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INTERIM REPORT
FAILURE MODES AND EFFECTS ANALYSIS
OF THE ICS/NNI ELECTRIC POWER
DISTRIBUTION CIRCUITRY

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1.0 INTRODUCTION

The interruption of electric power to nuclear power plant control systems has been recognized as an initiator of potentially severe plant transients. Among recorded plant transients resulting from this failure type, the Rancho Seco "dropped light bulb incident" was an example of a severe transient resulting from a control system power failure.

As part of an evaluation of control system failures and their potential impacts on nuclear plant safety, a failure modes and effects analysis (FMEA) of the electric power branch circuits of a nuclear power plant control system is being performed. The design of the Oconee Unit 1 Integrated Control System (ICS)/Non-Nuclear Instrumentation (NNI) and associated electric power circuitry was selected for analysis.

This interim report describes the results of the analysis obtained to date; the effects of electric power interruptions on the automatic control outputs of the ICS/NNI. A brief description of the ICS/NNI and its electric power distribution circuitry is given in Sections 2 and 3. The interim results of the power supply FMEA are presented and briefly discussed in Section 4 and the preliminary conclusions obtained from these results are summarized in Section 5.

The interim results discussed in this report are useful to demonstrate the FMEA methodology and to assess the initial response of the automatic control circuits to electric power interruptions. However, the results obtained to date do not include the effects of electric power interruptions on plant parameter indicator and alarm circuits, or the operator response to this potentially misleading information. This aspect of the FMEA will be covered in the final analysis report.

2.0 ICS/NNI FUNCTIONAL DESCRIPTION

The ICS/NNI is a series of fourteen electrical equipment cabinets containing the sensor and control circuits required for the controlled operation of the Oconee nuclear steam supply system (the reactor, steam generators and associated supporting systems). The ICS portion of the system provides the integrated control of the feedwater flowrate to the system generators, the reactor core power, the reactor coolant temperature and the pressure of the steam generated in the steam generators and supplied to the plant's high pressure turbine. The NNI portion provides sensor input signals to the ICS, reactor coolant system (RCS) inventory and pressure control and control of selected auxiliary systems' functions. In addition, the NNI provides plant parameter information to the plant operating staff through control room indicators, alarms and the plant computer. More detailed descriptions of the functions performed by the ICS/NNI may be found in the Oconee Final Safety Analysis Report.

The automatic control outputs of the NNI (Auxiliary Control Outputs) are listed in Table 1. Table 2 lists the process parameter signals transmitted from the NNI to the ICS. The control output signals developed in the ICS are listed in Table 3.

The principal source of design information on the ICS/NNI being used in this analysis is the Oconee ICS Instruction Book.[1] This document shows the detailed ICS/NNI circuits

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[1]Oconee 1 ICS - Instruction Book, Bailey Meter Co., 3/15/77 (latest Revision).

TABLE 1
SUMMARY OF NNI AUXILIARY CONTROL OUTPUTS

1. Lo-Lo pressurizer level interlock for heater Banks 1, 2, 3, and 4 (auto).
2. High and low pressure control contacts for the PORV (Relief Valve RC-V3) (auto).
3. High and low pressure control contacts for Heater Banks 2, 3, 4 (auto and manual).
4. Analog signal to SCR controller for heater Bank 1 (auto and manual).
5. High and low pressure control contacts for Pressurizer Spray (block) valve (auto and manual).
6. Open and close control contacts for pressurizer spray stop valve (manual).
7. Interlock contacts to prevent RC pump start on low RC temperature (auto).
8. Control contact on low letdown storage tank level - Function unknown, Drawing 8032326 missing (auto).
9. Control contact to switch 3-way valve EP-V10 to divert letdown reactor coolant to the letdown storage tank on low letdown storage tank level (B&W elementary drawing 136129E missing) (auto).
10. Interlock contact to prevent RC pump start on low seal inlet header flow (auto).
11. Analog signal to control makeup flow (auto and manual).
12. Analog signal to control pump seal inlet header flow (auto and manual).
13. Interlock contacts to prevent individual RC pump start on low seal pressure drop (auto).
14. Analog signal to control letdown flow (manual).

TABLE 2
ICS SIGNAL INPUTS FROM NNI

	Indicated Range	Voltage Range	Parameter Range
Temp. Compensated RC Flow	0 - 100%	0 - 10 V	0 - 100%
Unit Frequency	57 - 63 Hz	± 50 MV	57 - 63 Hz
MWe	0 - 999 MW	0 - 100 MV	0 - 874 MW
Turbine Header Press	600 - 1200 psia	4 - 20 MA	0 - 900 psia
Steam Gen. Press A	0 - 1200 psia	± 10 V	0 - 925 psia
Steam Gen. Press B	0 - 1200 psia	± 10 V	0 - 925 psia
RC Tav	520 - 620°F	± 10 VDC	120 - 579°F
Neutron Power	0 - 100%	0 - 10 VDC	0 - 100%
Temp. Compensated FW Flow A	0 - 5.67 x 10^6 #/hr	± 10 VDC	0 - 5.3 x 10^6 #/hr
Temp. Compensated FW Flow B	0 - 5.67 x 10^6 #/hr	± 10 VDC	0 - 5.3 x 10^6 #/hr
Feedwater Temp.	0 - 470°F	± 10 VDC	0 - 455°F
T RCS Loops A&B T_{cold}	520 - 620°F	± 10 VDC	± 10°F
RC T_{hot} Wide Range	0 - 650°F	± 10 VDC	120 - 555°F
RC Flow A&B	0 - 70 x 10^6 #/hr	± 10 VDC	0 - 65.66 x 10^6 #/hr

TABLE 2 (Continued)

	Indicated Range	Voltage Range	Parameter Range
SG A&B OP Level	0 - 400"	± 10 VDC	0 - 378"
SG A&B SU Level	0 - 400"	± 10 VDC	0 - 378"
FW Valve A&B Pressure Drop	0 - 100 psi	± 10 VDC	0 - 35 psi

TABLE 3
SUMMARY LIST OF ICS CONTROL OUTPUTS

1. Control contact to open and close turbine control valves (auto and manual).

2. Analog signal to open and close turbine bypass valves (auto and manual).

3. Analog signals to open and close startup feedwater valves (auto and manual).

4. Analog signals to open and close main feedwater valves (auto and manual).

5. Analog signals to control main feedwater pump speed (auto and manual).

6. Control contacts to insert and withdraw control rods (auto and manual).

and their sources of electric power. In addition to the instruction book, recent information supplied to ORNL by Duke Power is being used to modify the ICS/NNI circuitry.[2]

The major modifications not shown in the instruction book are summarized below:

1. The use of the Panelboard KU (Computer Power) to power the RC Pump seal injection automatic control circuit upon loss of Panelboard KI.
2. The use of Panelboard KU to power manual control circuits for makeup and letdown flow, the turbine bypass valves and pressurizer heater bank 2 from the control room or auxiliary shutdown panel.
3. The addition of manual control switches for the PORV and pressurizer spray valve in ICS Cabinet 13 powered independently of Panelboard KI.
4. The use of ICS steam generator level signals to trip the main feedwater pumps on high level.

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[2]The principal sources have been a letter from R. L. Gill (Duke) to R. C. Kryter (ORNL), 10/19/82 and Oconee Emergency Procedure EP/O/A/800/3, Loss of KI Bus (ICS Power), 1/21/81.

3.0 ICS/NNI ELECTRIC POWER DISTRIBUTION CIRCUITRY

The ICS/NNI is powered from 118 VAC Panelboard KI with transfer of selected circuits for Panelboard KU upon loss of KI. Panelboards KI and KU each are powered through inverters from 125 VDC buses DCA and DCB. In addition, these panelboards may be powered from 118 VAC regulated instrument bus KRA by automatic transfer.[3]

From Panelboard KI, power is distributed to the ICS/NNI through five separate branch circuits capable of being isolated by circuit breakers: KI-1, KI-3, KI-5, KI-9 and KI-22. The Hand Power, HX (KI-1), and Auto Power, H (KI-22), branches are distributed within the ICS/NNI cabinets through an additional three and eight circuit breakers, respectively.[4] The individual branch circuits feeding the ICS/NNI are listed in Table 4.

The circuits listed in Table 4 are being considered separate failure points in the FMEA of the ICS/NNI power distribution circuitry. It is assumed that an arbitrary fault in the circuitry will be isolated by a circuit breaker deenergizing all circuits fed through that breaker. Thus, a fault in the circuits fed by branch H1 may be isolated by the circuit breaker in H1 or the circuit breaker in the Auto Power branch, KI-22, or result in the entire KI Panelboard being isolated from its power sources. The power circuits listed

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[3]Oconee One Line Diagrams 0-705 and 0-705-A, 120 VAC and 125 VDC Station Auxiliary Circuits and 120/240 VAC Station Auxiliary Circuits.

[4]Oconee 1 ICS Instruction Book.

TABLE 4
ICS/NNI ELECTRIC POWER DISTRIBUTION CIRCUITS
(118 VAC, 60 HZ, 1 0)

1. ICS POWER PANELBOARD KI

   1.1 HAND POWER, BRANCH HX (KI-1)

      1.1.1 BRANCH H1X (HX to Aux. Shutdown Panel), 10 amp.

      1.1.2 BRANCH H2X, 2 amp.

      1.1.3 BRANCH H3X, 2 amp.

   1.2 EMERGENCY POWER #1, BRANCH HEX (KI-3)

   1.3 EMERGENCY POWER #2, BRANCH HEY (KI-5)

   1.4 EMERGENCY STEAM GENERATOR LEVEL CONTROL, BRANCH H-EL (KI-9)

   1.5 AUTO POWER, BRANCH H (KI-22)

      1.5.1 BRANCH H1, 30 amp.

      1.5.2 BRANCH H2, 2 amp.

      1.5.3 BRANCH H3, 2 amp.

      1.5.4 BRANCH H4, 2 amp.

      1.5.5 BRANCH H5, 2 amp.

      1.5.6 BRANCH H6, 2 amp.

      1.5.7 BRANCH H7

      1.5.8 BRANCH H8

2. COMPUTER POWER PANELBOARD KU

in Table 4 represent 18 separate electric power failures to be considered in the FMEA. For purposes of this interim report, however, only those power circuits feeding automatic control circuits are considered.

4.0 EFFECT OF ELECTRIC POWER BRANCH CIRCUIT FAILURES ON ICS/NNI AUTOMATIC CONTROL CIRCUITS

A FMEA of the automatic ICS/NNI control circuits' responses to failures of the electric power branch circuits listed in Table 4 has been performed. This analysis was performed by:

1. Listing all ICS/NNI sensor-to-output device circuits and identifying the branch circuit supplying power to each module in each circuit. (This step was performed as part of the overall ICS/NNI electric power distribution circuitry FMEA.)
2. Selecting those circuits with an automatic control output. (Computer input, alarm and indicator circuits will be considered in the overall FMEA.)
3. Selecting, for each applicable power distribution failure listed in Table 4, the control circuits affected by the failure.
4. Determining the response of the controlled component to the deenergized circuits (other control circuits and their controlled components are assumed to operate as designed).

The control circuit responses to the ICS/NNI power failures are discussed below.

4.1 FAILURE OF BRANCH H1

The control circuit output responses to failure of branch H1 are listed in Tables 5 and 6 for the NNI and ICS respectively. As shown, many control circuits switch to manual with the controlled devices remaining "as is." The response of the plant to this failure would be initially minor. The plant could continue to operate under manual control by the operators.

As shown in Table 6, if the pressurizer spray valve were open or the pressurizer heaters energized at the time of power failure, they could produce a transient leading to reactor trip unless controlled by the operator. In the event of reactor trip due to this or other causes, the operator must manually throttle main feedwater or the steam generators will be overfed. Failure of the operator to throttle would result in the main feedwater pumps being tripped automatically on high steam generator level. In this event the emergency feedwater system would be automatically started and controlled.

4.2 FAILURE OF BRANCH H2

The only control failure resulting from a failure of branch H2 is the spurious interlock of the RC pump starting circuitry as shown in Table 7. This would not affect power operation.

4.3 FAILURE OF AUTO POWER: BRANCH H (KI-22)

Failure of Branch H would deenergize both the H1 and H2 branch circuits. The response would be identical to that described for the H1 failure (see Section 4.1).

4.4 FAILURE OF BRANCH H1X

The responses of the ICS and NNI controls to an H1X failure are listed in Tables 8 and 9. The spurious throttling signal to the turbine, the potential for inserting or withdrawing control rods, and the potential for reducing main feedwater pump speed combined with the inability to throttle main feedwater flow probably would result in a reactor trip. The main feedwater flow to the steam

TABLE 5
ICS CONTROL RESPONSE:
H1 POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Turbine Throttle	As is	Cannot be increased or decreased by ICS. Manual controls operable.
2.	Turbine Bypass Valves	Manual control at ICS is lost	Control automatically on steam generator pressure; Manual control at Aux. shutdown panel operable.
3.	Reactor Power	As is	Can not be increased or decreased by ICS. Manual control of control rods operable.
4.	Main Feedwater Pump Speed	Switches to manual at operating value	Manual control operable.
5.	Main Feedwater Valve Position	Switches to manual at operating value	Manual control operable.
6.	Startup Feedwater Valve Position	Switches to manual at operating value	Manual control operable.

Note: Failure of control output or transfer to manual prevents spurious response to any failed input signals.

TABLE 6
NNI AUXILIARY CONTROLS
H1 POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Pressurizer Lo-Lo Interlock	Will not cut-off Heaters on Lo-Lo pressurizer level	Relays 183/PLL and 183-1/PLL Lose power (Dwg. D8032338G).
2.	Pressurizer Spray (Block) Valve RC-V1	Automatic control lost. Valve will remain closed or open depending on its position at time of power failure.	Manual control using H1X operable (Dwg. D8032338G).
3.	Pressurizer Heater Banks 2, 3, 4	Heater banks remain energized or deenergized depending on state at time of power failure.	Manual control operable.
4.	SCR Controlled Heater Bank #1	Heater bank may be energized due to low RCS pressure signal input to SCR controller.	Manual control operable. 0 volt input signal should be compared to heater bank setpoint.
5.	Relief Valve RC-RV3	Valve will close or remain closed.	Per Dwg. 8032332E. Actual control relay not found. Manual control operable.

TABLE 6 (Continued)

Item	Function	Failure Mode	Comments
6.	Makeup Flow Demand to Makeup Flow Control Valve	Probable transfer to manual. Valve remains in position existing prior to power failure.	Power to Relay 83/LT not shown on Dwg. 8032338G
7.	Reactor Coolant Pump Start Interlock	Permits RC pump start at low RC temp.	

TABLE 7
NNI AUXILIARY CONTROLS
H2 POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Reactor Coolant Pump Interlock - Low Seal Flow	Cannot start pumps due to indicated low seal flow.	

TABLE 8
ICS CONTROL RESPONSE:
H1X POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Turbine Throttle Valve	Valve closes due to apparent loss of turbine header pressure if sensor with H1X power is selected	
2.	Turbine Bypass Valves	Valves "freeze" as is	Loss of power to E/P converter
3.	Reactor Power	Increase, hold or decrease	Depends on temperature sensors selected and resulting increase, decrease, or constant value of Tav
4.	Main Feedwater Pump Speed	Probable decrease	Speed demand goes to 0 volt value
5.	Main Feedwater Valve Position	Valves "freeze" as is	Loss of power to E/P
6.	Startup Feedwater Valve Position	Opens or closes in automatic depends on input sensors selected. 1/2 open when ICS hand control is put on manual	Manual control at Aux. shutdown panel operable.

Note: Probable initial undercooling and/or overcooling transient due to control rod response to temperature signal failures. Main feedwater supply continues until terminated by other means.

TABLE 9
NNI AUXILIARY CONTROLS
H1X POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Pressurizer Spray Block Valve RC-V1	Valve remains in position existing prior to power failure.	Loss of power to 83/A and 83/M-O and 83/M-C prevent automatic or manual operation
2.	Pressurizer Heater Banks 2, 3, 4	Manual control lost	State indeterminant, Dwg. D8032341 missing, may be relevant
3.	SCR Controlled Pressurizer Heater Bank #1	Heater bank will be deenergized or remain deenergized.	Loss of drive signal
4.	Makeup Flow Control	Auto control remains operable. If manual control at ICS Hand Station selected valve will open or close to mid-position.	Manual control at Aux. shutdown panel or control room operable by manually transferring Hand Stations to KU power.
5.	Spray Line Isolation (Stop) Valve RC-V5	Valve opens.	Loss of power to 83-L/SSV.

generators would continue until the pumps were manually tripped by the operator or automatically tripped on high steam generator level. The trip of the feedwater pumps result in automatic initiation and control of the emergency feedwater system.

4.5 FAILURE OF BRANCH H2X

As shown in Table 10, the result of an H2X power failure is the loss of control of the makeup, letdown and seal injection flowrates.

The letdown flow is normally controlled through a block orifice with the bypass letdown valve closed. Since the makeup and seal injection valves remain in position, normal power operation would be expected to continue.

4.6 FAILURE OF HAND POWER: BRANCH HX (KI-1)

Failure of Branch HX would deenergize both the H1X and H2X circuits. The response of the plant would be similar to that described for the H1X failure (see Section 4.4).

4.7 FAILURE OF BRANCH HEX, HEY OR PANELBOARD KU

The makeup flowrate to the RCS can be terminated if the pressurizer level transmitter in the level control circuit is deenergized. There are three pressurizer level transmitters, LT-1, LT-2 and LT-3 powered, respectively, by circuits HEX, HEY and Panelboard KU. The control room operator selects one of the three level signals for input to the makeup control and low level pressurizer heater interlock circuits. If the selected transmitter is deenergized, the control circuitry will respond to the spurious high level signal by closing the makeup valve. In addition, the low level pressurizer heater interlock would be defeated.

TABLE 10
NNI AUXILIARY CONTROLS
B2X POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Makeup Flow Control	Valve fails as is	Loss of power to E/P converter. Power source for E/P transducer may be manually transferred to panelboard KU to allow manual control.
2.	Letdown Flow Control	Valve fails as is	Loss of power to E/P converter. Power source for E/P transducer may be manually transferred to panelboard KU to allow manual control.
3.	Pump Seal Inlet Header Flow	Valve fails as is	Loss of power to E/P converter. Power source for E/P tranducer may be manually transferred to panelboard KU to allow automatic or manual control.

In the event this power failure occurred, the operator would be able to manually control makeup flow or automatically control makeup flow by selecting an alternate, operable transmitter as shown in Tables 11, 12 and 13.

4.8 FAILURE OF THE RCS NARROW RANGE PRESSURE TRANSMITTER POWER

Verbal information received from Duke Power indicates that the normal RCS pressure input to the ICS/NNI is from a non-1E transmitter powered from Panelboard KI. However, the specific branch circuit for this transmitter is unknown. In Table 14, the specific response of the control circuits with RCS pressure inputs are listed for failures of possible transmitter power sources.

A branch circuit failure will result in a 0 volt RCS pressure signal input to the PORV, spray valve and pressurizer heater control circuits. This could result in the heaters being energized and the PORV and spray valve closing. In the event this failure occurred, the operator would be able to manually control the indicated devices.

These particular responses should be included with the more general plant responses to H1 or H1X power failures (see Tables 5, 6, 8 and 9) for overall plant response.

4.9 FAILURE OF PANELBOARD KI

The response of the plant to a failure of Panelboard KI (including all branch circuits) will be a loss of main feedwater transient, combined with the makeup flow, pressurizer heater, PORV, spray valve and turbine bypass valve controls switching to manual. Failure of KI will result in a spurious high steam generator level trip of the

TABLE 11
NNI AUXILIARY CONTROLS
HEX POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Makeup Flow	Makeup valve will close if pressurizer level transmitter LT-1 is selected.	Pressurizer level indicates full if level transmitter LT-1 is selected. Manual control operable. Manual selection of operable level transmitters LT-2 or LT-3 for auto control is possible.

TABLE 12
NNI AUXILIARY CONTROLS
BEY POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Makeup Flow Control	Makeup valve will close if pressurizer level transmitter LT-2 is selected.	Pressurizer level indicates full if level transmitters LT-2 is selected. Manual control operable. Manual selection of operable level transmitters LT-1 or LT-3 for auto control is possible.

TABLE 13
NNI AUXILIARY CONTROLS
PANELBOARD KU POWER FAILURE

Item	Function	Failure Mode	Comments
1.	Makeup Flow	Makeup valve will close if pressurizer level transmitter LT-3 is selected.	Pressurizer level indicates full if level transmitter LT-3 is selected. Manual control operable. Manual selection of operable level transmitters LT-1 or LT-2 for auto control is possible. Note: ICS/NNI Instruction Manual indicates that transmitter LT-3 is powered by HEY. However, information received from Duke power indicates that the power source for LT-3 has been changed to panelboard KU (computer power).

TABLE 14
NNI AUXILIARY CONTROLS
FAILURE OF RCS NARROW RANGE PRESSURE TRANSMITTER(S) POWER*

Item	Function	Failure Mode	Comments

*Note: The ICS/NNI Manual indicates that the RCS narrow range pressure signal is obtained from the RPS powered by the vital buses, KVIA - KVID. Verbal information received from Duke personnel, however, indicates that non-1E narrow range RCS pressure transmitter(s) have been added and powered from panelboard KI. The failures of possible branch circuits are discussed below:

Item	Function	Failure Mode	Comments
1.	<u>PORV (Relief Valve RC-RV3, RC-V66) Controls</u>		
1.1	Any Power Source to Selected Narrow Range RCS Pressure Transmitter	PORV will close or remain closed.	0 volt narrow range pressure signal is expected to be below "open" setpoint pressure. Manual control operable.
2.	<u>Pressurizer Heater Controls</u>		
2.1	H1 Power	Heater bank 1 may be energized due to low indicated RCS pressure. Heater banks 2, 3 & 4 will remain deenergized. However heater banks 2, 3 & 4 will remain energized if energized at the time of the power failure.	0 volt narrow range pressure signal should be compared to heater bank 1 setpoint. Manual control of heater bank 1 operable.

TABLE 14 (Continued)

Item	Function	Failure Mode	Comments
2.2	H1X Power	Heater bank 1 deenergized. Heater banks 2, 3 & 4 may be energized due to low indicated RCS pressure.	0 volt narrow range pressure signal should be compared to setpoints for heater banks 2, 3 & 4. Manual control operable.
2.3	Power Source Other Than H1 or H1X	Heater banks 1, 2, 3 & 4 may be energized due to low indicated RCS pressure.	0 volt narrow range pressure signal should be compared to setpoints for heater banks 1, 2, 3 & 4. Manual control operable.
3.	<u>Pressurizer Spray (Block) Valve (RC-V1) Controls</u>		
3.1	H1 Power	Spray valve will remain closed or open depending on its position at time of power failure.	Manual control operable.
3.2	Power Source Other Than H1	Spray valve will close due to low indicated RCS pressure.	0 volt narrow rarnge pressure signal should be compared to spray valve setpoint. Manual control operable.

main feedwater pumps, reactor and turbine trip and automatic initiation and control of emergency feedwater.

Selected manual control station power sources are automatically switched from KI to KU. This would allow the operator to manually position makeup flow control valves from the control room, the turbine bypass valves and pressurizer heater bank 2 from the auxiliary shutdown panel and, if required, position of the PORV and spray valve from ICS Cabinet 13 control switches. Although the operator would be able to position these devices, it is not known whether he would have adequate plant status information to maintain effective control.

5.0 SUMMARY

The initial response of the Oconee Nuclear Power Plant ICS/NNI control circuits to electric power branch circuit failures has been analyzed. The results of this analysis are summarized below:

1. The most severe plant transient resulted from a failure of the H1X or HX branch circuits. This failure could cause an overcooling transient or an undercooling transient followed by an overcooling transient depending on the particular selection of RCS temperature sensors for control system input. Without operator intervention, reactor and turbine trip, trip of the main feedwater pumps on high steam generator level and automatic initiation and control of emergency feedwater would occur.
2. Failures of the H1 or H branch circuits results in a transfer of automatic control circuits to manual. Although a transient would not immediately result, the plant would be incapable of automatically responding to perturbations to steady state operation. Should a perturbation occur (e.g., reactor trip), the steam generators would be initially overfed. Without operator intervention, reactor and turbine trip, trip of the main feedwater pumps on high steam generator level and automatic initiation and control of emergency feedwater would occur.
3. Most power supply failures resulted in the controlled devices "freezing" in position rather than responding to spurious control

signals. This feature reduced the severity of resulting transients.

4. For the transients investigated, necessary manual controls were available to the operator to control the plant. In many cases, continued power operation of the plant may be possible. However, the ability of the operator to manually control plant systems will depend on the availability of plant parameter indications for the operator which will be studied in the overall FMEA.