# CONTROL SYSTEMS FAILURES
# EVALUATION REPORT

AUGUST 1982

PREPARED

FOR

LONG ISLAND LIGHTING COMPANY
SHOREHAM NUCLEAR POWER STATION

PREPARED
BY


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## 1.0 OBJECT

This document constitutes:

- An analysis in response to the NRC concern that the failures of power sources or sensors which provide power or electrical signals to multiple control systems could result in consequences outside the bounds of the Shoreham Final Safety Analysis Report (FSAR) Chapter 15 analyses and beyond the capability of operators or safety systems.

- A positive demonstration that adequate review and analysis has been performed to ensure that despite such failure the Shoreham FSAR Chapter 15 analyses are bounding, and no consequence beyond the capability of operators on safety systems would result.

A comprehensive approach was developed to analyze the control systems capable of affecting reactor water level, pressure or power in the Shoreham plant.

This report with its attachments was prepared by the General Electric Company for the Long Island Lighting Company (LILCO) with a significant technical contribution from the Stone & Webster Engineering Corporation (SWEC).

## 2.0 CONCLUSIONS

This report, supplemented by the existing FSAR Chapter 15 transient analyses, documents an evaluation of the Shoreham Nuclear Power Station for system interaction by electrical means. The conclusion of this evaluation is that previously reported limits of minimum critical power ratio (MCPR), peak vessel and main steamline pressures, and peak fuel cladding temperature for the expected operational occurrence category of events would not be exceeded as a result of common power source or sensor failures. Although new transient category events have been postulated as a result of this study, the net effects have been positively determined to be less severe than those of the original, conservative, Chapter 15 events. It should be noted that this study uses the event - consequence logic of the Chapter 15 analysis, but starts the logic chain from a specific source (e.g., a single bus failure) rather than a system condition (e.g., feedwater runout). By approaching the study in this manner, a great deal of confidence can be placed in the study conclusions. The approach validated itself by uncovering previously unanalyzed interactions. The soundness of the total plant design is demonstrated by its being tolerant of these interactions.

## 3.0 ANALYSIS METHODOLOGY

The electrical control systems failure analysis was conducted in the following manner by GE and the SWEC:

| ACTIVITY | ASSIGNED TO |
|---|---|
| • DEFINE BUS STRUCTURE | SWEC |
| • DEFINE CONTROL SYSTEMS | SWEC & GE |
| • IDENTIFY LOADS | SWEC & GE |
| • DETERMINE CRITICAL LOADS | SWEC & GE |
| • SUMMARIZE CRITICAL LOADS | GE |
| • ANALYZE COMBINED EFFECTS | GE |
| • COMPARE RESULTS TO CHAPTER 15 | GE |
| • ANALYZE EXCEPTIONS | GE |
| • MODIFY/AUGMENT CHAPTER 15 IF NECESSARY | GE |

### 3.1 DEFINE BUS STRUCTURE

This step established the potential sources for system interaction by electrical means. Bus trees (see Figures 1 and 2) were constructed using one-line diagram information to show power distribution from the highest level not previously analyzed (the highest level previously analyzed is the loss of offsite power) down to the lowest level of plant distribution (Motor Control Center's, instrument busses, etc.).

### 3.2 DEFINE CONTROL SYSTEMS

This step established the scope of control systems to be analyzed. A complete list of Shoreham plant systems and subsystems was compiled. This list was then reviewed to confine the analysis to only those systems with the potential to affect reactor pressure, water level, or power.

To ensure that all necessary systems were considered, certain elimination criteria were established that documented the justification for not analysing that system further. If there was any uncertainty as to whether or not a system met the criteria, it was retained for further analysis. Those systems that met the criteria for elimination were removed from the complete system list to produce the final list of control systems for analysis. This final list, reviewed by GE and SWEC, is shown as follows:

3.2 DEFINE CONTROL SYSTEMS (Continued)

| MPL | SYSTEMS | MPL | SYSTEMS |
|---|---|---|---|
| B21 | Nuclear Boiler System | N42 | Hydrogen Seal System |
| B31 | Reactor Recirculation | N43 | Generator Cooling |
| C11 | CRD Hydraulic Control System | N44 | Air Removal |
| C32 | Feedwater Turbine | N45 | Generator Hydrogen & CO2 Purge |
| C51 | Neutron Monitoring | N51 | Main Generator Excitation |
| D11 | Process Radiation Monitor System | N62 | Off Gas |
| D21 | Area Radiation Monitor System | N71 | Circulating Water |
| G33 | Reactor Water Cleanup | P41 | Service Water |
| N11 | Main Steam | P42 | RB Closed Cooling Water System |
| N21 | Condensate | P43 | TB Closed Cooling Water System |
| N32 | Turbine Control | P50 | Compressed Air |
| N34 | Lube Oil | P71 | Low Conductivity Drains |
| N35 | Moisture Extraction | Z93 | Primary Containment Instrumentation |

3.3 IDENTIFY LOADS

This step provided the data base necessary to determine which electrical loads were to be analyzed. A set of load tables comprised of all electrical loads of the control systems in Paragraph 3.2 was assembled by GE and SWEC, each providing information on the loads within their respective scope of supply.

Each load was listed with its power bus source, its unique Master Parts List number, circuit description, and failure mode on power loss with primary and secondary effects. A sample of a load table is included in Appendix C.

3.4 DETERMINE CRITICAL LOADS

This step constituted the first analytical step in sorting out the loads with the potential for initiating events affecting reactor pressure, water level and power. The elimination criteria established earlier for the system list was refined in Appendix B for use in the component review for determining which individual loads were worthy of further consideration or could be deleted from the analysis. If there was any uncertainty as to whether or not a load met the elimination criteria it was retained for further analysis. The code associated with an elimination criterion was assigned to each eliminated load in the load tables discussed in the previous step.

3.5 SUMMARIZE CRITICAL LOADS

The non-critical loads were deleted from the load tables, and the remaining loads are grouped together by their common power busses. These tables are shown in Appendix A.

## 3.6 ANALYZE COMBINED EFFECTS

This step provided the basis for determining the worst case combinations of load and system failures that are credible events considering the interconnection by power distribution. Using the combined effects at the lowest level bus as a starting point, the next higher bus was postulated to fail and the total effects at that level analyzed. This process was continued up to the highest bus level. The combined effects at the lowest bus level are included in the Appendix A tables. Worst case effects at the higher levels are summarized in Section 4. The combined effects at intermediate bus levels less severe than their associated higher bus combined effects were analyzed but not included in Section 4. The intermediate level combined effect analysis is already represented in the higher bus analysis.

## 3.7 COMPARE RESULTS TO CHAPTER 15

This step evaluated the consequences of all potential system interaction events initiated by electrical means. A review of the information in the Appendix A tables was conducted in the course of developing the bus summaries of Section 4. At each bus level of the combined effects analysis, the review evaluated the effects as being bounded by a specific Chapter 15 transient analysis or not. Section 4 includes these evaluations considering the worst case effects.

## 3.8 ANALYZE EXCEPTIONS

The purpose of this step was to determine if a failure scenario not directly covered by a Chapter 15 transient analysis would be bounded by one with more severe effects. The cases of this type are included in the Section 4 descriptions of worst case failures.

## 3.9 MODIFY/AUGMENT CHAPTER 15 IF NECESSARY

This step was not necessary in the Shoreham analysis.

## 4.0 BUS LOSS SUMMARY RESULTS AND CHAPTER 15 COMPARISONS

AC Bus

1A (4.16KV) — Loss of this bus causes the loss of power to condensate booster pump A and reactor recirculation pump A. There is also a potential main turbine trip due to the circulating water pump A loss and its subsequent effect on condenser vacuum. Since a reduction of reactor recirculation flow would immediately start reducing reactor power, an immediate or delayed turbine trip would produce an equal or less severe transient than the turbine trip event of Chapter 15. Therefore this event is bounded.

1B (4.16KV) — The effects of the loss of this bus are similar to those of the loss of Bus 1A.

11 (4.16KV) — Loss of this bus will cause condensate pump A and circulating water pump C to be inoperative. The loss of the condensate pump will initiate reactor recirculation flow to run back and reduce reactor power corresponding to 67 percent of rated feedwater flow. In addition, a loss of feedwater heating of less than 10°F will occur, but this effect will be nullified by the recirculation runback. In the event that circulating water pump A or B is in the backwash operation, the loss of circulating water pump C may cause pump D to flow back and effectively reduce the circulating water flow to a one-pump operation; and the condenser back pressure may rise rapidly leading to a main turbine trip. The ensuing pressure excursion may even reach the bypass closure trip setpoint. However, this event will take place at reduced reactor power and it is bounded by the turbine trip without bypass transient already analyzed in FSAR Chapter 15.

Loss of the associated lower busses fed by Bus 11 will produce some or all of the following effects: Decrease in condenser vacuum, delayed main turbine trip, reduction in feedwater flow, and reduction in reactor recirculation flow.

The worst case reduction in feedwater temperature has been determined to be no more than 10°F. This reduction in feedwater heating will increase reactor power by less than three percent nuclear boiler rated (NBR) power.

The worst case scenario is the unlikely event of a loss of feedwater heating and a delayed turbine trip. A computer analysis was performed to determine the reactor parameters as a consequence of a turbine trip at approximately 103 percent of initial power. The results yielded a minimum critical power ratio (MCPR) of 1.10 and a maximum dome pressure of 1197 psia which is less severe than the most limiting transient analyzed in FSAR Chapter 15. This event is then, although previously not analyzed for the Shoreham plant, still bounded by existing analyses.

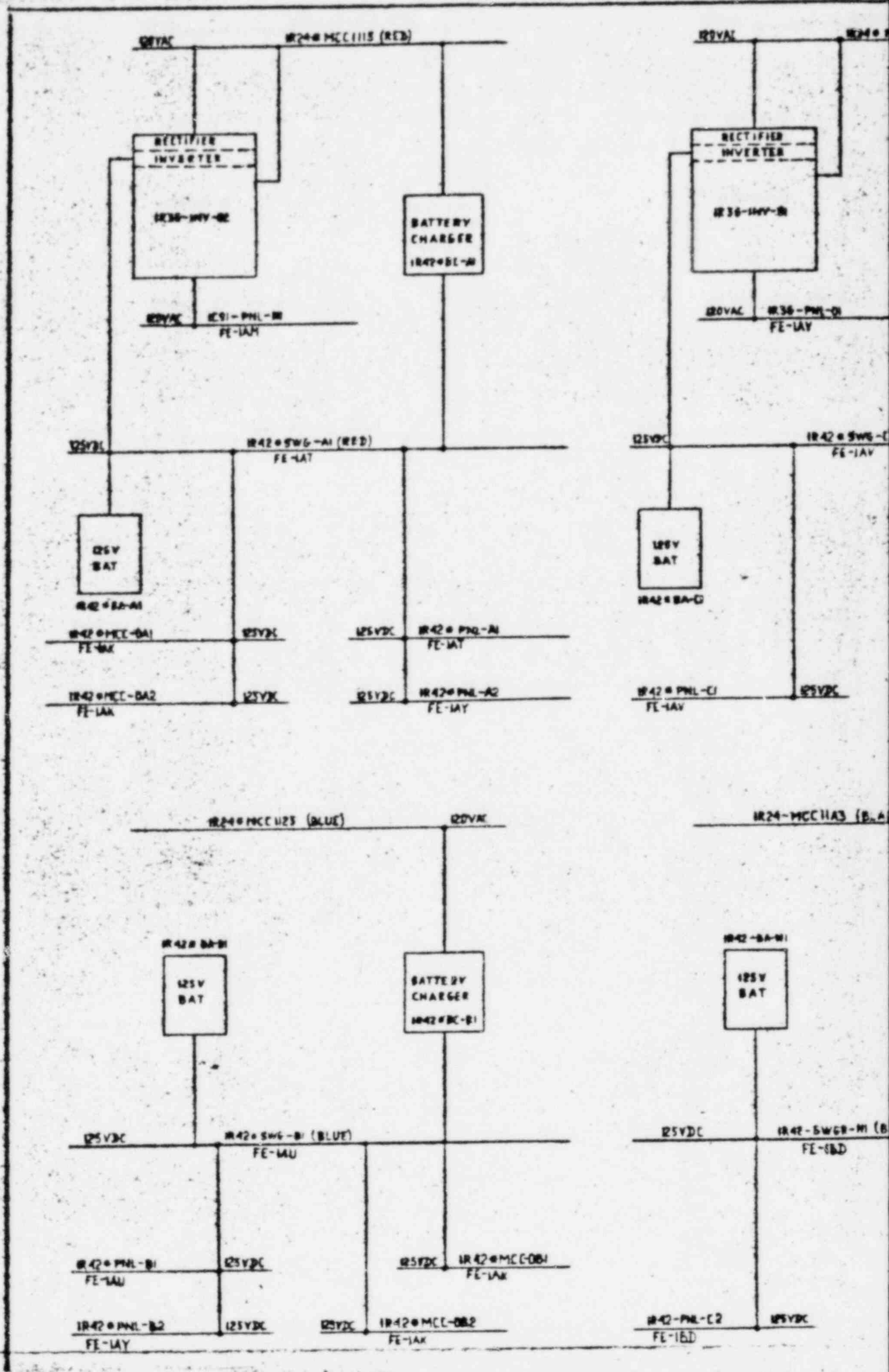
4.0 BUS LOSS SUMMARY RESULTS AND CHAPTER 15 COMPARISONS (Continued)

AC Bus

| | |
|---|---|
| 12 (4.16KV) | The effects of the loss of this bus are similar to those of the loss of Bus 11. |
| 101/102 (4.16KV) Emergency | The loss of either of these busses will cause a single channel trip from the APRM circuitry to the reactor protection system which produces no transient. |
| 103 (4.16KV) Emergency | Loss of this bus will cause a decrease in reactor recirculation flow and a lock of the feedwater pumps at-last-speed setting. An increase in level would ensue terminated by the level 8 feedwater pump and main turbine trip. This event is similar to and bounded by the feedwater runout event analyzed in Chapter 15. |

DC Bus

| | |
|---|---|
| 1R42-BA N1 & N2 | The worst case effect of the loss of either of these battery buses is a main turbine trip with no additional complications which is bounded by Chapter 15 load rejection analysis. |



MCC 111S (RED)
RECTIFIER
INVERTER
BATTERY CHARGER
FE-1AH
125VDC
SWG-A1 (RED)
FE-1AT
125V BAT
FE-1AK
125VDC
FE-1AY
120VAC
RECTIFIER
INVERTER
120VAC
FE-1AV
125VDC
FE-1AV
125V BAT
FE-1AV
125VDC
MCC 1I23 (BLUE)
120VAC
125V BAT
BATTERY CHARGER
125VDC
SWG-B1 (BLUE)
FE-1AU
FE-1AU
125VDC
125VDC
FE-1AK
FE-1AY
125VDC
125VDC
FE-1AK
1R24-MCC11A3
1R42-BA-N1
125V BAT
125VDC
FE-1BD
1R42-PNL-C2
125VDC
FE-1BD

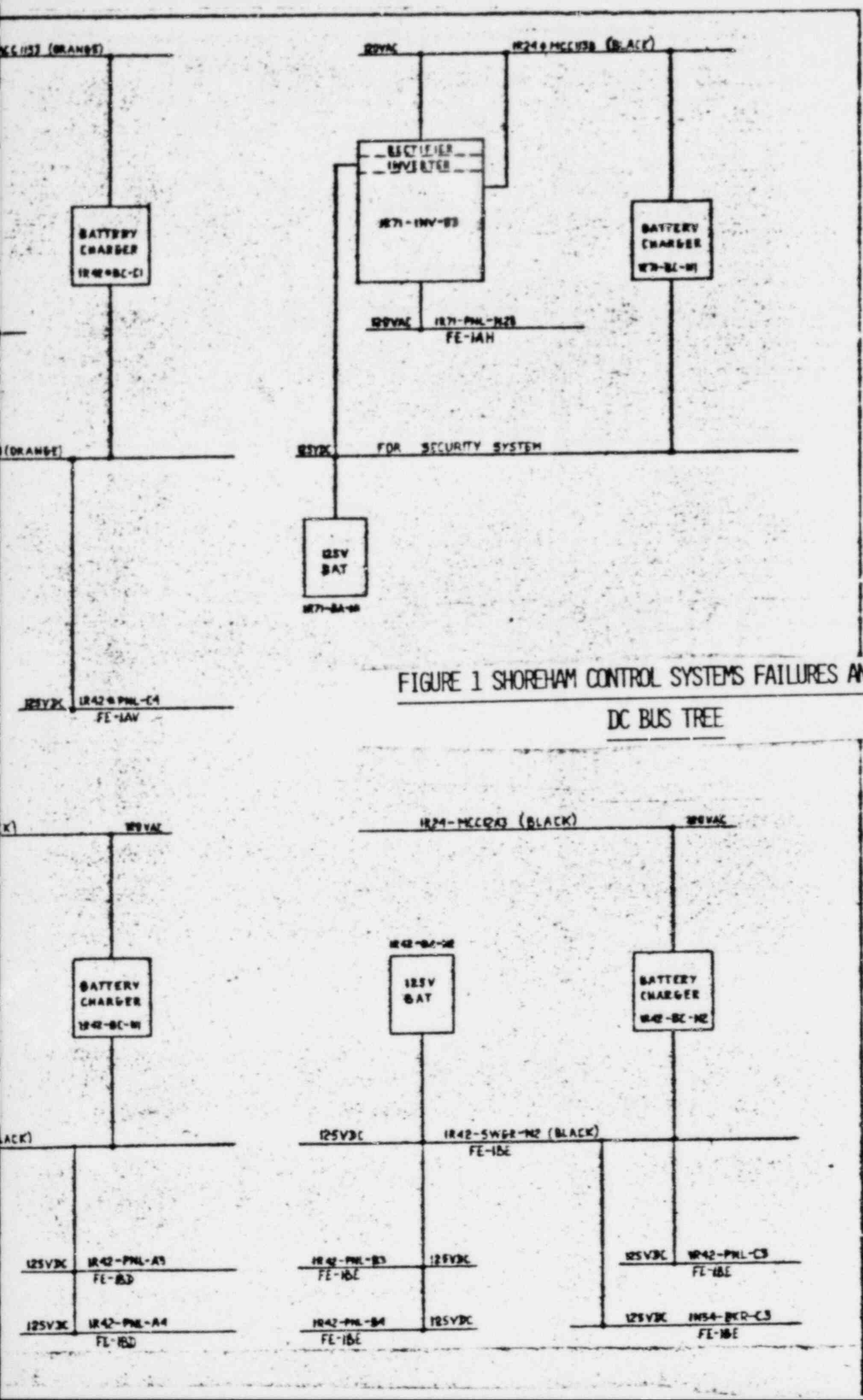
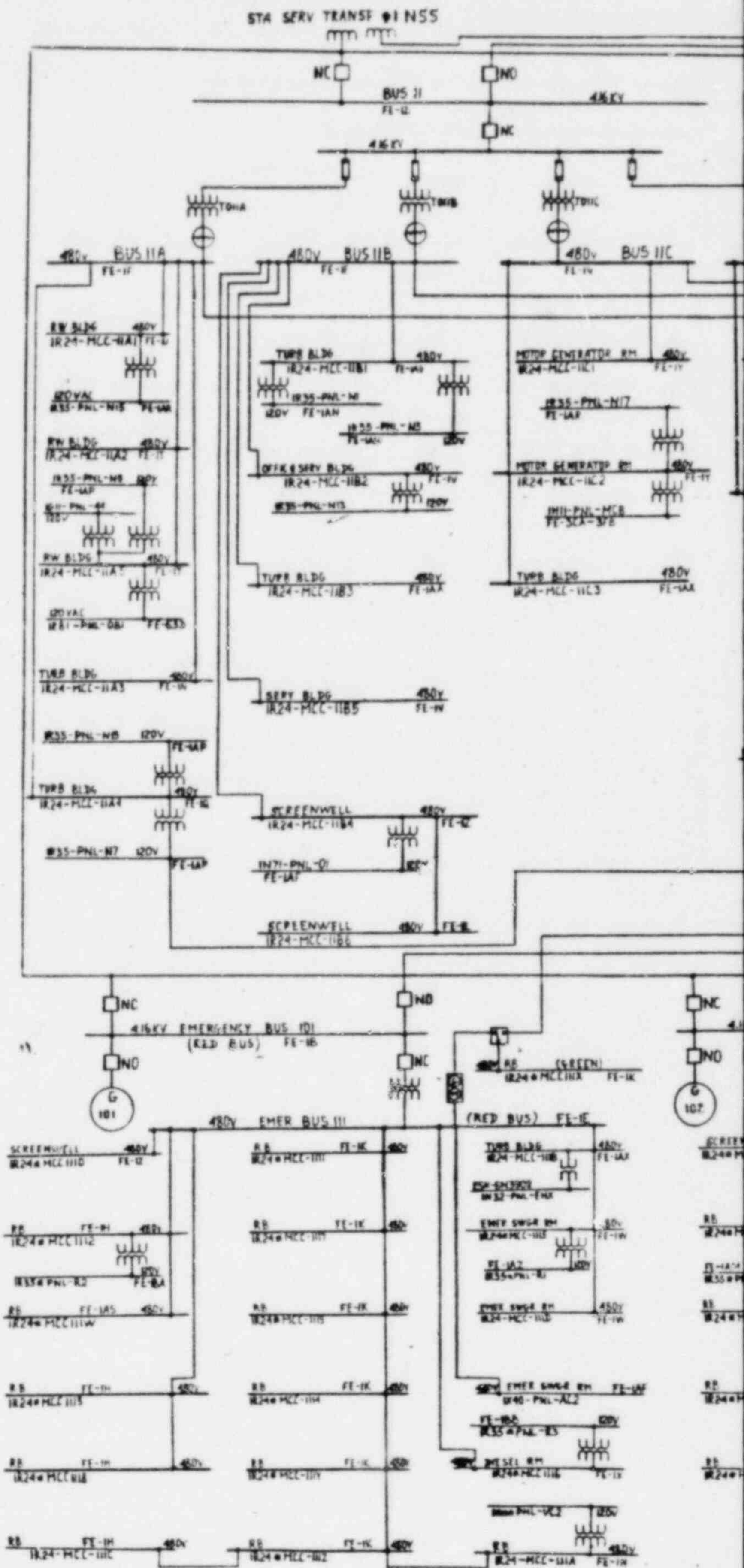



FIGURE 1 SHOREHAM CONTROL SYSTEMS FAILURES ANALYSIS

DC BUS TREE


STA SERV TRANSF #1 NSS
BUS 11
4.16KV
480V BUS 11A
480V BUS 11B
480V BUS 11C
SCREENWELL
4.16KV EMERGENCY BUS 101
(RED BUS)
480V EMER BUS 111
(RED BUS)

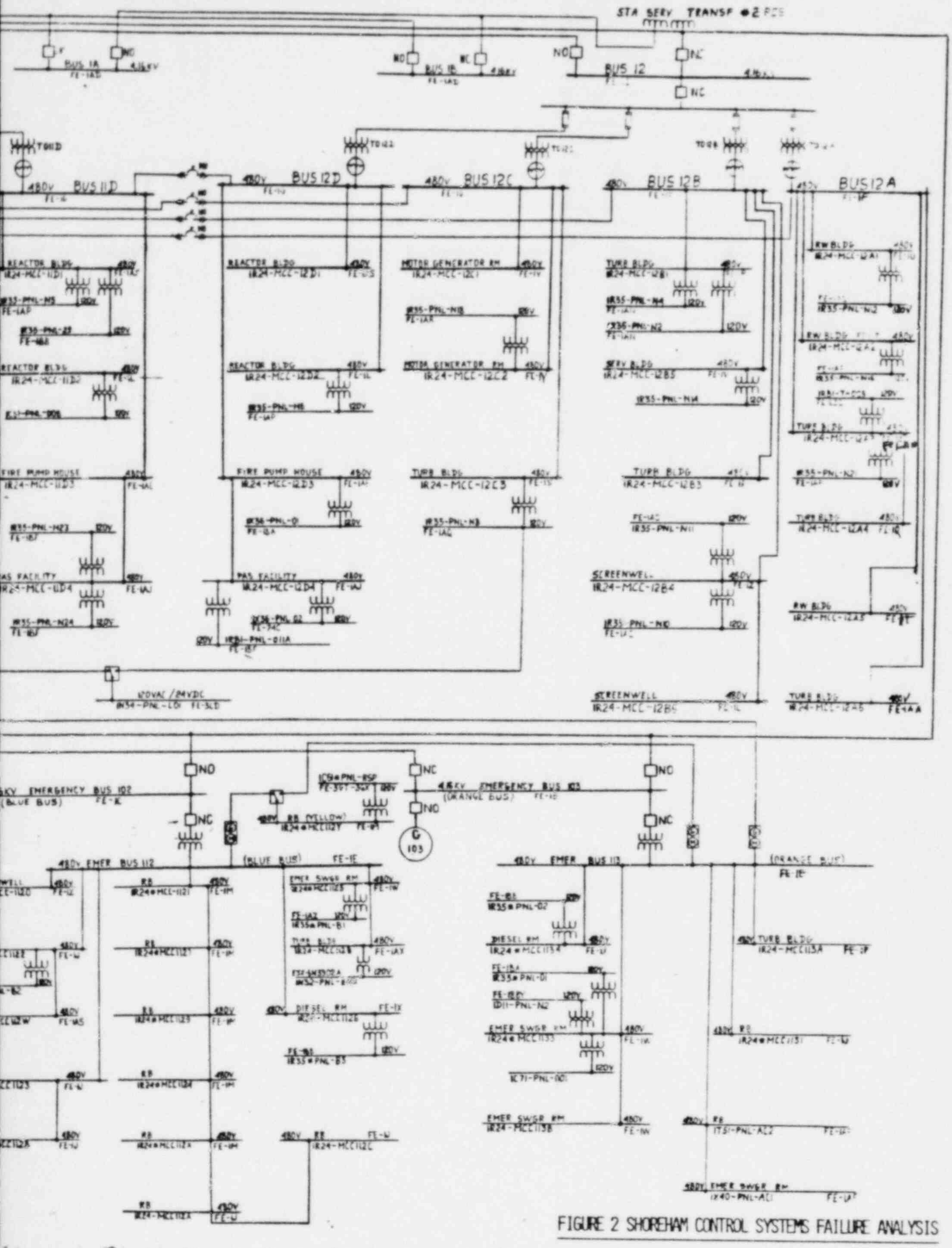



FIGURE 2 SHOREHAM CONTROL SYSTEMS FAILURE ANALYSIS

AC BUS TREE

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| AC BUS 1A | RECIRC | GENERATOR DRIVE MOTOR – S001A | LOSE GENERATOR DRIVE MOTOR – S001A | RUN BACK TO 65% POWER | REDUCTION OF FEEDWATER FLOW TO 67% OF RATED |
| | CIRC. WTR | CIRCULATIING WATER PUMP A (PUMP B - BUS 1B) (PUMP C - BUS 11) (PUMP D - BUS 12) | DECREASE CONDENSER VACUUM | SLIGHT DECREASE IN CONDENSER VACUUM | RECIRCULATION RUNBACK TO 65% REACTOR POWER<br>SLIGHT DECREASE IN CONDENSER VACUUM |
| | CONDENSATE | CONDENSATE BOOSTER PUMP A (PUMP B - BUS 1B) | REDUCTION OF FEEDWATER TO 67% OF RATED | RUNBACK TO 65% REACTOR POWER | |

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| AC BUS 1B | RECIRC | GENERATOR DRIVE MOTOR – S001B | LOSE GENERATOR DRIVE MOTOR – S001B | RUN BACK TO 65% POWER | REDUCTION OF FEEDWATER FLOW TO 67% OF RATED |
| | CIRC. WTR | CIRCULATING WATER PUMP B (PUMP A - BUS 1A) (PUMP C - BUS 11) (PUMP D - BUS 12) | DECREASE CONDENSER VACUUM | SLIGHT DECREASE IN CONDENSER VACUUM | RECIRCULATION RUNBACK TO 65% REACTOR POWER<br>SLIGHT DECREASE IN CONDENSER VACUUM |
| | CONDENSATE | CONDENSATE BOOSTER PUMP B (PUMP A- BUS 1A) | REDUCTION OF FEEDWATER FLOW TO 67% OF RATED | RUNBACK TO 65% REACTOR POWER | |

## APPENDIX A – BUS TABLES

AC
BUS 11

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| AC BUS 11 | CONDENSATE | CONDENSATE PUMP A (PUMP B-BUS 12) | FEEDWATER REDUCED TO 67% OF RATED | REACTOR PRESSURE VESSEL WATER LEVEL LOWER AND AT 65% POWER | (SEE SECTION 4) |
| | COMP. AIR | AIR COMPRESSOR A (COMPRESSOR B & C - BUS 12) | COMPRESSOR A INOPERATIVE | NONE – BACKED UP BY COMPRESSORS B & C | |
| | CIRC. WTR | CIRCULATION WATER PUMP C (PUMP A - BUS 1A) (PUMP B – BUS 1B) (PUMP D - BUS 12) | PUMP INOPERATIVE | DECREASE CONDENSER VACUUM. MAIN TURBINE TRIP. | |
| | SERVICE WATER TURBINE BUILDING | SERVICE WATER PUMP A (PUMPS B & C – BUS 12) | PUMP INOPERATIVE | NONE – BACKED UP BY PUMPS B & C | |
| BUS 11A – 1R24-MCC11A1 | COMP. AIR | WASTE NEUTRAL TANK INLET AIR MOV-81 | IF OPEN, WILL LOSE INSTRUMENT AIR (COMPRESSORS B & C BUS 12 AND 1R35-PNL-N8) | NONE | NONE |
| 1R24-MCC11A2 | OFFGAS | DRYER TRAIN A (TRAIN B – MCC12A2) | LOSS OF DRYER TRAIN A | NONE – BACKED UP BY DRYER TRAIN B | NONE |
| 1R24-MCC11A3 | CONDENSATE | HEATER TRAIN BYPASS MOV-30 | MOV FAILS AS IS | NONE | WORST CASE – DECREASE IN CONDENSER VACUUM |
| | GEN. COOLING | STATOR COOLING WATER PUMP A (PUMP B – BUS 12) | IF PUMP B NOT AVAILABLE, MAIN TURBINE TRIP | NONE – BACKED UP BY PUMP B | |
| | AIR REMOVAL | AIR EJECTOR ISOLATION MOV-45A<br>AIR EJECTOR ISOLATION MOV-46A | MOV'S FAIL AS IS | IF IN BACKWASH, SLIGHT DECREASE IN CONDENSER VACUUM | |
| | CIRC. WATER | CONDENSER INLET MOV-32A<br>CONDENSER DISCHARGE MOV-33A<br>CONDENSER BACKWASH VALVE MOV-34A | IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS<br>IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS | DECREASE CONDENSER VACUUM<br>DECREASE CONDENSER VACUUM | |

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

AC BUS 11

| Source | System | Component Description | Primary Effect | Secondary Effect | Combined Effects |
|---|---|---|---|---|---|
| BUS 11A / 1R24-MCC11A4 | COMP. AIR | COMPRESSOR START UP AUXILIARY OIL PUMP A | AUX OIL PUMP INOPERATIVE | UNABLE TO START AIR COMPRESSOR A | DECREASE CONDENSER VACUUM AND FEEDWATER TEMPERATURE |
| BUS 11A / 1R24-MCC11A4 | OFFGAS | HOT GAS BYPASS SOV-49A<br>LIQUID FREON SOV-31A | SOV'S DE-ENERGIZED | NONE - BACKED UP BY TRAIN B (TRAIN B – BUS 12A) | |
| BUS 11A / 1R35-PNL-N7 | CONDENSATE | REACTOR FEEDWATER PUMP A DISCHARGE SOV-42A | SOV DE-ENERGIZED | SLIGHT INCREASE IN REACTOR FEEDWATER PUMP TURBINE SPEED | DECREASE CONDENSER VACUUM AND FEEDWATER TEMPERATURE |
| BUS 11A / 1R35-PNL-N7 | MOISTURE EXTRACTION | GLAND STEAM EVAPORATOR DRAIN SOV-10L<br>STEAM SEAL EVAPORATOR DRAIN SOV-10H<br>RADWASTE STEAM GENERATOR DRAIN SOV-11L<br>RADWASTE STEAM GENERATOR DRAIN SOV-11H<br>1ST POINT HEATER SOV-01AH<br>1ST POINT HEATER SOV-01AN<br>2ND POINT HEATER SOV-02AH<br>2ND POINT HEATER SOV-02AN<br>3RD POINT HEATER SOV-03AH<br>3RD POINT HEATER SOV-03 AN<br>4TH POINT HEATER SOV-04 AH<br>4TH POINT HEATER SOV-04 AN<br>5TH POINT HEATER SOV-05 AH | SOV–10L VALVE CLOSES<br>SOV-10H VALVE OPENS<br>SOV-11L VALVE CLOSES<br>SOV-11H VALVE OPENS<br>SOV-01 AH VALVE OPENS<br>SOV-01 AN VALVE CLOSES<br>SOV-02 AH VALVE OPENS<br>SOV-02 AN VALVE CLOSES<br>SOV-03 AH VALVE OPENS<br>SOV-03 AN VALVE CLOSES<br>SOV-04 AH VALVE OPENS<br>SOV-04 AN VALVE CLOSES<br>SOV-05 AH VALVE OPENS | BYPASS HEATER STEAM TO CONDENSER<br>DECREASE IN FEEDWATER TEMPERATURE AND CONDENSER VACUUM<br>DECREASE FEEDWATER TEMPERATURE AND CONDENSER VACUUM | |
| BUS 11A / 1R35-PNL-N7 | COMP. AIR | AIR COMPRESSOR CONTROL CIRCUIT A (CIRCUITS B & C– 1R35-PNL-N8) | LOSS OF INSTRUMENT AIR COMPRESSOR A | NONE – BACKED UP BY AIR COMPRESSORS B & C | |

## APPENDIX A – BUS TABLES

### SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

AC BUS 11B

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| 1R24-MCC11B1 | CIRC. WATER | CIRCULATION WATER CONDEN-INLET MOV-32C<br>CIRCULATION WATER CONDEN-DISCHARGE MOV-33D<br>CONDENSER BACKWASH VALVE MOV-34C | IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS<br>IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS<br>IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS | DECREASE CONDENSER VACUUM<br>DECREASE CONDENSER VACUUM<br>DECREASE CONDENSER VACUUM | WORST CASE – DECREASE CONDENSER VACUUM.<br><br>RFPT A TRIP. FEEDWATER FLOW REDUCTION TO 67% OF RATED. MINIMUM SPEED ON RECIRC A & B PUMPS – 50% REACTOR POWER |
| | MAIN TURBINE CONTROL | MAIN TURBINE EHC FLUID PUMP A (PUMP B – MCC12B1) | PUMP A INOPERATIVE | NONE – BACKED UP BY PUMP B | |
| 1R35-PNL-N1 | FEEDWATER | CONTROL SIGNAL FAIL INITIATING CONTACT | LOSS OF REACTOR FEEDWATER PUMP'S CONTROL SIGNAL WILL NOT SET AT LAST SPEED | SCRAM IF REACTOR FEEDWATER PUMP'S CONTROL SIGNAL LOST | MINIMUM SPEED ON RECIRC A & B PUMPS – 50% POWER |
| | RECIRC | RECIRCULATION DIVISION 1 SPEED CONTROL | RECIRCULATION PUMPS A & B MINIMUM SPEED IF IN AUTO MODE | REACTOR AT 50% POWER | |
| 1R35-PNL-N3 | CONDENSATE | MINIMUM FLOW BYPASS SOV-28A | SOV DE-ENERGIZED FCV FAILS OPEN | RFP TURBINE A TRIP. FEEDWATER FLOW REDUCTION TO 67% OF RATED. RECIRC RUNBACK TO 65% POWER | RFP TURBINE A TRIP. FEEDWATER FLOW REDUCTION TO 67% OF RATED. RECIRC RUNBACK TO 65% POWER |
| 1R24-MCC11B4 | CIRC. WATER | CIRCULATION WATER PUMP A DISCHARGE MOV-31A<br>CIRCULATION WATER PUMP C DISCHARGE MOV-31C | MOV'S FAIL AS IS<br>MOV'S FAIL AS IS | FAILED CLOSED – UNABLE TO START PUMP(S)<br>FAILED OPEN – NO EFFECT ON PUMP(S) | LOSS OF TURBINE BUILDING SERVICE WATER STRAINER BACKWASH CAPABILITY<br><br>IF CIRC WATER DISCHARGE VALVES FAIL OPEN AND PUMPS STOP, UNABLE TO PREVENT BACK FLOW, DECREASE CONDENSER VACUUM – MAIN TURBINE TRIP |
| 1R24-MCC11B6 | SERVICE WATER | TURBINE BUILDING SERVICE WATER INLET MOV-113A | MOV FAILS AS IS – NORMALLY CLOSED. LOSS OF STRAINER BACKWASH CAPABILITY | WORST CASE – MAIN TURBINE AND RFP TURBINE TRIP AFTER MANY HOURS | WORST CASE – MAIN TURBINE AND RFP TURBINE TRIP AFTER MANY HOURS |

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

AC BUS 12

| Bus | System | Component Description | Primary Effect | Secondary Effect | Combined Effects |
|---|---|---|---|---|---|
| AC BUS 12 | CONDENSATE | CONDENSATE PUMP B (PUMP A– BUS 11) | FEEDWATER REDUCED TO 67% OF RATED | REACTOR PRESSURE VESSEL WATER LEVEL LOWER AND AT 65% POWER | (SEE SECTION 4) |
| AC BUS 12 | COMP. AIR | INSTRUMENT AIR COMPRESSOR B<br>INSTRUMENT AIR COMPRESSOR C<br>(COMPRESSOR A ON BUS 11) | AIR COMPRESSORS B & C INOPERATIVE | NONE – BACKED UP BY COMPRESSOR A | |
| AC BUS 12 | CIRC. WATER | CIRCULATION WATER PUMP D | PUMP INOPERATIVE | DECREASE CONDENSER VACUUM. MAIN TURBINE TRIP | |
| AC BUS 12 | SERVICE WATER TURBINE BUILDING | SERVICE WATER PUMP B<br>SERVICE WATER PUMP C | PUMPS INOPERATIVE | REDUCED TURBINE COOLING WATER. MAIN TURBINE TRIP AFTER SOME TIME | |
| BUS 12A – 1R24 MCC12A2 | OFFGAS | DRYER TRAIN B (TRAIN A– MCC11A2) | LOSS OF DRYER TRAIN B | NONE – BACKED UP BY TRAIN A | NONE |
| 1R24 MCC12A3 | GEN. COOLING | STATOR COOLING WATER PUMP B (PUMP A – BUS 11) | PUMP INOPERATIVE<br>IF PUMP A NOT AVAILABLE MAIN TURBINE TRIP | NONE – BACKED UP BY PUMP A | WORST CASE – DECREASE CONDENSER VACUUM |
| 1R24 MCC12A3 | CIRC. WATER | CIRCULATION WATER CONDENSATE INLET MOV-32B<br>CIRCULATION WATER CONDENSATE DISCHARGE MOV-33B<br>CONDENSER BACKWASH VALVE MOV-34B | IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS<br>IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS<br>IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS | DECREASE IN CONDENSER VACUUM<br>DECREASE IN CONDENSER VACUUM<br>DECREASE IN CONDENSER VACUUM | |
| 1R24 MCC12A4 | COMP. AIR | COMPRESSOR AUXILIARY OIL PUMP B<br>COMPRESSOR AUXILIARY OIL PUMP C | PUMPS INOPERATIVE | COMPRESSORS B & C WILL NOT START IF DEMAND ON AIR SYSTEM REQUIRES | WORST CASE – DECREASE CONDENSER VACUUM |
| 1R24 MCC12A4 | AIR REMOVAL | AIR EJECTOR ISOLATION MOV-45B<br>AIR EJECTOR ISOLATION MOV-46B | MOV'S FAIL AS IS | IF IN BACKWASH, SLIGHT DECREASE IN CONDENSER | |
| 1R24 MCC12A4 | OFFGAS | HOT GAS BYPASS SOV-49B<br>LIQUID FREON SOV-31B | SOV'S DE-ENERGIZE | NONE – BACKED UP BY TRAIN A (TRAIN A–BUS 11A) | |

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

AC
BUS 12

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| BUS 12B | | | | | |
| | MAIN TURBINE CONTROL | MAIN TURBINE EHC FLUID PUMP B (PUMP A – MCC11B1) | PUMP INOPERATIVE | NONE – BACKED UP BY PUMP A | WORST CASE – DECREASE IN CONDENSER VACUUM RFP TURBINE TRIP. FEED-WATER FLOW REDUCTION TO 67% OF RATED, MINIMUM SPEED ON RECIRC A & B PUMPS – 50% REACTOR POWER |
| 1R24-MCC12B1 | CIRC. WATER | CONDENSER BACKWASH VALVE MOV-34D | IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS | DECREASE CONDENSER VACUUM | |
| | | CIRCULATION WATER CONDENSATE INLET MOV-32D | IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS | DECREASE CONDENSER VACUUM | |
| | | CIRCULATION WATER CONDENSATE DISCHARGE MOV-33C | IF IN BACKWASH, REDUCE FLOW TO 2 QUADRANTS | DECREASE CONDENSER VACUUM | |
| 1R35-PNL-N2 | RECIRC | RECIRCULATION DIVISION II SPEED CONTROL | RECIRCULATION A & B MINIMUM SPEED IF IN AUTO MODE | RUN BACK TO 50% POWER | RECIRCULATION PUMPS A & B AT MINIMUM SPEED–50% REACTOR POWER |
| 1R35-PNL-N4 | CONDENSATE | MINIMUM FLOW BYPASS SOV-28B | SOV-DE-ENERGIZED FCV FAILS OPEN | RFP TURBINE TRIP. FEED-WATER FLOW REDUCTION TO 67% OF RATED. RECIRC RUNBACK TO 65% REACTOR POWER | RFP TURBINE TRIP. FEED-WATER FLOW REDUCTION TO 67% OF RATED. RECIRC RUNBACK TO 65% REACTOR POWER |
| 1R24-MCC12B4 | CIRC. WATER | CIRCULATION WATER PUMP DISCHARGE MOV-31B<br>CIRCULATION WATER PUMP DISCHARGE MOV-31D | MOV'S FAIL AS IS<br>MOV'S FAIL AS IS | FAILED CLOSED – UNABLE TO START PUMP(S). FAILED OPEN – NO EFFECT ON PUMP(S) | LOSS OF TURBINE BUILDING SERVICE WATER STRAINER BACKWASH CAPABILITY<br>IF CIRC WATER DISCHARGE VALVES FAIL OPEN AND PUMPS STOP, UNABLE TO PREVENT BACK FLOW, DECREASE CONDENSER VACUUM – MAIN TURBINE TRIP |
| 1R35-PNL-N10 | CIRC. WATER | STRAINER – S-81A<br>STRAINER – S-81B | STRAINER MOTOR INOPERATIVE | UNABLE TO BACKWASH–MAIN TURBINE TRIP AFTER SEVERAL HOURS | MAIN TURBINE TRIP |
| 1R35-PNL-N11 | CIRC. WATER | CIRCULATION WATER PUMPS CONTROL CIRCUIT INTERLOCK | CIRCULATION WATER PUMPS A, B, C & D CANNOT RE-START IF ANY SHOULD STOP | NONE | NONE |

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

AC
BUS 12

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| 1R24-MCC12B4<br>\|<br>1R24-MCC12B6 — — — — | SERVICE WATER | TURBINE SERVICE WATER STRAINER INLET MOV-113B | MOV FAILS AS IS – NORMALLY CLOSED. LOSS OF STRAINER BACKWASH CAPABILITY | WORST CASE – MAIN TURBINE AND RFP TURBINE TRIP AFTER MANY HOURS | WORST CASE – MAIN TURBINE AND RFP TURBINE TRIP AFTER MANY HOURS |

APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

AC
BUS 12

BUS 12C
1R24 MCC12C3
1R35-PNL-N8

| SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|
| COMP. AIR | AIR COMPRESSOR CONTROL CIRCUIT PUMP B<br>AIR COMPRESSOR CONTROL CIRCUIT PUMP C<br>(CIRCUIT A – 1R35-PNL-N7) | LOSE INSTRUMENT COMPRESSORS B & C | NONE – BACKED UP BY COMPRESSOR A | DECREASE CONDENSER VACUUM AND FEEDWATER TEMPERATURE |
| STEAM SYSTEM | STEAM SUPPLY REACTOR FEEDWATER PUMP TURBINE SOV-30A<br>STEAM SUPPLY REACTOR FEEDWATER PUMP TURBINE SOV-30B | VALVES INOPERABLE | NONE – STEAM FLOW TO RFPT'S AT NORMAL OPERATION UNAFFECTED | |
| CONDENSATE | OPERATES FEEDWATER DISCHARGE VALVE NRV-42B SOV-42B | SOV DE-ENERGIZED | SLIGHT INCREASE IN REACTOR FEEDWATER PUMP TURBINE SPEED | |
| MOISTURE EXTRACTION | 1ST STAGE DRAIN TANK DRAINS TO CONDENSER SOV-7AH SOV-7AL SOV-7BH SOV-7BL | DUMPS STEAM TO CONDENSER | DECREASE CONDENSER VACUUM | |
| | 2ND STAGE DRAIN TANK DRAINS TO CONDENSER SOV-8AH SOV-8AL SOV-8BH SOV-8BL | | DECREASE CONDENSER VACUUM | |
| | MOISTURE SEPARATOR & REHEATERS DRAIN TANK DRAINS TO CONDENSER SOV-9AH SOV-9AL SOV-9BH SOV-9BL | | | |
| | 1ST POINT HEATER DRAIN SOV-1BH<br>1ST POINT HEATER DRAIN SOV-1BN<br>2ND POINT HEATER DRAIN SOV-2BH<br>2ND POINT HEATER DRAIN SOV-2BN<br>3RD POINT HEATER DRAIN SOV-3BH<br>3RD POINT HEATER DRAIN SOV-3BN | BYPASS HEATER STEAM TO CONDENSER | DECREASE FEEDWATER TEMPERATURE AND CONDENSER VACUUM | |

## APPENDIX A – BUS TABLES

AC
BUS 12

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| BUS 12C<br>1R24 MCC12C3<br>1R35 PNL-N8 — — — — | MOISTURE EXTRACTION | 4TH POINT HEATER DRAIN SOV-4BH<br>4TH POINT HEATER DRAIN SOV-4BN<br>5TH POINT HEATER DRAIN SOV-5BH | BYPASS HEATER STEAM TO CONDENSER | DECREASE FEEDWATER TEMPERATURE AND CONDENSER VACUUM | |

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| AC BUS 101 – BUS 111 – 1R24-MCC1115 (BACK UP TO MGS B) | NEUTRON MONITORING | AVERAGE POWER RANGE MONITOR CHANNELS A, C, E<br>ROD BLOCK MONITOR CHANNEL A | HALF SCRAM TRIP | IF ALTERNATE CHANNELS ALSO TRIP, REACTOR SCRAM | ½ AVERAGE POWER RANGE MONITOR SCRAM – DIV. I |
| AC BUS 102 – BUS 112 – 1R24-MCC1125 (BACK UP TO MGS A) | NEUTRON MONITORING | AVERAGE POWER RANGE MONITOR CHANNELS B, D, F<br>ROD BLOCK MONITOR CHANNEL B | HALF SCRAM TRIP | IF ALTERNATE CHANNELS ALSO TRIP, REACTOR SCRAM | ½ AVERAGE POWER RANGE MONITOR SCRAM – DIV. II |
| AC BUS 103 – BUS 113 – 1R24-MCC1133 – 1R36-INV-01 125 VDC FROM INVERTER – 1R36-PNL-01 (NO BATTERY BACK UP) | FEEDWATER | REACTOR FEEDWATER PUMPS CONTROL SIGNAL CIRCUITRY | FEEDWATER PUMPS REMAIN AT LAST SPEED UNLESS 1R35-PNL-N1 IS LOST – THEN REACTOR FEEDWATER PUMP'S RUN DOWN | LOAD FOLLOWING MISMATCH WILL CAUSE MAIN TURBINE TRIP | RECIRCULATION PUMPS A & B AT MINIMUM SPEED–50% POWER |
| | REACTOR RECIRC | RECIRCULATION CONTROL SIGNAL CIRCUITRY | IF IN AUTO MODE, PUMPS WILL RUN BACK TO MINIMUM SPEED (APPROXIMATELY 50% POWER) | (SEE REACTOR FEEDWATER CONTROL CIRCUIT ABOVE) | |

## APPENDIX A – BUS TABLES

## SHOREHAM CONTROL SYSTEM FAILURE ANALYSIS

| | SYSTEM | COMPONENT DESCRIPTION | PRIMARY EFFECT | SECONDARY EFFECT | COMBINED EFFECTS |
|---|---|---|---|---|---|
| DC BUS 1R42-BA-N1 125 VDC — 1R42-PNL-A4 | RFPT CONTROL | REACTOR FEEDWATER PUMP TURBINE A PANEL 2 EHC (REACTOR FEEDWATER PUMP TURBINE B – PANEL 1R42-PNL-B4) | CONTINUES IF AT SPEED | NONE, IF AT SPEED | MAIN TURBINE TRIP |
| 1R42-PNL-C2 | MAIN TURBINE CONTROL | MAIN TURBINE PANEL 1 EHC | MAIN TURBINE TRIP | MAIN TURBINE TRIP | |
| DC BUS 1R42-BA-N2 125 VDC — 1R42-PNL-B4 | FEEDWATER | HIGH LEVEL B TRIP CIRCUIT | 2 OF 3 HIGH LEVEL TRIP INTACT, BUT B TRIPPED | | NONE |
| | RFPT CONTROL | REACTOR FEEDWATER PUMP TURBINE B PANEL 3 EHC (REACTOR FEEDWATER PUMP TURBINE A – PANEL 1R42-PNL-A4) | CONTINUES IF NOT AT SPEED | NONE, IF AT SPEED | |

## APPENDIX B

## ELIMINATION CRITERIA

| Elimination Criterion * | Basis |
|---|---|
| N1 | Components whose failure effects are clearly bounded by a dominant failure effect on the same bus can be eliminated by inspection. An example would be the loss of several trips such as feedwater turbine overspeed trip on the same bus as the solenoid that controls all remote trips. The solenoid loss is clearly the dominant effect. Also in the case of identical components, only one of the components on that bus need be listed. |
| N2 | Instrumentation with no direct or indirect controlling function or passive input (such as a permissive) into control logic. Instrumentation and other dedicated inputs to the process computer, as well as the computer itself, may be excluded. Operator actions as a result of indications are not considered control functions for the control systems failure analysis. |
| N3 | Control systems and controlled components (pumps, valves) which have no direct or indirect interaction with reactor operation/parameters. Examples are communications, most unit heaters and controls, lighting controls, ventilation control systems for exterior buildings, machine shop equipment, refueling or maintenance equipment controls, etc. |
| N4 | Control systems and controlled components (pumps, valves) that do interact or interface with reactor operating systems but which cannot affect the reactor parameters (water level, pressure or reactivity) either directly or indirectly. Examples are: some offgas components, area radiation monitors. |
| N5 | Systems which are not used during normal power operation. For example, eliminate start-up, shutdown or refueling systems not used during normal operation. |
| N6 | Some lube oil pumps are powered from AC busses but have a back-up pump powered from a DC source. Since a single electrical failure cannot disable the lube oil function these components can be eliminated from the analysis. |
| Y | Requires further analysis. |

* In some cases more than one of these criteria may apply.

# APPENDIX C

## SAMPLE LOAD TABLE

| Power Bus (AE Designation) | System (including MPL #) | System Control and Instrumentation Loads on Bus | GENERAL EFFECTS: Limitations on the system's capability to perform its principal function due to loss of bus | SPECIFIC EFFECTS OF BUS TO SYSTEM: Effect on System Subfunctions | Effect on other Systems | CODE[2] | Effects (within 10 mins) on REACTOR WATER LEVEL, PRESSURE or CPR | Inputs Required from other systems and effect of LOSS of input |
|---|---|---|---|---|---|---|---|---|
| *1N34-PNL-L01 | N34 | 1N34-LS002A | Pump 1N34-P-183 will be operable from 1N34-LS003 | None | None | D | None | |
| | | 1N34-LS002B | | " | " | " | " | |
| *1N34-PNL-L01 has two power supplies from 1R35-PNL-H7 (feed from Bus 11) and 1R35-PNL-H8 (feed from Bus 12) with an automatic switch. Therefore, panel will not lose power if one bus is interrupted (FE-SCD, FE-SLL) | | 1N34-LT002A | | " | " | " | " | |
| | | 1N34-LT002B | | " | " | " | " | |
| | | 1N34-TC009A | 1N34-TCV009A Falls Open | RFPT L.O. Cooler T.C.V. Falls Open | Increased TB CLCW flow cools oil. May create low oil temp alarm | " | " | |
| | | 1N34-TC009B | 1N34-TCV009B Falls Open | Same | Same | " | " | |
| 1N21-RK-21[1] | N11 | 1N11-PT001 | Loss of Signal | None | None | " | " | |
| | | 1N11-PT003 | " " " | " | " | " | " | |
| | | 1N11-PT011A | " " " | " | " | " | " | |
| | | 1N11-PT011B | " " " | " | " | " | " | |
| | | 1N11-PT013A | " " " | " | " | " | " | |
| | | 1N11-PT013B | " " " | " | " | " | " | |
| | | 1N11-PT014A | " " " | " | " | " | " | |
| | | 1N11-PT014B | " " " | " | " | " | " | |
| | | 1N11-PT014C | " " " | " | " | " | " | |
| | | 1N11-PT014D | " " " | " | " | " | " | |
| | | 1N11-PT015A | " " " | " | " | " | " | |
| | | 1N11-PT015B | " " " | " | " | " | " | |
| | | 1N11-PT016A | " " " | " | " | " | " | |
| | | 1N11-PT016B | " " " | " | " | " | " | |
| | | 1N11-PS015W | None | " | " | " | " | |
| | | 1N11-PS015X | None | " | " | " | " | |
| | | 1N11-PT017A | Loss of Signal | " | " | " | " | |
| | | 1N11-PT017B | " " " | " | " | " | " | |
| | | 1N11-PT019 | " " " | " | " | " | " | |
| | | 1N11-PS019 | " " " | " | " | " | " | |
| | | 1N11-PS019Y | None | " | " | " | " | |
| | | 1N11-PS015Z | None | " | " | " | " | |
| 1N21-RK-21 | N21 | 1N21-PS-005A | Loss of Signal | None Criteria N-2 | " | " | " | |
| | | 1N21-PS-005B | " " " | " " " | " | " | " | |
| | | 1N21-PT-005A | " " " | " " " | " | " | " | |
| | | 1N21-PT-005B | " " " | " " " | " | " | " | |
| | | 1N21-PT-007 | " " " | " " " | " | " | " | |
| | | 1N21-PT-008A | " " " | " " " | " | " | " | |
| | | 1N21-PT-008B | " " " | " " " | " | " | " | |
| | | 1N21-FC010 | 1N21-FCV010 Falls closed | Water Quality recirc normally closed FCV falls closed | None-Startup System | " | " | |