Id	Case Description	Case n	Case Id	Case Description
1	3b_LF01	Base Case (all in service)	2	3b_LF02_bx	Lamar Co 70254-Boone 70061 230 Line - PDC=-40 MW
3	3b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	3b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	3b_LF05	Boone 70061-Comanche 70122 230 Line (not s	6	3b_LF06	Boone 70061-Midwayps 70286 230 Line
7	3b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	3b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	3b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	3b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	3b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	3b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	3b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	3b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	3b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	3b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	3b_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus					Base	Cases where loading exceeds criteria															O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1	25.0 M																		14	1.039

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Multi-case Voltage Summary

Base Case 05ha1sa-4b - DC Power = 50 MW(Import), Wind Farm = 160 MW

Zones for the criteria check are:
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	4b_LF01	Base Case (all in service)	2	4b_LF02c	Lamar Co 70254-Boone 70061 230 Line - PDC=-60 MW
3	4b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	4b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	4b_LF05	Boone 70061-Comanche 70122 230 Line	6	4b_LF06	Boone 70061-Midwayps 70286 230 Line
7	4b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	4b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	4b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	4b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	4b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	4b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	4b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	4b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	4b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	4b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	4b_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria															Violation	Actual	
bus	name	kV	area	min volts	max volts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70549	APT MEM	115.0	12	0.95	1.05							x											1	0.922	0.922
70030	APT PARK	115.0	12	0.95	1.05							x											1	0.925	0.925
70031	APT TAP	115.0	12	0.95	1.05							x											1	0.932	0.932
70022	APT TAP2	115.0	12	0.95	1.05							x											1	0.919	0.919
70060	BOONE	115.0	12	0.95	1.05							x											1	0.901	0.901
70158	DOT	115.0	12	0.95	1.05							x											1	0.901	0.901
70159	DOT TAP	115.0	12	0.95	1.05							x											1	0.904	0.904
70247	LAJUNTAT	115.0	12	0.95	1.05							x											1	0.918	0.918
70249	LAJUNTAW	115.0	12	0.95	1.05							x											1	0.854	0.854
70301	NTHRIDGE	115.0	12	0.95	1.05							x											1	0.947	0.947

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-4b - DC Power = 50 MW(Import), Wind Farm = 160 MW**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	4b_LF01	Base Case (all in service)	2	4b_LF02c	Lamar Co 70254-Boone 70061 230 Line - PDC=-60 M
3	4b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	4b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	4b_LF05	Boone 70061-Comanche 70122 230 Line	6	4b_LF06	Boone 70061-Midwayps 70286 230 Line
7	4b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	4b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	4b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	4b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	4b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	4b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	4b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	4b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	4b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	4b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	4b_LF17	Boone 70060-Lajuntat 70247 115 Line			

no transmission lines in the selected area(s) and with the selected voltage level(s) have overloads greater than the criteria

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-4b - DC Power = 50 MW(Import), Wind Farm = 160 MW**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case	Case Id	Case Description	Case n	Case Id	Case Description
1	4b_LF01	Base Case (all in service)	2	4b_LF02c	Lamar Co 70254-Boone 70061 230 Line - PDC=-60 MW
3	4b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	4b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	4b_LF05	Boone 70061-Comanche 70122 230 Line	6	4b_LF06	Boone 70061-Midwayps 70286 230 Line
7	4b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	4b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	4b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	4b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	4b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	4b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	4b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	4b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	4b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	4b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	4b_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus						Base	Cases where loading exceeds criteria																O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct		rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1		25.0 M																		16	1.043
70253	LAMAR CO	115.0	712	70254	LAMAR CO	230.0	712	1		100.0 M																		0	0.984

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Base Case 05ha1sa-5b - DC Power = -210 MW(Export), Wind Farm = 160 MW

Zones for the criteria check are:
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	5b_LF01	Base Case (all in service)	2	5b_LF02	Lamar Co 70254-Boone 70061 230 Line
3	5b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	5b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	5b_LF05	Boone 70061-Comanche 70122 230 Line	6	5b_LF06	Boone 70061-Midwayps 70286 230 Line
7	5b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	5b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	5b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	5b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	5b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	5b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	5b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	5b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	5b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	5b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	5b_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria															Violation	Actual	
bus	name	kV	zone	min volts	max volts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70549	APT MEM	115.0	712	0.95	1.05							x											1	0.918	0.918
70030	APT PARK	115.0	712	0.95	1.05							x											1	0.921	0.921
70031	APT TAP	115.0	712	0.95	1.05							x											1	0.928	0.928
70022	APT TAP2	115.0	712	0.95	1.05							x											1	0.915	0.915
70060	BOONE	115.0	712	0.95	1.05							x											1	0.896	0.896
70158	DOT	115.0	712	0.95	1.05							x											1	0.897	0.897
70159	DOT TAP	115.0	712	0.95	1.05							x											1	0.900	0.900
70247	LAJUNTAT	115.0	712	0.95	1.05		x					x											2	0.923	0.934
70249	LAJUNTAW	115.0	712	0.95	1.05							x											1	0.849	0.849
70253	LAMAR CO	115.0	712	0.95	1.05		x																1	0.945	0.945
70301	NTHRIDGE	115.0	712	0.95	1.05							x											1	0.944	0.944
70472	WILOW CK	115.0	712	0.95	1.05		x																1	0.937	0.937

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-5b - DC Power = -210 MW(Export), Wind Farm = 160 MW**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	5b_LF01	Base Case (all in service)	2	5b_LF02	Lamar Co 70254-Boone 70061 230 Line
3	5b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	5b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	5b_LF05	Boone 70061-Comanche 70122 230 Line	6	5b_LF06	Boone 70061-Midwayps 70286 230 Line
7	5b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	5b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	5b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	5b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	5b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	5b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	5b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	5b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	5b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	5b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	5b_LF17	Boone 70060-Lajuntat 70247 115 Line			

no transmission lines in the selected area(s) and with the selected voltage level(s) have overloads greater than the criteria

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-5b - DC Power = -210 MW(Export), Wind Farm = 160 MW**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case n	Case Id	Case Description	Case n	Case Id	Case Description
1	5b_LF01	Base Case (all in service)	2	5b_LF02	Lamar Co 70254-Boone 70061 230 Line
3	5b_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	5b_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	5b_LF05	Boone 70061-Comanche 70122 230 Line	6	5b_LF06	Boone 70061-Midwayps 70286 230 Line
7	5b_LF07	Boone 70061-Boone 70060 230/115 Transf	8	5b_LF08	Comanche 70122-Midwayps 70286 230 Line
9	5b_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	5b_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	5b_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	5b_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	5b_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	5b_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	5b_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	5b_LF16	Boone 70060-Dot Tap 70159 115 Line
17	5b_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus						Base	Cases where loading exceeds criteria																	O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct		rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70060	BOONE	115.0	712	70061	BOONE	230.0	712	1		150.0 M																		1	1.023
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1		25.0 M																		16	1.033

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Appendix 4 – Load Flow Study Results
(+50/-20 MVAR AC Voltage Control Capability of HVDC Link)

Multi-case Voltage Summary

Zones for the criteria check are: **Base Case 05ha1sa-2c - DC Power = 210 MW(Import), dc bus at 1.04 p.u.**
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	2c_LF01	Base Case (all in service)	2	2c_LF02a	Lamar Co 70254-Boone 70061 230 Line - PDC 100 MW
3	2c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	2c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	2c_LF05	Boone 70061-Comanche 70122 230 Line	6	2c_LF06	Boone 70061-Midwayps 70286 230 Line
7	2c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	2c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	2c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	2c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	2c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	2c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	2c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	2c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	2c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	2c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	2c_LF17	Boone 70060-Lajuntat 70247 115 Line			

bus	Bus name	kV	zone	min volts	max volt	Cases where voltage is outside criteria 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Violation count	Actual min volts	Actual max volts
70549	APT MEM	115.0	712	0.95	1.05							x											1	0.928	0.928
70030	APT PARK	115.0	712	0.95	1.05							x											1	0.931	0.931
70031	APT TAP	115.0	712	0.95	1.05							x											1	0.937	0.937
70022	APT TAP2	115.0	712	0.95	1.05							x											1	0.925	0.925
70060	BOONE	115.0	712	0.95	1.05							x											1	0.909	0.909
70158	DOT	115.0	712	0.95	1.05							x											1	0.909	0.909
70159	DOT TAP	115.0	712	0.95	1.05							x											1	0.912	0.912
70247	LAJUNTAT	115.0	712	0.95	1.05							x											1	0.931	0.931
70249	LAJUNTAW	115.0	712	0.95	1.05							x											1	0.863	0.863

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-2c - DC Power = 210 MW(Import), dc bus voltage at 1.04 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	2c_LF01	Base Case (all in service)	2	2c_LF02a	Lamar Co 70254-Boone 70061 230 Line - PDC 100 MW
3	2c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	2c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	2c_LF05	Boone 70061-Comanche 70122 230 Line	6	2c_LF06	Boone 70061-Midwayps 70286 230 Line
7	2c_LF07	Boone 70061-Boone 70060 230/115 Trans	8	2c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	2c_LF09	Comanche 70122-Walsenbg 70459 230 Lir	10	2c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	2c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	2c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	2c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	2c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	2c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	2c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	2c_LF17	Boone 70060-Lajuntat 70247 115 Line			

no transmission lines in the selected area(s) and with the selected voltage level(s) have overloads greater than the criteria

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-2c - DC Power = 210 MW(Import), dc bus voltage at 1.04 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case	Case Id	Case Description	Case r	Case Id	Case Description
1	2c_LF01	Base Case (all in service)	2	2c_LF02a	Lamar Co 70254-Boone 70061 230 Line - PDC 100 MW
3	2c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	2c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	2c_LF05	Boone 70061-Comanche 70122 230 Line	6	2c_LF06	Boone 70061-Midwayps 70286 230 Line
7	2c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	2c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	2c_LF09	Comanche 70122-Walsenbg 70459 230 Lin	10	2c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	2c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	2c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	2c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	2c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	2c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	2c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	2c_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus					Base	Cases where loading exceeds criteria															O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1	25.0 M																		16	1.034
70253	LAMAR CO	115.0	712	70254	LAMAR CO	230.0	712	1	100.0 M																		1	1.007

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Multi-case Voltage Summary

Zones for the criteria check are: **Base Case 05ha1sa-3c - DC Power = -210 MW(Export), dc bus voltage at 1.022 p.u.**
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	3c_LF01	Base Case (all in service)	2	3c_LF02_bx	Lamar Co 70254-Boone 70061 230 Line - PDC= -48 MW
3	3c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	3c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	3c_LF05	Boone 70061-Comanche 70122 230 Line	6	3c_LF06	Boone 70061-Midwayps 70286 230 Line
7	3c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	3c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	3c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	3c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	3c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	3c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	3c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	3c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	3c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	3c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	3c_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria																Violation	Actual	
bus	name	kV	zone	min volts	max volts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70549	APT MEM	115.0	712	0.95	1.05							x											1	0.897	0.897
70030	APT PARK	115.0	712	0.95	1.05							x											1	0.901	0.901
70031	APT TAP	115.0	712	0.95	1.05							x											1	0.909	0.909
70022	APT TAP2	115.0	712	0.95	1.05							x											1	0.894	0.894
70060	BOONE	115.0	712	0.95	1.05							x											1	0.871	0.871
70061	BOONE	230.0	712	0.95	1.05					x													1	0.941	0.941
70158	DOT	115.0	712	0.95	1.05							x											1	0.872	0.872
70159	DOT TAP	115.0	712	0.95	1.05							x											1	0.875	0.875
70247	LAJUNTAT	115.0	712	0.95	1.05							x											2	0.903	0.903
70249	LAJUNTAW	115.0	712	0.95	1.05							x											1	0.821	0.821
70254	LAMAR CO	230.0	712	0.95	1.05					x													1	0.948	0.948
70301	NTHRIDGE	115.0	712	0.95	1.05							x											1	0.929	0.929

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-3c - DC Power = -210 MW(Export), dc bus voltage at 1.022 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case r	Case Id	Case Description	Case n	Case Id	Case Description
1	3c_LF01	Base Case (all in service)	2	3c_LF02_bx	Lamar Co 70254-Boone 70061 230 Line - PDC=-48 MW
3	3c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	3c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	3c_LF05	Boone 70061-Comanche 70122 230 Line	6	3c_LF06	Boone 70061-Midwayps 70286 230 Line
7	3c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	3c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	3c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	3c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	3c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	3c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	3c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	3c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	3c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	3c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	3c_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus						Base	Cases where loading exceeds criteria																O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	sect	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70060	BOONE	115.0	712	70247	LAJUNTAT	115.0	712	1	1	547.2 A																		1	1

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-3c - DC Power = -210 MW(Export), dc bus voltage at 1.022 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case	Case Id	Case Description	Case n	Case Id	Case Description
1	3c_LF01	Base Case (all in service)	2	3c_LF02_bx	Lamar Co 70254-Boone 70061 230 Line - PDC=-48 MW
3	3c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	3c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	3c_LF05	Boone 70061-Comanche 70122 230 Line	6	3c_LF06	Boone 70061-Midwayps 70286 230 Line
7	3c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	3c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	3c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	3c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	3c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	3c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	3c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	3c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	3c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	3c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	3c_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus					Base	Cases where loading exceeds criteria															O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70060	BOONE	115.0	712	70061	BOONE	230.0	712	1	150.0 M																		1	1.000
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1	25.0 M																		16	1.026

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Multi-case Voltage Summary

Base Case 05ha1sa-4c - DC Power = 50 MW(Import), Wind Farm = 160 MW, dc bus voltage 1.04 p.u.

Zones for the criteria check are:
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	4c_LF01	Base Case (all in service)	2	4c_LF02c	Lamar Co 70254-Boone 70061 230 Line - PDC=-60 MW
3	4c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	4c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	4c_LF05	Boone 70061-Comanche 70122 230 Line	6	4c_LF06	Boone 70061-Midwayps 70286 230 Line
7	4c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	4c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	4c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	4c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	4c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	4c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	4c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	4c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	4c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	4c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	4c_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria															Violation	Actual	
bus	name	kV	zone	min volts	max volts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70549	APT MEM	115.0	712	0.95	1.05							x											1	0.928	0.928
70030	APT PARK	115.0	712	0.95	1.05							x											1	0.931	0.931
70031	APT TAP	115.0	712	0.95	1.05							x											1	0.937	0.937
70022	APT TAP2	115.0	712	0.95	1.05							x											1	0.925	0.925
70060	BOONE	115.0	712	0.95	1.05							x											1	0.909	0.909
70158	DOT	115.0	712	0.95	1.05							x											1	0.909	0.909
70159	DOT TAP	115.0	712	0.95	1.05							x											1	0.912	0.912
70247	LAJUNTAT	115.0	712	0.95	1.05							x											1	0.931	0.931
70249	LAJUNTAW	115.0	712	0.95	1.05							x											1	0.863	0.863

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-4c - DC Power = 50 MW(Import), Wind Farm = 160 MW, dc bus voltage at 1.04 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	4c_LF01	Base Case (all in service)	2	4c_LF02c	Lamar Co 70254-Boone 70061 230 Line - PDC=-60 MW
3	4c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	4c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	4c_LF05	Boone 70061-Comanche 70122 230 Line	6	4c_LF06	Boone 70061-Midwayps 70286 230 Line
7	4c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	4c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	4c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	4c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	4c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	4c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	4c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	4c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	4c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	4c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	4c_LF17	Boone 70060-Lajuntat 70247 115 Line			

no transmission lines in the selected area(s) and with the selected voltage level(s) have overloads greater than the criteria

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-4c - DC Power = 50 MW(Import), Wind Farm = 160 MW, dc bus voltage at 1.04 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case	Case Id	Case Description	Case n	Case Id	Case Description
1	4c_LF01	Base Case (all in service)	2	4c_LF02c	Lamar Co 70254-Boone 70061 230 Line - PDC=-60 MW
3	4c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	4c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	4c_LF05	Boone 70061-Comanche 70122 230 Line	6	4c_LF06	Boone 70061-Midwayps 70286 230 Line
7	4c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	4c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	4c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	4c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	4c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	4c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	4c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	4c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	4c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	4c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	4c_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus					Base	Cases where loading exceeds criteria																O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1	25.0 M																		16	1.034
70253	LAMAR CO	115.0	712	70254	LAMAR CO	230.0	712	1	100.0 M																		0	0.991

Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Multi-case Voltage Summary

Base Case 05ha1sa-5c - DC Power = -210 MW(Export), Wind Farm = 160 MW, dc bus voltage 1.04 p.u.

Zones for the criteria check are:
704,712
Minimum bus voltage level 115.0 kV
Minimum voltage filter = 0.95 p.u.
Maximum voltage filter = 1.05 p.u.
Based on N-1 contigency power flow criteria

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	5c_LF01	Base Case (all in service)	2	5c_LF02	Lamar Co 70254-Boone 70061 230 Line
3	5c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	5c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	5c_LF05	Boone 70061-Comanche 70122 230 Line	6	5c_LF06	Boone 70061-Midwayps 70286 230 Line
7	5c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	5c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	5c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	5c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	5c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	5c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	5c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	5c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	5c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	5c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	5c_LF17	Boone 70060-Lajuntat 70247 115 Line			

Bus						Cases where voltage is outside criteria															Violation	Actual	
bus	name	kV	zone	min volts	max volts	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	min volts	max volts
70122	COMANCHE	230.0	704	0.95	1.05											x							1	1.050	1.050
70549	APT MEM	115.0	712	0.95	1.05							x											1	0.925	0.925
70030	APT PARK	115.0	712	0.95	1.05							x											1	0.928	0.928
70031	APT TAP	115.0	712	0.95	1.05							x											1	0.934	0.934
70022	APT TAP2	115.0	712	0.95	1.05							x											1	0.922	0.922
70060	BOONE	115.0	712	0.95	1.05							x											1	0.906	0.906
70158	DOT	115.0	712	0.95	1.05							x											1	0.906	0.906
70159	DOT TAP	115.0	712	0.95	1.05							x											1	0.909	0.909
70247	LAJUNTAT	115.0	712	0.95	1.05							x											1	0.938	0.938
70249	LAJUNTAW	115.0	712	0.95	1.05							x											1	0.860	0.860
70301	NTHRIDGE	115.0	712	0.95	1.05							x											1	0.949	0.949
70452	VILAS	115.0	712	0.95	1.05															x			1	1.052	1.052

Identifies the actual minimum voltage.
Identifies the actual maximum voltage.
x denotes a violation; f flags voltages outside of the range.

Transmission Line Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-5c - DC Power = -210 MW(Export), Wind Farm = 160 MW, dc bus voltage 1.04 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

Case no	Case Id	Case Description	Case no	Case Id	Case Description
1	5c_LF01	Base Case (all in service)	2	5c_LF02	Lamar Co 70254-Boone 70061 230 Line
3	5c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	5c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	5c_LF05	Boone 70061-Comanche 70122 230 Line	6	5c_LF06	Boone 70061-Midwayps 70286 230 Line
7	5c_LF07	Boone 70061-Boone 70060 230/115 Trar	8	5c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	5c_LF09	Comanche 70122-Walsenbg 70459 230 l	10	5c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	5c_LF11	Midwayps 70286-Midwaybr 73413 230 Li	12	5c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	5c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	5c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	5c_LF15	Lamar co 70253-Wilow Ck 70472 115 Lir	16	5c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	5c_LF17	Boone 70060-Lajuntat 70247 115 Line			

no transmission lines in the selected area(s) and with the selected voltage level(s) have overloads greater than the criteria

Transformer Multi-case Overload Summary

Zones for the criteria check are: **Base Case 05ha1sa-5c - DC Power = -210 MW(Export), Wind Farm = 160 MW, dc bus voltage 1.04 p.u.**
704,712
Branch rating level for overload assesment = 0
Minimum load on branch (p.u. of rating)to be reported = 0.98 p.u.
Minimum bus voltage level 115.0 kV

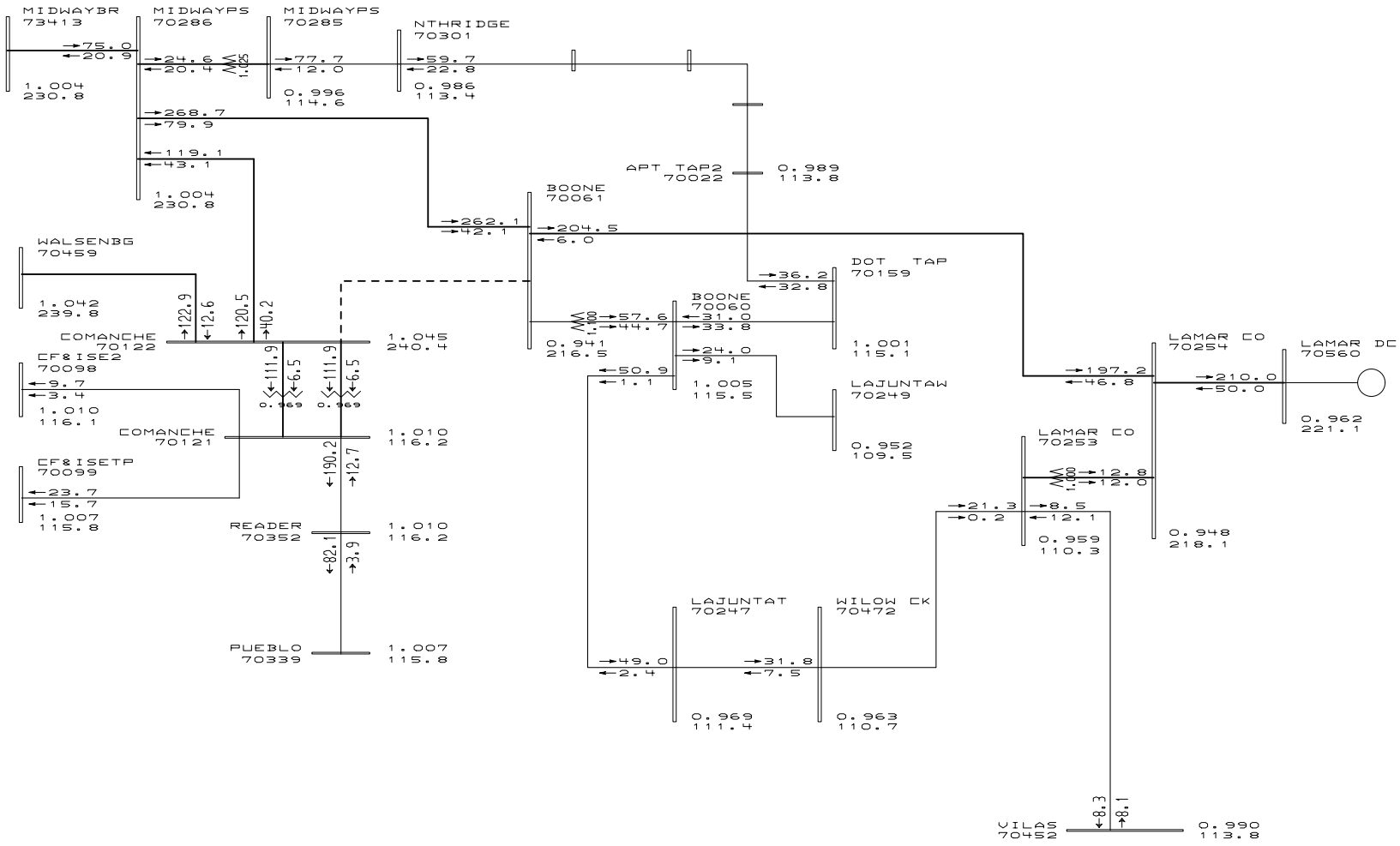
Case	Case Id	Case Description	Case n	Case Id	Case Description
1	5c_LF01	Base Case (all in service)	2	5c_LF02	Lamar Co 70254-Boone 70061 230 Line
3	5c_LF03	Lamar Co 70254-Lamar 70560 230 Line	4	5c_LF04	Lamar Co 70254-Lamar 70253 230/115 Transf
5	5c_LF05	Boone 70061-Comanche 70122 230 Line	6	5c_LF06	Boone 70061-Midwayps 70286 230 Line
7	5c_LF07	Boone 70061-Boone 70060 230/115 Transf	8	5c_LF08	Comanche 70122-Midwayps 70286 230 Line
9	5c_LF09	Comanche 70122-Walsenbg 70459 230 Line	10	5c_LF10	Comanche 70122-Comanche 70121 230/115 Transf
11	5c_LF11	Midwayps 70286-Midwaybr 73413 230 Line	12	5c_LF12	Midwayps 70286-Midwayps 70285 230/115 Transf
13	5c_LF13	Lajuntat 70247-Wilow Ck 70472 115 Line	14	5c_LF14	Lamar Co 70253-Vilas 70452 115 Line
15	5c_LF15	Lamar co 70253-Wilow Ck 70472 115 Line	16	5c_LF16	Boone 70060-Dot Tap 70159 115 Line
17	5c_LF17	Boone 70060-Lajuntat 70247 115 Line			

From Bus				To Bus					Base	Cases where loading exceeds criteria																O/L	Max
bus	name	kV	zone	bus	name	kV	zone	cct	rating	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	count	Load
70060	BOONE	115.0	712	70061	BOONE	230.0	712	1	150.0 M																		1	1.006
70250	LAJUNTAW	69.0	712	70249	LAJUNTAW	115.0	712	1	25.0 M																		16	1.040

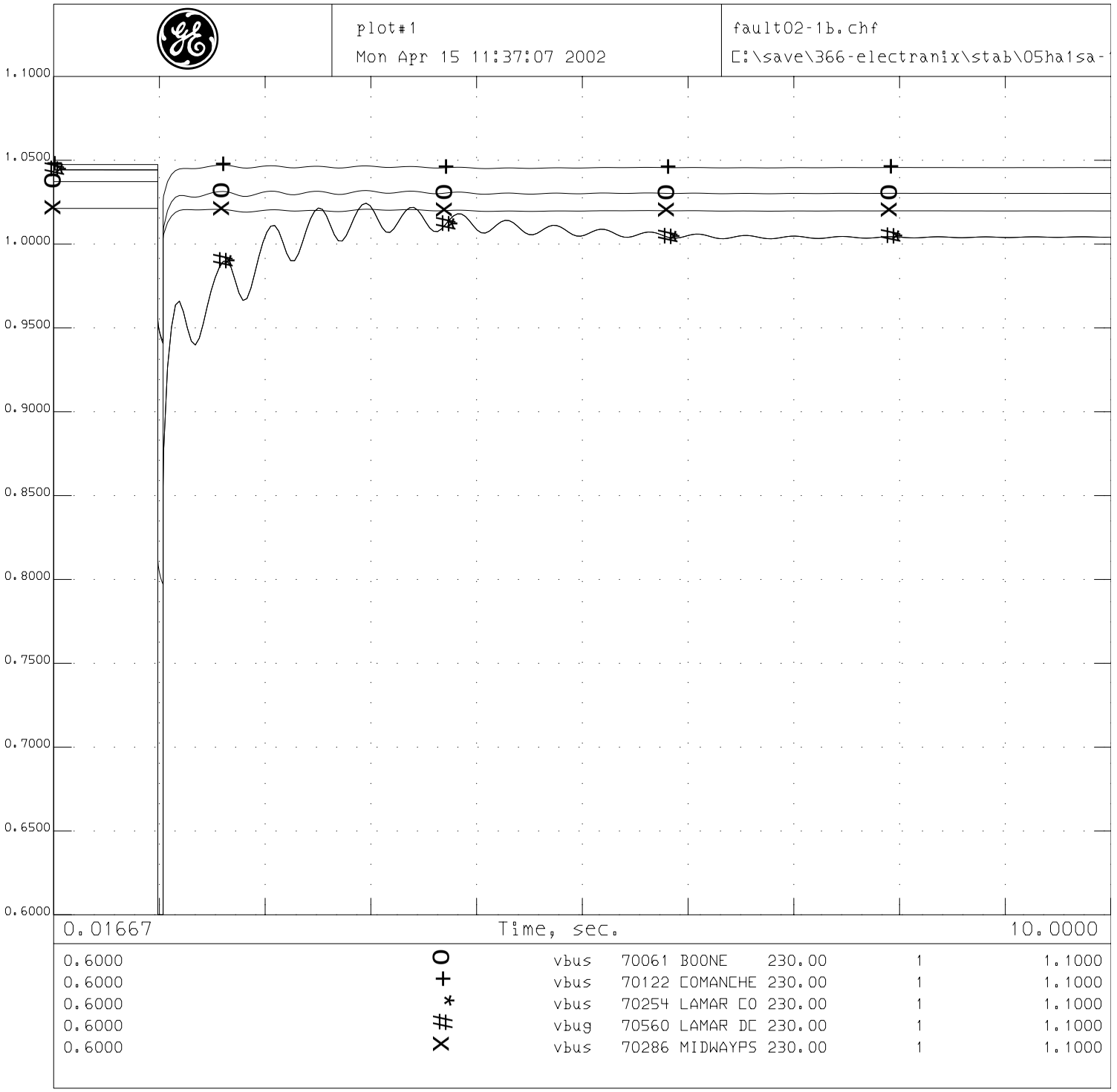
Indicates loads which are greater than 1 pu
Indicates loads which are equal to the maximum load
Indicates loads which are greater than 1 pu and equal to the maximum load

Appendix 5– Load Flow Study Result
(+50/-20 MVAR AC Voltage Control Capability of HVDC Link, Contingency 5 - Loss of BOONE-COMANCHE 230 Line)

Zones 704 & 712, 230kV & 115kV System

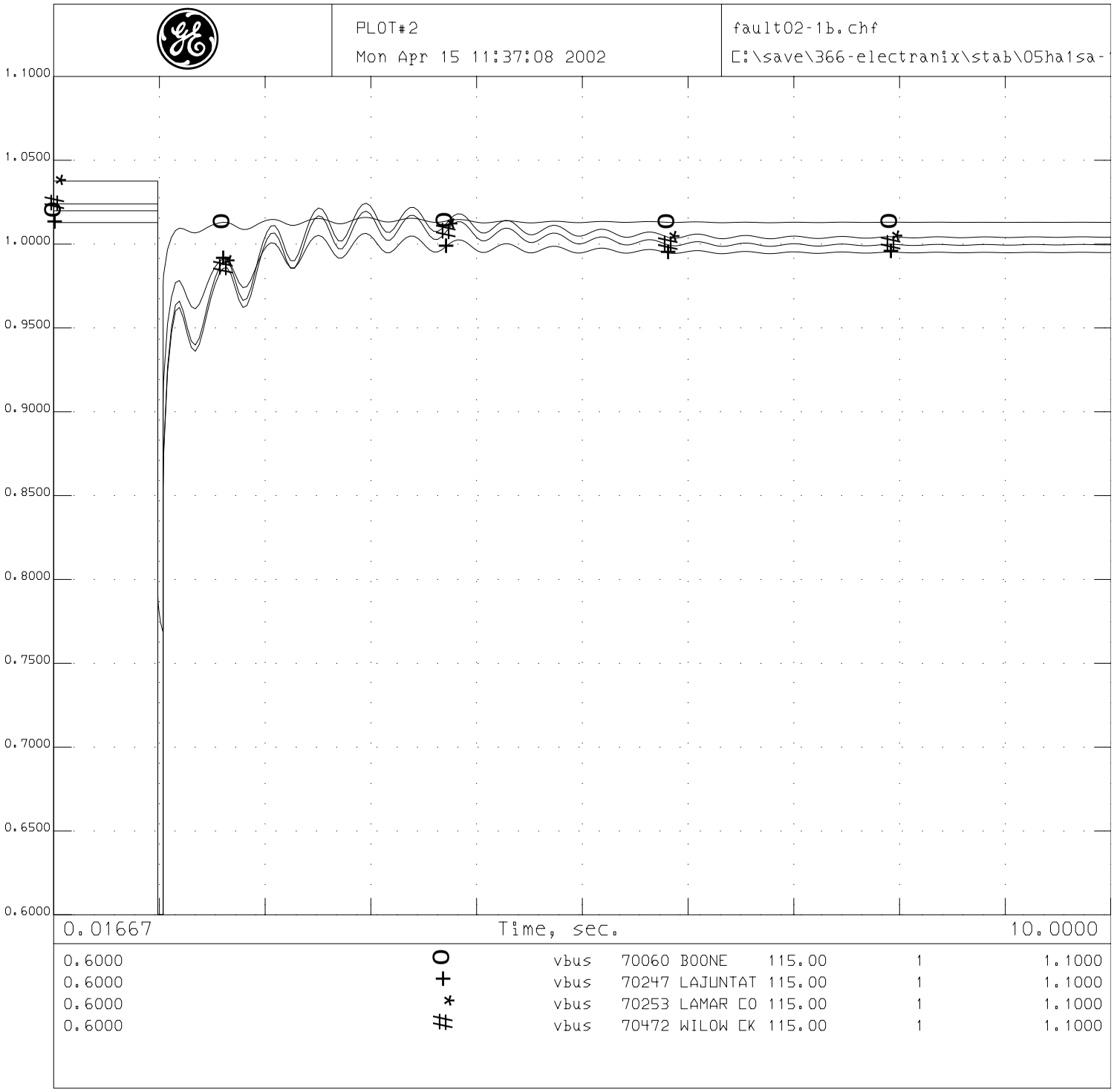


Appendix 6.1– Transient Stability Study Results (Original Base Case – Without HVDC Link)



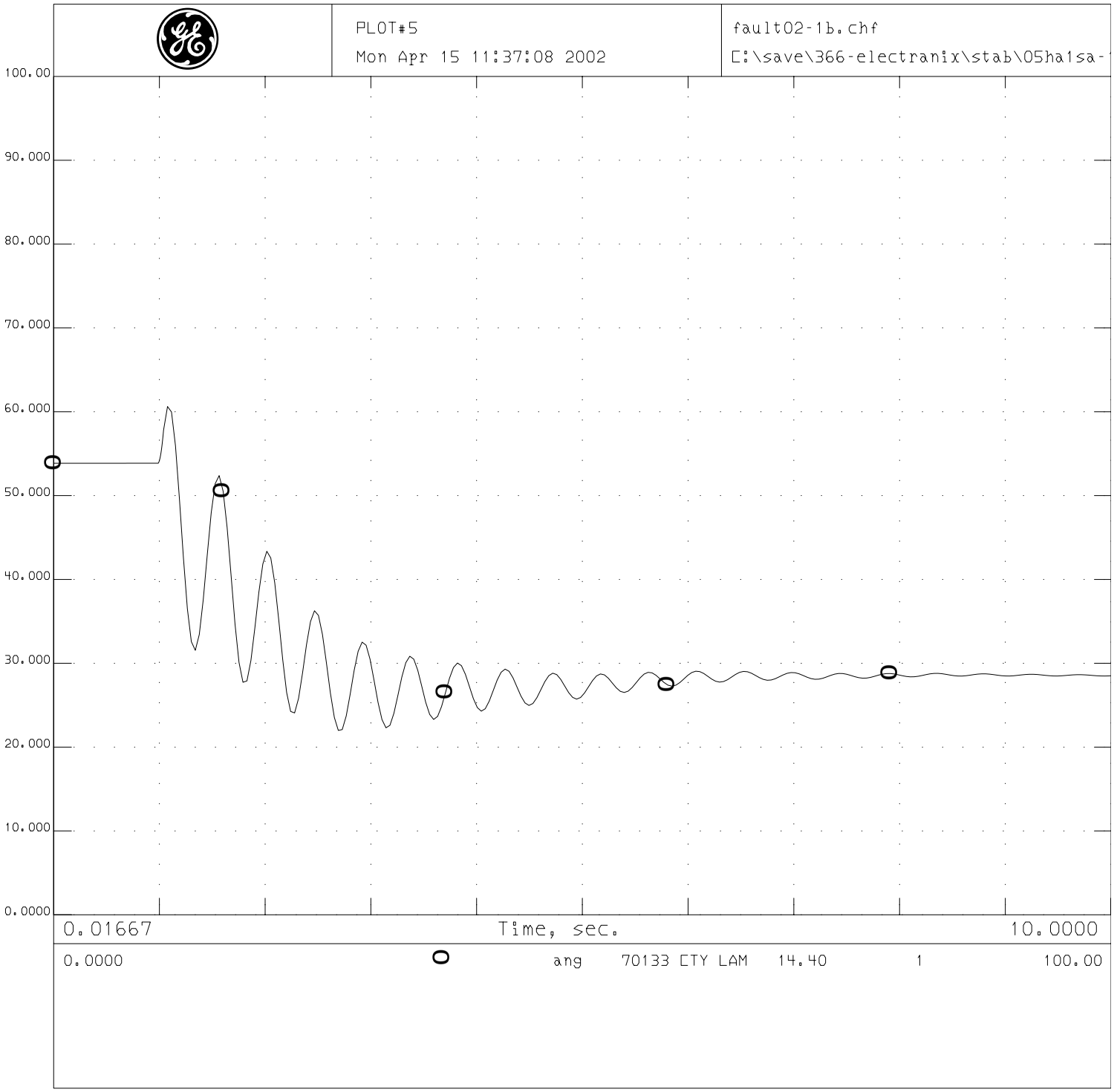
WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared



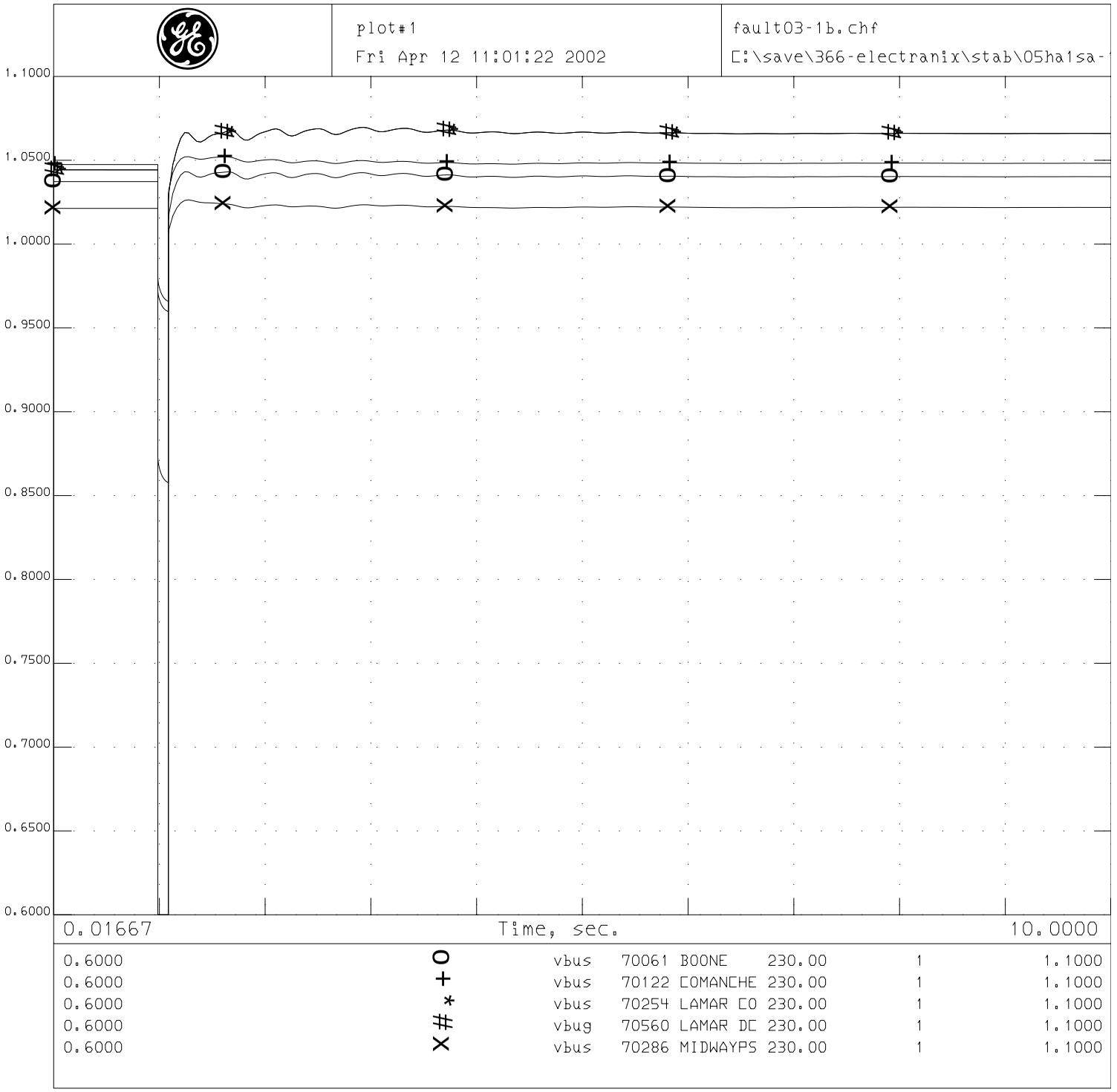
WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared



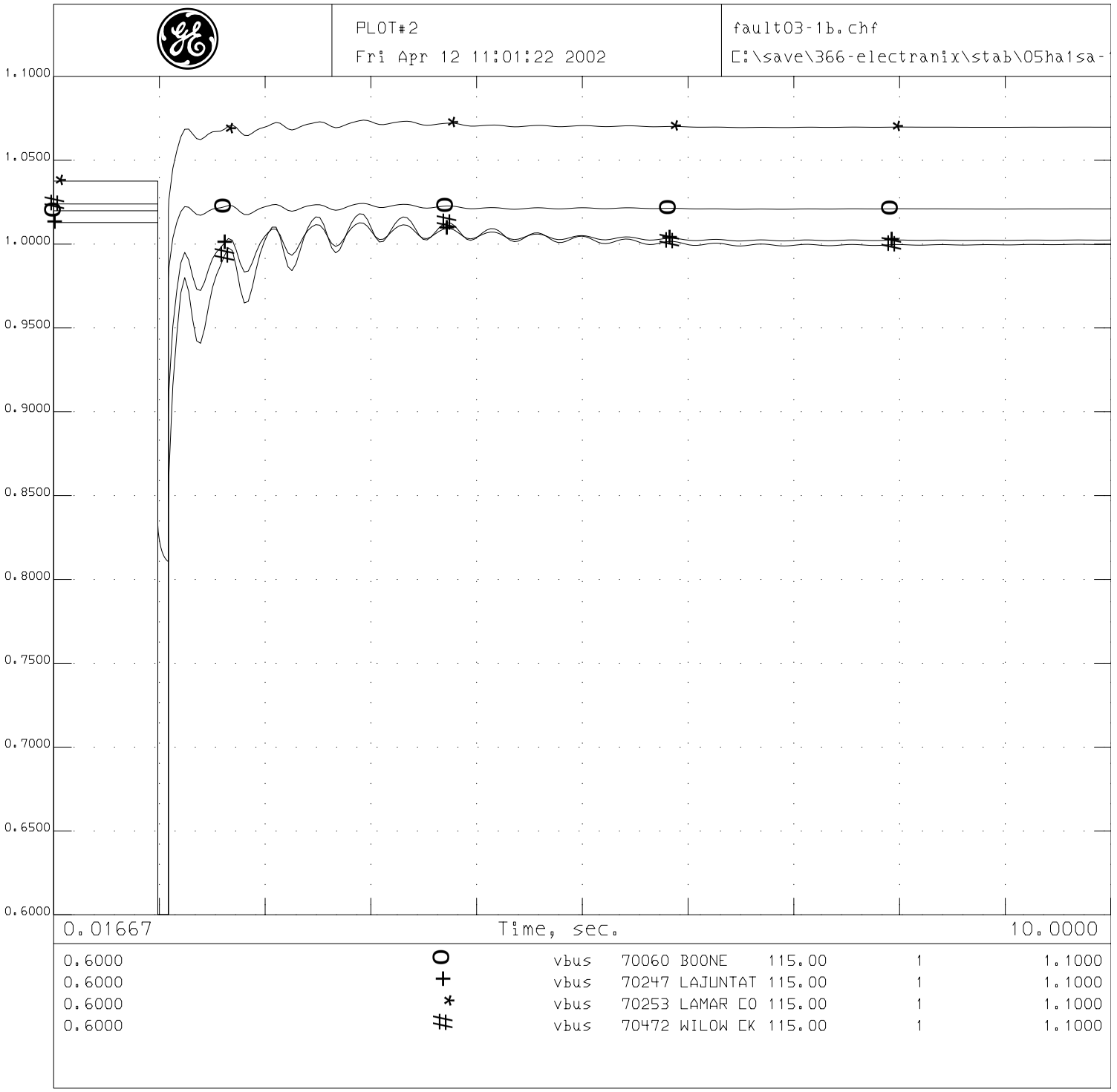
WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared



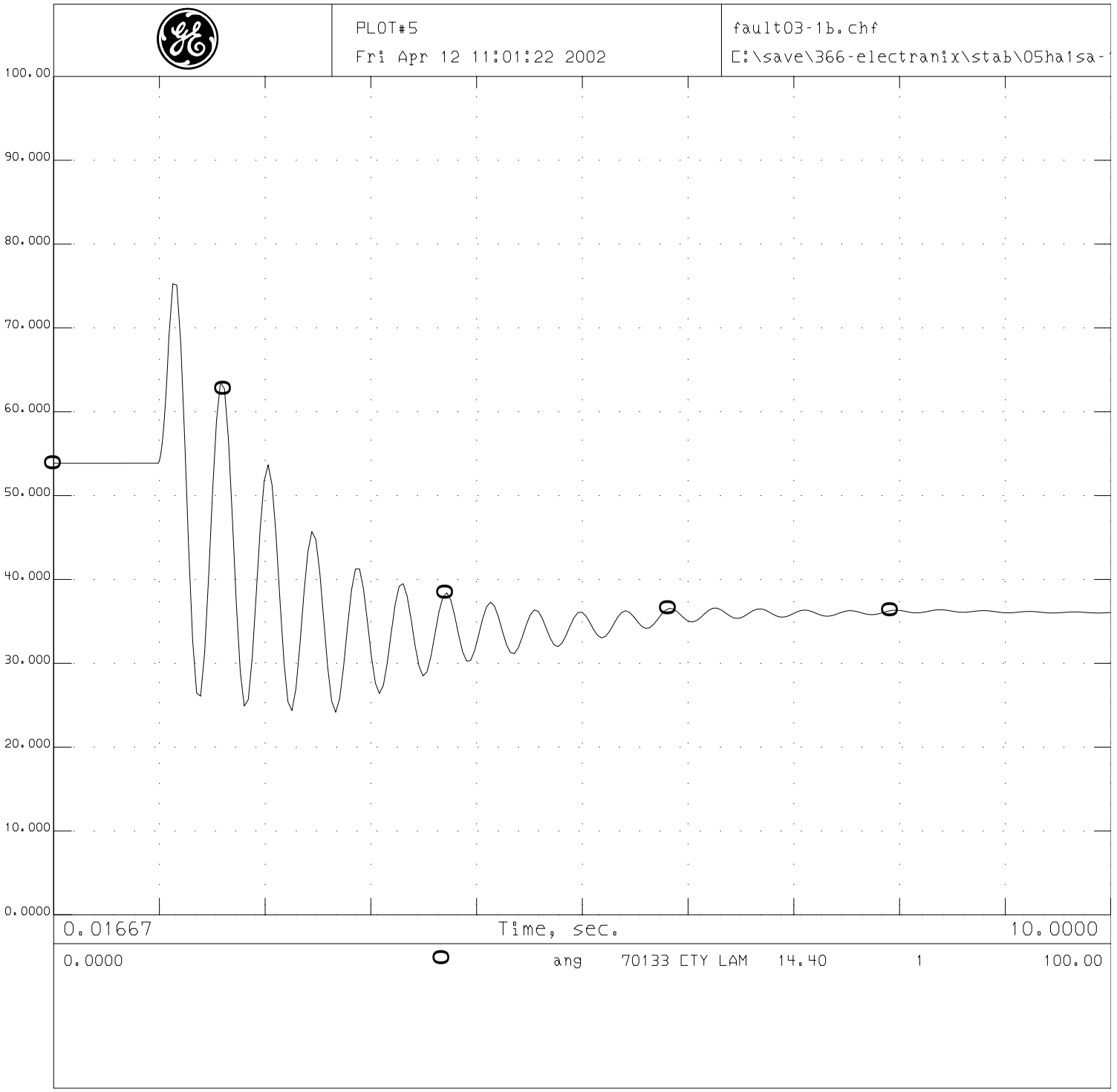
WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



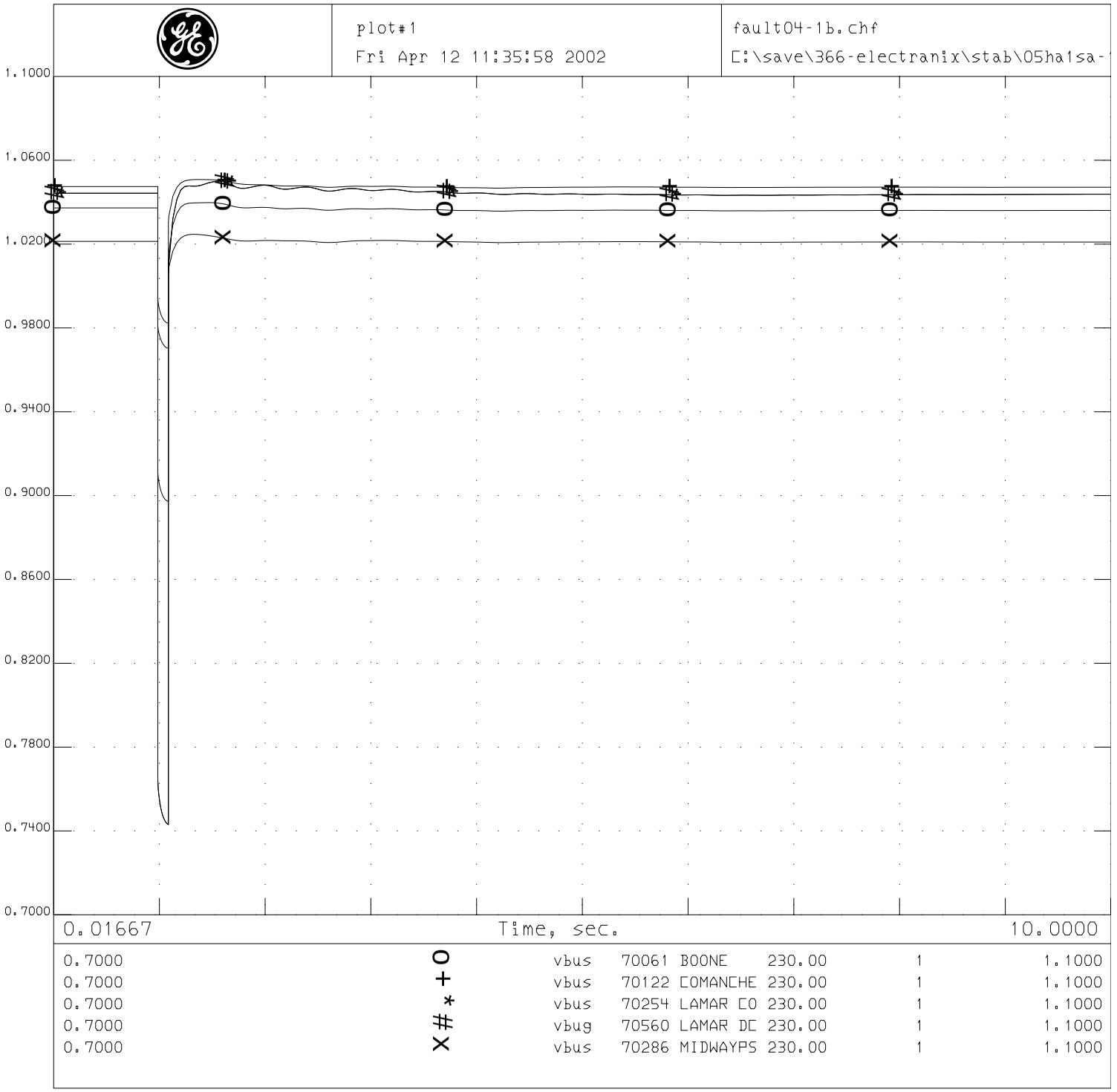
WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



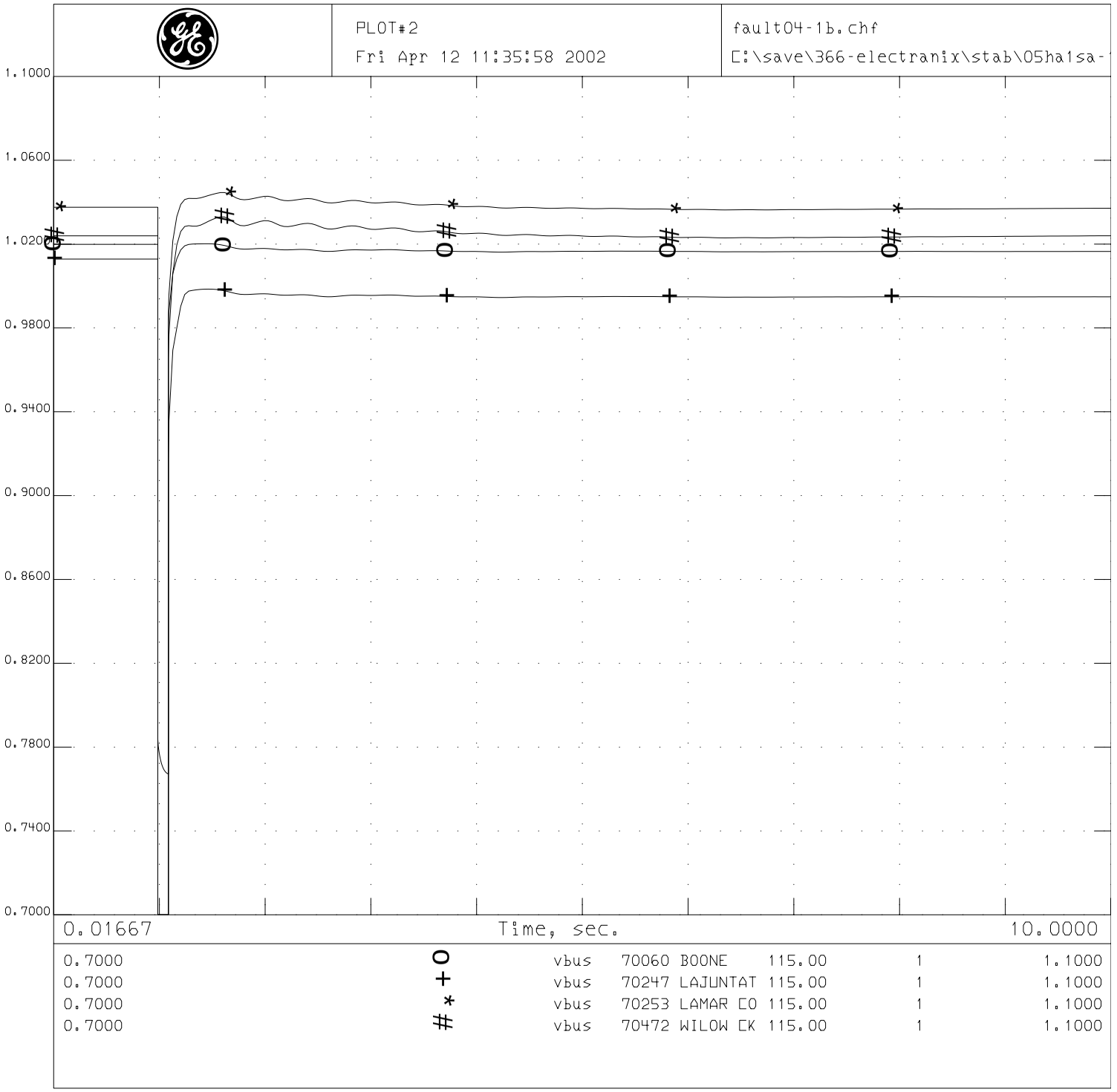
WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



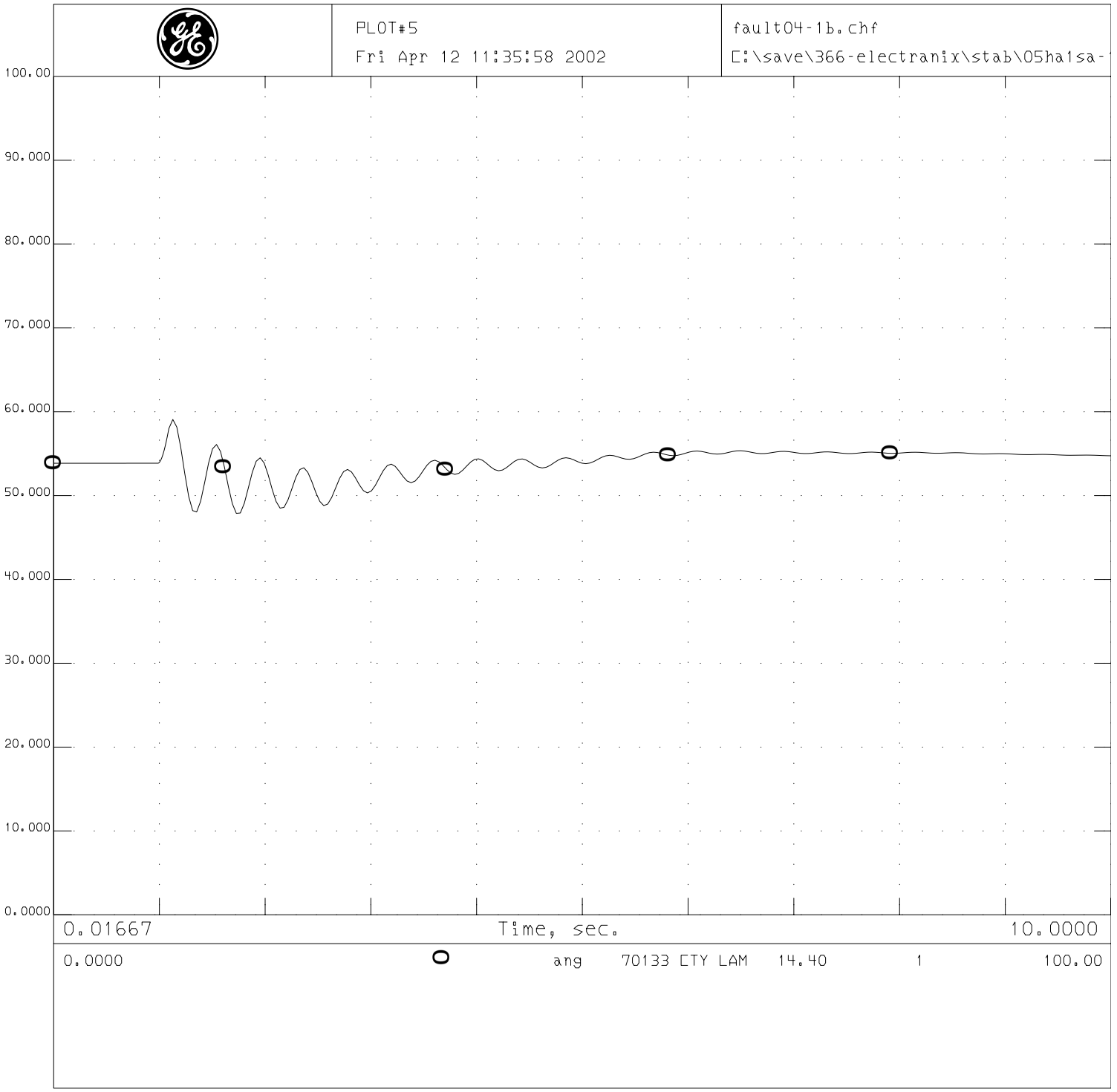
WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing



WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

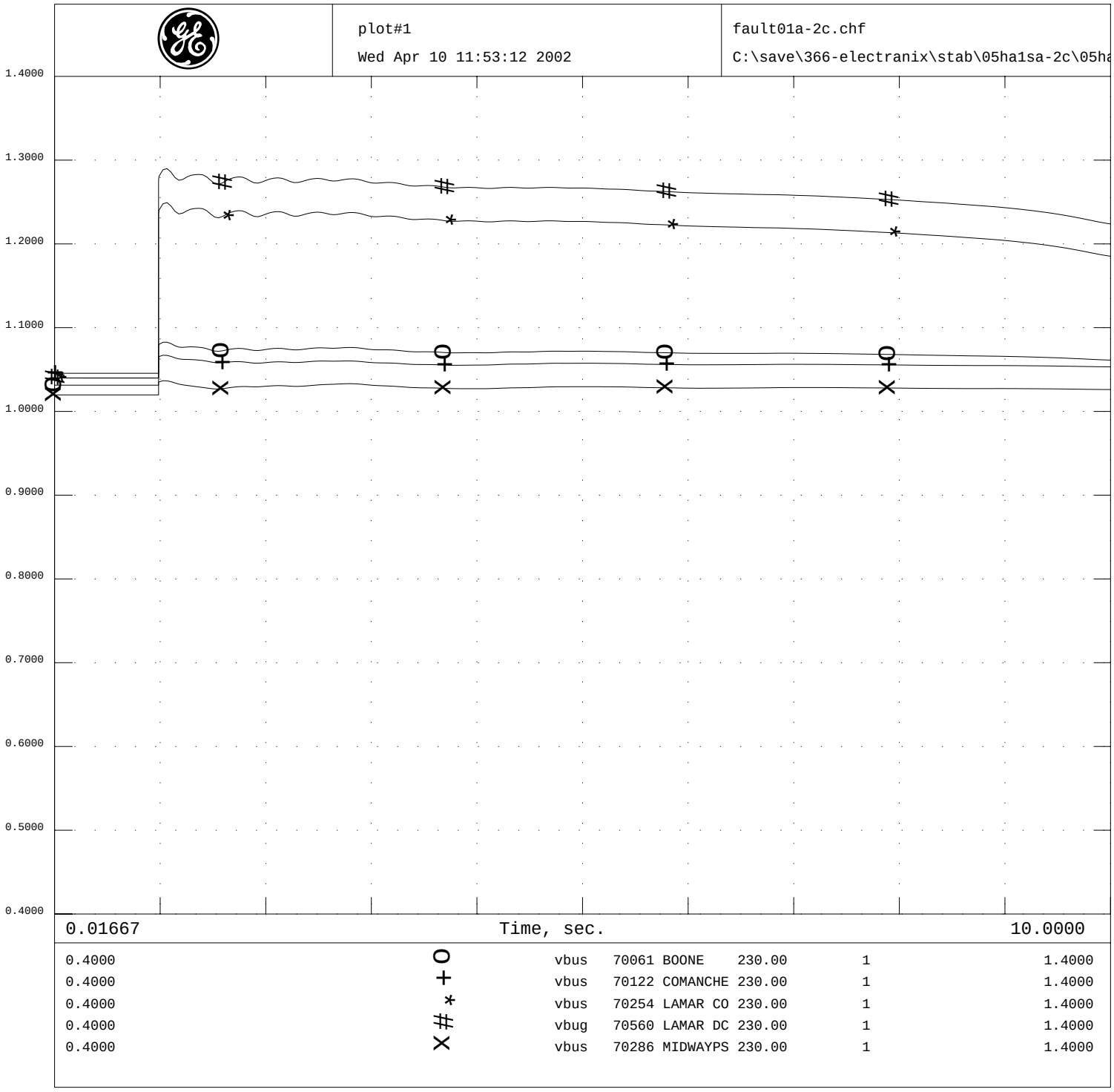
3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing



WESTERN SYSTEMS COORDINATING COUNCIL
2005 HA1-SA APPROVED BASE CASE
NOVEMBER 6, 2001, Case 05ha1sa-1b
Changed 70460 WALSH 69KV SVD type from 4 to 2 (continuous)
Boone 230/115kV xformer in type 12

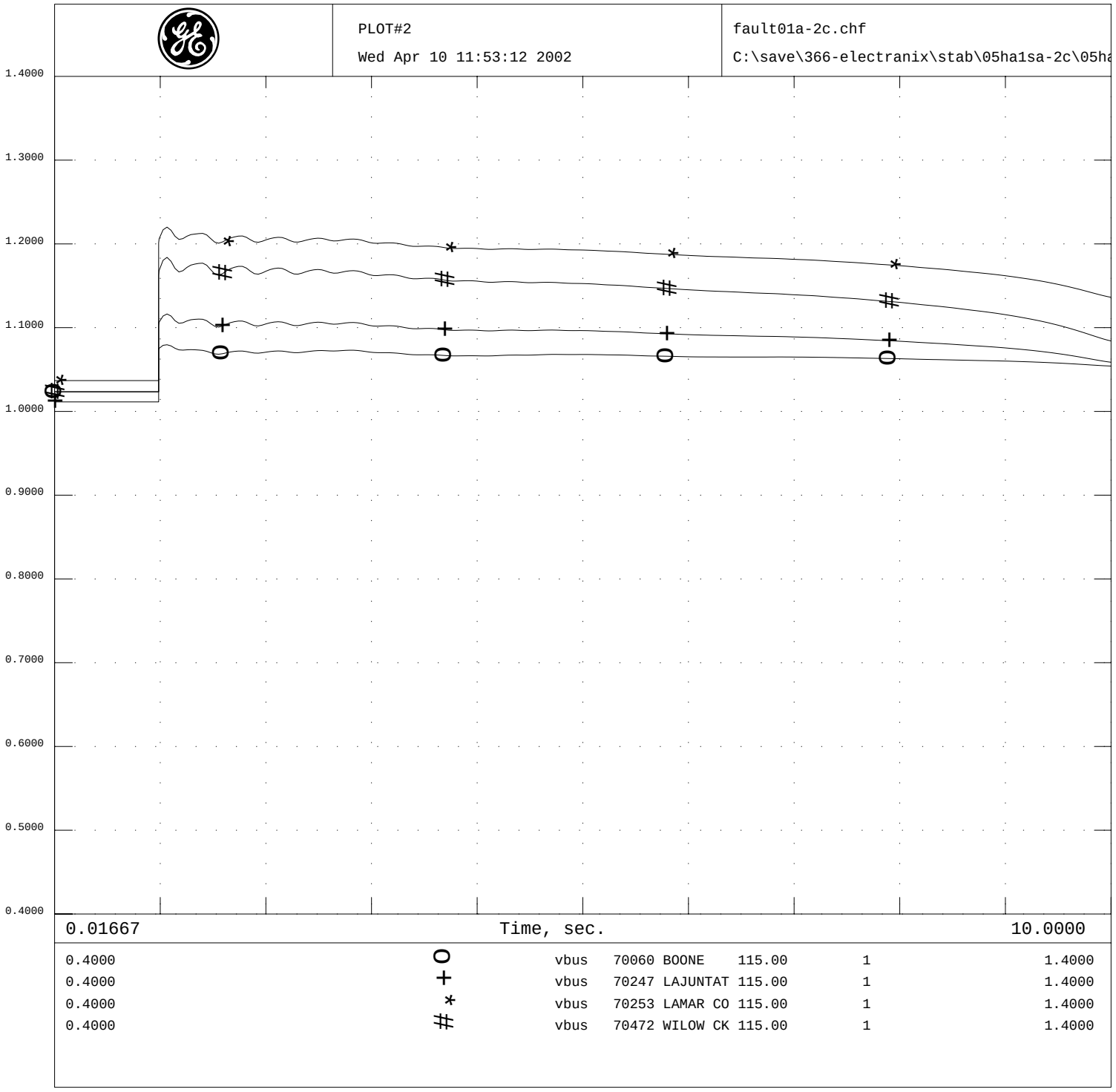
3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing

Appendix 6.2– Transient Stability Study Results
(HVDC Link Importing 210 MW into WSCC System)



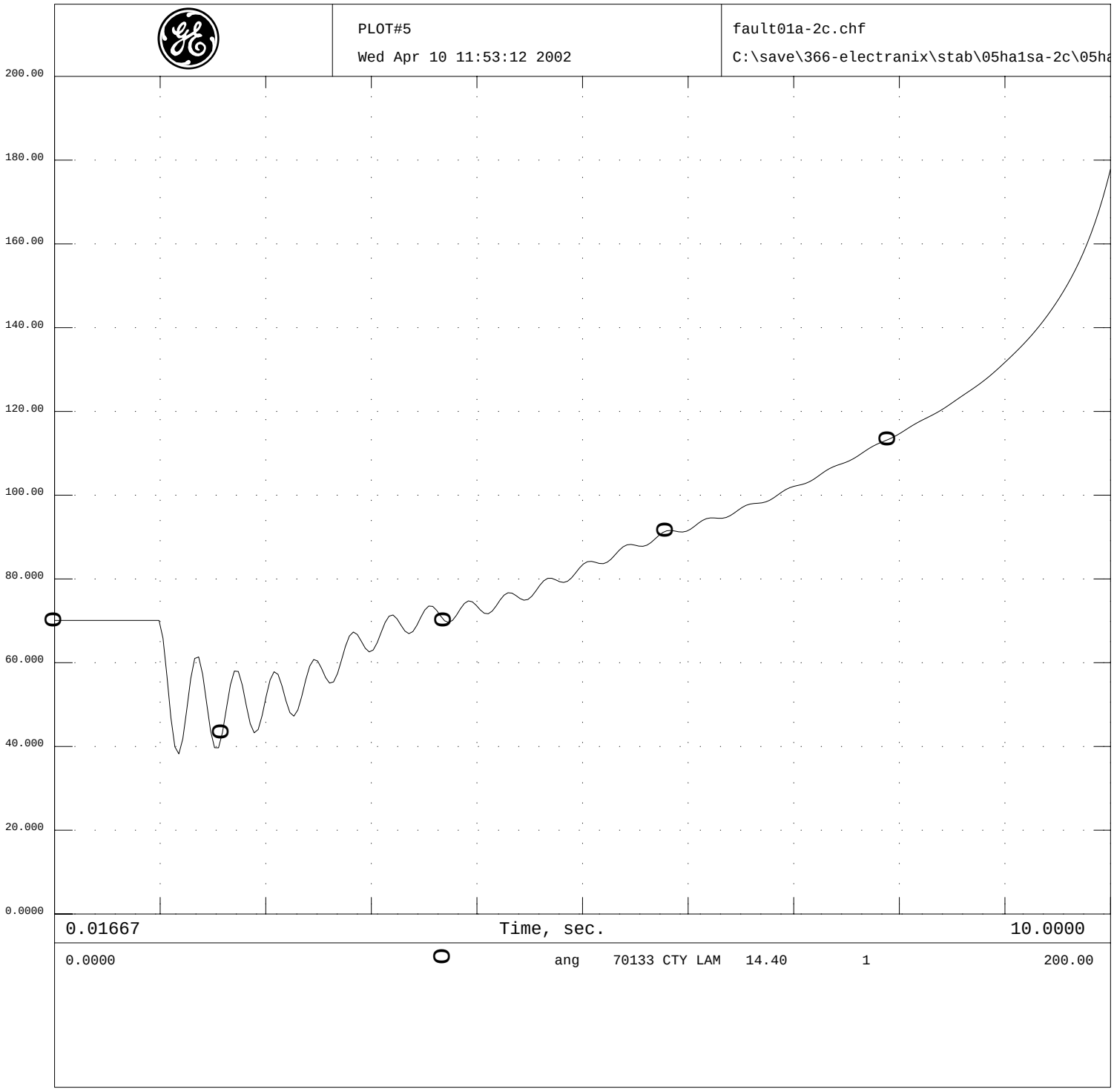
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

switch off Load at 70560 LAMAR DC 230kV bus simulate as dc block permanently



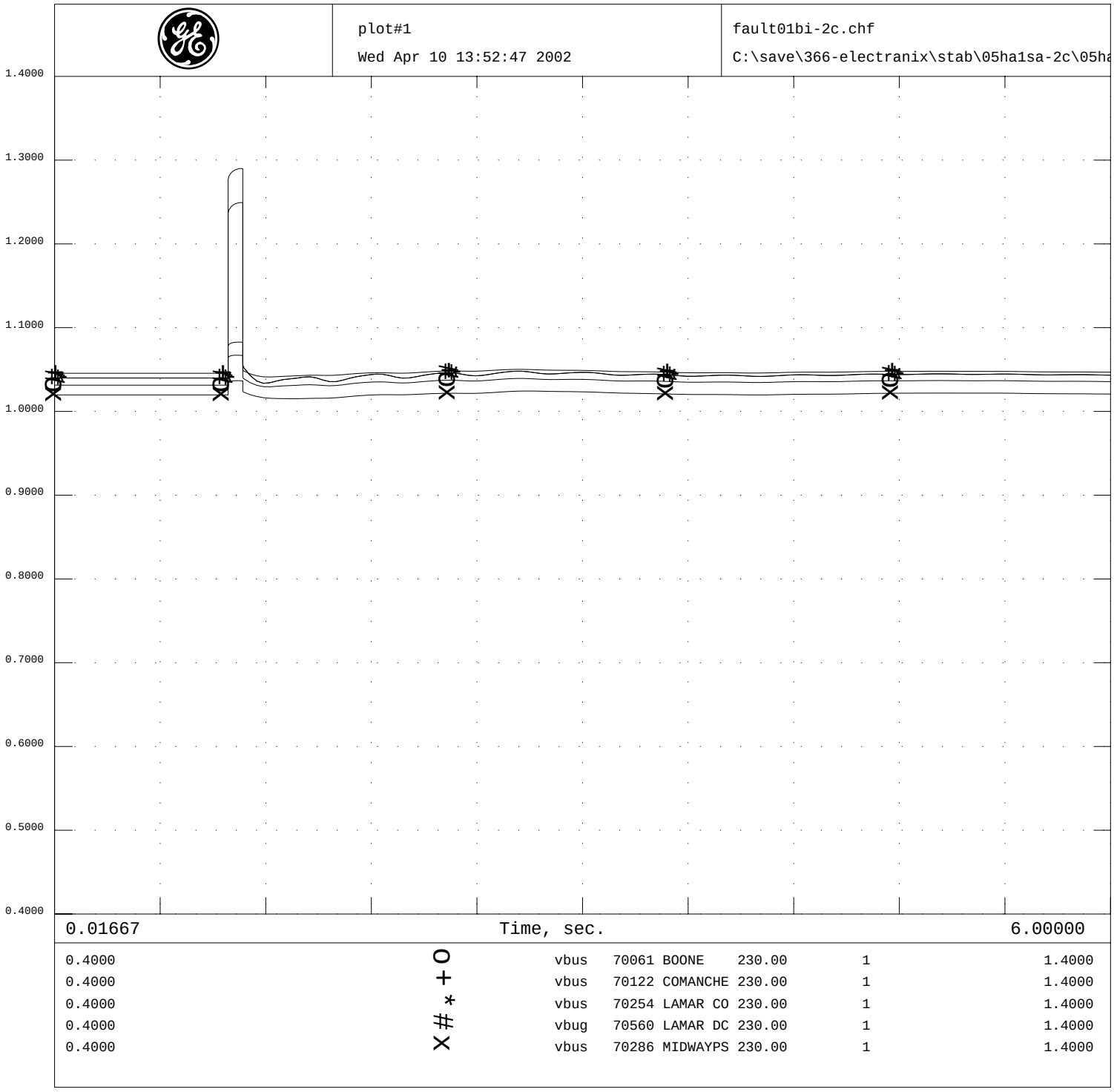
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

switch off Load at 70560 LAMAR DC 230kV bus simulate as dc block permanently



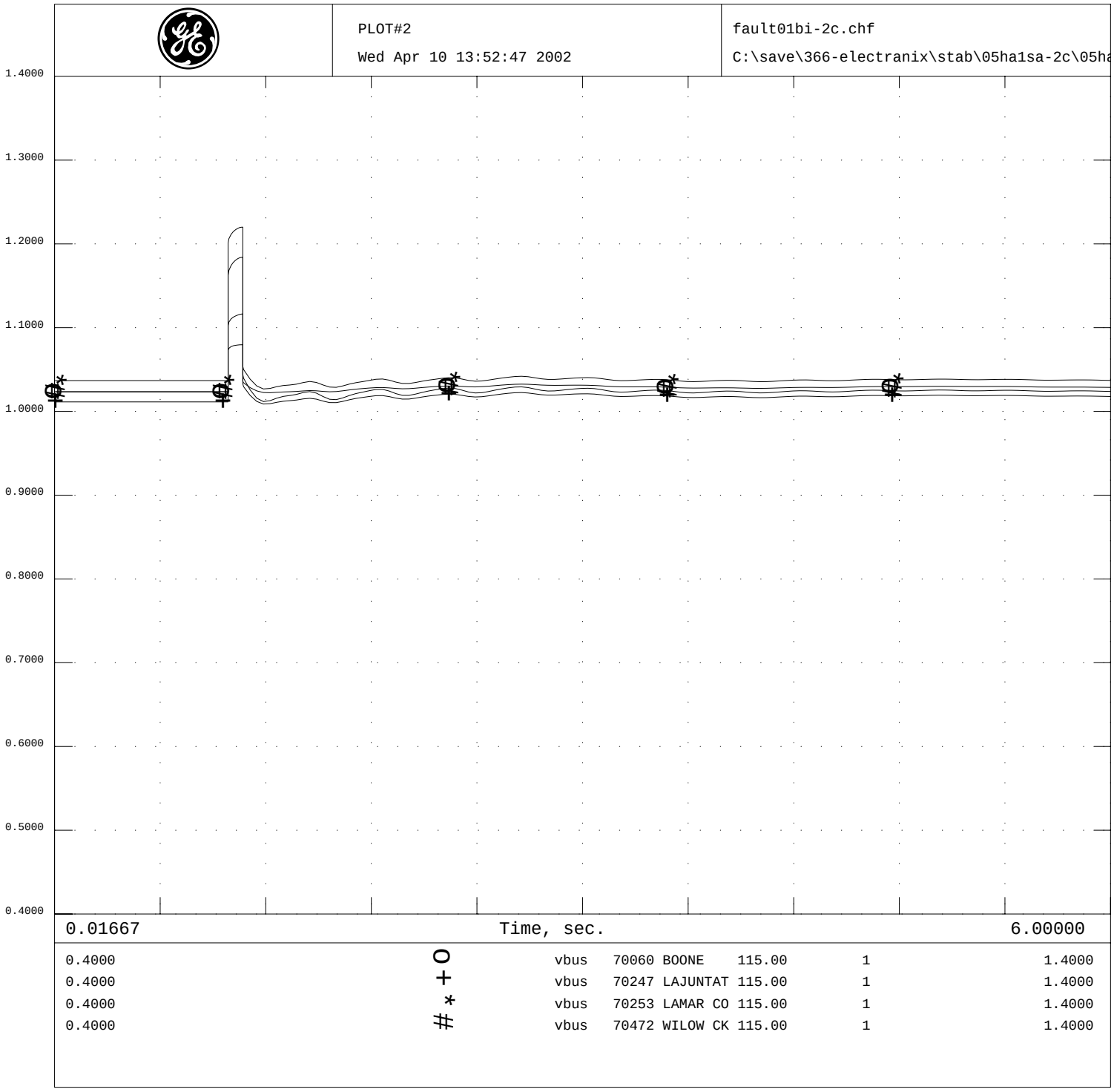
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

switch off Load at 70560 LAMAR DC 230kV bus simulate as dc block permanently



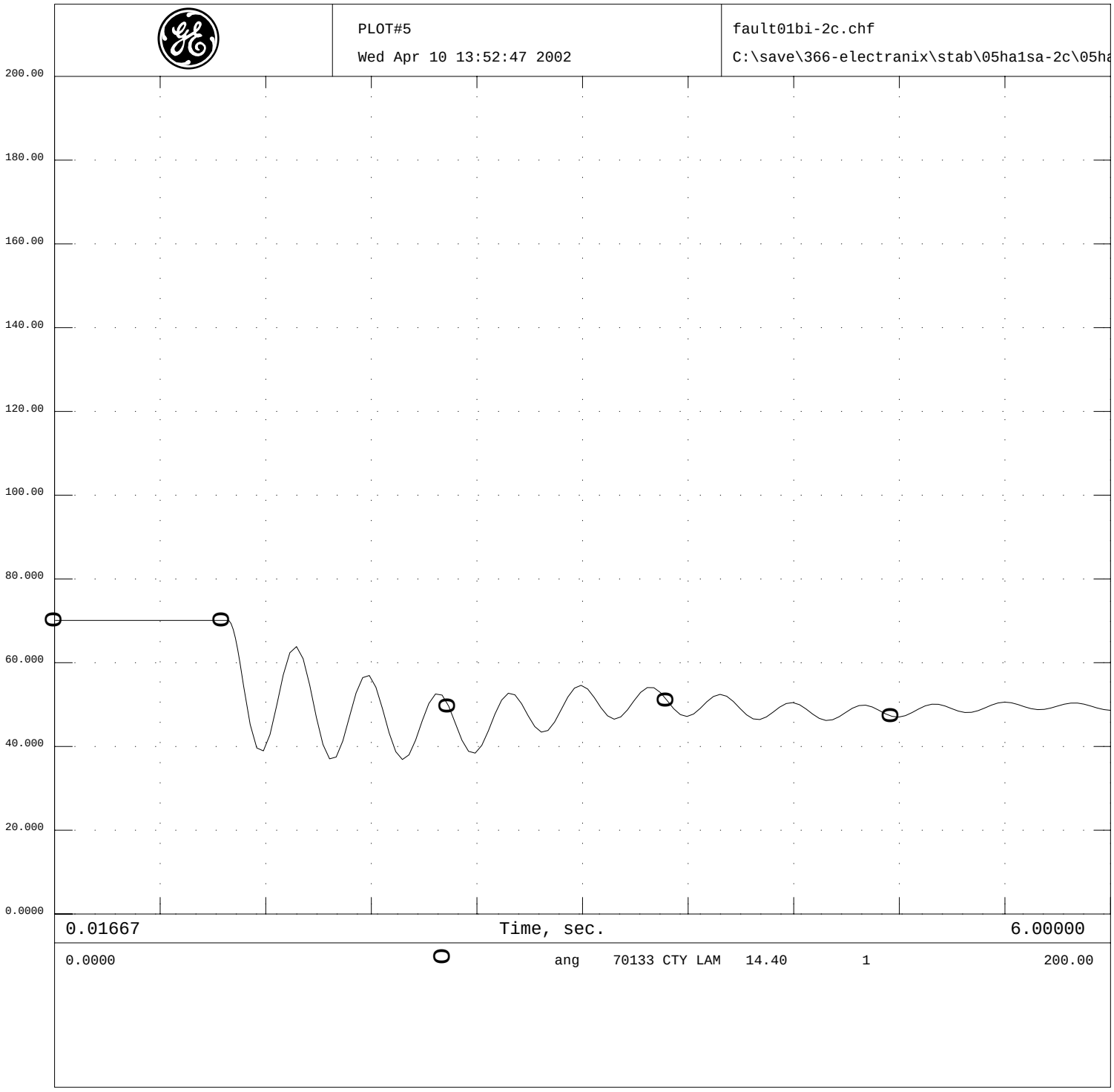
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

switch off Load at LAMAR DC 230kV(70560) bus simulate as dc block
trip all shunt capacitors at LAMAR DC(70560) 230kV bus after 5 cycles



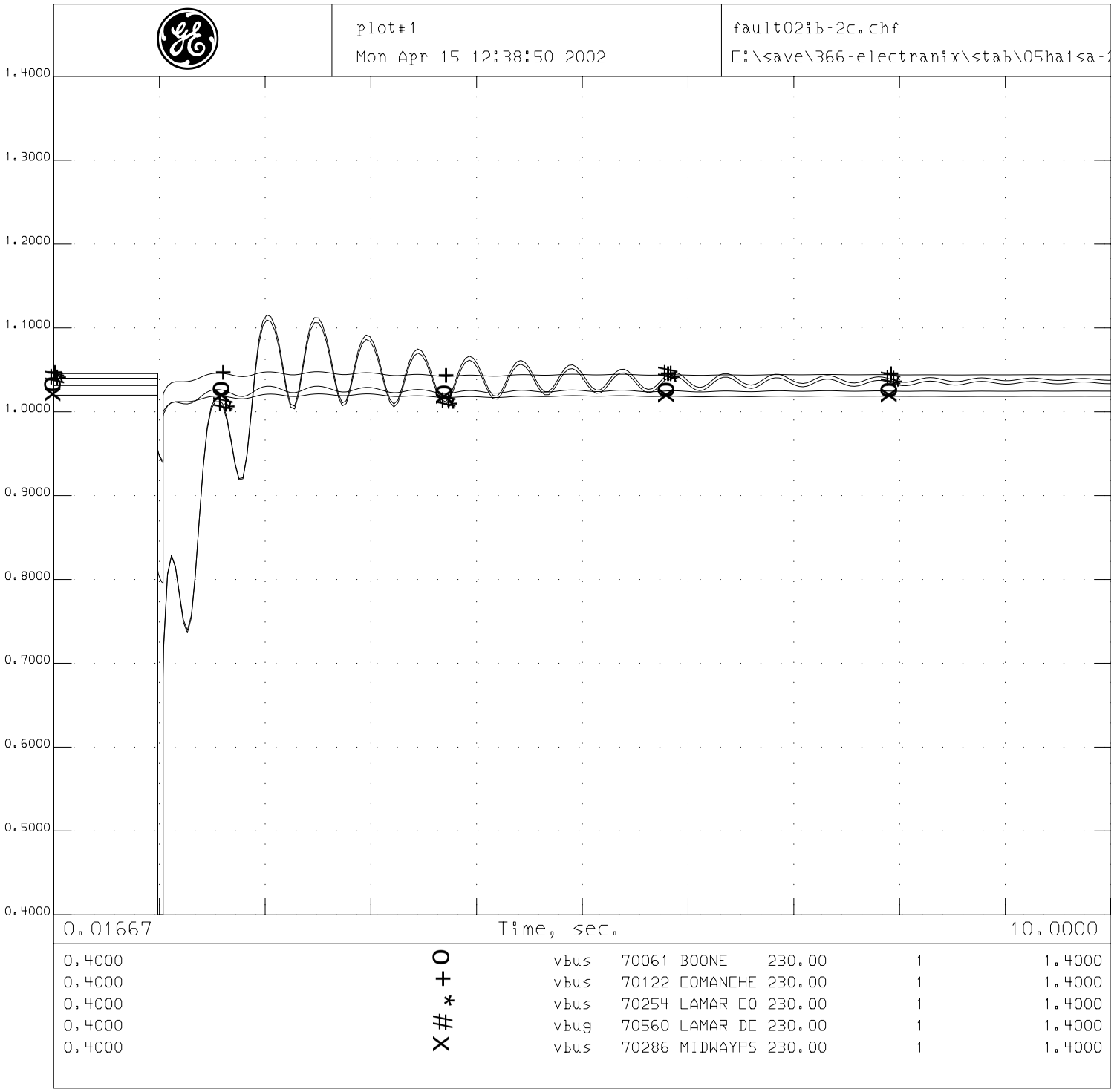
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

switch off Load at LAMAR DC 230kV(70560) bus simulate as dc block
trip all shunt capacitors at LAMAR DC(70560) 230kV bus after 5 cycles



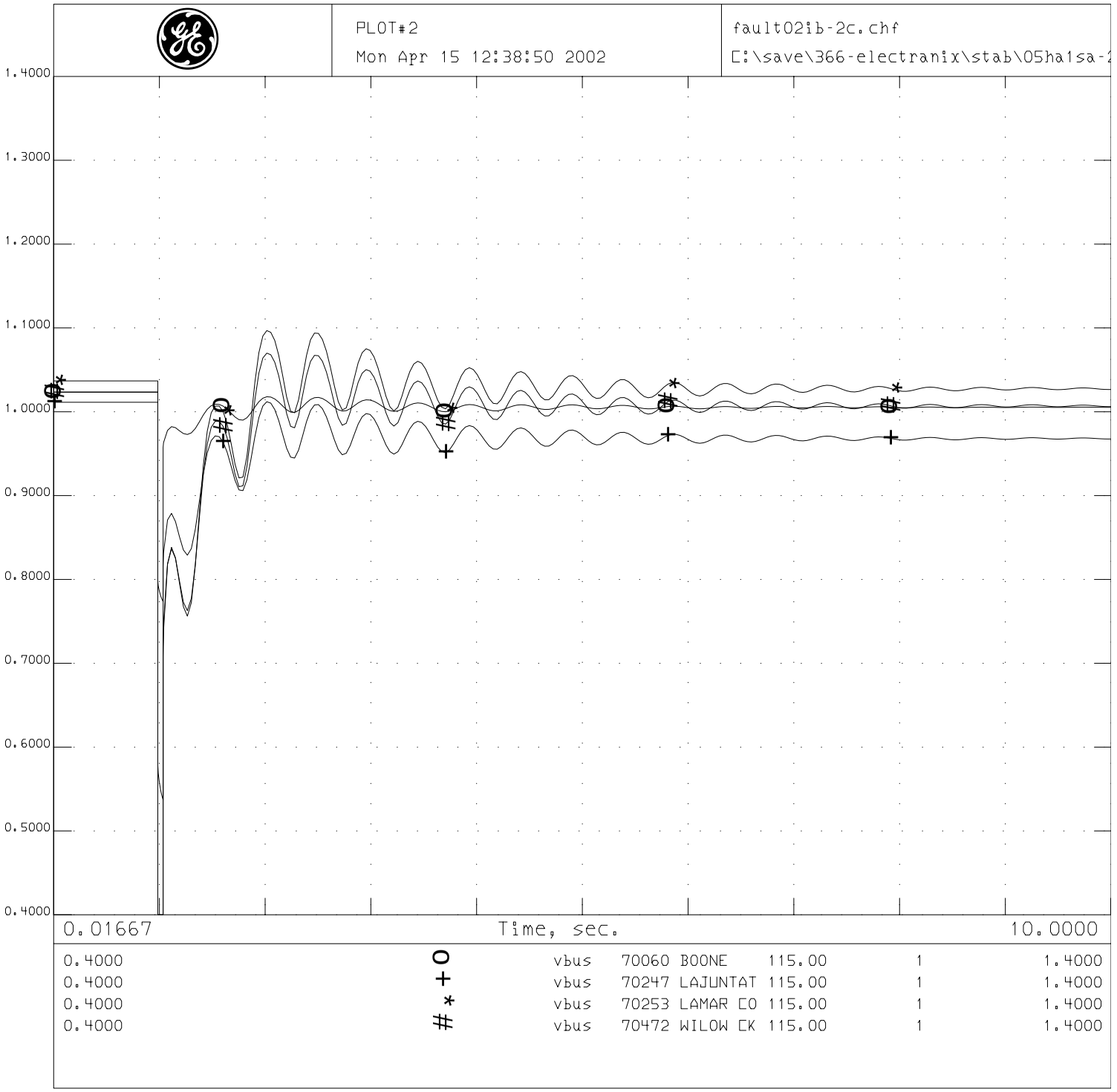
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

switch off Load at LAMAR DC 230kV(70560) bus simulate as dc block
trip all shunt capacitors at LAMAR DC(70560) 230kV bus after 5 cycles



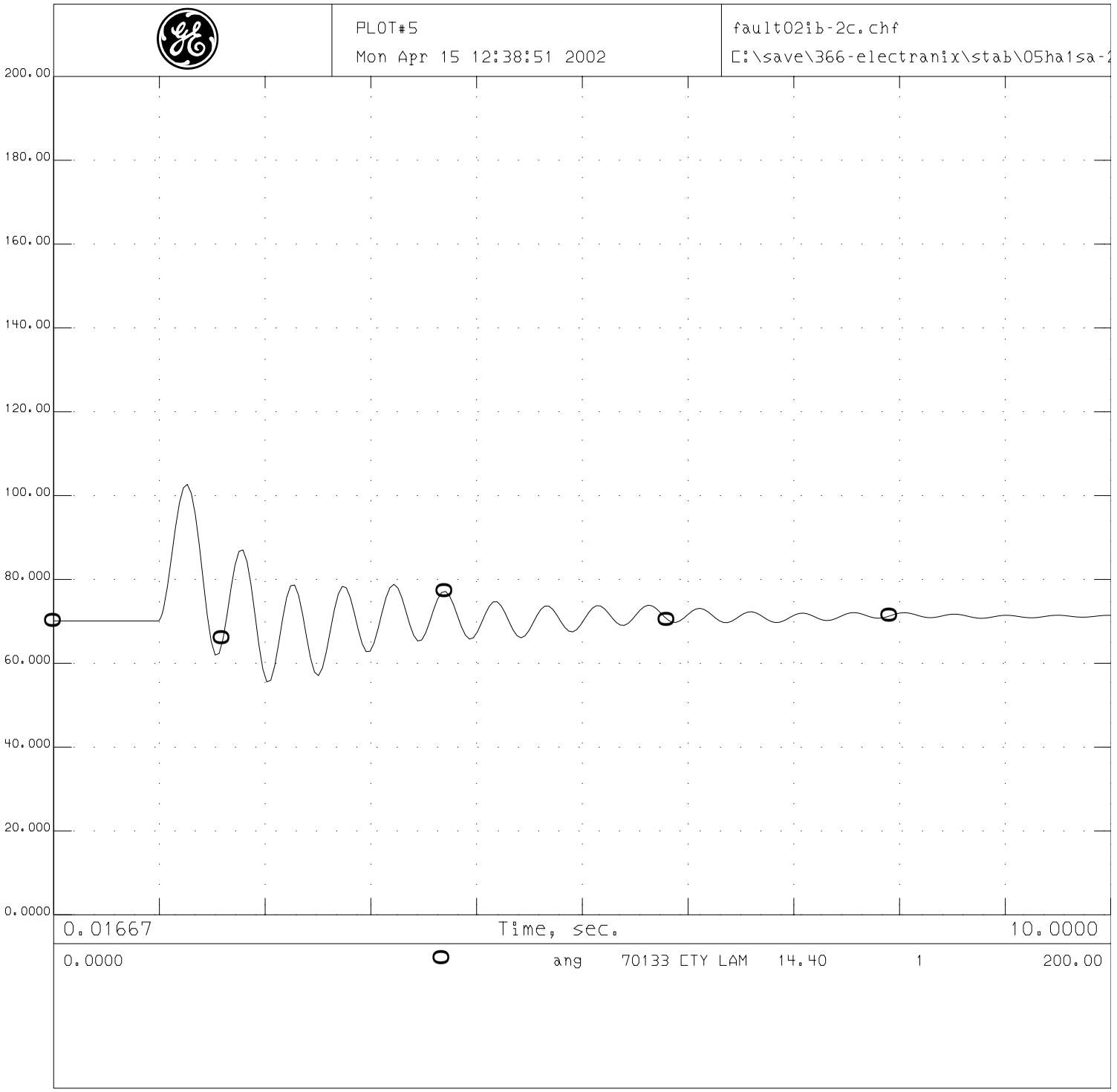
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared
dc reduced to -100 MW (import)



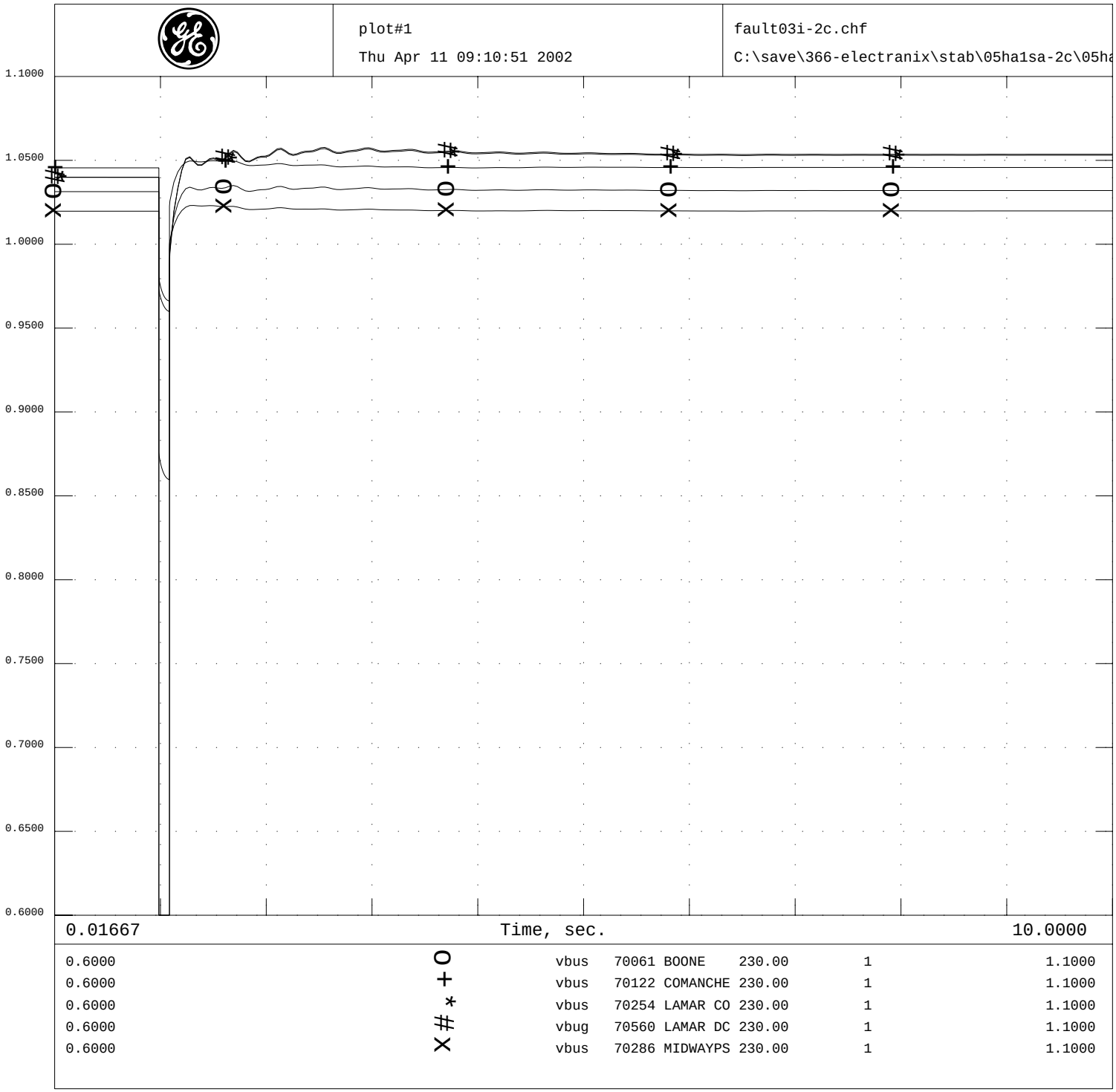
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared
dc reduced to -100 MW (import)



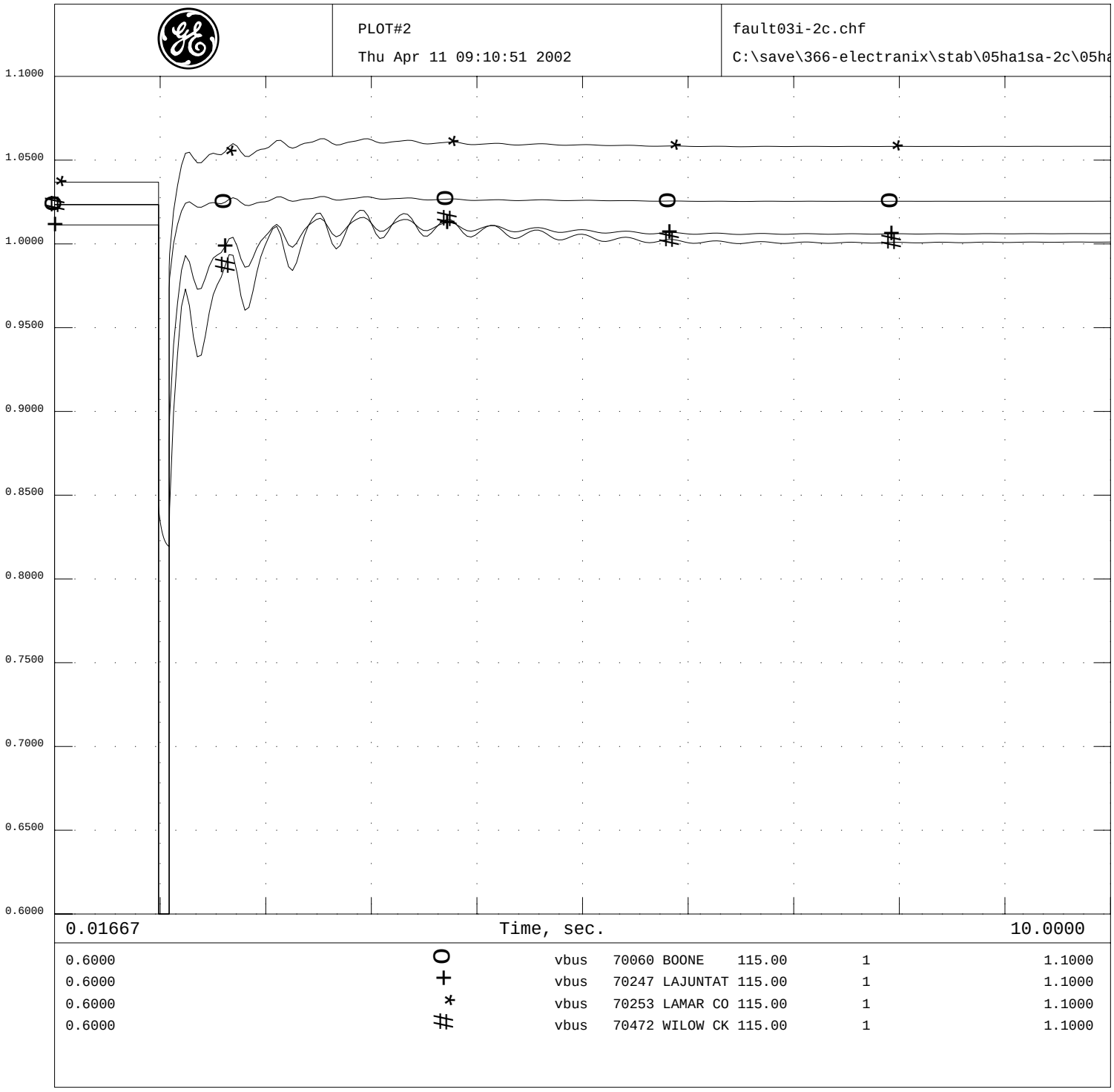
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared
dc reduced to -100 MW (import)



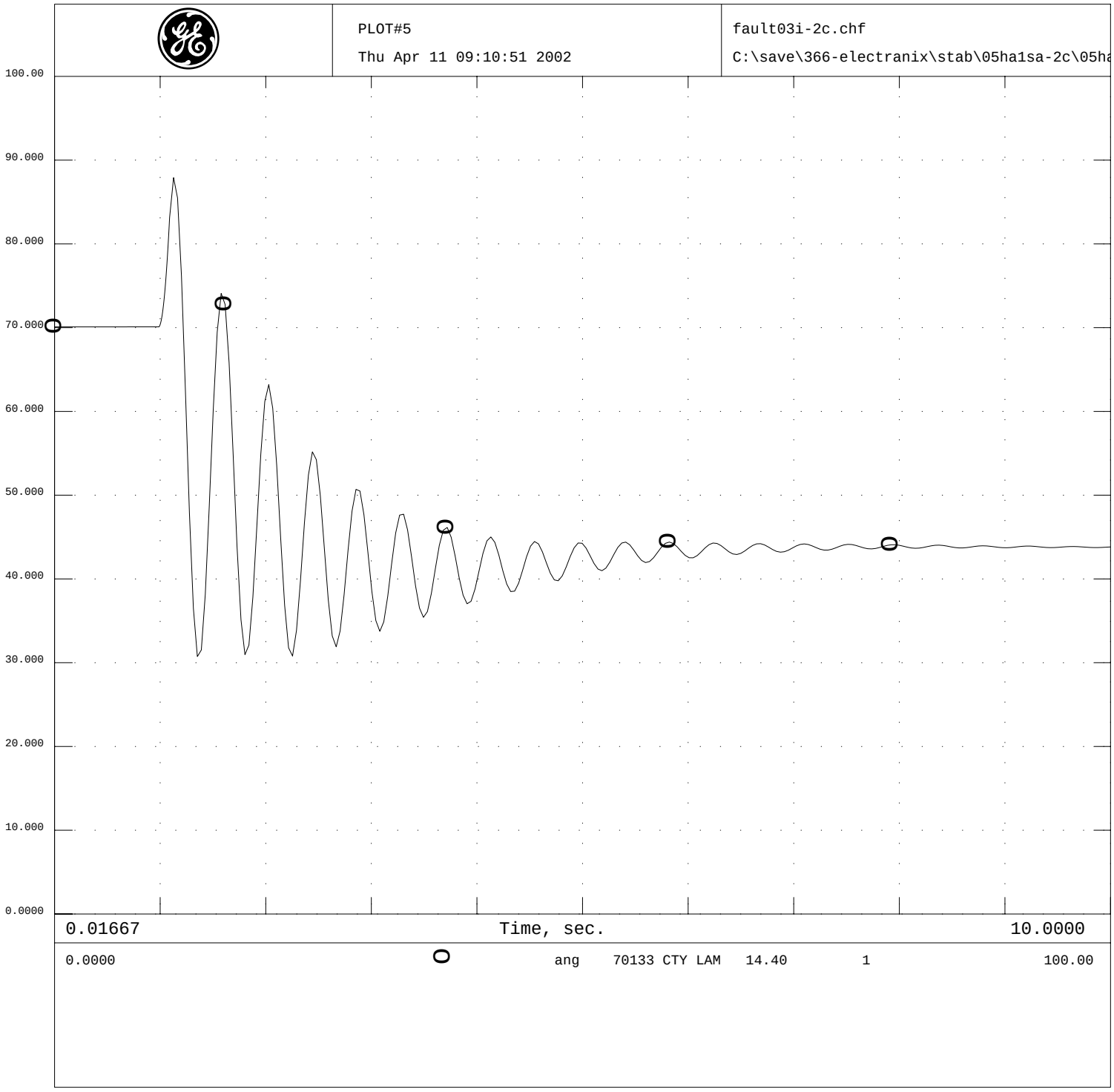
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



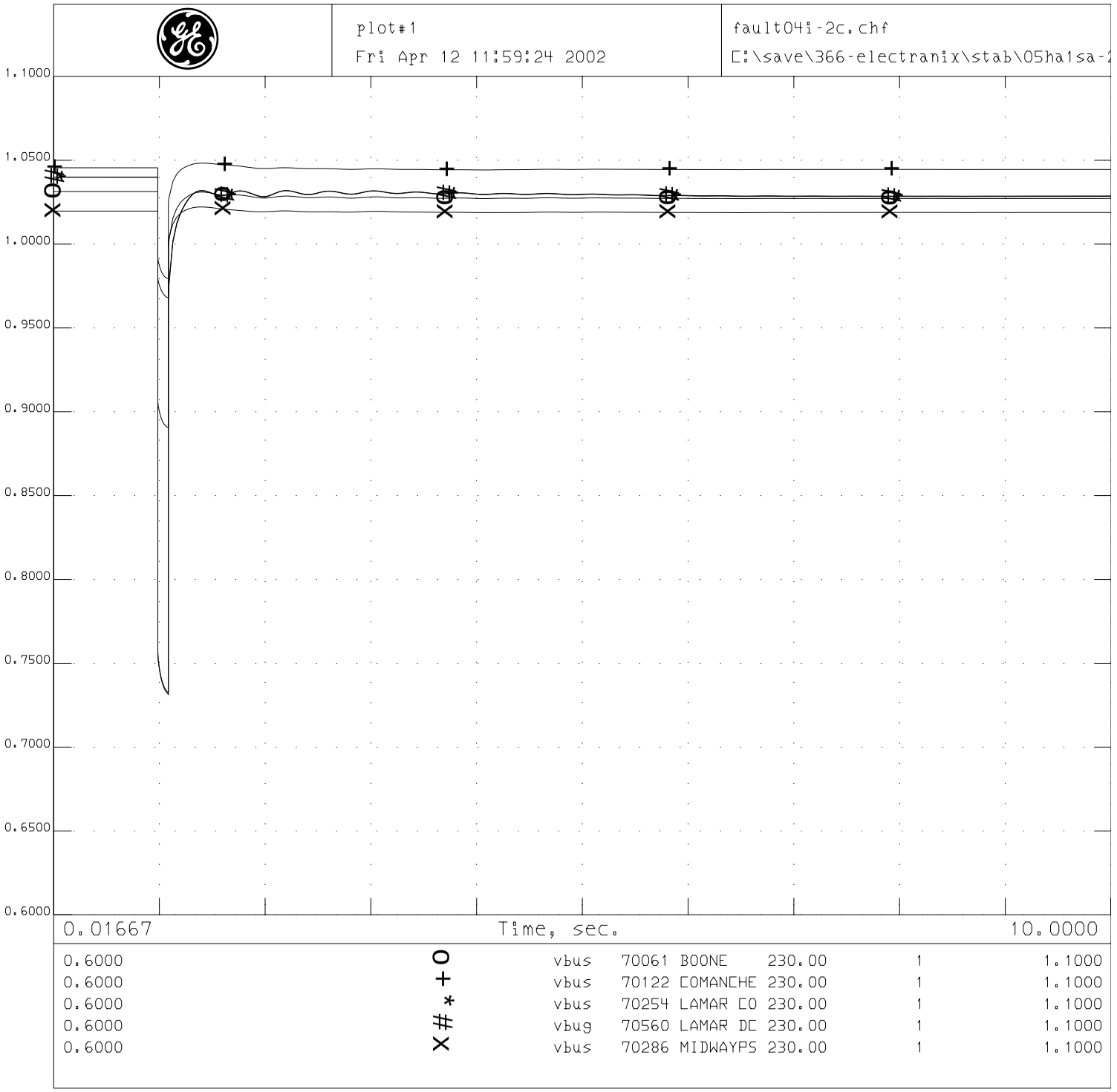
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



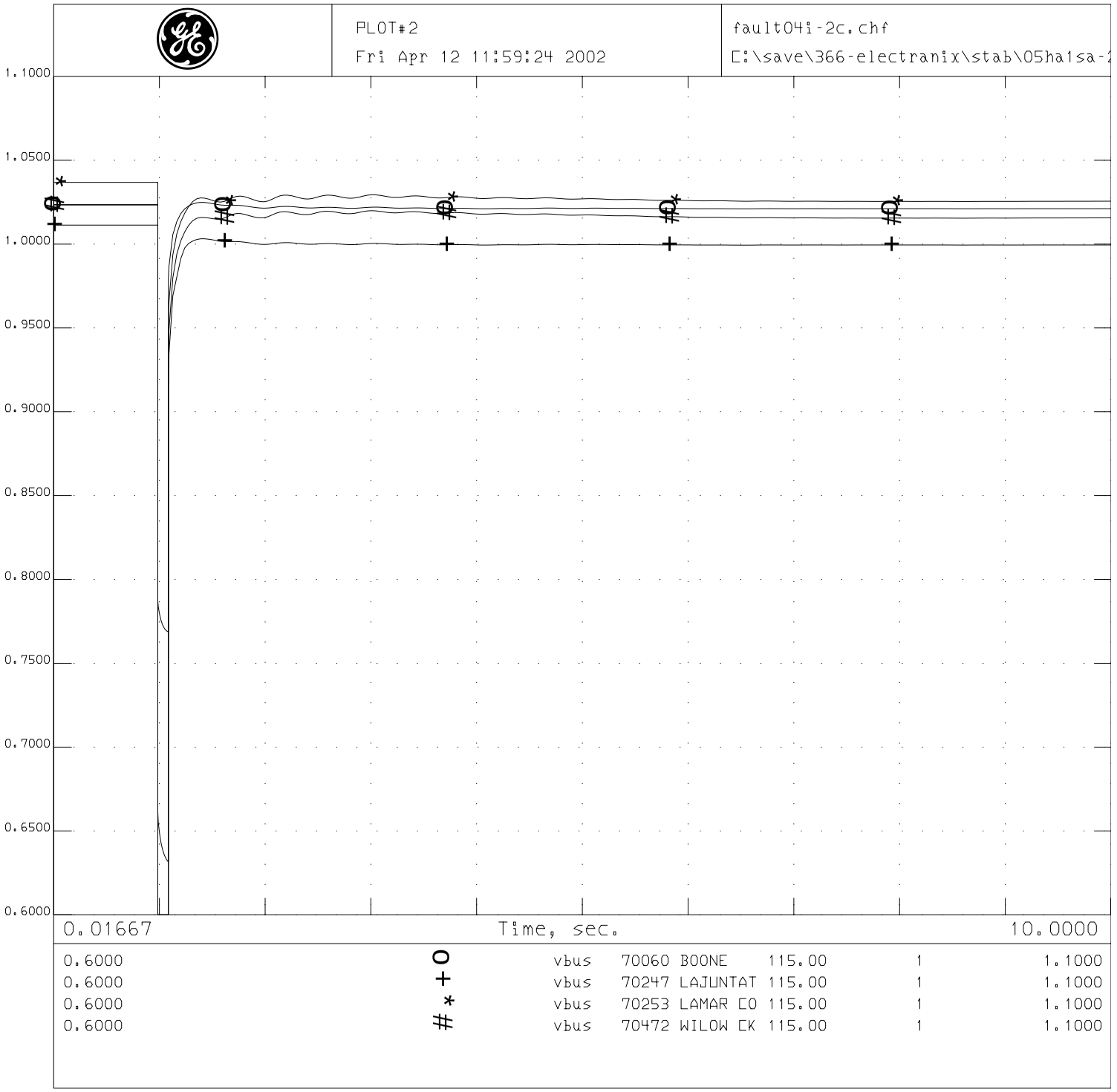
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



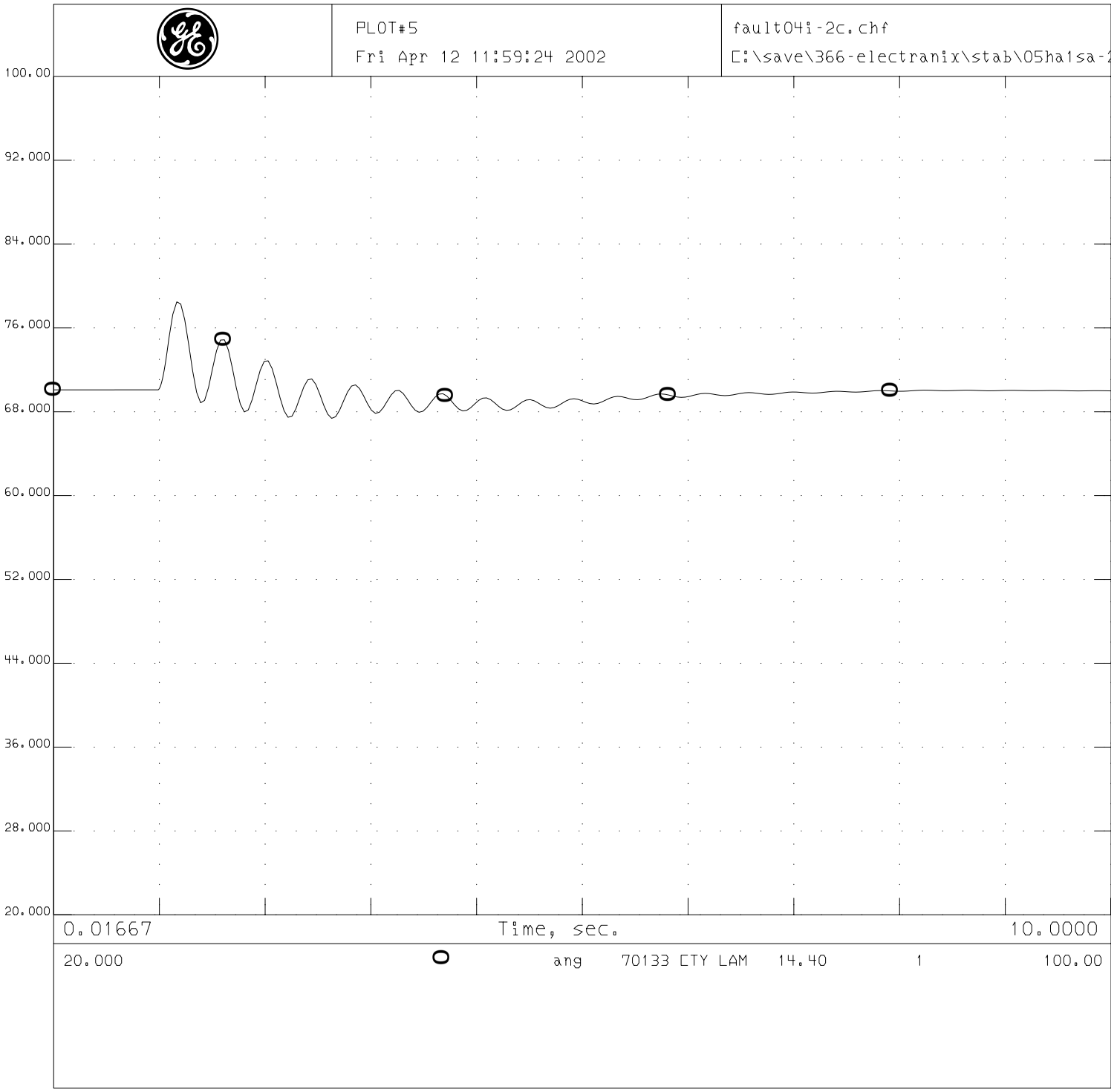
2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing



2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

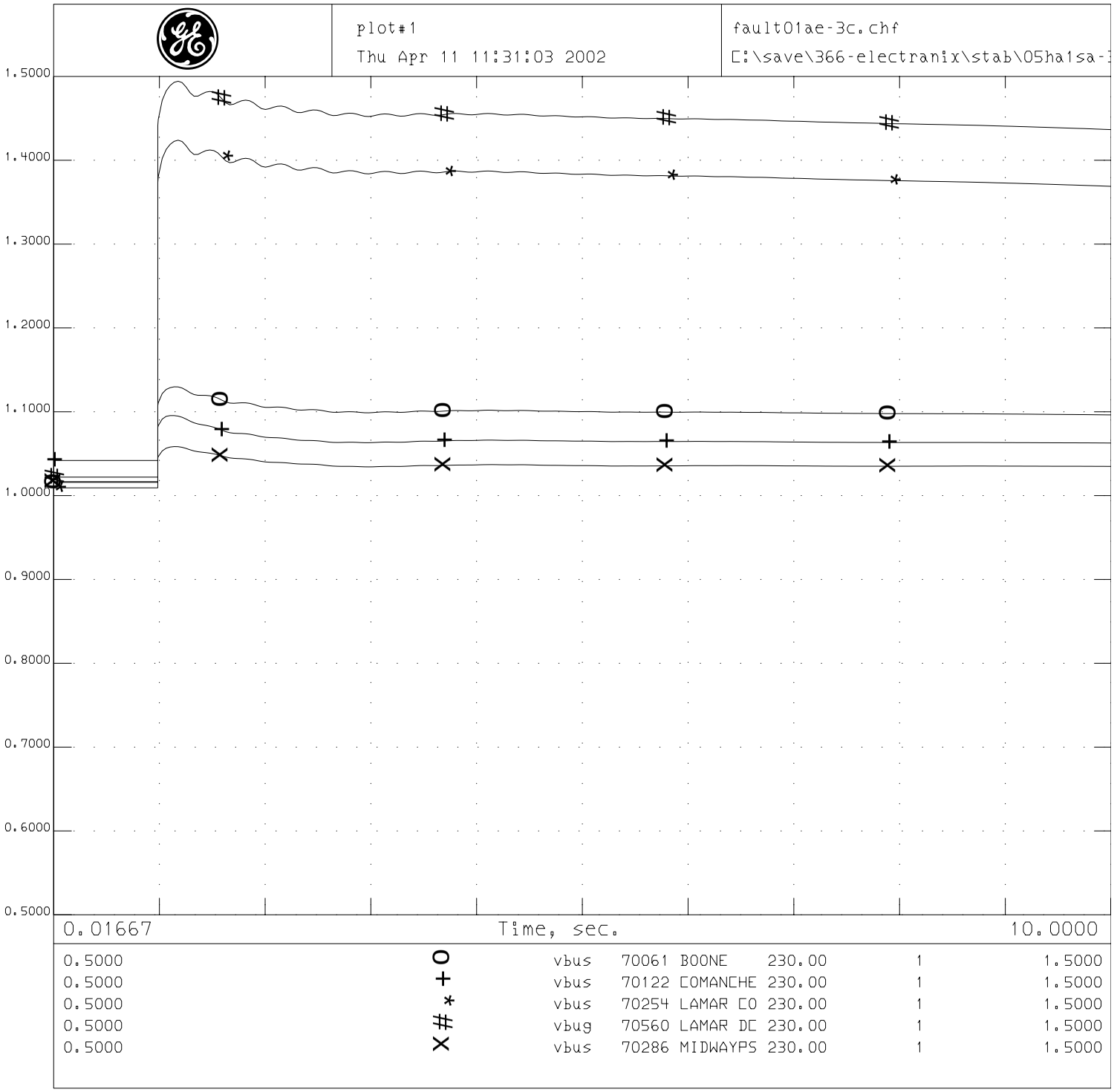
3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing



2005 HA1-SA-2C: 210MW import from SPP
dc bus voltage hold at 1.04 p.u. with Qmx=50Mvar & Qmn=-20MVar
Reduced 210MW generation in zones 700 & 706
Modified 70460 WALSH 69kV SVD type from 4 to 2 (continuous)
Boone 230/115kV transformer in type 12

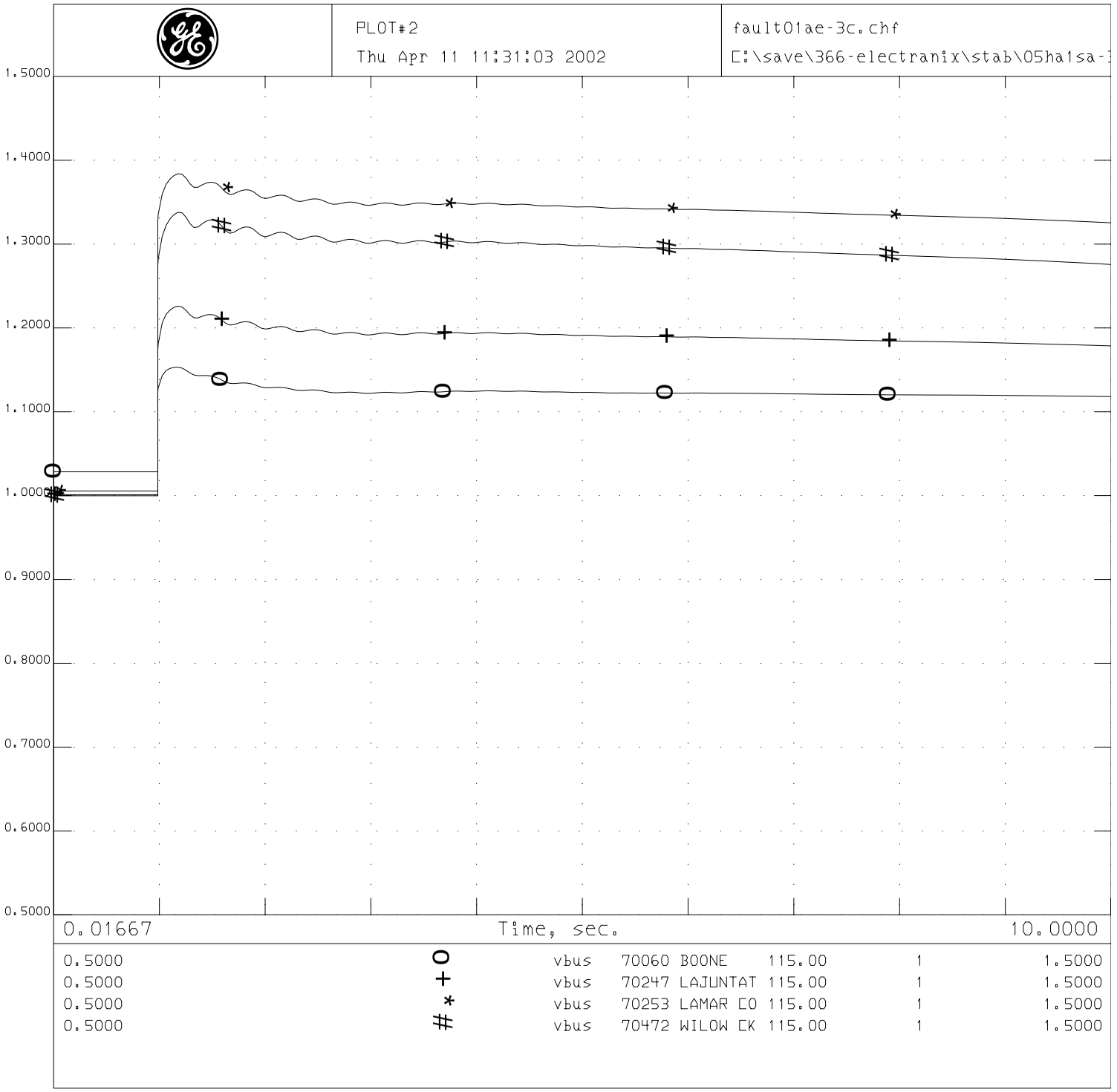
3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing

Appendix 6.3– Transient Stability Study Results
(HVDC Link Exporting 210 MW from WSCC System)



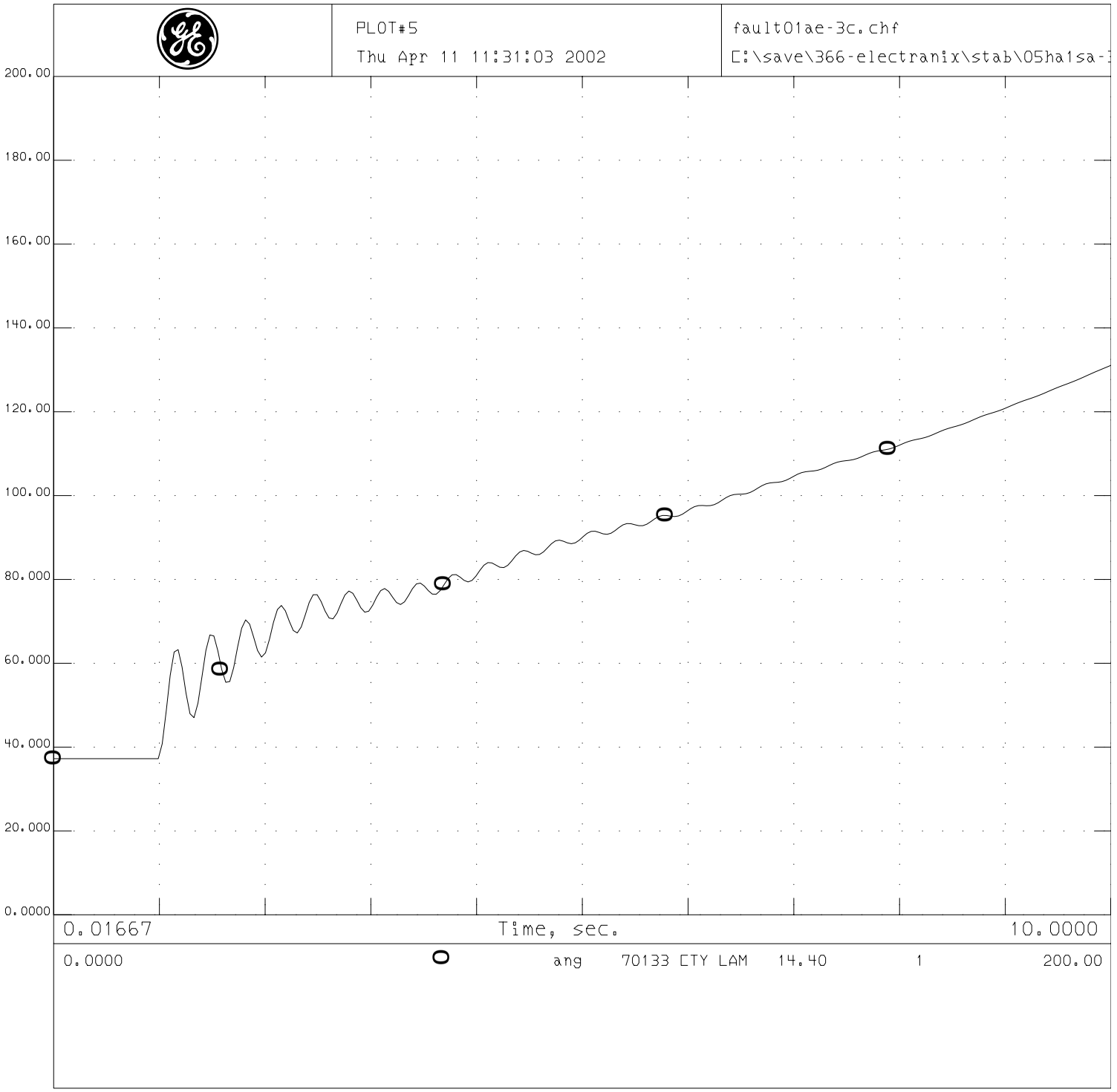
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

switch off Load at 70560 LAMAR DC 230kV bus simulate as dc block permanently



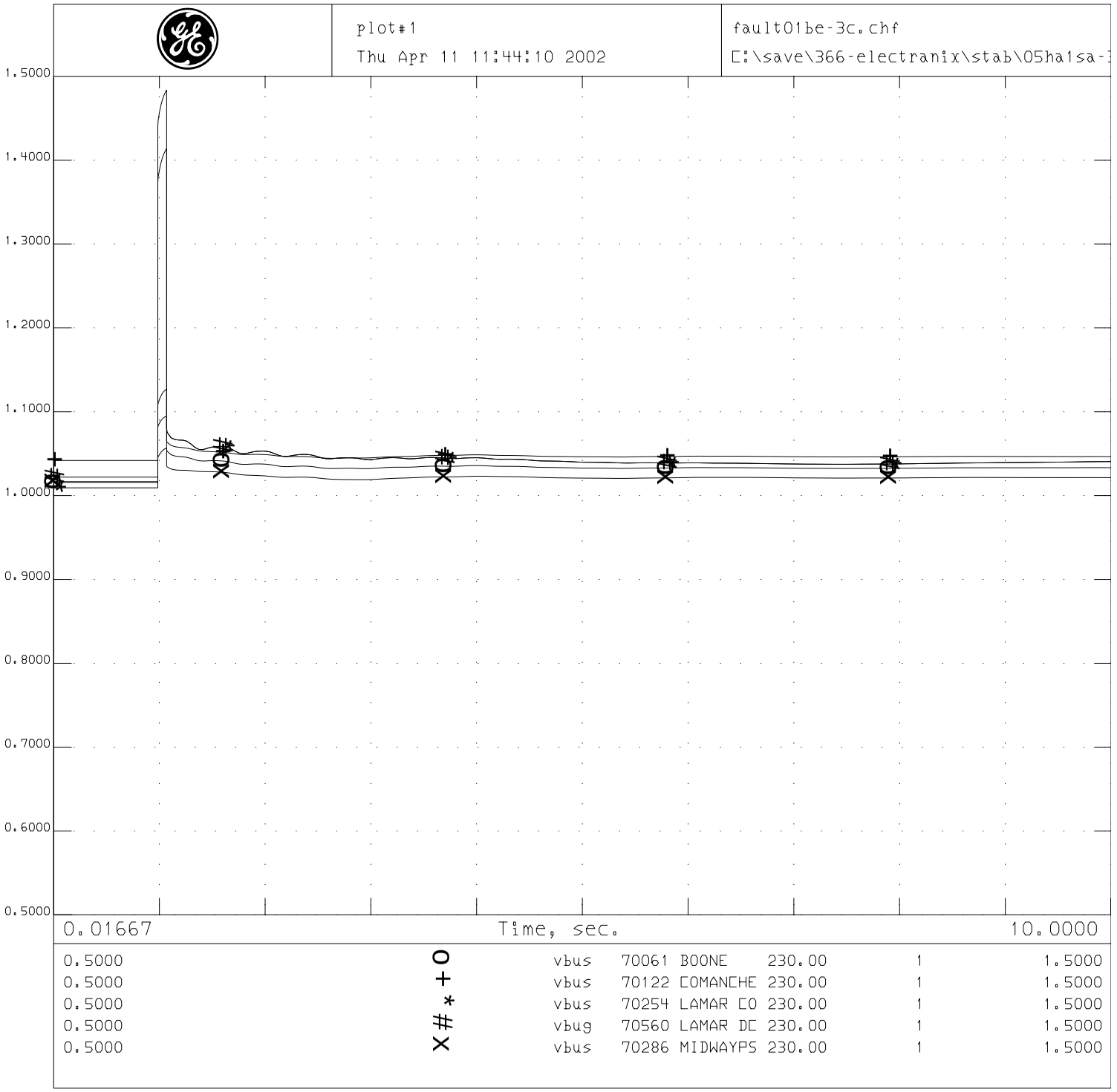
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

switch off Load at 70560 LAMAR DC 230kV bus simulate as dc block permanently



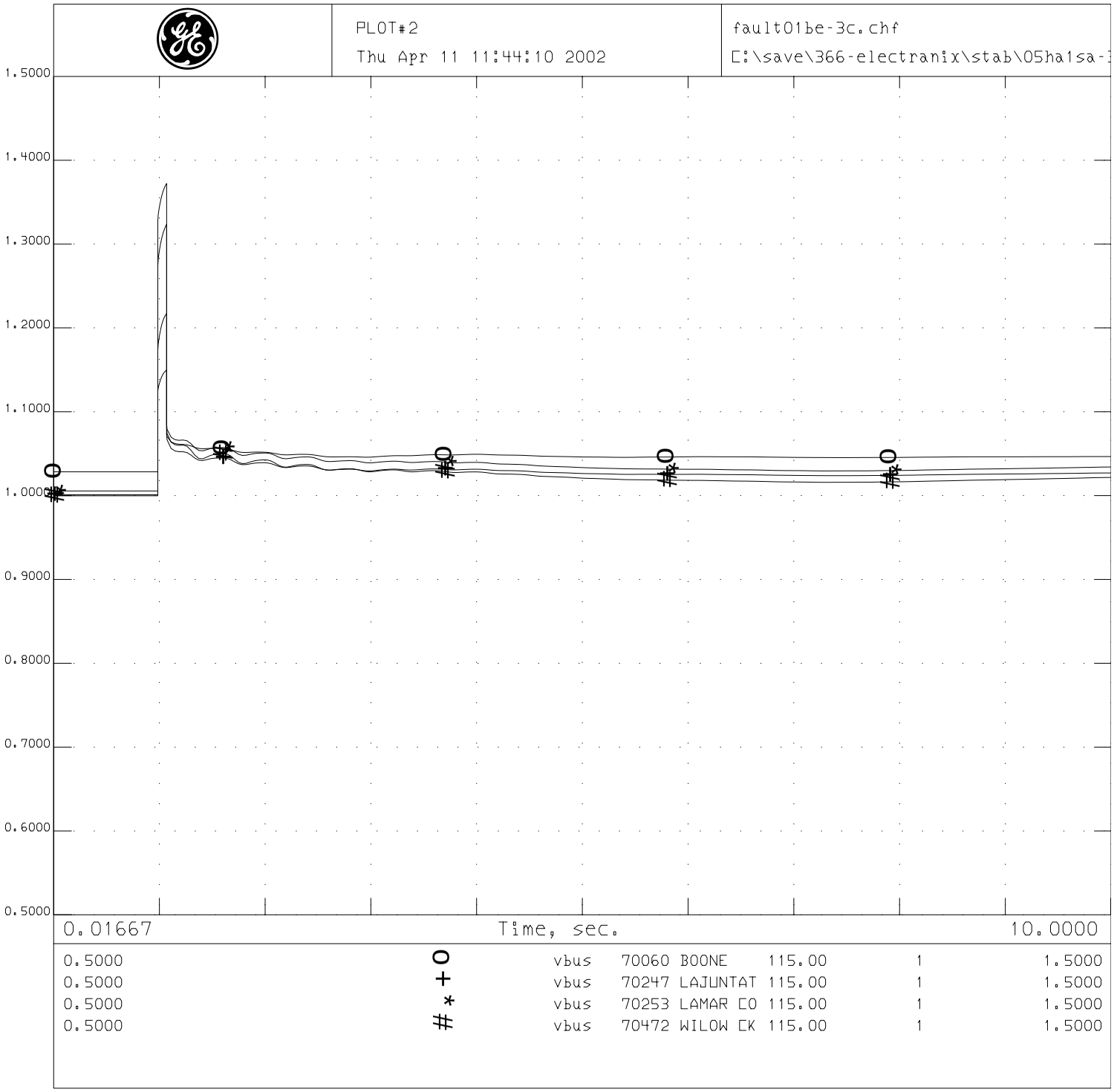
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

switch off Load at 70560 LAMAR DC 230kV bus simulate as dc block permanently



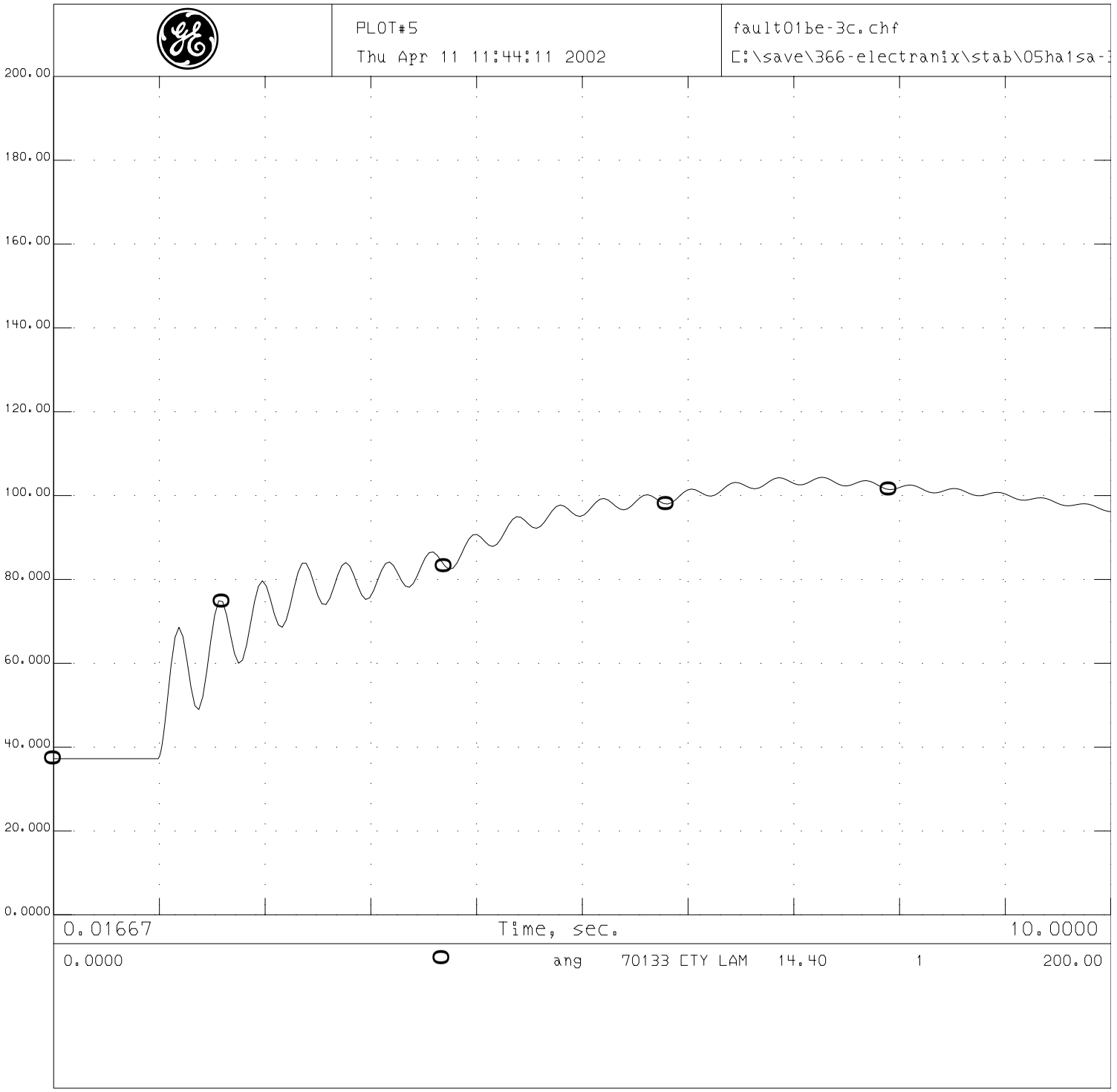
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

switch off Load at LAMAR DC 230kV(70560) bus simulate as dc block
trip all shunt capacitors at LAMAR DC(70560) 230kV bus after 5 cycles



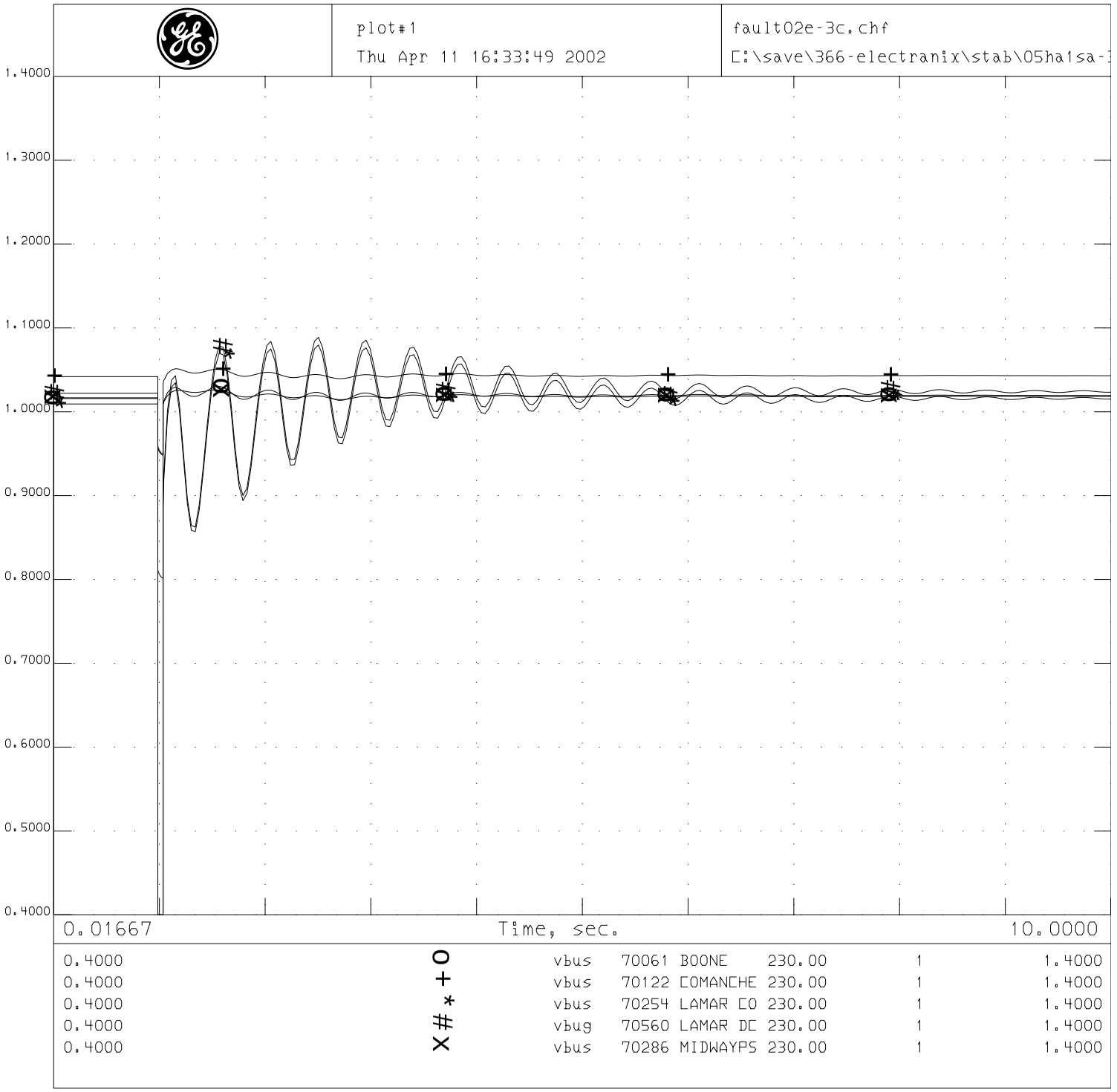
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

switch off Load at LAMAR DC 230kV(70560) bus simulate as dc block
trip all shunt capacitors at LAMAR DC(70560) 230kV bus after 5 cycles



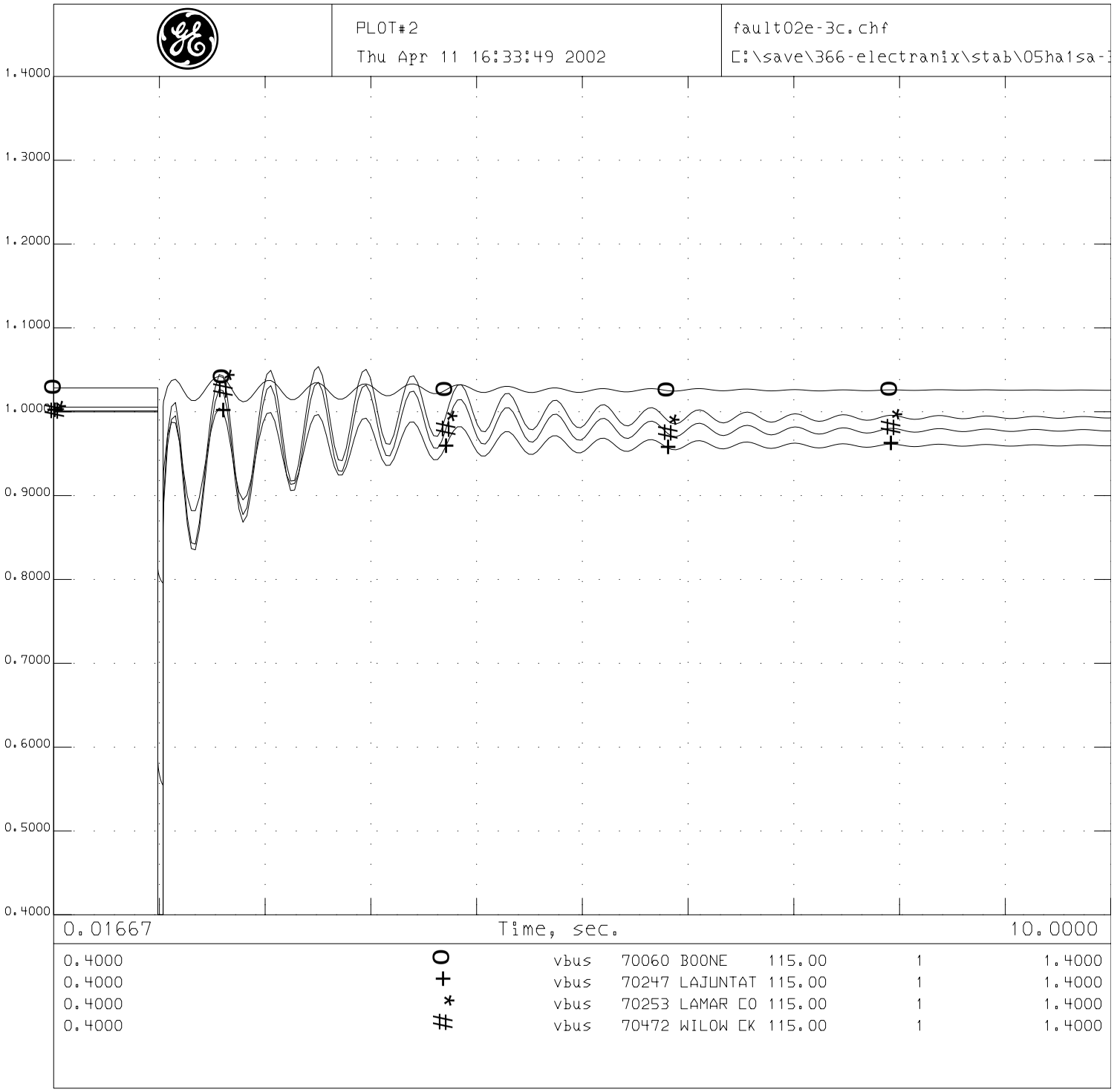
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

switch off Load at LAMAR DC 230kV(70560) bus simulate as dc block
trip all shunt capacitors at LAMAR DC(70560) 230kV bus after 5 cycles



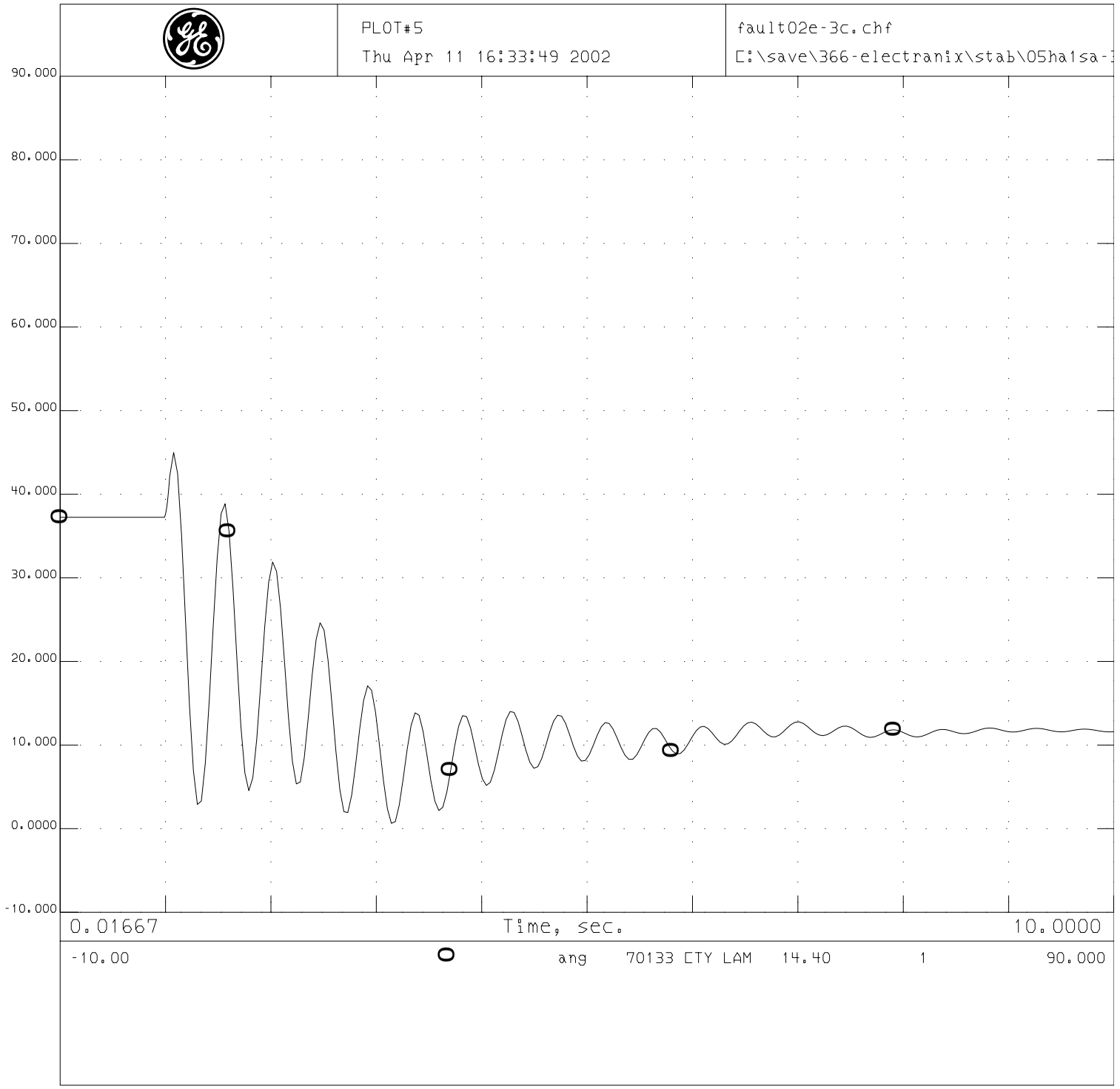
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared
dc reduced to 48 MW (export), 52Mvar capacitor left at dc bus



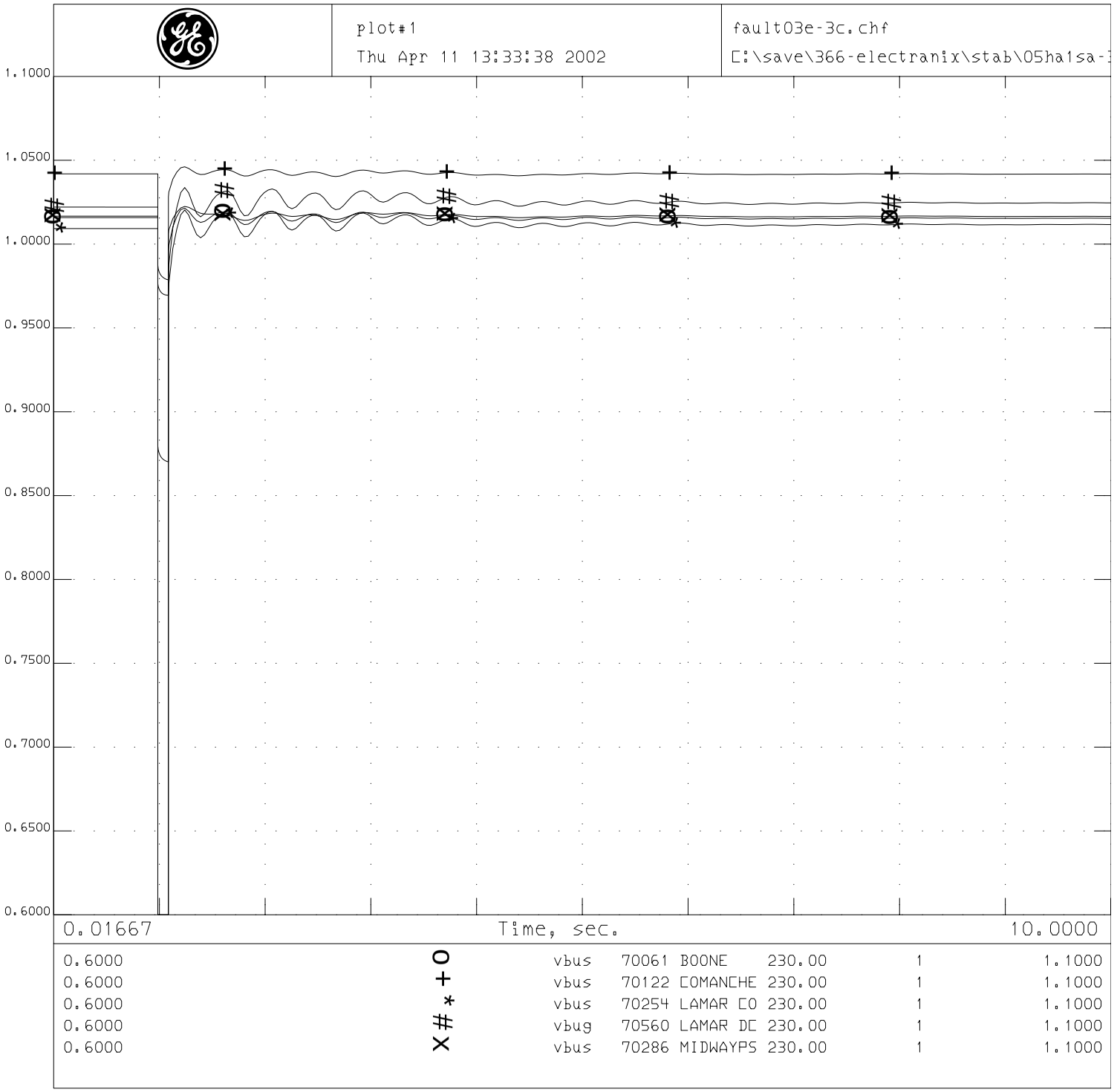
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared
dc reduced to 48 MW (export), 52Mvar capacitor left at dc bus



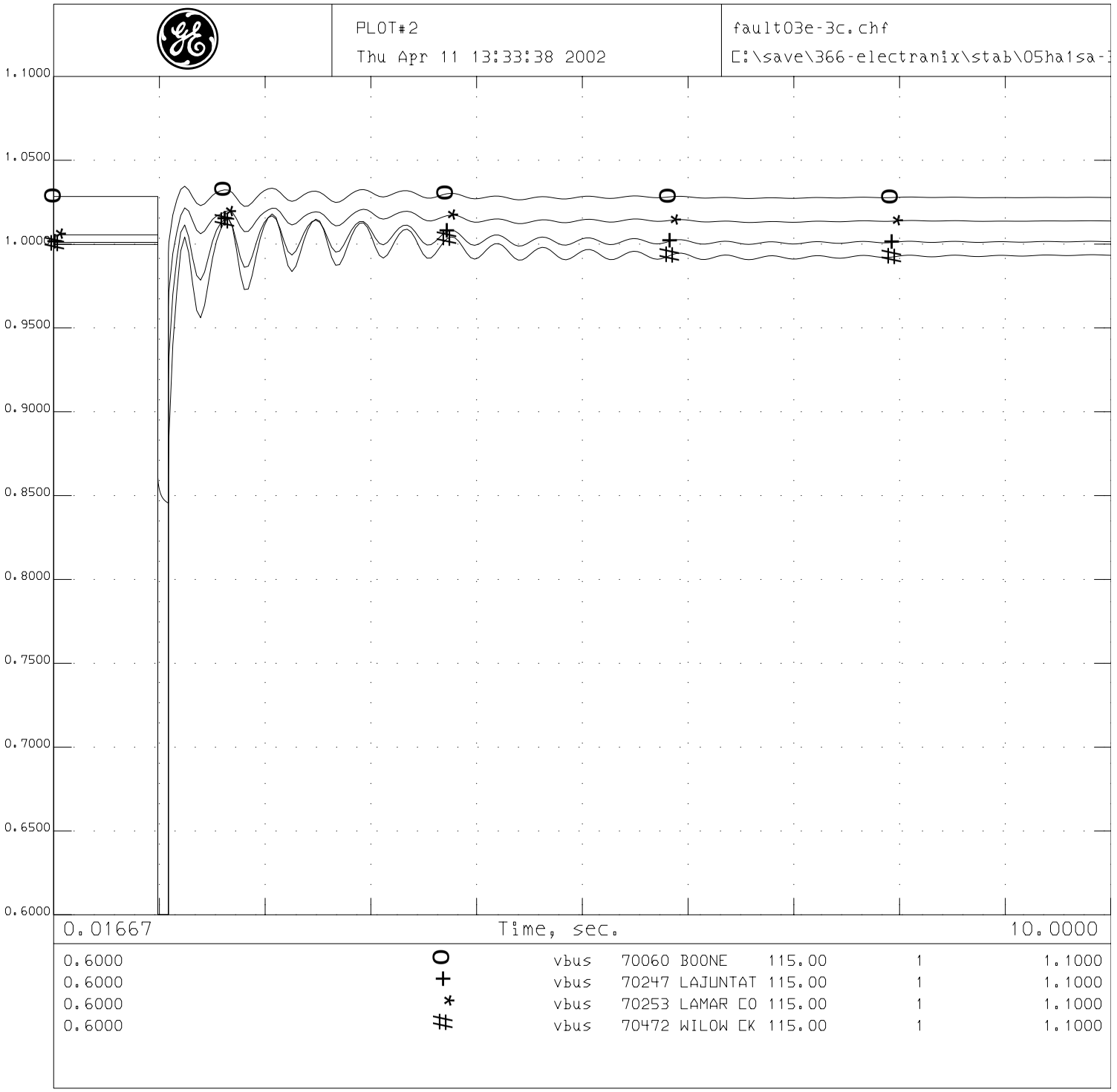
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

3 phase 3 cycle fault at LAMAR CO(70254) 230kV bus
open 230kV line LAMAR CO(70254) - BOONE(70061) after fault cleared
dc reduced to 48 MW (export), 52Mvar capacitor left at dc bus



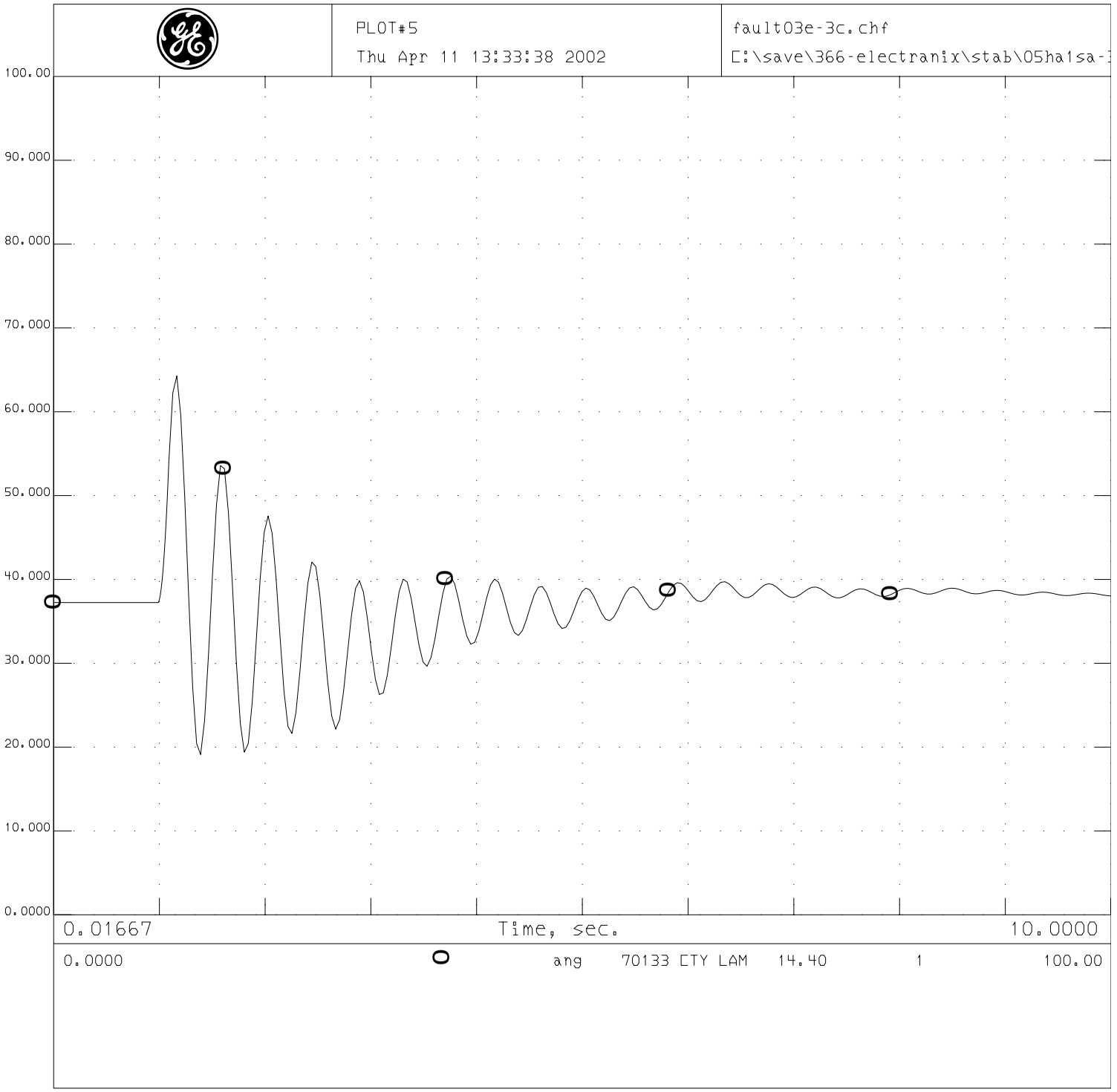
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



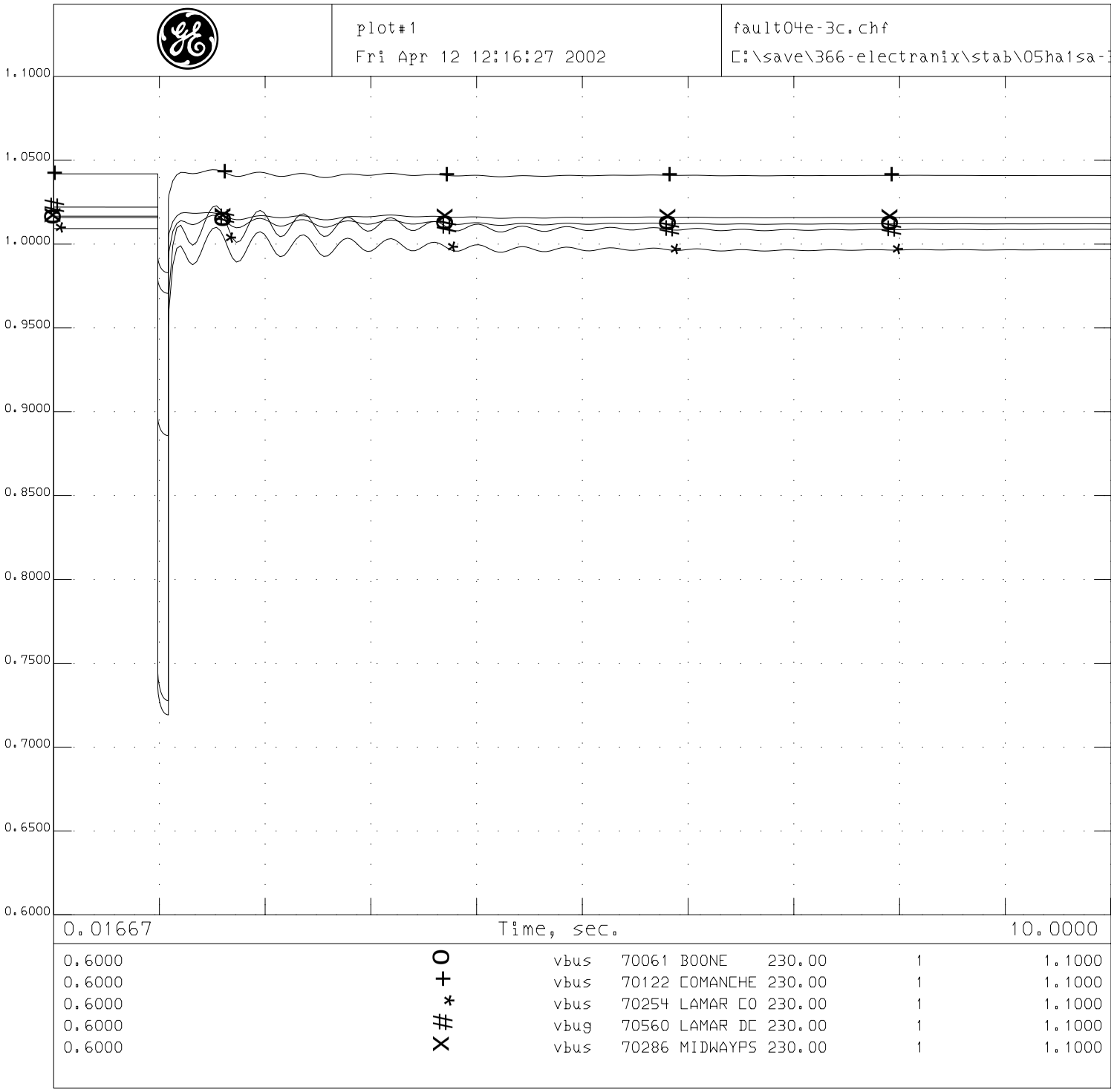
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



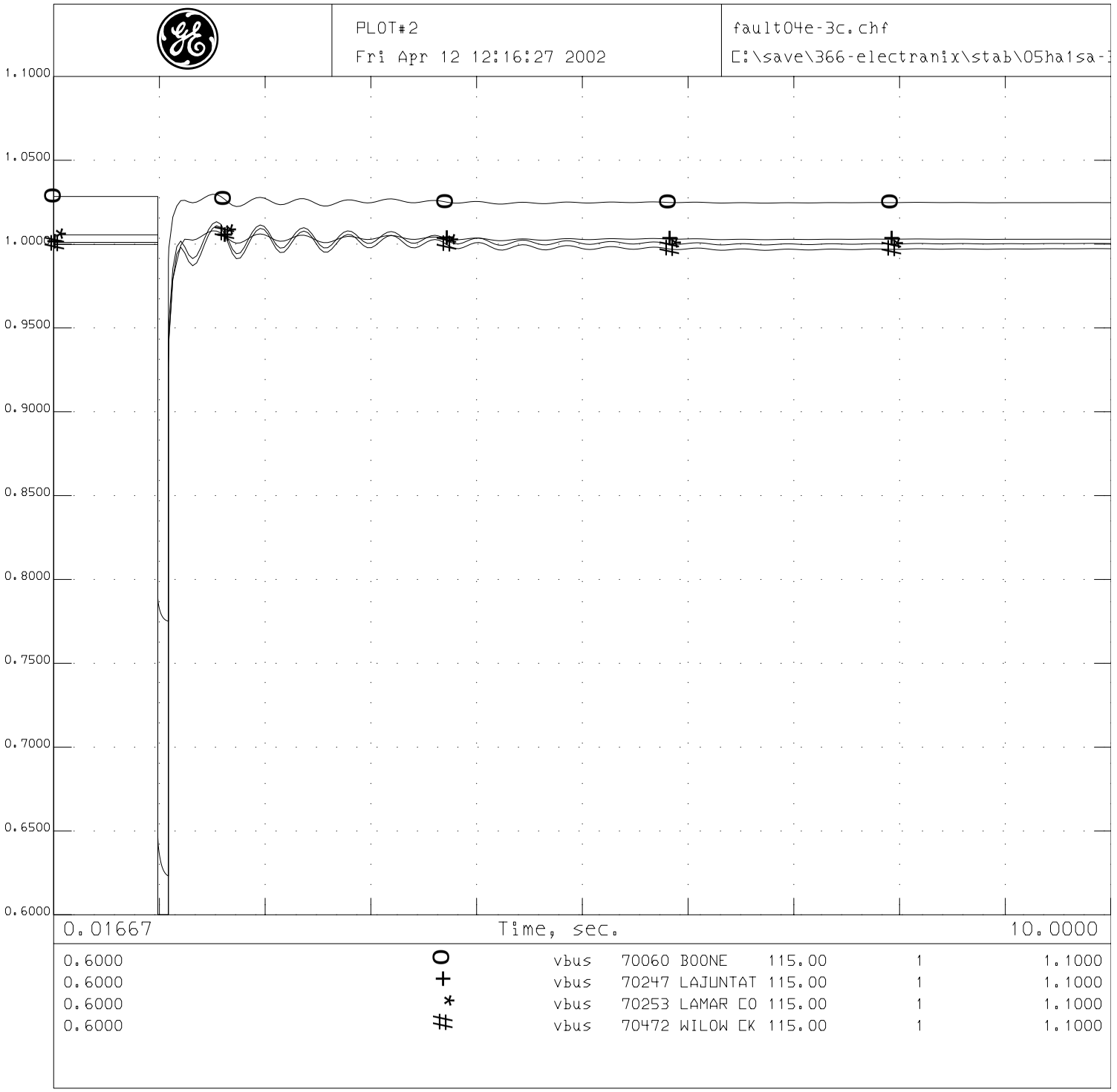
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

3 phase 6 cycle fault at LAMAR CO(70253)115kV bus
open 115 kV line LAMAR CO(70253) - WILOW CK(70472) after fault clearing



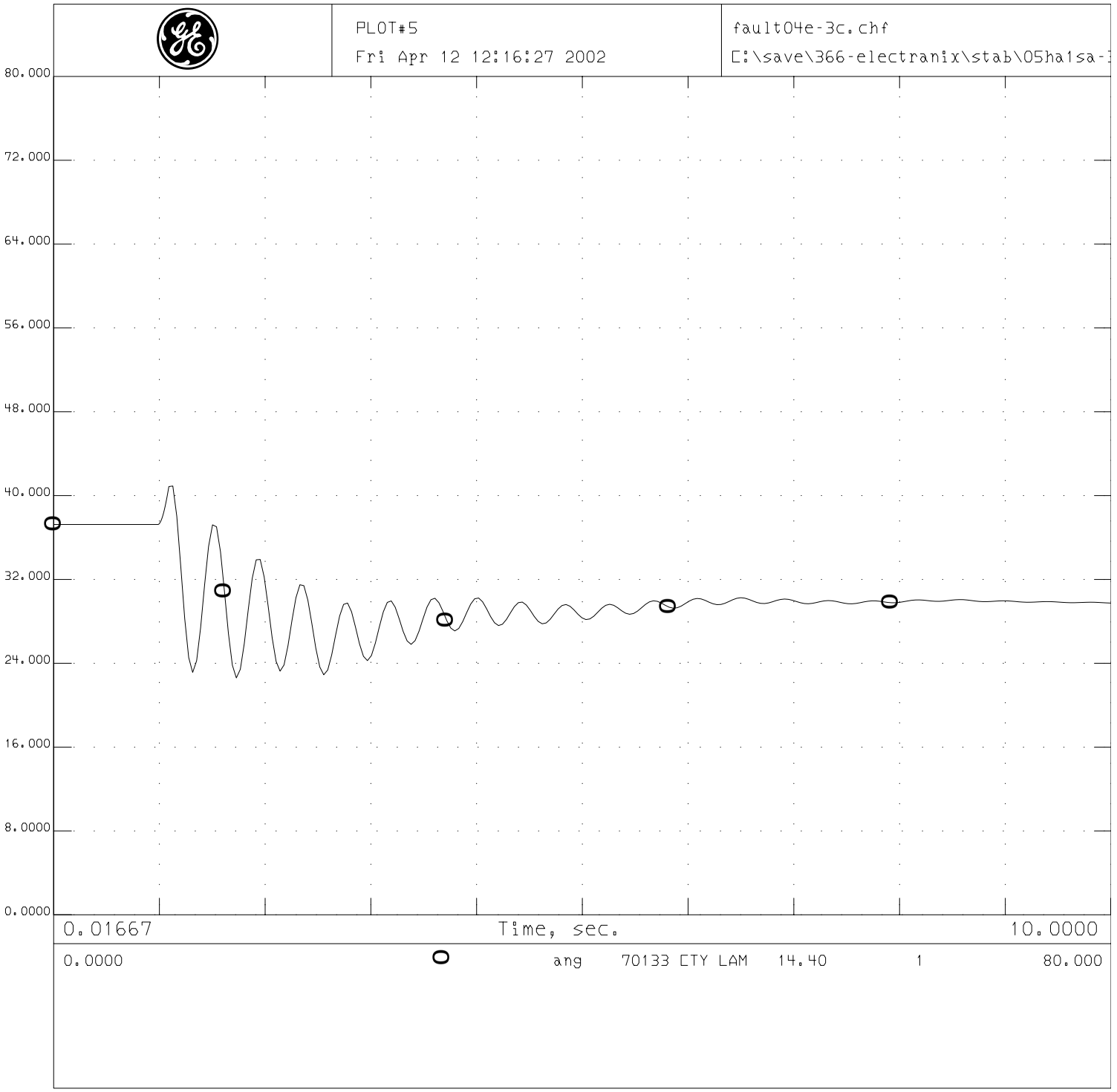
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing



2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

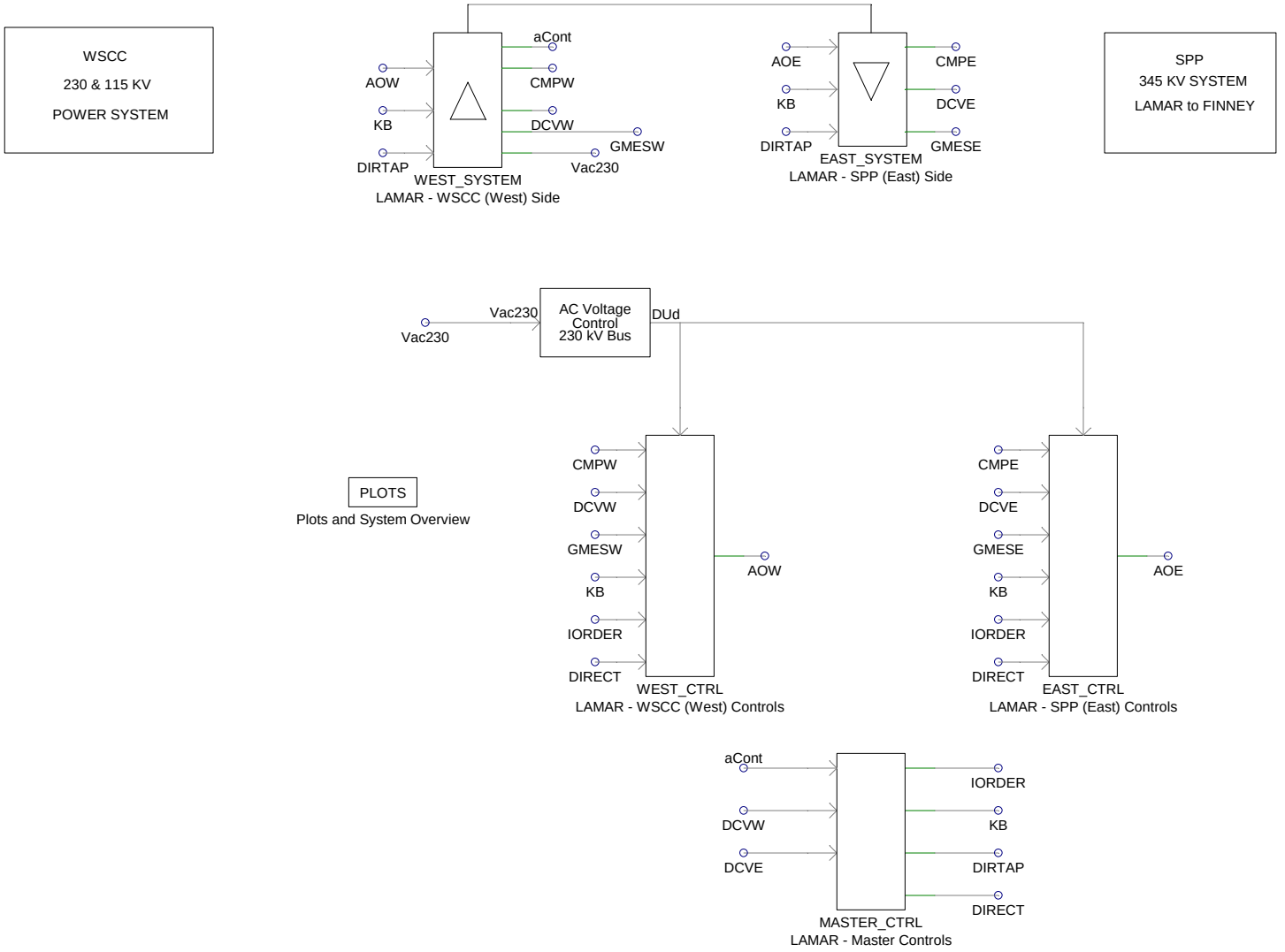
3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing

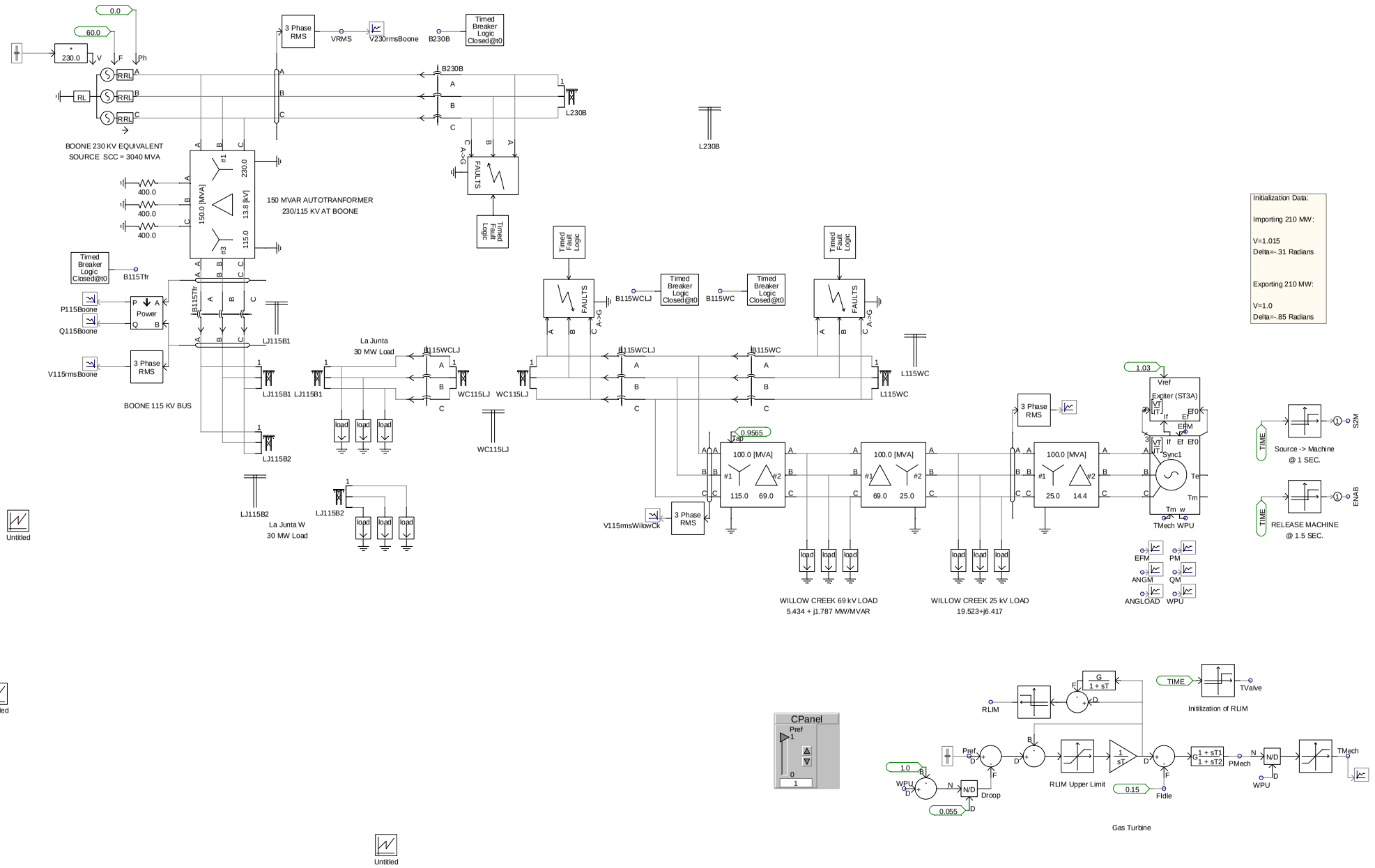


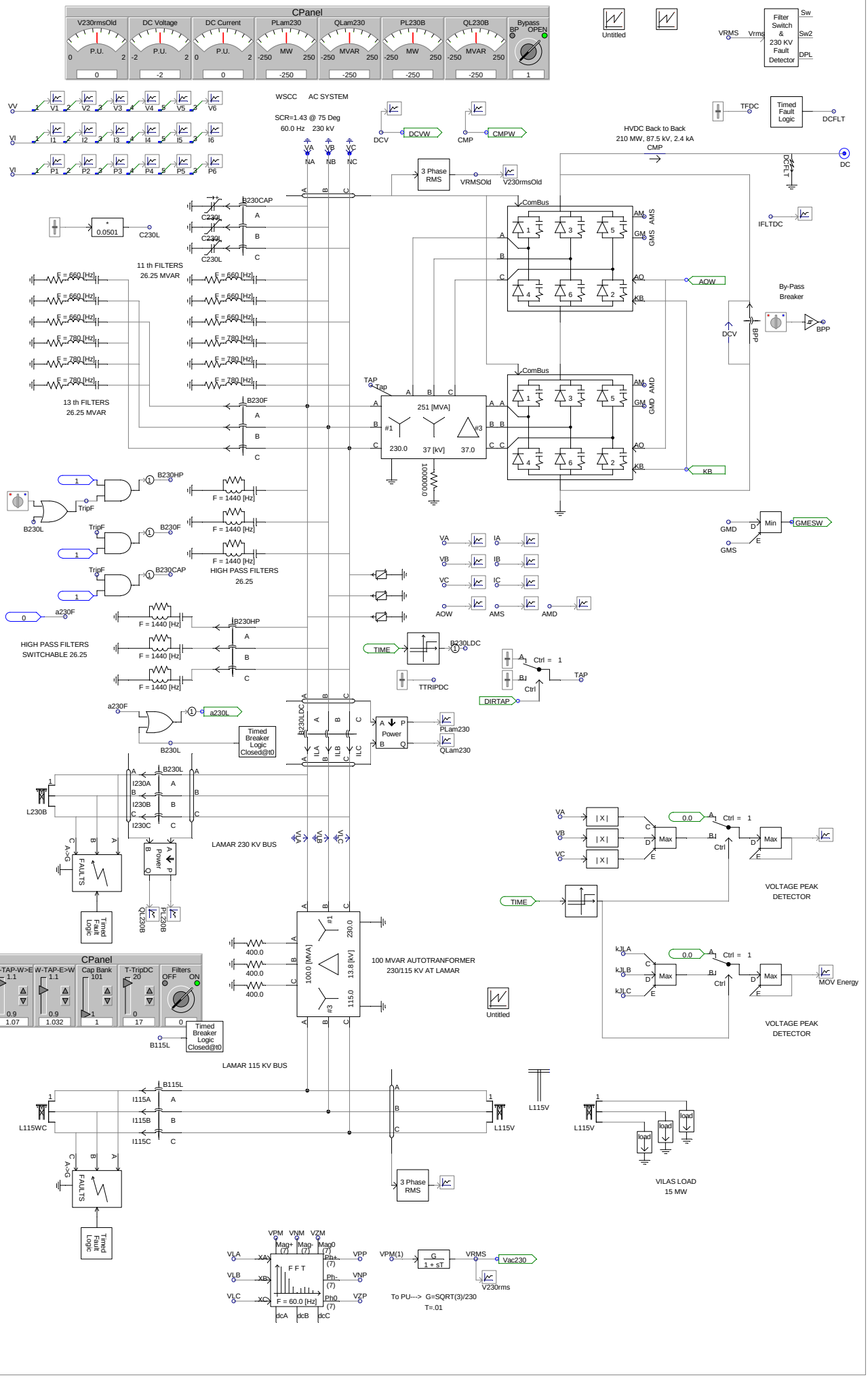
2005 HA1-SA-3C: 210MW export from WSCC to SPP
dc bus voltage hold at 1.022 p.u., Qdcmx=50MVar & Qdcmn=-20MVar
Dispatch generator 70589 for 190MW and 20MW additon to generator 70105
Modified 70460 WALSH 69kV SVD from type 4 to 2 (continuous)
Boone 230/115kV xfmr in type 12

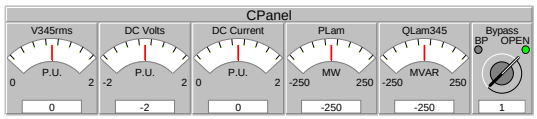
3 phase 6 cycle fault at LAJUNTAT(70247) 115kV bus
open 115 kV line LAJUNTAT(70247) - WILOW CK(70472) after fault clearing

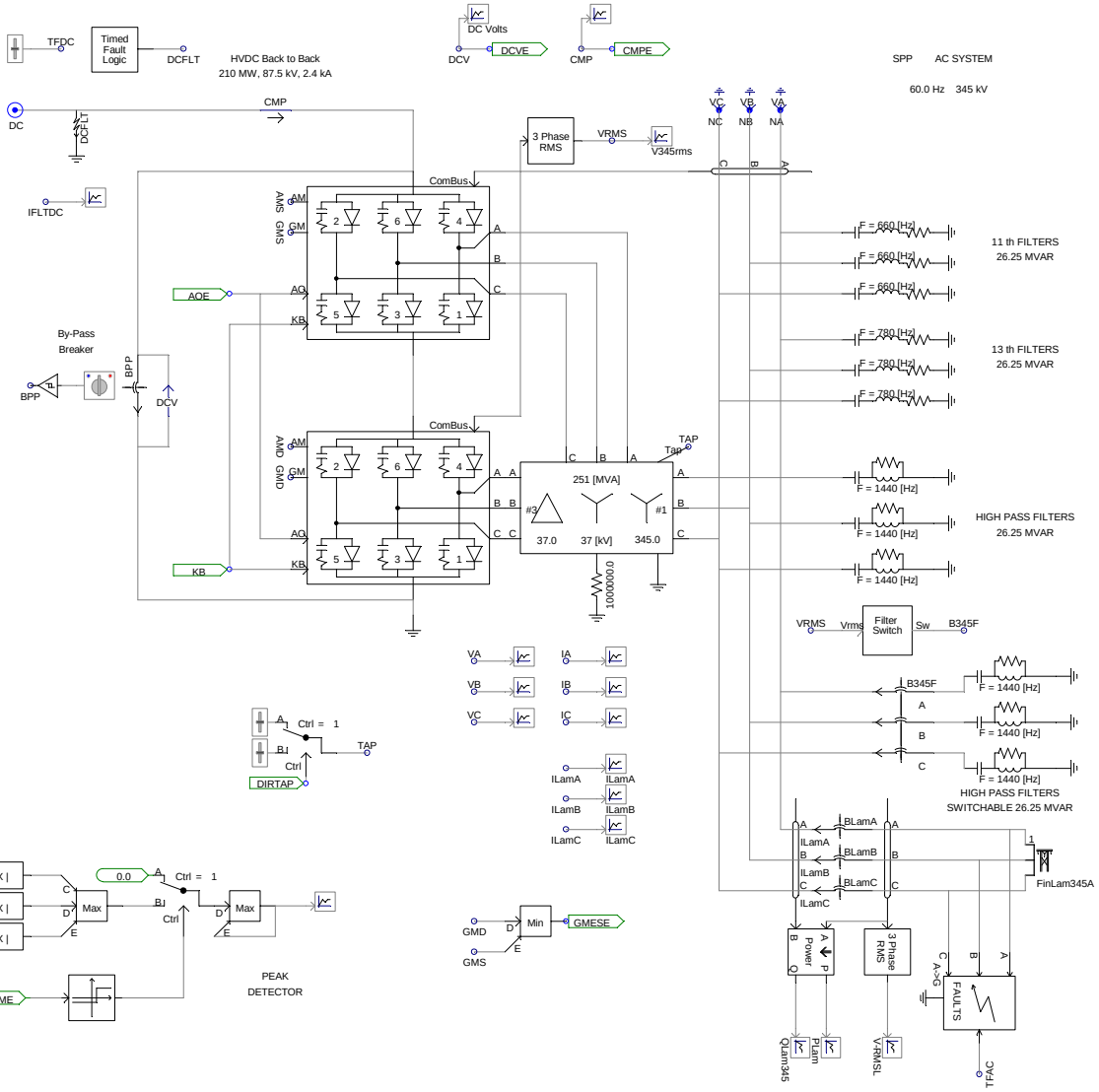
Appendix 7– PSCAD Transient Circuit (System and HVDC Controls Diagrams)

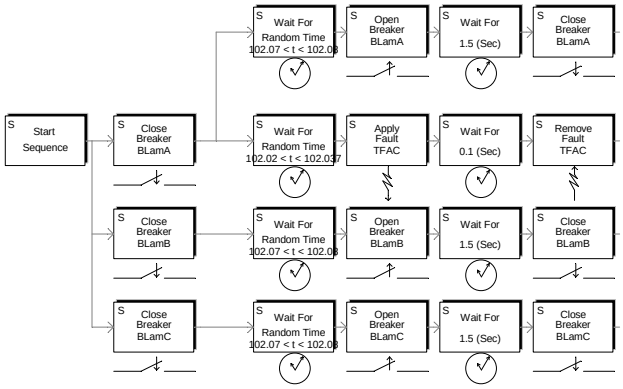

WSCC
230 & 115 KV
POWER SYSTEM
aCont
AOW
CMPW
KB
DCVW
GMESW
DIRTAP
Vac230
WEST_SYSTEM
LAMAR - WSCC (West) Side
AOE
CMPE
KB
DCVE
DIRTAP
GMESE
EAST_SYSTEM
LAMAR - SPP (East) Side
SPP
345 KV SYSTEM
LAMAR to FINNEY
Vac230
Vac230
AC Voltage Control 230 kV Bus
DUd
PLOTS
Plots and System Overview
CMPW
DCVW
GMESW
KB
IORDER
DIRECT
AOW
WEST_CTRL
LAMAR - WSCC (West) Controls
CMPE
DCVE
GMESE
KB
IORDER
DIRECT
AOE
EAST_CTRL
LAMAR - SPP (East) Controls
aCont
DCVW
DCVE
IORDER
KB
DIRTAP
DIRECT
MASTER_CTRL
LAMAR - Master Controls

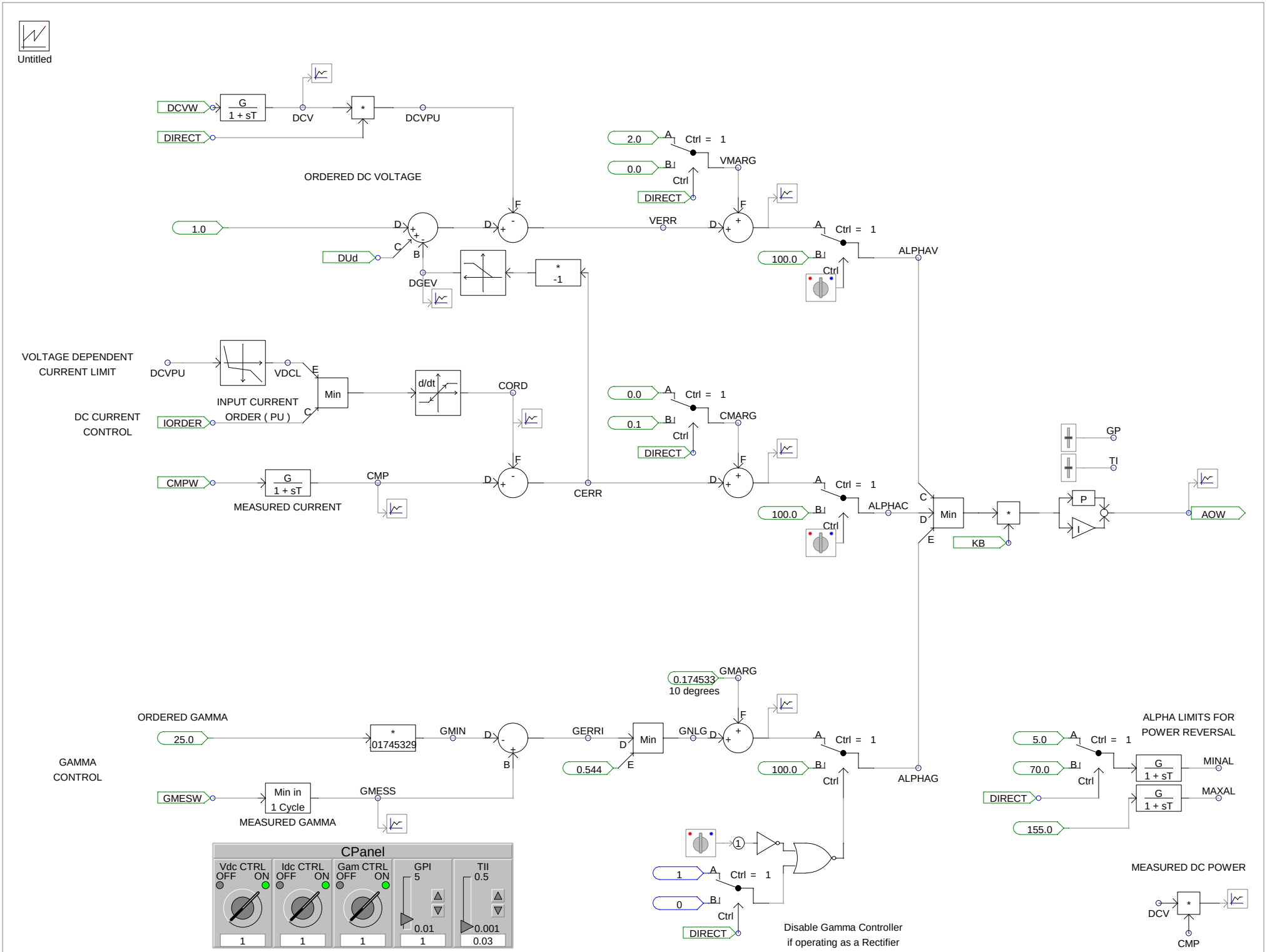

0.0
60.0
230.0
V
F
Ph
3 Phase RMS
VRMS
V230rmsBoone
B230B
Timed Breaker Logic Closed@t0
RRL
RL
A
B
C
L230B
BOONE 230 KV EQUIVALENT
SOURCE SCC = 3040 MVA
150.0 [MVA]
230.0
13.8 [kV]
115.0
#1
#3
400.0
150 MVAR AUTOTRANFORMER
230/115 KV AT BOONE
FAULTS
A->G
Timed Fault Logic
B115Tfr
P115Boone
Q115Boone
Power
V115rmsBoone
LJ115B1
LJ115B2
BOONE 115 KV BUS
La Junta
30 MW Load
B115WCLJ
WC115LJ
load
La Junta W
30 MW Load
B115WC
L115WC
Initialization Data:
Importing 210 MW:
V=1.015
Delta=-.31 Radians
Exporting 210 MW:
V=1.0
Delta=-.85 Radians
0.9565
Tap
100.0 [MVA]
115.0
69.0
25.0
14.4
V115rmsWilowCk
WILLOW CREEK 69 kV LOAD
5.434 + j1.787 MW/MVAR
WILLOW CREEK 25 kV LOAD
19.523+j6.417
1.03
Vref
Exciter (ST3A)
If
Ef
Ef0
EFM
Sync1
Te
Tm
Tm w
TMech WPU
EFM
PM
ANGM
QM
ANGLOAD
WPU
Source -> Machine
@ 1 SEC.
RELEASE MACHINE
@ 1.5 SEC.
TIME
M2S
EN4B
Untitled
CPanel
Pref
RLIM
TValve
Initilization of RLIM
RLIM Upper Limit
Droop
FIdle
PMech
TMech
Gas Turbine
1.0
0.055
0.15

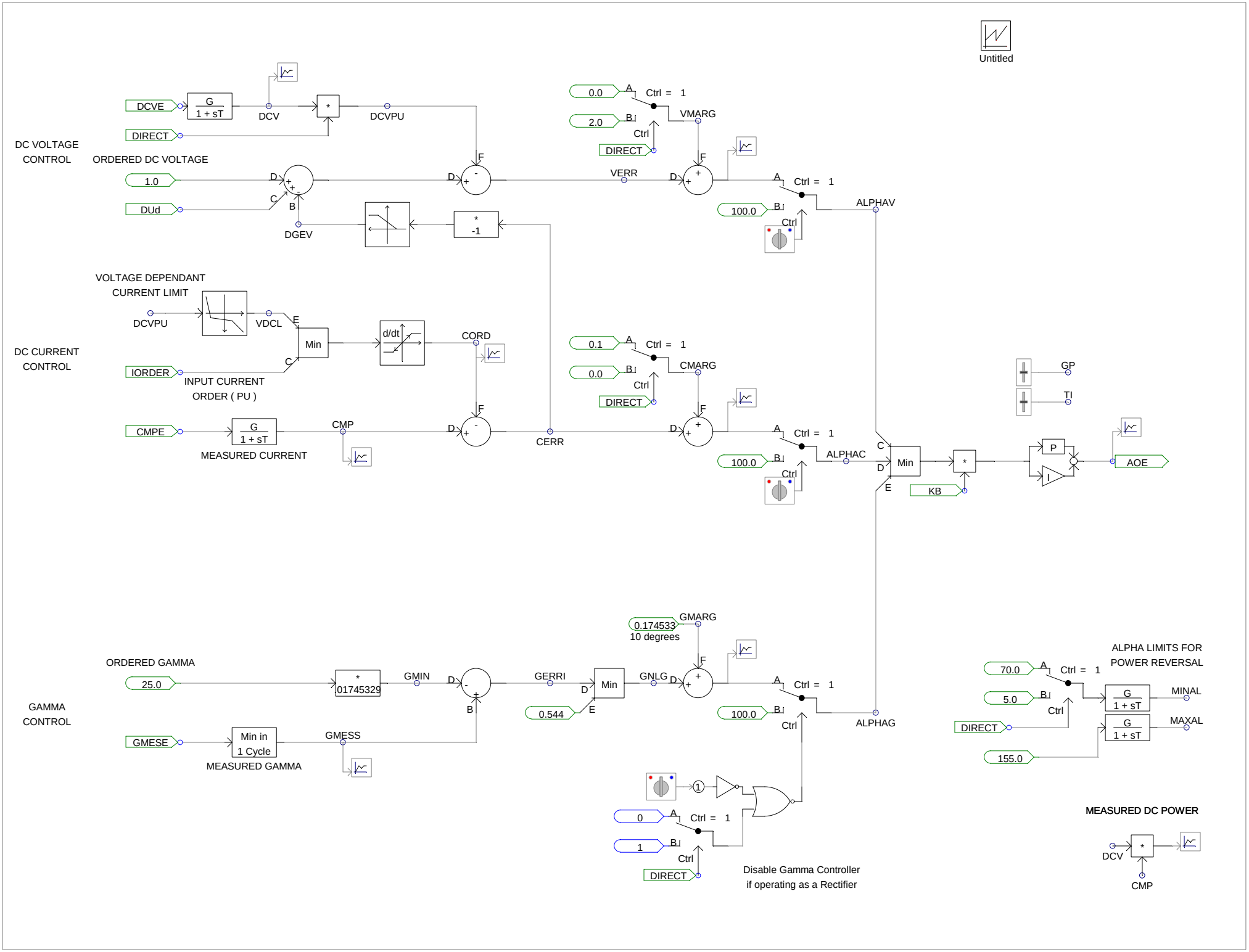

CPanel
V230rmsOld
DC Voltage
DC Current
PLam230
QLam230
PL230B
QL230B
Bypass
BP OPEN
P.U.
MW
MVAR
Untitled
VRMS Vrms
Filter Switch & 230 KV Fault Detector
Sw
Sw2
DPL
WSCC AC SYSTEM
SCR=1.43 @ 75 Deg
60.0 Hz 230 kV
DCV
DCVW
CMP
CMPW
HVDC Back to Back
210 MW, 87.5 kV, 2.4 kA
CMP
TFDC
Timed Fault Logic
DCFLT
DC
IFLTDC
3 Phase RMS
VRMSOld
V230rmsOld
ComBus
AMS
GMS
AMD
GMD
AO
KB
AOW
By-Pass Breaker
BPP
B230CAP
C230L
11 th FILTERS
26.25 MVAR
13 th FILTERS
26.25 MVAR
B230F
B230HP
HIGH PASS FILTERS
26.25
HIGH PASS FILTERS
SWITCHABLE 26.25
TAP
251 [MVA]
230.0
37 [kV]
37.0
100000.0
TripF
B230L
a230F
a230L
Timed Breaker Logic Closed@t0
TIME
B230LDC
TTRIPDC
DIRTAP
Ctrl
Power
PLam230
QLam230
L230B
I230A
I230B
I230C
FAULTS
A-G
LAMAR 230 KV BUS
100 MVAR AUTOTRANFORMER
230/115 KV AT LAMAR
400.0
100.0 [MVA]
13.8 [kV]
115.0
VOLTAGE PEAK DETECTOR
MOV Energy
CPanel
W-TAP-W>E
W-TAP-E>W
Cap Bank
T-TripDC
Filters
OFF ON
B115L
LAMAR 115 KV BUS
L115WC
I115A
I115B
I115C
L115V
VILAS LOAD
15 MW
load
VPM VNM VZM
Mag+ (7)
Mag- (7)
Mag0 (7)
Ph+ (7)
Ph- (7)
Ph0 (7)
VLA VLB VLC
VPP VNP VZP
F F T
F = 60.0 [Hz]
dcA dcB dcC
VPM(1)
G 1 + sT
VRMS
Vac230
V230rms
To PU---> G=SQRT(3)/230
T=.01

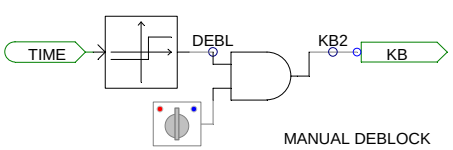

CPanel
V345rms
P.U.
0
2
0
DC Volts
P.U.
-2
2
-2
DC Current
P.U.
0
2
0
PLam
MW
-250
250
-250
QLam345
MVAR
-250
250
-250
Bypass
BP
OPEN
1


TFDC
Timed Fault Logic
DCFLT
HVDC Back to Back
210 MW, 87.5 kV, 2.4 kA
DC Volts
DCV
DCVE
CMP
CMPE
SPP
AC SYSTEM
60.0 Hz
345 kV
DC
DCFLT
CMP
3 Phase RMS
VRMS
V345rms
VC
VB
VA
NC
NB
NA
IFLTDC
ComBus
AM
GM
AMS
GMS
AQE
AQ
KB
By-Pass Breaker
BPP
DCV
ComBus
AMD
GMD
TAP
Tap
251 [MVA]
#3
#1
37.0
37 [kV]
345.0
1000000.0
F = 660 [Hz]
11 th FILTERS
26.25 MVAR
F = 780 [Hz]
13 th FILTERS
26.25 MVAR
F = 1440 [Hz]
HIGH PASS FILTERS
26.25 MVAR
Filter Switch
Vrms
Sw
B345F
HIGH PASS FILTERS
SWITCHABLE 26.25 MVAR
VA
VB
VC
IA
IB
IC
A
B
Ctrl = 1
Ctrl
TAP
DIRTAP
ILamA
ILamB
ILamC
BLamA
BLamB
BLamC
FinLam345A
GMD
GMS
Min
GMESE
| X |
Max
0.0
TIME
PEAK DETECTOR
Power
3 Phase RMS
FAULTS
A->G
QLam345
PLam
V-RMSL
TFAC

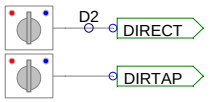

Start Sequence
Close Breaker BLamA
Wait For Random Time
102.07 < t < 102.08
Open Breaker BLamA
Wait For 1.5 (Sec)
Close Breaker BLamA
Wait For Random Time
102.02 < t < 102.037
Apply Fault TFAC
Wait For 0.1 (Sec)
Remove Fault TFAC
Close Breaker BLamB
Wait For Random Time
102.07 < t < 102.08
Open Breaker BLamB
Wait For 1.5 (Sec)
Close Breaker BLamB
Close Breaker BLamC
Wait For Random Time
102.07 < t < 102.08
Open Breaker BLamC
Wait For 1.5 (Sec)
Close Breaker BLamC


Untitled
DCVW
G
1 + sT
DCV
DCVPU
DIRECT
ORDERED DC VOLTAGE
1.0
DUd
DGEV
-1
VERR
2.0
0.0
VMARG
100.0
ALPHAV
VOLTAGE DEPENDENT
CURRENT LIMIT
DCVPU
VDCL
Min
d/dt
CORD
DC CURRENT
CONTROL
IORDER
INPUT CURRENT
ORDER (PU)
CMPW
CMP
MEASURED CURRENT
CERR
0.1
CMARG
ALPHAC
GP
TI
P
I
AOW
KB
ORDERED GAMMA
25.0
01745329
GMIN
GERRI
0.544
GNLG
0.174533
10 degrees
GMARG
GAMMA
CONTROL
GMESW
Min in
1 Cycle
GMESS
MEASURED GAMMA
ALPHAG
ALPHA LIMITS FOR
POWER REVERSAL
5.0
70.0
155.0
MINAL
MAXAL
MEASURED DC POWER
CPanel
Vdc CTRL
Idc CTRL
Gam CTRL
GPI
TII
OFF
ON
0.01
0.001
0.03
Disable Gamma Controller
if operating as a Rectifier


Untitled
DC VOLTAGE CONTROL
ORDERED DC VOLTAGE
DCVE
G
1 + sT
DCV
DCVPU
DIRECT
1.0
DUd
DGEV
-1
0.0
2.0
Ctrl = 1
VMARG
VERR
100.0
ALPHAV
VOLTAGE DEPENDANT CURRENT LIMIT
DCVPU
VDCL
Min
d/dt
CORD
DC CURRENT CONTROL
IORDER
INPUT CURRENT ORDER (PU)
CMPE
MEASURED CURRENT
CMP
CERR
0.1
0.0
CMARG
ALPHAC
KB
GP
TI
P
I
AOE
GAMMA CONTROL
ORDERED GAMMA
25.0
0.01745329
GMIN
GMESE
Min in 1 Cycle
MEASURED GAMMA
GMESS
GERRI
0.544
GNLG
0.174533
10 degrees
GMARG
ALPHAG
0
1
Disable Gamma Controller if operating as a Rectifier
ALPHA LIMITS FOR POWER REVERSAL
70.0
5.0
155.0
MINAL
MAXAL
MEASURED DC POWER



MANUAL DEBLOCK

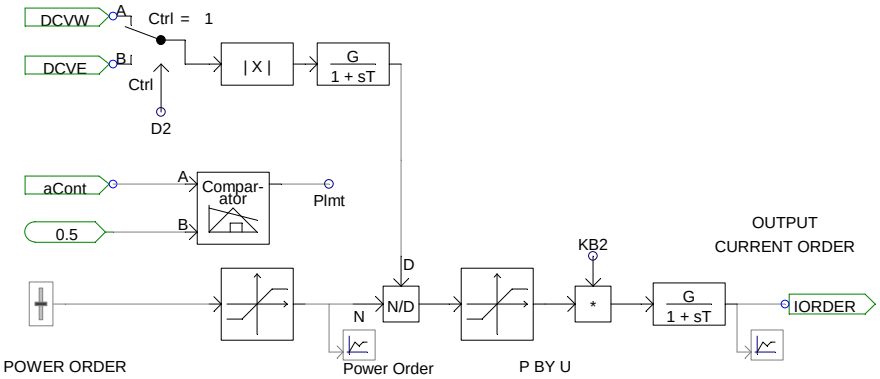


= 1 WEST>EAST
= -1 EAST>WEST

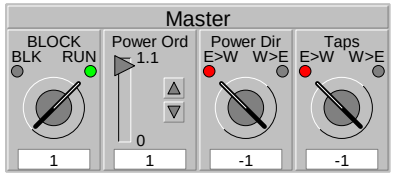
POWER DIRECTION

The Time is:
12:15:4

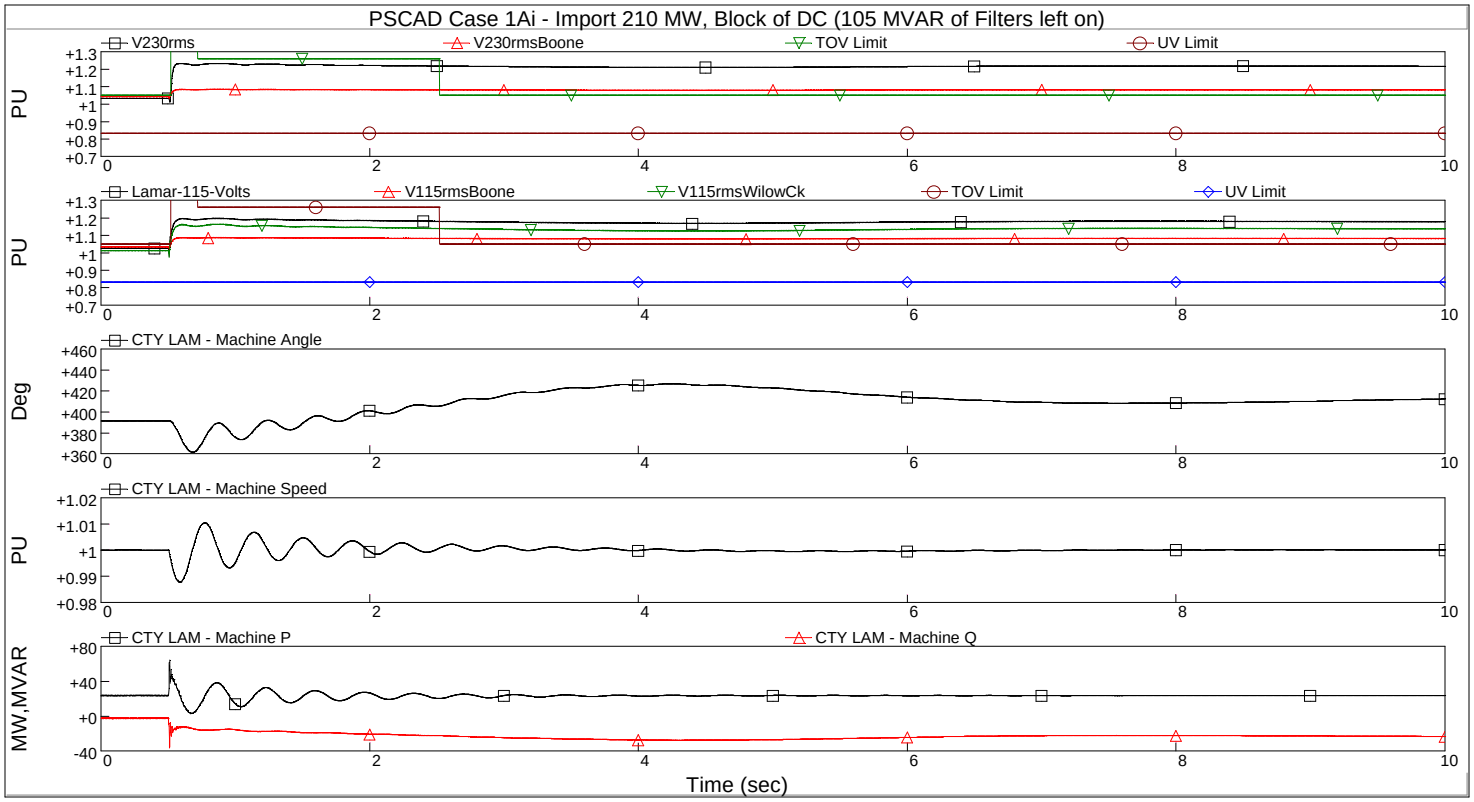
The Date is:
4/15/2002

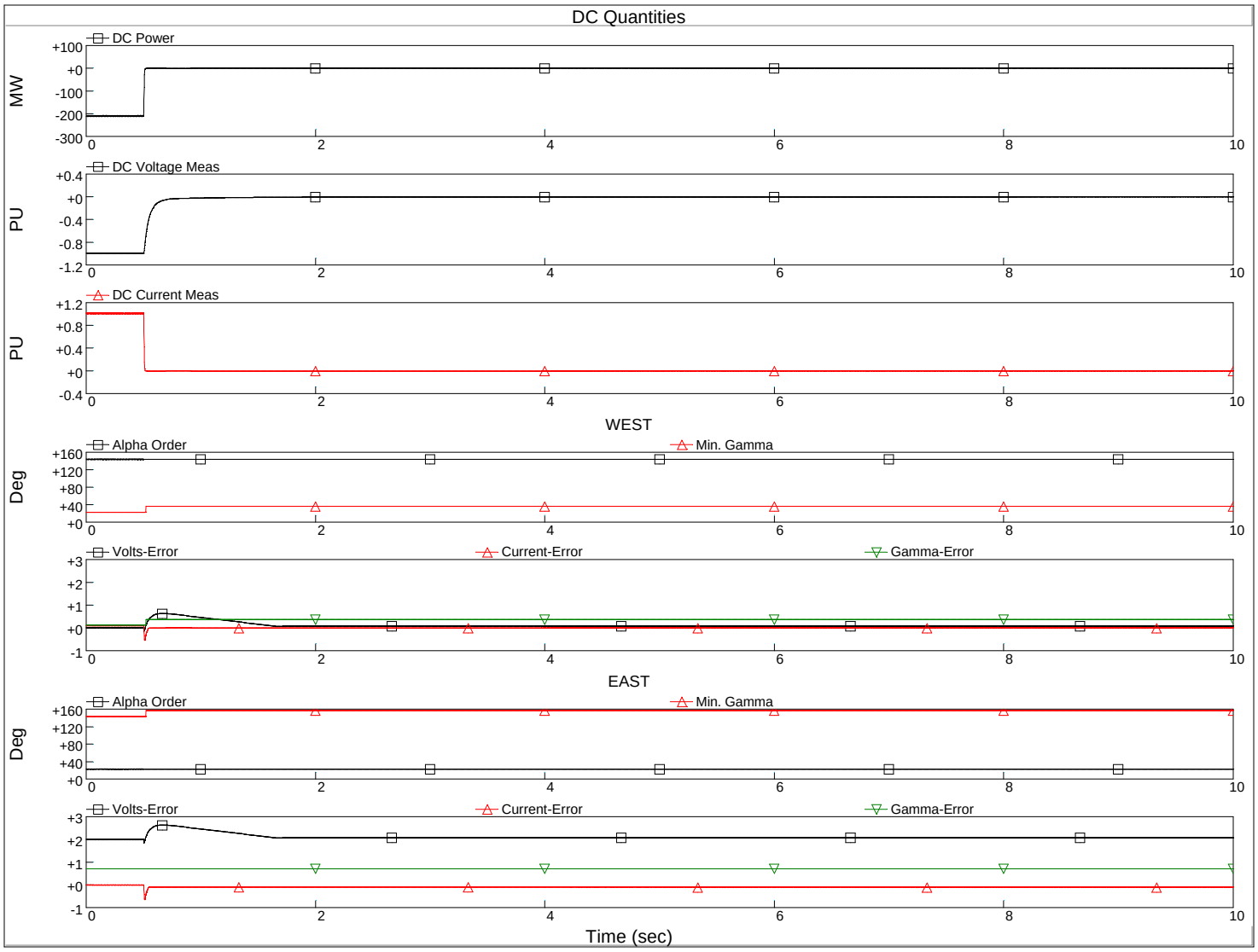


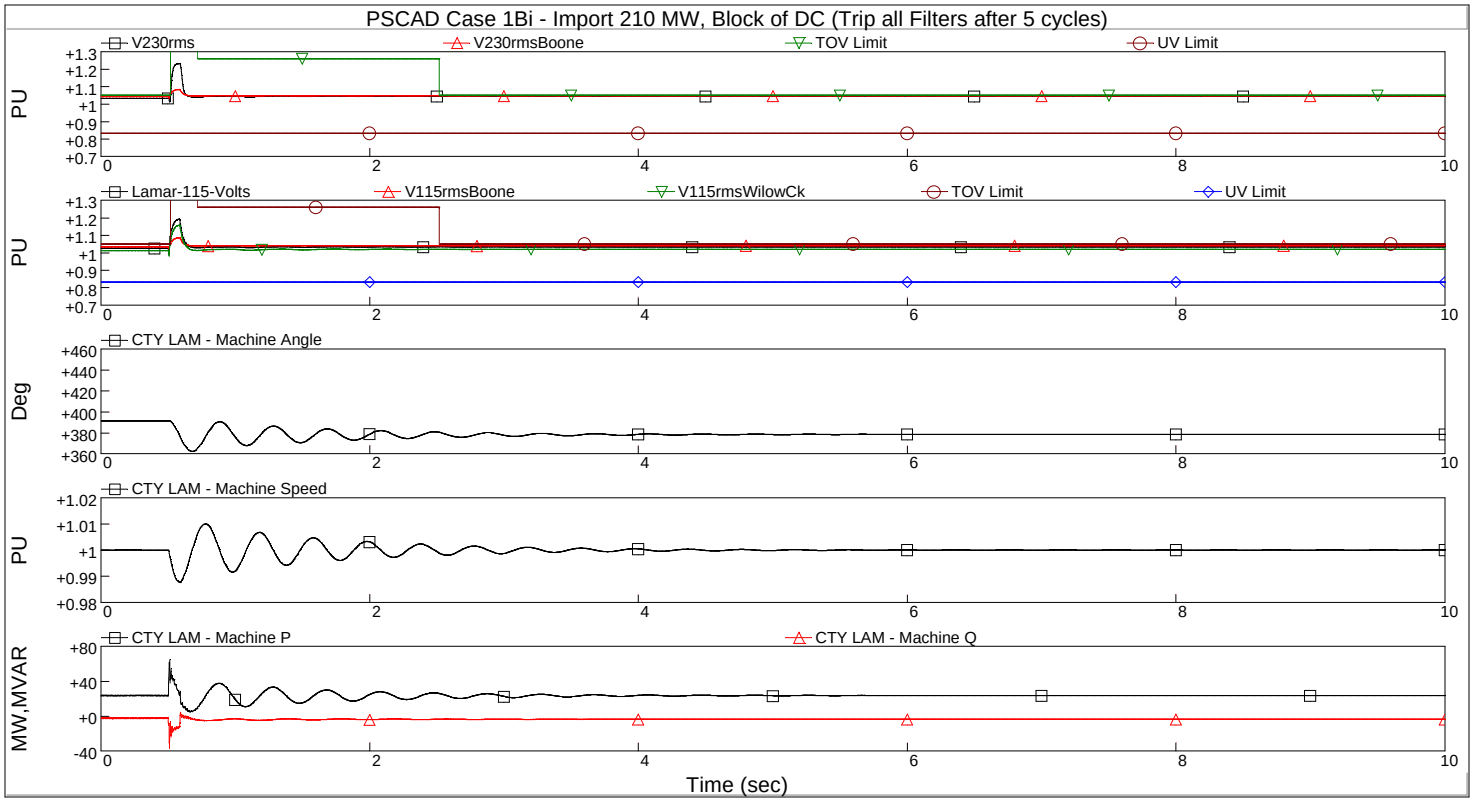
MASTER
POWER CONTROLS

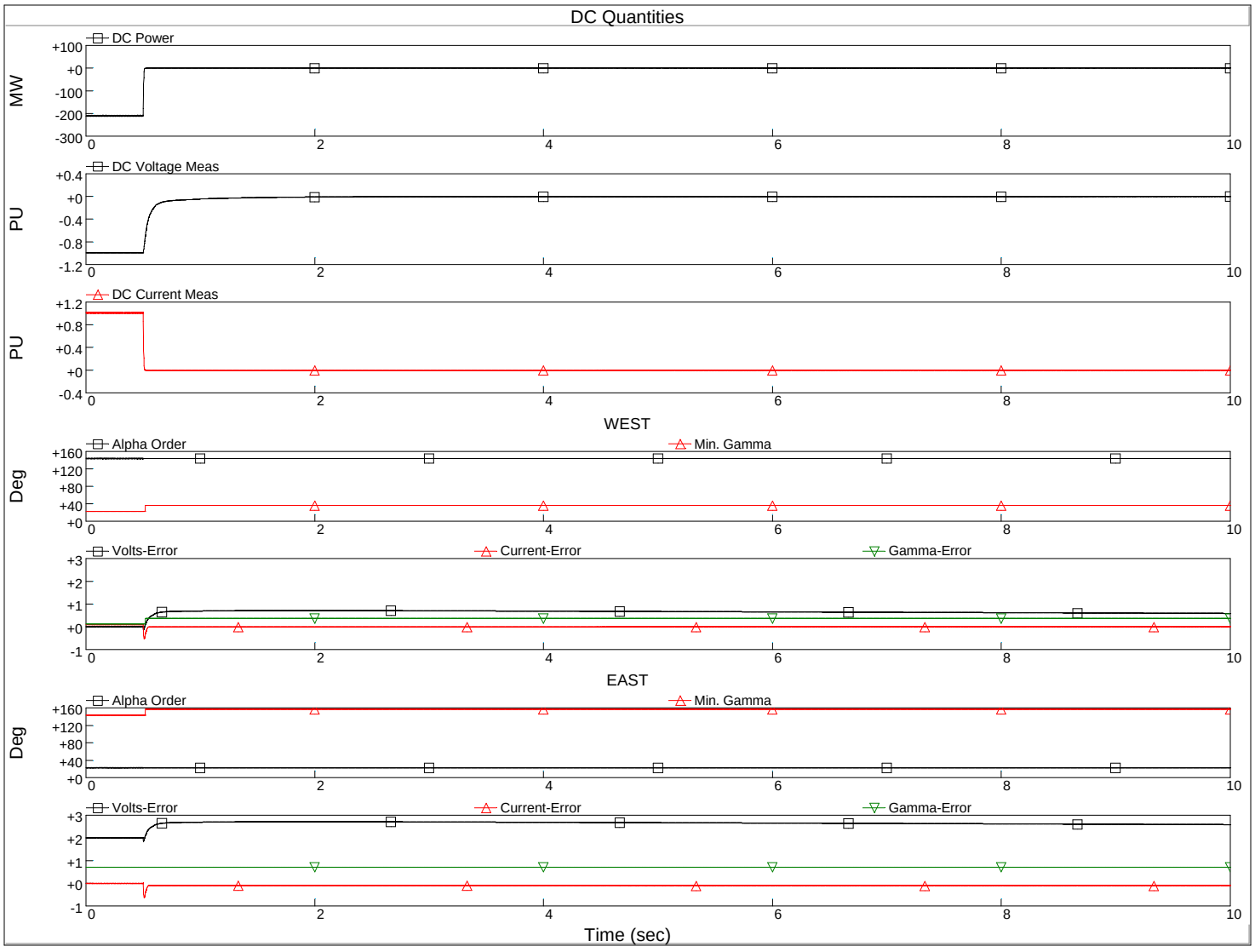


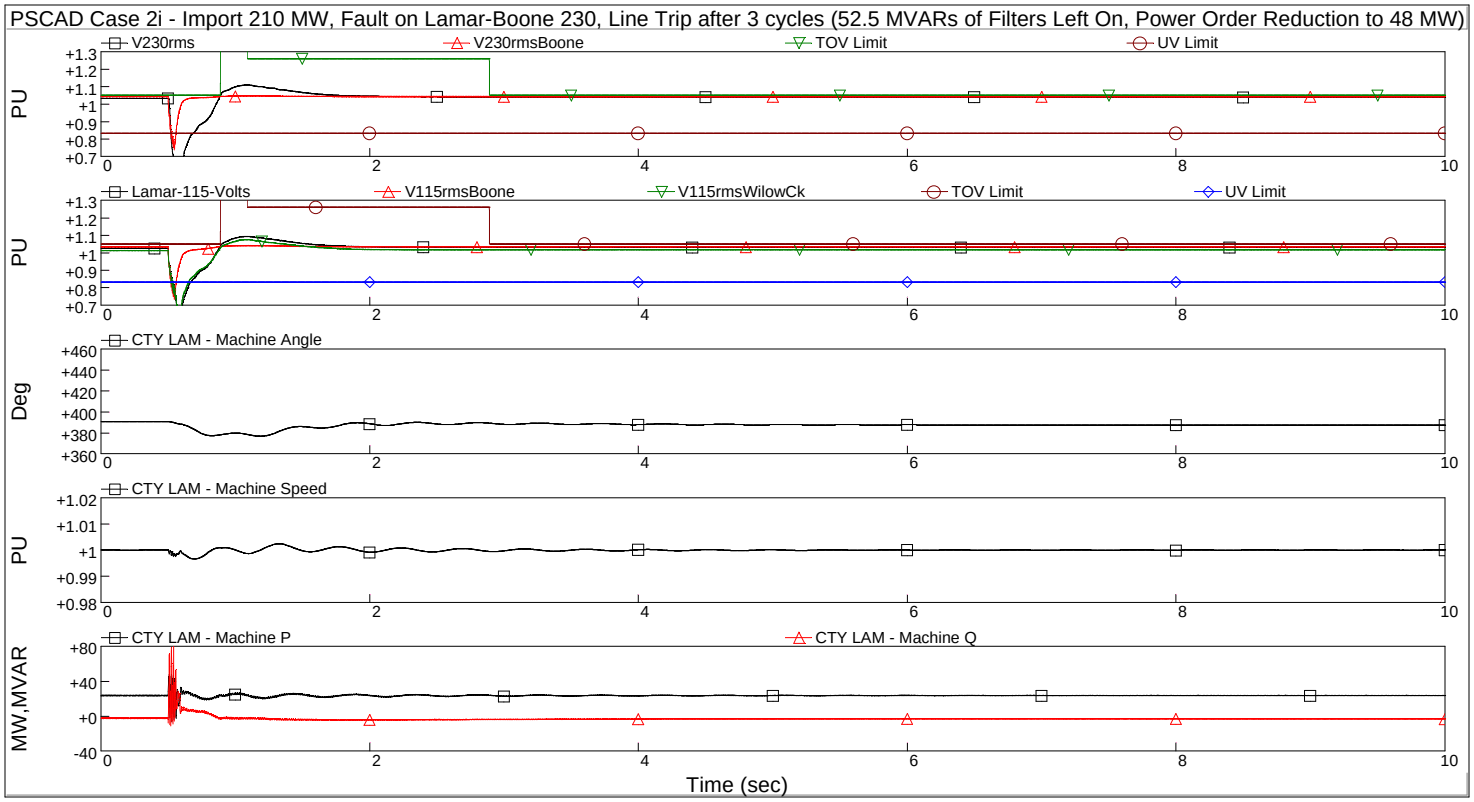
Appendix 8– PSCAD Transient Study Results

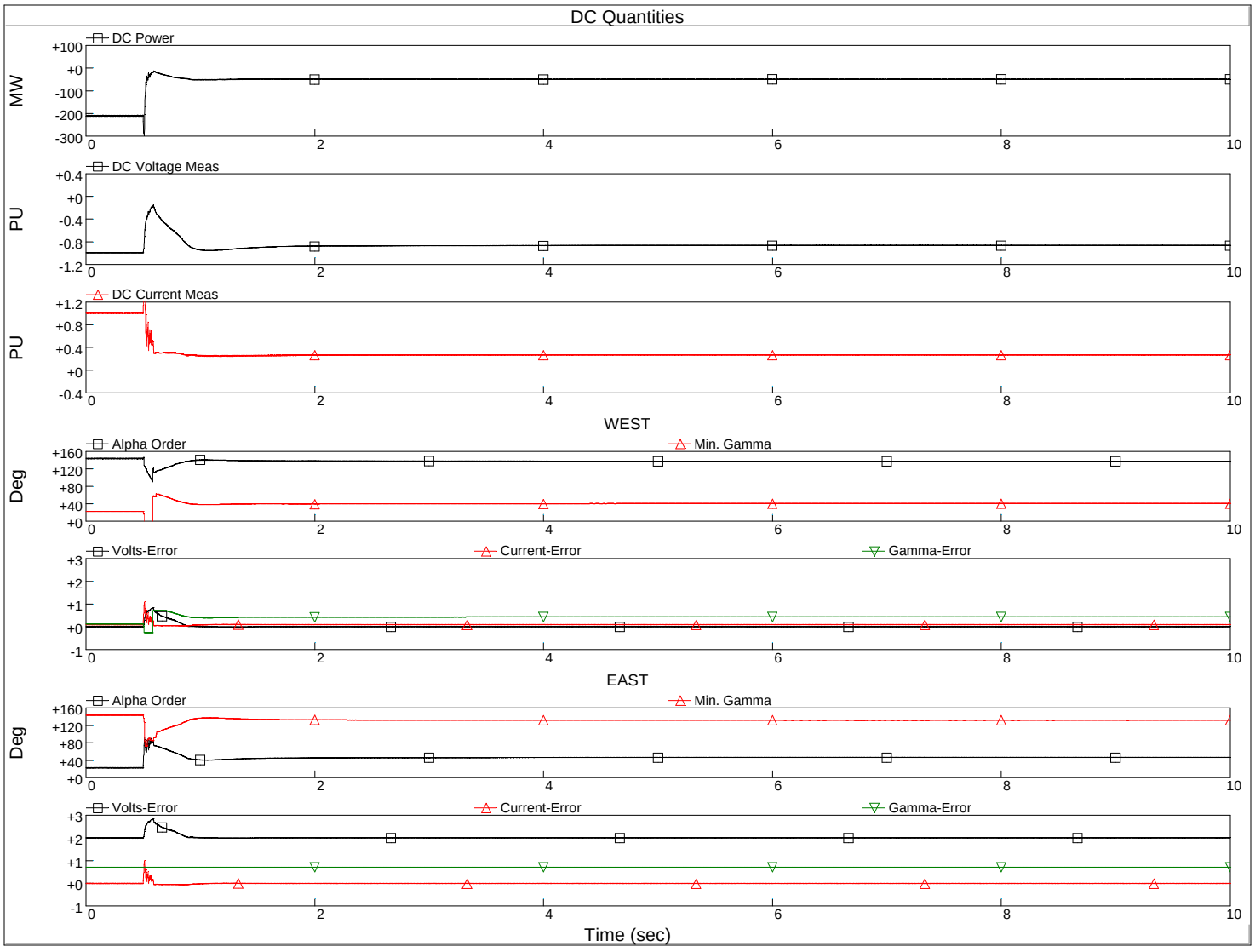

PSCAD Case 1Ai - Import 210 MW, Block of DC (105 MVAR of Filters left on)
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)

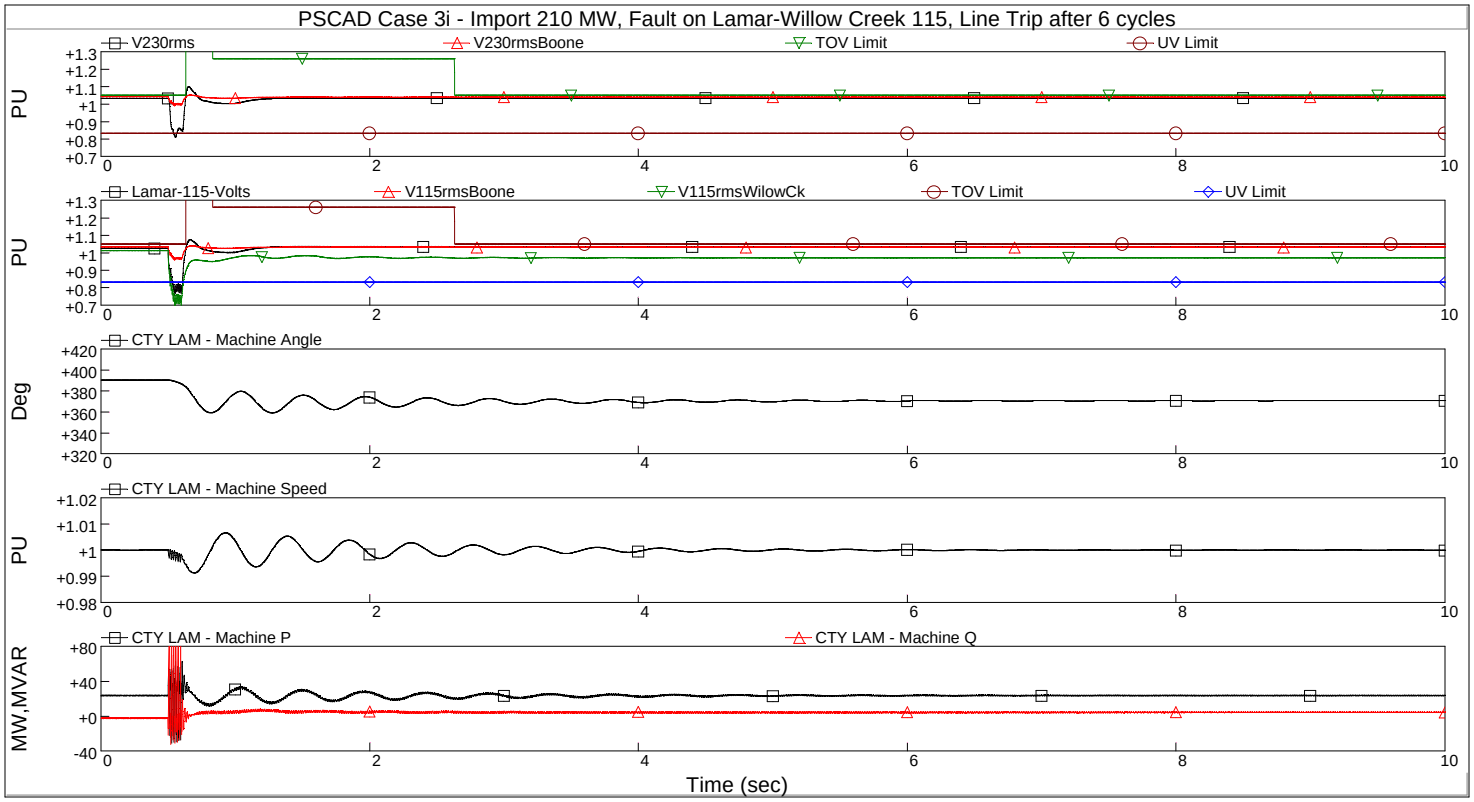

DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)

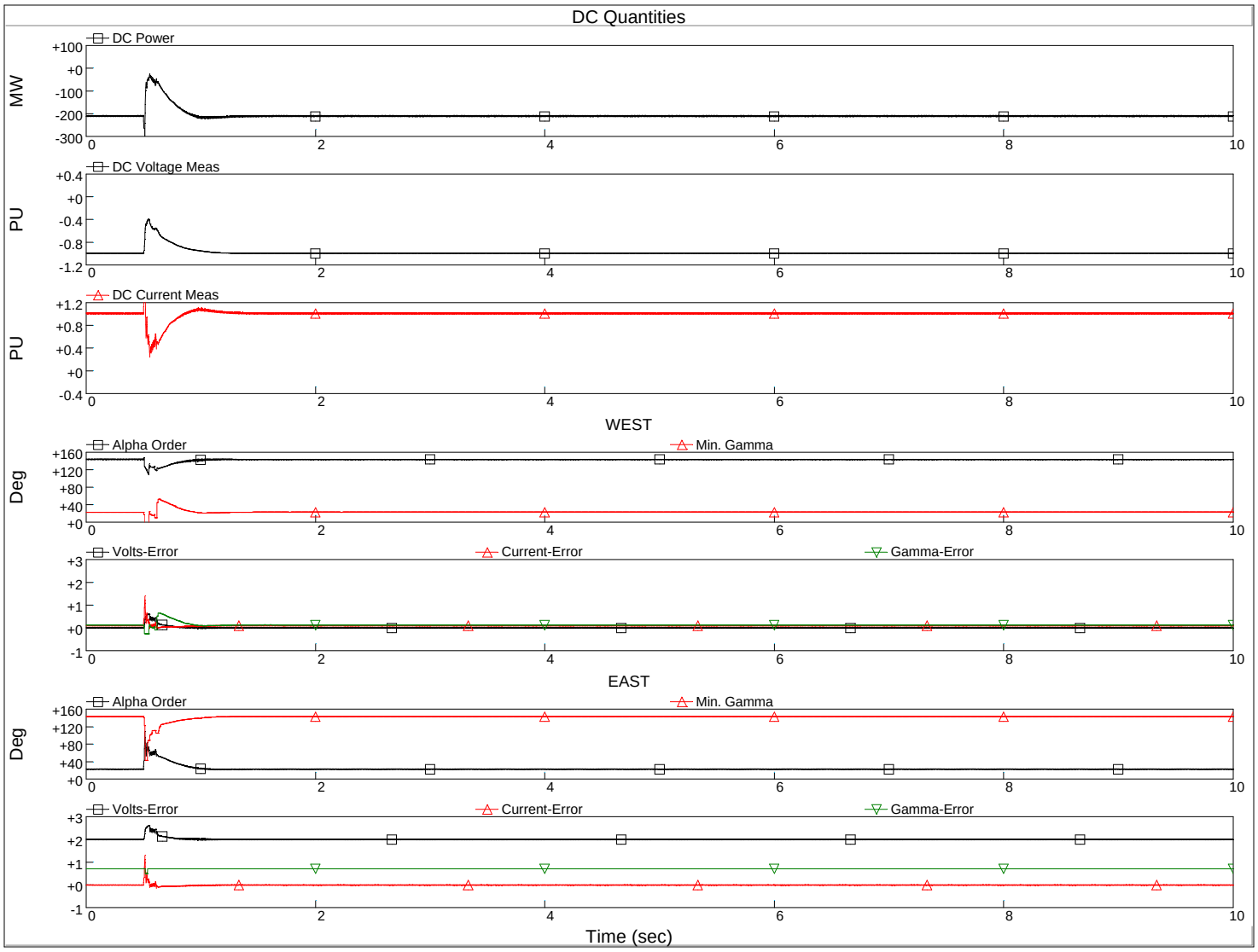

PSCAD Case 1Bi - Import 210 MW, Block of DC (Trip all Filters after 5 cycles)
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)

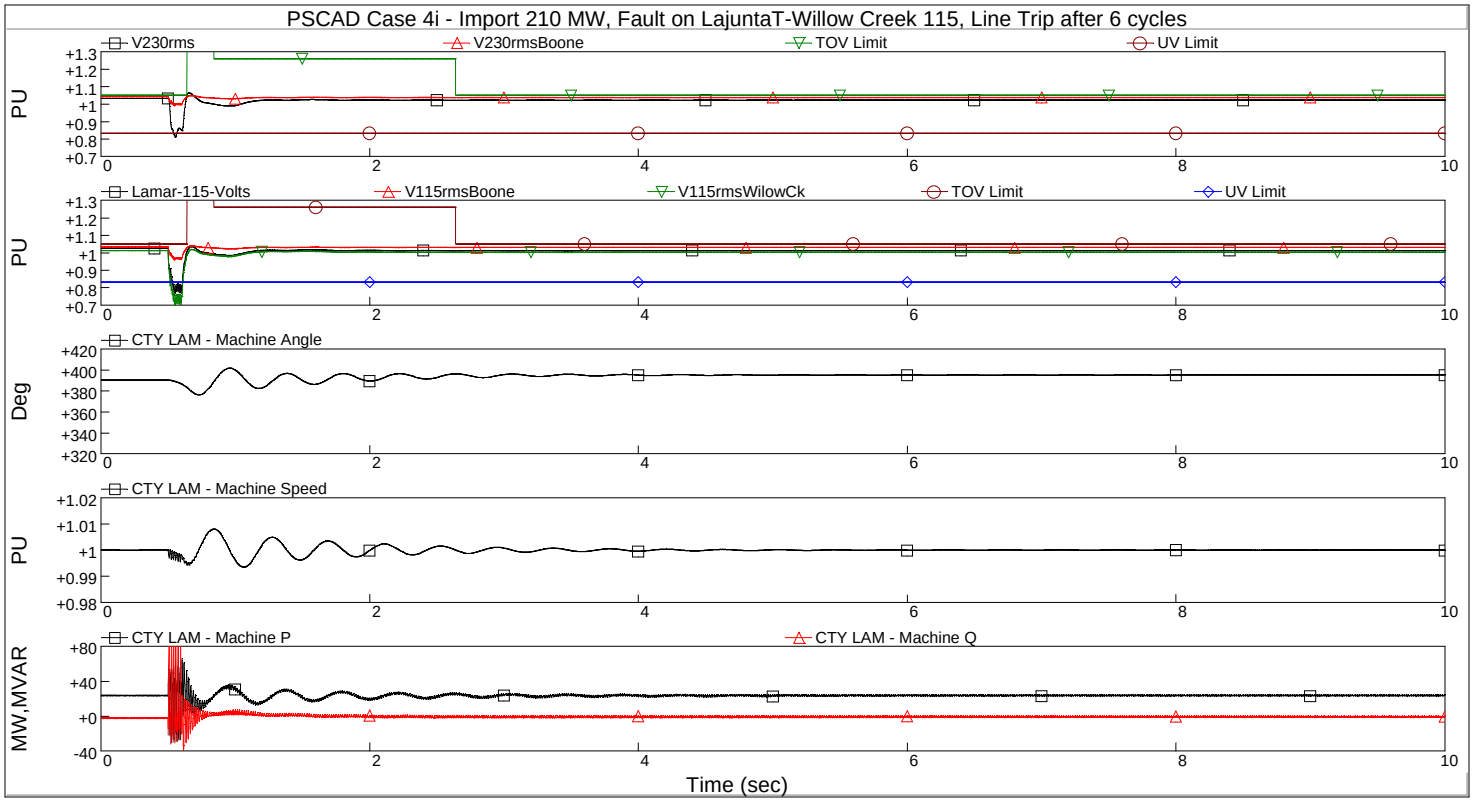

DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)

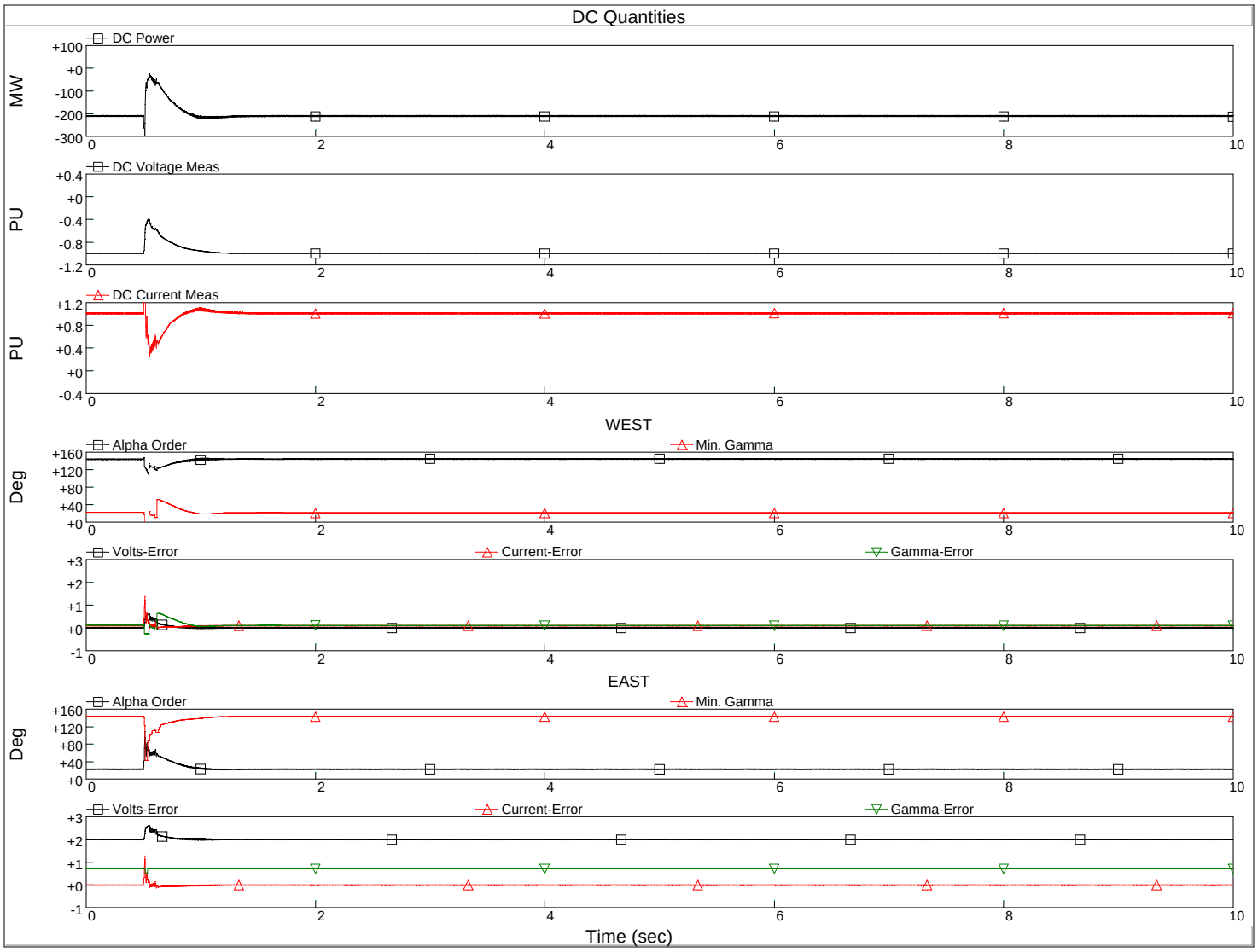

PSCAD Case 2i - Import 210 MW, Fault on Lamar-Boone 230, Line Trip after 3 cycles (52.5 MVARs of Filters Left On, Power Order Reduction to 48 MW)
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)

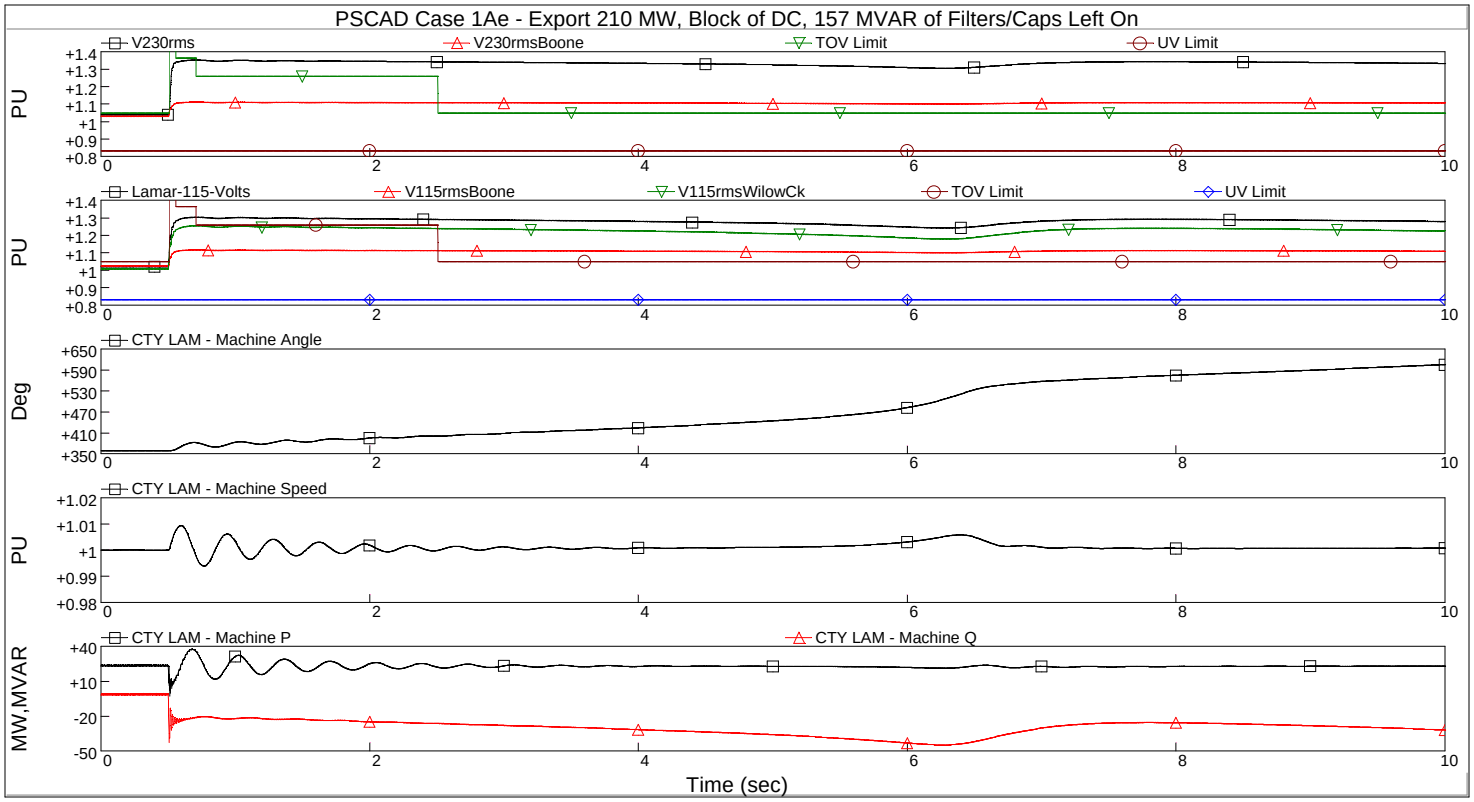

DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)

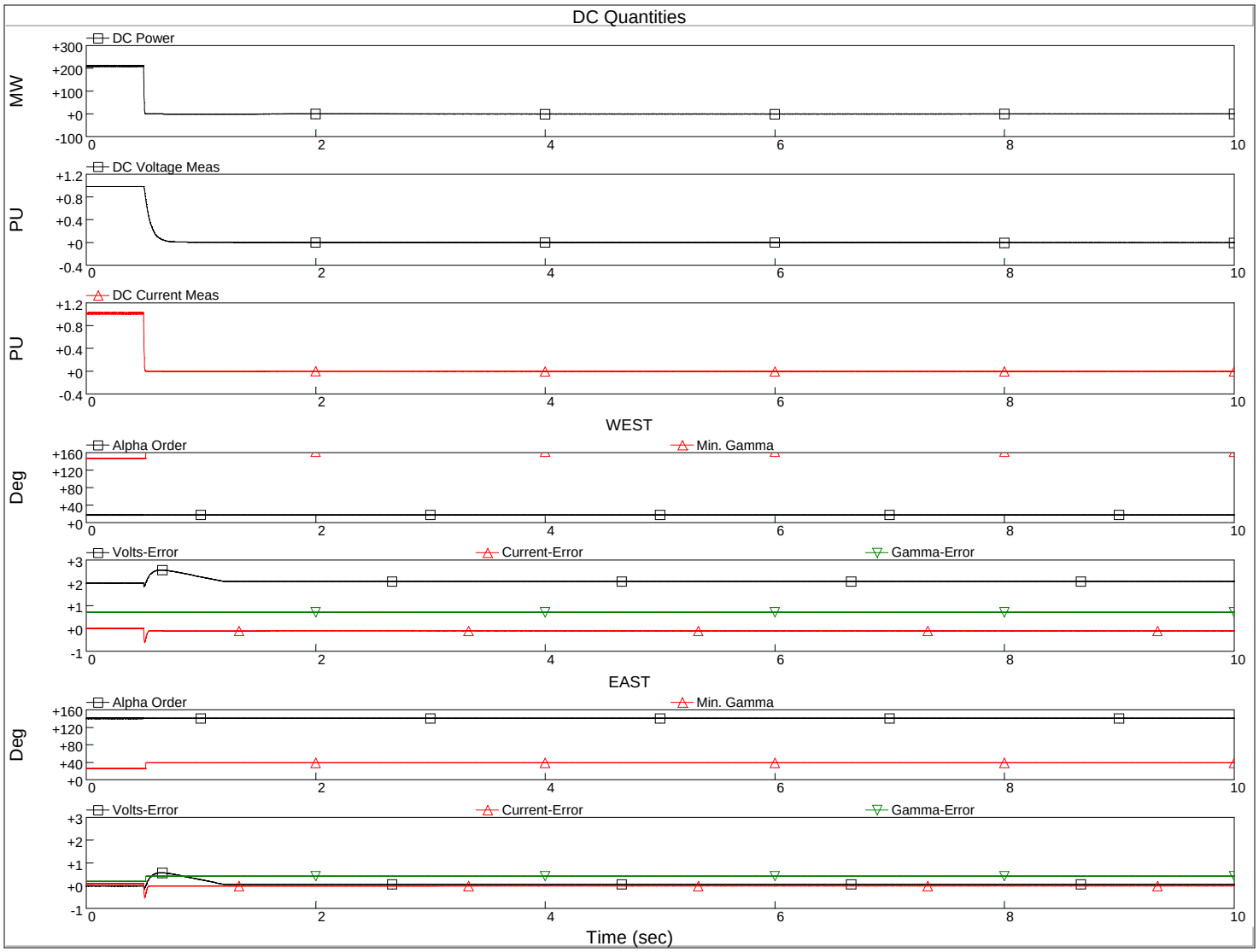

PSCAD Case 3i - Import 210 MW, Fault on Lamar-Willow Creek 115, Line Trip after 6 cycles
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)

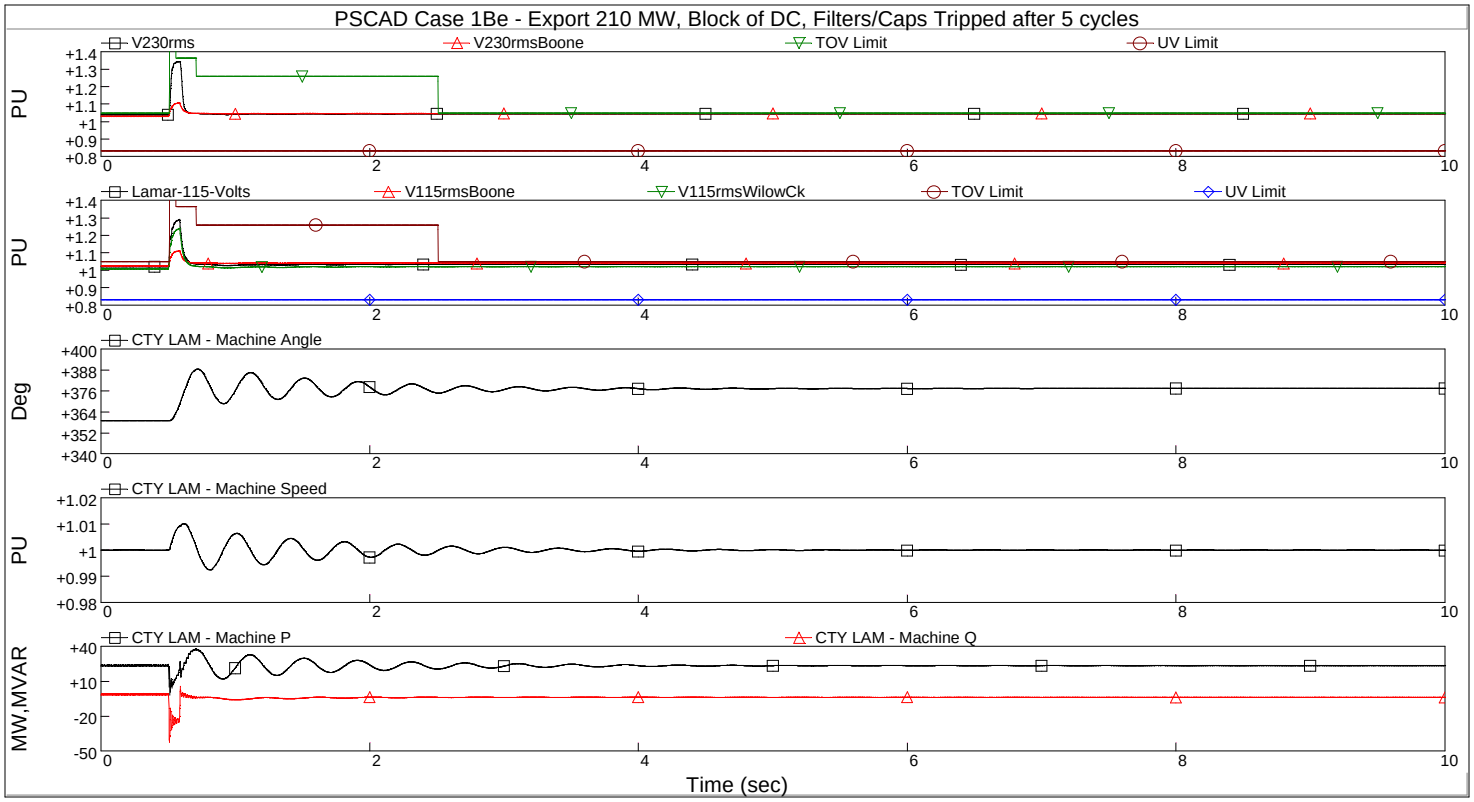

DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)

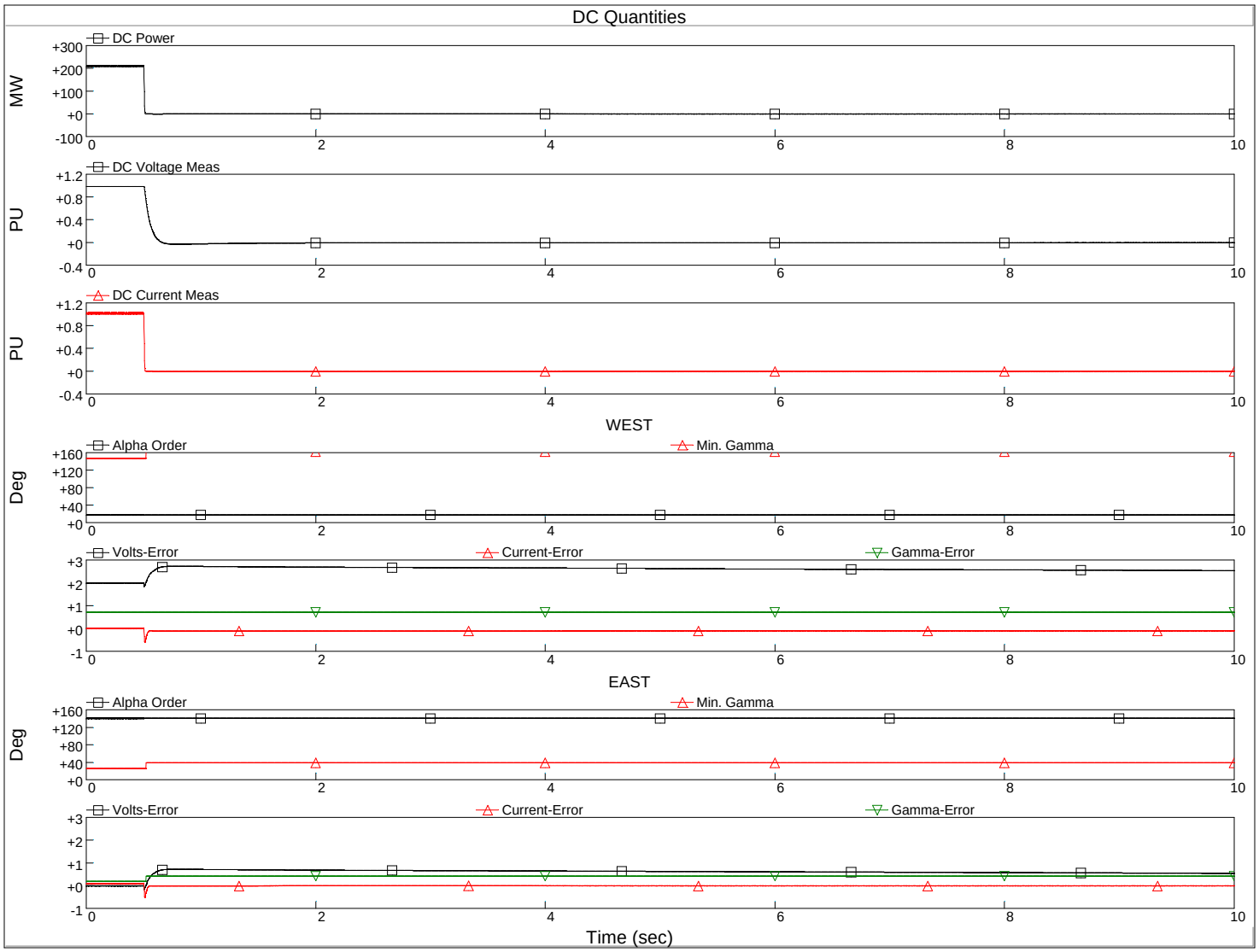

PSCAD Case 4i - Import 210 MW, Fault on LajuntaT-Willow Creek 115, Line Trip after 6 cycles
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)

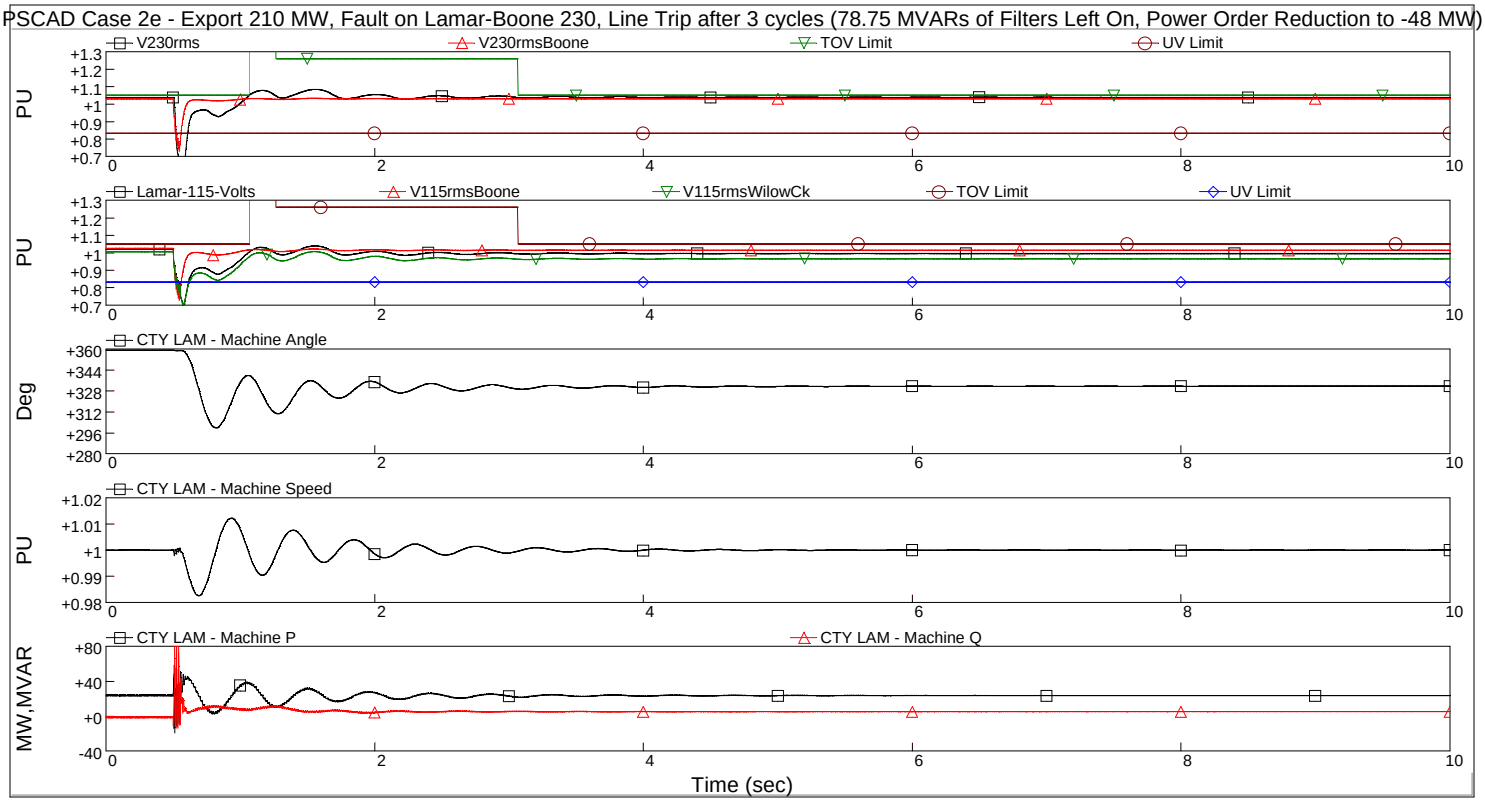

DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)

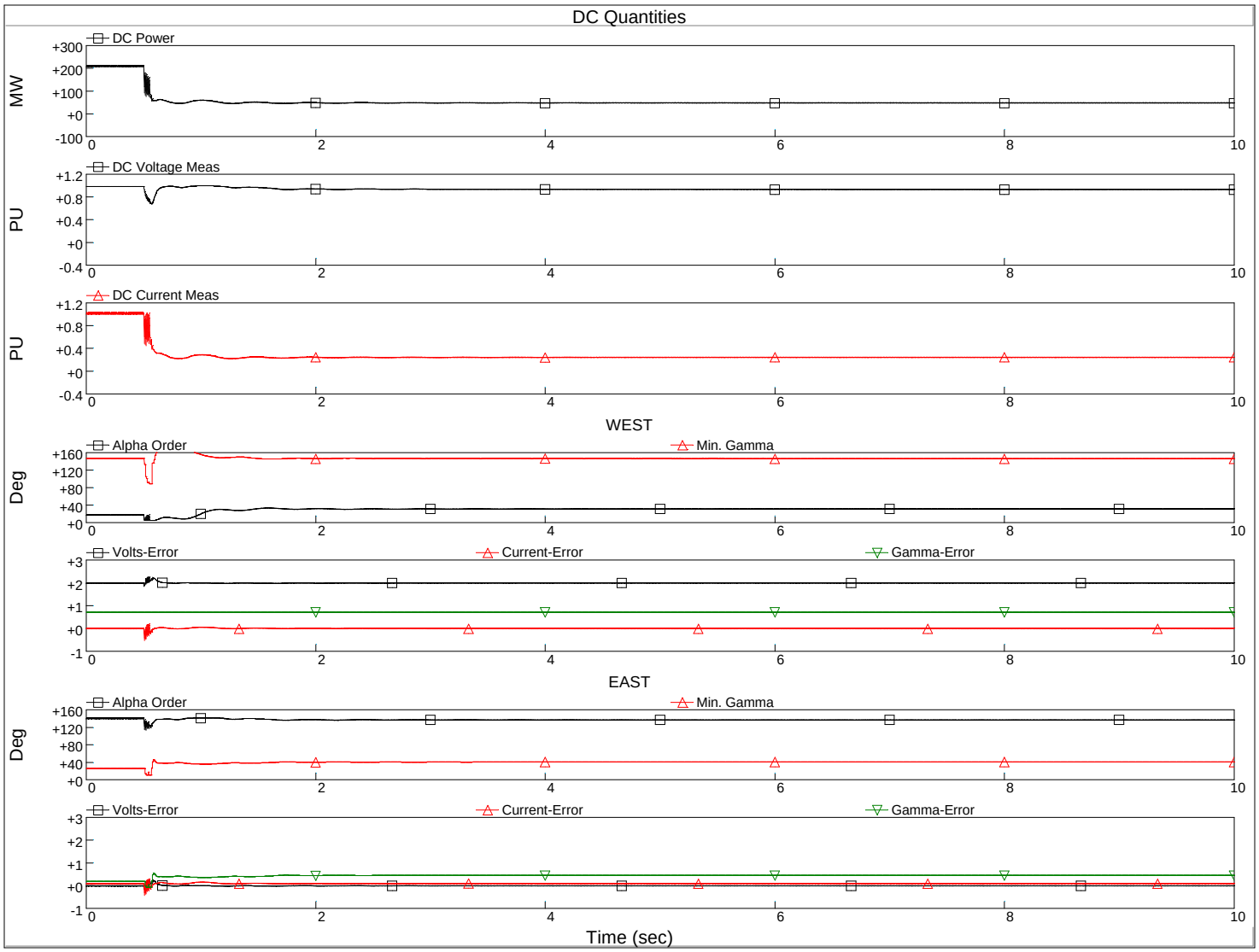

PSCAD Case 1Ae - Export 210 MW, Block of DC, 157 MVAR of Filters/Caps Left On
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)

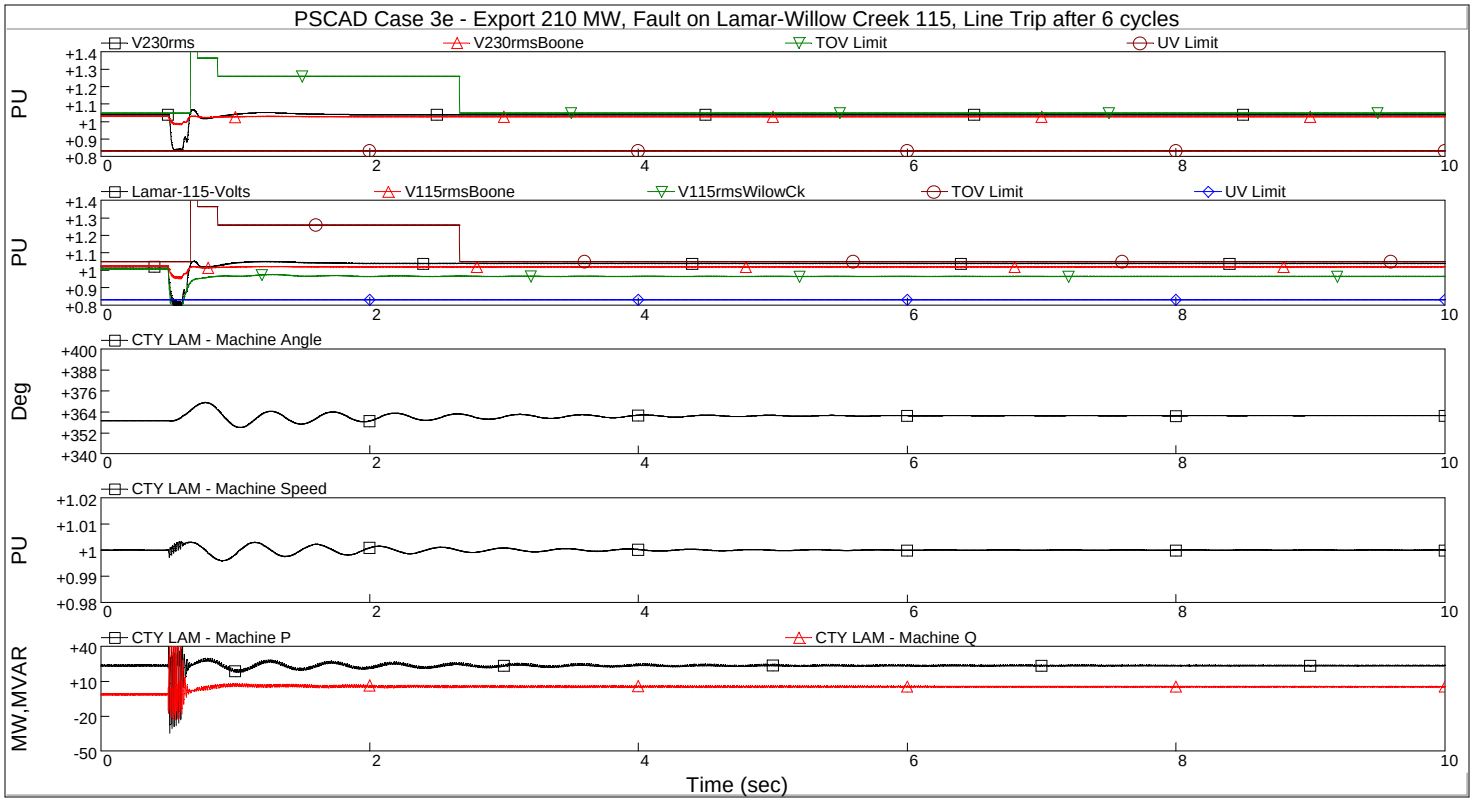

DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)

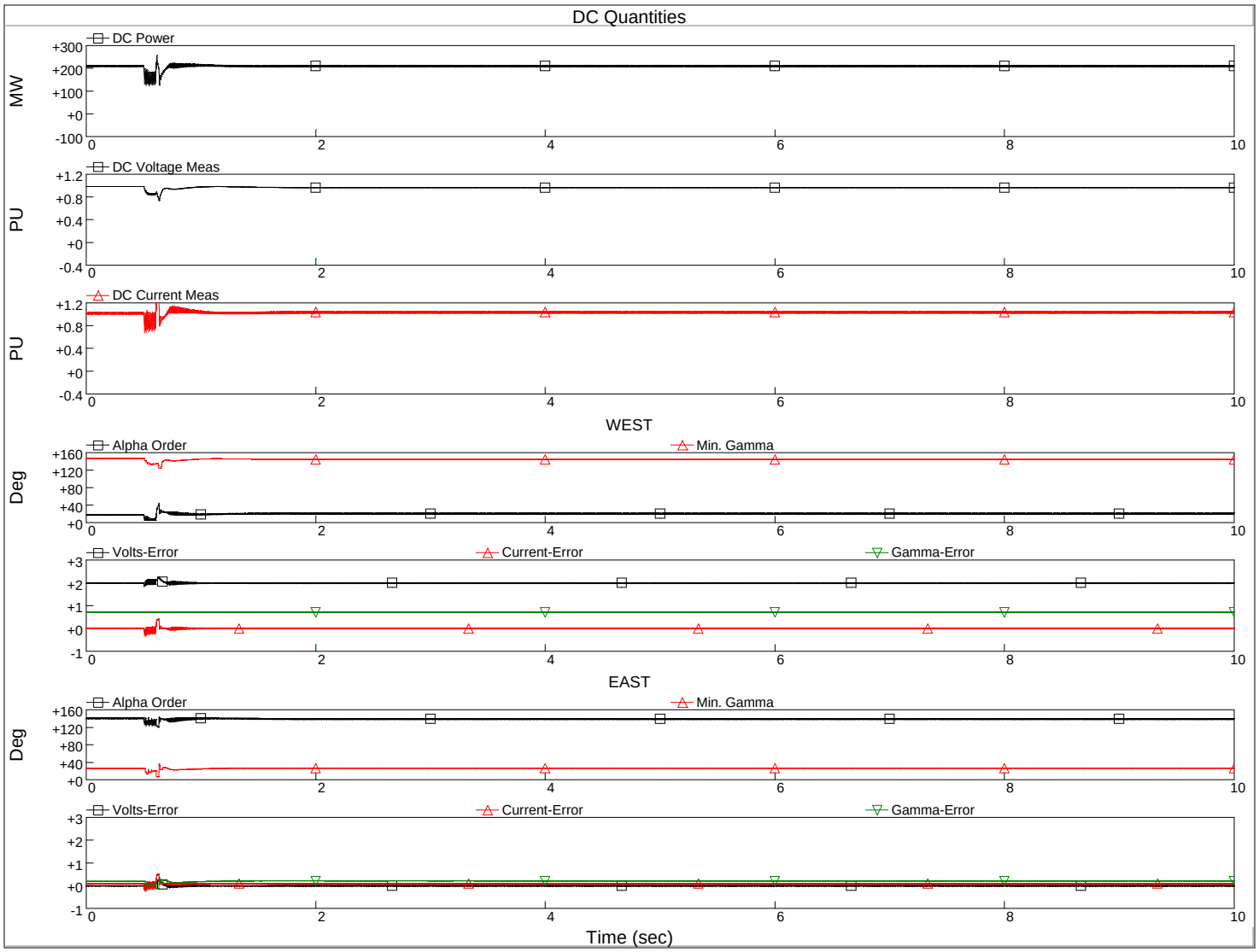

PSCAD Case 1Be - Export 210 MW, Block of DC, Filters/Caps Tripped after 5 cycles
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)

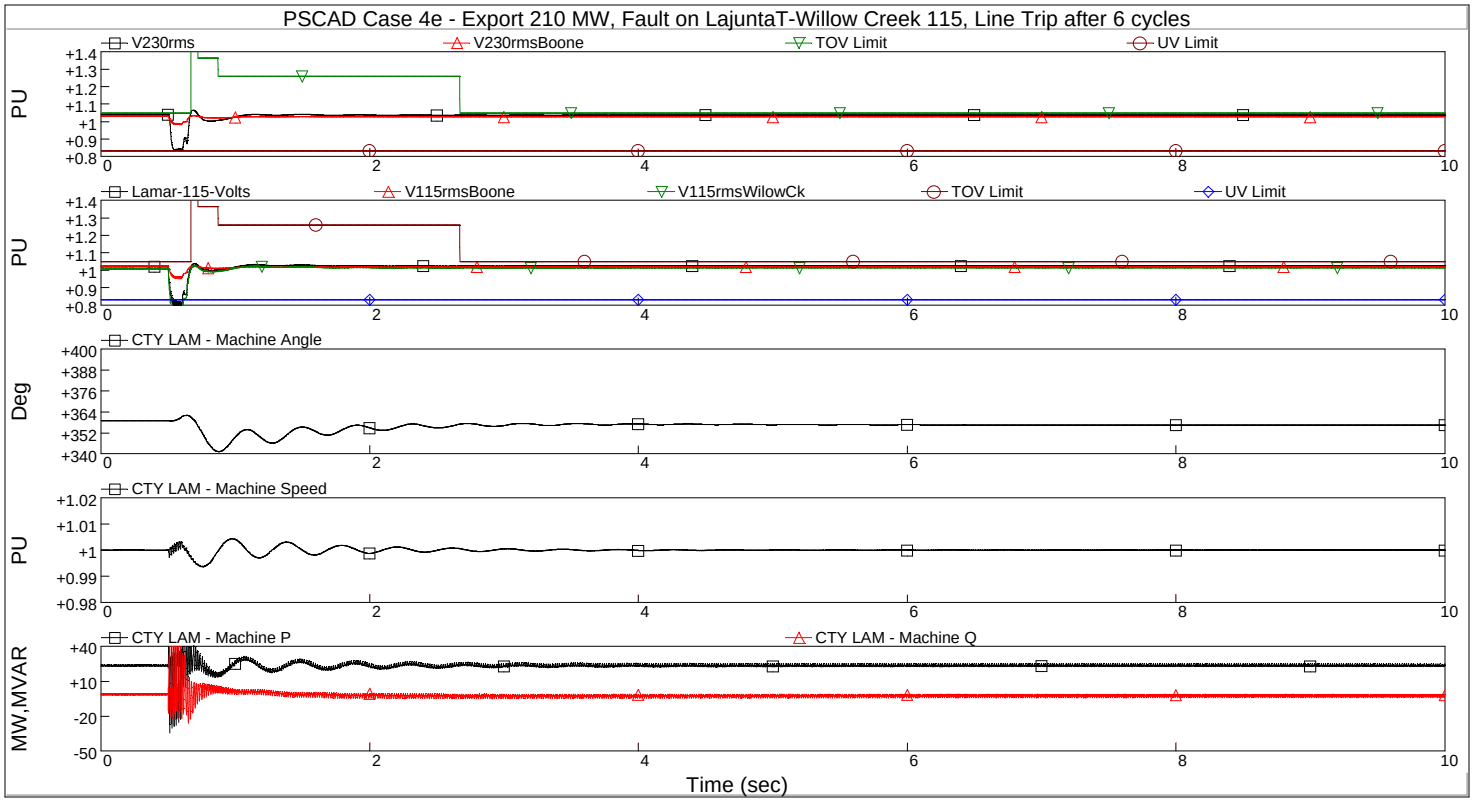

DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)

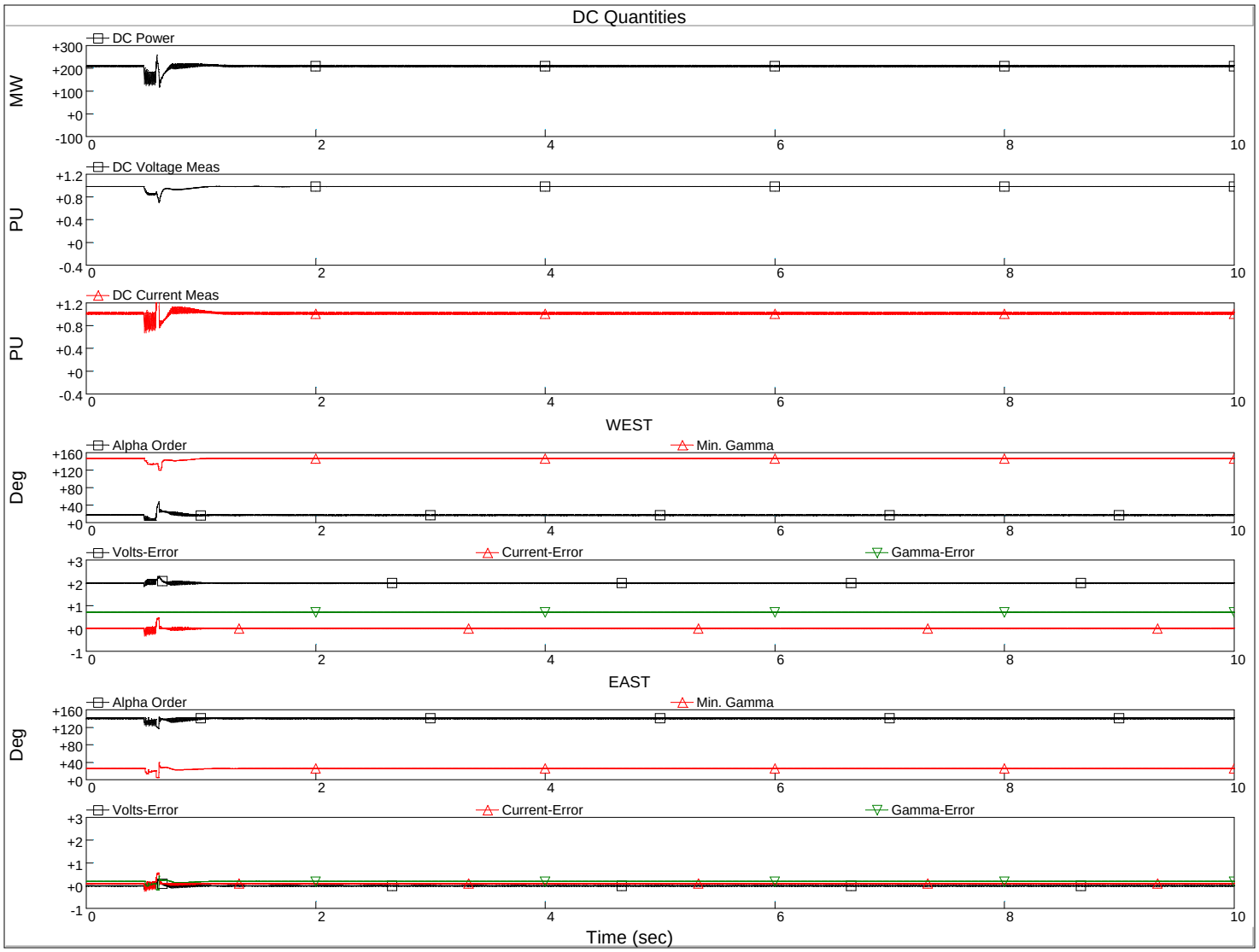

PSCAD Case 2e - Export 210 MW, Fault on Lamar-Boone 230, Line Trip after 3 cycles (78.75 MVARs of Filters Left On, Power Order Reduction to -48 MW)
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)


DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)


PSCAD Case 3e - Export 210 MW, Fault on Lamar-Willow Creek 115, Line Trip after 6 cycles
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)


DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)


PSCAD Case 4e - Export 210 MW, Fault on LajuntaT-Willow Creek 115, Line Trip after 6 cycles
V230rms
V230rmsBoone
TOV Limit
UV Limit
PU
Lamar-115-Volts
V115rmsBoone
V115rmsWilowCk
TOV Limit
UV Limit
PU
CTY LAM - Machine Angle
Deg
CTY LAM - Machine Speed
PU
CTY LAM - Machine P
CTY LAM - Machine Q
MW,MVAR
Time (sec)


DC Quantities
DC Power
MW
DC Voltage Meas
PU
DC Current Meas
PU
WEST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
EAST
Alpha Order
Min. Gamma
Deg
Volts-Error
Current-Error
Gamma-Error
Time (sec)