DUKE POWER COMPANY

OCONEE NUCLEAR STATION

ATTACHMENT 6

KEOWEE SINGLE FAILURE ANALYSIS

Form 01077 (R7-89)

FORM 101.1	REVISION 13

CERTIFICATION OF ENGINEERING CALCULATION

STATION AND UNIT NUMBER Oconee Unit 1, 2, & 3

TITLE OF CALCULATION Keowee Single Failure Analysis

CALCULATION NUMBER OSC-5096

ORIGINALLY CONSISTING OF:

PAGES 1 THROUGH 25

TOTAL ATTACHMENTS 8 TOTAL MICROFICHE ATTACHMENTS 0

TOTAL VOLUMES 1 TYPE 1 CALCULATIONS/ANALYSIS YES ☐ No ☑

TYPE 1 REVIEW FREQUENCY ________

THESE ENGINEERING CALCULATIONS COVER QA CONDITION 1 ITEMS. IN ACCORDANCE WITH ESTABLISHED PROCEDURES, THE QUALITY HAS BEEN ASSURED AND I CERTIFY THAT THE ABOVE CALCULATION HAS BEEN ORIGINATED, CHECKED OR APPROVED AS NOTED BELOW:

ORIGINATED BY C.E. Schaeffer [signature] DATE 1/20/93

CHECKED BY R.L. Beaver [signature] DATE 1/20/93

APPROVED BY [signature] DATE 1/21/93

ISSUED TO TECHNICAL SERVICES DIVISION [signature] DATE 4/20/93

REVIEWED BY TECHNICAL SERVICES DIVISION [signature] DATE 4/21/93

MICROFICHE ATTACHMENT LIST: YES ☐ No ☑ SEE FORM 101.4

REVN O.	CALCULATION PAGES (VOL)			ATTACHMENTS (VOL)			VOLUMES		ORIG	CHKD	APPR	ISSUE DATE
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A. **PROBLEM:**

This calculation is being performed to document a Single Failure Analysis of the Keowee Hydro units when operating in parallel with the offsite network. Concerns about this subject were raised during a Self Initiated Technical Audit of the Oconee Emergency Power system (reference 21), which was completed on May, 19,1992.

B. **RELATION TO QA CONDITION:** This Calculation is QA-1

C. **DESIGN METHODS:**

Section H documents an analysis of Emergency Power System response during Loss of Coolant Accident (LOCA), LOCA w/Degraded Grid (LOCA w/DG), and Loss of Offsite Power/LOCA (LOOP/LOCA) DBE's, concurrent with credible equipment failures or electrical faults, to determine if the potential exists for a common-mode loss of the redundant Emergency Power paths. One unit/path may be lost due to a Single Failure. A fault or failure on safety related equipment is referred to as a "Single Failure". Where the initial fault/failure is not a single failure (i.e. a fault on non-safety-related portion of the 230KV switchyard), an additional equipment failure (e.g. a PCB failing to trip to isolate a fault) is analyzed in combination with the fault/failure. As long as at least one Keowee unit and associated path remains available after the fault/failure (and additional single failure if applicable), emergency power would be available to all Oconee units through either the overhead or underground path, and a conclusion of "No Safety Significance" is reached for that failure.

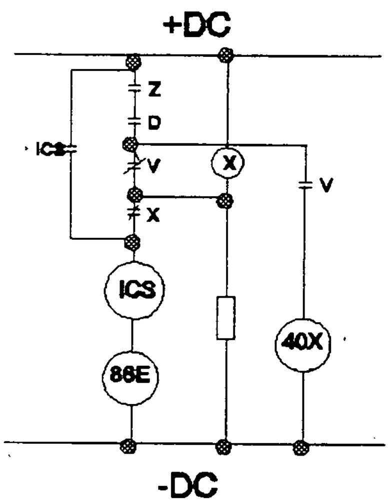
The equipment failure modes considered include; Spurious actuation of protective relaying; Failure of a circuit breaker to perform a function (Reposition Open or Closed) required during a DBE; Credible electrical faults (Ground & Phase-to-Phase) on 600V, 13.8KV and 230KV equipment; Failure of protective or control relaying to perform a function required during a DBE.

When considering electrical faults, it is necessary to consider if the fault will be cleared fast enough to ensure that the Keowee units remain stable. Instability could cause a common-mode loss of both units, due to damage from a large current pulse that would occur if synchronism with the rest of the system is lost. If damaged, the units would be unavailable to provide emergency power. An analysis of potential faults and system response times is located in section H of this document.

At the time of the Self Initiated Technical Audit, it was thought that a fault on the power grid could cause the lockout of both units due to actuation of the '40G' Loss of Field Relay. This was based on the knowledge that Keowee Unit characteristics will enter the operating region of the 40G impedance unit, which is one of the three units that the Type KLF-1 relays uses to detect a loss of field condition. This calculation will compare unit response curves during the fault and post-fault periods, as determined by a dynamic power system model, with relay operating curves, to analyze if there is a potential for 40G relay operation.

Keowee characteristics of voltage, impedance, and Reactive Power, during and after the clearing of a fault, will be compared to the KLF-1 relay operating curves to determine if relay operation may possibly occur. This will be analyzed by modeling the transient Keowee characteristics during and after a fault with the dynamic model mentioned previously, and comparing unit response to the 40G relay setting curves. Faults connected for times above 0.279 seconds (T_{cr}) have already been shown unsuitable due to stability concerns, and are protected against. For a fault which remains connected longer, unit transient swings will have larger amplitudes, and thus are more likely to enter and remain in the operating region of the 40G relay. Thus, the longest fault time less than T_{cr} (0.278 seconds) is used for this part of the analysis.

Figure 1: 40G Relay & 86E LOR Elementary Diagram



LEGEND

V - 40G UnderVoltage Unit (Operates @ 54V)
D - 40G Directional Unit (Contact Closes when Reactive Pwr flows into Keowee Unit).
Z - 40G Impedance Unit (Contact Cleses when Keowee enters Impedance Circle).
X - 40G Telephone Relay (Relay Drops Out 0.25 sec. after coil shorted out).
ICS - 40G Indicating Contactor Switch
40X - Loss of Field Alarm Relay
86E - Unit Emergency Lockout Relay

A lockout due to KLF-1 relay operation requires that all three of the relay's units [Directional (D), Impedance (Z), and Voltage (V)] are made concurrently for 0.25 seconds (see figure 1 and reference 22). The 0.25 seconds is the time required for the X unit in the 40G relay to drop out after it is shorted out by the D, Z, & V unit contacts. The Keowee 86E Unit LOR will pickup if all four contacts (X, D, Z, & V) are closed. If the D or Z unit drops out or the V unit re-energizes before the X relay times out, the X relay will re-energize, and the 86E relay will not trip.

The KLF-1 relay undervoltage (UV) unit setpoint will be compared to the Keowee Unit's voltage during the transient period, to eliminate time frames in which relay actuation is blocked by the UV unit. The period that Keowee terminal voltage is below the UV unit setpoint will be further analyzed by comparing Unit Impedance and Reactive Power with the Z & D unit operating curves, to examine if relay operation can be predicted.

D. **APPLICABLE CODES AND STANDARDS (NAME, NUMBER, DATE, REVISION):**

See References.

E. **OTHER DESIGN CRITERIA:**

OSS-0254.00-00-2004 • 230KV Switchyard DBD
OSS-0254.00-00-2005 • Keowee Emergency Power DBD

F. **RELATED SAR CRITERIA (PSAR OR FSAR, PAGE, AMENDMENT):**

FSAR Chapter 8 • Electrical Power
FSAR Table 8-3 • Single Failure Analysis of Keowee Hydro Station.
FSAR Table 8-4 • Single Failure Analysis for the Emergency Electric Power Systems

G. **ASSUMPTIONS:**

The analysis was performed using the following assumptions:

1) The LOCA (Engineered Safeguards Signal)/LOOP event is assumed to occur simultaneously at T=0.

2) A sustained Degraded Grid is assumed to exist prior to LOCA for LOCA w/DG events.

3) A Single Failure is assumed to occur on demand.

4) During a LOCA event, power will remain available to each unit's startup transformer from the switchyard unless interrupted by the fault/failure being considered. For most failures, the LOOP/LOCA DBE is more limiting, and the analysis will assume LOOP/LOCA unless specified.

5) Electrical faults on Keowee 13.8KV equipment which are protected by fast acting differential devices whose operating time + ACB-1 & 2 opening time is much less than T_{cr}. Since the equipment is safety related, no additional failures need be taken. No formal comparison to T_{cr} will be performed for these faults.

6) This calculation assumes normal Keowee Auxiliary Power system alignment with ACB-5 & 6 closed and transfer switches in automatic. It will also consider, where appropriate, the current Dedicated Alignment, which is a temporary configuration with the Auxiliary Load Center (1X & 2X) transfer switches in Manual and Standby transformer CX supplying the unit aligned to the underground.

7) Assume both Units generating to the grid through PCB-8 & 9, at rated output.

8) Values for various equipment operating times from manufacturer information are; Struthers Dunn 219XXB - 25mSec. Cutler Hammer Type M - 10mSec. GE Type HEA - 15mSec. GE Type PVD21 Differential Relay - 20mSec. Type AR High Speed Aux. Relay - 2mSec. BFU TD Setting - 133mSec. Switchyard PCB operating time - 33mSec (2 Cycles). Square D relay type XUD040 - 37mSec. Distance Relay type KD-4 - 25mSec. SDG Distance Relay - 12.5mSec. Type HU Differential Relay - 25mSec.

9) Spurious actuation of switchyard protective relays will not affect the Underground Path, or either Keowee Unit (other than causing a Normal Lockout on overspeed during Unit load rejection, which is covered section H, Failure #2). Thus, the worst case result of failures on switchyard protective relays would be a loss of the overhead path, and these failures will not be formally considered.

H. ANALYSIS

CALCULATION/ANALYSIS NO. OSC-5096
ORIGINATOR: C. Schaeffer DATE: 1/20/93
CHECKER: R.L. Beaver DATE: 1/20/93

FAULT/FAILURE ANALYSIS FOR OCONEE NUCLEAR STATION EMERGENCY
POWER SYSTEM WHEN TWO KEOWEE HYDRO UNITS ARE GENERATING TO THE GRID

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
1	Normal Lockout Relay 86N	Spurious Actuation	No Safety Significance - The Keowee unit and output to overhead (ACB 1 or 2) breaker associated with the failed relay would trip, but would remain available to provide emergency power since the 86N trip to both is overridden by an emergency start signal. The other Keowee unit would remain unaffected, and both units would remain available to provide emergency power. Ref. KEE-114-3
2	Protective relays that actuate 86N	Spurious Actuation	No Safety Significance - With the exception of three devices, signals which pick up the 86N relay would not affect unit emergency response. The following devices will override the Emergency Start signal and drop out shutdown solenoid 99SX which will trip the associated unit, Unit Overspeed (Device # 12), Turbine Guide Bearing Oil Level Switch (63TB), and Generator Bearing Oil Level Switch (63BL/HX & 63BL/LXTD). These trips are installed to protect the Keowee unit from damage, and with one exception, would be actuated only as a result of protective device, or unit support equipment failure. The failure of the protective device or support equipment, which are safety related, would be a single failure. The other Keowee unit and associated path would remain available to provide Emergency Power. Ref KEE-114-3 & KEE-111. The exception noted above is a scenario involving the overspeed device, which is picked up if the unit reaches 180RPM. If the unit is being operated fully loaded, and the load is shed, test results show the unit may reach peak speeds above 180RPM. Unit equipment trips that would normally occur on overspeed are bypassed by the presence of a Emergency Start signal, except a trip on the Generator Field breaker by auxiliary shutdown relay 99SY. A Field breaker close signal would be in place due to the Emer. Start signal and the breaker would be prevented to re-close due to the anti-pump device. This would not be a single failure. If both units are operating at full power, both may be lost without a failure. If only one unit was operating, a failure which affects the other unit would have to be assumed. Thus, for this scenario, the Keowee Power system does not meet required Single Failure Criterion. Ref. KEE-111, KEE-114-3, KEE-112-2, & PIP 0-093-0041.

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	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
3	Emergency Lockout relay 86E	Spurious Actuation	No Safety Significance - Spurious Actuation of relay 86E is a single failure. It would trip the associated Keowee unit, and both generator output breakers (ACB-1 & 3 or ACB-2 & 4) for that unit. These trips are not overridden by an emergency start signal, thus the unit would be unavailable for emergency power. The other unit would be unaffected and available to provide emergency power through the path to which the unit was preselected. Ref. KEE-114-3.
4	Protective relays that actuate 86E	Spurious Actuation	No Safety Significance - A fault which actuates any of these devices is a Single Failure. The affects of a spurious actuation is similar to 3 above. Unit transients which may cause pick of both unit's 40G relay are discussed below. KEE-114-3.
5	Transformer Differential Lockout relay 86T	Spurious Actuation	No Safety Significance - Spurious Actuation of 86T is a single failure. It would trip and lockout both generator overhead breakers (ACB 1 & 2), and also trip PCB's 8 & 9 through relay 94L1. This would eliminate the overhead as an emergency power path. Both units would continue running, since an Emergency Start signal is present. The underground path and associated unit will be available to provide emergency power. Ref. KEE-17-1
6	Protective relays that actuate 86T.	Spurious Actuation	No Safety Significance - A failure of these protective relays or actuation due to a fault would be a single failure. See 5 above.
7	Transformer Lockout relay 86/CT4	Spurious Actuation	No Safety Significance - A spurious actuation of this relay is a single failure. This would lockout the underground path through lockout relay 86EF, making it unavailable. The overhead path and both units would remain available. Ref. K-700 & O-702-A.
8	Underground Path Lockout Relay 86EF	Spurious Actuation	No Safety Significance - Failure of lockout relay 86EF is a single failure. This failure would trip and lockout ACB-3 & 4. The overhead path and both units would remain available to provide emergency power. Ref K-700.

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
9	Transformer Lockout Relay 86CX	Spurious Actuation	No Safety Significance - Failure of 86CX is a single failure. This would trip and/or lockout ACB-7 & 8 and 1TC-4. No power would be available to 1X & 2X during a LOCA/LOOP DBE until the overhead path is re-energized. Both Keowee units can "Black Start" and accelerate to rated speed on DC power only. After the overhead unit starts and the overhead ACB automatically closes, power will be restored to 1X & 2X. Both units would remain available to supply emergency power. With the current Dedicated Alignment (see Assumption 6), a failure of this relay would remove power to the auxiliaries of the Unit preselected to the underground. The overhead path and Unit would remain available. Ref. K-700 & KEE-27-2.
10	1X or 2X Load Center Normal Bus Incoming UV Relay 27N/1X or 27N/2X	Spurious Actuation	No Safety Significance - Failure of this relay is a single failure. This failure would cause the transfer of the associated load center to transformer CX. Both Keowee units would remain available. For the current dedicated Alignment, Automatic transfer of the Load Centers is prevented since the transfer switch in Manual, thus this failure will not affect either unit in this alignment. Both paths will remain available, Reference KEE-27-1, 2, & 3.

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
11	ACB-1 & 2	Fails to trip on Emergency Start	No Safety Significance - Assume that Unit 2 is preselected to the underground. Failure of ACB1 or ACB2 to trip on an Emergency Start signal is a single failure. In the event of a failure of ACB1 to trip, both units would remain available, Unit 1 through ACB1 & Unit 2 to the underground. Since ACB-1 does not trip, the time delay designed into the ACB Emergency Start close logic will be inoperative. The 4 second time delay to reclose PCB-9 serves as single failure protection for the ACB 1 & 2 timer, and will allow time for the RCP's to trip. A failure of ACB-2 to trip would prevent the reclosing of ACB-1 after receiving a switchyard isolate complete signal and time delay due to voltage still being supplied to 13.8KV bus # 1 from bus #2 through the Main Stepup transformer, and both the overhead and underground paths would be energized from unit 2. Both units remain available. If Unit 1 is preselected to feed the underground, the results of this failure would be similar. Reference K-700, KEE-114 & 214.
		Breaker aligned to overhead path fails to reclose.	No Safety Significance - Failure of the overhead breaker ACB1 or ACB2 to reclose as designed on a Switchyard Isolate Complete signal is a single failure. This failure would prevent the reenergization of the overhead path. The unit and underground path would remain available.
		Fault on breaker	This fault is a single failure. A fault on ACB-1 or 2 outside of the Transformer/Generator Bus Zone overlap region would be detected by only one zone and is discussed below (see F1, F2, F3, & F4). A fault inside the overlap region would be detected by both the Generator Bus (87GB) and Transformer (87T) differential relays. Assume Unit 1 is preselected to the underground. If the fault is in the overlap zone for ACB-2, the fault will cause a lockout of the overhead path (by 87T) and a lockout of the Unit 2 generator (by 87GB2). The unit selected to the underground would not be affected, and would remain available. If the fault is in the zone overlap region on ACB-1, the 87T relay would lockout the overhead path, and the 87GB1 relay will lockout the underground unit, allowing a single failure to disable both paths of Keowee emergency power to Oconee. If Unit 2 is preselected to the underground, the response to faults would be similar.

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
11	ACB-1 & 2 (Continued)	Fault on breaker (Continued)	The single failure mode identified can be removed on a temporary basis by opening the disconnects for the overhead ACB for the Unit preselected to the underground. If the overhead breaker disconnects for the underground unit are opened, the potential for a fault in this region is eliminated. A permanent solution will have to be implemented before both Units can again be used to Generate to the grid at the same time. Ref. K-700, KEE-114, KEE-214, & LER-269-92-16.
12	ACB-3 & 4	Spurious Trip	No Safety Significance - A spurious trip of the breaker aligned to the underground is a single failure. This would make the underground path unavailable. A modification to the control circuit for the overhead ACB's has been performed to eliminate the potential for both overhead ACB's to automatically close (if both ACB-3 & 4 are open) and tie the units together without synch. check protection, so the overhead path and unit would remain available. Reference K-700 & PIR 0-092-0409.
		Fault on breaker	No Safety Significance - The Underground path breakers are normally aligned such that one is closed and the other is open. These breakers require manual action to operate, do not operate on Emergency Start, and are located in a protected enclosure. In addition, after they are manually operated, procedural requirements test the underground path, which eliminates the potential for a fault occurring during breaker operation, and not being seen until the path is energized by an Emergency Start signal to the Underground unit. All faults that trip these breakers would be Single Failures, and are covered in other sections of this analysis. Due to the physical location, and the lack of breaker operation during a DBE, an electrical fault occurring on the underground breaker is not considered credible.
13	Load Center Lockout relay 86S/1X & 2X	Spurious Actuation	No Safety Significance - A spurious actuation of this relay is a single failure. This would trip and lockout the auxiliary load center for the affected side, making the unit technically unavailable. The other unit and associated power path would remain available. Reference K-700, 0-702-A, KEE-114-1, & KEE-214-1.

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
14	ACB-5 & 6	Spurious Trip	No Safety Significance - A spurious trip of ACB-5 or 6 (1X or 2X normal incoming breaker) is a single failure. If either ACB-5 or 6 trips spuriously, the affected breaker's anti-pump circuit will prevent it's reclosing. No mechanism exists for the closure of the Standby incoming breaker if voltage is available on the Keowee 13.8KV busses, thus the load center will remain de-energized, and that unit is assumed to be lost. During a LOCA w/DG DBE, power on the overhead is lost, while transformer CX will be available, and the load center will be re-energized from CX. When power is restored to the overhead, the under-voltage relay will attempt to transfer the load centers back to the Normal source, and trip the Standby Incoming breaker, removing power from the Load Center. The other Keowee unit and associated path will remain available. With the present Dedicated Alignment, this trip will de-energize the affected Load Center. The other Keowee unit and associated path will remain available. Ref. KEE-27, 27-1 & 2.
		Fails to Close When Power to Overhead is Restored (LOCA DBE w/DG)	No Safety Significance - This is a single failure. If ACB-5 or 6 fails to reclose, designed transfer logic will trip the Standby incoming breaker when power to the 13.8KV bus is restored, and the load center and Keowee unit for the affected side will again be lost. The other unit and associated path will remain available. Ref. KEE-27, 27-1 & 27-2.
		Fault on Breaker	This is a single failure. This fault is only considered credible during a LOCA w/DG DBE, since the breaker does not change positions during LOCA or LOOP/LOCA DBE's. A fault on ACB-5 or 6 would be detected by the 1X or 2X transformer differential relay (87T/1X or 87T/2X), which locks out the overhead path through LOR 86T. Since power from CX is available during DG, the load centers will transfer to the standby source, and the underground path and unit will remain available. If a fault occurs inside the 87T zone, on the load center side of the Normal Incoming breaker for the unit selected to the underground path, it would trip the overhead path through 86T, and would lockout the underground unit's auxiliaries by an 86S lockout. This would technically eliminate both paths, although the underground

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
14	Continued		unit would continue running and supply emergency power. PIP 5-092-0676 was written to address this problem. With the present Dedicated Alignment, Normal breaker operation is prevented since load center transfer switches are in Manual, and a fault on these breakers occurring on the load center side, within the Transformer Differential zone is not considered credible due to the small distance between the differential relay current transformer and the breaker contact assembly, and no breaker operation. Ref. KEE-27, 27-1 & 27-2.
15	ACB-7 & 8	Fails to Close	No Safety Significance - This is a single failure. These breakers may only be closed for a short period of time during a LOCA w/DG DBE. A failure of ACB-7 or 8 to close will temporarily deenergize the auxiliary power to the affected unit. Auxiliary power will be restored after ACB-1 or 2 close. The units are able to black start without auxiliary power on DC power only. Both units and paths would remain available. Reference K-700 and KEE-27, 27-1 & 27-2.
		Fault on breaker (LOCA w/ DG DBE only)	A fault on ACB-7 or 8 is a single failure. This fault is credible only in a Normal Auxiliary alignment during LOCA w/DG, since ACB-7 or 8 does not operate during LOCA or LOOP/LOCA DBE's, or any DBE when operating in the Dedicated lineup. It would lockout transformer CX. A fault on the load center side of the breaker would also lockout the auxiliary load center on the affected side, making that unit technically inoperable. The other Unit's auxiliaries would be temporarily de-energized, until the overhead path is reenergized. Both units would continue to run, and both paths would remain available. Ref. K-700.
16	Load Center 1X & 2X Standby Bus Incoming UV Relays 27E/CX1 & 27E/CX2	Spurious Actuation	No Safety Significance - Failure of this relay is a single failure. This failure would prevent the transfer of the associated load center to transformer CX when the overhead path is de-energized. The load center will be re-energized when power is restored to the overhead path. Both units and paths would remain available. Ref. KEE-27-1 & 2.

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	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
17	13.8KV Bus UV Relay 27T/1X & 27T/2X	Fails to Dropout When Bus is De-energized	No Safety Significance - Failure of this device is a Single Failure. If relay 27T on the unit aligned to the overhead path fails to dropout, the overhead breaker for that unit will not reclose on an emergency signal, resulting in a loss of the overhead path. The underground path will remain available. A failure on the unit aligned to the underground would not affect the designed emergency response of the unit, and both units would remain available. Ref KEE-114 & 214.
		Fails and Drops Out with Bus Energized	No Safety Significance - This failure is a single failure. This would not affect system operation of the associated overhead ACB since the lack of a Switchyard Isolate Complete signal prevents closure of the overhead ACB during LOCA DBE, and the only function provided by this relay during LOOP/LOCA or LOCA w/DG is a close permissive when the relay is de-energized. The Keowee Start/Run permissive function provided by this relay is bypassed by an Emergency Start signal, thus this failure will not affect unit operation. Both Units and paths will remain available. Reference KEE-113, 114, 213, & 214.
18	Emergency Start Signal Ch. A or B	Failure to Actuate	No Safety Significance - Failure of this device is a Single Failure. Failure of one Emergency Start channel will not affect Keowee operation. Each channel will independently start both Units, and both will remain available. Ref. KEE-112, 112-1, 113, 113-5, 114, 212, 212-1, 213, 213-5, & 214.
19	F1 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the Keowee Unit 1 output bus is a Single Failure. A phase-to-phase fault will be detected by the Generator Differential Protective Relays 87G1 or 87GB1. A ground fault will be detected by the generator neutral ground fault relay 59GN1. The 59GN1, 87G1, & 87GB1 relays actuate the emergency lockout relay 86E1. See 4 above. Unit 2 would remain available through its preselected path. Ref. K-700.

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
20	F2 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the Keowee Unit 2 output bus is a Single Failure. A phase-to-phase fault will be detected by the Generator Differential Protective Relays 87G2 or 87GB2. A ground fault will be detected by the generator neutral ground fault relay 59GN2. The 59GN2, 87G2, & 87GB2 relays both actuate the emergency lockout relay 86E2 (See 4 above). Unit 1 would remain available through its preselected path. Ref. K-700.
21	F3 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the underground path is a Single Failure. A phase-to-phase fault will be detected by the underground path 50/51 overcurrent relay and trip ACB-3 or 4. A ground fault will be detected by the 59GN relay for the unit tied to the underground and lockout that unit. The overhead path and unit will remain available. Ref K-700.
22	F4 on Attachment 1	Phase-to-Phase Fault	No Safety Significance - A fault on the Unit 1 13.8KV bus is a Single Failure. A phase-to-phase fault on this bus will be detected by Transformer Differential Relay 87T. The system will respond as described in 5 above, and the overhead path will be locked out. The underground unit and path will remain available. Ref. K-700.

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	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
22	F4 on Attachment 1 (Continued)	Ground Fault	No Safety Significance - Assume Unit 1 is preselected to the underground path. A ground fault on the Unit 1 13.8KV bus would be detected by the Generator Ground relay 59GN1, which will trip Keowee Unit 1 LOR 86E1. Due to the Delta configuration of the Main Stepup transformer primary, the ground fault will not be seen by the protective devices for Unit 2 13.8KV bus. A fault on the X or Z phase bus will drop one winding of the PT feeding the 27T/1X UV relay. There are no detrimental effects if 27T/1X drops out since the Generator & Overhead ACB for that Unit will be locked out by 86E1. Reference 26 & 27 address issues associated with, and provides a discussion on operating with bus ground. Day to day Unit operations for peaking power use would detect faults which might occur before an Event, which will limit the length of time running with a undetected ground. Unit 2 will remain available to provide emergency power through the overhead path. If Unit 1 is preselected to the overhead, this fault would trip and lockout the overhead unit and path. Unit 2 and the underground path will remain available. Ref. K-700, K-707-A, & Elements of Power System Analysis, section 12.1.
23	F5 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the Unit 2 13.8KV bus is a Single Failure. The consequences of this fault is similar to a fault on Unit 1, see 22 above.
24	F6 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the overhead line from Keowee to the switchyard is a single failure. F6 is assumed to occur inside the 87T differential zone. The fault would be detected by the 87T relay, and would lockout the overhead path through lockout relay 86T. Both Units and the underground path would remain available. Reference K-700.

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
25	F7 on Attachment 1		NOTE: Refer to attachment 3 for the trip logic path and fault clearing times for times listed in this and following sections.
		Electrical Fault	No Safety Significance - A fault on the overhead line from Keowee to the switchyard is a single failure. F7 is assumed to occur on the overhead line or between PCB-8 & 9, inside the 87L differential zone. The fault will be detected by the 87L differential relay, and will trip ACB-1 & 2 through 86T in 330mSec. Stability concerns are addressed by tripping PCB-8 & 9 60mSec after fault initiation. Both Keowee Units and the Underground path would remain available. Ref 0-800, OEE-39 Series.
26	F8 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the Yellow bus is a single failure. A phase-to-phase and ground fault on the Yellow bus would be detected by the Yellow Bus Differential relay 87BY and isolate the yellow bus within 83msec. The overhead path would be inoperable. Both Keowee Units and the underground path would remain available. Ref 0-800.
27	F9 on Attachment 1	Electrical Fault	No Safety Significance - The Red bus is not safety related, thus a stuck PCB will be considered. A phase-to-phase and ground fault on the Red bus would be detected by the Red Bus Differential relay 87BR and isolate the Red Bus PCB's within 83 msec. The affects of a stuck PCB are:
		PCB-7, 10, 13, 16, 19, or 22 fails to trip.	Breaker Failure schemes will trip the appropriate breaker (PCB-8, 11, 14, 17, 20, or 23) to isolate the fault in 218mSec. Both Keowee Units and both Emergency Power paths will remain available. A stuck PCB-4 does not impact Keowee.

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
27	F9 on Attachment 1 (Continued)	PCB-26 or 28 fails to trip	Failure of PCB-26 or 28 to trip is a Single Failure. Breaker Failure schemes will trip PCB-27 or 30 in 266mSec. Both Keowee units and the underground path will remain available. The overhead path to Oconee Unit 2 will be unavailable for a failure of PCB-26 due to a 86T/CT2 lockout, and the Unit 3 overhead path will be unavailable for a failure of PCB-28 due to a 86T/CT3 lockout.
		PCB-31 Fails to Trip	Breaker Failure schemes will trip PCB-33 in 251mSec, locking out the 230/525KV Autobank Transformer. Both Keowee Units, the overhead path and the underground path will remain available.
28	F10 on Attachment 1	Electrical Fault	No Safety Significance - Transmission lines are not safety related, and thus a sticking Bus or Bus Tie PCB will be considered simultaneously with the fault. The fault would normally be detected by either Directional Distance Phase (21L-1) or Ground (21G-1) relays and trip the Bus and Bus Tie breakers.
		Bus PCB-4, 7, 10, 13, 16, 19, or 22 fails to trip.	If the bus PCB's fail to trip, the Breaker Failure schemes will isolate the Red Bus by tripping the Red Bus Lockout Relay. The fault will be isolated within 227mSec. Both Keowee Units and both Emergency Power paths will remain available.
		Bus Tie Bkr PCB-11 or 14 Fails to trip.	Breaker Failure schemes will isolate the fault by tripping PCB-12 or 15 in 211mSec. Both Keowee units and paths will remain available.
		Bus Tie Bkr PCB-17 Fails to trip.	Failure of PCB-17 to trip is a Single Failure. Breaker Failure schemes will isolate the fault from Keowee by tripping PCB-18 in 251mSec. The overhead path will be lost due to a lockout of the startup transformers for ONS Unit 1. The underground path and both Keowee units will remain available.
		Bus Tie Bkr 20 or 23 Fails to trip.	Breaker Failure schemes will isolate the fault from Keowee by tripping PCB-21 or 24 in 251mSec. Both Keowee units and Emergency Power paths will remain available for PCB-20 or 23 failing to trip.

H. ANALYSIS

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
28	F10 on Attachment 1 (Continued)	Bus Tie Bkr PCB-8 Fails to trip.	Failure of PCB-8 to trip is a Single Failure. Normal protective logic will trip PCB-7 and the breaker at the other end of the Greenville line. Breaker Failure schemes will separate Keowee from the rest of the Grid by tripping PCB-9 in 203mSec, eliminating the potential for Keowee unit instability-induced damage. ACB-1 & 2 will be tripped through LOR 86T within 340mSec, isolating the fault. Both units and the underground path will remain available.
29	F11 on Attachment 1	Electrical Fault	No Safety Significance - The Autobank Feeder is not safety related, so a Breaker Failure will be considered. The fault would normally be detected by Autobank primary differential relay 87AT and trip PCB-31 & 33 in 93mSec.
		PCB-31 or 33 Fails to Trip	If PCB-31 or 33 fails to trip, Breaker Failure Logic will trip and lockout the Red or Yellow Bus in 236mSec, isolating the fault. Failure of PCB-33 to trip is a Single Failure, and the Yellow bus lockout would make the overhead path unavailable. The underground path and both Units would remain available. For a failure of PCB-31, both Units and paths would remain available. Ref. OEE-86-9.
30	F12 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the Startup transformer incoming bus is a single failure. This fault would be detected by CT bus or transformer differential relays and isolate the fault in 76mSec. The overhead path will not be available for the affected unit only. The underground path and both Units remain available.
31	F13 on Attachment 1	Electrical Fault	No Safety Significance - The ONS Generator output bus is not safety related, so a stuck PCB will be considered.
		PCB-20 or 23 Fails to Trip	Breaker Failure logic will trip PCB-19 or 22 in 235mSec. Both Units and paths remain available.
		PCB-21 or 24 Fails to Trip	Failure of PCB-21 or 24 to trip is a Single Failure. Breaker Failure logic will trip all Yellow Bus breakers in 236mSec. Both Units and the underground path will remain available.

H. ANALYSIS

CALCULATION/ANALYSIS NO. OSC-5096
ORIGINATOR: C. Schaeffer DATE: 1/20/93
CHECKER: R.L. Beaver DATE: 1/20/93

	COMPONENT	MALFUNCTION	SIGNIFICANCE/COMMENT
32	F14 on Attachment 1	Electrical Fault	No Safety Significance - A fault on the Jocassee transmission line is not a single failure, so an additional breaker failure will be assumed.
		PCB-11 or 14 Fails to Trip	Breaker Failure logic will trip PCB-10 or 13 in 205mSec. Both units and paths will remain available.
		PCB-12 or 15 Fails to Trip	Failure of PCB-12 or 15 to trip is a Single Failure. Breaker Failure logic will trip all Yellow Bus breakers in 228mSec. Both Units and the underground path will remain available.

H. ANALYSIS (Cont'd.)

The fault clearing times analyzed above and shown on Attachment 3, must be sufficiently fast to ensure the Keowee Units do not become unstable. Stability refers to the ability of the power system to generate forces required to recover from a disturbance. The relationship of the power angle of the sending unit (Keowee), with the power angle of the receiving unit (infinite bus), is the major factor is this determination. The two Keowee units' power angles should swing together during a fault, thus no problem with instability between the two units is expected. If the Keowee units are not connected to other power sources (the grid or the Oconee Units), no receiving unit exists and stability is no longer a concern. Thus, prevention of unit damage due to instability may be assured either by clearing the fault, or separating the unit from the infinite bus before the critical clearing time (T_{cr}). For a discussion of Stability, see Reference 23.

A study of the time required to ensure the Keowee Units will not become unstable was performed using a dynamic model of Keowee, the Duke power system, and the surrounding utilities (See Attachment 2). The value of T_{cr} from that study is .279 seconds. The response time for the protective devices necessary to isolate postulated faults is determined to insure that the fault is isolated in time to preclude instability (See Attachment 3).

For a fault on the Greenville line, the fault remains on the Units for 323msec (which is longer than T_{cr}), but when PCB-9 opens, the Units would be separated from the rest of the grid in 203msec (eliminating instability concerns).

A fault on the overhead line (F4 on A1) will also remain connected to Keowee for longer than the value (0.308 sec) provided by the study on Attachment 2. For this fault, no connection to the grid is available after PCB-8 & 9 trips (60msec), and thus no problems with instability will be encountered (See Attachment 7). All other faults are removed from Keowee faster than T_{cr}, and thus protection of Keowee from instability induced damage is assured.

ANALYSIS OF KEOWEE FAULT AND POST-FAULT TRANSIENT RESPONSE

The following is a comparison of Keowee Unit transient characteristics and the KLF-1 Loss of Field relay operating curves, during worst case fault and post-fault recovery periods, to examine if KLF-1 relay operation may occur. The KLF-1 relay will lockout it's respective Keowee unit through LOR 86E. If this relay has the potential to operate during the worst case transient, then a common mode event would exist that could lockout both Keowee Units, if both are being used to provide peaking power.

This analysis is being performed due to questions raised in May, 1992, during the SITA audit, where it was believed that these relays could operate during system faults, or during system transients during fault recovery. This belief was based on knowledge that Keowee impedance will enter the operating circle of the KLF-1 relay impedance unit. This analysis will look at the other two (Voltage & Directional) units of the relay, to see if all three units could actuate simultaneously. All three of the relay's units must actuate at the same time, and remain so for a period of 0.25 seconds, to allow the X relay to drop out and trip the 86E LOR.

Qualitatively, the probability of a Loss of Field relay actuation during DBE's occurring concurrently with the fault is low for the following reasons:

The directional unit can pickup if the Unit is acting as a MVAR sink when connected to a Reactive Power source. This makes a concurrent LOOP event unlikely.

During Degraded Grid condition, the 230KV switchyard voltage would be below normal, which would tend to make Keowee more of a MVAR source, instead of taking in MVAR's. Thus, Directional unit actuation is unlikely during a Degraded Grid condition.

For a LOCA DBE, the Emergency Start signal separates the unit from the grid, which requires relay actuation before the event. Power from the Oconee preferred source (230KV switchyard) is available.

If relay operation during fault recovery were quantitatively feasible, these factors tend to reduce the possibility of a common mode lockout of both Keowee Units, concurrent with an event where Keowee would be required to provide power to Oconee.

The settings for the KLF-1 relay is documented in calculation reference 13, OSC-4300, Oconee Protective Relay Setting Calculation. The operation of this relay is described in reference 22. This relay has three units:

1) The Voltage unit has a setpoint of 54V, which is factory set and cannot be adjusted (reference 22);

2) The Impedance unit, whose operating characteristics can be modeled as a circle on a R/X diagram. Present and recommended settings are documented in OSC-4300, and this calculation assumed the recommended settings. The Impedance unit is picked up for the entire time period in question, and the setting difference will not affect the Directional Unit setting, or Voltage Unit setpoint. Thus the difference in Impedance unit settings will not impact the results of this evaluation.

3) The Directional unit, whose operating curves are defined by contact close, maximum torque, and two torque reversal lines which are plotted on a R/X diagram, and are defined by an angle with the +R axis as a reference (See Reference 22).

A computer model of the power system (Keowee, Duke transmission grid, and surrounding utilities) was used to determine Keowee characteristics during the post-fault period. For the purposes of this calculation, a fault was placed on the grid, and cleared just before T_{cr} (0.279sec). [This is considered conservative since a fault present for a longer time would result in a larger deviation from normal steady state conditions (and thus bigger swings), than a fault of shorter duration. In addition, the analysis of the relay response times showed that either the fault would be cleared, or the Unit separated from all other reactive power sources in a time less than T_{cr}]. The model calculated and plotted Keowee characteristics of Voltage, Current, Reactive Power, Apparent Impedance, and Frequency, during and after the fault. These plots are given in Attachment 5 (A5).

After a period of 5 seconds, voltage approaches steady state (A5 pg.4), and Keowee voltage was less than the 77% KLF-1 relay undervoltage (UV) unit setpoint only for t = 0 to 0.75 seconds.

The 0 to 0.75 second period was further analyzed to verify that the Keowee impedance entered the operating circle of the Impedance unit (A5 pg.5). Then, an analysis of Keowee impedance versus Directional unit operating curves was performed to determine if the potential for KLF-1 relay operation can be eliminated during this period.

The Directional unit measures Reactive power (Q) flow into or out of a Keowee Unit by examining the phase relationship between Unit voltage and current. If Unit voltage angle is taken as a reference and assigned a value of 0°, Keowee Unit Q flow can be related to it's impedance angle (Θ), which is also the angle by which Keowee terminal current leads or lags terminal Voltage. Reactive power flow is given by formula (1), where $\Theta = \angle V / \angle I$, and cos(Θ) = the power factor (pf). If I & V are in phase, Θ=0, pf=1, & Q=0, thus the machine is generating only Real Power (P). Q flowing out of the machine is indicated by current lagging voltage (lagging pf or Θ>0). Q into the machine is indicated by current leading voltage (leading pf or Θ<0). The KLF-1 relay uses the impedance angle to detect Q Load Flow.

$$Q = V * I * \sin(\theta) \quad (1)$$

A characteristic of a power system fault is that the angle of system current during the fault becomes more lagging (reference 24), which corresponds to a smaller pf, more positive Θ, and more Reactive power out of the generators, as indicated on the Keowee Reactive Power Out plot on page 7 of Attachment 5. The directional unit of the KLF-1 relay is designed to respond to Reactive Power flow into the unit (negative Θ), thus will not operate during the fault. The initial jump of machine impedance to the +X axis, which is well outside of the directional unit contact closing zone (page 5 of Attachment 5), provides additional proof of this. Thus the KLF-1 relay will not operate during the time the fault is connected.

The Directional unit is designed and set such that the angle of the lines (with reference to the +R axis) is: Contact close line at -13°, maximum torque line at -43°, and the torque reversal lines are at -133° & -313°. The torque reversal lines are set and tested to a tolerance of ±1° at -133° and ±4° at -313°. No tolerances are specified by the manufacturer for the contact close and maximum torque lines, but discussions with Duke Power Company relay experts (see Attachment 4) indicate a ±4° tolerance for those lines would be a conservative estimate.

The Directional unit will generate a signal when the unit's contacts close, which is at the -13° contact close line. According to the KLF-1 instruction book, the Directional Unit's Contact Close line is set to exactly -13°, with no tolerance. To provide additional conservatism, the tolerance for this line will be taken to be ±4°, thus the minimum angle would be -9°. Keowee Transient Impedance during the 0 to .75 second period is shown plotted on A5 pg.6, along with a line representing -8°. From this figure, the times where Keowee impedance approaches the -8° line (R values between approximately 0.11 and 0.17) during the post-fault transient can be identified. The data from which these curves are plotted is given in Attachment 6. From this data, the exact Impedance angle can be calculated for the time band when the Unit response is closest to the -8° line. The following data points were analyzed to determine the minimum impedance angle.

TIME	R	X	IMPEDANCE ANGLE
0.6292	0.13524	-0.018401	-7.7482°
0.6500	0.14455	-0.020437	-8.0473°
0.6625	0.15153	-0.021644	-8.1289°
0.6667	0.15411	-0.022041	-8.1393°
0.6708	0.15683	-0.022434	-8.1407°
0.6750	0.15970	-0.022823	-8.1332°
0.6792	0.16272	-0.023206	-8.1164°
0.6833	0.16589	-0.023583	-8.0910°
0.6917	0.17274	-0.024310	-8.0107°

The minimum angle was found to be -8.1407°, which is > 4° above the directional unit Contact Close line, and also above the assumed tolerance. From this it is concluded that the directional unit, and thus the KLF-1 relay, will not pickup during post-fault system transients. (NOTE: This analysis did not require use of the 0.25 second time required for the KLF-1 "X" relay to drop out, which provides additional conservatism.)

I. CONCLUSION

This analysis identified four postulated Single Failure problems. One problem has been permanently corrected with a minor modification of the ACB-1 & 2 control circuits.

The problem of a potential complete loss of Emergency power due to a fault in the overlap region of ACB-1 or 2 has been eliminated by operating with the overhead ACB disconnects open for the unit preselected to the underground. A modification of the system to eliminate this potential problem should be implemented before these disconnects are returned to the normal closed condition. This will prevent the use of both Units to generate to the grid at the same time.

The problem of a fault which would be detected by the transformer differential relay and the Normal Incoming breaker amptector, on the Load Center side of ACB-5 or 6 is not credible in the present Dedicated Lineup, since these breaker do not operate during a DBE. The Keowee Auxiliary Load Centers should be kept in the Dedicated Lineup until a modification which eliminates this problem can be implemented.

The problem with the Generator Field breaker trip on unit overspeed is presently precluded by limiting the unit power to a maximum of 66MW, which tests have shown not to cause a speed excursion above the overspeed device setpoint of 180RPM.

The fault clearing times were shown in section H to be adequate to eliminate concerns of unit damage due to instability. These times are conservative, in that they were computed for this analysis using the electro-mechanical directional distance relays as the initiating device. The actual system response times will be shorter, due to redundant Static (Solid State) relays which are faster than the electro-mechanical devices.

Analysis of the fault and post-fault Keowee transient response demonstrates that the KLF-1 Loss of Field Relay will not pickup during these transients. The worst case transient swings are not large enough to enter the operating region of the relay's Directional unit. A history of no relay actuations due only to fault induced unit transients (See Attachment 4) supports this conclusion.

No scenarios were identified where it was significant that both units were generating at the same time. With corrections to the system, compliance with the Single Failure criteria can be accomplished, even with both units being used to generate commercial power. It is therefore concluded that, once the permanent changes discussed above are implemented, no credible Single Failure would exist that could render both units inoperable, and prevent the Emergency Power system from performing it's intended onsite safety function when operating with both Units generating peaking power to the grid.

J. REFERENCES

1. NRC I.E. Information Notice 84-69 dated Sept. 24, 1984.

2. NRC I.E. IN 84-69 Supplement 1 dated Feb. 24, 1986.

3. IEEE Std 308-1980 IEEE Standard for Class 1E Power Systems for Nuclear Power Generating Stations.

4. NRC Branch Technical Position ICSB-8, USE OF DIESEL-GENERATOR SETS FOR PEAKING.

5. OSS-0254.00-00-2005, Keowee Hydro Station Design Basis Document.

6. OSS-0254.00-00-2004, 230KV Switchyard Design Basis Document.

7. Duke One & Three Line Drawings.

8. K-700, Keowee 13.8/230KV Power System.

9. O-800, 800A & 800B 230KV Switchyard Oneline.

10. K-707 Series, Keowee Three Line Drawing.

11. Duke Elementary Diagrams
   a. KEE-27, 27-1 & 27-2 - Load Center 1X & 2X Control Elementary.
   b. KEE-112 & 212 Series - Generator Breaker Elementary Drawings.
   c. KEE-113 & 213 Series - Keowee Unit Startup Control Elementary.
   d. OEE-34 through 87 - 230KV PCB Control & Protective Relaying.
   e. KEE-17-1 - Transformer Differential Elementary.

12. Oconee Nuclear Station Relaying Training Manual (Nov. 1977 Edition)

13. OSC-4300, Oconee Protective Relay Setting Calculation.

14. Struthers Dunn Relay Catalog.

15. Cutler Hammer Relay Catalog.

16. OM-309-0063
   a. GE Type PVD Differential Relay Bulletin GEH-1770.
   b. GE Type HEA Aux. Relay Bulletin GEH-2058D.
   c. Westinghouse Type AR Bulletin I.L. 41-759.4B.
   d. Westinghouse Type KD-4 Bulletin I.L. 41-491.4J.

17. Square D Product Catalog.

18. Applied Protective Relaying, Chapter 19, System Stability and Out of Step Relaying.

19. Elements of Power System Analysis, 4th Addition by Stevenson.

20. Electrical Machinery, 5th Addition by Fitzgerald, Kingsley, and Umans.

21. Section 2.4.7 of "Operation of EHG in Parallel With Offsite Grid", of Report Oconee Nuclear Station Self Initiated Technical Audit [SITA 92-01 (ON)], Electrical Distribution System Functional Inspection (EDSFI) performed by Southern Technical Services inc".

22. Westinghouse Bulletin I.L. 41-748.1, Instruction Book for Westinghouse Type KLF-1 Loss of Field Relay.

23. Westinghouse Applied Protective Relaying Manual, chapter 19, System Stability and Out of Step Relaying.

24. Westinghouse Applied Protective Relaying Manual, chapter 2, section IV.B., Characteristics of Faults

25. FSAR Section 3.1, Conformance with NRC General Design Criteria, AEC criteria 39, Emergency Power for Engineered Safeguards Features (Category A).

26. Industrial Power Systems Handbook, D. Beeman, Mc Graw Book Co., 1955.

27. ANSI/IEEE C37.20.2, IEEE Standard for Metal-Clad and Station-Type Switchgear, 1987.

K. LIST OF ATTACHMENTS

A1 Drawing showing location of hypothetical Faults considered, 1 page.

A2 Study of Fault Clearing Time for Keowee Units, 20 pages.

A3 Isolation Logic and Device Times for Faults where Comparison with T_{cr} is necessary, 4 pages.

A4 Conversation Record Kept for Various Conversations Between P. Drum (Duke Power Co. Relay Expert) and C. Schaeffer, 1 page.

A5 Keowee Output Characteristic Plots as ran on the PSS/E-20 Power System Simulator for this calculation by W. Quaintence. Also includes a short Introduction of the Program (A5-pg.3). Significant Plots are the Keowee Voltage (A5-pg.4) and Keowee Impedance (A5-pgs.5-6).

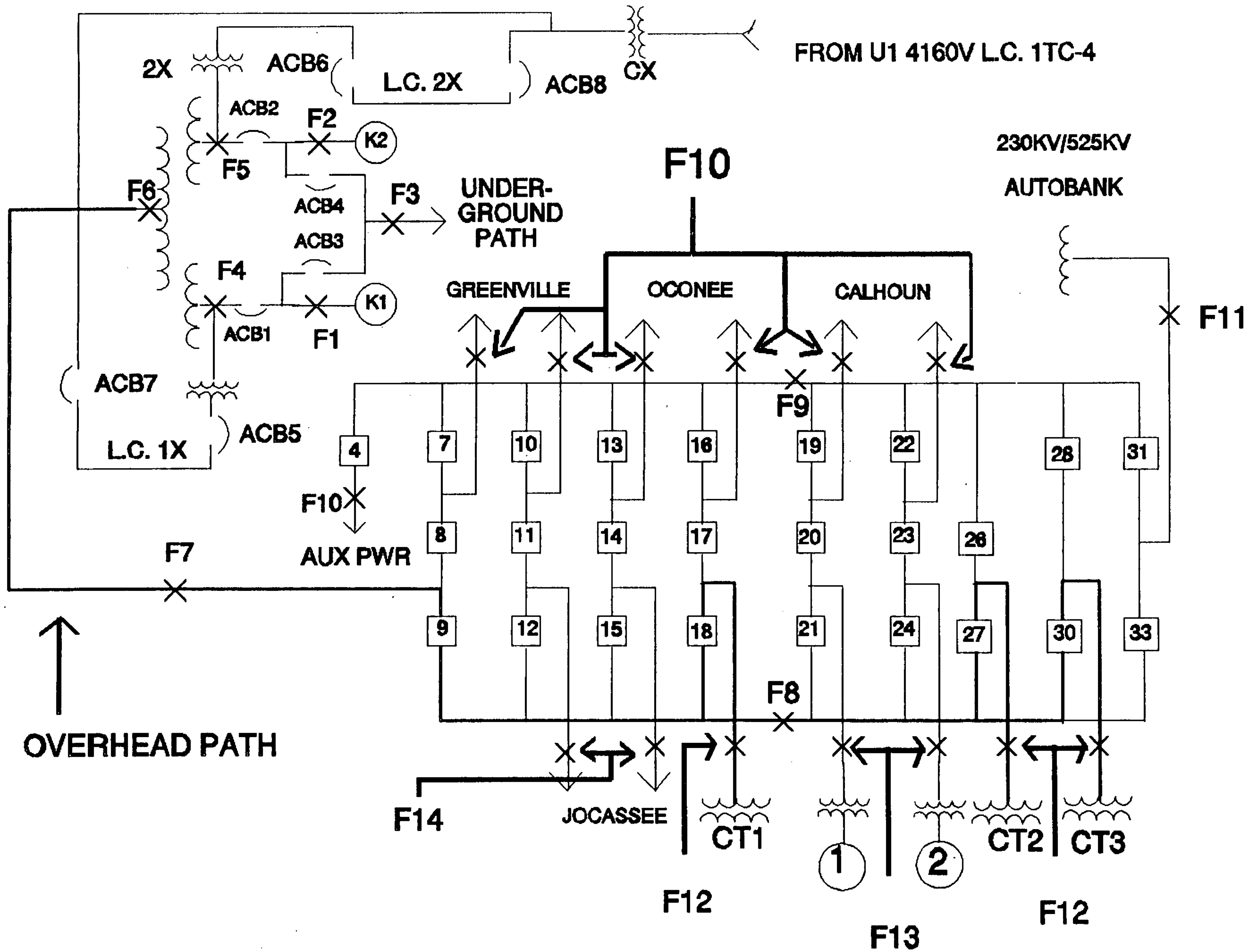
A6 Data Sheets for the Significant Time Period (0 to 1 sec), from which the Plots in Attachment 5 were created.

A7 Communication Records between D. Garrison of System Planning, and C. Schaeffer, ONS Electrical Engineering, discussing the method of calculation, and meaning of the times given in Attachment 2 (3 pages).

A8 Relay Cutsheets showing relay operating times (9 pages).

OSC-5096, Attachment 1 - FAULT LOCATIONS

Pg. 1 of 1



OSC-5296
ATTACHMENT 2
PAGE 1 of 20

April 30, 1992

TO: Dhiaa Jamil

SUBJECT: Fault Clearing Time for Keowee Units

Studies indicate a fault on the Oconee 230 kV bus must be cleared within 0.279 seconds for the Keowee Units to be stable.

A state-of-the-art dynamic model of Keowee, Duke and surrounding utilities was used for this study. This model is able to perform calculations of the Keowee rotor angle as a function of time for various system conditions.

For this study a fault was placed on the Oconee 230 kV bus and removed a fraction of a second later. The model was run an additional period of time to see if the Keowee rotor angle would settle back toward a constant value indicating stability. A constantly increasing angle would indicate instability.

A search process varying the fault clearing time was conducted. Once a clearing time which resulted in stable operation was determined, it was not necessary to check shorter clearing times since they would be less stressful and always result in stable operation. Successively longer clearing times were run until instability was indicated. A process of dividing the interval between stable and unstable operation was conducted to identify the maximum clearing time within 0.004 seconds. The maximum time for stable operation was identified as 0.279 seconds. A run with the clearing time increased to 0.283 seconds indicated unstable operation. Plots of the Keowee rotor angle as a function of time for these runs are attached.

Additional runs were completed in the same manner to determine the clearing time required for a fault at Keowee on the high side of the step-up transformer. The required time was found to be .308 seconds.

Lastly, per your request, a run was made to determine the electrical power, reactive power and terminal voltage for a Keowee unit. For this run a fault was placed at the Oconee 230 kV bus for 0.275 seconds and removed. Monitoring continued for several seconds beyond removal of the fault. A plot of this information is attached.

Dhiaa Jamil
Page 2
April 30, 1992

Data from these runs is also provided on the enclosed 3 1/2" disk on file KEOWEE.WK1.

David L. Garrison 332-4641

David L. Garrison
System Planning and Operating Dept.

DLG/dpw

Attachments

xc: John G. Dalton

OSC-5096
ATTACHMENT 2
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I N T E R A C T I V E   P L O T T I N G   P R O G R A M - - P S S P L T   TUE, APR 28 1992 16:18

CASE: DUKE.LF3   WITH MPT REPRESENTED EXPLICITLY
COMPATIBLE WITH 1991 SERIES SYSTEM BASE CASES

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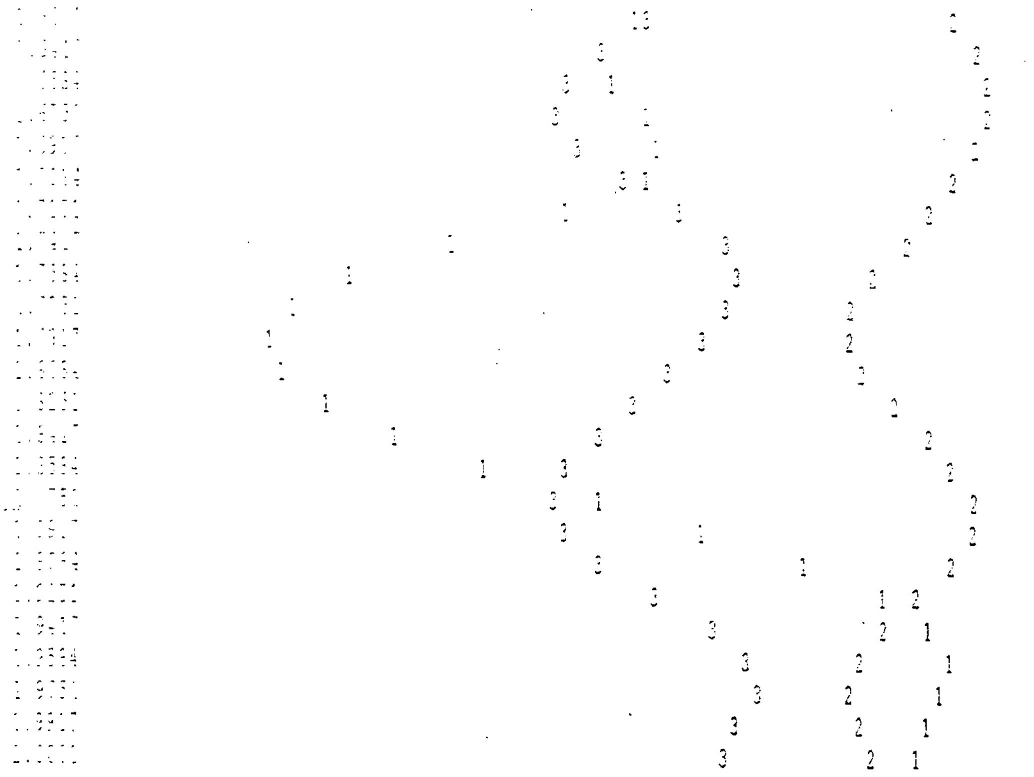
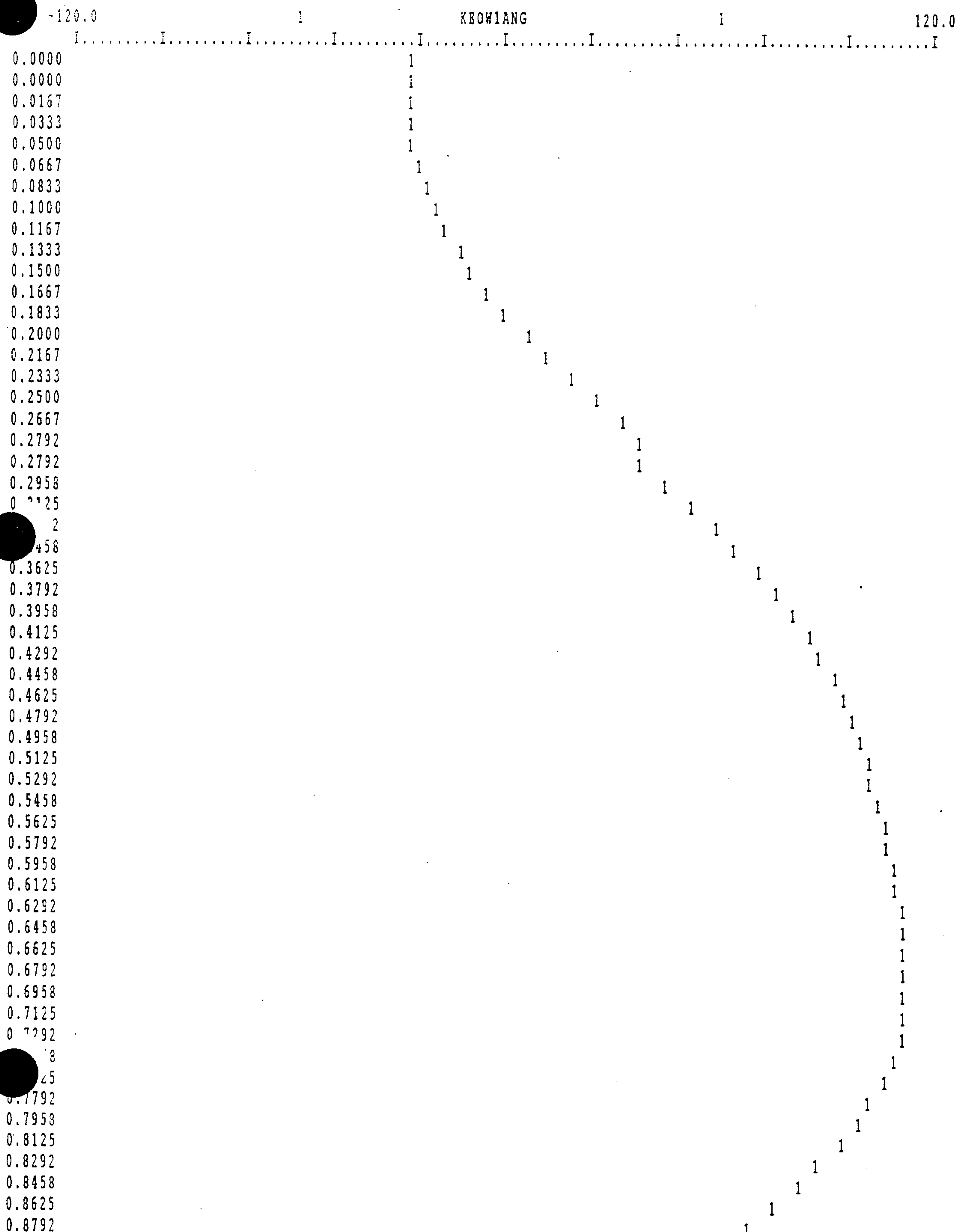
	3	KEOWEEV terminal voltage	3	2.000



PTI INTERACTIVE PLOTTING PROGRAM--PSSPLT TUE, APR 28 1992 11:35

OSC - 5096
ATTACHMENT 2
PAGE 6 of 20

FAULT ON OCONEE 230 WITH 50%I, 50%Y LOAD
FAULT CLEARS AFTER .279 SECONDS



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PAGE 7 of 20

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OSC 5196 Attachment - Page 8 of 20

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FAULT ON OCONEE 230 WITH 50%I, 50%Y LOAD
FAULT CLEARS AFTER .283 SECONDS


```
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P T I   I N T E R A C T I V E   P L O T T I N G   P R O G R A M - - P S S P L T   WED, APR 29 1992 09:35

FAULT ON KEOWEE 230 WITH 50%I, 50%Y LOAD
FAULT CLEARS AFTER .308 SECONDS

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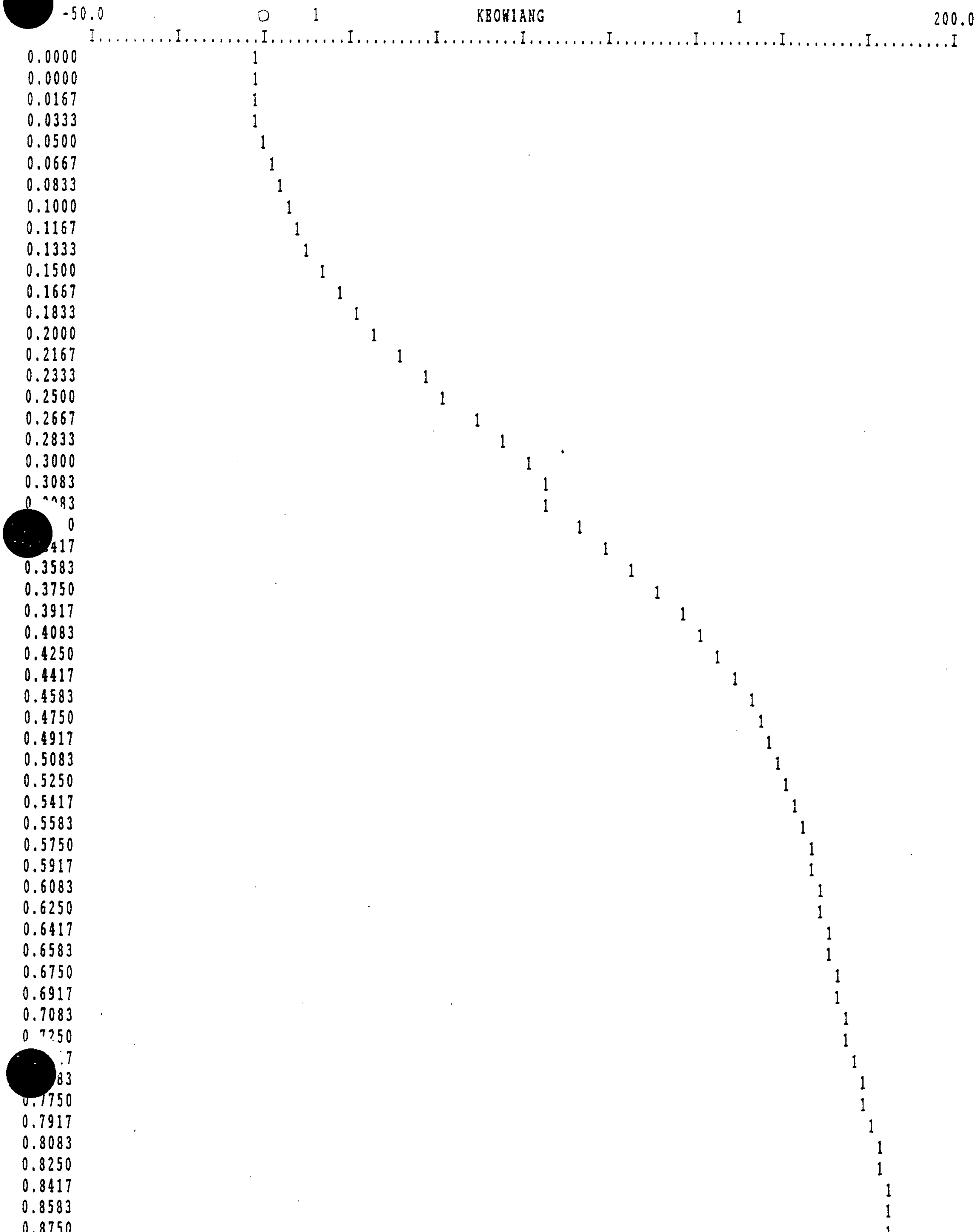

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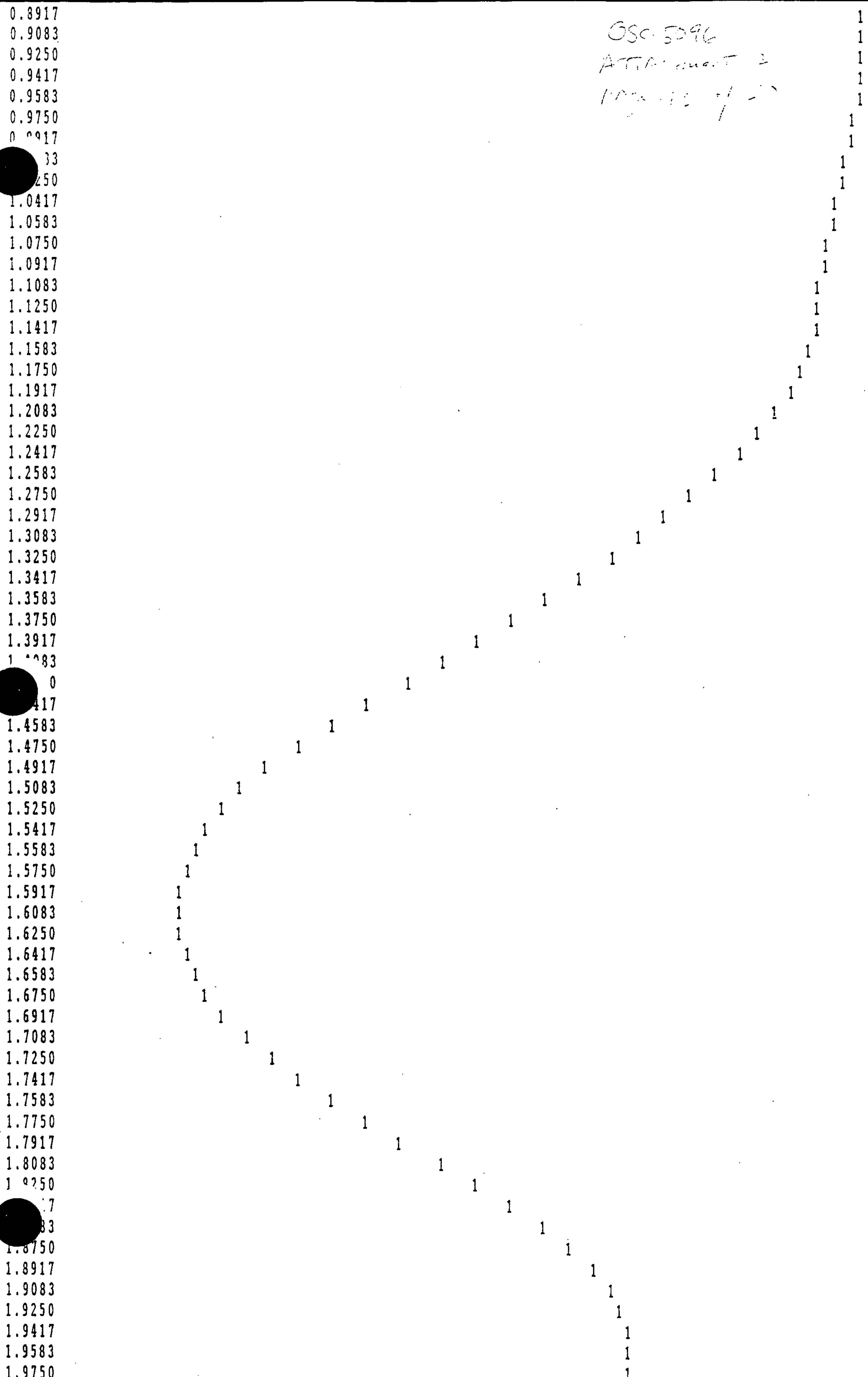
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ATTACHMENT I
PAGE 14 of 20

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ATTACHMENT 2
PAGE 1 of 20

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16 of 20

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FAULT ON KEOWEE 230 WITH 50%I, 50%Y LOAD
FAULT CLEARS AFTER .312 SECONDS

DSC-5096
ATTACHMENT 2
PAGE 16 OF 20

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ATTACHMENT __
PAGE 19 of 20

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Attachment 2
page 20 of 20

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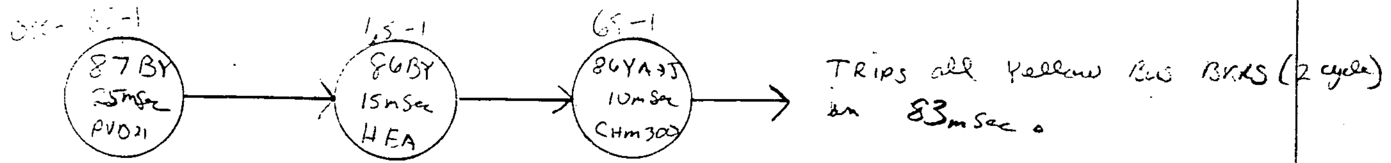
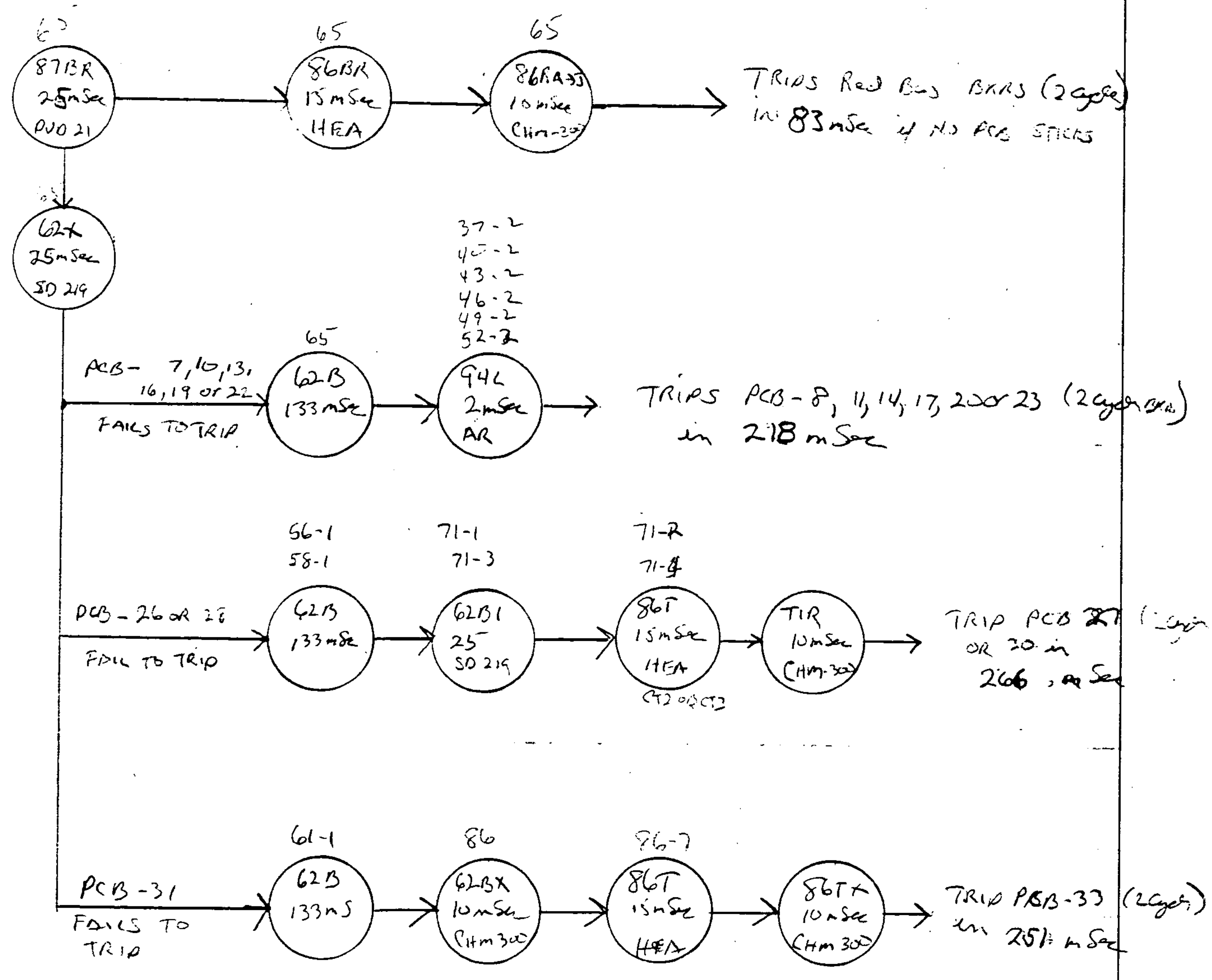
Bus Fault (may be QA or Non QA)

Yellow Bus Fault (F8 on Attachment 1) - Yellow Bus is QA-1

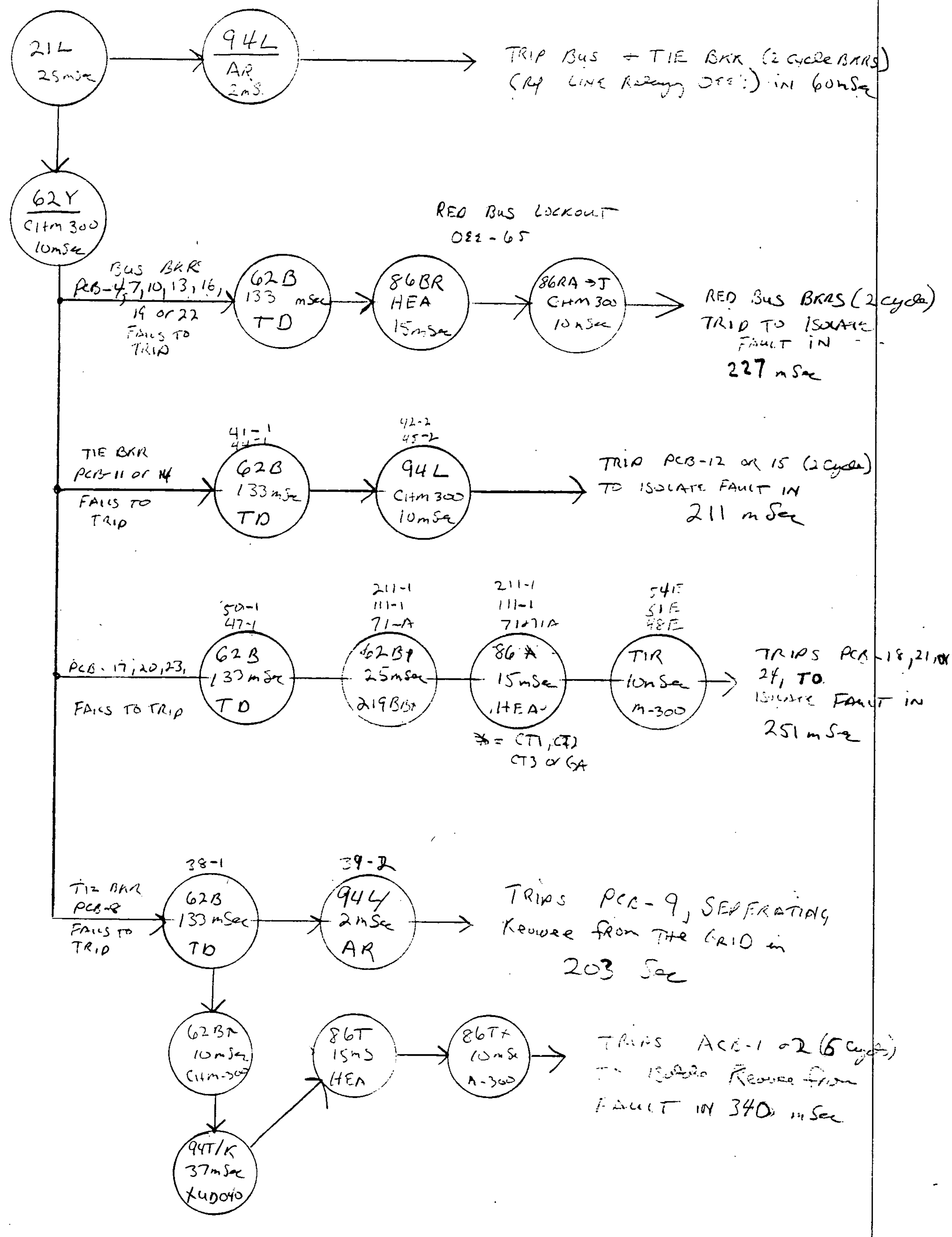


Red Bus Fault (F9 on Attachment 1) - Red Bus Non-QA



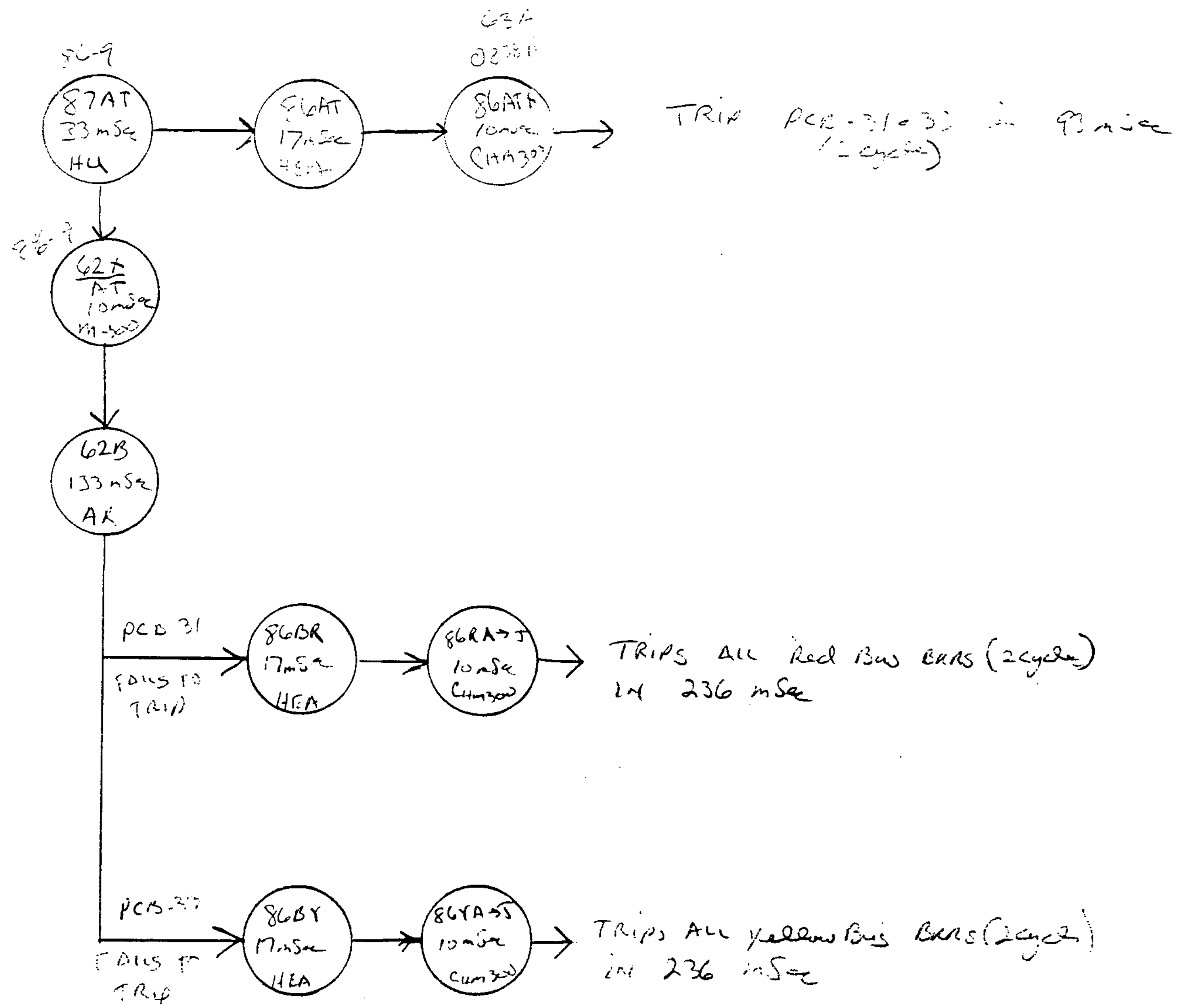
OSC - 5096
Keowee & 230KV Fault Analysis

LINE FAULTS (F10) - NON QA-1 EQUIPMENT ⇒

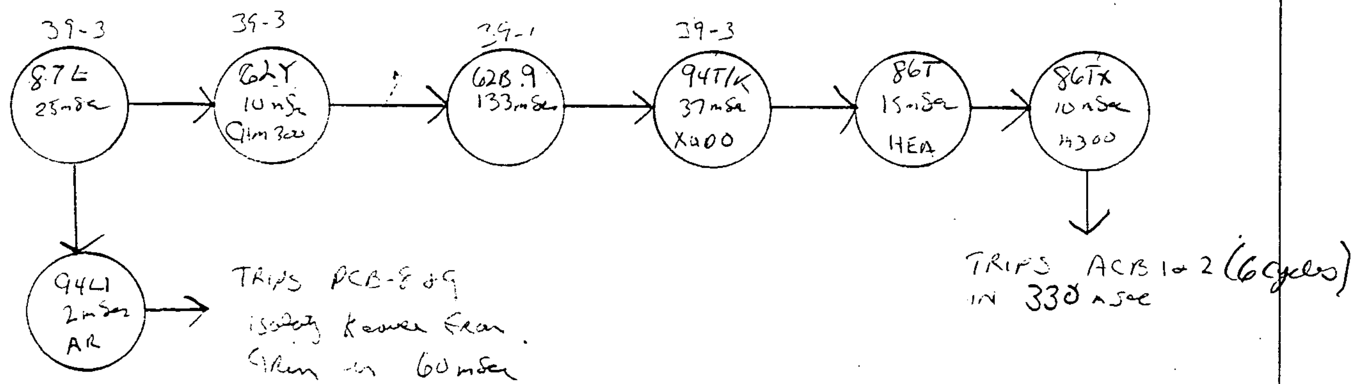


Kenosee + 230 kV ... Fault ... ATTACHMENT 3
OSC - 5096 PAGE ... /4

FAULT F 11



FAULT F 7 QA - 1 LINE



ATTACH 3

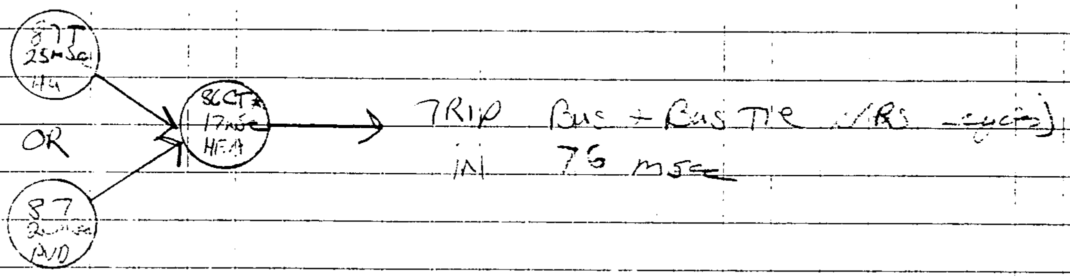
Station | Rev. | File No. | Sheet 4 of 4

Subject

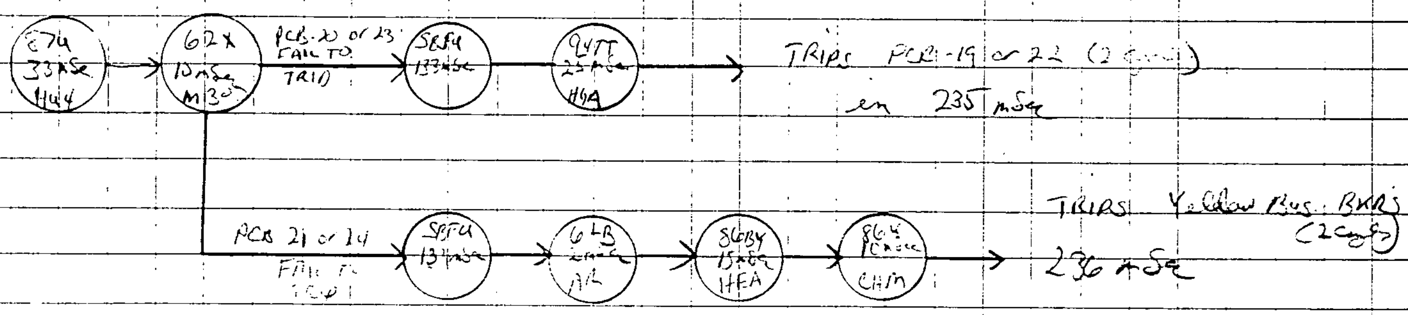
By | Date

Prob No. | Checked By | Date

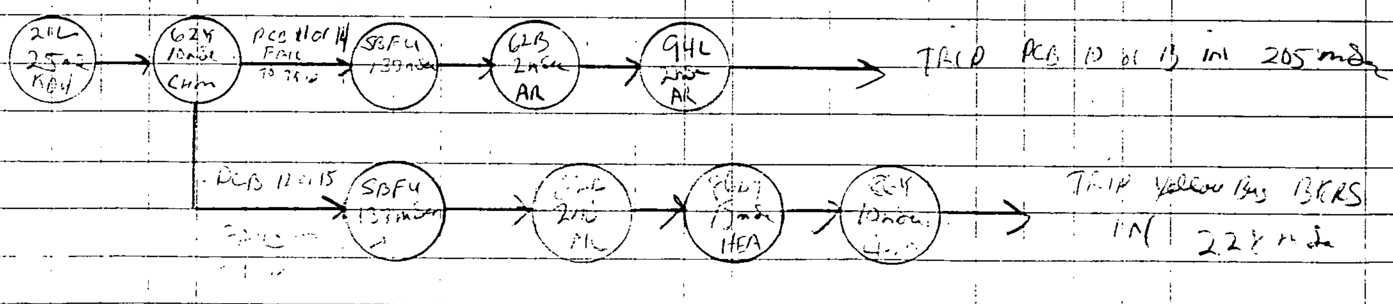
F12 - STARTING TRANS - SINGLE FAILURE



F13 - UNIT 1 or 2 GENERATOR OUTPUT - NOT S.F - TRIP CKT FAILURE



F14 - 500 kV TRANS. LINE - NOT S.F



Form 1021

ATTACHMENT 4
PAGE 1 of 1

DUKE POWER COMPANY
TELEPHONE CONVERSATION REPORT

PROJECT Oconee Emergency Power System Analysis FILE NO. OSC-5096

SUBJECT

PERSON CALLED Paul Drum, Relay Expert for Duke Power, Power Delivery 382-6505.

DATE 12/9/92, 12/10/92, & 12/16/92 TIME

PERSON CALLING Chris Schaeffer

SPECIFICATION NUMBER

SUBJECT DISCUSSED Discussed KLF-1 relay operation, tolerances, operating history, and Unit Stability Analyses.

RECOMMENDED RESOLUTION He said he believed an approach to insure against unit damage due to instability, by ensuring that the Keowee unit will be separated from, either the fault or the rest of the grid before the critical clearing time is a valid approach, since the subject of Stability addresses the relationship between a unit's power angle and the infinite bus power angle. He agreed that separation of Keowee from that infinite bus (i.e. all other units except the other Keowee unit, since they can be expected to swing together) will be sufficient to insure no instability-induced unit damage occurs, even though the Units are supplying the fault for a time longer than T_{Cr}.

We discussed the KLF-1 relay directional unit settings, the Max Torque line and the Torque Reversal Lines as represented on a R/X diagram. The KLF-1 instruction book lists a tolerance of ±4° for the Torque Reversal Lines, and Paul felt that 4° would also be an acceptable figure for the tolerance of the directional unit Contact Close zone. I asked him if had any knowledge of these relays picking up due to a fault. His only memory a KLF relay actuation occurred on Oconee Unit-3 when the 230KV & 525KV switchyards were being tied together. He said that the cause of that relay trip was due to a Unit-3 regulator problem, which was not set properly. He said the analysis after the trip indicated that only a miss-set regulator could have caused the trip and troubleshooting showed the regulator to be set exactly where the analysis predicted.

Paul called back a few minutes after we talked, and had taken a look at the Relay Test Procedure for the Keowee KLF-1 relay. The Directional unit is tested to ±4° regularly.

Called Paul on 12/15/92 and left him a phonemail questioning if the reduced system voltage present during the 0 - 0.75 time period would have an effect on the Directional Unit operating angles. On 12/16/92, I received a return message from him, and he reinforced my belief that the relay is designed to operate at reduced voltages and the reduced voltage will not affect the operating angles.

SIGNED Chris Schaeffer

Mike,

Here are the plots you wanted. The first one shows the terminal voltage for the full 5 sec. simulation. As you can see, it is below .77 pu for the first .75 sec. So then I plotted the impedance on the next page for the first .75 sec. The blue horizontal dashed line is the real axis. It looks like the relay won't trip for this fault at Oconee 230kV bus if you compare it to the attached relay description from the Westinghouse Relay Book. You might have to figure out the angle that the directional unit line makes with real axis to be sure. Good luck with the NRC audit. Let me know if you have any questions.

Bill Quaintance

System Planning + Operating

P.S. Also attached are plots of the machine apparent impedance for the full 5 sec. and plots of other quantities you mentioned.

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ATTACHMENT 5
PAGE 2

PSS/E-20
Power System Simulator
Program Operation Manual
Volume I

T.E. Kostyniak

Revised November 1991

Copy Number: OM1663

Assigned To: Duke Power Company

Introduction

The PTI Power System Simulator (PSS/E) is a package of programs for studies of power system transmission network and generation performance in both steady state and dynamic conditions. PSS/E handles power flow, fault analysis (balanced and unbalanced), network equivalent construction, and dynamic simulation.

PSS/E achieves its broad capabilities by a highly modular structure and, in dynamic simulation, by encouraging the engineer to introduce his own subroutines describing his particular problem whenever the standard calculation procedures are not appropriate. PSS/E is not set up to solve any specific problem. Rather, it is a carefully optimized data structure associated with a comprehensive array of computational tools which are directed by the user in an interactive manner. By applying these tools in the appropriate sequence, the engineer can handle a huge range of variations on the basic "load flow and stability" theme.

PSS/E is designed on the premise that the engineer can derive the greatest benefit from his computational tools by retaining the most intimate control over their application. The interactive structure of PSS/E, therefore, encourages the user to examine the results of each step in his computation before proceeding to the next. This assists the engineer in understanding the engineering capabilities of his tools without having to become a master of the mathematical fine points of computation. The execution of standard studies such as power flow and basic transient stability on PSS/E requires no programming expertise. An engineer who is able to translate his problem formulation into simple FORTRAN statements will find, however, that PSS/E allows him to handle virtually any system dynamics problem for which he can produce the requisite equipment models and input data.

The standard maximum capacities of PSS/E in terms of buses, branches, generators and other system components are the same in all of its "ACTIVITIES" and are summarized in Table i.1.

PSS/E and its auxiliary programs are documented in a set of Manuals. Your installation may not include all of the documents listed below, depending upon which of the optional program sections are included in your lease of PSS/E.

This Manual, PSS/E PROGRAM OPERATION MANUAL, is a guide to PSS/E operational procedures which are common to all host computers on which PSS/E is supported.

The Manual PSS/E PROGRAM APPLICATION GUIDE discusses engineering considerations in formulating problems for PSS/E and interpreting its results. These two Manuals discuss the use of PSS/E from different viewpoints and hence complement each other. The user is encouraged to become familiar with both of these Manuals.

Machine specific user procedures, as well as PSS/E installation instructions and documentation on several PTI supplied utility programs, are contained in a host dependent manual (e.g., PSS/E ON THE IBM VM/CMS, PSS/E ON THE APOLLO, etc.).

The Manual GUIDE TO PRINTING AND PLOTTING describes the interface between PSS/E and the graphics and tabular output devices supported by PSS/E on the host machine. It includes both program user information as well as system related instructions required by those responsible for PSS/E installation.

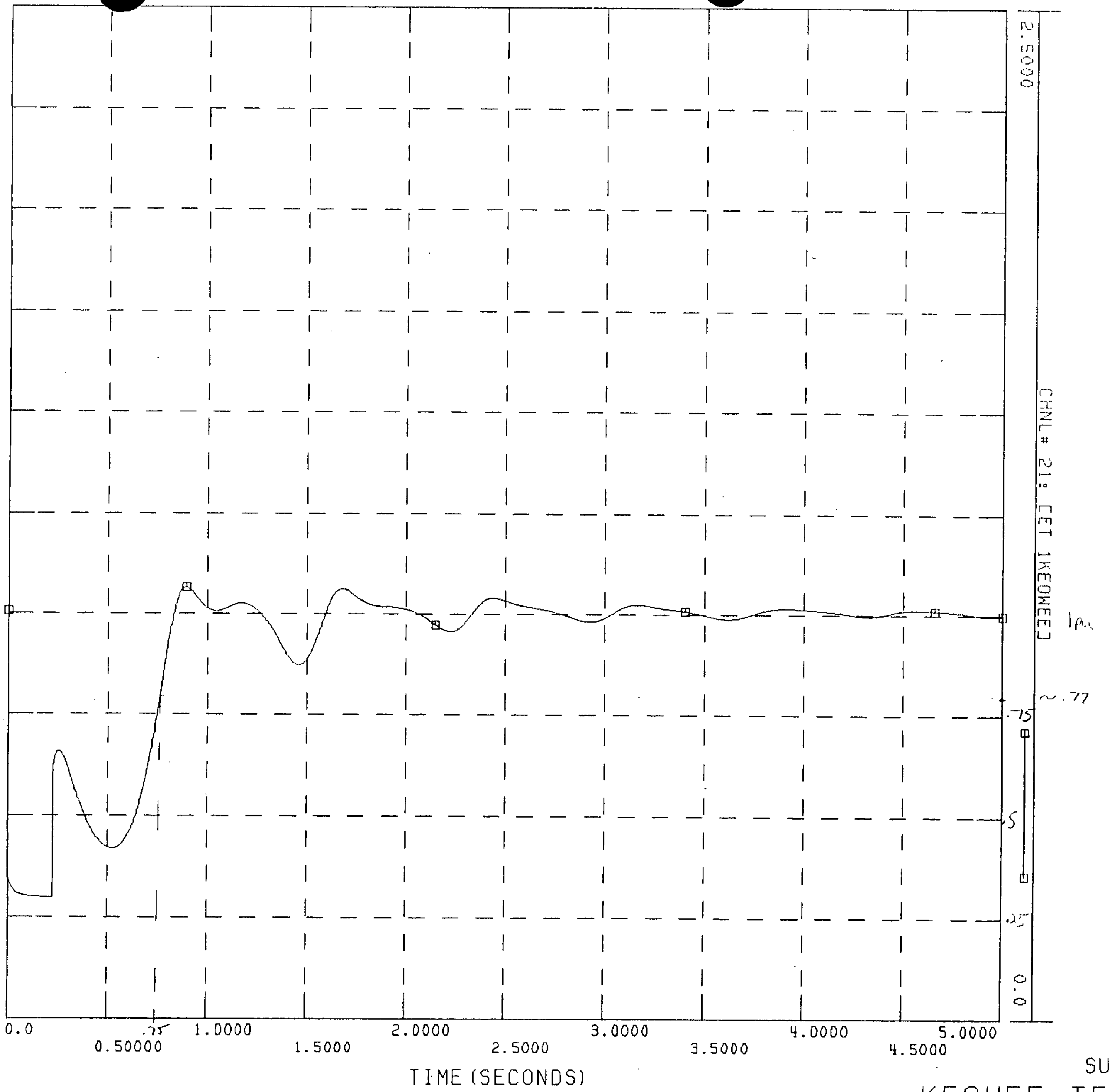
Three USER'S READY REFERENCE sheets summarize the commands recognized by activities GRPG, PSAS, and PSEB.

The PSSPLT PROGRAM OPERATION MANUAL describes the use of the simulation channel output file processing program.

LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY: KEOWEE ADDED; WHQ

FILE: JUNK2

Keowee Voltage vs Time (0-5 seconds)
w/ Voltage Limit Setpoint of 77%.



SUN, DEC 6 1992 13:04

KEOWEE TERMINAL VOLTAGE

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ATTACHMENT 5
PAGE 4

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ATTACHMENT 5
PAGE 5

LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY; KEOWEE ADDED; WHQ

POWER TECHNOLOGIES, INC.

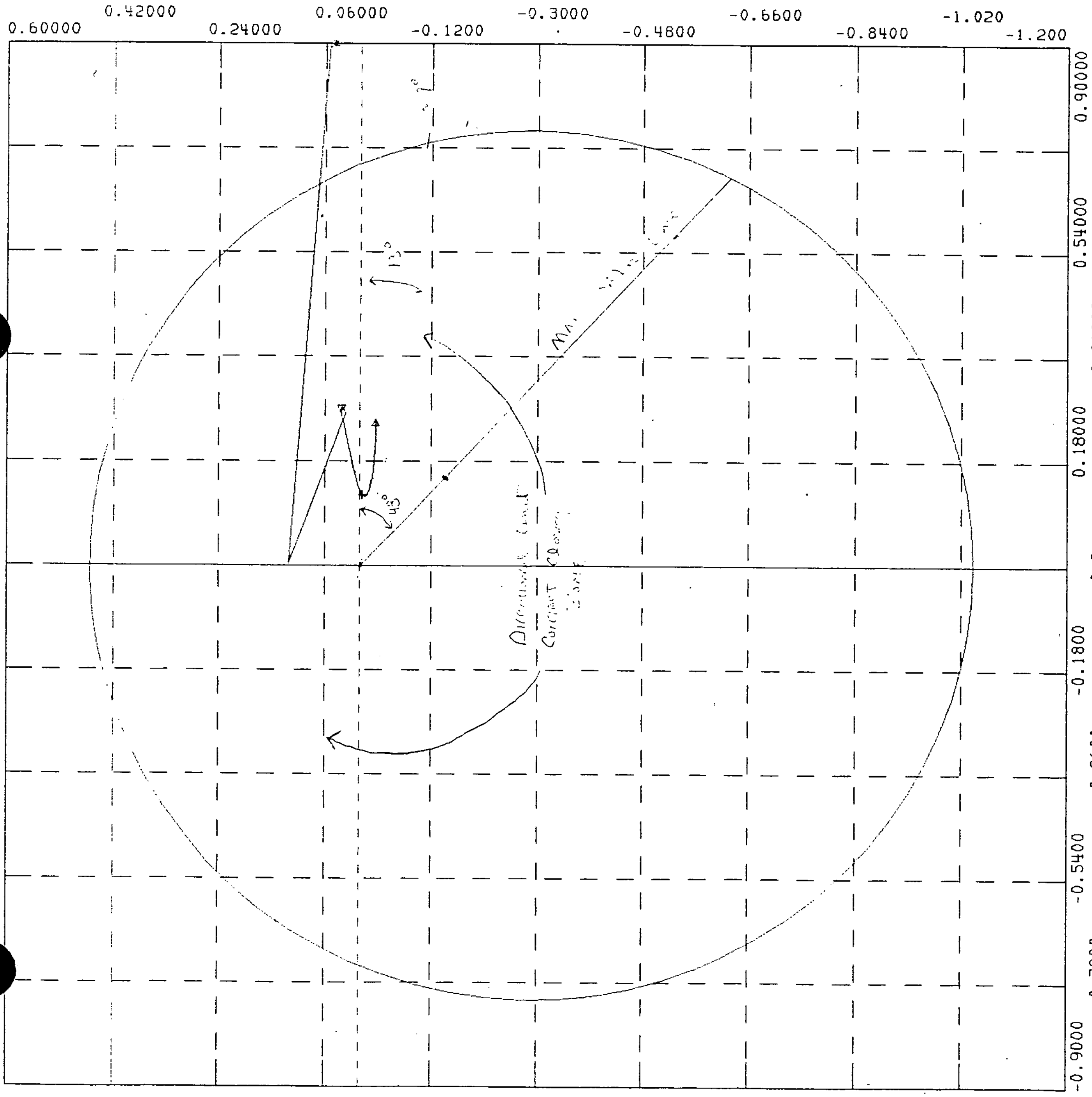
Keowee Impedence from 0→0.75 seconds
Circle Represents Impedance unit operating circle
Directional unit contact close line @ -13°
Max Torque line @ -43°

FILE: JUNK2

RELAY: LOEXR1

TSTART: 0.0 TSTOP: 0.7543 TIC INCREMENT: 0.25

CHNL# 28: [MCX1KEOWEE]



CHNL# 27: [MCR1KEOWEE]

SUN, DEC 6 1992 13:41

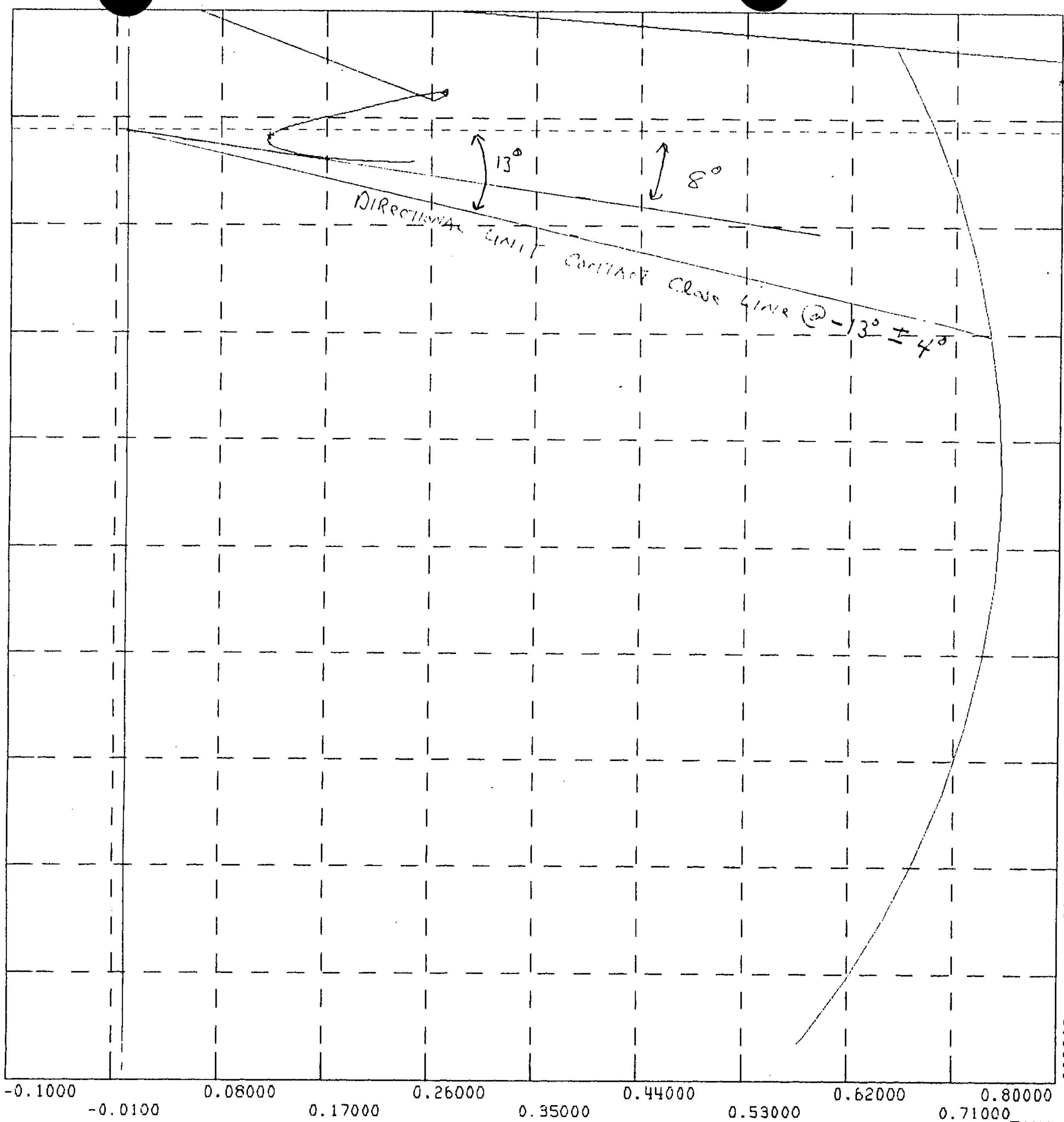
KEOWEE LOEXR UPTO .75 SEC

LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY: KEOWEE ADDED; WHO

OSC - 5096
ATTACHMENT 5
PAGE 6

Blown up Picture of Keowee Impedance from 0 → 0.75 Sec

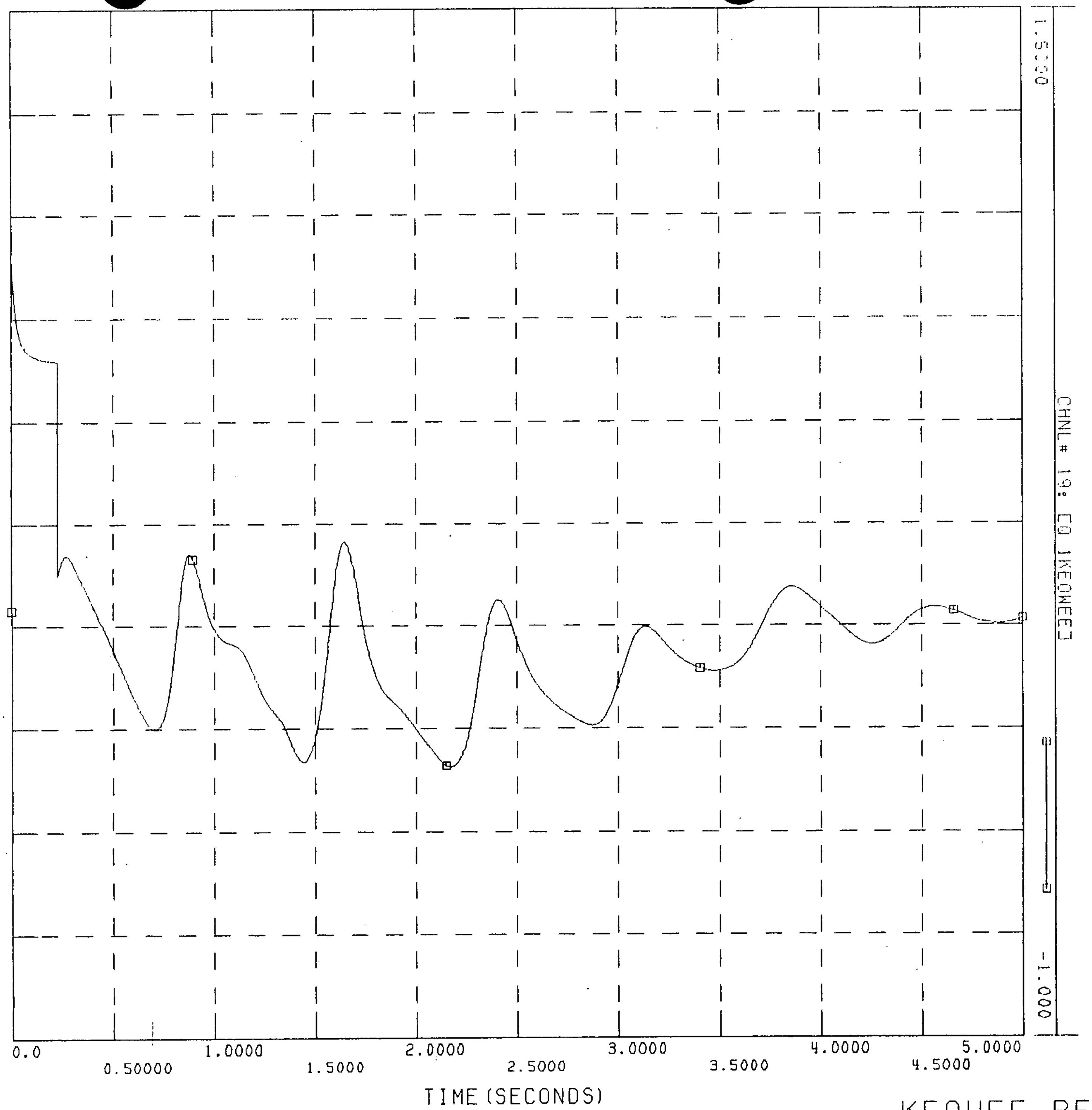
FILE: JUNK2
RELAY: LOEXR1
TSTART: 0.0 TSTOP: 0.75 TIC INCREMENT: 0.25
CHNL# 28: [MCX1KEOWEE]



CHNL# 27: [MCR1KEOWEE]

THU, DEC 10 1992 16:01

KEOWEE LOEXR UP TO .75 SE



POWER TECHNOLOGIES, INC.

LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY: KEOWEE ADDED; WHO

FILE: JUNK2

Keowee Reactive Power (Q) 0 → 5 seconds

OSC-5096
ATTACHMENT 5
PAGE 7

SUN, DEC 6 1992 13:10

KEOWEE REACTIVE POWER OUT

OSC-5096
ATTACHMENT 5
PAGE 8

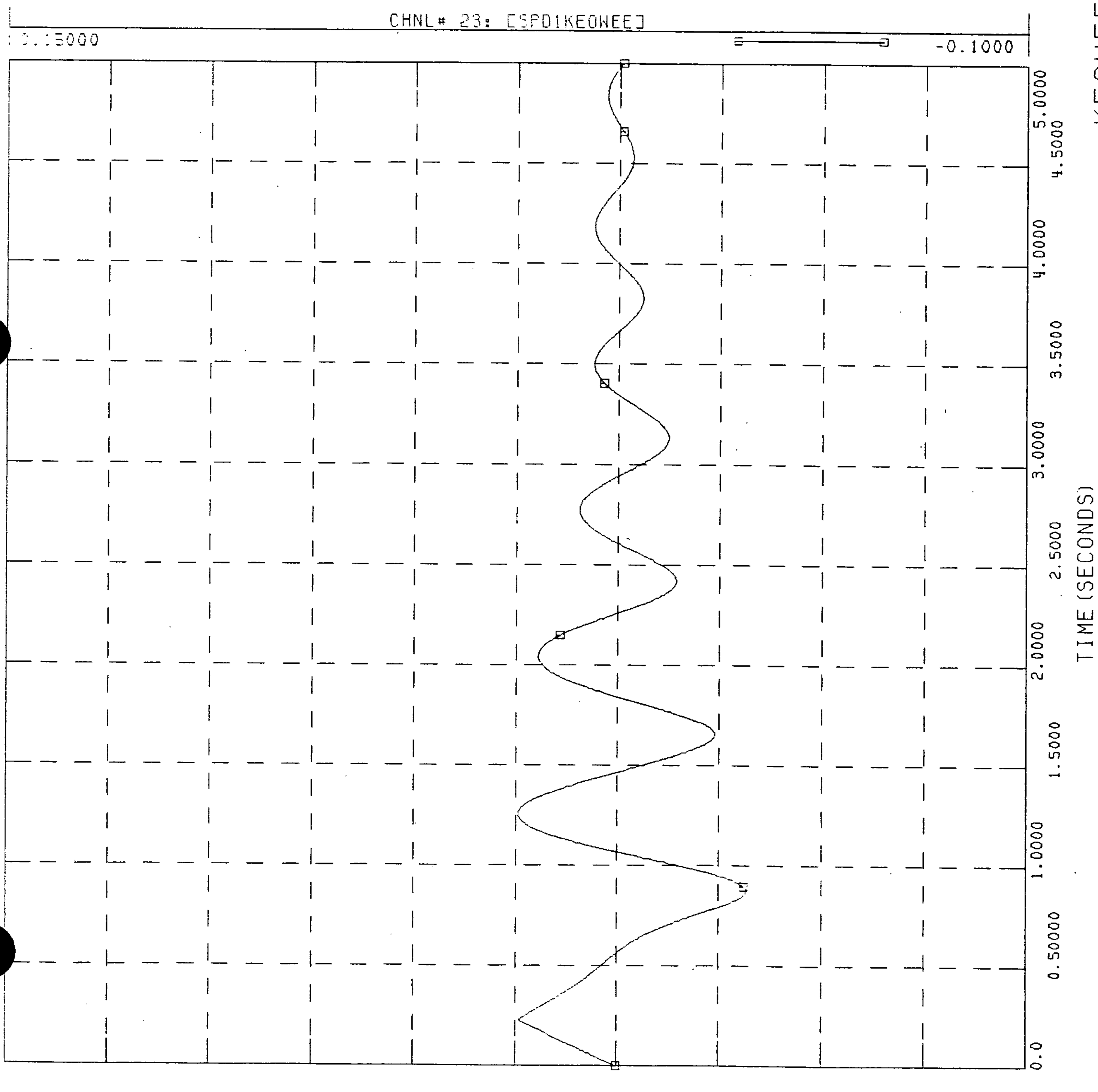
LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY: KEOWEE ADDED: WHQ

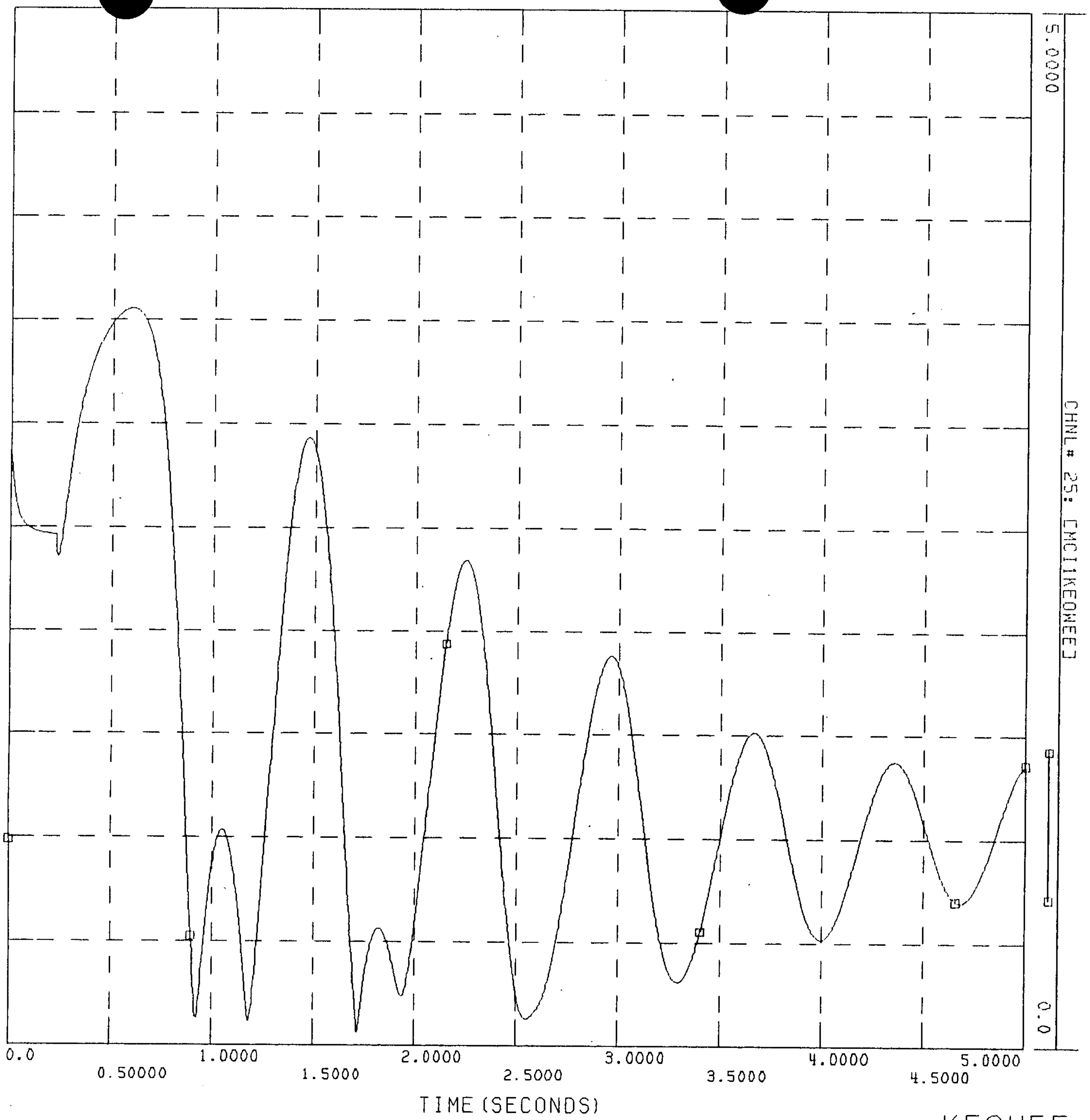
POWER TECHNOLOGIES, INC.

FILE: JUNK2

SUN, DEC 6 1992 13:20

KEOWEE FREQ. DEVIATION





POWER TECHNOLOGIES, INC.

LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY: KEOWEE ADDED; WHO

FILE: JUNK2

OSC-5096
ATTACHMENT 5
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SUN, DEC 6 1992 13:15

KEOWEE TERMINAL CURRENT

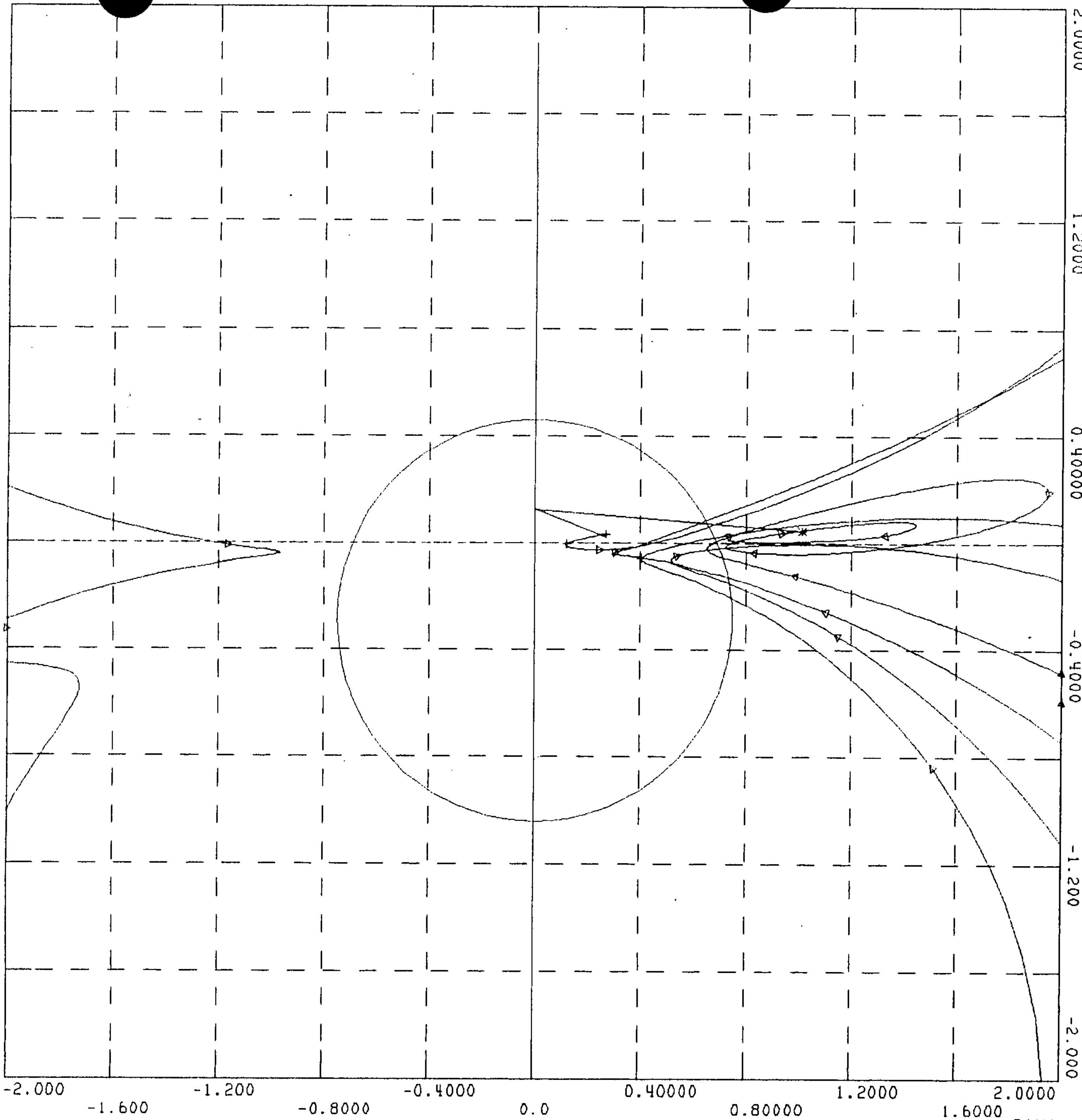
LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY; KEOWEE ADDED; WHO

FILE: JUNK2

RELAY: LOEXR1

TSTART: 0.0 TSTOP: 5.0 TIC INCREMENT: 0.25

CHNL# 28: [MCX1KEOWEE]



CHNL# 27: [MCR1KEOWEE]

SUN, DEC 6 1992 12:54

KEOWEE LOSS OF EXC. RELAY

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OSC-5096
ATTACHMENT 5
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LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY: KEOWEE ADDED: WHO

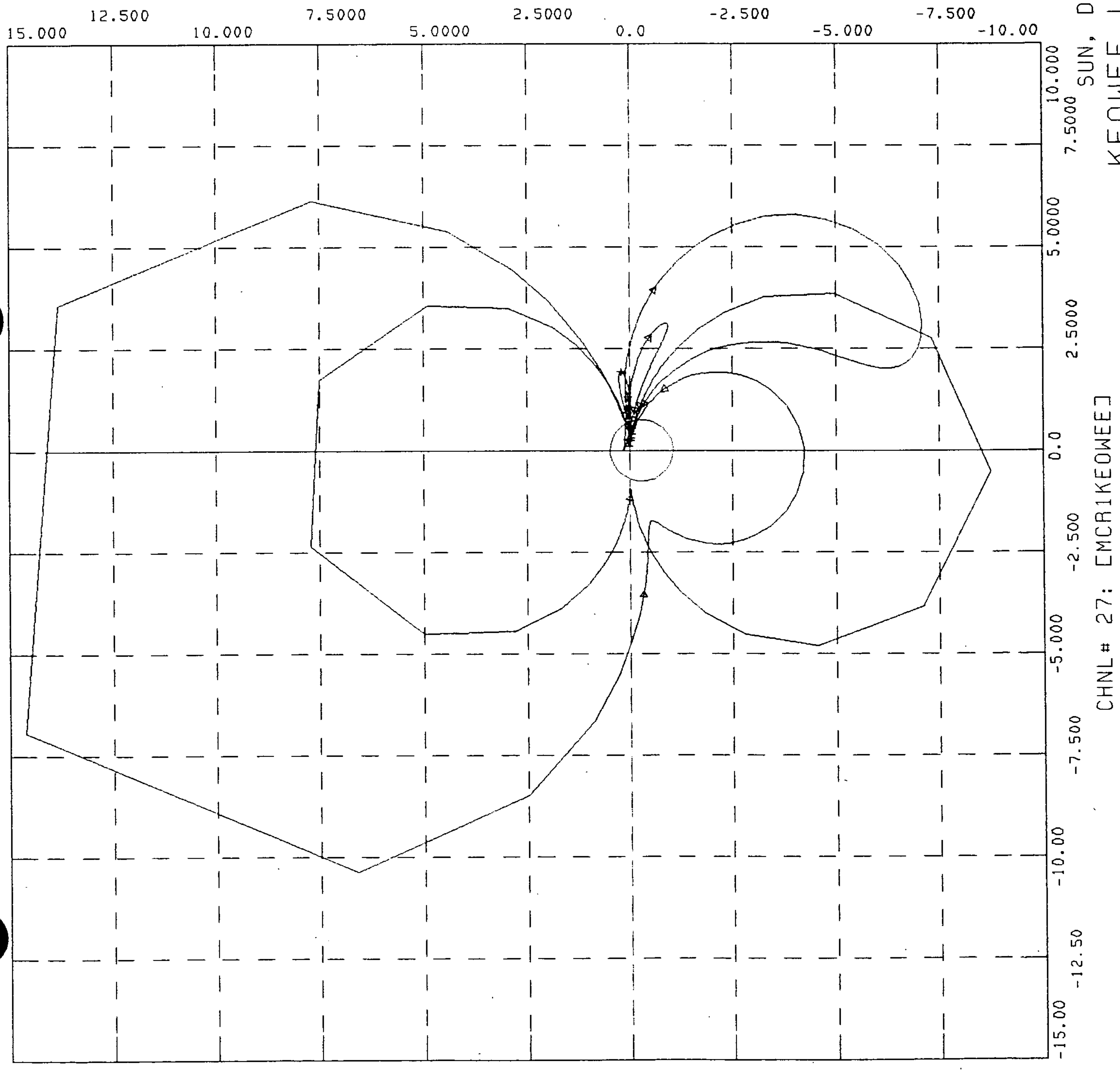
POWER TECHNOLOGIES, INC.®

SUN, DEC 6 1992 13:01
KEOWEE LOSS OF EXC. RELAY

Keowee Impedance 0 → 5 sec

FILE: JUNK2

RELAY: LOEXR1
TSTART: 0.0 TSTOP: 5.0 TIC INCREMENT: 0.25
CHNL# 28: [MCX1KEOWEE]



OSC - 5096
ATTACHMENT 6

KEOWEE POST FAULT TRANSIENT
ANALYSIS DATA FOR
t = 0 TO 1.16 Sec
(5 SHEETS)

PTI INTERACTIVE PLOTTING PROGRAM--PSSPLT FRI, DEC 11 1992 11:14
LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY; KEOWEE ADDED; WHQ

CHANNEL	00027	00028	00021	00019	00023
TIME	MCR1KEOWEE	MCX1KEOWEE	ET 1KEOWEE	Q 1KEOWEE	SPD1KEOWEE
0.0000	1.0140	0.43587E-01	1.0050	0.37401E-01	0.17085E-08
0.0000	0.24883E-02	0.12158	0.35512	0.90722	0.17085E-08
0.0042	0.24902E-02	0.12158	0.34808	0.87164	0.34016E-03
0.0083	0.24922E-02	0.12158	0.33878	0.82567	0.90696E-03
0.0125	0.24976E-02	0.12158	0.33357	0.80042	0.13600E-02
0.0167	0.24970E-02	0.12158	0.32899	0.77862	0.18126E-02
0.0208	0.24957E-02	0.12158	0.32517	0.76066	0.22648E-02
0.0250	0.24947E-02	0.12158	0.32195	0.74564	0.27165E-02
0.0292	0.24940E-02	0.12158	0.31920	0.73297	0.31678E-02
0.0333	0.24934E-02	0.12158	0.31685	0.72223	0.36186E-02
0.0375	0.24930E-02	0.12158	0.31483	0.71306	0.40689E-02
0.0417	0.24926E-02	0.12158	0.31309	0.70519	0.45186E-02
0.0458	0.24924E-02	0.12158	0.31158	0.69842	0.49678E-02
0.0500	0.24923E-02	0.12158	0.31027	0.69257	0.54164E-02
0.0542	0.24923E-02	0.12158	0.30913	0.68749	0.58645E-02
0.0583	0.24924E-02	0.12158	0.30814	0.68307	0.63120E-02
0.0625	0.24924E-02	0.12158	0.30727	0.67921	0.67589E-02
0.0667	0.24926E-02	0.12158	0.30650	0.67584	0.72053E-02
0.0708	0.24927E-02	0.12158	0.30583	0.67288	0.76510E-02
0.0750	0.24928E-02	0.12158	0.30524	0.67028	0.80962E-02
0.0792	0.24931E-02	0.12158	0.30471	0.66798	0.85408E-02
0.0833	0.24933E-02	0.12158	0.30425	0.66595	0.89847E-02
0.0875	0.24935E-02	0.12158	0.30384	0.66415	0.94281E-02
0.0917	0.24938E-02	0.12158	0.30347	0.66255	0.98709E-02
0.0958	0.24941E-02	0.12158	0.30314	0.66112	0.10313E-01
0.1000	0.24944E-02	0.12158	0.30285	0.65983	0.10755E-01
0.1042	0.24947E-02	0.12158	0.30259	0.65868	0.11196E-01
0.1083	0.24949E-02	0.12158	0.30235	0.65764	0.11636E-01
0.1125	0.24952E-02	0.12158	0.30213	0.65669	0.12076E-01
0.1167	0.24956E-02	0.12158	0.30193	0.65583	0.12515E-01
0.1208	0.24959E-02	0.12158	0.30175	0.65505	0.12953E-01
0.1250	0.24962E-02	0.12158	0.30158	0.65432	0.13391E-01
0.1292	0.24965E-02	0.12158	0.30143	0.65365	0.13829E-01
0.1333	0.24968E-02	0.12157	0.30128	0.65303	0.14265E-01
0.1375	0.24972E-02	0.12157	0.30115	0.65245	0.14701E-01
0.1417	0.24975E-02	0.12157	0.30103	0.65191	0.15137E-01
0.1458	0.24978E-02	0.12157	0.30091	0.65140	0.15572E-01
0.1500	0.24981E-02	0.12157	0.30080	0.65091	0.16006E-01
0.1542	0.24985E-02	0.12157	0.30069	0.65045	0.16439E-01
0.1583	0.24988E-02	0.12157	0.30059	0.65001	0.16872E-01
0.1625	0.24992E-02	0.12157	0.30049	0.64959	0.17305E-01
0.1667	0.24995E-02	0.12157	0.30040	0.64918	0.17736E-01
0.1708	0.24909E-02	0.12157	0.30030	0.64879	0.18167E-01
0.1750	0.24911E-02	0.12157	0.30022	0.64841	0.18598E-01
0.1792	0.24912E-02	0.12157	0.30013	0.64804	0.19027E-01
0.1833	0.24912E-02	0.12157	0.30005	0.64768	0.19457E-01
0.1875	0.24914E-02	0.12157	0.29996	0.64733	0.19885E-01
0.1917	0.24914E-02	0.12157	0.29988	0.64698	0.20313E-01
0.1958	0.24916E-02	0.12157	0.29981	0.64664	0.20740E-01

0.2042	0.24918E-02	0.12157	0.29965	0.64597	0.21593E-01
0.2083	0.24919E-02	0.12157	0.29957	0.64565	0.22018E-01
0.2125	0.24921E-02	0.12157	0.29950	0.64532	0.22442E-01

PTI INTERACTIVE PLOTTING PROGRAM--PSSPLT FRI, DEC 11 1992 11:14
LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY; KEOWEE ADDED; WHQ

CHANNEL	00027	00028	00021	00019	00023
TIME	MCR1KEOWEE	MCX1KEOWEE	ET 1KEOWEE	Q 1KEOWEE	SPD1KEOWEE
0.2167	0.24921E-02	0.12157	0.29943	0.64500	0.22866E-01
0.2208	0.24922E-02	0.12157	0.29935	0.64469	0.23289E-01
0.2250	0.24923E-02	0.12157	0.29928	0.64437	0.23712E-01
0.2292	0.24924E-02	0.12157	0.29921	0.64406	0.24134E-01
0.2292	0.26239	0.24556E-01	0.62651	0.12143	0.24134E-01
0.2333	0.26552	0.26088E-01	0.63246	0.12828	0.24042E-01
0.2375	0.27293	0.28900E-01	0.64654	0.14033	0.23602E-01
0.2417	0.27340	0.29978E-01	0.65181	0.14732	0.23320E-01
0.2458	0.27291	0.30904E-01	0.65603	0.15428	0.23029E-01
0.2500	0.27119	0.31384E-01	0.65868	0.15987	0.22728E-01
0.2542	0.26859	0.31502E-01	0.66003	0.16420	0.22417E-01
0.2583	0.26532	0.31307E-01	0.66021	0.16729	0.22097E-01
0.2625	0.26158	0.30859E-01	0.65937	0.16922	0.21767E-01
0.2667	0.25748	0.30213E-01	0.65763	0.17011	0.21430E-01
0.2708	0.25316	0.29418E-01	0.65512	0.17007	0.21084E-01
0.2750	0.24870	0.28516E-01	0.65194	0.16924	0.20732E-01
0.2792	0.24415	0.27540E-01	0.64818	0.16772	0.20375E-01
0.2833	0.23958	0.26521E-01	0.64393	0.16561	0.20012E-01
0.2875	0.23501	0.25477E-01	0.63926	0.16302	0.19645E-01
0.2917	0.23050	0.24428E-01	0.63423	0.16003	0.19274E-01
0.2958	0.22604	0.23384E-01	0.62891	0.15672	0.18901E-01
0.3000	0.22167	0.22356E-01	0.62335	0.15313	0.18526E-01
0.3042	0.21739	0.21351E-01	0.61758	0.14934	0.18150E-01
0.3083	0.21321	0.20372E-01	0.61167	0.14538	0.17773E-01
0.3125	0.20915	0.19423E-01	0.60563	0.14129	0.17397E-01
0.3167	0.20520	0.18506E-01	0.59952	0.13711	0.17021E-01
0.3208	0.20136	0.17621E-01	0.59334	0.13286	0.16646E-01
0.3250	0.19764	0.16768E-01	0.58714	0.12857	0.16273E-01
0.3292	0.19404	0.15947E-01	0.58093	0.12424	0.15902E-01
0.3333	0.19055	0.15157E-01	0.57473	0.11990	0.15533E-01
0.3375	0.18718	0.14397E-01	0.56857	0.11555	0.15167E-01
0.3417	0.18392	0.13664E-01	0.56246	0.11121	0.14805E-01
0.3458	0.18077	0.12958E-01	0.55641	0.10687	0.14445E-01
0.3500	0.17773	0.12276E-01	0.55044	0.10254	0.14089E-01
0.3542	0.17480	0.11618E-01	0.54456	0.98225E-01	0.13737E-01
0.3583	0.17197	0.10982E-01	0.53877	0.93924E-01	0.13389E-01
0.3625	0.16925	0.10365E-01	0.53309	0.89637E-01	0.13045E-01
0.3667	0.16662	0.97661E-02	0.52752	0.85360E-01	0.12704E-01
0.3708	0.16409	0.91842E-02	0.52207	0.81093E-01	0.12368E-01
0.3750	0.16165	0.86174E-02	0.51675	0.76834E-01	0.12037E-01
0.3792	0.15930	0.80646E-02	0.51155	0.72580E-01	0.11709E-01
0.3833	0.15704	0.75241E-02	0.50649	0.68325E-01	0.11386E-01
0.3875	0.15487	0.69952E-02	0.50157	0.64070E-01	0.11067E-01
0.3917	0.15278	0.64761E-02	0.49679	0.59809E-01	0.10752E-01
0.3958	0.15076	0.59663E-02	0.49214	0.55542E-01	0.10441E-01
0.4000	0.14883	0.54643E-02	0.48765	0.51260E-01	0.10135E-01
0.4042	0.14698	0.49698E-02	0.48329	0.46966E-01	0.98326E-02
0.4083	0.14519	0.44815E-02	0.47909	0.42654E-01	0.95341E-02
0.4125	0.14348	0.39989E-02	0.47503	0.38323E-01	0.92395E-02
0.4167	0.14184	0.35212E-02	0.47111	0.33968E-01	0.89487E-02
0.4208	0.14027	0.30477E-02	0.46735	0.29590E-01	0.86615E-02
0.4250	0.13876	0.25782E-02	0.46373	0.25186E-01	0.83779E-02
0.4292	0.13732	0.21119E-02	0.46026	0.20755E-01	0.80978E-02

PTI INTERACTIVE PLOTTING PROGRAM--PSSPLT FRI, DEC 11 1992 11:14
LOAD FLOW CASE FOR DYNAMIC STUDIES
FROM SOUTHERN COMPANY; KEOWEE ADDED; WHQ

CHANNEL	00027	00028	00021	00019	00023
TIME	MCR1KEOWEE	MCX1KEOWEE	ET 1KEOWEE	Q 1KEOWEE	SPD1KEOWEE
0.4333	0.13594	0.16488E-02	0.45694	0.16298E-01	0.78209E-02
0.4375	0.13462	0.11884E-02	0.45376	0.11812E-01	0.75472E-02
0.4417	0.13337	0.73002E-03	0.45073	0.72938E-02	0.72765E-02
0.4458	0.13217	0.27381E-03	0.44785	0.27509E-02	0.70086E-02
0.4500	0.13103	-0.18050E-03	0.44511	-0.18225E-02	0.67436E-02
0.4542	0.12994	-0.63298E-03	0.44252	-0.64233E-02	0.64811E-02
0.4583	0.12892	-0.10841E-02	0.44008	-0.11055E-01	0.62210E-02
0.4625	0.12794	-0.15334E-02	0.43778	-0.15707E-01	0.59632E-02
0.4667	0.12702	-0.19815E-02	0.43563	-0.20387E-01	0.57076E-02
0.4708	0.12616	-0.24280E-02	0.43362	-0.25090E-01	0.54538E-02
0.4750	0.12534	-0.28732E-02	0.43176	-0.29815E-01	0.52019E-02
0.4792	0.12458	-0.33169E-02	0.43005	-0.34559E-01	0.49516E-02
0.4833	0.12387	-0.37593E-02	0.42849	-0.39322E-01	0.47027E-02
0.4875	0.12322	-0.42002E-02	0.42707	-0.44100E-01	0.44551E-02
0.4917	0.12261	-0.46397E-02	0.42580	-0.48893E-01	0.42087E-02
0.4958	0.12205	-0.50775E-02	0.42460	-0.53695E-01	0.39631E-02
0.5000	0.12155	-0.55138E-02	0.42372	-0.58507E-01	0.37183E-02
0.5042	0.12110	-0.59485E-02	0.42290	-0.63327E-01	0.34740E-02
0.5083	0.12070	-0.63817E-02	0.42224	-0.68151E-01	0.32300E-02
0.5125	0.12035	-0.68130E-02	0.42174	-0.72977E-01	0.29863E-02
0.5167	0.12005	-0.72428E-02	0.42139	-0.77804E-01	0.27425E-02
0.5208	0.11980	-0.76708E-02	0.42120	-0.82629E-01	0.24984E-02
0.5250	0.11961	-0.80971E-02	0.42118	-0.87450E-01	0.22540E-02
0.5292	0.11947	-0.85217E-02	0.42132	-0.92265E-01	0.20088E-02
0.5333	0.11939	-0.89448E-02	0.42163	-0.97075E-01	0.17629E-02
0.5375	0.11936 MIN R	-0.93662E-02	0.42211	-0.10188	0.15158E-02
0.5417	0.11938	-0.97860E-02	0.42276	-0.10666	0.12674E-02
0.5458	0.11946	-0.10204E-01	0.42359	-0.11144	0.10174E-02
0.5500	0.11960	-0.10621E-01	0.42460	-0.11621	0.76569E-03
0.5542	0.11980	-0.11037E-01	0.42579	-0.12096	0.51193E-03
0.5583	0.12006	-0.11451E-01	0.42717	-0.12569	0.25590E-03
0.5625	0.12038	-0.11864E-01	0.42874	-0.13041	-0.26533E-05
0.5667	0.12076	-0.12276E-01	0.43050	-0.13510	-0.26399E-03
0.5708	0.12121	-0.12687E-01	0.43246	-0.13978	-0.52838E-03
0.5750	0.12172	-0.13097E-01	0.43463	-0.14444	-0.79609E-03
0.5792	0.12230	-0.13506E-01	0.43701	-0.14907	-0.10674E-02
0.5833	0.12295	-0.13915E-01	0.43960	-0.15368	-0.13426E-02
0.5875	0.12367	-0.14324E-01	0.44240	-0.15826	-0.16219E-02
0.5917	0.12446	-0.14732E-01	0.44543	-0.16282	-0.19057E-02
0.5958	0.12533	-0.15139E-01	0.44869	-0.16734	-0.21943E-02
0.6000	0.12627	-0.15547E-01	0.45217	-0.17183	-0.24879E-02
0.6042	0.12730	-0.15955E-01	0.45590	-0.17629	-0.27868E-02
0.6083	0.12840	-0.16362E-01	0.45986	-0.18071	-0.30914E-02
0.6125	0.12959	-0.16770E-01	0.46407	-0.18508	-0.34020E-02
0.6167	0.13086	-0.17178E-01	0.46853	-0.18941	-0.37189E-02
0.6208	0.13223	-0.17586E-01	0.47325	-0.19368	-0.40424E-02
0.6250	0.13368	-0.17994E-01	0.47823	-0.19790	-0.43728E-02
0.6292	0.13524	-0.18401E-01	0.48347	-0.20204	-0.47105E-02
0.6333	0.13689	-0.18810E-01	0.48899	-0.20612	-0.50556E-02
0.6375	0.13864	-0.19217E-01	0.49478	-0.21012	-0.54087E-02
0.6417	0.14050	-0.19624E-01	0.50085	-0.21403	-0.57699E-02
0.6458	0.14247	-0.20031E-01	0.50720	-0.21783	-0.61396E-02
0.6500	0.14455	-0.20437E-01	0.51384	-0.22153	-0.65180E-02

MAX UNIT IMP ANGLE SHOULD BE THIS RANGE

PTI INTERACTIVE PLOTTING PROGRAM--PSSPLT FRI, DEC 11 1992 11:14

LOAD FLOW CASE FOR DYNAMIC STUDIES

FROM SOUTHERN COMPANY; KEOWEE ADDED; WHQ

CHANNEL	00027	00028	00021	00019	00023
TIME	MCR1KEOWEE	MCX1KEOWEE	ET 1KEOWEE	Q 1KEOWEE	SPD1KEOWEE
0.6542	0.14675	-0.20841E-01	0.52077	-0.22510	-0.69055E-02
0.6583	0.14908	-0.21244E-01	0.52799	-0.22853	-0.73023E-02
0.6625	0.15153	-0.21644E-01	0.53551	-0.23181	-0.77086E-02
0.6667	0.15411	-0.22041E-01	0.54333	-0.23491	-0.81248E-02

0.6750	0.15970	-0.22823E-01	0.55986	-0.24052	-0.89874E-02
0.6792	0.16272	-0.23206E-01	0.56858	-0.24300	-0.94342E-02
0.6833	0.16589	-0.23583E-01	0.57760	-0.24521	-0.98916E-02
0.6875	0.16923	-0.23951E-01	0.58692	-0.24714	-0.10360E-01
0.6917	0.17274	-0.24310E-01	0.59654	-0.24877	-0.10839E-01
0.6958	0.17642	-0.24658E-01	0.60645	-0.25006	-0.11328E-01
0.7000	0.18030	-0.24993E-01	0.61666	-0.25099	-0.11828E-01
0.7042	0.18438	-0.25314E-01	0.62715	-0.25152	-0.12340E-01
0.7083	0.18866	-0.25617E-01	0.63792	-0.25162	-0.12861E-01
0.7125	0.19317	-0.25900E-01	0.64896	-0.25126	-0.13393E-01
0.7167	0.19791	-0.26160E-01	0.66026	-0.25040	-0.13936E-01
0.7208	0.20289	-0.26394E-01	0.67182	-0.24902	-0.14488E-01
0.7250	0.20813	-0.26599E-01	0.68361	-0.24706	-0.15050E-01
0.7292	0.21364	-0.26770E-01	0.69564	-0.24450	-0.15621E-01
0.7333	0.21945	-0.26902E-01	0.70788	-0.24131	-0.16201E-01
0.7375	0.22556	-0.26990E-01	0.72031	-0.23744	-0.16788E-01
0.7417	0.23200	-0.27028E-01	0.73292	-0.23286	-0.17383E-01
0.7458	0.23880	-0.27009E-01	0.74569	-0.22755	-0.17984E-01
0.7500	0.24596	-0.26927E-01	0.75860	-0.22146	-0.18591E-01
0.7542	0.25353	-0.26771E-01	0.77163	-0.21459	-0.19202E-01
0.7583	0.26153	-0.26532E-01	0.78474	-0.20689	-0.19817E-01
0.7625	0.26999	-0.26199E-01	0.79792	-0.19835	-0.20434E-01
0.7667	0.27895	-0.25759E-01	0.81114	-0.18897	-0.21052E-01
0.7708	0.28844	-0.25197E-01	0.82436	-0.17872	-0.21669E-01
0.7750	0.29851	-0.24496E-01	0.83756	-0.16760	-0.22285E-01
0.7792	0.30921	-0.23635E-01	0.85071	-0.15563	-0.22897E-01
0.7833	0.32059	-0.22590E-01	0.86378	-0.14279	-0.23504E-01
0.7875	0.33270	-0.21336E-01	0.87672	-0.12911	-0.24103E-01
0.7917	0.34562	-0.19839E-01	0.88952	-0.11461	-0.24694E-01
0.7958	0.35942	-0.18062E-01	0.90214	-0.99316E-01	-0.25274E-01
0.8000	0.37418	-0.15960E-01	0.91453	-0.83270E-01	-0.25841E-01
0.8042	0.39000	-0.13479E-01	0.92668	-0.66509E-01	-0.26394E-01
0.8083	0.40698	-0.10555E-01	0.93856	-0.49086E-01	-0.26929E-01
0.8125	0.42523	-0.71102E-02	0.95012	-0.31051E-01	-0.27446E-01
0.8167	0.44490	-0.30507E-02	0.96134	-0.12464E-01	-0.27942E-01
0.8208	0.46613	0.17370E-02	0.97220	0.66108E-02	-0.28415E-01
0.8250	0.48910	0.73923E-02	0.98266	0.26103E-01	-0.28863E-01
0.8292	0.51401	0.14089E-01	0.99271	0.45948E-01	-0.29284E-01
0.8333	0.54107	0.22040E-01	1.0023	0.66073E-01	-0.29676E-01
0.8375	0.57070	0.31282E-01	1.0114	0.85713E-01	-0.30038E-01
0.8417	0.60366	0.41504E-01	1.0197	0.10314	-0.30366E-01
0.8458	0.64036	0.53085E-01	1.0273	0.11873	-0.30659E-01
0.8500	0.68143	0.66322E-01	1.0342	0.13242	-0.30914E-01
0.8542	0.72763	0.81590E-01	1.0403	0.14412	-0.31129E-01
0.8583	0.77992	0.99379E-01	1.0457	0.15383	-0.31303E-01
0.8625	0.83949	0.12033	1.0503	0.16151	-0.31433E-01
0.8667	0.90784	0.14534	1.0543	0.16722	-0.31520E-01
0.8708	0.98693	0.17562	1.0575	0.17101	-0.31562E-01

PTI INTERACTIVE PLOTTING PROGRAM--PSSPLT FRI, DEC 11 1992 11:14

LOAD FLOW CASE FOR DYNAMIC STUDIES

FROM SOUTHERN COMPANY; KEOWEE ADDED; WHQ

CHANNEL	00027	00028	00021	00019	00023
TIME	MCR1KEOWEE	MCX1KEOWEE	ET 1KEOWEE	Q 1KEOWEE	SPD1KEOWEE
0.8750	1.0793	0.21289	1.0600	0.17296	-0.31559E-01
0.8792	1.1883	0.25965	1.0619	0.17316	-0.31511E-01
0.8833	1.3185	0.31967	1.0632	0.17177	-0.31417E-01
0.8875	1.4757	0.39915	1.0639	0.16914	-0.31279E-01
0.8917	1.6675	0.50856	1.0642	0.16581	-0.31096E-01
0.8958	1.9050	0.66426	1.0640	0.16166	-0.30871E-01
0.9000	2.2029	0.89592	1.0634	0.15676	-0.30603E-01
0.9042	2.5776	1.2597	1.0625	0.15118	-0.30294E-01
0.9083	3.0344	1.8681	1.0613	0.14499	-0.29946E-01
0.9125	3.5022	2.9513	1.0597	0.13825	-0.29559E-01
0.9167	3.5529	4.8948	1.0579	0.13102	-0.29135E-01
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

0.9250	-2.3423	[illegible].115	1.0535	0.11530	-0.28180E-01
0.9292	-4.4948	[illegible].0010	1.0511	0.10693	-0.27653E-01
0.9333	-4.4333	[illegible].8192	1.0485	0.98250E-01	-0.27095E-01
0.9375	-3.8563	[illegible].6383	1.0458	0.89310E-01	-0.26507E-01
0.9417	-3.3068	[illegible].5107	1.0431	0.80475E-01	-0.25890E-01
0.9458	-2.8673	0.35727	1.0403	0.71930E-01	-0.25247E-01
0.9500	-2.5257	0.44453	1.0376	0.63673E-01	-0.24578E-01
0.9542	-2.2584	0.30906	1.0349	0.55745E-01	-0.23885E-01
0.9583	-2.0461	0.21873	1.0323	0.48168E-01	-0.23169E-01
0.9625	-1.8746	0.15618	1.0298	0.40953E-01	-0.22431E-01
0.9667	-1.7340	0.11156	1.0273	0.34122E-01	-0.21673E-01
0.9708	-1.6171	0.78901E-01	1.0249	0.27665E-01	-0.20896E-01
0.9750	-1.5190	0.54494E-01	1.0227	0.21587E-01	-0.20101E-01
0.9792	-1.4356	0.35946E-01	1.0206	0.15885E-01	-0.19288E-01
0.9833	-1.3643	0.21614E-01	1.0186	0.10539E-01	-0.18460E-01
0.9875	-1.3030	0.10390E-01	1.0167	0.55345E-02	-0.17617E-01
0.9917	-1.2499	0.15044E-02	1.0150	0.86792E-03	-0.16760E-01
0.9958	-1.2038	-0.56327E-02	1.0134	-0.34929E-02	-0.15890E-01
1.0000	-1.1636	-0.11397E-01	1.0119	-0.75402E-02	-0.15008E-01
1.0042	-1.1287	-0.16125E-01	1.0106	-0.11310E-01	-0.14115E-01
1.0083	-1.0983	-0.20044E-01	1.0094	-0.14810E-01	-0.13212E-01
1.0125	-1.0719	-0.23321E-01	1.0084	-0.18049E-01	-0.12300E-01
1.0167	-1.0492	-0.26102E-01	1.0075	-0.21045E-01	-0.11380E-01
1.0208	-1.0297	-0.28484E-01	1.0067	-0.23804E-01	-0.10453E-01
1.0250	-1.0133	-0.30566E-01	1.0061	-0.26343E-01	-0.95192E-02
1.0292	-0.99961	-0.32417E-01	1.0056	-0.28677E-01	-0.85806E-02
1.0333	-0.98859	-0.34088E-01	1.0053	-0.30806E-01	-0.76378E-02
1.0375	-0.98005	-0.35637E-01	1.0051	-0.32750E-01	-0.66917E-02
1.0417	-0.97391	-0.37091E-01	1.0050	-0.34507E-01	-0.57434E-02
1.0458	-0.97011	-0.38515E-01	1.0050	-0.36112E-01	-0.47939E-02
1.0500	-0.96860	-0.39918E-01	1.0052	-0.37551E-01	-0.38442E-02
1.0542	-0.96937	-0.41349E-01	1.0054	-0.38851E-01	-0.28952E-02
1.0583	-0.97245	-0.42836E-01	1.0058	-0.40019E-01	-0.19481E-02
1.0625	-0.97787	-0.44421E-01	1.0063	-0.41075E-01	-0.10039E-02
1.0667	-0.98572	-0.46135E-01	1.0069	-0.42026E-01	-0.63690E-04
1.0708	-0.99607	-0.48028E-01	1.0075	-0.42897E-01	0.87155E-03
1.0750	-1.0091	-0.50153E-01	1.0083	-0.43705E-01	0.18007E-02
1.0792	-1.0249	-0.52568E-01	1.0091	-0.44469E-01	0.27227E-02
1.0833	-1.0438	-0.55341E-01	1.0100	-0.45207E-01	0.36366E-02
1.0875	-1.0660	-0.58562E-01	1.0109	-0.45943E-01	0.45411E-02
1.0917	-1.0918	-0.62333E-01	1.0119	-0.46696E-01	0.54353E-02

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CHANNEL	00027	00028	00021	00019	00023
TIME	MCR1KEOWEE	MCX1KEOWEE	ET 1KEOWEE	Q 1KEOWEE	SPD1KEOWEE
1.0958	-1.1216	-0.66800E-01	1.0129	-0.47498E-01	0.63181E-02
1.1000	-1.1559	-0.72108E-01	1.0139	-0.48356E-01	0.71884E-02
1.1042	-1.1953	-0.78491E-01	1.0149	-0.49307E-01	0.80453E-02
1.1083	-1.2404	-0.86235E-01	1.0160	-0.50377E-01	0.88877E-02
1.1125	-1.2922	-0.95684E-01	1.0170	-0.51577E-01	0.97146E-02
1.1167	-1.3517	-0.10734	1.0180	-0.52934E-01	0.10525E-01
1.1208	-1.4203	-0.12186	1.0190	-0.54477E-01	0.11318E-01
1.1250	-1.4998	-0.14013	1.0199	-0.56211E-01	0.12093E-01
1.1292	-1.5923	-0.16344	1.0208	-0.58164E-01	0.12849E-01
1.1333	-1.7006	-0.19357	1.0216	-0.60340E-01	0.13585E-01
1.1375	-1.8285	-0.23316	1.0223	-0.62752E-01	0.14300E-01
1.1417	-1.9810	-0.28621	1.0230	-0.65419E-01	0.14993E-01
1.1458	-2.1646	-0.35985	1.0236	-0.68332E-01	0.15665E-01
1.1500	-2.3984	-0.46100	1.0241	-0.71494E-01	0.16314E-01
1.1542	-2.6642	-0.60929	1.0245	-0.74909E-01	0.16939E-01
1.1583	-3.0077	-0.83285	1.0248	-0.78570E-01	0.17541E-01
1.1625	-3.4361	-1.1851	1.0249	-0.82455E-01	0.18119E-01

Form 1021

DUKE POWER COMPANY
TELEPHONE CONVERSATION REPORT

PROJECT Oconee Emergency Power System Analysis FILE NO. OSC-5096

SUBJECT Fault Clearing time for Keowee overhead line fault (F4).

PERSON CALLED Dave Garrison, System Planning & Operating 382-4641.

DATE 1/18/93 TIME

PERSON CALLING Chris Schaeffer

SPECIFICATION NUMBER

SUBJECT DISCUSSED Asked Dave if he could provide some insight into the method the program uses to analyze a fault and how instability is indicated. He sent me the Profs communication on page 2 of this attachment.

PERSON CALLED Dave Garrison, System Planning & Operating 382-4641.

DATE 1/20/93 TIME 12:30

PERSON CALLING Chris Schaeffer

SUBJECT DISCUSSED Fault on Keowee Overhead path on the 230KV side of the main stepup transformer. The study (A2) provided on the critical clearing time indicated that this fault should be cleared within 0.308 second to prevent instability. This analysis shows PCB-8 & 9 tripping in 60 msec, and ACB 1 & 2 tripping in 330msec. Dave agreed that the fault clearing time is not meaningful for a Unit where no other connection to the grid exists. The program assumed the fault was cleared by protective action occurring which separates the fault from the line, while the generator in question remains connected to the grid. I requested that he Profs me a written concurrence to be included in the calculation, and he sent the communication on page 3 of this attachment.

SIGNED Chris Schaeffer

OSC-5096
ATTACHMENT 7
PAGE 2 of 3

From: DLG8650 --PRDC
To: CES7423 --PRDC

Date and time 01/20/93 12:22:48

David L. Garrison
System PLanning & Operating
ECII-0465/EC04N Phone: 382-4641 Fax: 382-7228
Subject: Stability Simulations

The software used for stability simulations is designed to provide a time domain accounting of interconnected generating system parameters. In the normal course of a study a disturbance would be applied to the system (such as a fault) and remain on the system until protective devices act to remove the disturbance. System parameters would be recorded during the disturbance and for an additional period long enough to conclude whether the system returns to normal operation.

The parameters of primary interest for these stability studies are the rotor angles of generating units affected by the disturbance. A fault type disturbance causes the rotor angle of any affected unit to increase rapidly until the fault is removed. For stable operation, when the fault is removed, the rotor angle of the unit would decrease back to a normal value. Instability is indicated if the angle continues to increase. Protective devices are designed to disconnect units in a condition of instability.

The software is unable to continue to monitor units that become isolated from the interconnected system. Other software or analysis techniques must be employed to examine a unit once it is isolated.

OSC-5096
ATTACHMENT 7
PAGE 3 of 3

From: DLG8650 --PRDC
To: CES7423 --PRDC

Date and time 01/20/93 13:43:15

*** Reply to note of 01/20/93 12:37

David L. Garrison
System PLanning & Operating
ECII-0465/EC04N Phone: 382-4641 Fax: 382-7228

Subject: Stability Simulations

I concur for a situation such as this where the fault cannot be isolated without disconnecting the unit from the system that a clearing time determination is not meaningful.

LOGIC PRODUCTS
INDUSTRIAL CONTROL RELAYS
TYPE X — NEMA RELAYS
CLASS 8501

SQuare D "XUDOYO"

OSC-5096
PA ATTACHment 8
Page 1 of 89

APPLICATION DATA

AVERAGE OPERATING TIMES IN MILLISECONDS

[illegible]

Voltage Range: AC [illegible] DC operation [illegible] rated dc coils the range is [illegible] larger number and [illegible] number

OPERATING [illegible]

CONTACT RATINGS

Type of Cartridge	Volts	NEMA Rating	Inductive Make Amperes	Inductive Make VA	Inductive Break Amperes	Inductive Break VA	Continuous Amperes	Resistive [illegible] Amperes	Volts	NEMA Rating	Inductive [illegible]
Standard / Overlapping	120 / 240 / 480 / 600	A600	60 / 30 / 15 / 12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	125 / 250	P300	[illegible] / 0.55
									125	P150	[illegible]
Master*	—	A600	Same as standard cartridge above except substitute [illegible] ampere for the continuous ampere rating						125 / 250	P300	[illegible] / 0.55
Logic Reed	—	—	150 VAC 150VA 8W Maximum						—	—	[illegible] VDC 60MA

* Maximum of six 8501 Type XC-4 Master Cartridges may be used on any 7 and 8 pole ac device. Do not use any Master Cartridges on 9-12 pole ac or any dc-operated relays

CONTACT ARRANGEMENT

The following tables list all pole arrangements and the location of the N.O. and N.C. poles. Relays purchased from the factory will correspond to these tables. For example: an XO12 will have one N.O. pole in position 1; positions 2 and 3 will have N.C. poles; position 4 will be a space.

2, 3 and 4 Pole Relay All Contacts Convertible

No. of Poles	Type	1	2	3	4
2	XO20	S	O	O	S
	XO11	S	O	1	S
	XO02	S	1	1	S
3	XO30	O	O	O	S
	XO21	O	1	O	S
	XO12	O	1	1	S
	XO03	1	1	1	S
4	XO40	O	O	O	O
	XO31	O	1	O	O
	XO22	O	1	1	O
	XO13	O	1	1	1
	XO04	1	1	1	1

6 and 8 Pole Relay All Contacts Convertible

No. of Poles	Type	Pole Numbers 5 / 1	6 / 2	7 / 3	8 / 4
6	XO60	S	O	O	S
		O	O	O	O
	XO51	S	O	O	S
		O	1	O	O
	XO42	S	O	O	S
		O	1	1	O
	XO33	S	1	1	S
		O	1	O	O
	XO24	S	1	1	S
		O	1	1	O
	XO15	S	1	1	S
		O	1	1	1
	XO06	S	1	1	S
		1	1	1	1

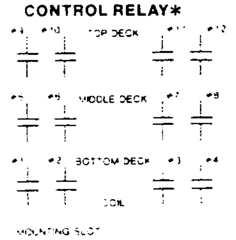
No. of Poles	Type	Pole Numbers 5 / 1	6 / 2	7 / 3	8 / 4
8	XO80	O	O	O	O
		O	O	O	O
	XO71	O	1	O	O
		O	O	O	O
	XO62	O	1	1	O
		O	O	O	O
	XO53	O	1	O	O
		O	1	1	O
	XO44	O	1	1	O
		O	1	1	O
	XO35	O	1	1	1
		O	1	1	O
	XO26	O	1	1	O
		1	1	1	1
	XO17	O	1	1	1
		1	1	1	1
	XO08	1	1	1	1
		1	1	1	1

10 and 12 Pole Relay All Contacts Convertible

No. of Poles	Type	Pole Numbers 9 / 5 / 1	10 / 6 / 2	11 / 7 / 3	12 / 8 / 4
10	XO1000	S	O	O	S
		O	O	O	O
		O	O	O	O
	XO0901	S	O	O	S
		O	1	O	O
		O	O	O	O
	XO0802	S	O	O	S
		O	1	1	O
		O	O	O	O
	XO0703	S	O	O	S
		O	1	1	O
		O	1	O	O
	XO0604	S	O	O	S
		O	1	1	O
		O	1	1	O
	XO0505	S	O	O	S
		O	1	1	1
		O	1	1	O
	XO0406	S	1	1	S
		O	1	1	O
		O	1	1	O
	XO0307	S	1	1	S
		O	1	1	1
		O	1	1	O
	XO0208	S	1	1	S
		O	1	1	O
		1	1	1	1
	8 N.C. Poles Maximum				

No. of Poles	Type	Pole Numbers 9 / 5 / 1	10 / 6 / 2	11 / 7 / 3	12 / 8 / 4
12	XO1200	O	O	O	O
		O	O	O	O
		O	O	O	O
	XO1101	O	1	O	O
		O	O	O	O
		O	O	O	O
	XO1002	O	1	1	O
		O	O	O	O
		O	O	O	O
	XO0903	O	1	1	O
		O	1	O	O
		O	O	O	O
	XO0804	O	1	1	O
		O	1	1	O
		O	O	O	O
	XO0705	O	1	1	O
		O	1	1	O
		O	1	O	O
	XO0606	O	1	1	O
		O	1	1	O
		O	1	1	O
	XO0507	O	1	1	O
		O	1	1	O
		O	1	1	1
	XO0408	O	1	1	O
		O	1	1	O
		1	1	1	1
	8 N.C. Poles Maximum				

CONTROL RELAY*

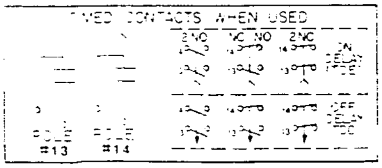


* For latch relay use same diagram as above except for the addition of an unlatch coil (8 poles maximum).

XTD & XTE Timer Attachments All Contacts Convertible

No. of Timed Contacts	Type	Pole Numbers 13	14
2	XTD XTE	O	1

O — Normally Open Contact
1 — Normally Closed Contact
S — Space for Future Contact



NORMALLY CLOSED CONTACTS

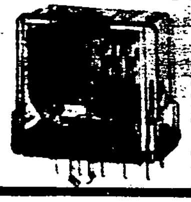
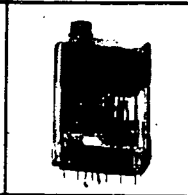
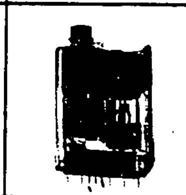
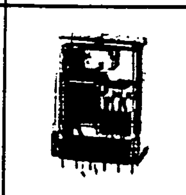
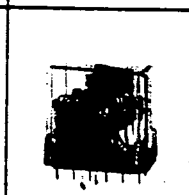
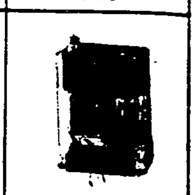
Contact co[illegible]on is so simple that it is generally more economical to purchase r[illegible] with all contacts N.O. and convert contacts to N.C. as required. I[illegible] preferred that relays be factory assembled with a combinatio[illegible] N.O. and N.C. contacts, change the type number so that follow[illegible]e "XO", the first number indicates the number of normally o[illegible]ontacts and the second number indicates the number of normally [illegible]ed contacts. Also, add **$12.00** to the price shown in the tables [illegible]ges 12-3 and 12-4 for a relay having the same total number of [illegible]cts. Example: a relay with 1 N.O. and 2 N.C. poles would be id[illegible]ed as a Type XO12 and priced at **$96.00**.

CP1		DISCOUNT SCHEDULE

We Respond.™

12

INDUSTRIAL PLUG IN, 5-10 AMP, 2-6 POLE

SERIES	219	T219	246	247	B255	A311	349
							
	12 PIN: 2.625" x 1.469" x 3.406" 14 PIN: 3.063" x 1.469" x 3.406"	2.625" x 1.469" x 5.250"	2.625" x 1.469" x 5.250"	2.625" x 1.469" x 5.250"	2.625" x 1.469" x 4.563"	2.625" x 1.469" x 3.406"	2.625" x 1.469" x 4.875"
	• 10 Amp Multi-Pole—to 4 Form C or 6 Form A • Industrial Plug-in with Locking Clip • Encapsulated Coil • Polycarbonate Cover • Gold Diff. Sil. Cad. Oxide Contacts • Single Level Socket Wiring	• Time Delay Relay: Delay-On Interval Flasher • Adjustable Timing: 0.1 sec to 36 Hrs. • C/MOS Circuitry • AC/DC Input—Not Polarity Sensitive • Repeatability: AC ±0.5%; DC ±0.2% • No False Contacting • Recycle Time: 60 ms • Single Level Socket Wiring	• Delay-On-Operate ISO Timer • Adjustable Timing: 0.1 to 300 sec • Repeatability: ±3% • No False Contacting • Polarity Protection • Recycle Time: 150 ms Max. • Transient Protection • Single Level Socket Wiring	• Delay-On-Release ISO Timer • Adjustable Timing: 0.1 to 300 sec • Repeatability ±3% • Recycle Time: 150 ms Max. • Transient Protection • Single Level Socket Wiring • No False Contacting	• 2 Coil Mechanical Latch • Single Level Socket Wiring • Continuous Duty Coils • Both Coils May Be Energized Simultaneously—No Damage	• Sequence (Stepping) Relay • Single Coil • Contact Transfer on Energizing/De-energizing Stroke of Relay • Single Level Socket Wiring • Continuous Duty Coil	• Over/Undervoltage Sensing Relay • Single Phase or Three Phase • Fixed or Adjustable Differential • Single Level Socket Wiring
	2 Form C to 4 Form C or up to 6 Form A-Form B Combinations	2 Form C to 2 Form A & 2 Form C	2 Form C to 2 Form A & 2 Form C	2 Form C; 3 Form C	2 Form C, 3 Form C or Up to Four Form A/B Combinations	2 Form C	2 Form C [illegible] & 2 [illegible] C
	Sil. Cad. Oxide—Gold Diffused	Sil. Cad. Oxide—Gold Diffused	Sil. Cad. Oxide—Gold Diffused	Sil. Cad. Oxide—Gold Diffused	Sil. Cad. Oxide—Gold Diffused	Sil. Cad. Oxide	Sil. Ca[illegible] Gold [illegible]
	Make 30A, Carry 10A, Break 10A	Make 30A, Carry 10A, Break 10A	Make 30A, Carry 10A, Break 10A	Make 30A, Carry 10A, Break 10A	Make 30A, Carry 10A, Break 10A	5A	Make 30A, Carry 10A, Break 10A
	Make 30A, Carry 10A, Break 5A	Make 30A, Carry 10A, Break 5A	Make 30A, Carry 10A, Break 5A	Make 30A, Carry 10A, Break 5A	Make 30A, Carry 10A, Break 5A	—	Make 30A, Carry 10A, Break 5A
	Make 30A, Carry 10A, Break 0.5A	Make 30A, Carry 10A, Break 0.5A	Make 30A, Carry 10A, Break 0.5A	Make 30A, Carry 10A, Break 0.5A	Make 30A, Carry 10A, Break 0.5A	0.1A	Make 30A, Carry 10A, Break 0.5A
	6 to 240	24 to 120	24 to 240	24 to 240	6 to 240	6 to 240	[illegible] to 120
	6 to 125 (250V with series resistor)	24 to 125	24 to 125	24 to 125	6 to 125 (250V with series resistor)	6 to 125 (250V with series resistor)	
	5	1.8W	5	5	5 OP 3 RESET	5	[illegible]
	1.8 (2.5W @ 125VDC)	1.8	1.8	1.8	1.8 OP 1.9 RESET	1.8	
	−10°C to +60°C	−20°C to +65°C	−10°C to +45°C AC −10°C to +70°C DC	−10°C to +45°C AC −10°C to +70°C DC	−10°C +60°C	−10°C to +60°C	−10°C to +60°C
	25 ms	As Selected	As Selected	20 ms	25 ms	35 ms	25 ms
	20 ms	20 ms	20 ms	As Selected	25 ms	35 ms	25 ms
	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	500,000	500,000	500,000	500,000	500,000	500,000	500,000
	10 million	20 million	10 million	10 million	10 million	5 million	20 million
	Indicator Lamp Manual Actuator Bifurcated Contacts Coil Suppression Perm. Mag. Blowout 130°C Coil Nuclear Qualified	Indicator Lamp Manual Actuator Bifurcated Contacts Perm. Mag. Blowout Fixed Timing	Indicator Lamp Manual Actuator Bifurcated Contacts Magnetic Blowout Fixed Timing Remote Adjust.	Indicator Lamp Manual Actuator Bifurcated Contacts Magnetic Blowout Fixed Timing Remote Adjust.	Indicator Lamp Manual Actuator Bifurcated Contacts Magnetic Blowout Coil Suppression Time Delay on Reset Coil	Indicator Lamp Coil Suppression Non-Standard Sequences	Indicator Lamp Bifurcated Contacts Magnetic Blowout
	UL, CSA	—	UL, CSA	UL	UL, CSA	UL	[illegible]

MSD, Inc., 700 Orange St., Darlington, SC 29532-9986; (803) 393-5421; FAX: (803) 393-4123; TELEX: 810-[illegible]

ESCRIPTION (Continued)

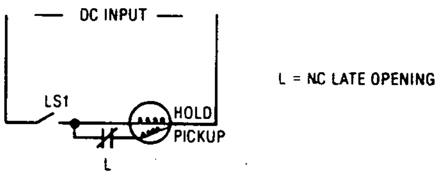
Ac Coils

Ac Coil Specifications						
Coil Power					Operating Time	
Relay	Watts		VA		Milliseconds	
	Inrush	Sealed	Inrush	Sealed		
2-12 Pole	95.0	9.	155.	22.	Pick-up	6-13
Latch Coil	18.5	11.	41.	17.	Drop-out	8-26

Ac Relay Coil Identification	
Volts/Hertz	Coil Pt. No.
120/60 - 110/50	9-1989-1
240/60 - 220/50	9-1989-2
480/60 - 440/50	9-1989-3
600/60 - 550/50	9-1989-4
208/60	9-1989-9
277/60	9-1989-10
380/50	9-1989-15
6/60	9-1989-5
12/60	9-1989-6
24/60	9-1989-7
32/60	9-1989-8

Dc Coils

When dc voltage is applied to the relay coil, both the pickup and hold windings are energized and the relay operates. As the armature moves to the sealed position, a late opening NC coil clearing contact (marked L) removes the voltage from the pickup winding. The armature is then held in the operated position until voltage is removed from the hold winding. This design does not require the use of external resistors.



DC TYPE M RELAY

Dc Relay Coil Specifications				
Coil Power			Operating Time	
Relay	Watts		Average Milliseconds	
	Inrush	Sealed		
2-11 Poles	168	13.2	Pick-up	10
Latch Coil	21.6 Intermittent		Drop-out	16

Dc Coil Identification	
Dc Volts	Coil Pt. No.
12	9-2404-5
24	9-2404-4
48	9-2404-3
120	9-2404-1
240	9-2404-2

Base

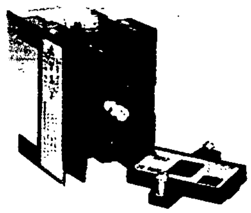
The base is an aluminum die casting. It houses the magnet assembly and mounts the decks. It provides a metal to metal mounting arrangement, eliminating the poor feel of mounting molded feet to a metal panel.

The casting provides guiding for the magnet carrier which actuates the contact push bar.

Rear Decks (D26MB)

The rear deck, which houses the I member of the magnet, is considered a part of the basic magnet assembly. It attaches to the base with four screws, making a complete operating unit.

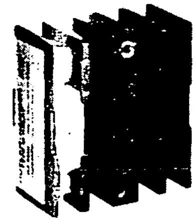
The rear deck has four slots for mounting four contact poles: either NC, NO or combinations of both. The contact poles are ordered separately. The poles are operated by the push bar actuator built into the rear deck. The poles are held in place by either a cover plate if the relay is to be a four pole relay or a front deck if the relay has more than 4 poles.



Projecting through and out the front of the deck is a pull rod indicator. Its function is to indicate relay energization and to permit manual operation. When the relay is energized, the rod extends out about a 1/4" exposing a band of red color on the rod. The nylon end is ribbed to permit manual operation of the pull rod.

Front Decks (D26MD10)

The front deck mounts up to four additional poles on the relay. It is constructed much like the rear deck, except that it is approximately 3/4" shorter in height.



The front deck has an insulator, within it for each pole. This insulator serves as electrical clearance between the rear pole and the front pole. It is held captive in the deck and need not be put in or taken out in the field.

A front deck can be added to any rear deck 4 pole relay in the field. The only requirement is that there is a rear pole for every front pole added. To mount the rear deck, remove the cover plate. Remove the short nylon pull rod

See note on installation and use of product at bottom of page 1.

Type MG-6, Type AR, and Type TD-5

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September [illegible]

[illegible]
[illegible] - [illegible]
[illegible] - [illegible]

The following tests were [illegible]

RELAY	TIME @ [illegible]	[illegible]	[illegible]	TIME @ [illegible]
MG-6 139B[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AR 606B0[illegible]A09	1.8ms	[illegible]	[illegible]Vdc	7.[illegible]ms ([illegible]V)
TD-5 293B301A16A	[illegible] 1.30s [illegible]	[illegible]Vdc [illegible] [illegible] [illegible]	20Vdc	1.55s(56V) 1.[illegible]s [illegible].62s

If these figures need any explanation call me at 373-6505.

Paul R. Drum
Transmission
RM&I

OSC-5096
ATTACHMENT 8
PAGE 5 of 89

GE TYPE HEA TIME VS DC VOLT CURVE

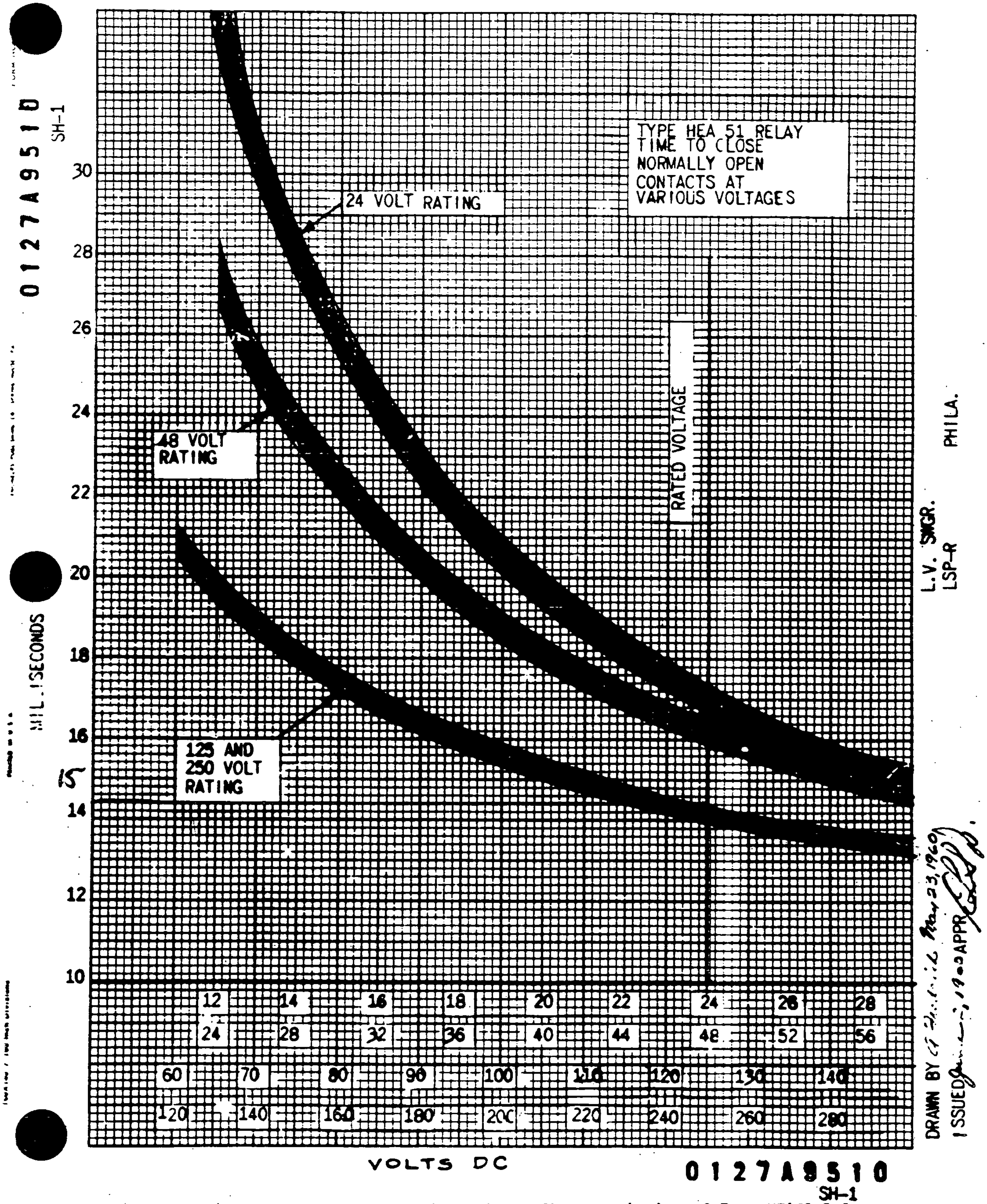

Fig. 4 (0127A9510-0) Typical Time-voltage Characteristics of Type HEA61 Relay

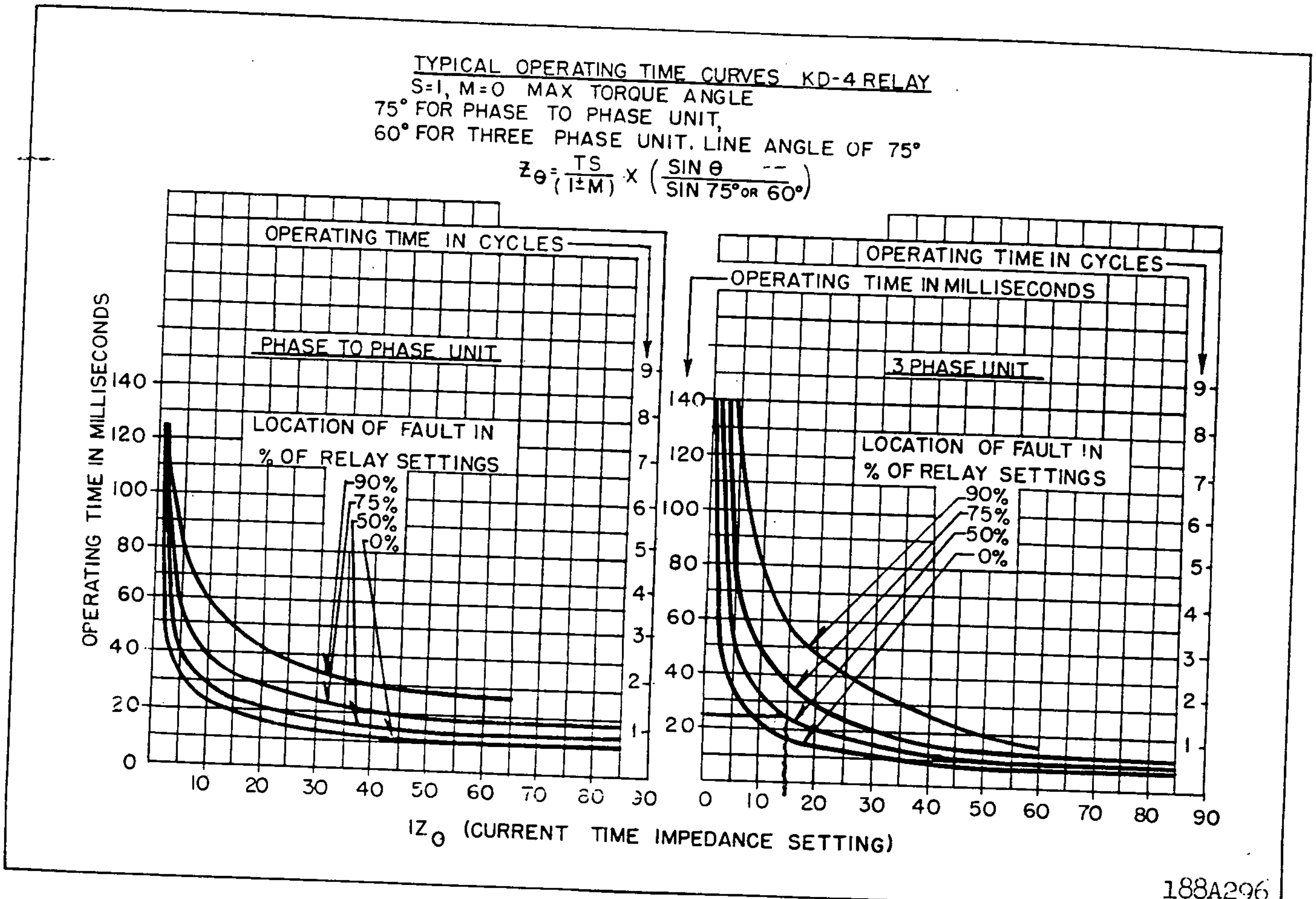

Fig. 10 Typical Operating Time curves of Type KD-4 Relay. Normal voltage before the faults is 120 volts.

directional sense for zero voltage phase-to-phase faults. For this condition the fault current must be not less than 0.030 relay amperes with an ohm setting of 1.23 with rated voltage on the unfaulted phase. Pick up current is proportionally higher in S = 2 and S = 3 taps.

The KD-4 relay may be set without regard to possible overreach due to d-c transients. Compensators basically are insensitive to d-c transients which attend faults on high-angle systems. The long time-constant of a high-angle system provides a minimum rate of change in flux-producing transient current with respect to time, and therefore induces a minimum of uni-directional voltage in the secondary. Asymetrical currents resulting from faults on low-angle systems having a short time constant can induce considerable voltage in the secondary, but for the first half cycle, the transient-derived voltage subtracts from the steady-state value. This transient decays so rapidly that it is insignificant during the second half cycle when it adds to the steady-state value.

Distance Characteristic - 3 Phase Unit

The three-phase unit has a characteristic circle which passes through the origin as shown in Figure 9. This circle is independent of source impedance. The three-phase unit is also inherently directional and does not require a separate directional unit.

If a solid-three phase fault occurs right at the relay location, the entire voltage triangle collapses to zero to give a balance point condition, as shown by the relay characteristic in Figure 9 which passes through the origin. However, since the YZ voltage also drops to zero, the relay would be unable to determine whether an internal or external fault existed. To correct this condition, a resonant circuit is added to the 23 voltage circuit of the relay which allows the YZ voltage to collapse gradually, thus giving a reference voltage to determine whether the fault is inside the protected line section or behind the relay.

The maximum torque angle of this unit is set for less than the line impedance angle of the phase-

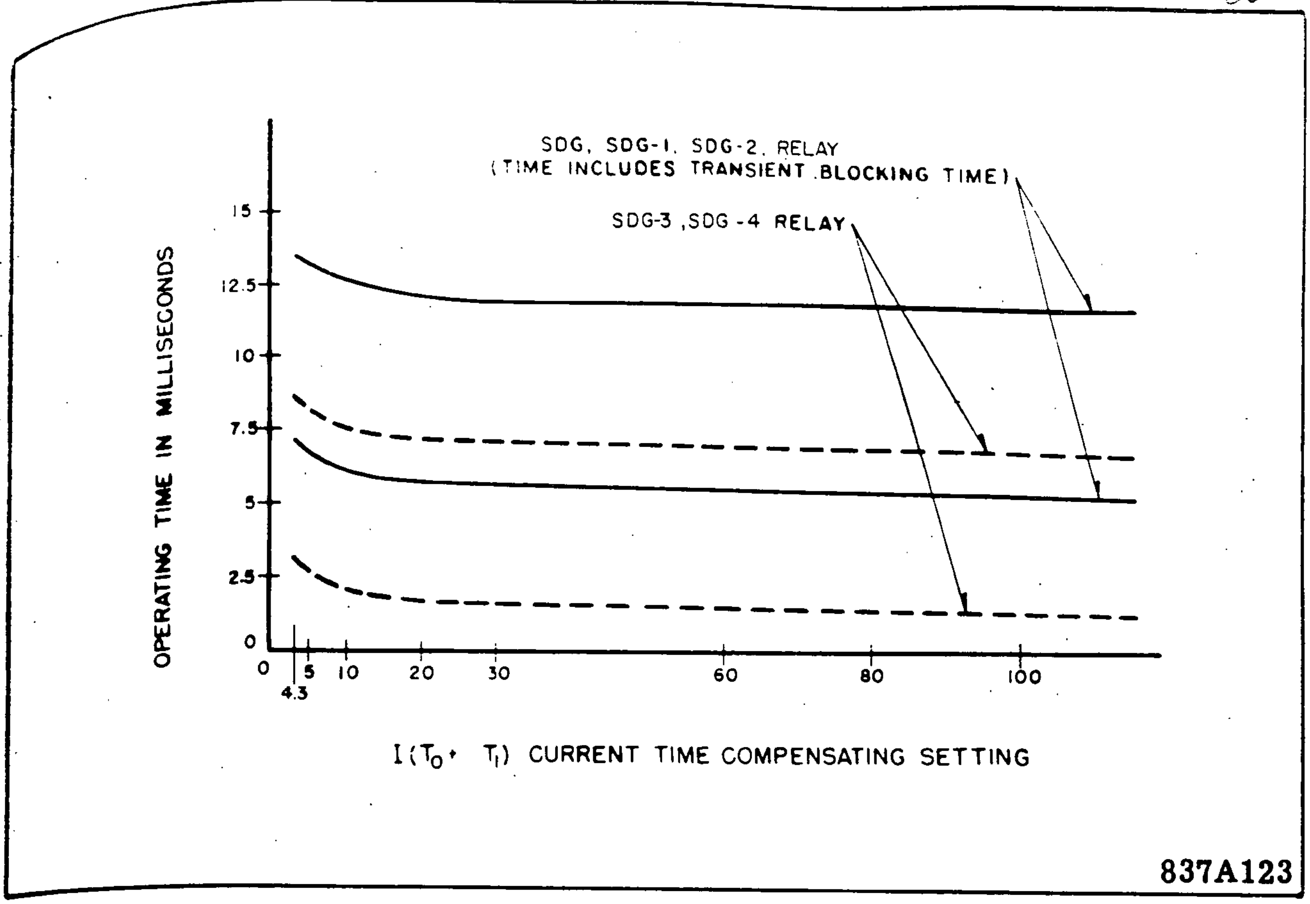

Fig. 21 Typical Operating Time Curves of the Type SDG-Line Relay.

TYPICAL OPERATING TIMES OF THE PVD21 RELAY 87L UNIT

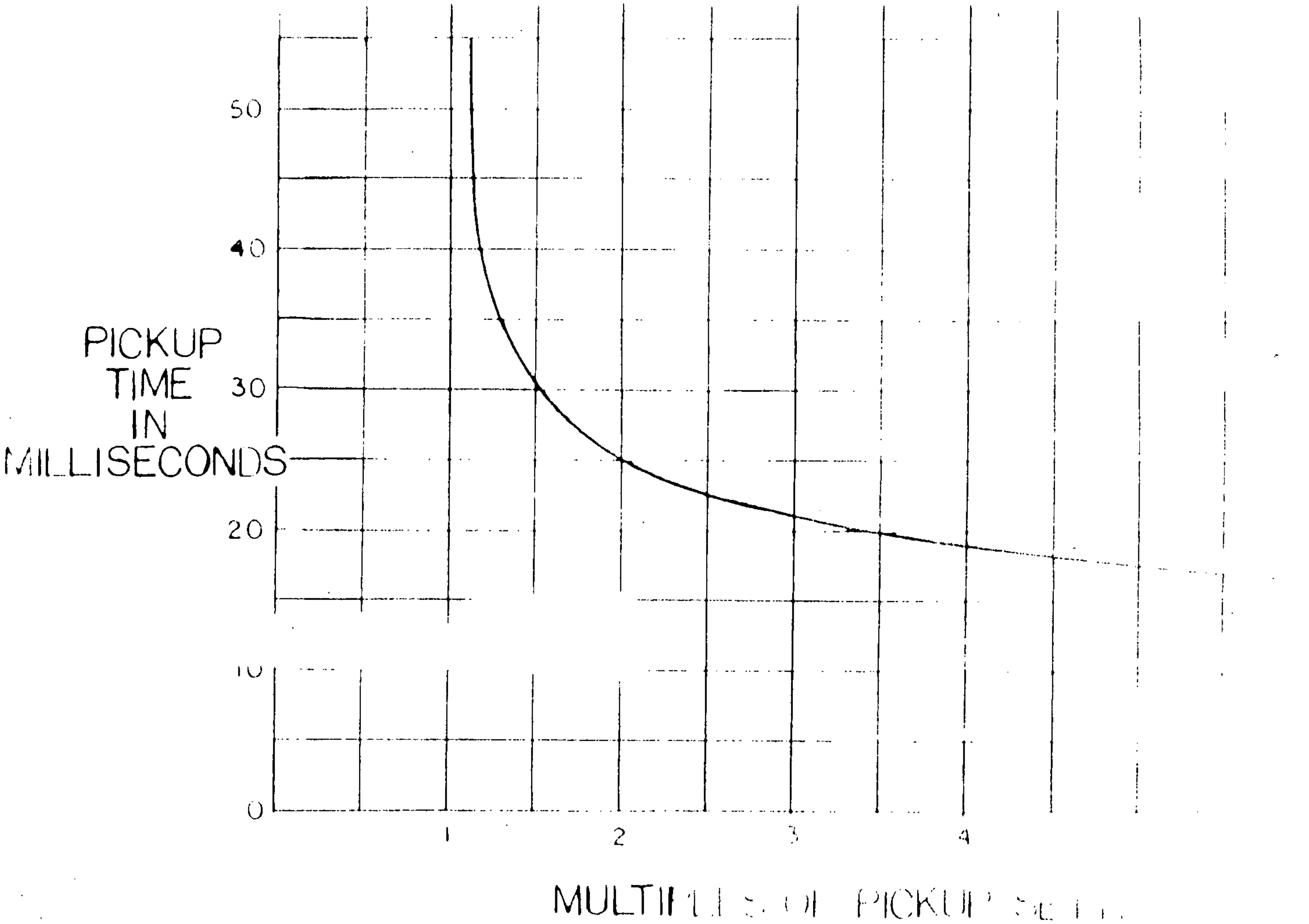

Figure 15 (0269A1798-1) Typical Operating T... s for the Type PVD21 Relay, 87L Unit

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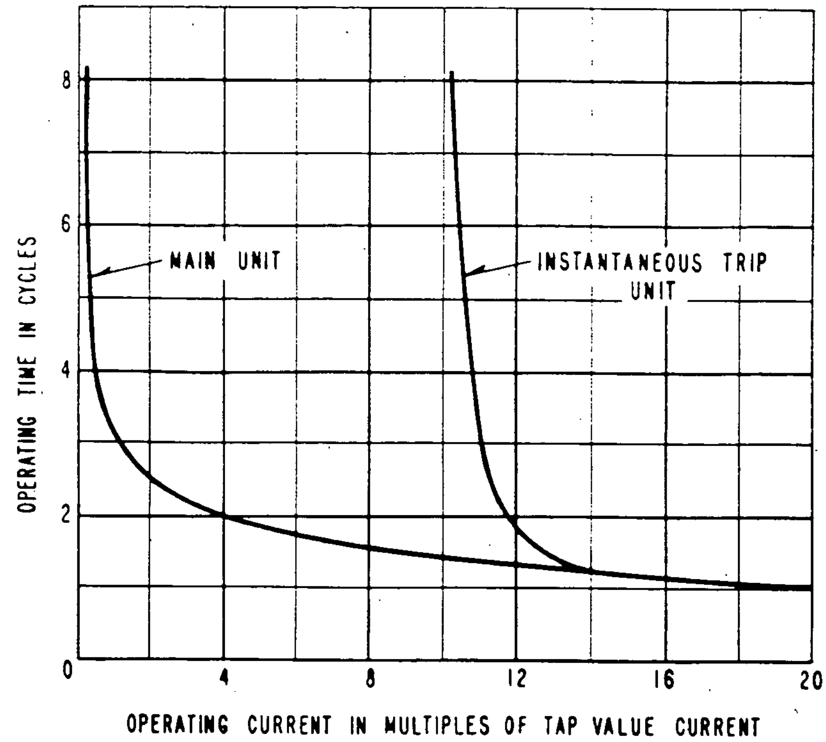
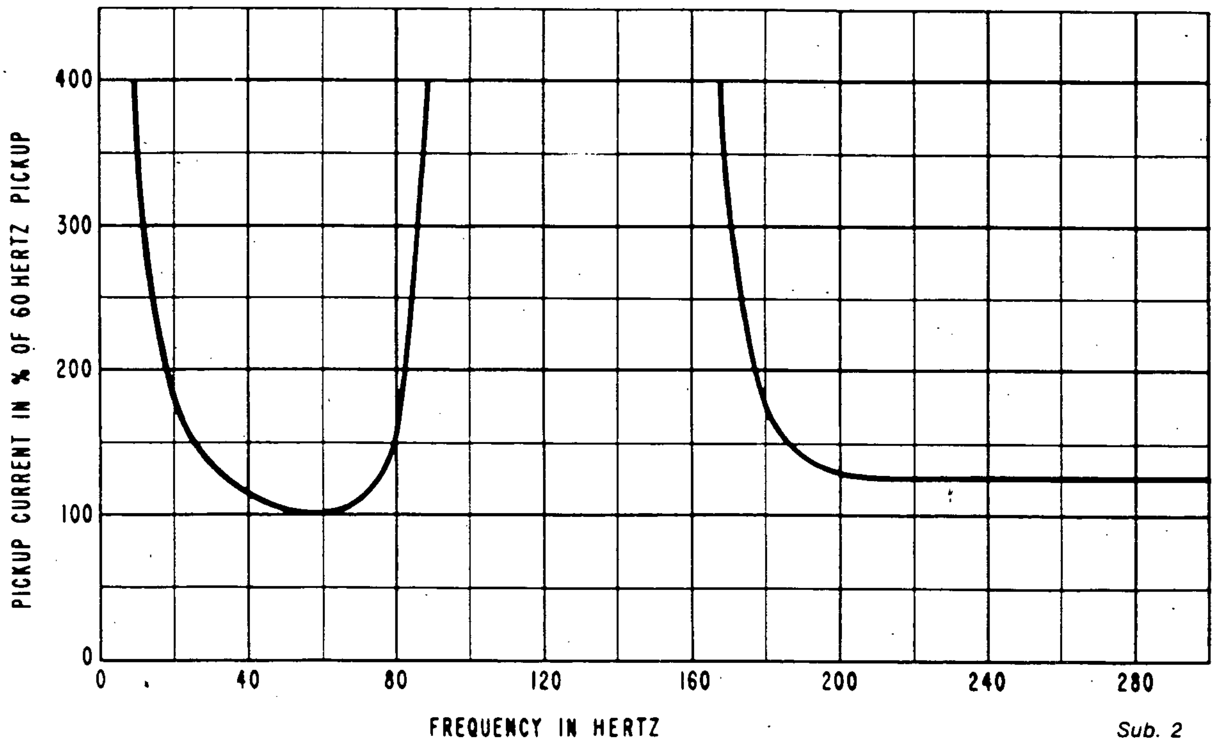


Curve 538029

Fig. 19. Typical Tripping Time Characteristic



Sub. 2
Curve 471052

Fig. 20. Typical Frequency Response of the HU and HU-1 Relays (60 Hertz).