Final Precursor Analysis

Accident Sequence Precursor Program --- Office of Nuclear Regulatory Research

Columbia Generating Station	Unreliable Breakers for Four Safety-Related Systems	
Event Date: 02/14/2002	**LER:** 397/02-001	**ΔCDP =** 6×10^{-6}

Operating Condition Summary

Description. On February 13, 2002, the plant was in Mode 1 at 100% of rated thermal power. During a planned online maintenance of the Emergency Diesel Generator (EDG)-2 at Columbia Generating Station (CGS), the plant operators attempted to close the EDG-2 output breaker. But, the breaker failed to close because the Mechanism-operated Cell (MOC) switch assembly in the breaker failed to change state on demand. Then, operators decided to shutdown the plant due to LCO requirements of TS 3.8.1, Action B.4. (Reference 1)

In calendar year 2002, first quarter, Region IV conducted a special inspection for MOC switch assemblies for breakers of safety-related systems (EDG, Standby Service Water (SSW) system, Low Pressure Core Spray (LPCS) system, Residual Heat Removal (RHR) system). Region IV documented their non-compliance findings and unreliability findings for breakers (References 2, 3, and 4). These findings were:

1. On June 29, 2001, the licensee completed design modification (new replacement breakers) for Division II SSW system. But the design control measures established by the licensee were not adequate to assure the suitability of the replacement breakers. Specifically, the licensee failed to incorporate vendor information regarding maintenance of MOC switches in these breakers. On November 19, 2001, the same Division II SSW system breaker MOC switch failed to close on demand a second time.

2. The licensee failed to identify the cause of the same condition and take corrective actions to preclude recurrence of MOC switch close-failures for other safety-related systems (EDGs, the LPCS system, and the RHR system) for which replacement breakers were installed previously. So, on February 14, 2002, a similar close-failure occurred involving the MOC switch associated with the Division II EDG breaker.

3. The licensee experienced 4 breaker MOC switch failures between June 29, 2001 and February 14, 2002. The failures were due to inadequate breaker maintenance combined with the marginal capability of a new breaker design. Four MOC switch failures occurred in 2 of the 4 safety-related systems (SSW and EDG).

4. The replacement breakers installed by the licensee for the above 4 safety-related systems did not render all safety-related pumps inoperable at the same time. Rather, it increased the probability of breaker failure-to-close on demand during the operating condition (Reference 2).

Cause. CGS system engineers determined that the failure of the MOC switches to not fully actuate was due to lack of preventive maintenance and a breaker replacement that produced less drive force to actuate the MOC assembly on close-demand. The root cause was the failure to recognize the importance of MOC assembly preventive maintenance.

Condition duration. The operating condition involving unreliable breaker MOC switches for 4 safety-related systems existed for 5216 hours (between 6/29/2001 and 2/14/2002).

Related events. None.

Recovery opportunity. During testing of replacement breakers, the licensee locally recovered 50% of the MOC switch close-failures (two successful recoveries out of four failures). A non-recoverable failure probability of 0.5 is applied to the increased probability of failure-to-close on demand for replacement breakers.

Analysis Results

- **Importance**[1]

  The risk significance of inoperable breakers for four safety-related systems for a condition duration of 5216 hours was determined by subtracting the nominal core damage probability (point estimate) from the conditional core damage probability (point estimate):

Conditional core damage probability (CCDP) =	1.19E-5
Nominal core damage probability (CDP) =	5.7E-6
Importance (ΔCDP = CCDP - CDP) =	6.2E-6

  The estimated importance (CCDP-CDP) for the operating condition was 6.2E-6.

  An uncertainty analysis was conducted for the operating condition. The mean estimates for CCDP, CDP, and importance were 1.230E-5, 6.165E-6, and 6.134E-6 respectively, as shown in Table 5.

- **Dominant sequence**

  Loss of offsite power involving successful operation of at least one of two emergency diesel generators followed by successful cycling of the safety relief valves and the High

[1] Since this condition did not involve an actual initiating event, the parameter of interest is the measure of the incremental change between the conditional probability for the period in which the condition existed and the nominal probability for the same period but with the condition nonexistent and plant equipment available. This incremental change or "importance" is determined by subtracting the CDP from the CCDP. This measure is used to assess the risk significance of hardware unavailabilities especially for those operating conditions where the nominal CDP is high with respect to the incremental change of the conditional probability caused by the hardware unavailability.

Pressure Core Spray system, but failure of containment heat removal function (failure of suppression pool cooling, shutdown cooling, and containment spray) due to RHR system failures, and failure of containment venting [Sequence 05]. Importance for this dominant sequence is = 1.9E-6. The events and important component failures in this sequence are as follows:

- Loss of offsite power- initiating event
- Successful reactor shutdown
- Successful start and run of two emergency diesel generators
- Successful cycling of safety relief valves
- Successful operation of the High Pressure Core Spray system
- Successful manual depressurization
- Failure of suppression pool cooling mode, shutdown cooling mode, and containment spray mode of the RHR system and the SSW system due to unreliable pump breakers
- Failure of containment venting
- Onset of potential core damage

Path for dominant sequence LOOP 05 is shown in Figure 1.

- **Results tables**

  – Table 1 provides the conditional probabilities for the dominant sequences.
  – Table 2a provides the event tree sequence logic for the dominant sequences listed in Table 1.
  – Table 2b provides the definitions of fault trees used in event tree logic listed in Table 2a.
  – Table 3 provides the conditional (CCDP) cut sets for the dominant sequences.
  – Table 4 provides the definitions and probabilities for added basic events and condition-affected basis events and frequencies for initiating events.

Modeling Assumptions

- **Assessment summary**

Assessment type - The breaker failures were for those installed in the plant and failed during actual surveillance test demands. Of the four breaker failures, two were intermittent and were recovered. It is also noted that the licensee corrected the MOC switch assembly problems on 2/14/2003. Therefore, the operating condition for the unreliable breakers was assessed using a condition assessment for a plant condition in which the plant was operated with replacement breakers with high probability of failures. The operating condition was assessed for a period of 5216 hours (between 6/29/2001 and 2/14/2002).

Operating experience for breakers- Based on licensee-provided information for these breakers in four safety-related systems, 4 failures in 103 test demands were observed and documented, with 2 of the 4 failures recovered (intermittent). A BETA distribution was assigned to characterize test-based failure probabilities using Reference 6 with a mean value

= (4/103)*(2/4) = 1.9E-2; and

Parameters a = 4.5; b = 103 - a = 98.5.

Model use - The Revision 3i Standardized Plant Analysis Risk (SPAR) model for Columbia Generating Station (formerly known as Washington Nuclear Plant) Unit 2 (Reference 5) was used for this assessment.

Model update to Revision 3i SPAR model - 8 basic events to represent the MOC switch-induced failures (EDG output breaker failure to close on demand, and pump breaker failure to close on demand) were added to four system fault trees (EDG, SSW, LPCS and RHR). Modified fault trees are shown in Figures 2 thru 9. Probability for these basic events in the base case was set to FALSE. Probability for these basic events in the current case (condition case) was set to 1.9E-2.

- Basic event probability changes

Table 4 provides the basic events that were added and modified to reflect the operating condition being analyzed. Revision 3i SPAR plant model did not model output breakers for EDGs and breakers for pumps of the four safety-related systems (EDG, SSW, RHR, LCS). If the fail-to-close failure mode of a breaker would occur, then the EDG power supply to the safety-related buses would fail, and the pumps would not start. Therefore, a basic event that would represent the fail-to-close failure mode of the affected breakers for each of the four safety-related system (a total of eight basic events) was added as part of the fault tree update for the above four systems. Each of the basic events was set to FALSE in the base case. A mean failure probability of 1.9E-2 with a BETA distribution (a = 4.5 and b = 98.5) was assigned in the condition assessment (current case) based on operating failures and recovery data for breakers. The basic events that were added to the base model are shown in Table 4.

Uncertainty analysis and range for total importance due to operating condition

Uncertainty analysis of the operating condition along with parameters was performed using the SAPHIRE code. Default distribution types for applicable initiating events (e.g. single unit loss of offsite power, transients) and basic events for components were documented in the Revision 3i SPAR model for CGS. These uncertainty values and uncertainty values for condition-affected basic events (eight basic events) were used in estimating mean condition-CDP values and mean condition-CCDP values. Other statistical values such as point values, median values, 5% values, and 95% values were also estimated for CDP and CCDP analysis cases. Estimated statistical values for the operating condition are shown in Table 5.

References

1. Energy North west, “LER 397-2002-001-00, Completion of Technical Specification required shutdown to comply with Technical Specification LCO 3.8.1 Required Action of Condition F” dated April 10, 2002. (ADAMS ACCESSION No. ML021130475)

2. USNRC, Region IV, “NRC SPECIAL INSPECTION TEAM REPORT FOR COLUMBIA GENERATING STATION - *50-397/02-05” dated May 22, 2002*. (ADAMS ACCESSION) No. ML021430088

3. USNRC Office of Enforcement, “FINAL SIGNIFICANCE DETERMINATION FOR A WHITE FINDING AND NOTICE OF VIOLATION (NRC INSPECTION REPORT NO. 50-39702-05) (COLUMBIA GENERATING STATION) - EA-02-107” dated June 24, 2002. (ADAMS ACCESSION No. ML021750255)

4. USNRC, Region IV, “COLUMBIA GENERATING STATION - NRC SUPPLEMENTAL AND BASELINE INSPECTION REPORT 50-397/02-06” dated January 23, 2003. (ADAMS ACCESSION No. ML030230794)

5. Richard E. Gregg, “Revision 3i Standardized Plant Analysis Risk (SPAR) Model for Washington Nuclear Plant Unit 2 (ASP PWR C)” by Idaho National Engineering and Environmental Laboratory, May 2000.

6. M. Englehardt, et. Al, , “Handbook of Parameter Estimation for Probabilistic Risk Assessment”, NUREG/CR-6823, SAND2003-3348P, Sandia National Laboratories, Albuquerque, NM, September 2003.

Table 1. Conditional probabilities (point values) for the dominant sequences

Event tree name	Sequence no.	Conditional core damage probability (CCDP)	Core damage probability (CDP)	Importance (CCDP - CDP)[2]
LOOP	05	2.8E-6	9.1E-7	1.9E-6
LOOP	36-16	1.4E-6	1.2E-6	2.0E-7
Total (all sequences)[1]		**1.2E-5**	**5.7E-6**	**6.2E-6**

Notes:
1. Total CCDP and CDP includes all sequences (including those not shown in this table).
2. Importance is calculated using the total CCDP and total CDP from all sequences of all applicable event trees. Sequence level importance measures are not additive.

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	05	(/RPS)*(/EPS)*(/SRV)*(/HCS)*(SPC)*(/DEP)*(SDC)*CSS)*(CVS)
LOOP	36-16	(/RPS)*(EPS)*(B1)*(P1)

Table 2b. Definitions of fault trees used in event tree logic listed in Table 2a

SRV	SRVs FAIL TO CLOSE
EPS	EMERGENCY POWER FROM 2 EDGs IS UNAVAILABLE
RPS	REACTOR SHUTDOWN FAILS
HCS	HPCS FAILS TO PROVIDE SUFFICIENT FLOW TO REACTOR VESSEL
SPC	SUPPRESSION POOL COOLING MODE OF RHR FAILS
DEP	MANUAL DEPRESSURIZATION FAILS
SDC	SHUTDOWN COOLING MODE OF RHR FAILS
CSS	CONTAINMENT SPRAY MODE OF RHR FAILS
CVS	CONTAIMENT VENTING FAILS
B1	DIVISION III POWER IS UNAVAILABLE
P1	ONE SRV FAILS TO CLOSE

Table 3a. CCDP cut sets for LOOP Sequence 05

CCDP	Percent contribution	Minimal cut sets[1]
Event Tree: LOOP, Sequence 05		
2.245E-7	**8.1**	**EPS-DGN-TM-DG2 * OEP-XHE-NOREC-12H * /SRV * RHR-MDP-MOC-1A**
2.245E-7	**8.1**	**EPS-DGN-TM-DG2 * OEP-XHE-NOREC-12H * /SRV * SSW-MDP-MOC-1A**
2.8E-006	Total[2]	

Table 3b. CCDP cut sets for LOOP Sequence 36-16

CCDP	Percent contribution	Minimal cut sets[1]
Event Tree: LOOP, Sequence 36-16		
5.738E-7	**43.4**	**EPS-DGN-CF-RUN * PPR-SRV-OO-1VLV**
7.302E-8	**28.3**	**EPS-DGN-CF-START * PPR-SRV-OO-1VLV**
1.4E-006	Total[2]	

1. See Table 4 for definitions and probabilities for the basic events.
2. Total CCDP includes all cut sets (including those not shown in this table).

Table 4 - Definitions and probabilities for modified and dominant basic events

Basic event name	Description	Added to Base model	Probabi.	Modified to reflect condition	Note
EPS-DGN-MOC-1A	EDG 1A BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
EPS-DGN-MOC-1B	EDG 1B BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
RHR-MDP-MOC-1A	RHR MDP 1A BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
RHR-MDP-MOC-1B	RHR MDP 1B BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
RHR-MDP-MOC-1C	RHR MDP 1C BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
SWS-MDP-MOC-1A	SWS MDP 1A BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
SWS-MDP-MOC-1B	SWS MDP 1B BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
LCS-MDP-MOC-P1	LCS MDP P1 BREAKER FAILS TO CLOSE	YES	1.9E-2	YES	1
OEP-XHE-NOREC-12H	OPERATOR FAILS TO RECOVER AC POWER IN 12 HOURS	NO	2.7E-2	NO	
PPR-SRV-OO-1VLV	ONE SRV FAILS TO CLOSE	NO	8.8E-2	NO	
SRV	SRVS FAILS TO CLOSE	NO	8.9E-2	NO	
EPS-DGN-TM-DG2	DIESEL GENERATOR 2 UNAVAILABLE DUE TO TEST AND MAINTENANCE	NO	3.1E-2	NO	
EPS-DGN-CF-START	COMMON CAUSE FAILURE OF DGS TO START	NO	2.8E-4	NO	
EPS-DGN-CF-RUN	COMMON CAUSE FAILURE OF DGS TO RUN	NO	4.3E-4	NO	

Notes:

1 **Basic event was affected by the operating condition. Basis for probability change is documented in Modeling Assumptions section of this report.**

Table 5 - Uncertainty values for the operating condition

Plant: Columbia Generating Station
IR ID: 50-397/2002-005
SDP: EA-02-107
LER: 397-2002-001-00

Analysis type: Monte Carlo
Samples: 10000; Seeds: 97453

Initiating event (IE)	IE ID	Point estimate	mean estimate	5% estimate	50% estimate	95% estimate
All internal initiating events	CCDP for 1 hour	2.278E-09	2.358E-09	3.000E-10	1.194E-09	7.509E-09
	CDP for 1 hour	1.097E-09	1.182E-09	1.483E-10	5.728E-10	3.631E-09
	CCDP for 5216 hours	1.188E-05	1.230E-05	1.565E-06	6.228E-06	3.917E-05
	CDP for 5216 hours	5.722E-06	6.165E-06	7.735E-07	2.988E-06	1.894E-05
	Importance for 5216 hours	6.160E-06	6.134E-06	7.913E-07	3.240E-06	2.023E-05

Figure 1 - Columbia Generating Station- Loss of Offsite Power Event Tree showing Sequence 05

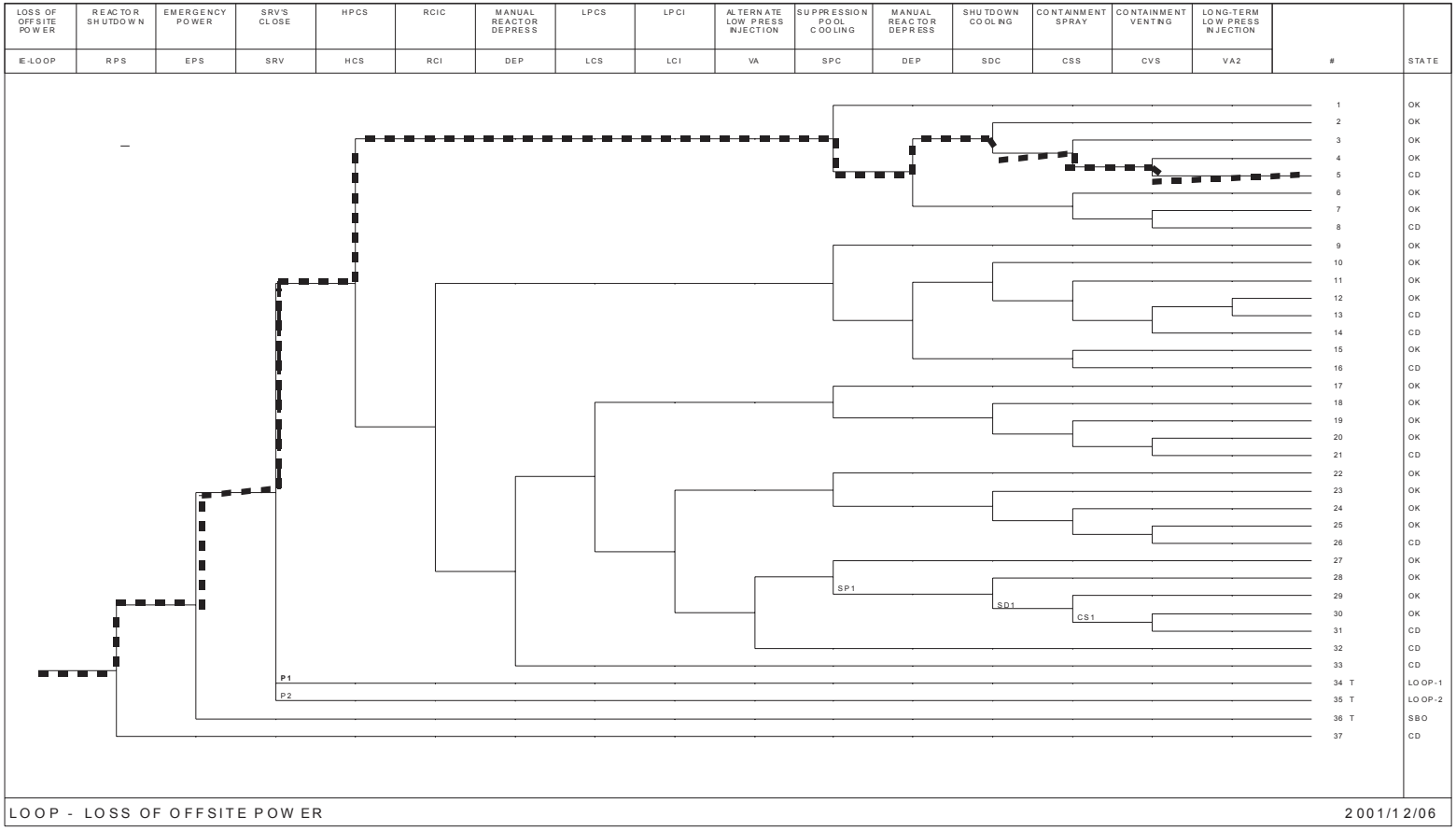
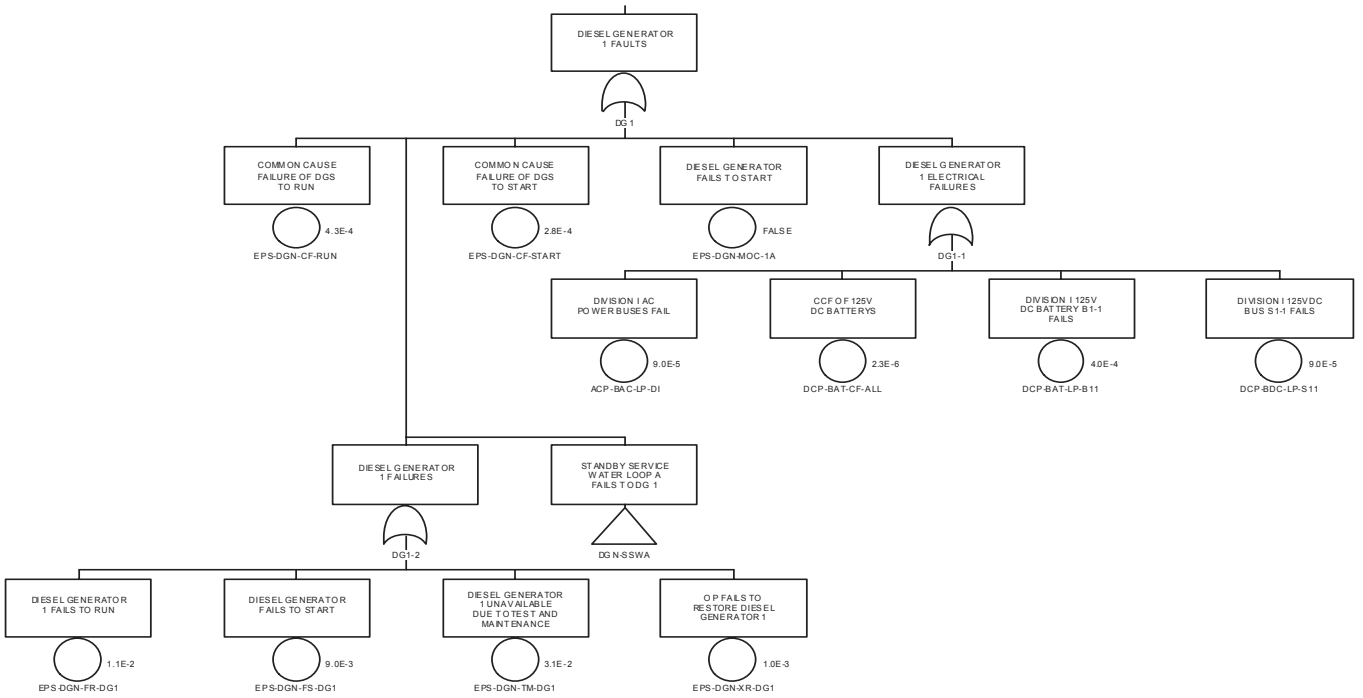


Figure 2 - WNPS - DIESEL GENERATOR 1 FAULTS



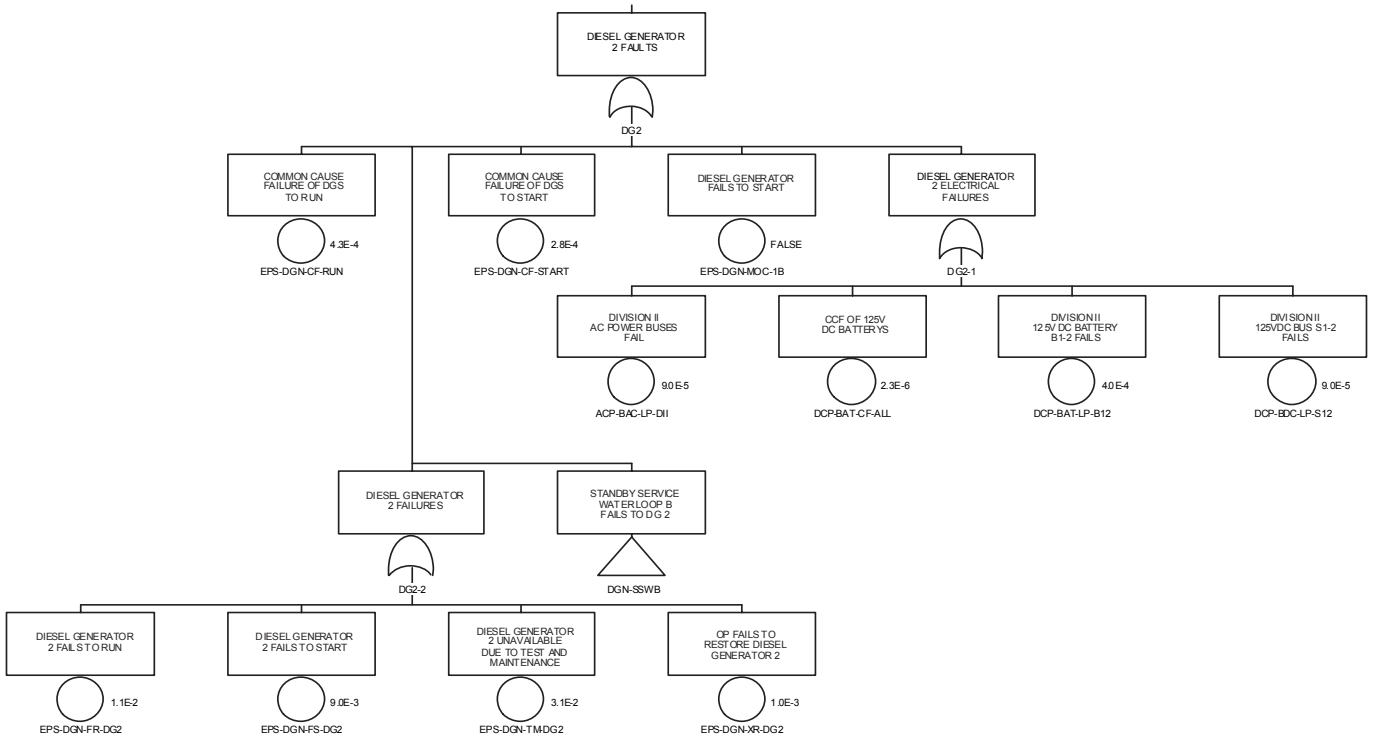

DIESEL GENERATOR 2 FAULTS
DG2
COMMON CAUSE FAILURE OF DGS TO RUN
4.3E-4
EPS-DGN-CF-RUN
COMMON CAUSE FAILURE OF DGS TO START
2.8E-4
EPS-DGN-CF-START
DIESEL GENERATOR FAILS TO START
FALSE
EPS-DGN-MOC-1B
DIESEL GENERATOR 2 ELECTRICAL FAILURES
DG2-1
DIVISION II AC POWER BUSES FAIL
9.0E-5
ACP-BAC-LP-DII
CCF OF 125V DC BATTERYS
2.3E-6
DCP-BAT-CF-ALL
DIVISION II 125V DC BATTERY B1-2 FAILS
4.0E-4
DCP-BAT-LP-B12
DIVISION II 125VDC BUS S1-2 FAILS
9.0E-5
DCP-BDC-LP-S12
DIESEL GENERATOR 2 FAILURES
DG2-2
STANDBY SERVICE WATER LOOP B FAILS TO DG 2
DGN-SSWB
DIESEL GENERATOR 2 FAILS TO RUN
1.1E-2
EPS-DGN-FR-DG2
DIESEL GENERATOR 2 FAILS TO START
9.0E-3
EPS-DGN-FS-DG2
DIESEL GENERATOR 2 UNAVAILABLE DUE TO TEST AND MAINTENANCE
3.1E-2
EPS-DGN-TM-DG2
OP FAILS TO RESTORE DIESEL GENERATOR 2
1.0E-3
EPS-DGN-XR-DG2

Figure 4 - WNPS - CORE SPRAY SYSTEM FAILS

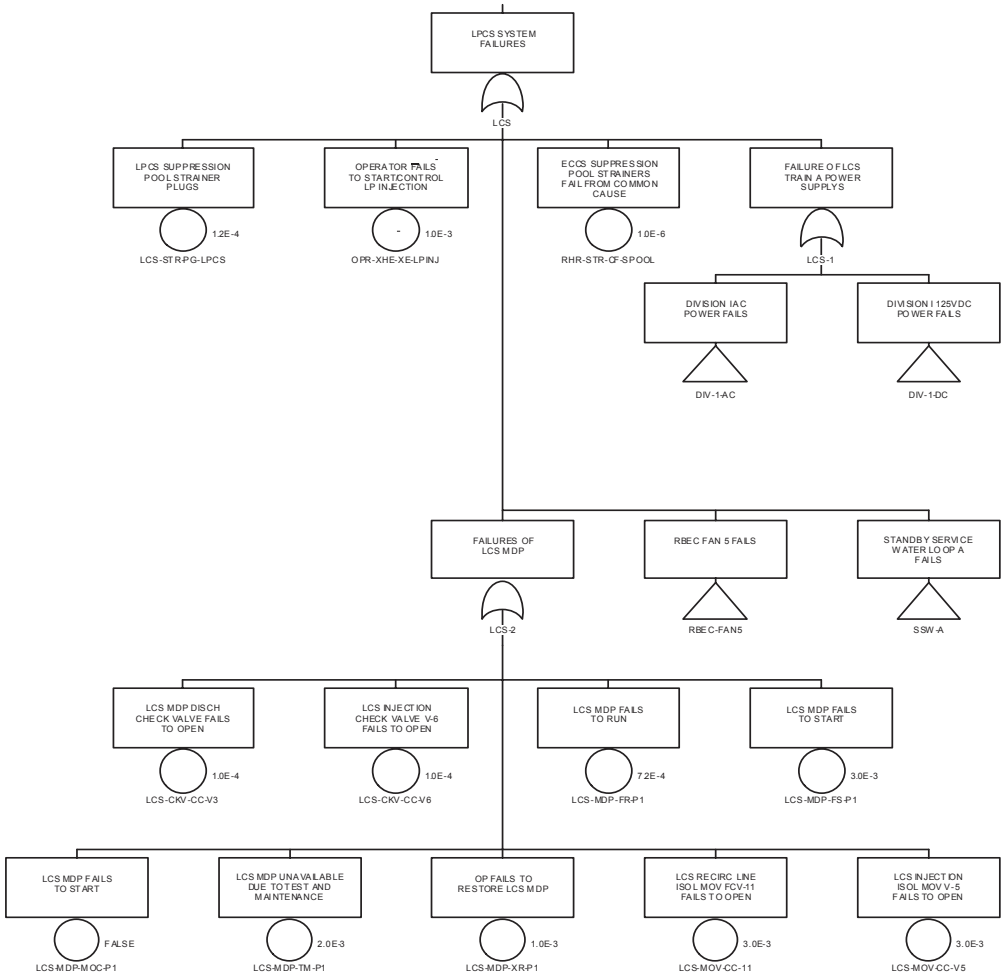


Figure 5 - WNPS - FAILURES OF RHR MDP 1A

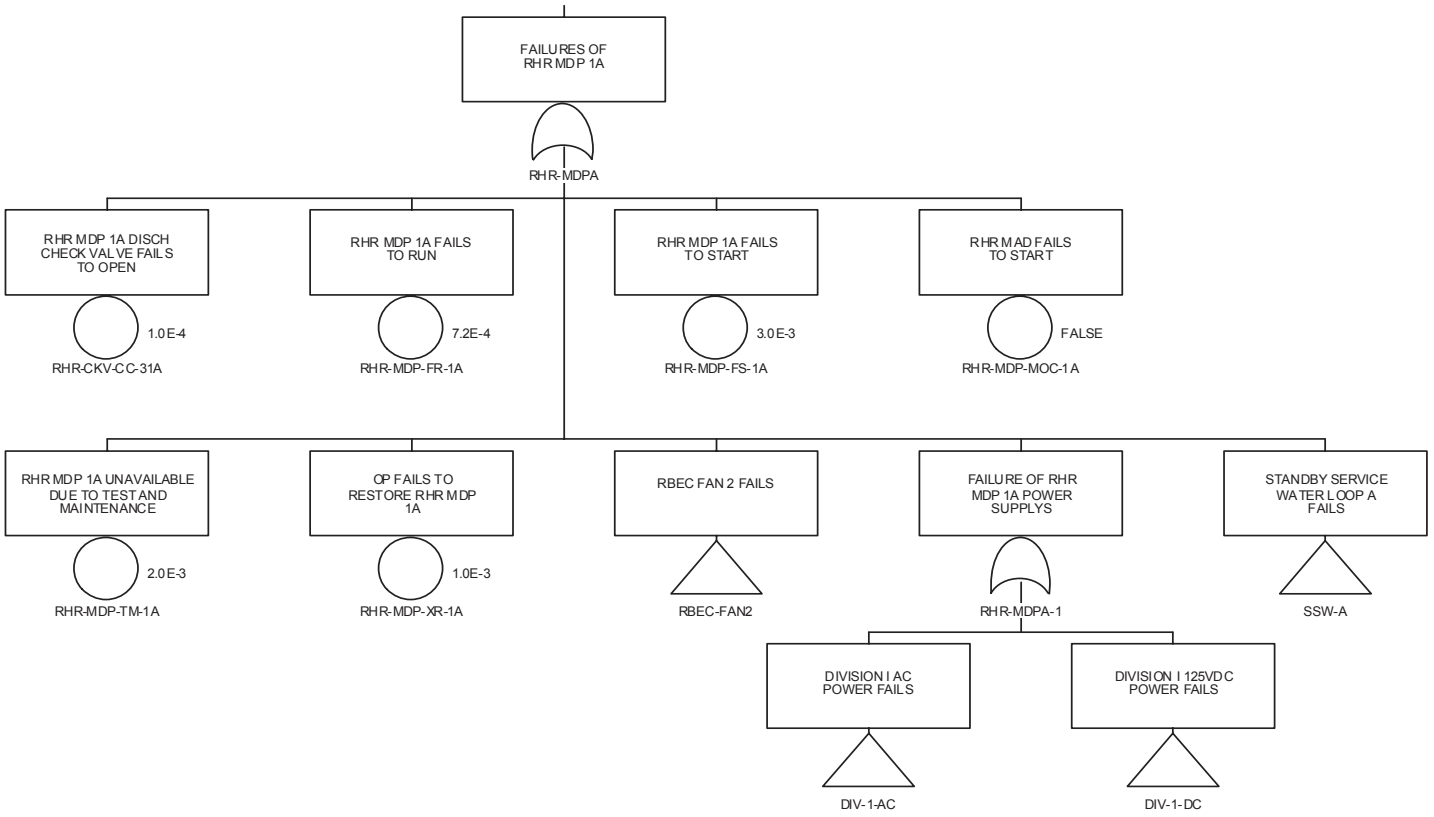


Figure 6 - WNPS - FAILURES OF RHR MDP 1B

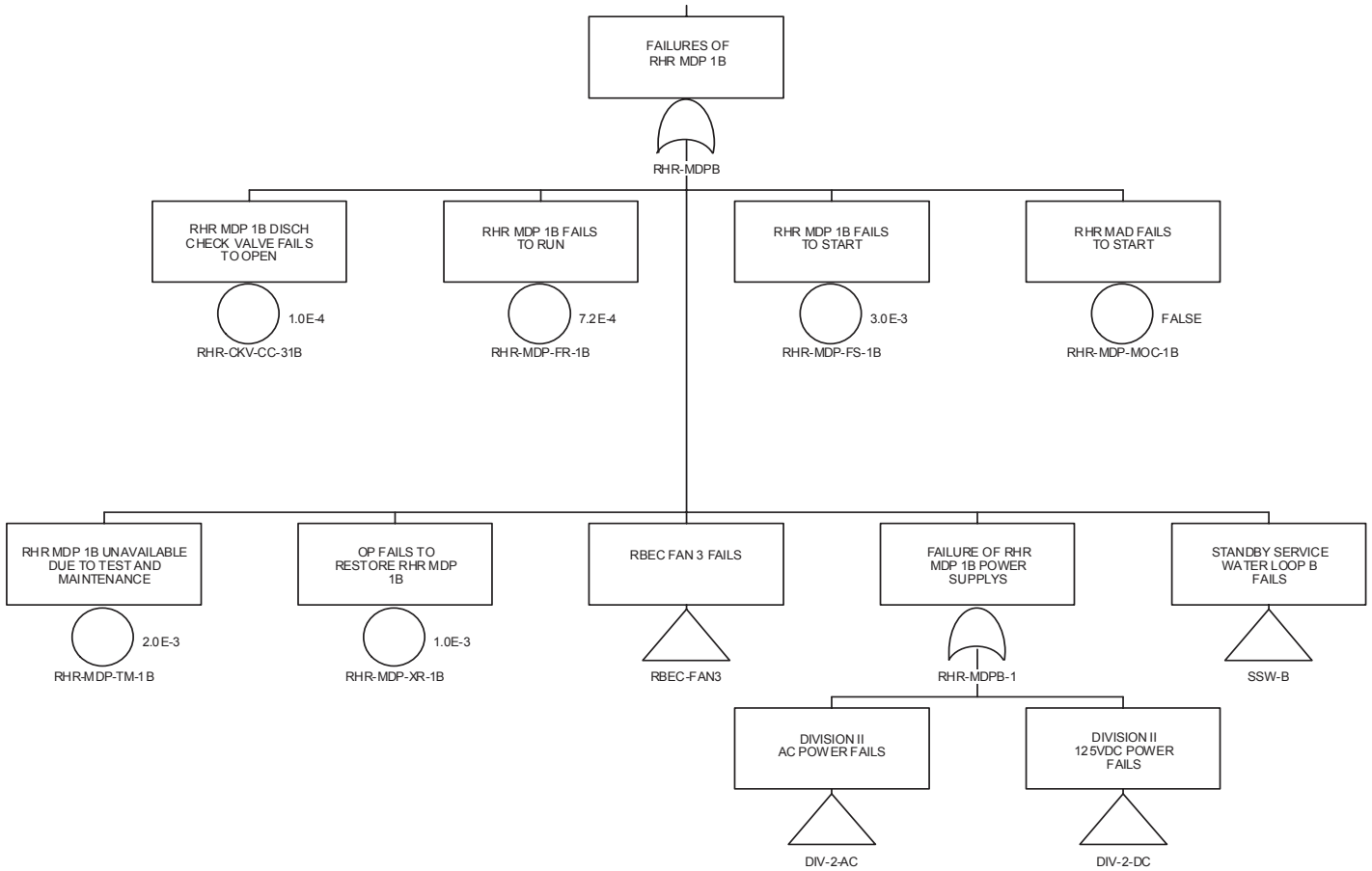


Figure 7 - WNPS - FAILURES OF RHR MDP 1C

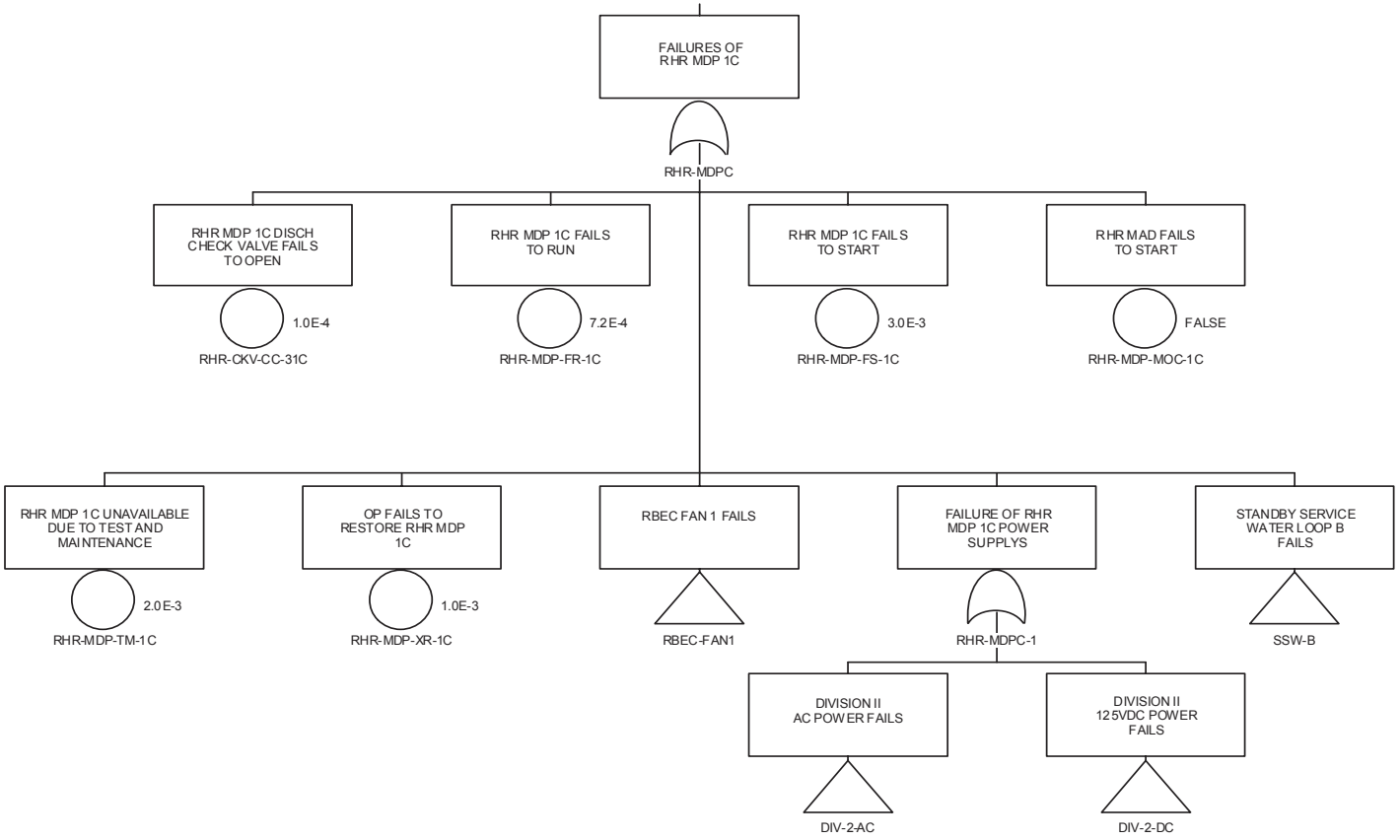


Figure 8 - WNPS - STANDBY SERVICE WATER LOOP A FAILS

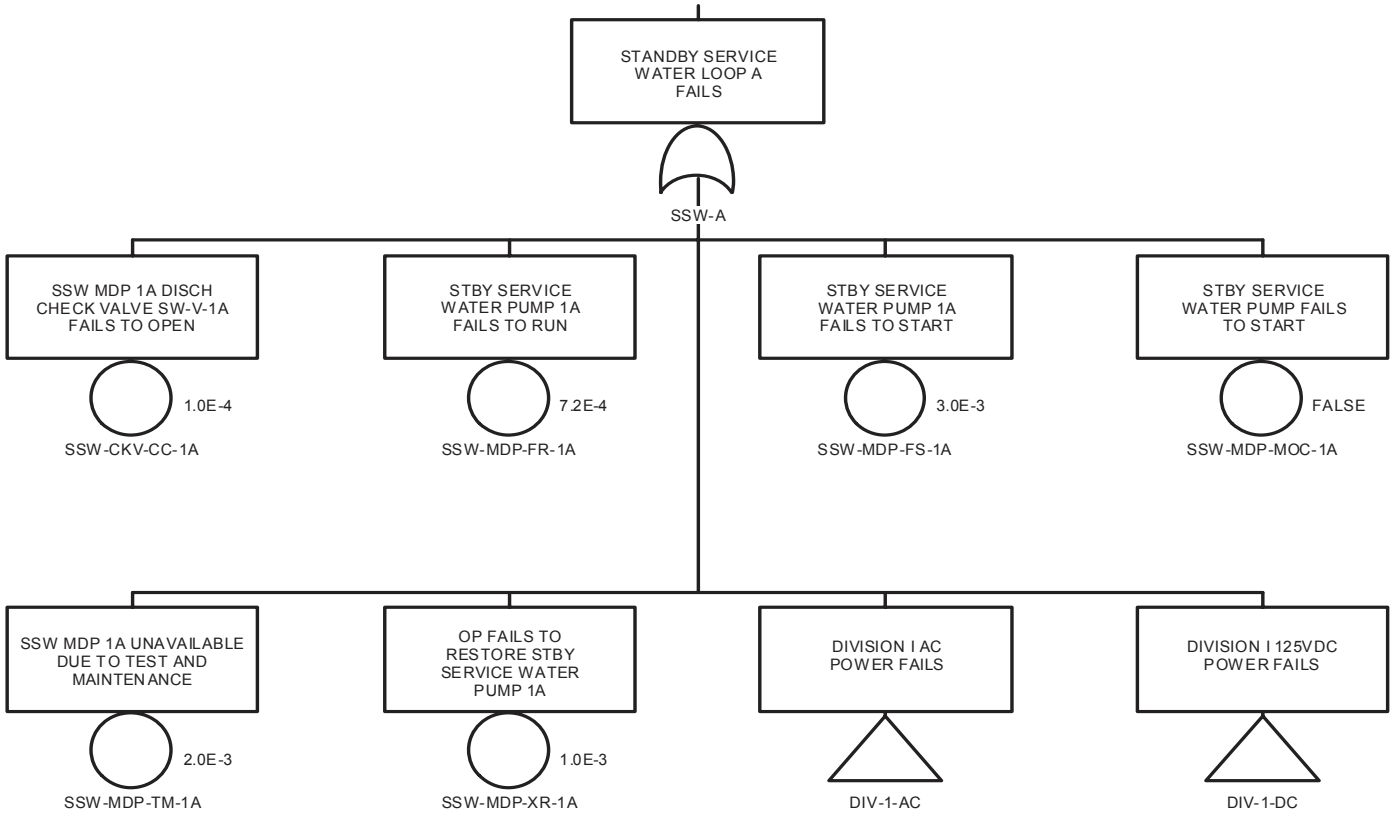


Figure 9 - WNPS - STANDBY SERVICE WATER LOOP B FAILs