Enclosure One

Preliminary Precursor Analysis

Accident Sequence Precursor Program — Office of Nuclear Regulatory Research

Diablo Canyon Unit 1	Extended loss of offsite power to safety-related buses due to 12-kV bus fault	
Event Date 05/15/2000	LER 275/00-004-01	CCDP = 3.1×10^{-4}

Event Summary

On May 15, 2000, at 0025 PDT, Diablo Canyon Unit 1 was operating at 100% power when the unit tripped (Ref. 1). The unit tripped because of an electrical phase-to-phase fault on the 12-kV non-segregated phase bus between the unit Auxiliary Transformer (UAT) 1-1 and 12-kV Bus D and Bus E (see Figure 1). The fault was immediately sensed by phase differential protective relays which initiated a reactor trip.

Even though the unit tripped immediately, it took several seconds for the voltage to decay from the main generator. Consequently, electrical current from the generator continued to feed the fault, resulting in electrical arcing and catastrophic damage to the faulted bus bar and duct. The electrical arcing damaged an adjacent 4-kV startup bus duct that feeds 4160-V Buses D, H, G, and F from Startup Transformer (SUT) 1-2. The damage to the 4-kV bus induced arcing in the 4-kV bus duct, resulting in a differential trip of SUT 1-2.

When Unit 1 tripped, the 4-kV buses lost their normal power supply via the UAT. When SUT 1-2 tripped, the 4-kV buses lost their startup supply. The loss of both power supplies to safety-related Buses F, G, and H caused the emergency diesel generators (EDGs) to start. Vital loads on 4-kV buses F, G, and H automatically sequenced onto their associated EDGs.

Startup Transformer 1-1 remained energized, supplying power to non-vital 12-kV loads consisting of the 4 reactor coolant pumps and one circulating water pump. The faults left non-vital 4-kV Buses D and E de-energized. Consequently, recognizing that the loss of non-vital 4-kV buses resulted in a loss of cooling to the running circulating water pump, the operators secured the pump before it overheated.

The onsite fire brigade entered the room and extinguished the fire with a CO_2 extinguisher within minutes. During the event response, an engineer performed augmented monitoring of the EDGs. On May 16, at 0959 PDT (approximately 33 hours after the unit trip), the licensee restored offsite power to vital and non-vital loads, and secured the EDGs.

Cause. The cause of the bus failure could not be conclusively determined because of the absence of evidence. The failed bus connection had vaporized. Several feet of conductor had burned or melted away. The licensee postulated that the immediate cause was a thermal failure of the bolted connection of the center conductor of the 12-kV bus bar.

Time period. As a result of this event, the vital and non-vital 4-kV buses were powered from the EDGs for approximately 33 hours. However, the NRC inspection team that reviewed this event determined that offsite power could have been recovered within 8 hours (Ref. 2).

Analysis Results

- ***Conditional core damage probability (CCDP).*** The CCDP for this reactor trip with an extended loss of offsite power to the vital 4-kV buses is 3.1×10^{-4}.

  In the Accident Sequence Precursor Program, precursors with CCDP greater than or equal to 1.0×10^{-4} are considered as "important" precursors.

- ***Dominant sequence.*** Figures 2 and 3 highlight the dominant core damage sequence for this event. Station Blackout Sequence 18-08, which contributes 71% of the total CCDP, includes the following:

  - Loss of offsite power to vital 4-KV Buses F, G, and H;
  - Successful reactor trip;
  - Failure of all emergency AC power (all three EDGs);
  - Successful operation of the auxiliary feedwater (AFW) system;
  - Pressurizer power-operated relief valves (PORVs) do not lift;
  - Reactor coolant pump (RCPs) seals fail; and
  - High-pressure injection fails.

- ***Results tables.***

  - Table 1 provides the conditional probability for the dominant sequences.
  - Table 2a provides the event tree sequence logic for the dominant sequences.
  - Table 2b defines the nomenclature used in Table 2a.
  - Table 3 provides the conditional cut sets for the dominant sequences.

Modeling Assumptions

- ***Assessment:*** This event was modeled as an initiating event using Revision 2QA of the Diablo Canyon SPAR model (Ref. 3). Several changes were made to the SPAR model to incorporate the increased risk significance of the extended time for recovery of offsite power to the vital buses. Other changes were made to consider the reduction in risk associated with the availability of the condenser heat sink several minutes immediately following the reactor trip. Additional changes were made to incorporate sequence-specific, non-recovery failure probabilities appropriate for this event. The discussion below provides the bases for significant changes.

- ***Basic event probability changes***: Table 4 provides the basic events which were modified to reflect the event condition being analyzed. The bases for these changes are as follows:

  - *Probability of challenging pressurizer PORV/SRVs after a reactor trip* - The condenser heat sink with one operating circulating water pump was available for about 10 minutes following the reactor trip. Then the operators secured the pump and closed the main steam isolation valves. The probability of challenges to the power-operated relief valves or safety-relief valves (PORVs/SRVs) was less than that expected during a typical loss of offsite power or station blackout event where the condenser heat sink would be immediately lost. The probability that pressurizer PORVs/SRVs open (basic events PPR-SRV-CO-L, PPR-SRV-CO-SBO) was reduced to 0.04–the value used in the SPAR model for general transients.

- *Non-recovery probabilities for offsite power*: During the event, because of the damage to the bus bars, offsite power was unavailable to the emergency buses for 33 hours. However, based on the NRC inspection report (Ref. 2), and discussions with NRC inspectors (Ref. 4), the operators could have recovered offsite power to the buses within approximately 8 hours (approximately 95% likelihood). Based on discussions with NRC inspectors, there was some likelihood (about 5% likelihood) of recovering power 5 hours after the event. Therefore, the probability of non-recovery of offsite power within 6 hours (basic event OEP-XHE-NOREC-6H) was assigned a probability of 0.95[1]. The probabilities of non-recovery of offsite power within 2 hours and in the short-term (within 2 hours) were assigned a probability of 1.0 (basic events OEP-XHE-NOREC-2H, OEP-XHE-NOREC-ST).

- *Non-recovery probabilities for individual sequences* - Table 4 shows the non-recovery probabilities of the dominant sequences. Table 5 provides the bases for those probabilities.

• ***Model update***: The SPAR model for Diablo Canyon was updated to account for updates of system/component failure probabilities based on recent operating experience; a change in the reactor coolant pump seal loss-of-coolant accident (LOCA) model; and changes in modeling assumptions based on design characteristics specific to Diablo Canyon. These updates are independent of the actual event being analyzed.

Basis for these updates are described in the footnotes to Tables 2b, 4 and 5. Updates specific to Diablo Canyon are summarized below.

- *Probability of failing RCP seals when seal cooling is lost* - In accordance with guidance provided in Reference 5, the Rhodes Model (described in Ref. 6) was used to estimate the probability of failure of the reactor coolant pump (RCP) seals. The RCPs at Diablo Canyon Unit 1 have "improved" Westinghouse seal assemblies. Based on the Rhodes Model, the probability of failing the RCP seals with improved Westinghouse seal assemblies (basic event RCP-MDP-LK-SEALS) is 0.22. Additional changes to the SPAR model relating to the Rhodes Model are summarized in the footnote to Table 2b.

- *Time available to recover high-pressure injection in the event of a RCP seal LOCA* - Based on the Rhodes Model (Ref. 6), the time available to prevent core damage by high-pressure injection, if the RCP seals fail, is four hours. Therefore, EDGs or offsite power must be recovered within four hours to avert core damage during a station blackout. From the SPAR model (Ref. 3), the probability of non-recovery of an EDG within 4 hours is 0.5. From the discussion above, the probability of non-recovery of offsite power within 4 hours is 1.0.

  These non-recovery probabilities were used to update non-recovery probabilities for RCP seal LOCA sequences in the station blackout event tree (Table 5).

- *Time available to recover high-pressure recirculation in the event of a stuck-open presssurizer SRV* - Based on the Diablo Canyon Individual Plant Examination (Section 1.4.1.2, Ref. 11), the time available during a small LOCA prior to deletion of the refueling water storage tank is five hours. Therefore, high-pressure (sump) recirculation via the low-pressure injection (LPI) pumps must occur within this time period. For those

[1] This failure probability (OEP-XHE-NOREC-6H) had no impact on the CCDP.

sequences (e.g., minimum cut sets) where LPI pumps are unavailable due to loss of offsite and emergency power, an EDG or offsite power must be recovered within five hours to avert core damage. From the SPAR model (Ref. 3), the probability of non-recovery of an EDG within 5 hours is 0.42. From the discussion above, the probability of non-recovery of offsite power within 5 hours is 0.95.

These non-recovery probabilities were used to update non-recovery probabilities for stuck-open pressurizer PORV/SRV sequences in the loss of offsite power event tree (Table 5).

- *Probability of battery depletion before recovery offsite power* - Based on information provided in calculations prepared by Pacific Gas and Electric Company (PGE), the battery depletion time for Unit 1 is at least 8 hours.[2] Based on the NRC inspection report (Ref. 2), and discussions with NRC inspectors (Ref. 4), the operators could have recovered offsite power to the buses within approximately 8 hours (approximately 95% likelihood). Therefore, the probability of non-recovery of offsite power within 8 hours (basic event OEP-XHE-NOREC-BD) is 0.05 (i.e., 5% likelihood that offsite power will not be recovered within 8 hours).

References

1. LER 275/00-004-01, "Unit 1 Unusual Event Due to a 12 kV Bus Fault," August 30, 2000.

2. U.S. Nuclear Regulatory Commission Inspection Report Nos. 50-275-00-09; 50-323-00-09, July 31, 2000.

3. Idaho National Engineering and Environmental Laboratory, "Simplified Plant Analysis Risk (SPAR) Model for Diablo Canyon Units 1 and 2," Revision 2QA, March 1998.

4. Personal communications between W. Jones (U.S. NRC, Region II) and S. Weerakkody (U.S. NRC, Office of Nuclear Regulatory Research), January 11, 2001.

5. Memorandum from Ashok C. Thadani to William D. Travers, "Closeout of Generic Safety Issue 23: Reactor Coolant Pump Seal Failure," U.S. Nuclear Regulatory Commission, November 8, 1999.

6. R.G. Neve and H.W. Heiselmann, "Cost/Benefit Analysis for Generic Issue 23: Reactor Coolant Pump Seal Failure," NUREG/CR-5167, April 1991.

7. Reserved.

[2] According to the licensee (S. Weerakkody, U.S. NRC, private communication with A. Afzali, Pacific Gas and Electric, December 6, 2000), PGE Engineering Calculation 369-DC, Revision 0, batteries 11, 13 (Unit 1 batteries for F and H vital buses, respectively) will supply adequate voltage to operate required devices under station blackout case for 8 hours (i.e., no aid from battery chargers is credited). Battery 12 will do the same for 7 hours. The PRA model credits 7 hours for the batteries. In consideration of the following two conservatisms, 8 hours was chosen as the battery depletion time for all batteries. The following two conservatisms are associated with the battery depletion time: Calculation 369-DC assumes a battery condition near the end of life (i.e., just before the need for battery replacement) and the battery depletion time calculation does not credit any load shedding. EOP ECA-0.0, "Loss of All Vital AC Power," Step 14, provides instructions to facilitate load shedding.

8. G. M. Grant, et al., "Reliability Study: Emergency Diesel Generator Power System, 1987-1993," NUREG/CR-5500, Vol. 5, September 1999.

9. F.M. Marshall, D.M. Rasmusson, and A. Mosleh, "Common-Cause Failure Parameter Estimations," NUREG/CR-5497, October 1998.

10. J. P. Poloski, et al., "Reliability Study: Auxiliary/Emergency Feedwater System, 1987-1995," NUREG/CR-5500, Vol. 1, August 1998.

11. Diablo Canyon Individual Plant Examination, April 1992.

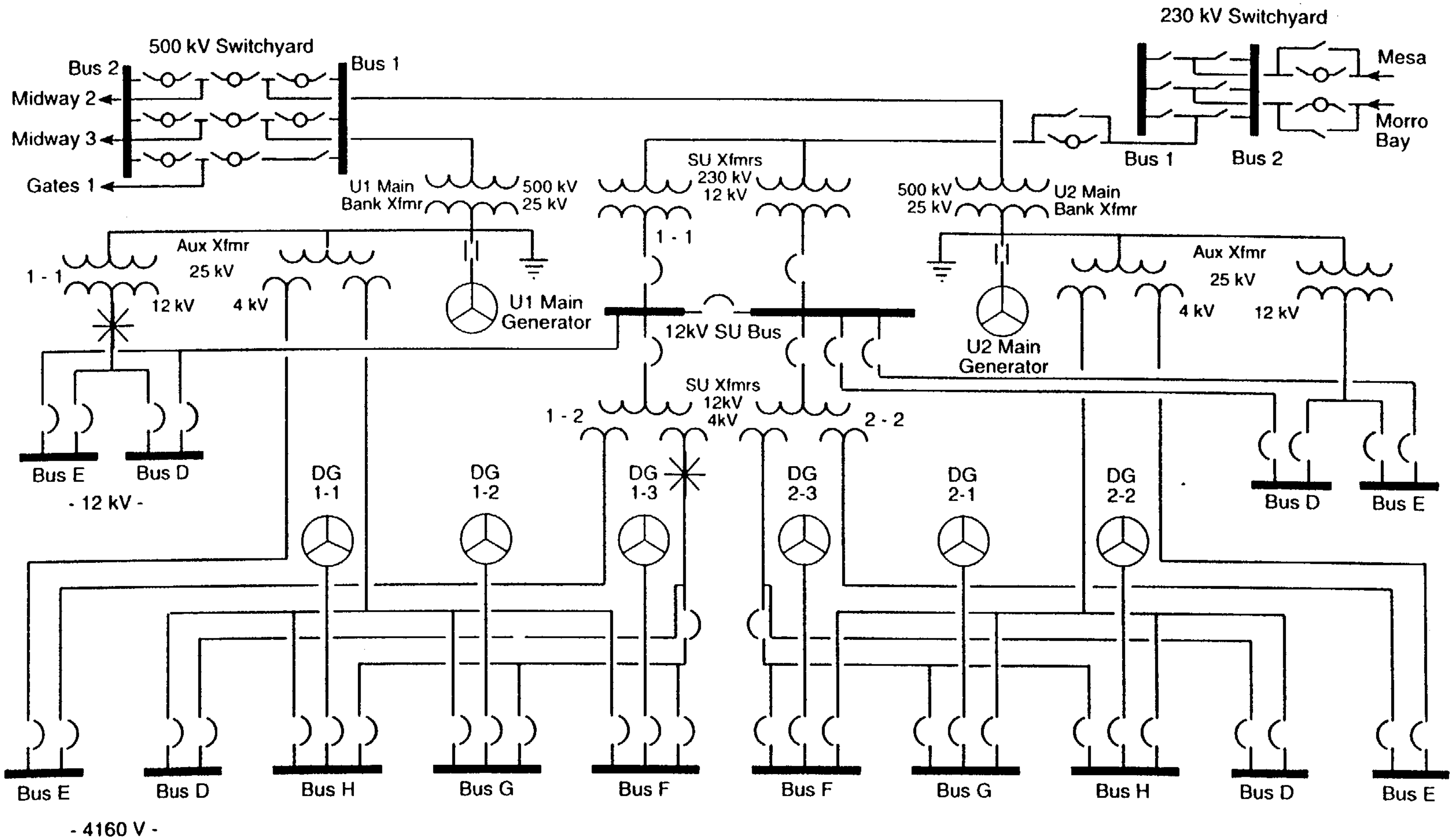

Figure 1. Electrical Power Distribution Diagram, Diablo Canyon (* Shows faulted bus bars)

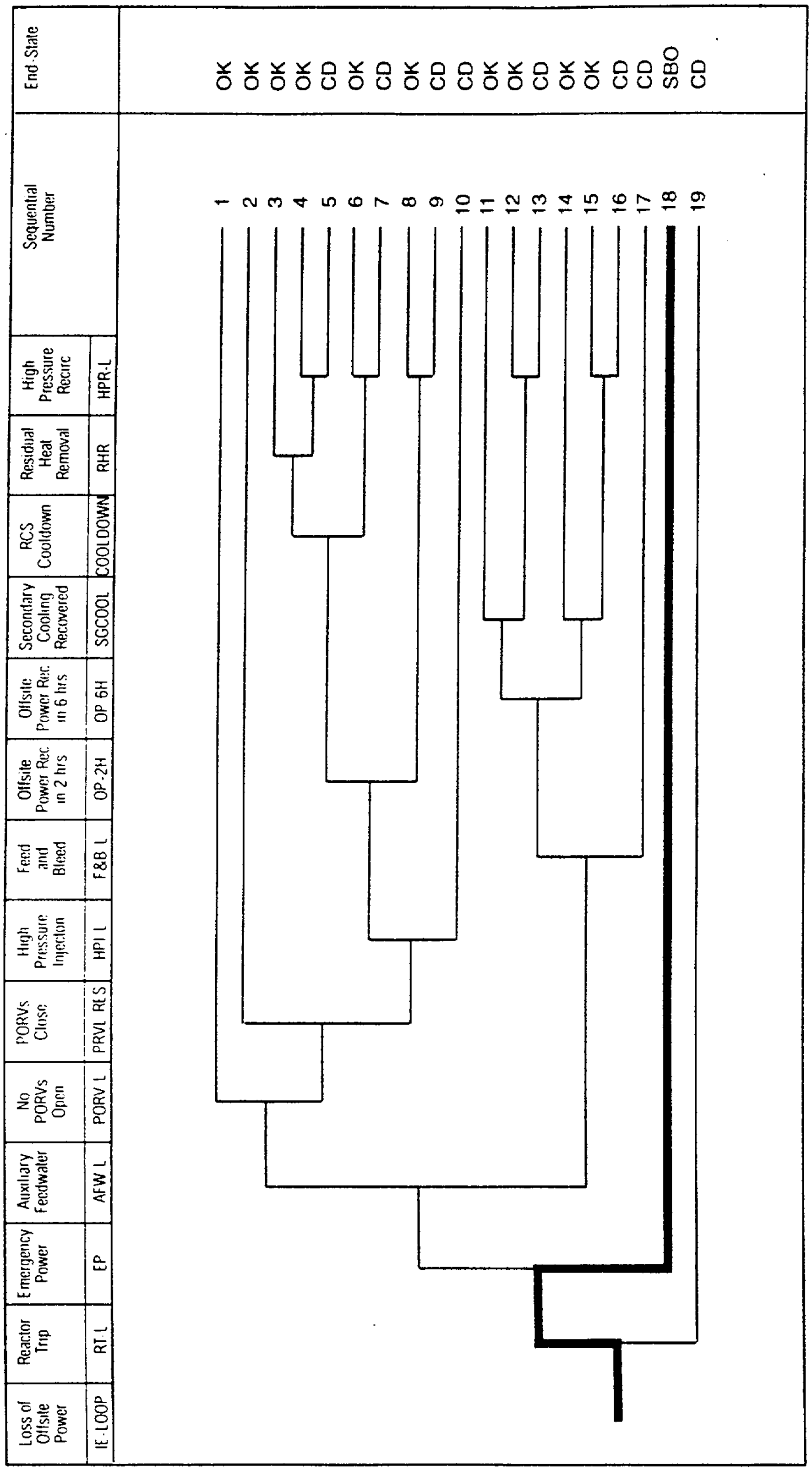

Figure 2. Loss of Offsite Power Event Tree (Sequence 18 Transfers to the Station Blackout Event Tree - Figure 3)

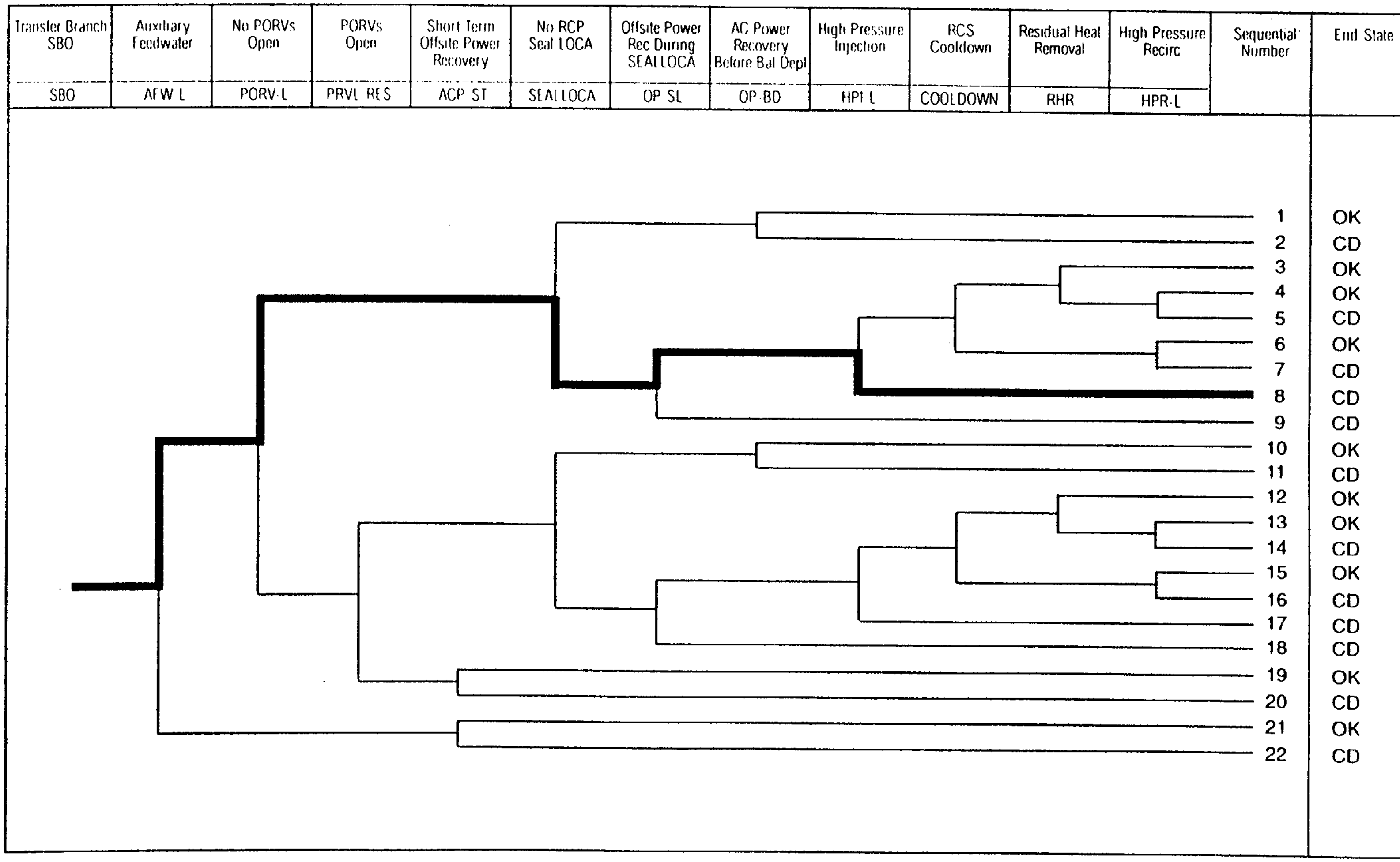

Figure 3. Station Blackout Event Tree

Table 1. Conditional probabilities associated with the highest probability sequences.

Event tree name	Sequence no.	Conditional core damage probability (CCDP)	Percent contribution
LOOP	18-08	2.2E-004	71.0
LOOP	18-22	3.0E-005	9.7
LOOP	18-02	2.0E-005	6.5
LOOP	09	1.3E-005	4.2
Total (all sequences)[1]		**3.1E-004**	**100**

1. Total CCDP includes all sequences (including those not shown in this table).

Table 2a. Event tree sequence logic for dominant sequences.

Event tree name	Sequence no.	Logic ("/" denotes success; see Table 2b for top event names)
LOOP	18-08	/RT-L EP /AFW-L /PORV-SBO SEALLOCA HPI-L
LOOP	18-22	/RT-L EP AFW-L ACP-ST
LOOP	18-02	/RT-L EP /AFW-L /PORV-SBO /SEALLOCA OP-BD
LOOP	09	/RT-L EP /AFW-L PORV-L PRVL-RES /HPI-L OP-2H HPR-L

Table 2b. Definitions of top events listed in Table 2a.

ACP-ST	Offsite power recovery in short term
AFW-L	No or insufficient auxiliary feedwater flow during loss of offsite power
EP	Failure of all trains of emergency power
HPI-L [1]	No or insufficient flow from the high-pressure injection system during loss of offsite power
HPR-L [1]	No or insufficient flow from the high-pressure injection system during recirculation and loss of offsite power
OP-2H	Operator fails to recover offsite power within two hours
OP-BD	Operator fails to recover offsite power prior to battery depletion
OP-SL [1]	Operator fails to recover offsite power prior to core uncovery given a reactor coolant pump (RCP) seal loss-of-coolant accident (LOCA)
PORV-L	Pressurizer power-operated relief valves/safety valves open during a loss of offsite power
PORV-SBO	Pressurizer power-operated relief valves/safety valves open during a station blackout
PRVL-RES	Pressurizer power-operated relief valves/block valves and safety valves fail to close
RT-L	Reactor fails to trip during loss of offsite power
SEALLOCA	Reactor coolant pump seals fail during loss of offsite power

1. In accordance with guidance provided in Ref. 5, the SPAR model was modified to replace the existing RCP seal LOCA model with the Rhodes Model (Ref. 6). In order to replace the RCP seal LOCA model without modifying the station blackout event tree, top event OP-SL was set to "False" (basic event OEP-XHE-NOREC-SL). To account for offsite power recovery, the non-recovery probabilities for offsite power and emergency diesel generators (EDGs) were added to the sequence-specific non-recovery probabilities for the RCP seal LOCA sequences in the station blackout event tree (see Table 5 and Figure 3). Based on the Rhodes Model, the time available to prevent core damage by high-pressure injection if RCP seals fail is 4 hours. Therefore, the non-recovery probabilities for EDGs and offsite power were modified to reflect the 4-hour recovery time to avert core damage (see Table 5). Finally, Event Tree Linking Rule Nos. 4 and 5 (Ref. 3, Table 2-1), which are triggered by the success of top event OP-SL, were negated by substituting fault tree HPI for HPI-L in LOOP Sequences 18-08 and 18-17 and HPR for HPR-L in LOOP Sequences 18-05, 18-07, 18-14, and 18-16.

Table 3. Conditional cut sets for the dominant sequence. (See Table 4 for definitions and probabilities for the basic events.)

CCDP	Percent Contribution	Minimum cut sets (of basic events)		
Event Tree: LOOP, Sequence 18-08				
1.4E-004	62.5	EPS-DGN-CF-ALL LOOP-18-08-NREC	RCS-MDP-LK-SEALS	/PPR-SRV-CO-SBO
8.2E-005	37.4	RCS-MDP-LK-SEALS EPS-DGN-FC-1C	EPS-DGN-FC-1A /PPR-SRV-CO-SBO	EPS-DGN-FC-1B LOOP-18-08-NREC
2.2E-004	**Total**[1]			
Event Tree: LOOP, Sequence 18-22				
1.9E-005	62.3	OEP-XHE-NOREC-ST LOOP-18-22-NREC	EPS-DGN-CF-ALL	AFW-TDP-FC-1A
1.1E-005	37.3	OEP-XHE-NOREC-ST EPS-DGN-FC-1B	AFW-TDP-FC-1A EPS-DGN-FC-1C	EPS-DGN-FC-1A LOOP-18-22-NREC
3.0E-005	**Total**[1]			
Event Tree: LOOP, Sequence 18-02				
1.2E-005	62.5	EPS-DGN-CF-ALL /PPR-SRV-CO-SBO	OEP-XHE-NOREC-BD LOOP-18-02-NREC	/RCS-MDP-LK-SEAL
7.3E-006	37.4	OEP-XHE-NOREC-BD EPS-DGN-FC-1B LOOP-18-02-NREC	/RCS-MDP-LK-SEALS EPS-DGN-FC-1C	EPS-DGN-FC-1A /PPR-SRV-CO-SBO
2.0E-005	**Total**[1]			
Event Tree: LOOP, Sequence 09				
4.1E-006	31.1	OEP-XHE-NOREC-2H EPS-DGN-FC-1B	PPR-SRV-CO-L PPR-SRV-OO-2	EPS-DGN-FC-1A LOOP-09-NREC
4.1E-006	31.1	OEP-XHE-NOREC-2H EPS-DGN-FC-1C	PPR-SRV-CO-L PPR-SRV-OO-2	EPS-DGN-FC-1B LOOP-09-NREC
4.1E-006	31.1	OEP-XHE-NOREC-2H EPS-DGN-FC-1B	PPR-SRV-CO-L PPR-SRV-OO-1	EPS-DGN-FC-1A LOOP-09-NREC
1.3E-005	**Total**[1]			

1. Total CCDP includes all cutsets (including those not shown in this table).

Table 4. Definitions and probabilities for selected basic events.

Event Name	Description	Probability	Modified
AFW-TDP-FC-1A	TURBINE-DRIVEN AUXILIARY FEEDWATER PUMP FAILS	3.5E-002	No
EPS-DGN-CF-ALL	COMMON CAUSE FAILURE OF DIESEL GENERATORS	1.3E-003	Yes(1)
EPS-DGN-FC-1A	DIESEL GENERATOR A FAILS	9.2E-002	Yes(2)
EPS-DGN-FC-1B	DIESEL GENERATOR B FAILS	9.2E-002	Yes(2)
EPS-DGN-FC-1C	DIESEL GENERATOR C FAILS	9.2E-002	Yes(2)
IE-LOOP	LOSS OF OFFSITE POWER INITIATING EVENT	1.0E+000	Yes(3)
IE-SGTR	STEAM GENERATOR TUBE RUPTURE INITIATING EVENT	0.0E+000	Yes(4)
IE-SLOCA	SMALL LOSS OF COOLANT ACCIDENT INITIATING EVENT	0.0E+000	Yes(4)
IE-TRANS	TRANSIENT INITIATING EVENT	0.0E+000	Yes(4)
LOOP-05-NREC	LOOP SEQUENCE 05 NON-RECOVERY PROBABILITY	4.0E-001	Yes(5)
LOOP-06-NREC	LOOP SEQUENCE 07 NON-RECOVERY PROBABILITY	4.0E-001	Yes(5)
LOOP-09-NREC	LOOP SEQUENCE 09 NON-RECOVERY PROBABILITY	4.0E-001	Yes(5)
LOOP-10-NREC	LOOP SEQUENCE 10 NON-RECOVERY PROBABILITY	7.0E-001	Yes(5)
LOOP-18-02-NREC	LOOP SEQUENCE 18-02 NON-RECOVERY PROBABILITY	2.5E-001	Yes(5)
LOOP-18-05-NREC	LOOP SEQUENCE 18-05 NON-RECOVERY PROBABILITY	5.0E-001	Yes(5)
LOOP-18-07-NREC	LOOP SEQUENCE 18-07 NON-RECOVERY PROBABILITY	5.0E-001	Yes(5)
LOOP-18-08-NREC	LOOP SEQUENCE 18-08 NON-RECOVERY PROBABILITY	5.0E-001	Yes(5)
LOOP-18-14-NREC	LOOP SEQUENCE 18-14 NON-RECOVERY PROBABILITY	5.0E-001	Yes(5)
LOOP-18-16-NREC	LOOP SEQUENCE 18-16 NON-RECOVERY PROBABILITY	5.0E-001	Yes(5)
LOOP-18-17-NREC	LOOP SEQUENCE 18-17 NON-RECOVERY PROBABILITY	5.0E-001	Yes(5)
LOOP-18-20-NREC	LOOP SEQUENCE 18-20 NON-RECOVERY PROBABILITY	7.0E-001	Yes(5)
LOOP-18-22-NREC	LOOP SEQUENCE 18-22 NON-RECOVERY PROBABILITY	4.1E-001	Yes(5)
OEP-XHE-NOREC-2H	OPERATOR FAILS TO RECOVER OFFSITE POWER WITHIN TWO HOURS	1.0E+000	Yes(6)
OEP-XHE-NOREC-6H	OPERATOR FAILS TO RECOVER OFFSITE POWER WITHIN SIX HOURS	9.5E-001	Yes(6)
OEP-XHE-NOREC-BD	OPERATOR FAILS TO RECOVER OFFSITE POWER BEFORE BATTERY DEPLETION	5.0E-002	Yes(6)
OEP-XHE-NOREC-SL	OPERATOR FAILS TO RECOVER OFFSITE POWER BEFORE REACTOR COOLANT PUMP SEAL LOCA	FALSE	Yes(7)
OEP-XHE-NOREC-ST	OPERATOR FAILS TO RECOVER OFFSITE POWER IN SHORT TERM	1.0E+000	Yes(6)
PPR-SRV-CO-L	PRESSURIZER PORVS/SRVS OPEN DURING LOSS OF OFFSITE POWER	4.0E-002	Yes(6)
PPR-SRV-CO-SBO	PRESSURIZER PORVS/SRVS OPEN DURING STATION BLACKOUT	4.0E-002	Yes(6)
PPR-SRV-OO-2	PRESSURIZER PORV NO. 2 FAILS TO RECLOSE AFTER OPENING	3.0E-002	No
RCS-MDP-LK-SEALS	RCP SEALS FAIL W/O COOLING AND INJECTION	2.2E-001	Yes(8)

1. Model update using data from NUREG-5497, Tables 5-2 and 5-5 (Ref. 9), and NUREG/CR-5500, Vol. 5 (Ref. 8).
2. Model update using data from NUREG/CR-5500, Vol. 5, Tables 3, C-4, and C-7 (Ref. 8). EDG non-recovery probabilities were excluded here and included under the sequence-specific, non-recovery probabilities (Table 5).
3. Even though this event was not caused by severe weather, to be able to examine and adjust probabilities of failure to recover offsite power on a sequence specific basis, the "Extreme Weather" category of loss of offsite power was chosen for the analysis.
4. Initiating event frequencies were set to 0.0 to reflect the event analyzed.
5. Model update. See Table 5 for basis.
6. See text (Section entitled "Modeling Assumptions,") for basis.
7. Model update based on Rhodes Model (Ref. 6). See note to Table 2B for details.
8. Model update based on Rhodes Model (Ref. 6).

Table 5. Basis for the non-recovery probabilities of selected sequences.

Sequence No. and Basic event	Failed systems [1] and recovery time [2]	Non-recovery probability	Combined failure probability	Modification Remarks (also see footnote)
5 LOOP-05-NREC	EDG (5 hours) Offsite Power (5 hours)	0.42 0.95	0.4	Revised RWST depletion time
7 LOOP-07-NREC	EDG (5 hours) Offsite Power (5 hours)	0.42 0.95	0.4	Revised RWST depletion time
9 LOOP-09-NREC	EDG (5 hours) Offsite Power (5 hours)	0.42 0.95/1.0 [5]	0.4	Revised RWST depletion time
10 LOOP-10-NREC	EDG (2 hours) Offsite Power (2 hours)	0.7 1.0	0.7	
18-02 LOOP-18-02-NREC	EDG (8 hours)	0.25	0.25	Revised battery depletion time
18-05 LOOP-18-05-NREC	EDG (4 hours) Offsite Power (4 hours)	0.5 1.0 [3]	0.5	Include Rhodes RCP seal LOCA model
18-07 LOOP-18-07-NREC	EDG (4 hours) Offsite Power (4 hours)	0.5 1.0 [3]	0.5	Include Rhodes RCP seal LOCA model
18-08 LOOP-18-08-NREC	EDG (4 hours) Offsite Power (4 hours)	0.5 1.0 [3]	0.5	Include Rhodes RCP seal LOCA model
18-14 LOOP-18-14-NREC	EDG (4 hours) Offsite Power (4 hours)	0.5 1.0 [3]	0.5	Include Rhodes RCP seal LOCA model
18-16 LOOP-18-16-NREC	EDG (4 hours) Offsite Power (4 hours)	0.5 1.0 [3]	0.5	Include Rhodes RCP seal LOCA model
18-17 LOOP-18-17-NREC	EDG (4 hours) Offsite Power (4 hours)	0.5 1.0 [3]	0.5	Include Rhodes RCP seal LOCA model
18-20 LOOP-18-20-NREC	EDG (2 hours) Offsite Power (2 hours)	0.7 1.0	0.7	
18-22 LOOP-18-22-NREC	EDG (2 hours) Turbine-driven AFW Offsite Power (2 hours)	0.7 0.58 [4] 1.0	0.41	Revised AFW non-recovery probability

1. Based on SPAR model (Ref. 3), non-recovery probability for an EDG is *exp(-0.173t)*, where *t* is recovery time in hours. When multiple EDGs are failed, only one EDG is considered for recovery, since operators would attempt to recover only one EDG.
2. Recovery times used in the SPAR model are as follows:
   - 2 hours--core uncovery due to loss of heat removal (from the SPAR model, Ref. 3);
   - 4 hours--core uncovery due to RCP seal LOCA (update based on Rhodes Model, Ref. 6);
   - 5 hours--core uncovery due to refueling water storage tank depletion and failure to establish high-pressure (sump) recirculation (update based on Ref. 11); and
   - 8 hours--battery depletion (update based on Ref. 7).
3. Offsite power not recoverable within 4 hours. See text (section entitled "Modeling Assumptions,") for basis. Non-recovery probability for offsite power was added to this sequence non-recovery probability to account for top event OP-SL in the station blackout event tree being set to "False" to account for the Rhodes Model. See note to Table 2b for details.
4. Based on recovery probabilities provided in Table 4 of NUREG/CR-5500, Vol.1 (Ref. 10).
5. Accounts for top event OP-2H in the loss of offsite power event tree (i.e., non-recovery of offsite power within 2 hours). Combined non-recovery probability for sequence LOOP-09 = (non-recovery probability of offsite power within five hours)/(non-recovery probability of offsite power within two hours) = 0.06/1.0.