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PRELIMINARY SYSTEMS-INTERACTION RESULTS
FROM THE DIGRAPH MATRIX ANALYSIS OF THE
WATTS BAR NUCLEAR POWER PLANT
SAFETY-INJECTION SYSTEMS

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ABSTRACT

This report provides preliminary results generated by a Digraph Matrix Analysis (DMA) for a Systems Interaction Analysis performed on the Safety Injection System of the Tennessee Valley Authority Watts Bar Nuclear Power Plant. An overview of DMA is provided along with a brief description of the computer codes used in DMA.

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CONTENTS

	<u>Page</u>
Abstract	111
Illustrations	vi
Tables	viii
1.0 Introduction	1
1.1 Background	1
1.2 Statement of Problem	3
1.3 Preliminary Results	3
1.4 Organization of Report	7
2.0 DMA Demonstration	9
2.1 Scope of Effort	9
2.2 General Summary of DMA	10
2.3 Watts Bar Safety Injection Systems' Description	19
2.4 System Modeling	27
2.4.1 Modeling Overview	27
2.4.2 Constructing the Success-Oriented Digraph	27
2.4.3 Expansion via Unit Models	35
2.4.4 Modeling Human Intervention	54
3.0 DMA Results on Safety Injection Pump Injection System	55
3.1 Scenarios Studied	55
3.2 Scenario 1 - Residual Heat Removal Unavailable	56

3.3 Scenario 2 - Residual Heat Removal Path Available	59
3.4 Scenario 3 - Safety Injection Instrumentation Fails, One Remote Operator, No Local	59
3.5 Scenario 4 - Safety Injection Instrumentation Fails, One Remote Operator, No Local Operators, Fuse Blows	66
4.0 Conclusion	69
References	73
Appendix A: Overview of DMA Computer Codes	75
Appendix B: Complete Digraph Set for SIPIS	93
Appendix C: Adjacency Element List for SIPIS	119

ILLUSTRATIONS

	<u>Page</u>
1. Singleton/Doubleton Results for SIPIS	5
2. Overview of DMA Procedure	13
3. Overview of Construction of Global Digraph	14
4. Overview Flowchart of Digraph Matrix Analysis	17
5. Flow Diagram - Safety Injection System	21
6. Systems Required for Safety Injection	25
7. Safety Injection Success Criteria	29
8. Success-Oriented Digraph of Safety Injection System	33
9. Failure-Oriented Digraph of Safety Injection System	37
10. Redundancy to Valve Link	41
11. Control of Motive Power to Valve Motor	41
12. Control Power Switching	41
13. Safety Injection Logic Activator	43
14. Remote Operator Switch	43
15. Indicator Light Actuation	43
16. Power for the Valve Heater	47

17. Backup Remote Operations	47
18. Local Operator Valve Actuation	47
19. Flow Control Valve Unit Model	51
20. Singletons and Doubletons for Scenario 1	57
21. Singletons and Doubletons for Scenario 2	61
22. Singletons and Doubletons for Scenario 3	63
23. Singletons and Doubletons for Scenario 4	67
24. Switch Modeling	71
APPENDIX A	
A-1 DMA Data Processing Flow	77
A-2 Input/Output for Code ADJ-	79
A-3 Condensation Program Operation	81
A-4 Reachability Code Flow	85
A-5 Processing the Deconditioned Graph	87
A-6 DMA Outputs	89
APPENDIX B	
B-1 Failure-Oriented Safety Injection Core Digraph (SIPISCORE)	95
B-2 Unit Model for Flow Control Valve (FCV.DAT)	97
B-3 Unit Model for Safety Injection Pump (SIP.DAT)	99
B-4 Unit Model for Safety Injection Logic (SILOGIC1.DAT)	101
B-5 Unit Model for Safety Injection Logic (SILOGIC2.DAT)	103
B-6 Unit Model for Safety Injection Logic (SILOGIC3.DAT)	105
B-7 Unit Model for Safety Injection Logic (SILOGIC4.DAT)	107
B-8 Unit Model for Safety Injection Logic (SILOGIC5.DAT)	109
B-9 Unit Model for Safety Injection Logic (SILOGIC6.DAT)	111
B-10 Unit Model for Safety Injection Logic (SILOGIC7.DAT)	113
B-11 Unit Model for Protection Set (PS.DAT)	115
B-12 Unit Model for Electrical Power System (EPS.DAT)	117

TABLES

	<u>Page</u>
1. Overview of Digraph Matrix Analysis	10
2. Adjacency Element Data for Flow Control Valve	53
3. Comparison of DMA Processing Times	70

1.0 INTRODUCTION

1.1 Background

The term Systems Interaction (SI) has been introduced by the NRC to identify the concepts of spatial and functional coupling of nuclear power plant systems which lead to system interdependencies. Spatial coupling refers to dependencies resulting from shared environmental conditions within the plant; functional systems interactions include coupling due to shared support systems (process coupling) and interdependencies due to dynamic human error.

The Office of Nuclear Reactor Regulation of the NRC is developing a program to further define and subsequently implement SI regulatory requirements for light water reactors (LWR's). Battelle Columbus/Pacific Northwest Laboratories¹, Brookhaven National Laboratory², and Lawrence Livermore National Laboratory³, assisting the NRC, unanimously recommended that risk assessment techniques, such as event tree/fault tree methods, combined with walk-through inspections could be used for identifying SI's. The Power Authority of the State of New York (PASNY) has independently developed a systems interaction methodology for application to the interconnected systems at Indian Point-3^{4,5}. The method was based on "shutdown logic diagrams" which were success-paths of operational sequences.

At present, NRC is considering three concepts of how to integrate a systems interaction study with existing Probabilistic Risk Assessment (PRA) techniques.

One concept is that systems interactions can be adequately analyzed by expanding the scope and boundary conditions of the fault tree analysis portion of PRA and putting additional emphasis on dependency analysis techniques such as generic analysis⁶ and minimum cut-set common cause/mode analysis⁶. NRC's initial guidance for this point of view has already begun⁷.

A second, and closely related concept is that systems interactions can be incorporated into a PRA at the event tree stage of analysis. This approach attempts to capture systems interactions at an earlier stage of analysis. By

treating dependencies in the event tree analysis portion of a PRA, the requirement of fault tree modeling at additional levels of detail is reduced⁷.

The third concept is based on matrix representation of logic diagrams and is called Digraph Matrix Analysis (DMA)^{8,9}. This technique would be applied after an event tree analysis has identified the accident sequences, but prior to fault tree construction. It treats an accident sequence consisting of several systems along with their support systems as a single success-oriented model. Thus, instead of constructing a reliability block diagram (or equivalent) and a fault tree for each individual system in an accident sequence, as in the Reactor Safety Study¹⁰, the entire accident sequence is modeled as a single success-oriented operational logic diagram (which includes AND and OR gates). The advantages of such a model are based on the ease of success-oriented modeling and highly efficient computer processing for singletons and doubleton cut-sets. Once the systems interactions are identified, the fault trees and the rest of a PRA could be completed.

A review of the fundamental mathematical aspects of fault-oriented and success-oriented risk analysis (including Digraph-Matrix Analysis) was presented in reference 8, which offered insight into the trade-off advantages and disadvantages of each. Initial guidance for DMA was presented in reference 9.

1.2 Statement of the Problem

The NRC is exploring which of the available systems interaction methodologies can be recommended in future regulatory requirements.

This report provides preliminary results from the DMA demonstration on the Watts Bar safety injection systems for NRC review.

The DMA study began in early September, 1982 using information contained in the Watts Bar Final Safety Analysis Report (FSAR). A trip to Watts Bar was made in mid-November to inspect and gather detailed P&I diagrams for the reactor. At this time approximately 75% of the target systems have been modeled and analyzed.

1.3 Preliminary Results

To date, the portion of the safety injection system which is driven by the safety injection pumps has been modeled and analyzed. The complete model for the Safety Injection System consists of 1012 nodes. Approximately 100 of these nodes represent operator inputs. Each of these operator inputs is considered to be an independent event, even though there are only a small number of operators at the facility. The effects of grouping these operator inputs will be discussed in Section 3. The results presented in this section give credit to all possible manual overrides, hence perhaps overestimate the robustness of the safety injection system. This arises from the assumption that the operators will, if possible, override any failure of the automatic actuation of the Safety Injection components. A more complete discussion of the results of the DMA can be found in Section 3 of this report along with a reduction in the independent manual override ability.

The Watts Bar Safety Injection System has been analyzed for all sets of single failures (Singletons) and double failures (Doubletons) which will cause a failure of the safety injection pump side of the safety injection system. In addition, the safety injection system is now being analyzed for special tripletons which include specific failures such as the loss of off-site power, operator failure, etc.

The singletons for the safety injection pump portion of the safety injection system are shown in Figure 1. The analysis for this figure was based on the assumption that alternate flow paths through the residual heat removal pumps could not provide adequate flow for safety injection. Singletons for the systems are VC63510, FCV635, and RWST. Singletons VC63510 and FCV635 are a check valve and motor operated valve in series with the borated water source of the SIPIS,* the refueling water storage tank (RWST). Failure of any one of these three components will prevent successful safety injection via SIPIS. If a path through the residual heat removal pumps could provide adequate flow, then only RWST would be a singleton. This will be further discussed in Section 3.

The doubletons for the safety injection pump portion of the safety injection system are shown in the matrix of Figure 1. The data in the matrix is read in the following manner: a set of components represented by a row/column pair indicated by an asterisk is a doubleton. For example COIL2 forms a doubleton with COIL2S.

The doubletons fall into two categories: 1) Failure of both pump TRAIN A and pump TRAIN B hardware, and 2) Operator induced systems interactions. The TRAIN B block in the doubleton array has safety injection pump 1B-B (SIP1BB) and valves in series with it as well as MOT2, R2, and COIL2 which are the pump motor, actuating relay and relay actuating coil, respectively. There are also 2 "degradation nodes", DSARWST1 and DSDRHR1, which contribute to system degradation and not failure. These valves could divert some flow from safety injection if they were to fail, but their failure must be considered a degradation as opposed to complete failure. DFE6320 is an inline flow restricting orifice for a differential pressure transducer and DUM1 is a dummy node used only to simplify input. The TRAIN A block has elements corresponding to those in TRAIN B. A second type of doubleton arises from the two trained 6900 volt shutdown boards. The component labeled 6900VS1A-A is the electrical shutdown board which powers safety injection pump (SIP1AA) and 6900VS1B-B is the shutdown board which powers pump, SIP1B-B.

* SIPIS - Safety Injection Pump Injection System.

Figure 1. Singleton/Doubleton Results for SIPIS

Doubletons were also found which involved operator corrective action. If the safety injection instrumentation were to fail the operators would not know that the flow control valve FCV6322, the primary path to the core must be bypassed if it failed. Thus the safety injection instrumentation, SIINST, forms a doubleton with FCV6322. Finally, a doubleton was found which involved the action of an operator, OPWF20, who could disable the automatic safety injection actuation logic. Should this occur simultaneously with failure of SIINST, the pumps would not receive automatic actuation and the operators would not be aware of the need for manual safety injection system actuation.

1.4 Organization of this Report

The remainder of this report contains a more detailed description of the DMA demonstration.

In section 2.0, the details of the modeling of the Safety Injection System are discussed along with a brief review of DMA. Section 3.0 presents a more complete discussion of the results of the analysis including the impact of various types of operator failures. In Section 4.0, a short discussion of the lessons learned from the DMA demonstration is presented. Appendix A provides an overview of the computer codes used for Digraph Matrix Analysis. A complete set of digraphs for the SIPIIS and the corresponding computer input are contained in Appendices B and C, respectively.

2.0 DIGRAPH MATRIX ANALYSIS DEMONSTRATION

2.1 Scope of Effort

The objective of this effort is to demonstrate the utility of Digraph Matrix Analysis, DMA, in the determination of systems interactions within the high pressure safety injection systems of the Watts Bar Nuclear Plant (WBNP). The scope has been restricted to the two safety injection systems which would be called upon to respond to a small LOCA.* These systems are the Safety Injection Pump Injection System, SIPIS, and the Centrifugal Charging Pump Injection System, CCPIS. This systems interaction study covers necessary support systems which include:

1. Electrical Power (down to 480v)
 - 1.1 Off-Site
 - 1.2 On-Site
 - Generators
 - 4 Auxiliary Diesel Generators
2. Vital Instrumentation Power (to 120v)
 - 2.1 Transformers
 - 2.2 Vital Batteries
 - 2.3 Distribution to all Four Protection Sets
3. Safety Injection Logic
 - 3.1 Automatic
 - 3.2 Manually Initiated

The effect of common component location has been excluded from this study by sponsor directive.** System interactions due to human errors have been

* Loss of cooling accident. Small LOCA defined as 3/4" to 1 1/2" diameter break in the reactor coolant loops.

** DMA can be used to analyze the effects of common component location, however, this analysis would have required the determination of the physical location of each component, which was beyond the scope of this effort.

studied, including the effects of:

1. operator non-action in overriding a failed automatic system; and
2. incorrect or malevolent operator action.

An example of the first situation is the failure to manually switch from a dead power bus to a live bus. An example of the second type would be the accidental or deliberate turn-off of the safety injection system.

2.2 General Summary of DMA*

A full Digraph Matrix Analysis of a reactor can be broken down into the 4-step effort as listed below in Table 1.

Step 1: Select combinations of systems for detailed evaluation.
(This is equivalent to the PRA event tree analysis designed to find accident sequences).

Step 2: Construct a global digraph model for each accident sequence.

Step 3: Partition digraph models into independent subdigraphs and find singleton and doubleton minimum cut-sets of accident sequences using Reachability/Path-Set Codes.

Step 4: Evaluate singletons and doubletons and display answers.

Table 1. Overview of Digraph Matrix Analysis.

The first step in a DMA is equivalent to the start of a traditional PRA, and so DMA could be treated as a Black Box that plugs into a PRA after event tree analysis, but prior to the fault tree construction. Step One starts with the studying of plant design and continues with the development of both functional

* Digraph Matrix Analysis is described in NUREG/CR-2915, "Initial Guidance on Digraph-Matrix Analysis for Systems Interaction Studies at Selected LWR's".

event trees relating to the safety functions and systemic event trees to find the accident sequences. Then, in Step 2, instead of constructing reliability block diagrams and conducting an independent fault tree analysis on each front-line system in the accident sequences as in a PRA, the entire accident sequence and all of the nonsafety grade support systems as one success-oriented model are considered. This greatly expands the computer problem size. In order to perform computer analysis of such an expanded problem, only singleton (common modes/causes), doubleton and special tripleton cut-sets are searched out. The dual model is then formed by changing the original AND gates to OR gates and vice versa. To solve for singletons, doubletons, and tripletons of very large models, DMA uses a computer reachability code which finds the connectivity of the logic model.

Step three is a computer efficiency effort that attacks the large computer problem by partitioning and condensing each accident sequence model. In step four, the importance of each singleton and doubleton is evaluated.

Figure 2 provides an overview of the DMA procedure. Digraphs of subsystems of the facility are drawn by the analyst using plant P&I diagrams, schematics, and operating procedures. The resulting digraph is a diagram very similar to the P&ID, but with logic gates. This type of model is very easy for NRC to review and verify. The digraph is then analyzed for a set of single, double, and special triple cut-sets which will cause a system failure. This analysis is performed using a special code called a reachability code.

The construction of the global digraph follows the iterative procedure illustrated in Figure 3, using a series of expansion steps. These expansions, which are centered on each of the components identified in the digraph, follow a specified algorithm. The expansion of each of these components identifies new components that must then be expanded. This expansion procedure is repeated until all components of the subsystems have been included. As noted, each successive expansion identifies new components such as indicator lights, batteries, motors, etc.

S.O. = SUCCESS ORIENTED

F.O. = FAILURE ORIENTED

Figure 2. Overview of DMA Procedure

Figure 3. Overview of Construction of Global Digraph

The expansion process is complete when no new components are identified or when all new components are outside of the physical or functional boundaries chosen for the system interaction analysis. This set of components may, at some later time, become a new set for expansion. The expansion of each component is performed using a specified algorithm called a "unit model", which specifies a description of the direct relationships of each component to the other components in the system.

Figure 4 illustrates the procedure to be used in global digraph construction and analysis. The procedure follows the broad outline described above and includes substeps that allow the verification of the modeling procedure and the generation of intermediate results prior to the completion of the global digraph. These intermediate results are useful both for verifying the input data and for identifying components that can cause system failure before the complete digraph is constructed.

The construction of the global digraph in Substep 2a starts with a single success-oriented digraph built for each accident sequence* and includes a combination of front-line systems and their support systems. This digraph serves as the foundation on which the global digraph can be constructed by successive expansions. Substep 2b is the conversion of the success-oriented digraph into the dual digraph. The dual digraph is created by converting all original AND gates to OR gates and all original OR gates to AND gates. Subsequent expansions are performed on this dual digraph.

 * The success-oriented digraph for each accident sequence will be composed of the success-oriented digraphs for the systems involved in the accident sequence. Thus, the construction of a success-oriented digraph for each accident sequence involves interconnection of the appropriate system digraphs.

Figure 4. Overview Flowchart of Digraph Matrix Analysis

In substep 2c, the dual digraph is converted into the adjacency input required by a reachability code. The reachability code used in Substep 2d uses a path-finding procedure capable of Boolean manipulation to process adjacency input to find all common mode failures (singletons). The codes used provide a printed list of the input data, the component mnemonics, and the singletons. In Substep 2e, this output is used to identify errors in the input data or models. After correcting any errors, the adjacency information is processed through the reachability code to determine all singletons and doubletons in Substep 2f.

In Substep 2g, the model is expanded through the use of a detailed model for each component based on the unit models contained in a unit model library. Substep 2g eventually results in the detailed global digraph. The expanded digraph is now processed in the same manner as the original digraph (Substeps 2h - 2j). After analyzing the results from this stage of expansion, the digraph is again expanded around the new components introduced in the preceding step. This iterative expansion and analysis procedure leads to the global digraph and all of the singleton and doubleton cut-sets of the accident sequence. As the digraph grows in size, it may eventually exceed the size limitation of the computer code. At this point, it becomes necessary to partition it into subdigraphs and then to combine the results of processing each subdigraph.

2.3 Watts Bar Safety Injection System Description

Two high pressure injection systems are used to deliver coolant to the Watts Bar reactor core in the event of a small LOCA. These systems are:

- Safety Injection Pump Injection System (SIPIS), and
- Centrifugal Charging Pump Injection System (CCPIS).

Both systems are triggered by a safety injection signal generated by the safety injection logic. The flow diagram for the Watts Bar Safety Injection System is shown in Figure 5, with a typical coolant flow path traced in heavy dashed black lines.

POWERHOUSE
UNITS 1 & 2

FLOW DIAGRAM
SAFETY INJECTION SYSTEM

WATTS BAR NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY

2. SMYTH	RECOMMENDED	1. SMYTH
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Both injection systems draw borated water from the refueling water storage tank (RWST) and electrical power from Electrical Power Support (EPS). Charging pump injection requires the changing of the state of several flow control valves whereas safety injection pump injection requires no valve position changes. Flow from the Charging Pump Safety Injection System will generally pass through the boron injection tank, with alternate paths possible if manually actuated. Injection flow from both injection systems is generally into the cold leg of each of the four coolant loops with alternate injection paths provided into the hot legs.

Another alternate set of flow paths exists from the RWST through the residual heat removal pumps to the Safety Injection and Charging pumps. At this time, no information is available as to the adequacy of this paths for safety injection.

Power for both sets of injection pumps is provided by the Electrical Power Support system (EPS). This system provides all electrical power down to 480 vac. Motor operated flow control valves are also operated from this electrical power source. Electrical power to vital instrumentation is provided by the Protection Set (PS) system which converts the 480 vac to 120 vac.

Safety injection is actuated automatically from the safety injection logic (SILOGIC). Inputs to SILOGIC are derived from the vital instrumentation. Extensive manual backups and overrides have been incorporated into the Safety Injection System. Figure 6 represents the connectivity of the systems required for safety injection.

KEY

EPA ELECTRICAL POWER SUPPORT
 PS PROTECTION SETS
 SILOGIC SAFETY INJECTION SIGNAL ACTUATION LOGIC
 SIPIS SAFETY INJECTION PUMP INJECTION SYSTEM
 CCPIS CENTRIFUGAL CHARGING PUMP INJECTION SYSTEM
 SIP SAFETY INJECTION PUMPS
 CCP CENTRIFUGAL CHARGING PUMPS
 FCV FLOW CONTROL VALVES
 PATH FLOW PATH TO RCS

Figure 6. Systems Required for Safety Injection

2.4 Safety Injection System Modeling

2.4.1 Modeling Overview

In this section, the generation of the complete system digraph will be discussed.

The first step in the construction of the digraph is the review of the reactor piping and instrumentation diagrams (P&ID's). A success-oriented digraph is then drawn which represents successful operating of the safety injection system. The scenario which was modeled is the emergency coolant injection (ECI) in response to a loss of coolant accident (LOCA). This scenario corresponds to the S-1 scenario of WASH-1400 [10]. It has been assumed for the purpose of this study that both safety injection pumps or at least 1 SI pump and 1 centrifugal charging pump would be required to supply adequate flow at early times in this scenario.* Following page 15.3-3 of the FSAR, we have not considered use of injection from the residual heat removal (RHR) pumps for this early time portion of the scenario. Figure 7 gives the success oriented digraph for this situation. This digraph shows that in order to achieve successful safety injection, at least one path (PATH) must be open to the core from the RWST and there must be sufficient pressure. Sufficient pressure is represented by the AND'ing of the combination of pumps as shown. At the present time (Feb 1983), the modeling of the Safety Injection Pump portion of the Safety Injection system is complete and will be discussed in the following section.

2.4.2 Constructing the Success-Oriented Digraph

Modeling of PATH to the core is accomplished by mapping the P&ID (Figure 5) into a Success-Oriented digraph. This mapping is accomplished by tracing all paths from the source of the borated safety injection water to the core. Figure 8 shows the S.O. digraph. A typical path is traced in with a heavy dashed line in both the P&ID and the S.O. digraph. In addition, some

* This LOCA is called a "small LOCA" in Reference 13. The success inertia used for early times in this study is consistent with the criteria of Reference 13.

Figure 7. Safety Injection Success Criteria

corresponding components on the digraph and P&ID of Figure 5 have been highlighted with the same symbols and notation consistent with the P&ID has been used throughout the digraphs to assist the reader. Each component on each of the paths in the P&ID is represented by a node in the S.O. graph.

The success-oriented digraph shows that the continuity of flow in any one of eight paths to the core is adequate for safety injection. Thus a failure in all eight paths is required for a failure of safety injection. Flow to subgroups of these eight paths passes through one of three flow control valves, FCV63157, FCV6322 or FCV63156. The safety injection pump flow paths are "trained" to these valves with the upper train on the S.O. graph corresponding to pump 1B-B and the lower train corresponding to pump 1A-A.

The Watts Bar designers have provided a cross-over from safety injection pump B to FCV6322 and FCV63156. A cross-over from TRAIN A is provided to corresponding valves in TRAIN B. This cross-over is shown by the double-sided AND gates in the center of Figure 8. This double-sided gate means that flow in either direction is possible provided that the Flow Control Valve is open.

Borated water for both trains is provided from the Refueling Water Storage Tank, RWST, through check valve, VC63510 and flow control valve, FCV635. Inspection of the main path of the success-oriented digraph shows no single components (except VC63510, FCV635, or RWST) which would cause all eight injection paths to fail given residual heat removal pump flow or path inadequacy. This model is of course not complete, in that the supporting systems have not been included. These support systems could add singletons. Shown in dashed lines on the S.O. digraph are the paths available through the residual heat removal pumps which bypass VC63510 and FCV635. An analysis presented in Section 3 will consider the case of flow through these pumps.

The next step in the DMA procedure is the creation of the failure oriented digraph from the success-oriented graph. This dual digraph models the flow of "failures" throughout the safety injection system. The dualing operation is performed by converting all AND gates to OR gates and vice versa. The failure-oriented digraph is shown in Figure 9. In this digraph, the eight input OR gate to the node PATH has been replaced by an eight input AND gate.

Thus all eight paths would have to fail in order for a failure to reach PATH. The paths for the eight parallel injection paths are identical to the S.O. paths back to the three flow control valves FCV63157, FCV6322, FCV63156. The cross-over of the S.O. digraph is replaced with the network in the center of the figure.

In the absence of flow through the residual heat removal pumps, flow to this cross-over network follows the identical paths as in the S.O. digraph since there are no AND or OR gates in the S.O. digraph. It can be seen from this digraph that a failure in RWST would propagate forward through both safety injection pump trains to the cross-over network. Thus a failure in either RWST, FCV635 or VC63510 would cause the flow in both trains to fail. At this level of modeling, the only singletons for safety injection are RWST, FCV635 AND VC63510 (without residual heat removal paths). Flow through the residual heat removal pumps and associated hardware would remove the two valve singletons. This flow has not been modeled in detail. Doubletons occur due to failures in both safety injection pump trains. For example, SIPIB-B and SIPIA-A form a doubleton.

Each of the components is now expanded by using unit models. This unit model expansion will add to the network the components which the system depends on for operation. Thus, unit model expansions may uncover a component (or component pair) for which each side of a redundant system depends.

2.4.3 Expansion via Unit Models

Each of the components identified in the digraph must now be expanded using the appropriate unit model. This expansion procedure, in addition to providing detail about the operation and construction of specific components, identifies support systems necessary for safety injection. For example, unit model expansion for a Flow Control Valve identifies Electrical Power Support (EPS), Protection Set (PS), and Safety Injection Logic (SILOGIC) as support systems for safety injection as well as operator inputs needed for manual actuation.

Unit models are constructed using detailed information about the mechanical

Figure 9. Failure-Oriented Digraph of Safety Injection System

configuration, operation, and connectivity of a component in the system. Unit models for the specific use of a component are generally created from a generic unit model for the component type. Thus a unit model may be used many times in a system digraph with appropriate modification and notation. In modeling the safety injection pump portion of the safety injection system, the following unit models were used:

FCV - Flow Control Valve
SIP - Safety Injection Pump
EPS - Electrical Power Support
SILOGIC - Safety Injection Logic
PS - Protection Set

The safety injection pump injection system consists of two flow control valves which have to be reoriented for S.I.,* two electrical power (EPS) distribution networks, four nearly identical protection sets, two identical safety injection pumps, and two identical logic trains. Each of these "components" was modeled in detail and then fit to the specific application within the failure oriented system digraph. Each of these unit models was independently tested, debugged and revised before being integrated into the global failure-oriented digraph. The digraph and commented adjacency element data for each of these models is presented in Appendices B and C, respectively. The unit model for the flow control valve will be used here to illustrate the construction procedure.

FLOW CONTROL VALVE UNIT MODEL

The Flow Control Valve Unit model will be developed in the series of steps and figures described below. The flow control valve** can be actuated in three ways, two by the motor (remote and local), and one by manual cranking of the

* In the absence of a failure, no FCV's need to be reoriented. To use alternate injection paths, at least one FCV must reoriented.
** Details about the valve operation and construction were obtained from TVA Drawings: 45W60-63-8 and 45W751-8.

link (LINK2) to the valve plug. The valve is normally driven from an electric motor, MOT1, which draws power from a 480 vac Reactor Motor Operated Valve Board (POWER1) in the Electrical Power Support (EPS) system. If the motor drive were to fail, the operator (OPRA1) could override. Thus both the motor and the operator would have to fail for the link not to be turned. This redundancy is shown in Figure 10 as an AND gate to the valve link.

Control of Motive Power to Valve Motor (See Figure 11)

The valve motor, MOT1, needs both a control signal and electrical power to operate. The control signal energizes the relay coil, COIL1, which closes Switch, SW1. Motive power from the variable magnetic overcurrent trip, VMOT1, then flows through switch, SW1, to contact 1, CON1, and then to the motor. The current to the over current trip, VMOT1, passes through Relay, R1, and comes from a 480 vac Reactor Motor Operated Valve Board, POWER1.

Control Power Switching (See Figure 12)

Power to relay coil, COIL1, is supplied by one of four "switches". These are:

- SWA1 - The normal remote operator actuated switch
- SWB1 - A local operator switch (at the valve)
- SWC1 - Alternate remote operator actuated switch
- SWS12 - The automatic actuation switch.

Safety Injection Logic Activator (See Figure 13)

The flow control valve automatic actuation occurs when SWS12 closes. This switch closes on receipt of the safety injection logic signal, SILOGIC1, if the switch, SWA4, has been placed in the "auto" position by the operator, OPWF1. The node OPWF1 represents the failure of the operator to leave this switch in the "auto" position. Control power which will pass through this switch comes through the fuse, FUSE2, from the transformer, XFMR1.

Legend

FCV1 = Flow Control Valve 1
 LINK2 = Mechanical shaft which moves valve plug
 MOT1 = Valve Motor
 OPRA1 = Operator who overrides valve motor

Figure 10. Redundancy to Valve Link

Legend

VMOT1 = Variable magnetic overcurrent trip
 CON1 = Contact
 COIL1 = Relay coil
 SW1 = Switch
 R1 = Relay
 POWER1 = Reactor power board

Figure 11. Control of Motive Power to Valve Motor

Legend

COIL1 = Relay coil
 SWA1 = Normal remote operator actuated switch
 SWSI2 = Automatic actuation switch
 SWC1 = Alternate remote operator actuated switch
 SWB1 = Local operator operator switch (at the valve)

Figure 12. Control Power Switching

Figure 13. Safety Injection Logic Activation

Legend

XFMR1 = Transformer 1
 FUSE2 = Fuse 2
 OPWF1 = Operator
 SWA4 = Switch
 SILOGIC1 = Safety injection logic signal
 SWSI2 = Automatic actuation switch

Figure 14. Switch SWA1

Legend

LT1 = Indicator light
 LT2 = Indicator light
 SW2 = Switch 2
 SW3 = Switch 3
 LINK1 = Mechanical sensing link

Figure 15. Indicator Light Actuation

Remote Operator Switch (Figure 14)

Switch SNA1, the normal remote operator actuated switch, receives its power from FUSE2. The switch is actuated by a remote operator, OPRF1, in the main control room who receives information on the need for safety injection from the safety injection instrumentation, SIINST, and from the knowledge that the valve is in the wrong position, DUM11. He can get this information in one of five ways, all of which must fail in order for no information to be available. These are:

1. The local operator at the valve, OPRC1;
2. An indicator light, LT2 (Red or Green);
3. An indicator light, LT1 (Green or Red);
4. Flow data, FDATA; and
5. A local operator at the valve who manually operates the valve, OPRA1.

Indicator Light Actuation (See Figure 15)

The indications of valve position, LT1 and LT2, are derived from two separate switches, SW3 and SW2 which are driven by the mechanical sensing link, LINK1, attached to the valve plug.

Power for the Valve Heater (See Figure 16)

Power for the valve heater, VHTR1, comes through either FUSE1 or FUSE2 from transformer, XFMR1. The power is routed generally through FUSE2, unless the remote operator, OPRF3, switches the transfer switch SWX1. The operator would switch over on the basis of an indicator light, LT5 or on indication of a lack of flow, FDATA.*

* A modification to this model would be to give the remote operator, OPRF3, the same valve position data as OPRF2, thus replacing FDATA with DUM11 in the AND gate input to OPRF3.

Figure 16. Power for the Valve Heater

Figure 17. Backup Remote Operations, SWC1

Figure 18. Local Operator Valve Actuation

Backup Remote Operations (See Figure 17)

Switch SWC1, the remote backup actuation switch receives its power from FUSE1 and must be actuated by a remote operator, OPRF2, who needs information from the safety injection instrumentation and the valve position indication, DUM11.

Local Operator Valve Actuation (See Figure 18)

Switch SWB1, the local operator actuated switch which enables control power from either fuse, DUM12, is actuated by the local operator OPRC1. This operator responds to valve position indication, DUM13. Indicators LT4 and LT3 are separate local indicators, hence separate from LT1 and LT2. This operator is also allowed all of the information available to the remote operators, DUM11. LINK3 represents the direction of the resistance to manually cranking the valve stem.

Each of the parts of the operation of the Flow Control Valve are combined into the unit model of Figure 19. Depending on the specific implementation of the FCV, various nodes, such as links or operators, may be fed from a single master node with the restriction that feedback links such as LINK3 not be combined with actuating links such as LINK2. It is easy to see how common location, manufacturer, and maintenance could be added to the unit model.

Table 2 is the adjacency element data for the FCV unit model. The decomposition of multiple input AND gates into a series of two input AND gates is done to fit within the constraints of the present codes.

Each FCV valve which must change state to enable injection paths in the SIPIS has been expanded into a similar unit model. Other components such as the safety injection pumps have also been expanded into unit models. Appendix B contains the unit model digraphs for all components in the SIPIS. The complete, commented adjacency element input for SIPIS is given in Appendix C.

The complete model for the SIPIS contains 1012 nodes, approximately 100 of these are operator actions, and about 100 are dummy nodes added for ease of modeling.

OPRC1,SWB1,1	OPRC1 is local operator who ascertains valve position
DUM13,OPRC1,1	by inputs to DUM13 (see 1st comment).
DUM12,SWB1,1	SWB1 is actuator for both normal and emerg. power.

Inputs to DUM13	
LINK3,DUMAND18,DUMAND12	
DUMAND12,DUMAND18,LINK3	
DUMAND13,DUM13,DUM11	
DUM11,DUM13,DUMAND13	
FDATA1,DUMAND13,DUMAND18	
DUMAND18,DUMAND13,FDATA1	
LT4,DUMAND12,LT3	LT3 and LT4 are valve position sensing lights located
LT3,DUMAND12,LT4	next to the valve.

SW3,LT3,1	SW3 is valve position sensing switch.
LINK1,SW3,1	LINK1 is connection of valve plug to SW3 and SW2.
SW2,LT4,1	SW2 is valve position sensing switch.
LINK1,SW2,1	

OPRF2,SWC1,1	
FUSE1,SWC1,1	SWC1 is actuator for emergency control power.
DUM11,OPRF2,1	
OPRF1,SWA1,1	
FUSE2,SWA1,1	SWA1 is actuator for normal control power.
DUM11,OPRF1,1	

Inputs to DUM11	
LT1,DUMAND14,LT2	LT1, LT2 are red and green valve plug position
SW3,LT1,1	indicator lights located in unit main control room.
LT2,DUMAND14,LT1	
SW2,LT2,1	
DUMAND14,DUMAND17,OPRC1	
OPRC1,DUMAND17,DUMAND14	
DUMAND17,DUMAND15,OPRA1	
OPRA1,DUMAND15,DUMAND17	
DUMAND15,DUM11,FDATA1	
FDATA1,DUM11,DUMAND15	

Self-loops for grouping nodes

The following self-loops do not interact with the above model. They will be used when it is desired to group nodes of a kind together. This is accomplished by substituting the J node in the self-loop with the nodes that will be treated identically, e.g., OPLOCAL,OPRA1,1 and OPLOCAL,OPRC1,1 serves to tie OPLOCAL to the 2 local operator nodes. OPLOCAL then may show up as a singleton or doubleton depending upon the aggregate effect of the local operators on the system.

Including the non-interacting self-loops below keeps the variable list from changing if it is desired to do grouping.

OPLOCAL,OPLOCAL,1	
OPREMOTE,OPREMOTE,1	
LINK,LINK,1	
OPREQUIRED,OPREQUIRED,1	OPREQUIRED fails if operator fails to do req'd task.
OPWRONG,OPWRONG,1	OPWRONG fails if operator does wrong task.
0,0,0	

Table 2. Adjacency Element Data for Flow Control Valve

2.4.4 Modeling Human Intervention

The Watts Bar Safety Injection System depends on human operator as backup to the automatic Safety Injection Logic. Consequently, the unit models used in the global digraph have inputs which correspond to operator actions. Two types of these operations have been identified: Those which result in a beneficial result and those which result in a detrimental result. Operators may also be local (at the component) or remote (generally in the main control room). Operators also are sometimes used to override power or control. By grouping these operator nodes by location, impact, power or control, etc., it is possible to assess the aggregate effect on system operation.

In the Flow Control Valve of the previous section, six operator nodes have been identified. In the complete model for safety pump safety injection, over 100 of these operator nodes are used. During normal plant operations, there are only two remote operators, so grouping of these nodes is necessary. This grouping is performed by creating a "master node" which is adjacent to a set of operator nodes. For example, we could study the operation of the system, if all remote operators failed to perform a manual override operation. Several of these cases are being studied and the results for one are presented in the next section.

3.0 DMA RESULTS ON SAFETY INJECTION PUMP INJECTION SYSTEM

3.1 Scenarios Studied

The Watts Bar Safety Injection Pump Injection System has been analyzed for all sets of single (singleton) and double (doubleton) failures which could cause a failure in safety injection in response to a small LOCA for four different scenarios. These scenarios represent different plant conditions and operator responses. These scenarios were:

1. The path through the residual heat removal pumps (RHR) was unavailable. All potential operator overrides are treated as independent.
2. The path through the residual heat removal pumps was available. All potential operator overrides are treated as independent.
3. Safety Injection Instrumentation used by operators to monitor injection fails. There is only one remote (reactor control room) operator with no local operator overrides.
4. Safety Injection Instrumentation used by operators fails. Fuse 3 to SI pump 1B-B fails. There is only one remote operator, all local operators are independent.

The first two scenarios yield the most systems with the least doubletons due to the redundancy provided by having 100 operators who can override failures. Human operators, by Watts Bar design, are an integral part of the safety injection systems. The general DMA model for safety injection uses a separate operator node for each of these potential operator overrides. Thus the system appears considerably more robust than does the actual situation in which there are only a few operators. The model also contains operators (OPW'S) who can cause an incorrect safety injection action. The use of these is somewhat restricted since the model was configured to highlight actions necessary to assure safety rather than to deter malicious or incompetent operators. In the third scenario, all of the operators who can override failures in the safety

injection system are grouped together into one single remote operator. By keeping OPW's separate, the effects of individual, incorrect operator actions can be determined. The results from each of the scenarios will now be discussed.

3.2 Scenario 1 - Residual Heat Removal Unavailable

The results of the first scenario in which flow through the residual heat pumps is unavailable are presented in Figure 20. As can be seen from this figure, the singleton failures are the refueling water storage tank (RWST) and each of the two valves directly in series with it. Doubleton failures fall into two categories: (1) hardware failure in both safety injection pump trains, and (2) failures relative to operator failure override. There are four unique doubletons of the first category. The two pump trains A and B and their electrical support are indicated by nodes 18, 24, 121, and 91. Node 18 is pump train B. The failure of this pump train, with either the failure of pump train A (node 24) or the 6.9 kv shutdown board (node 121) which supports pump SIP1A-A will cause SIPIS to fail. A failure in node 91, which is the power to pump SIP1B-B, will cause safety injection to fail in a manner identical to the failure caused by node 18. Two unique doubletons arise from the failure of operator actions. Both doubletons involve SIINST (node 44), the safety injection instrumentation which would indicate to the operators that safety injection is necessary. Failure of flow control valve FCV6322 (node 22), along with SIINST causes a safety injection failure since the flow control valve is needed for normal injection paths and since all alternate paths require manual actuation of their flow control valves. This manual actuation would not occur if SIINST failed. Failure of node 153, OPWF20, represents the effect of an operator manually overriding automatic safety injection. In this case, safety injection failure would result when either node 153 or 44 failed, since the safety injection pumps would not receive automatic actuation signal or be manually actuated.

3.3 Scenario 2 - Residual Heat Removal Path Available

The results of the analysis of the second scenario are presented in Figure 21. With the additional flow paths provided by paths through the residual heat removal pumps, there is only one singleton, the RWST. This occurs because coolant from the RWST could flow either through the direct path to the safety injection pumps or through a path which branches into two paths in the RHR system and then back to the safety injection pump trains. The doubletons in Figure 21 are the same as the doubletons in Figure 20 with the exception of FCV6348 from pump train B and FCV6347 from pump train A. These valves do not enter into pump train failure because the path from RHR connects downstream from them. New hardware doubletons arise from what amounts to a trained input from the RWST. The valves in the direct lines to the pump trains are the valve singletons from the first scenario, FCV635 and VC63510. The corresponding valves in the residual heat removal lines are FCV631 and VC63502. Failure of either valve in one line with either valve in the other line stops flow from reaching the pump trains, thus creating a doubleton. The failures due to operator interactions remain unchanged.

3.4 Scenario 3 - Safety Injection Instrumentation Fails, One Remote Operator, No Local

The third scenario considers the situation in which the Safety Injection Instrumentation has failed. This instrumentation would be needed by the remote operators to determine a need for manual safety injection actuation. Also, in this scenario there is only one remote operator (or a group of remote operators acting as one) and no local operators to manually actuate the valves and pumps. The singletons and doubletons are shown in Figure 22 for this scenario. The singletons are the same as for Scenario 1 with the addition of FCV6322, the normal injection path valve, and OPWF20, the operator who overrides automatic safety injection. The first new singleton (FCV6322) arises from the fact that, since the operators are unaware of the need for safety injection, they would not enable the alternate injection paths. Since all flow through the normal paths passes through FCV6322, its failure (i.e., failure to be open) causes safety injection to fail. The second new singleton, OPWF20, is another singleton to the automatic injection system.

	18	24	121	91	44	22	153
18	-	*	*	-	-	-	-
24	*	-	-	*	-	-	-
121	*	-	-	*	-	-	-
91	-	*	*	-	-	-	-
44	-	-	-	-	-	*	*
22	-	-	-	-	*	-	-
153	-	-	-	-	*	-	-

UNSUPPRESSED SINGLETONS

29	VC63510
29	FCV635
29	RWST

18	DFE6320
18	VGA63527
18	VC63526
18	DSARWST1
18	SIP188
18	DSDRHR1
18	FCV6348
18	MOT2
18	R2
18	COIL2
24	DFE63151
24	VGA63525
24	VC63524
24	DSARWST2
24	SIP1AA
24	DSDRHR3
24	FCV6347
24	MOT2S
24	R2S
24	COIL2S
121	6900VS1AA
91	6900VS1BB
44	SIINST
22	FCV6322
22	DPAVR63535
153	OPWF20

Figure 21. Singletons and Doubletons for Scenario 2

	9	24	25	26	10	16	20	36	37	12	14	21
9	-	*	*	*	-	-	-	-	-	*	*	*
24	*	-	-	-	*	*	*	*	*	-	-	-
25	*	-	-	-	*	*	*	*	*	-	-	-
26	*	-	-	-	*	*	*	*	*	-	-	-
10	-	*	*	*	-	-	-	-	-	*	*	*
16	-	*	*	*	-	-	-	-	-	*	*	*
20	-	*	*	*	-	-	-	-	-	*	*	*
36	-	*	*	*	-	-	-	-	-	*	*	*
37	-	*	*	*	-	-	-	-	-	*	*	*
12	*	-	-	-	*	*	*	*	*	-	-	-
14	*	-	-	-	*	*	*	*	*	-	-	-
21	*	-	-	-	*	*	*	*	*	-	-	-

UNSUPPRESSED SINGLETONS

11	FCV6322
15	VC63510
15	FCV635
15	RWST
27	OPWF20

Figure 22. Singletons and Doubletons for Scenario 3

9	DFE6320
9	DUM1
9	VGA63527
9	VC63526
9	DSARWST1
9	SIP1BB
9	FCV6348
9	MOT2
9	R2
9	COIL2
9	SWS11
9	FUSE3
9	SWA3
9	OPWF 5
24	S1S1GA
24	SW1A
24	OR11A
24	AND8A
24	RCTRP1A
24	NOT6A
24	AND1A
24	OR1A
24	OR2A
24	AND7A
24	SW4A
24	TIMDEL1A
24	FCV63153
24	6900VS1BB
24	S1S1GB
24	SW1B
24	OR11B
24	AND8B
24	RCTRP1B
24	NOT6B
24	AND1B
24	OR1B
24	OR2B
24	AND7B
24	SW4B
24	TIMDEL1B
24	DUM3
24	DFE63151
24	VGA63525
24	VC63524
24	DSARWST2
24	SIP1AA
24	FCV6347
24	MOT2S
24	R2S
24	COIL2S
24	SWS11S
24	FUSE3S
24	SWA3S
24	OPWF 5S
24	FCV63152
24	6900VS1AA

With the failure of SIINST, manual injection actuation fails. By turning off automatic injection actuation, OPWF20 prevents the automatic safety injection pump injection system from succeeding.

Doubleton failures correspond to the failure of anything in Column A below with anything in Column B. The items in both columns range from safety injection pumps (SIP-) and 6900 V shutdown boards (6900VS-), to logic elements (OR-, NOT-, AND-), relays (R-), switches (SW-), and operator inputs (OP-).

<u>Column A</u>	<u>Column B</u>
SISIGA	DFE6320
SW1A	VGA63527
OR11A	VC63526
AND8A	DSARWST1
RCTRP1A	SIP18B
NOT6A	FCV6348
AND1A	MOT2
OR1A	R2
OR2A	COIL2
AND7A	SWSI1
SW4A	FUSE3
TIMDEL1A	SWA3
DFE63151	OPWF5
VGA63525	FCV63153
VC63524	6900VS18B
DSARWST2	SISIGB
SIP1AA	SW1B
FCV6347	OR11B
MOT2S	AND8B
R2S	RCTRP1B
COIL2S	NOT6B
SWSI1	AND1B
FUSE3S	OR1B
SWA3S	OR2B
OPWF5S	AND7B
FCV63152	SW4B
6900VS1AA	TIMDEL1B

3.5 Scenario 4 - Safety Injection Instrumentation Fails, One Remote Operator, No Local Operators, Fuse Blown

The fourth scenario is identical to the previous scenario, except that a fuse has blown. This fuse is a conduit for the normal control power on safety injection pump IAA. When the automatic safety injection switch closes on receipt of the logic signal, it permits the normal control power to energize an actuator coil which closes a relay, thus enabling power to flow to the pump motor. Should the fuse fail, the motor fails and with it the pump and the pump train. Singletons and doubletons are shown in Figure 23 for this scenario. Singleton failures include the third scenario items from Column B above. With train A not functioning, any failure that prevents train B from functioning also prevents safety injection from occurring.

Doubleton failures reflect failure of both trains of normal control power in the remaining safety injection pump.

	16	18	17
16	*	*	*
18	*	-	-
17	*	-	-

UNSUPPRESSED SINGLETONS

9	FCV6322		
9	VGA63527		
9	VC63526		
9	SIP18B		
9	FCV6348	16	R5
9	MOT2	16	FUSE101I
9	R2	18	OPRREMOTE
9	COIL2	17	R6
9	SWS11	17	FUSE101V
9	FUSE3	17	SWX4
9	SWA3	17	NCONPWR11
9	OPWF5		
10	FCV63153		
14	VC63510		
14	FCV635		
14	RWST		
15	6900VS18B		
15	SISIGB		
26	OPWF20		
35	SW1B		
35	OR11B		
35	AND8B		
35	RCTRP1B		
35	NDT6B		
35	AND1B		
35	OR1B		
35	OR2B		
36	AND7B		
36	SW4B		
36	TIMDEL1B		

Figure 23. Singletons and Doubletons for Scenario 4

4.0 CONCLUSION

To date, about three quarters of the Safety Injection System at Watts Bar has been modeled. The results show the previous known singletons (RWST, VC63510, FCV635) and indicate safety injection is disabled by: 1) Simultaneous failures of two trained components; or 2) Failure of the safety injection instrumentation on which the operators depend coupled with operator suppression of automatic actuation logic, or the failure of a single valve. The results presented in Section 3 indicate that the safety injection system is extremely sensitive to manual backup operations.

As this project progresses, more details will be added about the residual heat removal pump loops which may bypass some singletons thus far uncovered.

As with any analysis, DMA is only as good as the data input. Figure 4 in Section 2 shows repeated analysis/correction loops in the DMA processing flow. Fortunately, each unit model can be constructed, analyzed, and modified before insertion into the global system digraph.

The first several cycles of DMA processing generally produce unexpected results due to modeling errors. Once the model appears to be debugged and a plausible set of singletons and doubletons is determined, further investigation with the triplet code can assist in investigating the accuracy of the global digraph. This can be done by forcing specific groups of components to fail and analyzing the new set of singletons and doubletons. These "triplet" sets should provide insight into the model accuracy.

The present model for the safety injection pump portion of the Safety Injection System contains over 1000 nodes. This corresponds to over 1000 Boolean equations. Many nodes arise from a modeling philosophy which credits manual overrides with perfect effectiveness; a separate node has been assigned to each possible operator input into the system even though there are only a few operators present at the reactor. A more realistic model would have few operators. We have analyzed the effect of grouping the operators and shown the results in Section 3. Even with this grouping, the problem remains quite large. Thus either a large computer or partitioning is necessary.

A minicomputer was used to produce the results discussed in this report. The computer was a Digital Equipment Corporation PDP 11/34, a 16 bit machine with 124K words of memory. The reachability code utilized bit vector storage and was able to process problems containing about 700 nodes after condensation. Running times are a strong function of the problem's complexity, including the number of nodes, the sparsity of the adjacency matrix, and the number of AND gates. Table 3 gives a comparison of the computer processing time on a particular problem for the PDP 11/34 and a CRAY-1. The times shown for the CRAY-1 could be shortened by optimizing the code for the CRAY.

	<u>Original</u>	<u>Condensed</u>	<u>PDP11/34</u> (sec)	<u>CRAY-1</u> (sec)*
Problem: SIPIS	1011	600	11 hr., 52 min.	16 min.

Table 3. Comparison of DMA Processing Times

The large computer also provides more addressable memory, thus allowing larger problems to be run without partitioning.

Unit model creation is relatively straightforward but must be done very carefully. For example, Figure 24 shows two ways to model an operator controlling a switch. Only the model on the right is correct since the power does not flow through the operator.

 * Time estimate from the PDP11/34 code run on the CRAY. Optimization of the code to the CRAY hardware will significantly shorten the running time.

Figure 24. Switch Modeling

Inattention to details such as these lead to logical inconsistencies, especially when similar nodes are grouped for tripton analysis. The modeling of a component (or system) requires detailed and exact knowledge of its functioning. This information is not available in the FSAR and is perhaps known only to a few designers of the reactor subsystems.

The Charging Pump portion of the safety injection system has not been modeled as yet, but large portions of this system will be similar (and in some cases, identical) to portions of the SIPIS.

Several lessons have been learned to this point from the demonstration effort. These include:

1. Data verification and reverification are critical.
2. Models tend to be larger than expected.
3. Use of a minicomputer such as PDP11/34 is practical for testing and debugging system digraphs up to about 1000 nodes.
4. Creation of the unit models is straightforward but must be done very carefully.
5. A tripton code is needed to analyze special conditions.

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APPENDIX A. BRIEF OVERVIEW OF DMA COMPUTER CODES

Figure A-1. DMA Data Processing Flow

DMA utilizes a family of computer programs which work together to find singleton and doubleton cut-sets of a digraph. A brief overview of the computer programs used in the processing of DMA data is presented in this appendix. Figure A-1 shows the data processing flow used for this implementation of DMA. A brief description of the operation of each program will now be given:

ADJ

Program ADJ connects the alphanumeric adjacency element data into a numeric input and provides a count of the number of variables used in the alphanumeric input data. Example input to and output from ADJ is shown in Figure A-2.

Figure A-2. Input/Output for Code ADJ

The 0,0,0 at the end of the alphanumeric data is used to indicate the end of data.

CONDENSE

Program CONDENSE removes redundant node (numbers) from the numeric adjacency element list by a process of forward condensation. The rule for forward condensation is:

If a node is adjacent to only one other node, it's number can be replaced by the adjacent node.*

The digraph of Figure A-2a would condense into the digraph of Figure A-3. The condenser program also renumbers the nodes, eliminating any condensed variables. Typical output is shown in Figure A-3b and A-3c.

Figure A-3. Condensation Program Operation

Condensation has a high payoff in the use of the reachability code since the reachability code processing time is approximately proportional to the third power of the number of elements in the adjacency list and the computer memory requirement is proportional to the square of the number of elements. Condensation typically reduces problem size by 1/3. For example, the safety injection pump injection system (SIPIS) condensed from 1004 nodes to 625 nodes.

* This is equivalent to a Boolean absorption step.

COMPRESS

The COMPRESS program eliminates repeated lines in the output from CONDENSE. Repetition of lines with conditional entries causes both an excessive storage requirement and increased running time of the Reachability Code.

Reachability Code

The reachability code finds all of the singletons and doubletons from the numeric adjacency list. This operation is performed using the logic shown in Figure A-4.

All unconditional adjacency data (e.g., A,B,1) is processed by a fast binary reachability algorithm. To conserve storage and enhance speed, each element in the reachability (or adjacency) matrix is represented by one bit, and computer hardware Boolean logic operations are used on words containing N bits. Thus, a reachability matrix of 16 elements would take 1 x 16 words of storage in a 16 bit machine. One of the algorithms* used for this binary reachability calculation is given below:

Marshall Algorithm

```
S1 (Initialization) A is the adjacency matrix of G
S2 DO S3 for i = 1, 2, ---, n
S3 DO S4 for j = 1, 2, ---, n
S4 If A(j,k) = 1, DO S5 for k = 1, 2, ---, n
S5 A(j,k) = A(j,k) + A(i,k)
S6 HALT
```

Note: + represents the Boolean OR operation.

* The Marshall algorithm listed here is sometimes used. An alternate, the Warren Algorithm, is also used and appears to be more efficient for sparse matrices. The choice of algorithm depends on the sparsity of the adjacency matrix. A good summary of Reachability algorithms can be found in Reference 12.

Figure A-4. Reachability Code Flow

The result of the binary reachability calculation is the singletons of the digraph with all AND gates removed. Figure A-5 shows this case.

Figure A-5. Processing the Deconditioned Graph

An inner product operation is then performed on each conditional adjacency entry. This inner product AND's the columns given by the two input entries (B and C in our example) and places the result in the column indicated by the output entry (D). Each conditioned entry is processed through this inner product.

The reachability matrix which results from this inner product process is then processed through the Warshall algorithm to "connect up" all of the new partial paths found by the inner product operation. This inner product/reachability loop is repeated until the reachability matrix stops changing. The resulting matrix is the Single Dependency Reachability Matrix which contains all singletons.

Double dependency is found in a similar manner with one difference. One of the nodes in the problem is "turned-on" and the single dependency calculation is repeated. The resulting "single dependency matrix" is conditional on the "turned-on" node. Thus, the process has identified double dependencies (doubletons). Each node is "turned-on" and a single dependency matrix generated. Thus, the output will ultimately contain all singletons and doubletons.

OUTPUT CODES

The three types of output codes used generate:

1. A list of the singletons and doubletons (SHORT);
2. A set of Reachability Matrices (MATRIX); and
3. A Singleton/Doubleton Matrix (OUT)

The three types of output are shown in Figure A-6.

				SINGLE DEPENDENCY REACHABILITY MATRIX	DOUBLETONS
J=	51=	5TEMP=	1COND=	1	2 5 3
J=	41=	3TEMP=	5COND=	0	
J=	41=	5TEMP=	3COND=	0	2 - * -
J=	41=	4TEMP=	1COND=	1	5 * - *
J=	41=	2TEMP=	1COND=	5	3 - * *
J=	41=	3TEMP=	1COND=	5	****SINGLETONS****
J=	41=	5TEMP=	1COND=	3	4 D
J=	41=	5TEMP=	1COND=	2	
				1 00000	
				2 00100	
				3 00000	
				4 00000	
				5 00000	

a) Short Output

b) Matrix Output

c) Singleton/
Doubleton

Figure A-6. DMA Outputs

SPECIAL PURPOSE CODES

There are several codes intended for special purposes. The most significant of these are:

TURN1500, WVTRIP, and ADJNEW.

TURN1500 allows the analyst to "turn on" specific nodes for a tripton analysis. For example the analyst may wish to see the impact of grouping all of the operators or the loss of off-site power. WVTRIP, a special version of the reachability code, is used in conjunction with the output from TURN1500 to generate specific triptonions. Thus Triptonions would always include the node which has been turned on by TURN1500.

ADJNEW is used for verification of the input data.

APPENDIX B. COMPLETE SET OF FAILURE-ORIENTED DIGRAPHS FOR SIPIS.

2

Figure B-1. Failure-Oriented Safety Injection Core Digraph (SIPISCORE)

Figure B-2. Unit Model for Flow Control Valve (FCV.DAT)

Figure B-3. Unit Model for Safety Injection Pump (SIP.DAT)

Figure B-4. Unit Model for Safety Injection Logic (SILOGIC1.DAT)

Figure B-5. Unit Model f.
(SILOGIC2.DA)

B-5. Unit Model for Safety Injection Logic
(SILOGIC2.DAT)

103/109

Figure B-6. Unit Model for Safety Injection Logic (SILOGIC3.DAT)

(3.DAT)

Figure B-7. Unit Model for Safety Injection Logic
(SILOG4.DAT)

2

Figure B-9. Unit Model for Safety Injection Logic (SILOGIC6.DAT)

Figure B-10. Unit Model for Safety Injection Logic (SILOGIC7.DAT)

Figure B-12. Unit Model for Electrical Power System (EPS.DAT)

APPENDIX C. COMPLETE ADJACENCY INPUT FOR SAFETY INJECTION PUMP SYSTEM

 *
 * ADJACENCY INPUT FOR SAFETY INJECTION PUMP INJECTION SYSTEM *
 *

THE SIX SUBSYSTEMS ARE INPUT IN THE FOLLOWING ORDER:

- 1)SIPIS Central digraph onto which others connect
- 2)FCV Flow Control Valves
- 3)SIP Safety Injection Pumps
- 4)SILOGIC Safety Injection actuation Logic
- 5)PS Protection Sets
- 6)EPS Electrical Power Support

ADJACENCY INPUT FOR CENTRAL SIPIS

DATA FROM TVA DWG. 47W811-1

Expanded AND-gate input to PATH

VC63641,PATH,DUMAND26 VC- is a check valve.
 DUMAND26,PATH,VC63641
 VC63644,DUMAND26,DUMAND25
 DUMAND25,DUMAND26,VC63644
 VC63563,DUMAND25,DUMAND24
 DUMAND24,DUMAND25,VC63563
 VC63562,DUMAND24,DUMAND23
 DUMAND23,DUMAND24,VC63562
 VC63561,DUMAND23,DUMAND22
 DUMAND22,DUMAND23,VC63561
 VC63560,DUMAND22,DUMAND21
 DUMAND21,DUMAND22,VC63560
 VC63558,DUMAND21,VC63559
 VC63559,DUMAND21,VC63558

There are normal and alternate paths to the core. The normal paths consist of one group of 4 branches which channel flow from pump trains A and/or B. The alternate paths consist of two groups of 2 branches. One group channels flow from pump train A through flow control valve FCV63156. The other group channels flow from pump train B through flow control valve FCV63157. Both FCV-'s are normally closed and require manual actuation and their models follow SIPIS.DAT. Models of the two safety injection pumps SIP1AA and SIP1BB follow FCV- models.

Train B and alternate paths through FCV63157.

VC63547,VC63559,1	
VGA63546,VC63547,1	VGA- is a gate valve.
DFE63160,VGA63546,1	DFE- is a primary element flowmeter orifice.
DUM2,DFE63160,1	
DSDCVCS1,VC63558,1	DS- is a secondary degradation node. It represents a possible flow diversion.
VC63549,VC63558,1	
VGA63548,VC63549,1	DP- (from 5 lines down) is a primary deg. node.
DFE63159,VGA63548,1	
DUM2,DFE63159,1	
DSACVCS1,DUM2,1	
FCV63157,DUM2,1	FCV- is flow control valve. ADJ input for this valve follows SIPIS.DAT.
DPAVR63,36,FCV63157,1	

Crosstie connection between train A and train B

DFE6320,FCV63157,DUM5
DUM5,FCV63157,DFE6320
DFE6320,DUM1,1
FCV63153,DUM1,1
DUM1,FCV6322,DUM3
DUM3,FCV6322,DUM1
DFE63151,DUM3,1
DFE63151,DUM5,1
DUMCROSTIE,DUM5,1
FCV63153,DUMCROSTIE,1
FCV63152,DUMCROSTIE,1
DUMCROSTIE,DUM6,1
FCV63152,DUM3,1
DFE6320,DUM6,1
DUM6,FCV63156,DFE63151
DFE63151,FCV63156,DUM6

FCV6322 is valve through which all flow passes to reach normal injection paths.

If DUMCROSTIE fails, there is no open path between the two trains thus keeping one pump train from being able to inject into the other's alternate injection paths.

VGA63527,DFE6320,1
VC63526,VGA63527,1
DSARWST1,VC63526,1
SIP1BB,VC63526,1
FCV6348,SIP1BB,RHRPATH2
RHRPATH2,SIP1BB,FCV6348
VC63510,FCV6348,1
FCV635,VC63510,1
RWST,FCV635,1
RWST,FCV631,1
FCV631,VC63502,1
VC63502,RHRPATH2,1

SIP- is a safety injection pump. ADJ input follows FCV ADJ input.
RHRPATH2 is possible path through RHR system.

Train A and paths through normal branches.

VC63551,VC63560,1
VGA63550,VC63551,1
DFE63122,VGA63550,1
FCV6322,DFE63122,1
DPAVR63535,FCV6322,1
FCV63153,FCV6322,FCV63152
FCV63152,FCV6322,FCV63153
VGA63525,DFE63151,1
VC63524,VGA63525,1
DSARWST2,VC63524,1
SIP1AA,VC63524,1
FCV6347,SIP1AA,RHRPATH1
RHRPATH1,SIP1AA,FCV6347
VC63502,RHRPATH1,1
VC63510,FCV6347,1
VC63553,VC63561,1
VGA63552,VC63553,1
DFE63123,VGA63552,1
FCV6322,DFE63123,1
VC63555,VC63562,1
VGA63554,VC63555,1
DFE63124,VGA63554,1
FCV6322,DFE63124,1
VC63557,VC63563,1
VGA63556,VC63557,1
DFE63125,VGA63556,1
FCV6322,DFE63125,1

RHRPATH1 is possible path through RHR system.

Alternate paths from Train A through FCV63156:

VC63545,VC63644,1
VGA63544,VC63545,1
DFE63161,VGA63544,1
DUM4,DFE63161,1
DSACVCS2,DUM4,1
FCV63156,DUM4,1
DSBCVCS1,FCV63156,1
DPAYR63534,FCV63156,1
VC63543,VC63641,1
VGA63590,VC63543,1
DFE63162,VGA63590,1
DUM4,DFE63162,1

ADJACENCY INPUT FOR MOTOR OPERATED FLOW CONTROL VALVE UNIT MODEL

DATA FROM TVA DWGs 45W751-8, 45W760-63-8

** FCV63156 **

LINK2,FCV63156,1
MOT1,LINK2,OPRA1
OPRA1,LINK2,MOT1
DUM13,OPRA1,1

MOT1 is motor which moves the valve plug, FCV63156.
LINK2 is connection from MOT1 to FCV63156. OPRA1 determines whether FCV63156 is open or closed from flow data, valve position indicating lights, and direction of resistance to cranking of LINK3.
LINK3 is the connection from the operator's hand to the valve plug. These valve status parameters for local OP's are AND-ed inputs to DUM13.

CON1,MOT1,1
SW1,CON1,1
VMOT1,SW1,1
R1,VMOT1,1
48OMOV1A1A,R1,1

CON1 is wire connection.
SW1, when closed, allows power to flow to MOT1.
VMOT1 is Variable Magnetic Overcurrent Trip.
R1 is a relay.
48OMOV1A1A is process electrical power.

VHTR1,MOT1,1
DUM12,VHTR1,1
FUSE2,DUM12,FUSE1
XFMR1,FUSE2,1
VMOT1,XFMR1,1
FUSE1,DUM12,FUSE2
XFMR1,FUSE1,1
SWX1,FUSE1,1
OPRF3,SWX1,1
LT5,OPRF3,FDATA1
FDATA1,OPRF3,LT5
COIL1,SW1,1

VHTR1 is valve heater.
FUSE2 is normal fuse. FUSE1 is auxillary fuse.
XFMR1 is potential transformer.
OPRF3 monitors with LT5 the power out of the control power fuse and can use SWX1 to switch to the auxillary fuse.
COIL1, when energized, closes SW1.

SWB1,COIL1,DUMAND11
DUMAND11,COIL1,SWB1

SWB1 is local switch which electrically energizes COIL1.

Connections for hardware connected to SILOGIC

Indented 1 tab since not used in SIPIIS. If used, remove tabs and indent the 2 lines of code above this insert.

SWB1,SWB1,1	Self loops to keep variable list from changing
DUMAND11,DUMAND11,1	
SWSI2,COIL1,DUMAND16	SWSI2 closes upon receipt of SILOGIC signal.
DUMAND16,COIL1,SWSI2	When SWSI2 is closed, normal control power
FUSE2,SWSI2,1	flows to COIL1 which closes SW1.
OPWF1,SWA4,1	OPWF1 switches SWA4 so that SWSI2 is enabled
SWA4,SWSI2,1	to close upon receipt of SILOGIC.
SILOGIC1,SWSI2,1	
SWB1,DUMAND16,DUMAND11	
DUMAND11,DUMAND16,SWB1	
SWC1,DUMAND11,SWA1	SWC1 is auxillary remote control switch.
SWA1,DUMAND11,SWC1	SWA1 is normal remote control switch.
SIINST,OPRF1,1	SIINST is safety injection indication instrumentation.
SIINST,OPRA1,1	All valve actuating operators need this input to
SIINST,OPRF2,1	know that injection is necessary.
SIINST,OPRC1,1	
OPRC1,SWB1,1	OPRC1 is local operator who ascertains valve position
DUM13,OPRC1,1	by inputs to DUM13 (see 1st comment).
DUM12,SWB1,1	SWB1 is actuator for both normal and emerg. power.
Inputs to DUM13	
LINK3,DUMAND18,DUMAND12	
DUMAND12,DUMAND18,LINK3	
DUMAND13,DUM13,DUM11	
DUM11,DUM13,DUMAND13	
FDATA1,DUMAND13,DUMAND18	
DUMAND18,DUMAND13,FDATA1	
LT4,DUMAND12,LT3	LT3 and LT4 are valve position sensing lights located
LT3,DUMAND12,LT4	next to the valve.
SW3,LT3,1	SW3 is valve position sensing switch.
LINK1,SW3,1	LINK1 is connection of valve plug to SW3 and SW2.
SW2,LT4,1	SW2 is valve position sensing switch.
LINK1,SW2,1	
OPRF2,SWC1,1	
FUSE1,SWC1,1	SWC1 is actuator for emergency control power.
DUM11,OPRF2,1	
OPRF1,SWA1,1	
FUSE2,SWA1,1	SWA1 is actuator for normal control power.
DUM11,OPRF1,1	

Inputs to DUM11

LT1,DUMAND14,LT2	LT1, LT2 are red and green valve plug position
SW3,LT1,1	indicator lights located in unit main control room.
LT2,DUMAND14,LT1	
SW2,LT2,1	
DUMAND14,DUMAND17,OPRC1	
OPRC1,DUMAND17,DUMAND14	
DUMAND17,DUMAND15,OPRA1	
OPRA1,DUMAND15,DUMAND17	
DUMAND15,DUM11,FDATA1	
FDATA1,DUM11,DUMAND15	

** FCV63157 **

LINK2F,FCV63157,1	MOT1 is motor which moves the valve plug, FCV63157.
MOT1F,LINK2F,OPRA1F	LINK2 is connection from MOT1 to FCV63157. OPRA1
OPRA1F,LINK2F,MOT1F	determines whether FCV1 is open or closed from
DUM13F,OPRA1F,1	flow data, valve position indicating lights, and
	direction of resistance to cranking of LINK3.
	LINK3 is the connection from the operator's hand
	to the valve plug. These valve status parameters
	for local OP's are AND-ed inputs to DUM13.
CON1F,MOT1F,1	CON1 is wire connection.
SW1F,CON1F,1	SW1, when closed, allows power to flow to MOT1.
VMOT1F,SW1F,1	VMOT1 is Variable Magnetic Overcurrent Trip.
R1F,VMOT1F,1	R1 is a relay.
480MOV1B1B,R1F,1	480MOV1B1B is process electrical power.
VHTR1F,MOT1F,1	VHTR1 is valve heater.
DUM12F,VHTR1F,1	
FUSE2F,DUM12F,FUSE1F	FUSE2 is normal fuse. FUSE1 is auxillary fuse.
XFMR1F,FUSE2F,1	XFMR1 is potential transformer.
VMOT1F,XFMR1F,1	
FUSE1F,DUM12F,FUSE2F	
XFMR1F,FUSE1F,1	
SWX1F,FUSE1F,1	OPRF3 monitors with LT5 the power out of the control
OPRF3F,SWX1F,1	power fuse and can use SWX1 to switch to the
LT5F,OPRF3F,FDATA1F	auxillary fuse.
FDATA1F,OPRF3F,LT5F	
COIL1F,SW1F,1	COIL1, when energized, closes SW1.
SWB1F,COIL1F,DUMAND11F	SWB1 is local switch which electrically energizes
DUMAND11F,COIL1F,SWB1F	COIL1.

Connections for hardware connected to SILOGIC

Indented 1 tab since not used in SIPIS. If used, remove tabs and indent the 2 lines of code above this insert.

SWB1F,SWB1F,1 Self loops to keep variable list unchanged.
 DUMAND11F,DUMAND11F,1
 SWSI2F,COIL1F,DUMAND16F SWSI2 closes upon receipt of SILOGIC signal.
 DUMAND16F,COIL1F,SWSI2F When SWSI2 is closed, normal control power
 FUSE2F,SWSI2F,1 flows to COIL1 which closes SW1.
 OPWF1F,SWA4F,1 OPWF1 switches SWA4 so that SWSI2 is enabled
 SWA4F,SWSI2F,1 to close upon receipt of SILOGIC.
 SILOGIC1F,SWSI2F,1
 SWB1F,DUMAND16F,DUMAND11F
 DUMAND11F,DUMAND16F,SWB1F

SWC1F,DUMAND11F,SWA1F SWC1 is auxillary remote control switch.
 SWA1F,DUMAND11F,SWC1F SWA1 is normal remote control switch.
 SIINST,OPRF1F,1 SIINST is safety injection indication instrumentation.
 SIINST,OPRA1F,1 All valve actuating operators need this input to
 SIINST,OPRF2F,1 know that injection is necessary.
 SIINST,OPRC1F,1

OPRC1F,SWB1F,1 OPRC1 is local operator who ascertains valve position
 DUM13F,OPRC1F,1 by input to DUM13 (see 1st comment).
 DUM12F,SWB1F,1 SWB1 is actuator for both normal and emerg. power.

Inputs to DUM13F

LINK3F,DUMAND18F,DUMAND12F
 DUMAND12F,DUMAND18F,LINK3F
 DUMAND13F,DUM13F,DUM11F
 DUM11F,DUM13F,DUMAND13F
 FDATA1F,DUMAND13F,DUMAND18F
 DUMAND18F,DUMAND13F,FDATA1F
 LT4F,DUMAND12F,LT3F LT3 and LT4 are valve position sensing lights located
 LT3F,DUMAND12F,LT4F next to the valve.

SW3F,LT3F,1 SW3 is valve position sensing switch.
 LINK1F,SW3F,1 LINK1 is connection of valve plug to SW3 and SW2.
 SW2F,LT4F,1 SW2 is valve position sensing switch.
 LINK1F,SW2F,1

OPRF2F,SWC1F,1
 FUSE1F,SWC1F,1 SWC1 is actuator for emergency control power.
 DUM11F,OPRF2F,1
 OPRF1F,SWA1F,1
 FUSE2F,SWA1F,1 SWA1 is actuator for normal control power.
 DUM11F,OPRF1F,1

Inputs to DUM11F

LT1F,DUMAND14F,LT2F LT1, LT2 are red and green valve plug position
 SW3F,LT1F,1 indicator lights located in unit main control room.
 LT2F,DUMAND14F,LT1F
 SW2F,LT2F,1
 DUMAND14F,DUMAND17F,OPRC1F
 OPRC1F,DUMAND17F,DUMAND14F
 DUMAND17F,DUMAND15F,OPRA1F
 OPRA1F,DUMAND15F,DUMAND17F
 DUMAND15F,DUM11F,FDATA1F
 FDATA1F,DUM11F,DUMAND15F

ADJACENCY INPUT FOR SAFETY INJECTION PUMP UNIT MODEL

DATA FROM TVA DWG's 45W724-1, 45W760-63-1

** SIP1BB **

MOT2,SIP1BB,1	MOT2 is driving motor and SIP1 is Safety Injection Pump 1.
R2,MOT2,1	R2 is relay.
6900VS1BB,MOT2,1	6900VS1BB is process electrical power.
COIL2,R2,1	COIL2, when energized, closes R2.

Multiple AND-gate for inputs of switches to COIL2

SWS11,COIL2,DUMAND8	SWS11 switches on receipt of SIS.
DUMAND8,COIL2,SWS11	
SWA2,DUMAND8,DUMAND7	SWA2 uses normal control power to energize COIL2.
DUMAND7,DUMAND8,SWA2	
SWC2,DUMAND7,SWB2	SWC2 uses emergency control power to energize COIL2.
SWB2,DUMAND7,SWC2	SWB2 is local control and uses normal or emerg. power.

OPRC2,SWB2,1	OPRC2 is local operator.
SIINST,OPRC2,1	SIINST is control room SIS instrumentation.
DUM34,OPRC2,1	

Multiple AND-gate for inputs of transmitters to DUM34

PT6318,DUMAND5,PT6319	Both PT-'s are pressure transmitters.
PT6319,DUMAND5,PT6318	
DUMAND5,DUMAND19,FT6320	FT- is a flowrate transmitter.
FT6320,DUMAND19,DUMAND5	
DUMAND19,DUM34,FDATA2	FDATA2 is flow data indicating operation of pump.
FDATA2,DUM34,DUMAND19	
VGL63385A,PT6318,1	VGL- is valve to PT-, a pressure transmitter.
VGL63304A,PT6319,1	(same as above)
VGL63308A,FT6320,1	
VGL63307A,FT6320,1	

FUSE4,SWC2,1	FUSE4 is fuse for emergency control power.
R3,FUSE4,R4	
R4,FUSE4,R3	
FUSE101V,R3,1	
FUSE101I,R4,1	
SWX3,R4,1	
OPRF7,SWX3,1	
SWX2,FUSE4,1	SWX2 is switch from normal to emerg. control power.
OPRF4,SWX2,1	OPRF4 operates SWX2.

Multiple AND-gate for inputs of transmitters/indicators to OPRF4

DUM34,OPRF4,DUMAND10
DUMAND10,OPRF4,DUM34
LT8,DUMAND10,DUMAND9
DUMAND9,DUMAND10,LT8
LT7,DUMAND9,DUMAND6
DUMAND6,DUMAND9,LT7
LT6,DUMAND6,OPRC2
OPRC2,DUMAND6,LT6

LT8 indicates SWA2 status.

LT7 indicates SWA3 status.

LT6 indicates control power status.

OPRF6,SWC2,1
DUM35,OPRF6,1

OPRF6 operates auxiliary control switch SWC2.

DUM34,DUM35,OPRC2
OPRC2,DUM35,DUM34
SIINST,OPRF6,1

FUSE3,SWA2,1
SIINST,SWA2,1
FUSE3,SWB2,FUSE4
FUSE4,SWB2,FUSE3
R5,FUSE3,R6
R6,FUSE3,R5
FUSE10II,R5,1
FUSE10IV,R6,1

FUSE3 is fuse for normal control power.

SWX4,R6,1
OPRF8,SWX4,1
FUSE3,SWA3,1
OPRF5,SWA2,1
SWA3,SWSI1,1
OPWF5,SWA3,1
SISIGB,SWSI1,1

SWA3 enables auto receipt of SIS.

OPRF5 operates SWA2, SWA3 which are both part of same actuator.

OPWF5 fails by not enabling SISIG receipt.

SISIGB is input from Safeguards Actuation Logic.

** SIP1AA **

MOT2S,SIP1AA,1
R2S,MOT2S,1
6900VS1AA,MOT2S,1
COIL2S,R2S,1

MOT2 is driving motor and SIP1 is Safety Injection Pump 1.
R2 is relay.

6900VS1AA is process electrical power.
COIL2S, when energized, closes R2.

Multiple AND-gate for inputs of switches to COIL2

SWSI1S,COIL2S,DUMAND8S
DUMAND8S,COIL2S,SWSI1S
SWA2S,DUMAND8S,DUMAND7S
DUMAND7S,DUMAND8S,SWA2S
SWC2S,DUMAND7S,SWB2S
SWB2S,DUMAND7S,SWC2S

SWSI1 switches on receipt of SIS.

SWA2 uses normal control power to energize COIL2.

SWC2 uses emergency control power to energize COIL2.

SWB2 is local control and uses normal or emerg. power.

OPRC2S,SWB2S,1
SIINST,OPRC2S,1
DUM34S,OPRC2S,1

OPRC2 is local operator.

SIINST is control room SIS indicator instrumentation.

Multiple AND-gate for inputs of transmitters to DUM34S

PT63149,DUMAND5S,PT63150 Both PT-'s are pressure transmitters.

PT63150,DUMAND5S,PT63149

DUMAND5S,DUMAND19S,FT63151 FT- is a flowrate transmitter.

FT63151,DUMAND19S,DUMAND5S

DUMAND19S,DUM34S,FDATA2S

FDATA2S,DUM34S,DUMAND19S

VGL63386A,PT63149,1 VGL- is valve to PT-S, a pressure transmitter.

VGL63303A,PT63150,1 (same as above)

VGL63306A,FT63151,1

VGL63305A,FT63151,1

FUSE4S,SWC2S,1

FUSE4 is fuse for emergency control power.

R3S,FUSE4S,R4S

R4S,FUSE4S,R3S

FUSE10111,R3S,1

FUSE101,R4S,1

SWX3S,R4S,1

OPRF7S,SWX3S,1

SWX2S,FUSE4S,1

SWX2 is switch from normal to emerg. control power.

OPRF4S,SWX2S,1

OPRF4 operates SWX2.

Multiple AND-gate for inputs of transmitters/indicators to OPRF4

DUM34S,OPRF4S,DUMAND10S

DUMAND10S,OPRF4S,DUM34S

LT8S,DUMAND10S,DUMAND9S LT8 indicates SWA2 status.

DUMAND9S,DUMAND10S,LT8S

LT7S,DUMAND9S,DUMAND6S LT7 indicates SWA3 status.

DUMAND6S,DUMAND9S,LT7S

LT6S,DUMAND6S,OPRC2S LT6 indicates control power status.

OPRC2S,DUMAND6S,LT6S

OPRF6S,SWC2S,1

OPRF6 operates auxillary control switch SWC2.

DUM35S,OPRF6S,1

DUM34S,DUM35S,OPRC2S

OPRC2S,DUM35S,DUM34S

SIINST,OPRF6S,1

FUSE3S,SWA2S,1

FUSE3 is fuse for normal control power.

SIINST,SWA2S,1

FUSE3S,SWB2S,FUSE4S

FUSE4S,SWB2S,FUSE3S

R5S,FUSE3S,R6S

R6S,FUSE3S,R5S

FUSE101,R5S,1

FUSE10111,R6S,1

SWX4S,R6S,1

OPRF8S,SWX4S,1

FUSE3S,SWA3S,1

SWA3 enables auto receipt of SIS.

OPRF5S,SWA2S,1

OPRF5 operates SWA2S, SWA3 which are both part of same actuator.

SWA3S,SWI11S,1

OPWF5S,SWA3S,1

OPWF5S fails by not enabling SISIG receipt.

SISIGA,SWI11S,1

SISIGA is input from Safeguards Actuation Logic.

ADJACENCY INPUT FOR SAFETY INJECTION LOGIC UNIT MODEL

DATA FROM TVA DWG. 47W611-63-1, FSAR FIG. 7.2-1, WESTINGHOUSE DWG. 108D408

Page numbers (e.g. PAGE 1) refer to digraph page number

Only header comments are consistent with two trains. Comments on side are in Train A nomenclature only.

** PAGE 1 **

SAFETY INJECTION SIGNAL (SIS) CENTRAL LOGIC

Train A central logic.

SW1A, SISIGA, 1	SW1A is SIS actuation switch. SISIGA is train A SIS.
AND7A, SW1A, 1	
SW4A, AND7A, 1	SW4A, operated by OPWF20, resets SW1A after time delay.
OPWF20, SW4A, 1	
SW1A, TIMDEL1A, 1	TIMDEL1A is a 1-2 minute signal delay.
TIMDEL1A, AND7A, 1	
AND7A, OR11A, AND8A	
AND8A, OR11A, AND7A	
OR11A, AND8A, 1	
RCTRPIA, AND8A, 1	RCTRPIA is train A reactor trip signal.
AND8A, NOT6A, 1	
NOT6A, AND1A, 1	

Manual safety injection signal actuation logic and connections of the instrumentation and bistable networks to SW1A.

Networks monitor pressurizer pressure, main steam lines, steam line differential pressure, and hi containment pressure.

OR1A, SW1A, 1	
OR1, OR1A, AND1A	OR1 comes from manual SIS actuation logic.
AND1A, OR1A, OR1	
SW5, OR1, SW6	Either SW5 or SW6 can actuate SIS.
SIINST, OPRF11, 1	OPRF11 knows to manually actuate from SIINST.
OPRF11, SW5, 1	OPRF11 operates SW5, OPRF12 operates SW6.
SW6, OR1, SW5	
SIINST, OPRF12, 1	OPRF12 knows to manually actuate from SIINST.
OPRF12, SW6, 1	
OR2A, AND1A, 1	OR2A is junction of all network inputs.

Expanded AND-gate of all inputs to OR2A

AND2A, OR2A, DUMAND1A	AND2A is junction of all pressurizer pressure inputs.
DUMAND1A, OR2A, AND2A	
AND5A, DUMAND1A, DUMAND2A	AND5A is junction of all main steam line inputs.
DUMAND2A, DUMAND1A, AND5A	
OR10A, DUMAND2A, 20F3C7A	20F3C7A is hi containment pressure.
20F3C7A, DUMAND2A, OR10A	

Connections of steam line networks to AND5A

NOT4A, AND5A, 1	
AND4A, AND5A, 1	
OR8A, AND4A, 1	
20F4C2A, OR8A, 20F4C3A	20F4C2A is low steam line pressure.
20F4C3A, OR8A, 20F4C2A	20F4C3A is steam line to lo average temperature.
20F4C1A, AND4A, 1	20F4C1A is hi steam line flow.

Train B central logic.

SW1B,SIS1GB,1 SW1A is SIS actuation switch. SIS1GA is train A SIS.
 AND7B,SW1B,1
 SW4B,AND7B,1 SW4A, operated by OPWF20, resets SW1A after time delay.
 OPWF20,SW4B,1
 SW1B,TIMDEL1B,1 TIMDEL1A is a 1-2 minute signal delay.
 TIMDEL1B,AND7B,1
 AND7B,OR11B,AND8B
 AND8B,OR11B,AND7B
 OR11B,AND8B,1
 RCTRP1B,AND8B,1 RCTRP1A is train A reactor trip signal.
 AND8B,NOT6B,1
 NOT6B,AND1B,1
 OR1B,SW1B,1
 OR1,OR1B,AND1B OR1 comes from manual SIS actuation logic.
 AND1B,OR1B,OR1

OR2B,AND1B,1 OR2A is junction of all network inputs.
 Expanded AND-gate of all inputs to OR2A
 AND2B,OR2B,DUMAND1B AND2A is junction of all pressurizer pressure inputs.
 DUMAND1B,OR2B,AND2B
 AND5B,DUMAND1B,DUMAND2B AND5A is junction of all main steam line inputs.
 DUMAND2B,DUMAND1B,AND5B
 OR10B,DUMAND2B,20F3C7B 20F3C7A is hi containment pressure.
 20F3C7B,DUMAND2B,OR10B
 Connections of steam line networks to AND5A
 NOT4B,AND5B,1
 AND4B,AND5B,1
 OR8B,AND4B,1
 20F4C2B,OR8B,20F4C3B 20F4C2A is low steam line pressure.
 20F4C3B,OR8B,20F4C2B 20F4C3A is steam line 70 to average temperature.
 20F4C1B,AND4B,1 20F4C1A is hi steam line flow.

PRESSURIZER PRESSURE INSTRUMENTATION AND BISTABLE LOGIC NETWORKS

Train A logic.

NOT1A,AND2A,1 Inputs to AND2A are lo press. pressure and hi
 AND3A,NOT1A,1 press. pressure (which has a manual block/reset).
 NOT2A,AND3A,1 AND3A is connected to block/reset.
 SW2A,NOT2A,1 SW2A is block/reset switch.
 OPWF13,SW2A,1 OPWF13 operates SW2A.
 SW2A,OR3A,AND3A
 AND3A,OR3A,SW2A
 OR3A,AND3A,1
 NOT3A,AND3A,1 Input to NOT3A is hi pressurizer pressure.
 20F3C2A,NOT3A,1

Train B logic.

NOT1B,AND2B,1
AND3B,NOT1B,1
NOT2B,AND3B,1
SW2B,NOT2B,1
OPWF13,SW2B,1
SW2B,OR3B,AND3B
AND3B,OR3B,SW2B
OR3B,AND3B,1
NOT3B,AND3B,1
2OF3C2B,NOT3B,1

Inputs to AND2A are lo press. pressure and hi press. pressure (which has a manual block/reset). AND3A is connected to block/reset. SW2A is block/reset switch. OPWF13 operates SW2A.

Input to NOT3A is hi pressurizer pressure.

Note on component nomenclature:

Components are coded with the 6 character label (A1)(A2)(NNN)(A3) of which the first two characters are the useful descriptors. A1 is the parameter being monitored with P=Pressure, F=Flow, and T=Temperature. A2 is the type of component with B=Bistable, L=Light, S=Switch, and T=Transducer.

Expanded 2/3 coincidence gates 2OF3C2A and 2OF3C2B

PB455B,2OF3C2A,PB456B
PB455B,2OF3C2B,PB456B
OPWF14,PB455B,1
PL455B,PB455B,PS455B
PS455B,PB455B,PL455B
PT455,PB455B,1
PS1,PT455,1
PB456B,2OF3C2A,PB455B
PB456B,2OF3C2B,PB455B
OPWF14,PB456B,1
PL456B,PB456B,PS456B
PS456B,PB456B,PL456B
PT456,PB456B,1
PS11,PT456,1
PB455B,2OF3C2A,PB457B
PB455B,2OF3C2B,PB457B
OPWF14,PB457B,1
PL457B,PB457B,PS457B
PS457B,PB457B,PL457B
PT457,PB457B,1
PS111,PT457,1
PB457B,2OF3C2A,PB455B
PB457B,2OF3C2B,PB455B
PB456B,2OF3C2A,PB457B
PB456B,2OF3C2B,PB457B
PB457B,2OF3C2A,PB456B
PB457B,2OF3C2B,PB456B

Each bistable can be disabled if operator leaves it in test mode or if the test mode switch and light fail to indicate that bistable is in test mode.

PS- is protection system power supply I - IV.

20F3C1A,AND2A,1
20F3C1B,AND2B,1

Input to 20F3C1A is 10 pressurizer pressure.

Expanded 2/3 coincidence gate 20F3C1A,B

PB457D,20F3C1A,PB455D
PB457D,20F3C1B,PB455D
OPWF15,PB457D,1
PL457D,PB457D,PS457D
PS457D,PB457D,PL457D
PT457,PB457D,1
PB455D,20F3C1A,PB457D
PB455D,20F3C1B,PB457D
OPWF15,PB455D,1
PL455D,PB455D,PS455D
PS455D,PB455D,PL455D
PT455,PB455D,1
PB457D,20F3C1A,PB456D
PB457D,20F3C1B,PB456D
OPWF15,PB456D,1
PL456D,PB456D,PS456D
PS456D,PB456D,PL456D
PT456,PB456D,1
PB456D,20F3C1A,PB457D
PB456D,20F3C1B,PB457D
PB455D,20F3C1A,PB456D
PB455D,20F3C1B,PB456D
PB456D,20F3C1A,PB455D
PB456D,20F3C1B,PB455D

HI MAIN STEAM LINE FLOW INSTRUMENTATION AND BISTABLE LOGIC
Expanded 2/4 coincidence gate 20F4C1A,B. Failure orientation is
based upon failure of any three inputs.

OR4A,DUMAND3A,OR5A
OR5A,DUMAND3A,OR4A
DUMAND3A,20F4C1A,OR6A
OR6A,20F4C1A,DUMAND3A
OR4A,DUMAND4A,OR5A
OR5A,DUMAND4A,OR4A
DUMAND4A,20F4C1A,OR7A
OR7A,20F4C1A,DUMAND4A
OR4A,20F4C1A,DUMAND5A
DUMAND5A,20F4C1A,OR4A
OR6A,DUMAND5A,OR7A
OR7A,DUMAND5A,OR6A
OR5A,20F4C1A,DUMAND6A
DUMAND6A,20F4C1A,OR5A
OR6A,DUMAND6A,OR7A
OR7A,DUMAND6A,OR6A

OR4B,DUMAND3B,OR5B
OR5B,DUMAND3B,OR4B
DUMAND3B,20F4C1B,OR6B
OR6B,20F4C1B,DUMAND3B
OR4B,DUMAND4B,OR5B
OR5B,DUMAND4B,OR4B
DUMAND4B,20F4C1B,OR7B
OR7B,20F4C1B,DUMAND4B
OR4B,20F4C1B,DUMAND5B
DUMAND5B,20F4C1B,OR4B
OR6B,DUMAND5B,OR7B
OR7B,DUMAND5B,OR6B
OR5B,20F4C1B,DUMAND6B
DUMAND6B,20F4C1B,OR5B
OR6B,DUMAND6B,OR7B
OR7B,DUMAND6B,OR6B

FB522B,OR4A,FB523B
FB522B,OR4B,FB523B
OPWF15,FB522B,1
FL522B,FB522B,FS522B
FS522B,FB522B,FL522B
FT522,FB522B,1
PS1,FT522,1
FB523B,OR4A,FB522B
FB523B,OR4B,FB522B
OPWF15,FB523B,1
FL523B,FB523B,FS523B
FS523B,FB523B,FL523B
FT523,FB523B,1
PS11,FT523,1

FB512B,OR5A,FB513B
FB512B,OR5B,FB513B
OPWF15,FB512B,1
FL512B,FB512B,FS512B
FS512B,FB512B,FL512B
FT512,FB512B,1
PS1,FT512,1
FB513B,OR5A,FB512B
FB513B,OR5B,FB512B
OPWF15,FB513B,1
FL513B,FB513B,FS513B
FS513B,FB513B,FL513B
FT513,FB513B,1
PS11,FT513,1

FB532B,OR6A,FB533B
FB532B,OR6B,FB533B
OPWF15,FB532B,1
FL532B,FB532B,FS532B
FS532B,FB532B,FL532B
FT532,FB532B,1
PS1,FT532,1
FB533B,OR6A,FB532B
FB533B,OR6B,FB532B
OPWF15,FB533B,1
FL533B,FB533B,FS533B
FS533B,FB533B,FL533B
FT533,FB533B,1
PS11,FT533,1

FB542B,OR7A,FB543B
FB542B,OR7B,FB543B
OPWF15,FB542B,1
FL542B,FB542B,FS542B
FS542B,FB542B,FL542B
FT542,FB542B,1
PS1,FT542,1
FB543B,OR7A,FB542B
FB543B,OR7B,FB542B
OPWF15,FB543B,1
FL543B,FB543B,FS543B
FS543B,FB543B,FL543B
FT543,FB543B,1
PS11,FT543,1

LO MAIN STEAM LINE PRESSURE INSTRUMENTATION AND BISTABLE LOGIC
Expanded 2/4 coincidence gate 20F4C2A. Failure orientation is
based upon failure of any three inputs.

PB516A, DUMAND7A, PB526A
PB526A, DUMAND7A, PB516A
DUMAND7A, 20F4C2A, PB536A
PB536A, 20F4C2A, DUMAND7A
PB516A, DUMAND8A, PB526A
PB526A, DUMAND8A, PB516A
DUMAND8A, 20F4C2A, PB546A
PB546A, 20F4C2A, DUMAND8A
PB516A, DUMAND9A, PB536A
PB536A, DUMAND9A, PB516A
DUMAND9A, 20F4C2A, PB546A
PB546A, 20F4C2A, DUMAND9A
PB526A, DUMAND10A, PB536A
PB536A, DUMAND10A, PB526A
DUMAND10A, 20F4C2A, PB546A
PB546A, 20F4C2A, DUMAND10A
PB516A, DUMAND7B, PB526A
PB526A, DUMAND7B, PB516A
DUMAND7B, 20F4C2B, PB536A
PB536A, 20F4C2B, DUMAND7B
PB516A, DUMAND8B, PB526A
PB526A, DUMAND8B, PB516A
DUMAND8B, 20F4C2B, PB546A
PB546A, 20F4C2B, DUMAND8B
PB516A, DUMAND9B, PB536A
PB536A, DUMAND9B, PB516A
DUMAND9B, 20F4C2B, PB546A
PB546A, 20F4C2B, DUMAND9B
PB526A, DUMAND10B, PB536A
PB536A, DUMAND10B, PB526A
DUMAND10B, 20F4C2B, PB546A
PB546A, 20F4C2B, DUMAND10B

OPWF16, PB516A, 1
PL516A, PB516A, PS516A
PS516A, PB516A, PL516A
PT516, PB516A, 1
PSIV, PT516, 1

OPWF16, PB526A, 1
PL526A, PB526A, PS526A
PS526A, PB526A, PL526A
PT526, PB526A, 1
PSI11, PT526, 1

OPWF16, PB536A, 1
PL536A, PB536A, PS536A
PS536A, PB536A, PL536A
PT536, PB536A, 1
PSI11, PT536, 1

OPWF16, PB546A, 1
PL546A, PB546A, PS546A
PS546A, PB546A, PL546A
PT546, PB546A, 1
PSIV, PT546, 1

LO LO MAIN STEAM LINE Tavg AND MANUAL BLOCK/RESET LOGIC
 AND6A,NOT4A,1 Inputs to AND6A are from lo lo Tavg and blk/reset.
 NOT5A,AND6A,1
 SW3A,NOT5A,1
 OPWF18,SW3A,1 OPWF18 operates blk/reset switch SW3A.
 SW3A,OR9A,AND6A
 AND6A,OR9A,SW3A
 OR9A,AND6A,1
 20F4C3A,AND6A,1 Input to 20F4C3A is lo lo Tavg.

Expanded 2/3 coincidence gate 20F4C3A
 TB412D,DUMAND11A,TB422D
 TB422D,DUMAND11A,TB412D
 DUMAND11A,20F4C3A,TB432D
 TB432D,20F4C3A,DUMAND11A
 TB412D,DUMAND12A,TB422D
 TB422D,DUMAND12A,TB412D
 DUMAND12A,20F4C3A,TB442D
 TB442D,20F4C3A,DUMAND12A
 TB412D,DUMAND13A,TB432D
 TB432D,DUMAND13A,TB412D
 DUMAND13A,20F4C3A,TB442D
 TB442D,20F4C3A,DUMAND13A
 TB422D,DUMAND14A,TB432D
 TB432D,DUMAND14A,TB422D
 DUMAND14A,20F4C3A,TB442D
 TB442D,20F4C3A,DUMAND14A

AND6B,NOT4B,1 Inputs to AND6A are from lo lo Tavg and blk/reset.
 NOT5B,AND6B,1
 SW3B,NOT5B,1
 OPWF18,SW3B,1 OPWF18 operates blk/reset switch SW3A.
 SW3B,OR9B,AND6B
 AND6B,OR9B,SW3B
 OR9B,AND6B,1
 20F4C3B,AND6B,1 Input to 20F4C3A is lo lo Tavg.

Expanded 2/3 coincidence gate 20F4C3B
 TB412D,DUMAND11B,TB422D
 TB422D,DUMAND11B,TB412D
 DUMAND11B,20F4C3B,TB432D
 TB432D,20F4C3B,DUMAND11B
 TB412D,DUMAND12B,TB422D
 TB422D,DUMAND12B,TB412D
 DUMAND12B,20F4C3B,TB442D
 TB442D,20F4C3B,DUMAND12B
 TB412D,DUMAND13B,TB432D
 TB432D,DUMAND13B,TB412D
 DUMAND13B,20F4C3B,TB442D
 TB442D,20F4C3B,DUMAND13B
 TB422D,DUMAND14B,TB432D
 TB432D,DUMAND14B,TB422D
 DUMAND14B,20F4C3B,TB442D
 TB442D,20F4C3B,DUMAND14B

OPWF17, TB412D, 1
TL412D, TB412D, TS412D
TS412D, TB412D, TL412D
TE411A, TB412D, 1
TE411B, TB412D, 1
PSI, TE411A, 1
PSI, TE411B, 1

OPWF17, TB422D, 1
TL422D, TB422D, TS422D
TS422D, TB422D, TL422D
TE421A, TB422D, 1
TE421B, TB422D, 1
PS11, TE421A, 1
PS11, TE421B, 1

OPWF17, TB432D, 1
TL432D, TB432D, TS432D
TS432D, TB432D, TL432D
TE431A, TB432D, 1
TE431B, TB432D, 1
PS111, TE431A, 1
PS111, TE431B, 1

OPWF17, TB442D, 1
TL442D, TB442D, TS442D
TS442D, TB442D, TL442D
TE441A, TB442D, 1
TE441B, TB442D, 1
PSIV, TE441A, 1
PSIV, TE441B, 1

STEAM LINE DIFFERENTIAL PRESSURE INSTRUMENTATION AND BISTABLE LOGIC

Expanded AND-gate for OR10A. Inputs are four 2/3 coincidence gates.

20F3C3A,DUMAND15A,20F3C5A
 20F3C5A,DUMAND15A,20F3C3A
 DUMAND15A,DUMAND16A,20F3C6A
 20F3C6A,DUMAND16A,DUMAND15A
 DUMAND16A,OR10A,20F3C4A
 20F3C4A,OR10A,DUMAND16A
 20F3C3B,DUMAND15B,20F3C5B
 20F3C5B,DUMAND15B,20F3C3B
 DUMAND15B,DUMAND16B,20F3C6B
 20F3C6B,DUMAND16B,DUMAND15B
 DUMAND16B,OR10B,20F3C4B
 20F3C4B,OR10B,DUMAND16B

Expanded 2/3 coincidence gate 20F3C3A,B

PB514A,20F3C3A,PB515A
 PB514A,20F3C3B,PB515A
 OPWF18,PB514A,1
 PL514A,PB514A,PS514A
 PS514A,PB514A,PL514A
 PT514,PB514A,1
 PT524,PB514A,1
 PSI,PT514,1
 PSI,PT524,1
 PB515A,20F3C3A,PB514A
 PB515A,20F3C3B,PB514A
 OPWF18,PB515A,1
 PL515A,PB515A,PS515A
 PS515A,PB515A,PL515A
 PT515,PB515A,1
 PT535,PB515A,1
 PSII,PT515,1
 PSII,PT535,1
 PB514A,20F3C3A,PB516C
 PB514A,20F3C3B,PB516C
 PB516C,20F3C3A,PB514A
 PB516C,20F3C3B,PB514A
 OPWF18,PB516C,1
 PL516C,PB516C,PS516C
 PS516C,PB516C,PL516C
 PT516,PB516C,1
 PT546,PB516C,1
 PSIV,PT516,1
 PSIV,PT546,1
 PB515A,20F3C3A,PB516C
 PB515A,20F3C3B,PB516C
 PB516C,20F3C3A,PB515A
 PB516C,20F3C3B,PB515A

Expanded 2/3 coincidence gate 20F3C5A,B

PB534A,20F3C5A,PB515B
 PB534A,20F3C5B,PB515B
 OPWF18,PB534A,1
 PL534A,PB534A,PS534A
 PS534A,PB534A,PL534A
 PT534,PB534A,1
 PT544,PB534A,1
 PSI,PT534,1
 PSI,PT544,1
 PB515B,20F3C5A,PB534A
 PB515B,20F3C5B,PB534A
 OPWF18,PB515B,1
 PL515B,PB515B,PS515B
 PS515B,PB515B,PL515B
 PT515,PB515B,1
 PT535,PB515B,1
 PSII,PT515,1
 PSII,PT535,1
 PB534A,20F3C5A,PB526D
 PB534A,20F3C5B,PB526D
 OPWF18,PB526D,1
 PL526D,PB526D,PS526D
 PS526D,PB526D,PL526D
 PT526,PB526D,1
 PT536,PB526D,1
 PSIII,PT526,1
 PSIII,PT536,1
 PB526D,20F3C5A,PB534A
 PB526D,20F3C5B,PB534A
 PB515B,20F3C5A,PB526D
 PB515B,20F3C5B,PB526D
 PB526D,20F3C5A,PB515B
 PB526D,20F3C5B,PB515B

Expanded 2/3 coincidence gate 20F3C6A,B

PB534B,20F3C6A,PB525B
 PB534B,20F3C6B,PB525B
 OPWF18,PB534B,1
 PL534B,PB534B,PS534B
 PS534B,PB534B,PL534B
 PT534,PB534B,1
 PT544,PB534B,1
 PS1,PT534,1
 PS1,PT544,1
 PB525B,20F3C6A,PB534B
 PB525B,20F3C6B,PB534B
 OPWF18,PB525B,1
 PL525B,PB525B,PS525B
 PS525B,PB525B,PL525B
 PT525,PB525B,1
 PT545,PB525B,1
 PS11,PT525,1
 PS11,PT545,1
 PB534B,20F3C6A,PB516D
 PB534B,20F3C6B,PB516D
 OPWF18,PB516D,1
 PL516D,PB516D,PS516D
 PS516D,PB516D,PL516D
 PT516,PB516D,1
 PT546,PB516D,1
 PS1V,PT516,1
 PS1V,PT546,1
 PB516D,20F3C6A,PB534B
 PB516D,20F3C6B,PB534B
 PB525B,20F3C6A,PB516D
 PB525B,20F3C6B,PB516D
 PB516D,20F3C6A,PB525B
 PB516D,20F3C6B,PB525B

Expanded 2/3 coincidence gate 20F3C4A,B

PB514B,20F3C4A,PB525A
PB514B,20F3C4B,PB525A
OPWF18,PB514B,1
PL514B,PB514B,PS514B
PS514B,PB514B,PL514B
PT514,PB514B,1
PT524,PB514B,1
PSI,PT514,1
PSI,PT524,1
PB525A,20F3C4A,PB514B
PB525A,20F3C4B,PB514B
OPWF18,PB525A,1
PL525A,PB525A,PS525A
PS525A,PB525A,PL525A
PT545,PB525A,1
PT525,PB525A,1
PS11,PT545,1
PS11,PT525,1
PB514B,20F3C4A,PB526C
PB514B,20F3C4B,PB526C
OPWF18,PB526C,1
PL526C,PB526C,PS526C
PS526C,PB526C,PL526C
PT526,PB526C,1
PT536,PB526C,1
PS111,PT526,1
PS111,PT536,1
PB526C,20F3C4A,PB514B
PB526C,20F3C4B,PB514B
PB525A,20F3C4A,PB526C
PB525A,20F3C4B,PB526C
PB526C,20F3C4A,PB525A
PB526C,20F3C4B,PB525A

HI CONTAINMENT PRESSURE INSTRUMENTATION AND BISTABLE LOGIC

Expanded 2/3 coincidence gate 20F3C7A,B

PB936B,20F3C7A,PB935B
 PB936B,20F3C7B,PB935B
 OPWF19,PB936B,1
 PL936B,PB936B,PS936B
 PS936B,PB936B,PL936B
 PT936,PB936B,1
 PS11,PT936,1
 PB935B,20F3C7A,PB936B
 PB935B,20F3C7B,PB936B
 OPWF19,PB935B,1
 PL935B,PB935B,PS935B
 PS935B,PB935B,PL935B
 PT935,PB935B,1
 PS111,PT935,1
 PB936B,20F3C7A,PB934B
 PB936B,20F3C7B,PB934B
 OPWF19,PB934B,1
 PL934B,PB934B,PS934B
 PS934B,PB934B,PL934B
 PT934,PB934B,1
 PS1V,PT934,1
 PB934B,20F3C7A,PB936B
 PB934B,20F3C7B,PB936B
 PB935B,20F3C7A,PB934B
 PB935B,20F3C7B,PB934B
 PB934B,20F3C7A,PB935B
 PB934B,20F3C7B,PB935B

ADJACENCY INPUT FOR PROTECTION SET UNIT MODEL

DATA FROM TVA DWG 45N700-1

** PSI **

R13I,PSI,1
SWX5I,R13I,R12I
OPRF9I,SWX5I,1
R16I,SWX5I,1
TR1A,R16I,1
FUSE9I,TR1A,1
SW4I,FUSE9I,1
OPWF10I,SW4I,1
DUM7I,SW4I,1
R3I,DUM7I,1
SWX3I,R3I,480VSI1A1A
OPRF6I,SWX3I,1
480VSI1B1B,SWX3I,1
480VSI1A1A,R3I,SWX3I

R13 is a pair of relays interlocked for switching (using SWX5 and OPRF9) between normal and auxillary instrument power.
R16 is a relay in the 120VAC Instr. Power Dist. Panel.
TR1A is a transformer which feeds into 120VAC IPDP.

SW4 can cut power to 120VAC IPDP.
OPWF10 operates SW4.

R3 is a pair of relays interlocked for switching (using SWX3 and OPRF6) between normal and alternate feeder 480VAC shutdown boards 1A1A and 1B1B, respectively.

R12I,R13I,SWX5I
STATINVI,R12I,1
R15I,STATINVI,1
TR1A,R15I,1
TR1I,STATINVI,R11I
R10I,TR1I,1
DUM7I,R10I,1
R11I,STATINVI,TR1I
R9I,R11I,1
FUSE8I,R9I,1
DUM8I,FUSE8I,1
DUM8I,FUSE10I,1

R12 is relay connecting inverter to instr. power bd.
STATINVI is static inverter which needs synch signal from 120VAC IPDP.
R15 is relay in 120VAC IPDP.
TR1I is transformer within the 120VAC vital inverter.
R10 is a relay which connects the 120VAC vital inverter to the 480VAC shutdown feeders.
R11 connects to alternate path to static inverter.
R9 is relay in 125 VDC vital battery board.

FUSE10 connects to 6.9kv shutdown bd. control power.

Expanded AND-gate input to DUM8

R8I,DUM8I,DUMAND11I
DUMAND11I,DUM8I,R8I

R8 connects DUM8 to battery BATI.

FUSE6I,DUMAND11I,FUSE5I FUSE6 connects DUM8 to auxillary 480VAC boards.
FUSE5I,DUMAND11I,FUSE6I FUSE5 connects DUM8 to normal 480VAC boards.

R4I,FUSE5I,1
CHGRI,R4I,1
DUM7I,CHGRI,1
R5I,FUSE6I,1
R7I,R5I,1
SWX6I,R7I,1
OPRF8I,SWX6I,1
CHGRIS,SWX6I,1
R6I,CHGRIS,1
SWX4I,R6I,480VAV1A1A
OPRF7I,SWX4I,1
480VAV1B1B,SWX4I,1
480VAV1A1A,R6I,SWX4I
FUSE7I,R6I,1
BATI,FUSE7I,1

CHGRI is battery charger which is connected to normal 480VAC boards (i.e.,normal inverter feeder boards).

R7 is normally open and is closed by operator OPRF8 actuating switch SWX6.

CHGRIS is spare battery charger.

R6 is a pair of relays interlocked for switching (using SWX4 and OPRF7) between the 2 aux. 480VAC bds.

BATI is battery.

**** PS11 ****

R1311,PS11,1
 SWX511,R1311,R1211
 OPRF911,SWX511,1
 R1611,SWX511,1
 TR1B,R1611,1
 FUSE911,TR1B,1
 SW411,FUSE911,1
 OPWF1011,SW411,1
 DUM711,SW411,1
 R311,DUM711,1
 SWX311,R311,480VS1B2B
 OPRF611,SWX311,1
 480VS1A2A,SWX311,1
 480VS1B2B,R311,SWX311

R13 is a pair of relays interlocked for switching (using SWX5 and OPRF9) between normal and auxillary instrument power.
 R16 is a relay in the 120VAC Instr. Power Dist. Panel.
 TR1A is a transformer which feeds into 120VAC IPDP.

SW4 can cut power to 120VAC IPDP.
 OPWF10 operates SW4.

R3 is a pair of relays interlocked for switching (using SWX3 and OPRF6) between normal and alternate feeder 480VAC shutdown boards 1A1A and 1B1B, respectively.

R1211,R1311,SWX511
 STATINV11,R1211,1
 R1511,STATINV11,1
 TR1B,R1511,1
 TR11,STATINV11,R1111
 R1011,TR11,1
 DUM711,R1011,1
 R1111,STATINV11,TR111
 R911,R1111,1

R12 is relay connecting inverter to instr. power bd.
 STATINV1 is static inverter which needs synch signal from 120VAC IPDP.
 R15 is relay in 120VAC IPDP.
 TR11 is transformer within the 120VAC vital inverter.
 R10 is a relay which connects the 120VAC vital inverter to the 480VAC shutdown feeders.
 R11 connects to alternate path to static inverter.
 R9 is relay in 125 VDC vital battery board.

Expanded AND-gate input to DUM8

FUSE811,R911,1
 DUM811,FUSE811,1
 DUM811,FUSE1011,1
 R811,DUM811,DUMAND1111
 DUMAND1111,DUM811,R811
 FUSE611,DUMAND1111,FUSE511
 FUSE511,DUMAND1111,FUSE611

R8 connects DUM8 to battery BAT1.
 FUSE6 connects DUM8 to auxillary 480VAC boards.
 FUSE5 connects DUM8 to normal 480VAC boards.

R411,FUSE511,1
 CHGR11,R411,1
 DUM711,CHGR11,1
 R511,FUSE611,1
 R71,R511,1
 SWX61,R71,1
 OPRF81,SWX61,1
 CHGR1S,SWX61,1
 R61,CHGR1S,1
 SWX41,R61,480VAV1A1A
 OPRF71,SWX41,1
 480VAV1B1B,SWX41,1
 480VAV1A1A,R61,SWX41
 FUSE711,R811,1
 BAT11,FUSE711,1

CHGR1 is battery charger which is connected to normal 480VAC boards (i.e.,normal inverter feeder boards).

R7 is normally open and is closed by operator OPRF8 actuating switch SWX6.

CHGR1S is spare battery charger.
 R6 is a pair of relays interlocked for switching (using SWX4 and OPRF7) between the 2 aux. 480VAC bds.

BAT1 is battery.

**** PSIII ****

R13III,PSIII,1 R13 is a pair of relays interlocked for switching (using SWX5 and OPRF9) between normal and auxillary instrument power.
 SWX5III,R13III,R12III
 OPRF9III,SWX5III,1
 R16III,SWX5III,1 R16 is a relay in the 120VAC Instr. Power Dist. Panel.
 TR2A,R16III,1 TR1A is a transformer which feeds into 120VAC IPDP.
 FUSE9III,TR2A,1
 SW4III,FUSE9III,1 SW4 can cut power to 120VAC IPDP.
 OPWF10III,SW4III,1 OPWF10 operates SW4.
 DUM7III,SW4III,1
 R3III,DUM7III,1 R3 is a pair of relays interlocked for switching (using SWX3 and OPRF6) between normal and alternate feeder 480VAC shutdown boards 1A1A and 1B1B, respectively.
 SWX3III,R3III,480VS2A1A
 OPRF6III,SWX3III,1
 480VS2B1B,SWX3III,1
 480VS2A1A,R3III,SWX3III

R12III,R13III,SWX5III R12 is relay connecting inverter to instr. power bd.
 STATINVIII,R12III,1 STATINV1 is static inverter which needs synch signal from 120VAC IPDP.
 R15III,STATINVIII,1 R15 is relay in 120VAC IPDP.
 TR2A,R15III,1 TR1III,STATINVIII,R11III TR1I is transformer within the 120VAC vital inverter.
 R10III,TR1III,1 R10 is a relay which connects the 120VAC vital inverter to the 480VAC shutdown feeders.
 DUM7III,R10III,1 R11III,STATINVIII,TR1III R11 connects to alternate path to static inverter.
 R9III,R11III,1 R9 is relay in 125 VDC vital battery board.

Expanded AND-gate input to DUM8

FUSE8III,R9III,1
 DUM8III,FUSE8III,1
 DUM8III,FUSE10III,1
 R8III,DUM8III,DUMAD11III R8 connects DUM8 to battery BATI.
 DUMAD11III,DUM8III,R8III
 FUSE6III,DUMAD11III,FUSE5III FUSE6 connects DUM8 to auxillary 480VAC boards.
 FUSE5III,DUMAD11III,FUSE6III FUSE5 connects DUM8 to normal 480VAC boards.

R4III,FUSE5III,1
 CHGR1II,R4III,1 CHGR1 is battery charger which is connected to normal 480VAC boards (i.e.,normal inverter feeder boards).
 DUM7III,CHGR1II,1
 R5III,FUSE6III,1
 R7II,R5III,1 R7 is normally open and is closed by operator OPRF8 actuating switch SWX6.
 SWX6II,R7II,1
 OPRF8II,SWX6II,1
 CHGR1IS,SWX6II,1 CHGR1IS is spare battery charger.
 R6II,CHGR1IS,1 R6 is a pair of relays interlocked for switching (using SWX4 and OPRF7) between the 2 aux. 480VAC bds.
 SWX4II,R6II,480VAV2A1A
 OPRF7II,SWX4II,1
 480VAV2B1B,SWX4II,1
 480VAV2A1A,R6II,SWX4II
 FUSE7III,R8III,1
 BATIII,FUSE7III,1 BATI is battery.

**** PSIV ****

R13IV,PSIV,1
 SWX5IV,R13IV,R12IV
 OPRF9IV,SWX5IV,1
 R16IV,SWX5IV,1
 TR2B,R16IV,1
 FUSE9IV,TR2B,1
 SW4IV,FUSE9IV,1
 OPWF10IV,SW4IV,1
 DUM7IV,SW4IV,1
 R3IV,DUM7IV,1
 SWX3IV,R3IV,480VS2B2B
 OPRF6IV,SWX3IV,1
 480VS2A2A,SWX3IV,1
 480VS2B2B,R3IV,SWX3IV

R13 is a pair of relays interlocked for switching (using SWX5 and OPRF9) between normal and auxillary instrument power.
 R16 is a relay in the 120VAC Instr. Power Dist. Panel.
 TR1A is a transformer which feeds into 120VAC IPDP.

SW4 can cut power to 120VAC IPDP.
 OPWF10 operates SW4.

R3 is a pair of relays interlocked for switching (using SWX3 and OPRF6) between normal and alternate feeder 480VAC shutdown boards 1A1A and 1B1B, respectively.

R12IV,R13IV,SWX5IV
 STATINIV,R12IV,1
 R15IV,STATINIV,1
 TR2B,R15IV,1
 TR1IV,STATINIV,R11IV
 R10IV,TR1IV,1
 DUM7IV,R10IV,1
 R11IV,STATINIV,TR1IV
 R9IV,R11IV,1

R12 is relay connecting inverter to instr. power bd.
 STATINIV is static inverter which needs synch signal from 120VAC IPDP.
 R15 is relay in 120VAC IPDP.
 TR1I is transformer within the 120VAC vital inverter.
 R10 is a relay which connects the 120VAC vital inverter to the 480VAC shutdown feeders.
 R11 connects to alternate path to static inverter.
 R9 is relay in 125 VDC vital battery board.

Expanded AND-gate input to DUM8

FUSE8IV,R9IV,1
 DUM8IV,FUSE8IV,1
 DUM8IV,FUSE10IV,1
 R8IV,DUM8IV,DUMAND11IV
 DUMAND11IV,DUM8IV,R8IV
 FUSE6IV,DUMAND11IV,FUSE5IV
 FUSE5IV,DUMAND11IV,FUSE6IV

R8 connects DUM8 to battery BATI.
 FUSE6 connects DUM8 to auxillary 480VAC boards.
 FUSE5 connects DUM8 to normal 480VAC boards.

R4IV,FUSE5IV,1
 CHGRIV,R4IV,1
 DUM7IV,CHGRIV,1
 R5IV,FUSE6IV,1
 R7II,R5IV,1
 SWX6II,R7II,1
 OPRF8II,SWX6II,1
 CHGRIS,SWX6II,1
 R6II,CHGRIS,1
 SWX4II,R6II,480VAV2A1A
 OPRF7II,SWX4II,1
 480VAV2B1B,SWX4II,1
 480VAV2A1A,R6II,SWX4II
 FUSE7IV,R8IV,1
 BATIV,FUSE7IV,1

CHGR1 is battery charger which is connected to normal 480VAC boards (i.e.,normal inverter feeder boards).

R7 is normally open and is closed by operator OPRF8 actuating switch SWX6.

CHGRIS is spare battery charger.
 R6 is a pair of relays interlocked for switching (using SWX4 and OPRF7) between the 2 aux. 480VAC bds.

BATI is battery.

ADJACENCY INPUT FOR ELECTRICAL POWER SUPPORT
DATA FROM TVA DWG. 15N500 AND FSAR PP. 8.2-7,8,9

**** UNIT 1 POWER ****

Connections back to 6.9KV shutdown board 1BB (6900VS1BB).

R25,480MOV1B2B,R56	All R-'s are relays. 480MOV1B2B is MOV board 1B2B.
R24,R25,1	
X1,R24,1	X- is a component of unknown type.
480VS1B2B,X1,R28	480VS1B2B is 480V shutdown board 1B2B.
R19,480VS1B2B,1	
TR1B2B,R19,1	TR- is a transformer.
R18,TR1B2B,1	
6900VS1BB,R18,1	6900VS1BB is 6.9KV shutdown board 1BB.
R56,480MOV1B2B,R25	
OPRE42,MXFR20,1	OPRE42 operates R56 by actuation of MXFR20.
MXFR20,R56,1	MXFR- is man. transfer controller for closing relays.
R32,R56,1	
X2,R32,1	
R28,X1,480VS1B2B	
MXFR15,R28,1	
OPRE37,MXFR15,1	
TR1BB,R28,1	
R27,TR1BB,1	
MXFR14,R27,1	
OPRE36,MXFR14,1	
6900VS1BB,R27,1	
R26,480MOV1B1B,F33	480MOV1B1B is MOV board 1B1B.
OPRE39,MXFR17,1	
MXFR17,R26,1	
R24,R26,1	
R33,480MOV1B1B,R26	
R32,R33,1	
R23,480VAV1B1B,F35	480VAV1B1B is cont. and aux. bldg. vent bd. 1B1B.
MXFR18,R23,1	
OPRE40,MXFR18,1	
R22,R23,1	
X1,R22,1	
R35,480VAV1B1B,F23	
R34,R35,1	
X2,R34,1	
R37,480VAV1B2B,P21	
MXFR19,R37,1	
OPRE41,MXFR19,1	
R36,R37,1	
X2,R36,1	
R21,480VAV1B2B,F37	
R20,R21,1	
X1,R20,1	
R29,X2,480VS1B1B	
MXFR16,R29,1	
OPRE38,MXFR16,1	
TR1BB,R29,1	
480VS1B1B,X2,R29	
R31,480VS1B1B,1	
TR1B1B,R31,1	
R30,TR1B1B,1	
6900VS1BB,R30,1	

Connections back to 6.9KV shutdown board 1AA (6900VS1AA).

R44, 480MOV1A2A, R52 480MOV1A2A is MOV board 1A2A.
R43, R44, 1
X3, R43, 1
480VS1A2A, X3, R47 480VS1A2A is 480V shutdown board 1A2A.
R38, 480VS1A2A, 1
TR1A2A, R38, 1
R58, TR1A2A, 1
6900VS1AA, R58, 1 6900VS1AA is 6.9KV shutdown board 1AA.
R52, 480MOV1A2A, R44
MXFR26, R52, 1
OPRE48, MXFR26, 1
R51, R52, 1
R47, X3, 480VS1A2A
MXFR22, R47, 1
OPRE47, MXFR22, 1
TR1AA, R47, 1
R46, TR1AA, 1
MXFR21, R46, 1
OPRE43, MXFR21, 1
6900VS1AA, R46, 1
R45, 480MOV1A1A, R53 480MOV1A1A is MOV board 1A1A.
MXFR24, R45, 1
OPRE45, MXFR24, 1
R43, R45, 1
R53, 480MOV1A1A, R45
R51, R53, 1
X4, R51, 1
R42, 480VAV1A1A, R55 480VAV1A1A is 480V cont. and aux. bldg. vent bd. 1A1A.
MXFR25, R42, 1
OPRE46, MXFR25, 1
R41, R42, 1
X3, R41, 1
R55, 480VAV1A1A, R42
R54, R55, 1
X4, R54, 1
R40, 480VAV1A2A, R57 480VAV1A2A is 480V cont. and aux. bldg. vent bd. 1A2A.
R39, R40, 1
X3, R39, 1
R57, 480VAV1A2A, R40
MXFR27, R57, 1
OPRE49, MXFR27, 1
R55, R57, 1
X4, R55, 1
R48, X4, 480VS1A1A 480VS1A1A is 480V shutdown board 1A1A.
MXFR23, R48, 1
OPRE44, MXFR23, 1
TR1AA, R48, 1
480VS1A1A, X4, R48
R50, 480VS1A1A, 1
TR1A1A, R50, 1
R49, TR1A1A, 1
6900VS1AA, R49, 1

Connections from offsite and onsite power supplies to 6900VS1BB.

Expanded AND-gate for connections to 6900VS1BB.

R1728,DUMAND28,R1934

R1934,DUMAND28,R1728

DUMAND28,DUMAND27,R1914

R1914,DUMAND27,DUMAND28

DUMAND27,6900VS1BB,R1726

R1726,6900VS1BB,DUMAND27

MXFR1,R1728,AXFR3

AXFR3,R1728,MXFR1

OPRE22,MXFR1,1

R1724,R1728,6900VSUB3

R1728,6900VSUB3,1

6900VSUB3,R1728,R1724

R2814,6900VSUB3,1

OPRB50,6900VSUB3,1

CSSTDY,R2814,1

161KVBAY4,CSSTDY,1

R1124,R1724,R1624

USST1BY,R1124,1

500KVBAY8,USST1BY,MNGEN1

500KV,500KVBAY8,1

OPRE54,500KV,AXFR7

AXFR7,500KV,OPRE54

MNGEN1,USST1BY,500KVBAY8

R1624,R1724,R1124

MXFR2,R1624,1

OPRE23,MXFR2,1

6900VSBB,R1624,1

IVOLT1,6900VSBB,DUM21

DUM21,6900VSBB,IVOLT1

R1612,DUM21,R1514

ICURR1,R1612,CSSTBY

CSSTBY,R1612,ICURR1

161KVBAY13,CSSTBY,1

161KV,161KVBAY13,1

OPRE55,161KV,AXFR8

AXFR8,161KV,OPRE55

R1514,DUM21,R1612

ICURR2,R1514,CSSTAY

CSSTAY,R1514,ICURR2

AXFR1,R1514,MXFR4

MXFR4,R1514,AXFR1

OPRE24,MXFR4,1

AXFR3 is automatic switch to alternate feeder

6900VSUB- is 6.9KV utility bus (FSAR p. 8.3-5)

Power is bi-directional to/from utility buses. This permits interconnection of 6.9KV shutdown buses.

Access to 6900VSUB-'s requires 2 op.'s (e.g.,#50,#22).

CSSTDY is common sta. serv. trans. D, wind. X.

USST1BY= unit sta. serv. transformer 1B, winding Y.

500KVBAY8 is 1 500KV power line/conn. to plant,

MNGEN1 is unit generator, and 500KV is 500KV source.

Offsite power is enabled only after switching (FSAR p. 8.3-1)

6900VSBB is 6.9KV start bus B.

IVOLT- is a voltage monitor.

ICURR- is current monitor.

CSSTBY is common sta. serv. transformer B, wind. Y.

161KVBAY13 is 1 161KV power line/conn. to plant.

161KV is 161KV source.

Offsite power is enabled only by switching.

AXFR- is automatic transfer (auto relay close on UV).

161KVBAY4,CSSTAY,1
 161KV,161KVBAY4,1
 MXFR5,R1934,1
 OPRE25,MXFR5,1
 6900VSUB1,R1934,1
 OPRB51,R1934,1
 R1934,6900VSUB1,1
 R2714,6900VSUB1,1
 CSSTCX,R2714,1
 161KVBAY13,CSSTCX,1
 MXFR6,R1914,AXFR4
 AXFR4,R1914,MXFR6
 OPRE26,MXFR6,1
 DSLGEN1BB,R1914,1
 SISIGA,DUM10,SISIGB
 SISIGB,DUM10,SISIGA
 OPRE27,DSLGEN1BB,DUM10
 DUM10,DSLGEN1BB,OPRE27
 DUM10,AXFR4,1
 R1722,R1726,1
 R1524,R1722,R1122
 MXFR7,R1524,1
 OPRE28,MXFR7,1
 6900VSBA,R1524,1
 IVOLT2,6900VSBA,DUM22
 DUM22,6900VSBA,IVOLT2
 R1512,DUM22,R1614
 ICURR3,R1512,CSSTAY
 CSSTAY,R1512,ICURR3
 R1614,DUM22,R1512
 ICURR4,R1614,CSSTBY
 CSSTBY,R1614,ICURR4
 AXFR2,R1614,MXFR8
 MXFR8,R1614,AXFR2
 OPRE29,MXFR8,1
 R1122,R1722,R1524
 USST1BY,R1122,1

161KVBAY4 is 1 161KV power line/conn. to plant.

CSSTCX is com. sta. serv. trans. C, wind. X.

DSLGEN1BB is diesel generator 1BB.
 Either SISIG automatically turns on all DSLGEN's.

AXFR4 is automatic actuator dependent upon SILOGIC.

6900VSBA is 6.9KV start bus A.

Connections from offsite and onsite power supplies to 6900VS1AA.

Expanded AND-gate for inputs to 6900VS1AA.

R1718,DUMAND30,R1932
R1932,DUMAND30,R1718
DUMAND30,DUMAND29,R1912
R1912,DUMAND29,DUMAND30
DUMAND29,6900VS1AA,R1716
R1716,6900VS1AA,DUMAND29
R1714,R1718,1
R1114,R1714,R1622
USST1AY,R1114,1 USST1AY is unit sta. serv. trans. 1A, wind. Y.
MNGEN1,USST1AY,500KVBAY8
500KVBAY8,USST1AY,MNGEN1
R1622,R1714,R1114
MXFR9,R1622,1
OPRE30,MXFR9,1
6900VSBB,R1622,1
MXFR10,R1932,1
OPRE31,MXFR10,1
6900VSUB2,R1932,1
OPRB52,R1932,1
R1932,6900VSUB2,1
R3812,6900VSUB2,1
CSSTDY,R3812,1 CSSTDY is com. sta. serv. trans. D, wind. Y.
161KVBAY4,CSSTDY,1
MXFR11,R1912,AXFR5
AXFR5,R1912,MXFR11
OPRE32,MXFR11,1
DSLGEN1AA,R1912,1 DSLGEN1AA is diesel generator 1AA.
OPRE33,DSLGEN1AA,DUM10
DUM10,DSLGEN1AA,OPRE33
DUM10,AXFR5,1
MXFR12,R1716,AXFR6
AXFR6,R1716,MXFR12
OPRE34,MXFR12,1
R1712,R1716,6900VSUB4
R1716,6900VSUB4,1
6900VSUB4,R1716,R1712
R3712,6900VSUB4,1
OPRB53,6900VSUB4,1
CSSTCY,R3712,1 CSSTCY is com. sta. serv. trans. C, wind. Y.
161KVBAY13,CSSTCY,1
R1112,R1712,R1522
USST1AY,R1112,1
R1522,R1712,R1112
MXFR13,R1522,1
OPRE35,MXFR13,1
6900VSBA,R1522,1

**** UNIT 2 POWER ****

All comments (except headers) are Unit 1 nomenclature.

Connections back to 6.9KV shutdown board 2B8 (6900VS2B8).

R25B,480MOV2B2B,R56B	All R-'s are relays. 480MOV1B2B is MOV board 1B2B.
R24B,R25B,1	
X1B,R24B,1	X- is a component of unknown type.
480VS2B2B,X1B,R28B	480VS1B2B is 480V shutdown board 1B2B.
R19B,480VS2B2B,1	
TR2B2B,R19B,1	TR- is a transformer.
R18B,TR2B2B,1	
6900VS2B8,R18B,1	6900VS1B8 is 6.9KV shutdown board 1B8.
R56B,480MOV2B2B,R25B	
OPRE42B,MXFR20B,1	OPRE42 operates R56 by actuation of MXFR20.
MXFR20B,R56B,1	MXFR- is man. transfer controller for closing relays.
R32B,R56B,1	
X2B,R32B,1	
R28B,X1B,480VS2B2B	
MXFR15B,R28B,1	
OPRE37B,MXFR15B,1	
TR28B,R28B,1	
R27B,TR28B,1	
MXFR14B,R27B,1	
OPRE36B,MXFR14B,1	
6900VS2B8,R27B,1	
R26B,480MOV2B1B,R33B	480MOV1B1B is MOV board 1B1B.
OPRE39B,MXFR17B,1	
MXFR17B,R26B,1	
R24B,R26B,1	
R33B,480MOV2B1B,R26B	
R32B,R33B,1	
R23B,480VAV2B1B,R35B	480VAV1B1B is cont. and aux. bldg. vent bd. 1B1B.
MXFR18B,R23B,1	
OPRE40B,MXFR18B,1	
R22B,R23B,1	
X1B,R22B,1	
R35B,480VAV2B1B,R23B	
R34B,R35B,1	
X2B,R34B,1	
R37B,480VAV2B2B,R21B	
MXFR19B,R37B,1	
OPRE41B,MXFR19B,1	
R36B,R37B,1	
X2B,R36B,1	
R21B,480VAV2B2B,R37B	
R20B,R21B,1	
X1B,R20B,1	
R29B,X2B,480VS2B1B	
MXFR16B,R29B,1	
OPRE38B,MXFR16B,1	
TR28B,R29B,1	
480VS2B1B,X2B,R29B	
R31B,480VS2B1B,1	
TR2B1B,R31B,1	
R30B,TR2B1B,1	
6900VS2B8,R30B,1	

Connections back to 6.9KV shutdown board 2AA (6900VS2AA).

R44B, 480MOV2A2A, R52B 480MOV1A2A is MOV board 1A2A.

R43B, R44B, 1

X3B, R43B, 1

480VS2A2A, X3B, R47B

480VS1A2A is 480V shutdown board 1A2A.

R38B, 480VS2A2A, 1

TR2A2A, R38B, 1

R58B, TR2A2A, 1

6900VS2AA, R58B, 1

6900VS1AA is 6.9KV shutdown board 1AA.

R52B, 480MOV2A2A, R44B

MXFR26B, R52B, 1

OPRE48B, MXFR26B, 1

R51B, R52B, 1

R47B, X3B, 480VS2A2A

MXFR22B, R47B, 1

OPRE47B, MXFR22B, 1

TR2AA, R47B, 1

R46B, TR2AA, 1

MXFR21B, R46B, 1

OPRE43B, MXFR21B, 1

6900VS2AA, R46B, 1

R45B, 480MOV2A1A, R53B

480MOV1A1A is MOV board 1A1A.

MXFR24B, R45B, 1

OPRE45B, MXFR24B, 1

R43B, R45B, 1

R53B, 480MOV2A1A, R45B

R51B, R53B, 1

X4B, R51B, 1

R42B, 480VAV2A1A, R55B

480VAV1A1A is 480V cont. and aux. bldg. vent bd. 1A1A.

MXFR25B, R42B, 1

OPRE46B, MXFR25B, 1

R41B, R42B, 1

X3B, R41B, 1

R55B, 480VAV2A1A, R42B

R54B, R55B, 1

X4B, R54B, 1

R40B, 480VAV2A2A, R57B

480VAV1A2A is 480V cont. and aux. bldg. vent bd. 1A2A.

R39B, R40B, 1

X3B, R39B, 1

R57B, 480VAV2A2A, R40B

MXFR27B, R57B, 1

OPRE49B, MXFR27B, 1

R55B, R57B, 1

X4B, R55B, 1

R48B, X4B, 480VS2A1A

480VS1A1A is 480V shutdown board 1A1A.

MXFR23B, R48B, 1

OPRE44B, MXFR23B, 1

TR2AA, R48B, 1

480VS2A1A, X4B, R49B

R50B, 480VS2A1A, 1

TR2A1A, R50B, 1

R49B, TR2A1A, 1

6900VS2AA, R49B, 1

Connections from offsite and onsite power supplies to 6900VS2BB.

Expanded AND-gate for connections to 6900VS2BB.

R1828,DUMAND22B,R1938
R1938,DUMAND22B,R1828
DUMAND22B,DUMAND21B,R1924
R1924,DUMAND21B,DUMAND22B
DUMAND21B,6900VS2BB,R1826
R1826,6900VS2BB,DUMAND21B

MXFR1B,R1828,AXFR3B AXFR3B is automatic switch to alternate feeder

AXFR3B,R1828,MXFR1B

OPRE22B,MXFR1B,1

R1824,R1828,6900VSUB3

6900VSUB3,R1828,R1824

R1828,6900VSUB3,1

R2814,6900VSUB3,1

OPRB50B,6900VSUB3,1

R1224,R1824,R1634

USST2BY,R1224,1

USST1BY= unit sta. serv. transformer 1B, winding Y.

500KV BAY4,USST2BY,MNGEN2 500KV BAY8 is 1 500KV power line/conn. to plant,

500KV,500KV BAY4,1 MNGEN1 is unit generator, and 500KV is 500KV source.

MNGEN2,USST2BY,500KV BAY4

R1634,R1824,R1224

MXFR2B,R1634,1

OPRE23B,MXFR2B,1

6900VSBB,R1634,1

6900VSBB is 6.9KV start bus B.

MXFR5B,R1938,1

OPRE25B,MXFR5B,1

6900VSUB1,R1938,1

OPRB51B,R1938,1

R1938,6900VSUB1,1

MXFR6B,R1924,AXFR4B

AXFR4B,R1924,MXFR6B

OPRE26B,MXFR6B,1

DSLGEN2BB,R1924,1

DSLGEN1BB is diesel generator 1BB.

OPRE27B,DSLGEN2BB,DUM10

DUM10,DSLGEN2BB,OPRE27B

DUM10,AXFR4B,1

R1822,R1826,1

R1534,R1822,R1222

MXFR7B,R1534,1

OPRE28B,MXFR7B,1

6900VSBA is 6.9KV start bus A.

6900VSBA,R1534,1

R1222,R1822,R1534

USST2BY,R1222,1

Connections from offsite and onsite power supplies to 6900VS2AA.

Expanded AND-gate for inputs to 6900VS2AA.

R1818,DUMAND42B,R1936
R1936,DUMAND42B,R1818
DUMAND42B,DUMAND32B,R1922
R1922,DUMAND32B,DUMAND42B
DUMAND32B,6900VS2AA,R1816
R1816,6900VS2AA,DUMAND32B
R1814,R1818,1
R1214,R1814,R1632
USST2AY,R1214,1 USST1AY is unit sta. serv. trans. 1A, wind. Y.
MNGEN2,USST2AY,500KVBAY4
500KVBAY4,USST2AY,MNGEN2
R1632,R1814,R1214
MXFR9B,R1632,1
OPRE30B,MXFR9B,1
6900VSBB,R1632,1
MXFR10B,R1936,1
OPRE31B,MXFR10B,1
6900VSUB2,R1936,1
OPRB52B,R1936,1
R1936,6900VSUB2,1
MXFR11B,R1922,AXFR5B
AXFR5B,R1922,MXFR11B
OPRE32B,MXFR11B,1
DSLGEN2AA,R1922,1 DSLGEN1AA is diesel generator 1AA.
OPRE33B,DSLGEN2AA,DUM10
DUM10,DSLGEN2AA,OPRE33B
DUM10,AXFR5B,1
MXFR12B,R1816,AXFR6B
AXFR6B,R1816,MXFR12B
OPRE34B,MXFR12B,1
R1812,R1816,6900VSUB4
R1816,6900VSUB4,1
6900VSUB4,R1816,R1812
OPRB53B,6900VSUB4,1
R1212,R1812,R1532
USST2AY,R1212,1
R1532,R1812,R1212
MXFR13B,R1532,1
OPRE35B,MXFR13B,1
6900VSBA,R1532,1
0,0,0