LER No. 247/99-015

Event Description: Loss of offsite power to safety-related buses following a reactor trip and tripping of an EDG output breaker

Date of Event: August 31, 1999

Plant: Indian Point No. 2

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Event Summary

On August 31, 1999, while the licensee was replacing a defective bi-stable in a pressurizer low pressure instrument channel, the reactor tripped (Refs. 1,2). After the reactor trip, the station blackout logic matrix generated a blackout signal as a result of a sustained under-voltage condition at the safety-related 480-V buses. The station blackout signal stripped the 480-V buses and reloaded them onto the emergency diesel generators (EDGs). The EDG output breaker to the 480-V bus 6A tripped within 14 seconds after closing due to an over-current condition on the bus.

The conditional core damage probability (CCDP) for this event is 6.4×10^{-5}. Core damage sequences where the all safety-related batteries deplete, and reactor coolant pump (RCP) seals fail are the dominant contributors to the CCDP.

Event Description

On August 31, 1999, while the licensee was replacing a defective bi-stable in a pressurizer low pressure instrument channel, a spurious electrical spike occurred in an over-temperature delta-temperature (OTDT) channel. In order to support replacing of the defective bi-stable in the pressurizer low pressure channel, the operators had already set a different OTDT channel to tripped condition. The spurious electrical spike in one OTDT channel, together with the tripped condition of the second OTDT channel satisfied the logic required to trip the reactor and caused a reactor trip.

After the reactor tripped, the main generator tripped and the generator output breakers opened as designed. (See Figure 1 for details of the electrical distribution system.) The 6.9-kV service buses fast-transferred to the external 138-kV supply via the station auxiliary transformer (STAUX). During the fast-transfer, while power was supplied via STAUX, an under-voltage (voltage dropping below the degraded voltage set point of 421-V +/- 6V) condition was detected on all safety-related 480-V buses.

When the voltage degraded, if the Tap changer of STAUX was operating in its automatic mode, it would have moved automatically to restore the voltage within one minute. However, due to a defective voltage control relay, the Tap changer was in manual mode. As a result, the under-voltage condition sustained over a period which exceeds its allowable value (180 sec +/- 30 seconds). Consequently, the station blackout logic matrix generated a blackout signal. The station blackout signal stripped the 480-V buses and reloaded them onto the emergency diesel generators (EDGs).

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Bus 6A loaded onto its EDG (EDG 23). Eight seconds after starting EDG 23, the output breaker from the EDG to bus 6A closed. Approximately 14 seconds later, the breaker tripped to its open position due to an over-current condition. Consequently, Bus 6A lost power from both the EDG and offsite power supply. The other 480-V buses were energized by their respective EDGs.

The blackout logic did not allow the transfer of safety-related 480-V buses 2A, 3A, 5A, and 6A back to their 6.9-kV buses until the blackout logic signal was reset. With Bus 6A de-energized, the under-voltage interlock prevented the reset of the blackout logic. Consequently, Bus 6A remained de-energized. Battery Charger 24 is powered from Bus 6A. After approximately 7.4 hours Instrument Bus 24 was lost when the voltage on DC Bus 24 became low. Offsite power was restored to the 480-V Bus 5A approximately 12 hours following event initiation.

Additional Event Related Information

Loss of 480-V Bus 6A and consequences

During this event, the reactor trip was followed by a loss of offsite power to 480-V buses. Due to tripping of the output breaker of EDG 23, emergency onsite power from EDG 23 was unavailable to 480-V Bus 6A. That is, both offsite and onsite power was unavailable to Bus 6A. De-energization of Bus 6A caused the unavailability of power to following risk-important equipment:

- Motor-driven auxiliary feedwater pump P-23;
- High-pressure safety injection pump P-23;
- Charging pump P-23;
- Sump recirculating pump P-22;
- Residual heat removal pump P-22;
- Block valve for one of the two pressurizer power-operated relief valve; and
- Battery charger 24.

Even though power was unavailable to loads powered from Bus 6A, offsite power was available to non-safet-related loads powered from the 6.9 kV buses. Further, buses 2A, and 3A were powered from EDG 22. Bus 5A was powered from EDG 21.

Loss of DC bus 24 and consequences

DC Bus 24 is fed from two power sources. One of these sources is Battery Charger 24, which is powered from Bus 6A. When power supply to Bus 6A failed, there was no power supply to Battery Charger 24. The second power supply to the DC Bus 24 is Battery 24. This battery is designed to supply its shutdown loads for a period of two hours following a plant trip and loss of all AC power. However, during this event, the battery supported the DC loads for approximately 7.4 hours without any power to the battery charger. During that period of time, power was not restored to Battery Charger 24. As a result, Battery 24 continued to drain and the DC Bus 24 voltage continued to drop. Instrument Bus 24 was lost when the voltage on the DC Bus 24 became too low for Inverter 24 to provide AC power to the instrument bus.

When the Instrument Bus 24 lost power, the auxiliary feedwater (AFW) flow control to the Steam Generator 24 lost power. As a result, the flow control valve assumed its fully open position. In

response, the operators secured the AFW Pump 22 (the turbine-driven AFW pump). Water levels in steam generators were maintained by starting and stopping the turbine-driven AFW pump three times (in lieu of running the pump continuously while taking local-manual control of the flow control valves).

Potential for steam generator tube rupture
The event analyzed in this report occurred on August 31, 1999. On February 15th of 2000, (i.e., approximately six months later) a steam generator tube leak occurred at Indian Point 2 (LER 247-00-001). Therefore, a degraded steam generator tube existed when the reactor tripped and offsite power was lost on August 31 of 1999.

Modeling Details and Key Assumptions

Several changes were made to the Revision 2QA of the SPAR model (Ref. 3) in order incorporate the increased risk significance due to loss of Bus 6A. Other changes were made to incorporate reduction in the risk since power was available to balance-of-plant loads on 6.9-kV buses. Additional changes were made to incorporate sequence specific non-recovery factors appropriate for this event. Table B.X.1 summarizes changes made to the SPAR model. The discussion below provide the basis for significant changes:

- *Loss of offsite power* - The loss of offsite power initiator was chosen[1].

- *Probability of failing main feedwater (MFW)* - During this event, MFW and the main condenser which are powered from the 6.9-kV buses remained available to remove decay heat (Ref. 2). The SPAR model was modified to credit MFW[2].

- *Probability of failing the turbine-driven AFW pump* - The failure probability of the turbine-driven AFW train to start and run (basic event AFW-TDP-FC-22) is changed from 0.033 to 0.093 { = 0.003 (fail to run) + 3x0.03 (fail to start)}. Since the operators cycled the turbine-driven AFW pump three times in order to compensate for the failed-open flow control valve, the failure probability of the turbine-driven feedwater pump includes probability of failure in three start attempts.

- *Probability of failing feed-and-bleed cooling* - Indian Point 2 operates with both block valves to the pressurizer PORVs in closed position (basic events PPR-MOV-FC-BLK1 and PPR-MOV-FC-BLK2). Indian Point-2 has two PORVs and it requires both of them to feed-and-bleed. With the power supply via 480 Bus 6A unavailable, that block valve cannot be opened to bleed the

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1 Even though the loss of power to Bus 6A did not fail due to extreme severe weather, in order examine and adjust probabilities of offsite non-recovery probabilities by individual sequences, the extremely severe weather loss of offsite power category in the SPAR model was used in the analysis.

2 MFW was credited by creating an external tranfer to the MFW fault tree from the AFW fault tree used for loss of offsite power analysis.

.RCS in support of feed-and-bleed cooling. Therefore, the probability of failure of the feed-and-bleed cooling function is 1.0.

- *Probability of failing to recover tripped output breaker of EDG 23* - During this event, the power on Bus 6A failed because the EDG 23 output breaker tripped on over-current. The operators did not attempt to re-close the breaker since the other two EDGs functioned properly. If the other two EDGs failed, the operators would attempt to recover Bus 6A by closing the EDG output breaker. The fault tree for EDG 23 was modified by adding a new basic event, EPS-DGN-FC-23-OB, to model the capability to re-close the output breaker. The probability of failing to re-close the output breaker of EDG 23 after it trips open (basic event EPS-DGN-FC-23-OB) is 0.11. Section 1 of Attachment 1 provides additional details of the calculation.

- *Probability of EDG failures* - For this event, the probability of EDGs failures is 0.07. For the three EDGs, common-cause failure (CCF) probability is 7.7×10^{-4}. References 4 and 5 provides the basis for these probabilities.

- *Probability of failing to recover offsite power to 480-V buses from 6.9-kV buses* - During this event, the power on bus 6A failed because the EDG 23 output breaker tripped on over-current. AC power was available in the switchyard. The operators did not rush to bypass the interlock and re-close the breakers from the switchyard (6.9-kV) buses to safety-related 480-V buses (2A, 3A, 5A, and 6A) since two of the three EDGs functioned properly. If EDG 21 and 21 failed, operators would have attempted to recover power to the 480-V buses from the 6.9-kV buses.

  Two types of parameters involving recovery of offsite power via the 6.9-kV buses were modified to reflect the actual condition: basic events probabilities in fault trees and sequence-specific non-recovery probabilities in event trees. The SPAR model includes in the model offsite power recovery times of 2 and 6 hours, and prior to core uncovery from reactor coolant pump seal LOCA (4 hours) and battery depletion (7 hours for Indian Point 2). The probabilities for failure to recover offsite power to the 480-V safety-related buses (via the 6.9-kV buses) are **0.51** (when time available for recovery is within 2 hours) and **0.06** (when time available for recovery is greater than or equal to 4 hours). These non-recovery probabilities are based on human reliability analysis methods used in the ASP Program. Section 2 of Attachment 1 provides additional details for these calculations.

  Changes to basic events failure probabilities (OEP-XHE-NOREC-2H, OEP-XHE-NOREC-6H, OEP-XHE-NOREC-BD, OEP-XHE-NOREC-SL, and OEP-XHE-NOREC-ST) and sequence-specific non-recovery probabilities are summarized in Tables B.X.1 and B.X.2, respectively. The probabilities of failing to recover the 480-V buses from the 6.9-kV buses are 0.51 (when time available for recovery is less than fours) and 0.06 (when time available for recovery is greater than or equal to four hours). Table B.X.2 gives the nominal failure probabilities and the performance shaping factors (PSFs) used in the analysis. Section 2 of Attachment 1 provides additional details.

- *Probability of failure to recover offsite power by starting and aligning gas turbines* - Throughout the event, the 6.9-kV buses were powered from the offsite power supply. The capability to

supply power to the 6.9-kV buses from gas turbines (basic events OEP-XHE-XM-GTSL, OEP-XHE-XM-GTST, OEP-XHE-XM-GT2, OEP-XHE-XM-GT6, OEP-XHE-XM-GTBD) do not provide an additional benefit. Therefore, recovery actions associated with the gas turbines are not credited in the analysis.

- *Probability of failing RCP seals when seal cooling is lost* - Based on the Rhodes model (Ref. 4), the probability of failing the seals for RCPs with improved Westinghouse seal assemblies (basic event RCP-MDP-LK-SEALS) is 0.22.

- *Probability of opening PORVs/SRVs during transient* - Power to balance-of-plant systems used for condenser heat removal was available throughout the event. Therefore, the probability of challenges to the pressurizer PORVs and SRVs is less than that expected during a typical loss of offsite power or station blackout event where secondary system is lost. The probability that pressurizer safety valves open (PPR-SRV-CO-L, PPR-SRV-CO-SBO) was reduced to 0.04–the valve used in the SPAR model for general transients.

- Non-recovery probabilities for individual sequences - Table B.X.1 shows the sequence specific non-recovery probabilities. Table B.X.3 provide the basis for those probabilities.

Analysis Results

The conditional core damage probability (CCDP) for this event is 6.4×10^{-5}. Tables B.X.4 and B.X.5 gives details on the dominant sequences. CCDP is dominated by sequences in which all EDGs failed and power could not be restored to the emergency buses before battery depletion (Sequence Nos. 18-02, 48.4% of CCDP), RCP seal failure (Sequence No. 18-08, 23.4% of CCDP). A third dominant sequence involved loss of auxiliary feedwater (Sequence No. 17, 17.2% of CCDP). The impact of the degraded steam generator tube in Steam Generator 24 on CCDP is negligible. The basis for this conclusion is included in Section 3 of Attachment 1.

Figures 2 and 3 shows the event trees with dominant sequences highlighted.

Acronyms

AC	alternating current
AFW	auxiliary feedwater
CCDP	conditional core damage probability
CCF	common-cause failure
DC	direct current
EDG	emergency diesel generator
LOCA	loss of coolant accident
LOOP	loss of offsite power
MFW	main feedwater
OTDT	over-temperature delta-temperature
PORV	power-operated relief valve

RCP	reactor coolant pump
SBO	station blackout
SRV	safety relief valve
STAUX	station auxiliary transformer

References

1. LER 247/99-015, "Reactor Trip, ESF Actuation, Entry into TS 3.0.1, and Notification of Unusual Event," August 31, 1999.

2. U.S. Nuclear Regulatory Commission, "NRC Augmented Inspection Team - Reactor Trip with Complications," Report No. 50-247/99-08, October 19, 1999.

3. Idaho National Engineering and Environmental Laboratory, Simplified Plant Analysis Risk Model for Indian Point Unit 2, Revision 2QA, April 1998.

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

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

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

7. Personal communication between Sunil Weerakkody (U.S. NRC, Office of Nuclear Regulatory Research), James Trapp (U.S., NRC, RGN-I) and Licensee (Tony Reese, Phil Griffith), Nov. 20, 2000.

Table B.X.1: Definitions and Probabilities for Selected Basic Events for LER No. 247/99-015

Event name	Description	Base probability	Current probability	Type	Modified for this event
IE-LOOP	Initiating Event–LOOP	3.1 E-005	1.0		Yes
IE-SGTR	Initiating Event–Steam Generator Tube Rupture	1.6 E-006	0.0 E+000		Yes
IE-SLOCA	Initiating Event–Small Loss-of-Coolant Accident (SLOCA)	2.3 E-006	0.0 E+000		Yes
IE-TRANS	Initiating Event-Transients	2.7 E-004	0.0 E+000		Yes
AFW-TDP-FC-22	AFW turbine-driven pump 22 fails	3.3E-002	9.3E-002		Yes
EPS-DGN-CF-ALL	Common-cause failure of diesels	8.5E-004	7.7E-004		Yes[1]
EPS-DGN-FC-21	Diesel generator 21 fails	3.3E-002	7.0E-002		Yes[1]
EPS-DGN-DC-22	Diesel generator 22 fails	3.3E-002	7.0E-002		Yes[1]
EPS-DGN-FC-23	Diesel generator 23 fails	3.3E-002	7.0E-002		Yes[1]
EPS-DGN-FC-23-OB	Operator fail to close output breaker of EDG 23		0.11	New	
LOOP-05-NREC	LOOP Sequence 5 non-recovery	1.0	3.0E-002		Yes[2]
LOOP-09-NREC	LOOP Sequence 9 non-recovery	1.0	5.9E-002		Yes[2]
LOOP-17-NREC	LOOP Sequence 17 non-recovery	.22	9.0E-002		Yes[2]
LOOP-18-02-NREC	LOOP Sequence 18-02 non-recovery	0.8	0.3		Yes[2]
LOOP-18-05-NREC	LOOP Sequence 18-05 non-recovery	0.8	3.0E-002		Yes[2]
LOOP-18-07-NREC	LOOP Sequence 18-07 non-recovery	0.8	3.0E-002		Yes[2]
LOOP-18-08-NREC	LOOP Sequence 18-08 non-recovery	0.67	3.0E-002		Yes[2]
LOOP-18-11-NREC	LOOP Sequence 18-11 non-recovery	0.8	0.3		Yes[2]

LOOP-18-14-NREC	LOOP Sequence 18-14 non-recovery	0.8	3.0E-002		Yes[2]
LOOP-18-17-NREC	LOOP Sequence 18-17 non-recovery	0.67	3.0E-002		Yes
LOOP-18-20-NREC	LOOP Sequence 18-20 non-recovery	0.8	0.7		Yes
LOOP-18-22-NREC	LOOP Sequence 18-22 non-recovery	0.27	0.18		Yes
OEP-XHE-NOREC-2H	Operator fails to recover offsite power within 2 hours	3.2E-002	0.51		Yes
OEP-XHE-NOREC-6H	Operator fails to recover offsite power within 6 hours	1.4E-002	0.06		Yes
OEP-XHE-NOREC-BD	Operator fails to recover offsite power before battery depletion (within 7 hours)	8.6E-004	6.0E-002		Yes
OEP-XHE-NOREC-SL	Operator fails to recover offsite power (seal LOCA) (within 4 hours)	0.66	0	False	Yes
OEP-XHE-NOREC-ST	Operator fails to recover offsite power in short-term (within 2 hours)	0.17	0.51		Yes
OEP-XHE-XM-GTSL	Operator fails to start and align gas turbines during seal LOCA	0..34	0	False	Yes
OEP-XHE-XM-GT2	Operator fails to start and align gas turbines in 2 hours	0.34	Ignore		Yes
OEP-XHE-XM-GT6	Operator fails to start and align gas turbines in 2 hours	0.34	Ignore		Yes
OEP-XHE-XM-GTBD	Operator fails to start and align gas turbines before battery depletion	0.34	Ignore		Yes
OEP-XHE-XM-GTST	Operator fails to start and align gas turbines in short-term	0.34	Ignore		Yes
PPR-MOV-FC-BLK1	PORV block valve is in open position			True	No
PPR-MOV-FC-BLK2	PORV block valve is in open position			True	No
PPR-SRV-CO-L	PORVs/SRVs open during LOOP	0.16	4.0E-002		Yes
PPR-SRV-CO-SBO	PORVs/SRVs open during station blackout	0.37	4.0E-002		Yes

RCP-MDP-LK-SEALS	RCP seals fail w/o seal cooling	3.4E-002	0.22		Yes

Note 1: Updated using data from Refs. 5 and 6. Time dependent EDG non-recovery probabilities are included in the sequence specific non-recovery probabilities. Refer to table B.x.2.

Note 2: Refer to table B.X.2.

Table B.X.2: Summary of human error probabilities

Error Type	Time available (minutes)	Time required (minutes)	PSF[2] for available time	PSF for stress level	PSF for procedu -res	PSF for complexity of task	HEP[1]
Operator fails to close EDG output breaker when it trips due to over current basic event EPS-DGN-FC-23-OB							
Diagnostic error	≈120	few minutes	0.1	5	1	2	0.01
Manipulation error	≈120	120	10	5	1	2	0.1
Operator fails to clear SBO signal and close 6.9-kV/480-V breakers within 2 hours							
Diagnostic	≈120	few minutes	0.1	5	1	2	0.01
Action	≈120	≈120	10	5	5	2	.5
Operator fails to clear SBO signal and close 6.9-kV/480-V breakers within 6 hours							
Diagnostic	≈240	few minutes	0.1	5	1	2	0.01
Action	≈240	≈180	1	5	5	2	0.05
Operator fails to clear SBO signal and close 6.9-kV/480-V breakers before battery depletion (7.5 hours)							
Diagnostic	≈450	few minutes	0.1	5	1	2	0.01
Action	≈450	≈180	1	5	5	2	0.05
Operator fails to clear SBO signal and close 6.9-kV/480-V breakers before core uncovery following a seal LOCA (4 hours)							
Diagnostic	≈240	few minutes	0.1	5	1	2	0.01
Action	≈240	≈180	1	5	5	2	0.05

1. The human error probability uses a base value of 1×10^{-2} for cognitive error and 1×10^{-3} for the action failure probability.

2. Performance shaping factor

Table B.X.3: Basis for the probabilities of sequence recovery actions

Seq. No. and basic event	Failed systems and recovery time (Note 1)	Probability of failing to recover	Combine failure probability and remarks
5 LOOP-05-NREC	EDGs (4hours) Offsite power (4 hours)	0.5 (Note 2) 0.06	0.03
9 LOOP-09-NREC	EDGs (4 hours) Offsite power (4 hours)	0.5 0.06/0.51	0.059 (Event tree top event OP-2H includes offsite power non-recovery within 2 hours - basic event OEP-XHE-NOREC-2H. Since injection was succesful, additional time is available to recover AC power)
17 LOOP-17-NREC	EDG (2 hours) AFW Offsite power (2 hours)	0.7 0.26 (Note 3) 0.51	0.09
18-02 LOOP-18-02-NREC	EDG (7 hours)	0.3	0.3 (Top event OP-BD includes offsite power non-recovery prior to battery depletion - basic event OEP-XHE-NOREC-BD)
18-05 LOOP-18-05-NREC	EDGs (4 hours) Offsite power (4 hours)	0.5 0.06	0.03
18-08 LOOP-18-08-NREC	EDGs (4 hours) Offsite power (4 hours)	0.5 0.06	0.03
18-07 LOOP-18-07-NREC	EDGs (4 hours) Offsite power (4 hours)	0.5 0.06	0.03
18-11 LOOP-18-11-NREC	EDG (7 hours) Offsite power (4 hours)	0.3	0.3 (Top event OP-BD includes offsite power non-recovery prior to battery depletion - basic event OEP-XHE-NOREC-BD)
18-14 LOOP-18-14-NREC	EDG (4 hours) Offsite power (4 hours)	0.5 0.06	0.03
18-16 LOOP-18-16-NREC	EDG (4 hours) Offsite power (4 hours)	0.5 0.06	0.03

Seq. No. and basic event	Failed systems and recovery time (Note 1)	Probability of failing to recover	Combine failure probability and remarks
18-17 LOOP-18-17-NREC	EDG (4 hours) Offsite power (4 hours)	0.5 0.06	0.03
18-20 LOOP-18-20-NREC	EDG (2 hours)	0.7	0.7 (basic event OEP-XHE-NOREC-ST credits offsite power recovery)
18-22 LOOP-18-22-NREC	EDG (2 hours) AFW	0.7 0.26 (Note 3)	0.18 (basic event OEP-XHE-NOREC-ST credits offsite power recovery)

Note 1: Recovery times used in the SPAR model are as follows: core uncovery due to loss of heat removal - 2 hours; core uncovery due to RCP seal LOCA - 4 hours; battery depletion - 7 hours (based on observed failure during event)

Note 2: Based on SPAR model, the median recovery time for EDGs is 4 hours. Even when multiple EDGs are failed, since operators would attempt to recover only one EDG, only one EDG is considered for recovery.

Note 3: From SPAR model

Table B.X.4. Sequence Conditional Probabilities for LER No. 247/99-015

Event tree name	Sequence number	Conditional core damage probability (CCDP)	Percent contribution	[illegible]
LOOP	18-02	3.1E-005	48.4	Yes (B[illegible]
LOOP	18-08	1.5E-005	23.4	No ([illegible]) ([illegible] LOCA
LOOP	17	1.1E-005	17.2	Yes
LOOP	09	1.7E-006	2.7	No
LOOP	18-20	1.6E-006	2.5	No
LOOP	18-22	1.6E-006	2.5	Yes
LOOP	18-11	1.3E-006	2.0	Yes
LOOP	10	6.7E-007	1.1	
Total (all sequences)		**6.4E-005**		

Table B.X.5. Sequence Logic for Dominant Sequences for LER No. 247/99-015

Event tree name	Sequence number	Logic
LOOP	18-02	/RT-L, EP, /AFW-L, /PORV-SBO, /SEALLOCA, OP-BD
LOOP	18-08	/RT-L, EP, /AFW-L, /PORV-SBO, SEALLOCA, /OP-SL, HPI
LOOP	17	/RT-L, /EP, AFW-L, F&B-L
LOOP	09	/RT-L, /EP, PORV-L, PRVL-RES, /HPI-L, OP-2H, HPR-L
LOOP	18-20	/RT-L, EP, /AFW-L, PORV-SBO, /PRVL-RES, /SEALLOCA, OP-BD
LOOP	18-22	/RT-L, EP, AFW-L, ACP-ST
LOOP	18-11	/RT-L, EP, /AFW-L, PORV-SBO, /PRVL-RES, /SEALLOCA, OP-BD
LOOP	10	/RT-L, /EP, /AFW-L, PORV-L, PRVL-RES, HPI-L

Table B.X4. System Names for LER No. 247/99-015

System name	Logic
ACP-ST	Offsite power recovery in short-term
AFW-L	No or Insufficient EFW Flow During a LOOP
COOLDOWN	Rcs Cooldown to RHR Pressure Using TBVs, Etc.
EP	Emergency Power Fails
F&B-L	Failure to Provide Feed And Bleed Cooling - LOOP
OP-BD	Operator Fails to Recover Offsite Power Before Battery Depletion
OP-SL	Operator Fails to Offsite Power Before a Seal LOCA Occurs
OP-2H	Operator Fails to Recover Offsite Power Within 2 Hrs
HPI	No or Insufficient Flow from the HPI System
HPI-L	No or Insufficient Flow from HPI System - LOOP
HPR	No or Insufficient Flow from the HPR System
HPR-L	No or Insufficient Flow from HPR System - LOOP
PORV-L	PORVs/Safety Relief Valves Open During a LOOP
PORV-SBO	PORVs/SRVs Open During Station Blackout
PRVL-RES	PORVs and Block Valves and SRVs Fail to Reseat
RT-L	Reactor Fails to Trip During a LOOP
RHR	No or Insufficient Flow from the Rhr System
SEALLOCA	Reactor Coolant Pump Seals Fail During a LOOP

Attachment 1

Section 1: Additional details on the probability of failing to close the output breaker of EDG 23 to emergency Bus 6A

Recovery of Bus 6A by re-closing the EDG 23 output breaker entail the following tasks:

- Recognize the need to re-close output breaker to bus 6A.
- Close output breaker

Recognize the need to re-close output breaker
The operators will recognize that the EDG 23 output breaker tripped because of multiple alarms and annunciators. Compared to the time available for recovery (approximately 120 minutes), the time needed to recognize that EDG 23 is available and the output breaker must be closed is small. Therefore, the performance shaping factor (PSF) associated with available time is 0.1. Since all emergency 480-V buses have lost AC power, PSF level of stress is "extreme" (PSF factor is 5). In consideration of ambiguities on the part of the operators to close breakers to buses, the PSF factor for complexity is 2 (moderately complex) Therefore, the probability of cognitive error is 0.01 (= 5x 2 x 0.1 x 0.01).

Close output breaker
During the event, when EDG 23 output breaker tripped, to find the cause of that failure the operators tagged out Bus 6A. Subsequently, if the operators decided to recover Bus 6A, they must clear the tag placed on bus. Based on discussions with the licensee (Ref. 7), this activity requires about two hours. Since "available time" is approximately equal to the "time required" the PSF for available time is 10. Since all emergency 480-V buses have lost AC power, PSF level of stress is "extreme" (PSF factor is 5). When the operators decide to close the output breaker, that action can be implemented from the control room (Ref. 7). This action does not require a detailed procedure. In consideration of ambiguities on the part of the operators to close breakers to buses, the PSF factor for complexity is 2 (moderately complex). Therefore, the probability of human error to implement task is 0.1 (= 10 x 5 x 2 x .001).

Therefore, the total probability of failure is 0.11 (=0.01 + 0.1).

Output breaker does not trip open again due to over-current
During the event that occurred on August 31, 1999, due to an anomaly associated with the automatic sequencer, three large loads (an auxiliary feedwater pump, a service water pump, and a component cooling water pump) loaded onto Bus 6A within 4 seconds (see Page 8 of NRC inspection report for details.) During manual loading, this anomaly does not occur. The 3000- AMP range (over-current set point in the "as-found" condition) is sufficient to power an AFW pump, a CCW pump, and a SW pump and their auxiliaries. Therefore, even though the breaker tripped due to over-current when loads were sequenced automatically, if Bus 6A was recovered and essential loads (e.g., AFW pumps) were loaded on the bus manually, the output breaker would not trip.

Section 2: Additional details on the probability of failing to recover power to 480-V buses from 6.9-kV buses

If EDGs 21 and 22 failed, the operators would attempt to recover buses by closing the breakers between the 6.9-kV buses and the safety-related 480-V buses 2A, 3A, 4A, and 5A. The probabilities of failing to recover power to 480-V emergency buses from 6.9-kV buses are 0.51 (recovery within two hours) and 0.06 (recovery within four or more hours). The basis of these probabilities are as follows. To recover 480-V buses using power from 6.9-kV buses, the operators must (a) recognize the need to bypass the under-voltage interlock that prevents closing breakers between 6.9-kV and 480-V buses, (b) determine a method to bypass the interlock and generate a procedure to bypass that interlock, (c) bypass the interlock using the procedure, and (d) close breakers.

Recognize the need to bypass the under-voltage interlock
Based on communications with the licensee (Ref. 7), as a result of training received by reactor operators, it is common knowledge on the part of the operator that once the SBO signal occurs, the under-voltage signal must be reset before the 6.9-kV buses can be reconnected to the 480-V buses. The nominal failure probability for this cognitive error is .01. Since there is more than adequate time, the PSF factor for time available is 0.1. Since there is a SBO condition, the PSF factor for stress is 5. In consideration of ambiguities on the part of the operators to close breakers to buses, the PSF factor for complexity is 2 (moderately complex). Therefore, the probability of failure is .01 (=.01 x .1 x 5 x 2)

Determine a method to bypass the interlock and generate a procedure to bypass the interlock, generate procedure, and bypass interlock, and close breakers
The following information was provided by the licensee during a telephone call (Ref. 7). During the operating history of Indian Point-2, the operators have used a temporary facility change (TFC) to bypass the under-voltage interlock. To bypass the interlock, the operators must locate and retrieve this TFC. All TFCs are located in a computer database Bypass the under-voltage interlock. This computer database will not lose power even if power all emergency 480-V buses fail. During the actual event, it took operators approximately eight hours to locate and review this TFC (Page 8, Attachment 1 to NRC Inspection Report, Ref. 2). However, there was no urgency on the part of the operators to bypass the interlock since power was available from two out of three EDGs. Based on discussions with operations and PRA personnel at Indian Point-2, during a SBO, it may take ½ to three hours to retrieve the TFC and review and prepare it to implement the bypass. Therefore, in human reliability analysis (HRA) calculations, the PSF factor for time available was 1 (if time available is greater than four hours) and 10 (if time available was less than four hours). Since an SBO has occurred, the PSF factor for stress is 5. Since the TFC has to be reviewed and prepared during the event, PSF factor for procedure is 5 (i.e., procedure available but poor). In consideration of ambiguities on the part of the operators to close breakers to buses, the PSF factor for complexity is 2 (moderately complex). Consequently the probability of operators error is .05 (=.001 x 1 x 5 x 5 x 2) if time available to recover is greater or than or equal to four hours and .5 (=.001 x 10 x 5 x 5 x 2) if time available is less than four hours.

Therefore the total failure potabilities are 0.06 (=0.01+0.05) and 0.51 (=.01 + 0.5).

Bypassing the interlock (making a connection using a wire that has crocodile clips at its two ends) and closing breakers are relatively simple tasks. Once a decision is made to bypass the interlock, it can be accomplished within minutes. Therefore, the probability of failure of these actions are negligible in comparison to the probability of failure to retrieve, review and prepare the TFC (discussed above).

Section 3: Potential for steam generator tube rupture

failure

The event analyzed in this report occurred on August 31, 1999. On February 15th of 2000, (i.e., approximately six months later) a steam generator tube leak occurred at Indian Point 2 (LER 247-00-001). Therefore, a degraded steam generator tube existed when the reactor tripped and offsite power was lost on August 31 of 1999. Therefore, when the loss of offsite power event occurred on August 31, if a subsequent accident scenario lead to sequences in which the differential pressure between the tube and the reactor coolant system (ΔP) increased significantly, then a tube rupture could have occurred. The potential impact of this condition on the core damage frequency was considered negligible due to the following:

- The tube degradation is a time dependent function. Therefore, on August 31 (six months before the tube leak event), the degraded condition was less than the condition of that tube in February. (But, EMCB projected tube was susceptible to 2275 psid for a year.)
- In order to increase ΔP, either the RCS pressure should increase, or the secondary side pressure should decrease.
  - On August 31, when power was lost to the emergency buses, the power remained available to the balance of plant systems used for condenser heat removal. Therefore, the likelihood of a RCS pressure increase, even if the emergency electric power from EDGS failed was low.
  - The frequency sequence where AFW is failed with electric power available may pose a challenge to the degraded steam generator tube. However, since feed and bleed cooling was unavailable, this sequence is already treated as a core damage frequency sequence. Therefore, the degraded tube would not have increased the CDP.
  - The frequency of the sequence in which electric power fails and RCS pressure increase to challenge PORVs is approximately 2.1×10^{-5}. Therefore, even if the tube fails on this sequence, unless all follow up mitigation capabilities (e.g, depressurization and faulted steam generator isolation) failed, this change in CDP will be small compared to the CDP of this event (6.4×10^{-5}). Since power was available to the balance of plant events, the operators had some capbility to mitigate a consequential steam generator tube rupture.

- The tube could have failed as a result of a drop in the secondary side pressure. The likelihood of a random independent event (e.g., spurious opening of a steam generator relief valve or a steam line break) occurring within the mission time of this accident is low. Therefore, contribution to CDP is low.

- A steam generator relief valve could open as a result of a pressure rise in the secondary. If this were to occur, since the ΔP across tubes reduce (rather than increase) the tube will not rupture. (But, if valve sticks, then SG pressure decreases and ΔP can rise.

- In CP sequences where AFW failure occurs, SGs are likely to be depressurized by the operators in accordance with EOPs or SAMGs. Failure of the tube would not affect the CCDP, but would affect the CLERP. Calculation of CLERPs is outside the scope of the ASP Program.

Figure 1
Figure 2
Figure 3

I N I T I A T I N G   E V E N T   A S S E S S M E N T

Code Ver : 6:57
Model Ver : 1998/04/14
Init Event: IE-LOOP
Total CCDP: 6.9E-005

Fam : IPT2_2QA
User :
Ev ID: FINAL-LOSP-ESW
Desc : Initiating Event Assessment

BASIC EVENT CHANGES

Event Name	Description	Base Prob	Curr Prob	Type
AFW-TDP-FC-22	AFW TURBINE DRIVEN PUMP 22 F	3.3E-002	9.3E-002	
EPS-DGN-CF-ALL	COMMON CAUSE FAILURE OF DIES	8.5E-004	1.0E-003	
EPS-DGN-FC-21	DIESEL GENERATOR 21 FAILS	3.3E-002	8.2E-002	
EPS-DGN-FC-22	DIESEL GENERATOR 22 FAILS	3.3E-002	8.2E-002	
EPS-DGN-FC-23	DIESEL GENERATOR 23 FAILS	3.3E-002	8.2E-002	
IE-LOOP	LOSS OF OFFSITE POWER INITIA	3.1E-005	1.0E+000	
IE-SGTR	STEAM GENERATOR TUBE RUPTURE	1.6E-006	+0.0E+000	
IE-SLOCA	SMALL LOCA INITIATING EVENT	2.3E-006	+0.0E+000	
IE-TRANS	TRANSIENT INITIATING EVENT	2.7E-004	+0.0E+000	
LOOP-05-NREC	LOOP SEQUENCE 05 NONRECOVERY	1.0E+000	3.0E-002	
LOOP-09-NREC	LOOP SEQUENCE 08 NONRECOVERY	1.0E+000	5.9E-002	
LOOP-17-NREC	LOOP SEQUENCE 17 NONRECOVERY	2.2E-001	9.0E-002	
LOOP-18-02-NREC	LOOP SEQUENCE 18-02 NONRECOV	8.0E-001	3.0E-001	
LOOP-18-05-NREC	LOOP SEQUENCE 18-05 NONRECOV	8.0E-001	3.0E-002	
LOOP-18-07-NREC	LOOP SEQUENCE 18-07 NONRECOV	8.0E-001	3.0E-002	
LOOP-18-08-NREC	LOOP SEQUENCE 18-08 NONRECOV	6.7E-001	3.0E-002	
LOOP-18-11-NREC	LOOP SEQUENCE 18-11 NONRECOV	8.0E-001	3.0E-001	
LOOP-18-14-NREC	LOOP SEQUENCE 18-14 NONRECOV	8.0E-001	3.0E-002	
LOOP-18-16-NREC	LOOP SEQUENCE 18-16 NONRECOV	8.0E-001	3.0E-002	
LOOP-18-17-NREC	LOOP SEQUENCE 18-17 NONRECOV	6.7E-001	3.0E-002	
LOOP-18-20-NREC	LOOP SEQUENCE 18-20 NONRECOV	8.0E-001	7.0E-001	
LOOP-18-22-NREC	LOOP SEQUENCE 18-22 NONRECOV	2.7E-001	1.8E-001	
OEP-XHE-NOREC-2H	OPERATOR FAILS TO RECOVER OF	3.2E-002	1.0E+000	
OEP-XHE-NOREC-6H	OPERATOR FAILS TO RECOVER OF	1.4E-002	6.0E-002	
OEP-XHE-NOREC-BD	OPERATOR FAILS TO RECOVER OF	8.6E-004	6.0E-002	
OEP-XHE-NOREC-SL	OPERATOR FAILS TO RECOVER OF	6.6E-001	+0.0E+000	FALSE
OEP-XHE-NOREC-ST	OPERATOR FAILS TO RECOVER OF	1.7E-001	1.0E+000	
OEP-XHE-XM-GT2	OPERATOR FAILS TO START AND	3.4E-001	+0.0E+000	IGNORE
OEP-XHE-XM-GT6	OPERATOR FAILS TO START AND	3.4E-001	+0.0E+000	IGNORE
OEP-XHE-XM-GTBD	OPERATOR FAILS TO START AND	3.4E-001	+0.0E+000	IGNORE
OEP-XHE-XM-GTSL	OPERATOR FAILS TO START AND	3.4E-001	+0.0E+000	FALSE
OEP-XHE-XM-GTST	OPERATOR FAILS TO START AND	3.4E-001	+0.0E+000	IGNORE
PPR-SRV-CO-L	PORVs/SRVs OPEN DURING LOOP	1.6E-001	4.0E-002	
PPR-SRV-CO-SBO	PORVs/SRVs OPEN DURING STATI	3.7E-001	4.0E-002	
RCS-MDP-LK-SEALS	RCP SEALS FAIL W/O COOLING A	3.4E-002	2.2E-001	

SEQUENCE PROBABILITIES

Truncation : Cummulative : 100.0% Individual : 1.0%

Event Tree Name	Sequence Name	CCDP	%Cont
LOOP	09	3.2E-006	4.6
LOOP	17	1.1E-005	15.9
LOOP	18-02	3.1E-005	44.9
LOOP	18-08	1.5E-005	21.7
LOOP	18-11	1.3E-006	1.9
LOOP	18-20	3.1E-006	4.5
LOOP	18-22	3.1E-006	4.5

SEQUENCE LOGIC

Event Tree	Sequence Name	Logic	
LOOP	09	/RT-L	/EP
		/AFW-L	PORV-L
		PRVL-RES	/HPI-L
		OP-2H	HPR-L
LOOP	17	/RT-L	/EP
		AFW-L	FB-L
LOOP	18-02	/RT-L	EP
		/AFW-L	/PORV-SBO
		/SEALLOCA	OP-BD
LOOP	18-08	/RT-L	EP
		/AFW-L	/PORV-SBO
		SEALLOCA	/OP-SL
		HPI	
LOOP	18-11	/RT-L	EP
		/AFW-L	PORV-SBO
		/PRVL-RES	/SEALLOCA
		OP-BD	
LOOP	18-20	/RT-L	EP
		/AFW-L	PORV-SBO
		PRVL-RES	ACP-ST
LOOP	18-22	/RT-L	EP
		AFW-L	ACP-ST

Fault Tree Name	Description
ACP-ST	OFFSITE POWER RECOVERY IN SHORT TERM
AFW-L	NO OR INSUFFICIENT AFW FLOW DURING LOOP
EP	EMERGENCY POWER SYSTEM FAILS

FB-L	FAILURE TO PROVIDE FEED AND BLEED COOLING - LOOP
HPI	NO OR INSUFFICIENT FLOW FROM THE HPI SYSTEM
HPI-L	NO OR INSUFFICIENT FLOW FROM HPI SYSTEM - LOOP
HPR-L	NO OR INSUFFICIENT FLOW FROM HPR SYSTEM - LOOP
OP-2H	OPERATOR FAILS TO RECOVER OFFSITE POWER WITHIN 2 HRS
OP-BD	OPERATOR FAILS TO RECOVER OFFSITE POWER BEFORE BATTER
OP-SL	OPERATOR FAILS TO RECOVER OFFSITE POWER (SEAL LOCA)
PORV-L	PORVs/SRVs OPEN DURING LOOP
PORV-SBO	PORVs/SRVs OPEN DURING STATION BLACKOUT
PRVL-RES	PORVs AND BLOCK VALVES AND SRVs FAIL TO RECLOSE
RT-L	REACTOR FAILS TO TRIP DURING LOOP
SEALLOCA	RCP SEALS FAIL DURING LOOP

SEQUENCE CUT SETS

Truncation: Cummulative: 100.0% Individual: 1.0%

Event Tree: LOOP CCDP: 3.2E-006
Sequence: 09

CCDP	% Cut Set	Cut Set Events	
3.4E-007	10.6	EPS-DGN-FC-21	OEP-XHE-NOREC-2H
		PPR-SRV-CO-L	PPR-SRV-OO-SR3
		EPS-DGN-FC-23-OB	LOOP-09-NREC
3.4E-007	10.6	EPS-DGN-FC-21	OEP-XHE-NOREC-2H
		PPR-SRV-CO-L	PPR-SRV-OO-SR2
		EPS-DGN-FC-23-OB	LOOP-09-NREC
3.4E-007	10.6	EPS-DGN-FC-21	OEP-XHE-NOREC-2H
		PPR-SRV-CO-L	PPR-SRV-OO-SR1
		EPS-DGN-FC-23-OB	LOOP-09-NREC
2.5E-007	7.9	EPS-DGN-FC-21	EPS-DGN-FC-23
		OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR3	LOOP-09-NREC
2.5E-007	7.9	EPS-DGN-FC-21	EPS-DGN-FC-22
		OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR2	LOOP-09-NREC
2.5E-007	7.9	EPS-DGN-FC-21	EPS-DGN-FC-23
		OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR2	LOOP-09-NREC
2.5E-007	7.9	EPS-DGN-FC-21	EPS-DGN-FC-22
		OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR1	LOOP-09-NREC
2.5E-007	7.9	EPS-DGN-FC-21	EPS-DGN-FC-23
		OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR1	LOOP-09-NREC
2.5E-007	7.9	EPS-DGN-FC-21	EPS-DGN-FC-22
		OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR3	LOOP-09-NREC
1.1E-007	3.5	OEP-XHE-NOREC-2H	PPR-SRV-CO-L

		PPR-SRV-OO-SR1	HPR-MOV-OO-RWST
		LOOP-09-NREC	
1.1E-007	3.5	OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR2	HPR-MOV-OO-RWST
		LOOP-09-NREC	
1.1E-007	3.5	OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR3	HPR-MOV-OO-RWST
		LOOP-09-NREC	
3.8E-008	1.2	OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR1	HPR-XHE-XM-L
		LOOP-09-NREC	
3.8E-008	1.2	OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR2	HPR-XHE-XM-L
		LOOP-09-NREC	
3.8E-008	1.2	OEP-XHE-NOREC-2H	PPR-SRV-CO-L
		PPR-SRV-OO-SR3	HPR-XHE-XM-L
		LOOP-09-NREC	

Event Tree: LOOP CCDP: 1.1E-005
Sequence: 17

CCDP	% Cut Set	Cut Set Events	
3.0E-006	26.7	AFW-TDP-FC-22	EPS-DGN-FC-22
		MFW-SYS-UNAVAIL	MFW-XHE-NOREC
		EPS-DGN-FC-23-OB	LOOP-17-NREC
3.0E-006	26.7	AFW-TDP-FC-22	EPS-DGN-FC-22
		MFW-XHE-ERROR	MFW-SYS-TRIP
		EPS-DGN-FC-23-OB	LOOP-17-NREC
2.3E-006	19.9	AFW-TDP-FC-22	EPS-DGN-FC-22
		EPS-DGN-FC-23	MFW-XHE-ERROR
		MFW-SYS-TRIP	LOOP-17-NREC
2.3E-006	19.9	AFW-TDP-FC-22	EPS-DGN-FC-22
		EPS-DGN-FC-23	MFW-SYS-UNAVAIL
		MFW-XHE-NOREC	LOOP-17-NREC
1.4E-007	1.3	AFW-MDP-FC-21	AFW-TDP-FC-22
		MFW-XHE-ERROR	MFW-SYS-TRIP
		EPS-DGN-FC-23-OB	LOOP-17-NREC
1.4E-007	1.3	AFW-MDP-FC-21	AFW-TDP-FC-22
		MFW-SYS-UNAVAIL	MFW-XHE-NOREC
		EPS-DGN-FC-23-OB	LOOP-17-NREC

Event Tree: LOOP CCDP: 3.1E-005
Sequence: 18-02

CCDP	% Cut Set	Cut Set Events	
1.4E-005	43.6	EPS-DGN-CF-ALL	OEP-XHE-NOREC-BD
		/PPR-SRV-CO-SBO	/RCS-MDP-LK-SEALS
		LOOP-18-02-NREC	
1.0E-005	32.2	EPS-DGN-FC-21	EPS-DGN-FC-22
		OEP-XHE-NOREC-BD	/PPR-SRV-CO-SBO

		/RCS-MDP-LK-SEALS LOOP-18-02-NREC	EPS-DGN-FC-23-OB
7.4E-006	24.0	EPS-DGN-FC-21 EPS-DGN-FC-23 /PPR-SRV-CO-SBO LOOP-18-02-NREC	EPS-DGN-FC-22 OEP-XHE-NOREC-BD /RCS-MDP-LK-SEALS

Event Tree: LOOP
Sequence: 18-08

CCDP: 1.5E-005

CCDP	% Cut Set	Cut Set Events	
6.3E-006	43.6	EPS-DGN-CF-ALL RCS-MDP-LK-SEALS	/PPR-SRV-CO-SBO LOOP-18-08-NREC
4.7E-006	32.2	EPS-DGN-FC-21 /PPR-SRV-CO-SBO EPS-DGN-FC-23-OB	EPS-DGN-FC-22 RCS-MDP-LK-SEALS LOOP-18-08-NREC
3.5E-006	24.0	EPS-DGN-FC-21 EPS-DGN-FC-23 RCS-MDP-LK-SEALS	EPS-DGN-FC-22 /PPR-SRV-CO-SBO LOOP-18-08-NREC

Event Tree: LOOP
Sequence: 18-11

CCDP: 1.3E-006

CCDP	% Cut Set	Cut Set Events	
5.6E-007	43.6	EPS-DGN-CF-ALL PPR-SRV-CO-SBO LOOP-18-11-NREC	OEP-XHE-NOREC-BD /RCS-MDP-LK-SEALS
4.2E-007	32.2	EPS-DGN-FC-21 OEP-XHE-NOREC-BD /RCS-MDP-LK-SEALS LOOP-18-11-NREC	EPS-DGN-FC-22 PPR-SRV-CO-SBO EPS-DGN-FC-23-OB
3.1E-007	24.0	EPS-DGN-FC-21 EPS-DGN-FC-23 PPR-SRV-CO-SBO LOOP-18-11-NREC	EPS-DGN-FC-22 OEP-XHE-NOREC-BD /RCS-MDP-LK-SEALS

Event Tree: LOOP
Sequence: 18-20

CCDP: 3.1E-006

CCDP	% Cut Set	Cut Set Events	
4.5E-007	14.5	OEP-XHE-NOREC-ST PPR-SRV-OO-SR1 LOOP-18-20-NREC	EPS-DGN-CF-ALL PPR-SRV-CO-SBO
4.5E-007	14.5	OEP-XHE-NOREC-ST PPR-SRV-OO-SR3 LOOP-18-20-NREC	EPS-DGN-CF-ALL PPR-SRV-CO-SBO
4.5E-007	14.5	OEP-XHE-NOREC-ST PPR-SRV-OO-SR2 LOOP-18-20-NREC	EPS-DGN-CF-ALL PPR-SRV-CO-SBO

3.3E-007	10.8	OEP-XHE-NOREC-ST EPS-DGN-FC-22 PPR-SRV-CO-SBO LOOP-18-20-NREC	EPS-DGN-FC-21 PPR-SRV-OO-SR3 EPS-DGN-FC-23-OB
3.3E-007	10.8	OEP-XHE-NOREC-ST EPS-DGN-FC-22 PPR-SRV-CO-SBO LOOP-18-20-NREC	EPS-DGN-FC-21 PPR-SRV-OO-SR2 EPS-DGN-FC-23-OB
3.3E-007	10.8	OEP-XHE-NOREC-ST EPS-DGN-FC-22 PPR-SRV-CO-SBO LOOP-18-20-NREC	EPS-DGN-FC-21 PPR-SRV-OO-SR1 EPS-DGN-FC-23-OB
2.5E-007	8.0	OEP-XHE-NOREC-ST EPS-DGN-FC-22 PPR-SRV-OO-SR1 LOOP-18-20-NREC	EPS-DGN-FC-21 EPS-DGN-FC-23 PPR-SRV-CO-SBO
2.5E-007	8.0	OEP-XHE-NOREC-ST EPS-DGN-FC-22 PPR-SRV-OO-SR2 LOOP-18-20-NREC	EPS-DGN-FC-21 EPS-DGN-FC-23 PPR-SRV-CO-SBO
2.5E-007	8.0	OEP-XHE-NOREC-ST EPS-DGN-FC-22 PPR-SRV-OO-SR3 LOOP-18-20-NREC	EPS-DGN-FC-21 EPS-DGN-FC-23 PPR-SRV-CO-SBO

Event Tree: LOOP
Sequence: 18-22

CCDP: 3.1E-006

CCDP	% Cut Set	Cut Set Events	
6.7E-007	21.8	OEP-XHE-NOREC-ST EPS-DGN-CF-ALL MFW-SYS-TRIP	AFW-TDP-FC-22 MFW-XHE-ERROR LOOP-18-22-NREC
6.7E-007	21.8	OEP-XHE-NOREC-ST EPS-DGN-CF-ALL MFW-XHE-NOREC	AFW-TDP-FC-22 MFW-SYS-UNAVAIL LOOP-18-22-NREC
5.0E-007	16.1	OEP-XHE-NOREC-ST EPS-DGN-FC-21 MFW-XHE-ERROR EPS-DGN-FC-23-OB	AFW-TDP-FC-22 EPS-DGN-FC-22 MFW-SYS-TRIP LOOP-18-22-NREC
5.0E-007	16.1	OEP-XHE-NOREC-ST EPS-DGN-FC-21 MFW-SYS-UNAVAIL EPS-DGN-FC-23-OB	AFW-TDP-FC-22 EPS-DGN-FC-22 MFW-XHE-NOREC LOOP-18-22-NREC
3.7E-007	12.0	OEP-XHE-NOREC-ST EPS-DGN-FC-21 EPS-DGN-FC-23 MFW-SYS-TRIP	AFW-TDP-FC-22 EPS-DGN-FC-22 MFW-XHE-ERROR LOOP-18-22-NREC
3.7E-007	12.0	OEP-XHE-NOREC-ST EPS-DGN-FC-21 EPS-DGN-FC-23 MFW-XHE-NOREC	AFW-TDP-FC-22 EPS-DGN-FC-22 MFW-SYS-UNAVAIL LOOP-18-22-NREC

BASIC EVENTS (Cut Sets Only)

Event Name	Description	Curr Prob
AFW-MDP-FC-21	AFW MOTOR DRIVEN PUMP 21 FAILS	3.9E-003
AFW-TDP-FC-22	AFW TURBINE DRIVEN PUMP 22 FAILS	9.3E-002
EPS-DGN-CF-ALL	COMMON CAUSE FAILURE OF DIESEL GENERATORS	1.0E-003
EPS-DGN-FC-21	DIESEL GENERATOR 21 FAILS	8.2E-002
EPS-DGN-FC-22	DIESEL GENERATOR 22 FAILS	8.2E-002
EPS-DGN-FC-23	DIESEL GENERATOR 23 FAILS	8.2E-002
EPS-DGN-FC-23-OB		1.1E-001
HPR-MOV-OO-RWST	HPI RWST SUCTION MOV FAILS TO CLOSE	3.0E-003
HPR-XHE-XM-L	OPERATOR FAILS TO INITIATE HPR SYSTEM - LOOP	1.0E-003
LOOP-09-NREC	LOOP SEQUENCE 08 NONRECOVERY PROBABILITY	5.9E-002
LOOP-17-NREC	LOOP SEQUENCE 17 NONRECOVERY PROBABILITY	9.0E-002
LOOP-18-02-NREC	LOOP SEQUENCE 18-02 NONRECOVERY PROBABILITY	3.0E-001
LOOP-18-08-NREC	LOOP SEQUENCE 18-08 NONRECOVERY PROBABILITY	3.0E-002
LOOP-18-11-NREC	LOOP SEQUENCE 18-11 NONRECOVERY PROBABILITY	3.0E-001
LOOP-18-20-NREC	LOOP SEQUENCE 18-20 NONRECOVERY PROBABILITY	7.0E-001
LOOP-18-22-NREC	LOOP SEQUENCE 18-22 NONRECOVERY PROBABILITY	1.8E-001
MFW-SYS-TRIP	MAIN FEEDWATER SYSTEM UNAVAILABLE GIVEN RX TR	8.0E-001
MFW-SYS-UNAVAIL	MAIN FEEDWATER SYSTEM UNAVAILABLE	2.0E-001
MFW-XHE-ERROR	OPERATOR FAILS TO RESTORE MFW FLOW	5.0E-002
MFW-XHE-NOREC	OPERATOR FAILS TO RECOVER MFW FLOW	2.0E-001
OEP-XHE-NOREC-2H	OPERATOR FAILS TO RECOVER OFFSITE POWER WITH	1.0E+000
OEP-XHE-NOREC-BD	OPERATOR FAILS TO RECOVER OFFSITE POWER BEFOR	6.0E-002
OEP-XHE-NOREC-ST	OPERATOR FAILS TO RECOVER OFFSITE POWER IN SH	1.0E+000
PPR-SRV-CO-L	PORVS/SRVS OPEN DURING LOOP	4.0E-002
PPR-SRV-CO-SBO	PORVS/SRVS OPEN DURING STATION BLACKOUT	4.0E-002
PPR-SRV-OO-SR1	FAILURE OF SRV 1 TO RECLOSE	1.6E-002
PPR-SRV-OO-SR2	FAILURE OF SRV 2 TO RECLOSE	1.6E-002
PPR-SRV-OO-SR3	FAILURE OF SRV 3 TO RECLOSE	1.6E-002
RCS-MDP-LK-SEALS	RCP SEALS FAIL W/O COOLING AND INJECTION	2.2E-001