Final ASP Program Analysis – Reject

<table>
<tr><th colspan="4">Accident Sequence Precursor Program – Office of Nuclear Regulatory Research</th></tr>
<tr><td colspan="2">Browns Ferry Nuclear Plant, Unit 3</td><td colspan="2">Inoperable Residual Heat Removal Pump and Improperly Installed Switch Result in Conditions Prohibited by Technical Specifications and Safety System Functional Failure</td></tr>
<tr><td colspan="2">Event Date: 1/19/2016</td><td>LER: 296-2016-001, 296-2016-002, 296-2016-003, 296-2016-004
IR: 05000296/2016002, 05000296/2016003</td><td>ΔCDP = 2×10⁻⁸</td></tr>
<tr><td colspan="4">Plant Type: General Electric BWR-4, Wet Mark I containment</td></tr>
<tr><td colspan="4">Plant Operating Mode (Reactor Power Level): Mode 1 (79% Reactor Power)</td></tr>
<tr><td>Analyst:
Ian Gifford</td><td>Reviewer:
Keith Tetter</td><td>Contributors:
N/A</td><td>BC Review Date:
5/1/2017</td></tr>
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EVENT DETAILS

Event Description. On January 13, 2016, operations personnel noticed that the Main Control Room (MCR) green light above the 3A Residual Heat Removal (RHR) pump handswitch was not illuminated. On January 19th, with the reactor operating at 79% rated thermal power, the 3A RHR pump was declared inoperable upon discovery of a malfunctioning Motor Breaker Transfer Switch (MBTS). The licensee performed a Past Operability Evaluation and concluded that the 3A RHR pump was inoperable from January 9th until replacement of the MBTS on January 20th. During this time, it is possible that the 3A RHR pump would not have started automatically or manually from the control room [local manual start from the 3EA 4kV Shutdown Board (SD BD) was possible]. The 3B and 3D RHR pumps were inoperable concurrently with the 3A RHR pump for less than one hour on January 14, resulting in a loss of safety function for the RHR System [Low Pressure Coolant Injection (LPCI) requires two of four RHR pumps during an accident]. Additional details of this event can be found in licensee event report (LER) 296-2016-001 (Ref. 1) and inspection report (IR) 05000296/2016002 (Ref. 2).

On February 22, 2016, during routine maintenance of the Core Spray (CS) System with the reactor in Mode 5 at 0% rated thermal power, relays on the 3ED 4kV SD BD were found de-energized. As a result, the automatic start function of the 3B and 3D CS pumps, 3D RHR pump, and D1 RHR Service Water (RHRSW) pump was not operable with normal power supplied to the 3ED 4 kV SD BD. The licensee performed a Past Operability Evaluation and concluded that the relays were de-energized since their last successful actuation on October 28, 2015. During the period from October 28, 2015, through February 20, 2016 (when the reactor was placed in Mode 4), automatic start of the 3B and 3D CS, 3D RHR, and D1 RHRSW pumps was not available (manual start of the pumps was possible). The automatic start of the pumps would have functioned if the 3ED 4kV SD BD were powered by other than normal sources. On February 23rd, the 52STA switch and cam linkage were declared operable following inspection, cleaning, and adjustment. During this time of inoperability, additional equipment was inoperable as follows:

- A1 RHRSW pump inoperable for approximately 11 hours on November 23, 2015 (test and maintenance).
- B1 RHRSW pump inoperable for approximately 4 hours on November 18th (test and maintenance).
- 3A RHR pump inoperable between November 13-19th (failure of transfer switch).
- 3B RHR train inoperable for approximately 19 hours on November 20th and November 21st (failure of flow control valve).

Additional details of this event can be found in LER 296-2016-002 (Ref. 3) and IR 05000296/2016003 (Ref. 4)

From March 14, 2014, to March 24, 2016, the 3B Outboard Main Steam Isolation Valve (MSIV) failed to meet its leak rate limit due to wear on the seating surface of the pilot poppet seat. During this time, the 3B Inboard MSIV was available to perform its safety function and, therefore, this condition was not modeled in this ASP analysis. Additional details of this event can be found in LER 296-2016-003 (Ref. 5).

On April 6, 2016, as-found testing results indicated that 3 of 13 Main Steam Relief Valves (MSRVs) exceeded the +/- 3 % setpoint required for operability. The failure was attributed to corrosion bonding of the valve discs to the valve seats. It was determined that the three MSRVs were inoperable from March 19, 2014, to February 20, 2016. However, the valves remained capable of performing their required safety function by maintaining reactor pressure within the American Society of Mechanical Engineers code limits. The valves remained capable of opening by remote-manual operation, activation through the Automatic Depressurization System, and MSRV Automatic Actuation Logics. Because the valves were capable of performing their required safety function, this condition was not modeled in this ASP analysis. Additional details of this event can be found in LER 296-2016-004 (Ref. 6).

Causes. The licensee determined that the 3A RHR Pump MBTS 3-43-074-0005 (General Electric SB-1 switch) failed to fully latch due to binding in the ball detent and position sprocket mechanism caused by in-service use of the MBTS in excess of its 21-year service life (with no preventative maintenance). The binding resulted in incorrect positioning of 4-4C contacts in the open configuration.

The licensee determined that the NVA-D1 and NVA-D2 relays on the 3ED 4 kV SD BD were de-energized due to failure of the 6-6C contacts and binding of the 52STA cam linkage on the MJ(52STA) switch. The cause of the failure was improper installation of the switch to linkage interface.

MODELING

Basis for ASP Analysis/SDP Results. The ASP Program uses Significance Determination Process (SDP) results for degraded conditions when available and applicable. The ASP Program performs independent analyses for initiating events. ASP analyses of initiating events account for all failures/degraded conditions and unavailabilities (e.g., equipment out for test/maintenance) that occurred during the event, regardless of licensee performance.[1]

[1] ASP analyses also account for any degraded condition(s) that were identified after the initiating event occurred if the failure/degradation exposure period(s) overlapped the initiating event date.

LER 296-2016-001 was closed in IR 05000296/2016002 with no findings. LER 296-2016-002 was closed in IR 05000296/2016003 with no findings. LER 296-2016-003 was closed in IR 05000296/2016003 with no findings. LER 296-2016-004 was closed in IR 05000296/2016003 with a Green Non-cited Violation of Technical Specifications (TS) 3.4.3 (Safety Relief Valves) for two required MSRVs being inoperable longer than allowed by TS. The performance deficiency was screened using Inspection Manual Chapter 0609, Appendix A, Exhibit 2.

The four LERs represent windowed conditions that must be analyzed by the ASP Program to determine the combined risk significance of the events. As stated in the Event Details section, LERs 296-2016-003 and 296-2016-004 do not represent conditions where the equipment safety function was lost and, therefore, these conditions are not modeled in the event assessment. However, the combination of degraded conditions and unavailability due to test and maintenance for equipment detailed in LERs 296-2016-001 and 296-2016-002 is modeled for this ASP analysis.

Analysis Type. A condition assessment was performed using the Browns Ferry 3 Standardized Plant Analysis Risk (SPAR) model Revision 8.18, created in May 2014.

SPAR Model Modifications. In order to provide operator recovery credit for the failure to start of the 3B and 3D CS, 3D RHR, and D1 RHRSW pumps due to the de-energized relays, four fault trees were modified (LCS-B, LCS-D, SDC-B, and RSW-D1).

For 3B CS, a new AND gate LCS-B25 (BUS RELAY FAILURE RESULTS IN FAILURE OF PUMP) was created in the LCS-B fault tree. An AND gate LCS-B250 (RELAY FAILURE RESULTS IN PUMP FAILURE TO AUTO-START) was placed beneath AND gate LCS-B25. In addition, basic event PUMP-XHE-MANUAL (OPERATORS FAIL TO MANUALLY START PUMP) was created and placed under LCS-B25. Basic event BUS-RELAY-FAILURE (FAILURE OF BUS RELAY RESULTS IN FAILURE OF PUMP TO AUTO-START) was created and added under AND gate LCS-B250. The complement of HE-LOOP (HOUSE EVENT – LOSS OF OFFSITE POWER IE HAS OCCURRED) was also added under AND gate LCS-B250. This change is illustrated in Figure 1 of Appendix B.

As stated in LER 296-2016-002 (Ref. 3), the pumps would not have started when powered by normal sources; however, the automatic start functioning capability of these pumps was available when powered by other than normal sources. Therefore, it can be assumed that in the event of a loss of offsite power (LOOP), the equipment loaded onto the emergency diesels would have functioned as designed. To account for this, the complement of house event HE-LOOP was added to the fault trees to negate the risk increase from the bus relay failure during LOOP events.

Fault trees LCS-D, SDC-B, and RSW-D1 were modified in the same manner (with different gate names) as fault tree LCS-B. These changes are illustrated in Figures 2-4 of Appendix B.

The new basic events were set to FALSE in the nominal case.

Key Modeling Assumptions. To properly model the windowed conditions discussed in the Event Details section, six separate SAPHIRE conditions were analyzed and summed to determine the overall risk significance. The following changes were made for all of the conditions:

- BUS-RELAY-FAILURE (FAILURE OF BUS RELAY RESULTS IN FAILURE OF PUMP TO AUTO-START) was set to TRUE.
- PUMP-XHE-MANUAL (OPERATORS FAIL TO MANUALLY START PUMP) was set to a screening value of 0.1.

The duration and additional equipment unavailabilities for the six conditions are as follows:

Condition #1

- The condition duration was set to 17 days (combines the two separate 6 and 11-day exposure periods with the same equipment unavailability).
- RHR-MDP-FS-PUMP3A (RHR PUMP A FAILS TO START) was set to TRUE.

Condition #2

- The condition duration was set to 1 hour.
- RHR-MDP-TM-TRN3B (RHR TRAIN B IS UNAVAILABLE BECAUSE OF MAINTENANCE) was set to TRUE.
- RHR-MDP-TM-TRN3D (RHR TRAIN D IS UNAVAILABLE BECAUSE OF MAINTENANCE) was set to TRUE.
- RHR-MDP-FS-PUMP3A (RHR PUMP A FAILS TO START) was set to TRUE.

Condition #3

- The condition duration was set to 97 days for the time only 3B and 3D CS, 3D RHR, and D1 RHRSW pumps were failed.
- No additional equipment unavailability.

Condition #4

- The condition duration was set to 4 hours.
- RHR-MDP-FS-PUMP3A (RHR PUMP A FAILS TO START) was set to TRUE.
- RSW-MDP-TM-TRNB1 (RHRSW PUMP B1 IS UNAVAILABLE BECAUSE OF MAINTENANCE) is set to TRUE.

Condition #5

- The condition duration was set to 19 hours.
- RHR-MOV-CC-F073 (SPC LOOP B INJEC VLV 74-73 FAILS TO OPEN) was set to TRUE.

Condition #6

- The condition duration was set to 11 hours.
- RSW-MDP-TM-TRNA1 (RHRSW PUMPA1 IS UNAVAILABLE BECAUSE OF MAINTENANCE) was set to TRUE.

A screening value of 0.1 was used to model operator manual restart recovery of the equipment powered by de-energized relays. This analysis conservatively assumes no recovery actions for all other equipment unavailabilities (including equipment undergoing test and maintenance).

ANALYSIS RESULTS

∆CDP/Rejection Basis. The point estimate increase in core damage probability (∆CDP) for this set of events is 2.3×10^{-8}. The calculated risk is below the ASP precursor threshold of 1×10^{-6}; therefore, this event is not considered a precursor under the ASP Program. A summary of each conditions' contribution to the ∆CDP is provided in the following table:

Condition	∆CDP
#1	1.17E-8
#2	4.01E-10
#3	2.71E-10
#4	3.23E-10
#5	1.05E-8
#6	1.28E-12
TOTAL	2.32E-8

Dominant Sequence. The dominant accident sequence is medium loss of coolant accident (MLOCA) Sequence 06 (∆CDP = 4.6×10^{-9}) that contributes approximately 20% of the total internal events ∆CDP. This sequence is illustrated in Figure 1 of Appendix A.

Sequence	Δ CDP	% Contribution	Description
MLOCA 6	4.60E-09	19.86%	Medium loss of coolant accident initiating event; reactor shutdown (RPS) succeeds; vapor and suppression (VSS) succeeds; high pressure core injection (HCI) succeeds; condensate system (CDS) succeeds; suppression pool cooling (SPC) fails; containment spray (CSS) fails; and late injection (LI) fails
LOCHS 33	3.21E-09	13.86%	Loss of containment heat sink initiating event; RPS succeeds; SRVs succeed; high pressure injection (HPI) succeeds; SPC fails; manual depressurization (DEP) fails; and control rod drive (CRD) pump injection fails
LOOPGR 4	2.50E-09	10.82%	Grid-related loss of offsite power (LOOP) initiating event; RPS succeeds; emergency power (EPS) succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP succeeds; LPI succeeds; RHR fails; containment venting (CVS) succeeds; and late injection fails
LOOPGR 6	2.41E-09	10.40%	Grid-related LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP succeeds; LPI succeeds; residual heat removal (RHR) fails; CVS fails; and late injection fails
LOOPWR 6	1.85E-09	8.01%	Switchyard-centered LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP

			succeeds; LPI succeeds; RHR fails; CVS succeeds; and late injection fails
LOOPWR 4	1.75E-09	7.55%	Weather-related LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP succeeds; low pressure injection (LPI) succeeds; RHR fails; CVS succeeds; and late injection fails
LOOPGR 13	1.20E-09	5.20%	Grid-related LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; and DEP fails
LOPCA 28	8.31E-10	3.58%	Loss of plant control air initiating event; RPS succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP fails; and CRD fails
IORV 13	7.67E-10	3.31%	Inadvertent open relief valve initiating event; RPS succeeds; power conversion system (PCS) fails; HPI succeeds; CRD fails; CDS succeeds; RHR fails; PCS recovery fails; CVS fails; and late injection fails
LOOPSC 4	5.92E-10	2.56%	Switchyard-centered LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP succeeds; LPI succeeds; RHR fails; CVS succeeds; and late injection fails
LOOPSC 6	5.09E-10	2.20%	Switchyard-centered LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP succeeds; LPI succeeds; RHR fails; CVS fails; and late injection fails
LLOCA 6	4.58E-10	1.97%	Large loss of coolant initiating event; RPS succeeds; VSS succeeds; core spray (LCS) succeeds; SPC fails; CSS fails, CVS fails; and late injection fails
LOOPSC 13	4.43E-10	1.91%	Switchyard-centered LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; and DEP fails
LOOPWR 13	3.53E-10	1.52%	Weather-related LOOP initiating event; RPS succeeds; EPS succeeds; SRVs succeed; HPI succeeds; SPC fails; and DEP fails
LOSWS 9	2.96E-10	1.28%	Loss of service water initiating event; RPS succeeds; SRVs succeed; HPI succeeds; SPC fails; DEP succeeds, LPI succeeds; RHR fails; service water recovery (SWSR) fails; and late injection fails
MLOCA 31	2.85E-10	1.23%	Medium loss of coolant accident initiating event; RPS succeeds; VSS succeeds; HCI fails; DEP succeeds; CDS succeeds; SPC fails; CSS fails; CVS fails; and late injection fails

REFERENCES

1. Tennessee Valley Authority, "Browns Ferry Nuclear Plant – Units 3, Licensee Event Report 2016-001-00, Inoperable Residual Heat Removal Pump Results in Condition Prohibited by Technical Specifications and Safety System Functional Failure," dated March 21, 2016 (ML16078A138).
2. U.S. Nuclear Regulatory Commission, "Browns Ferry Nuclear Plant – NRC Integrated Inspection Report 05000296/2016002," dated August 11, 2016 (ML16225A208).
3. Tennessee Valley Authority, "Browns Ferry Nuclear Plant – Units 3, Licensee Event Report 2016-002-01, Improperly Installed Switch Results in Condition Prohibited by Technical Specifications," dated July 28, 2016 (ML16211A055).
4. U.S. Nuclear Regulatory Commission, "Browns Ferry Nuclear Plant – NRC Integrated Inspection Report 05000296/2016003," dated November 9, 2016 (ML16315A108).
5. Tennessee Valley Authority, "Browns Ferry Nuclear Plant – Units 3, Licensee Event Report 2016-003-00, Main Steam Isolation Valve Leaking in Excess of Technical Specification Requirements," dated April 25, 2016 (ML16116A378).
6. Tennessee Valley Authority, "Browns Ferry Nuclear Plant – Units 3, Licensee Event Report 2016-004-00, Main Steam Relief Valves Lift Settings Outside of Technical Specifications Required Setpoints," dated June 6, 2016 (ML16158A139).

Appendix A: Key Event Tree

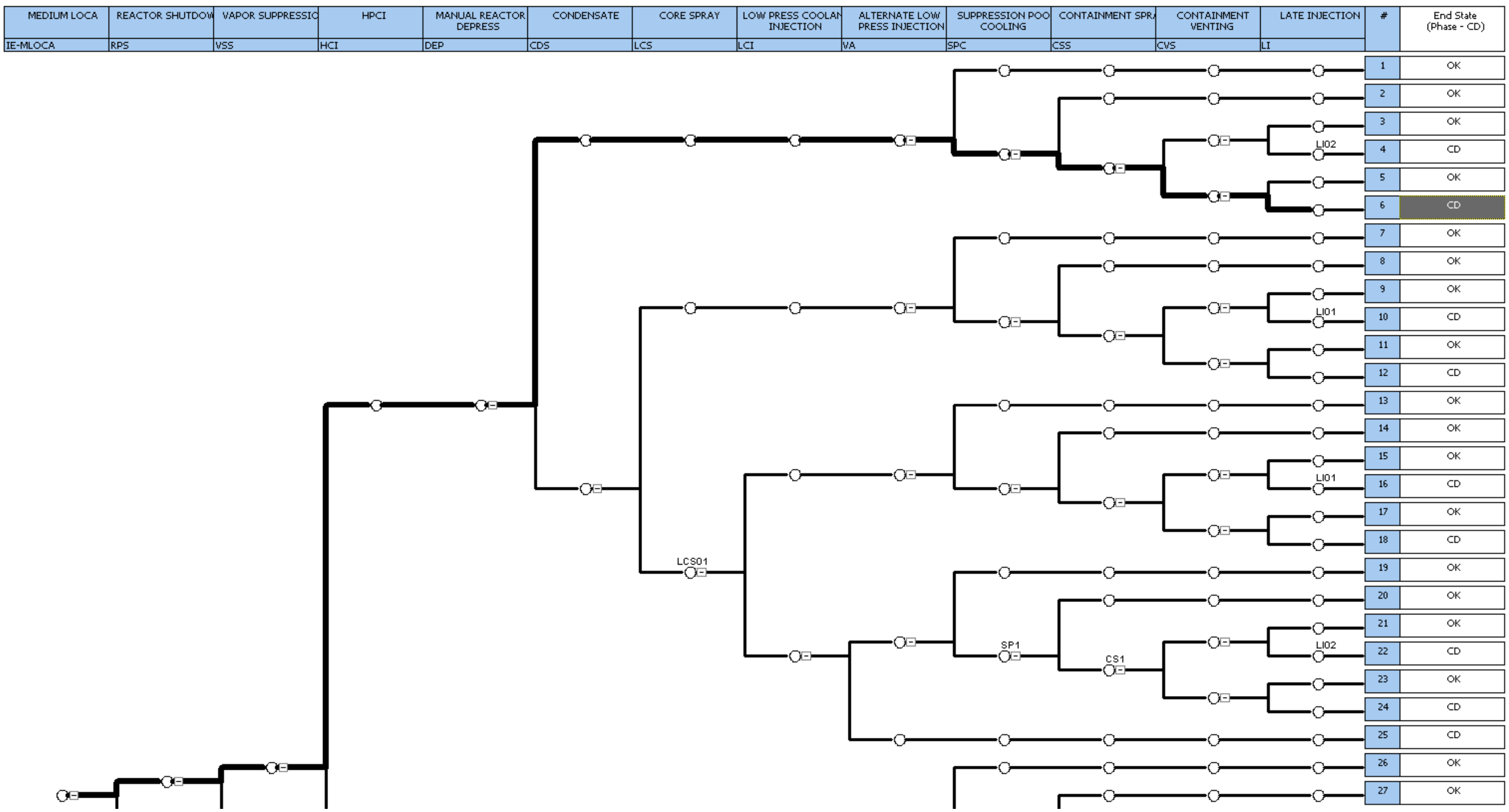

Figure 1: MLOCA Event Tree

Appendix B: SPAR Model Modifications

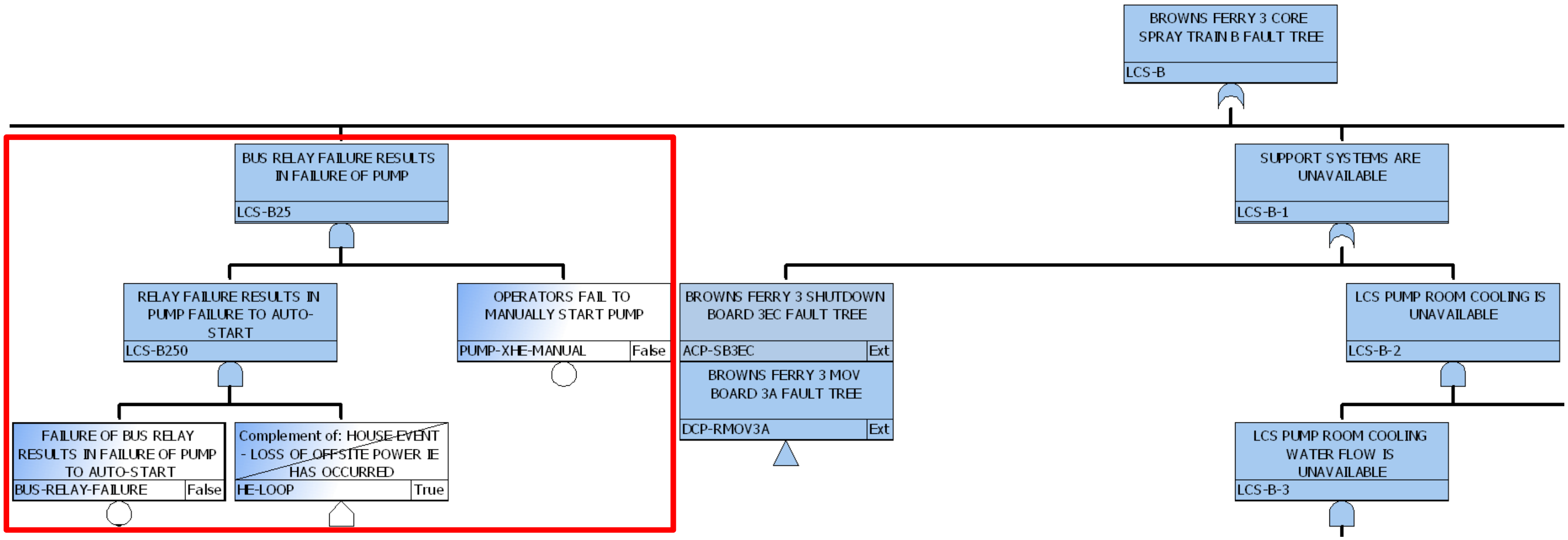

Figure 1: Core Spray Train B Fault Tree Modification

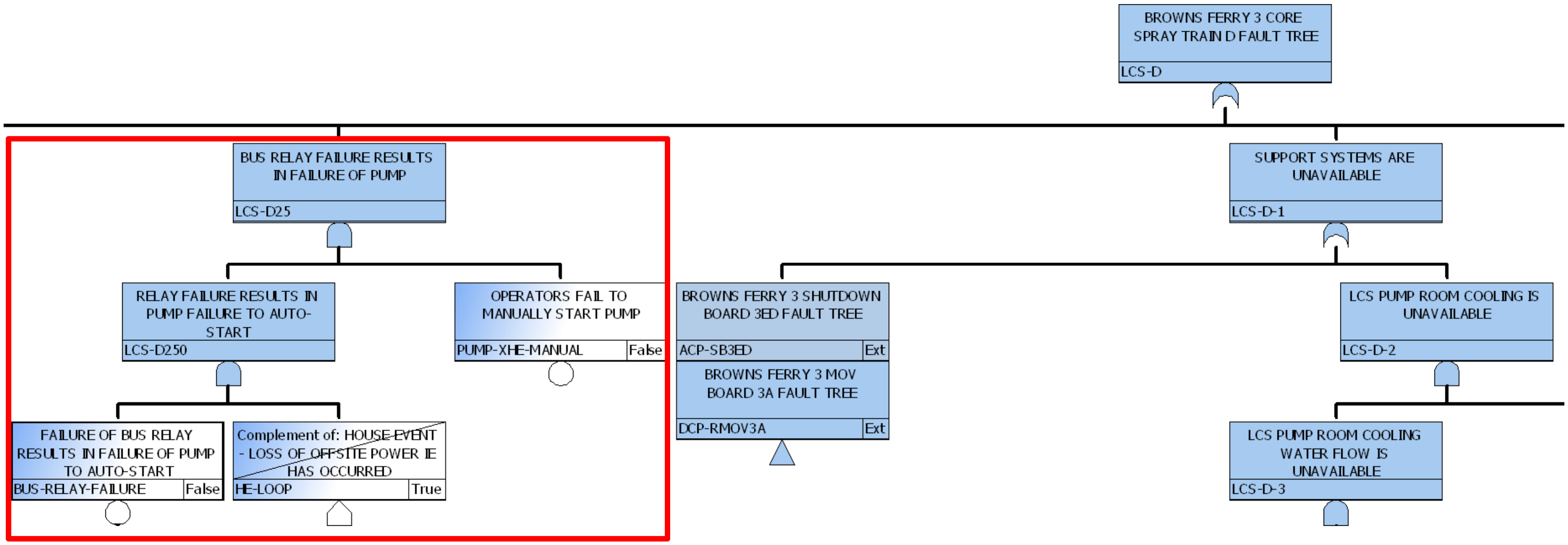

Figure 2: Core Spray Train D Fault Tree Modification

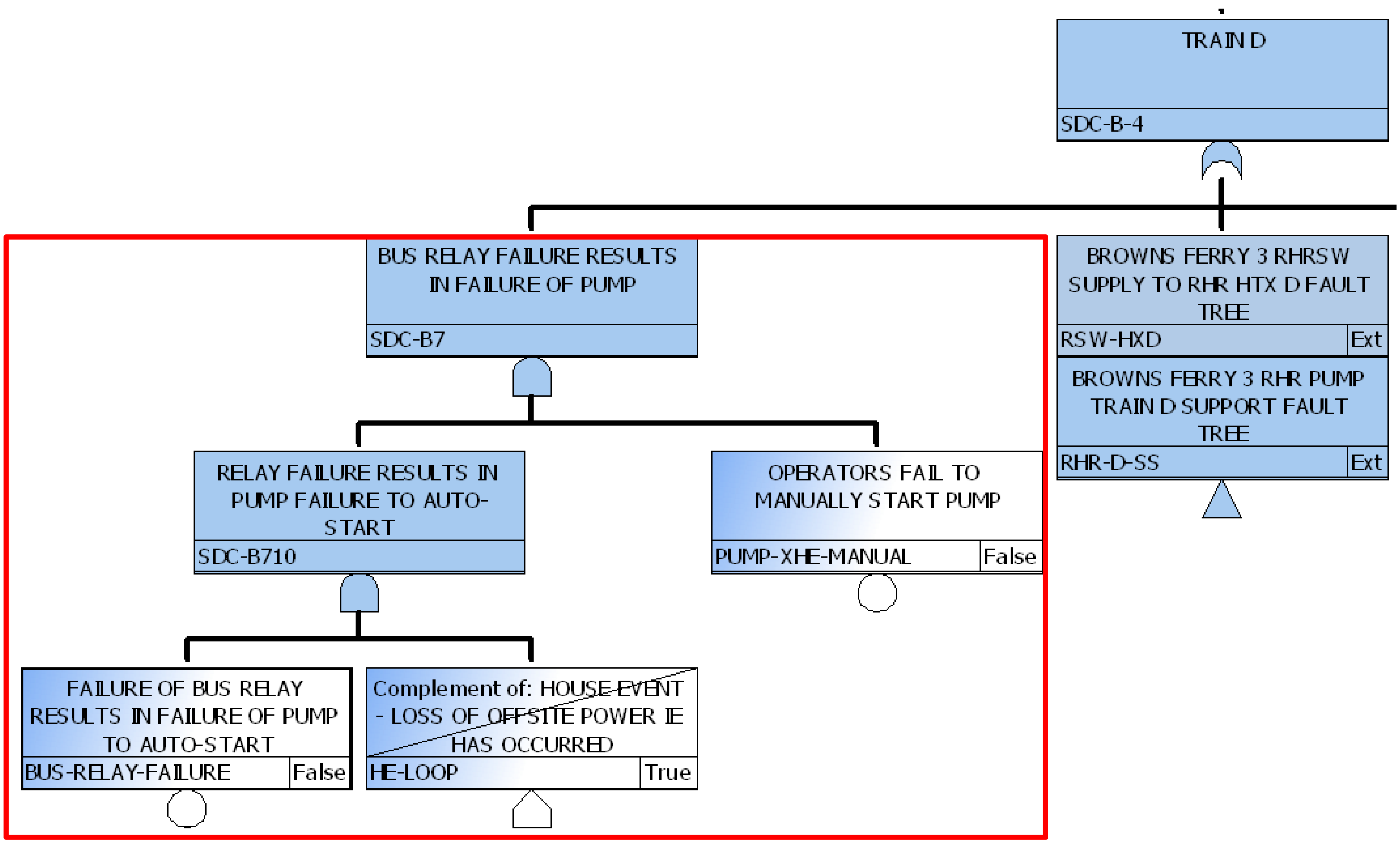

Figure 3: Shutdown Cooling System B Fault Tree Modification

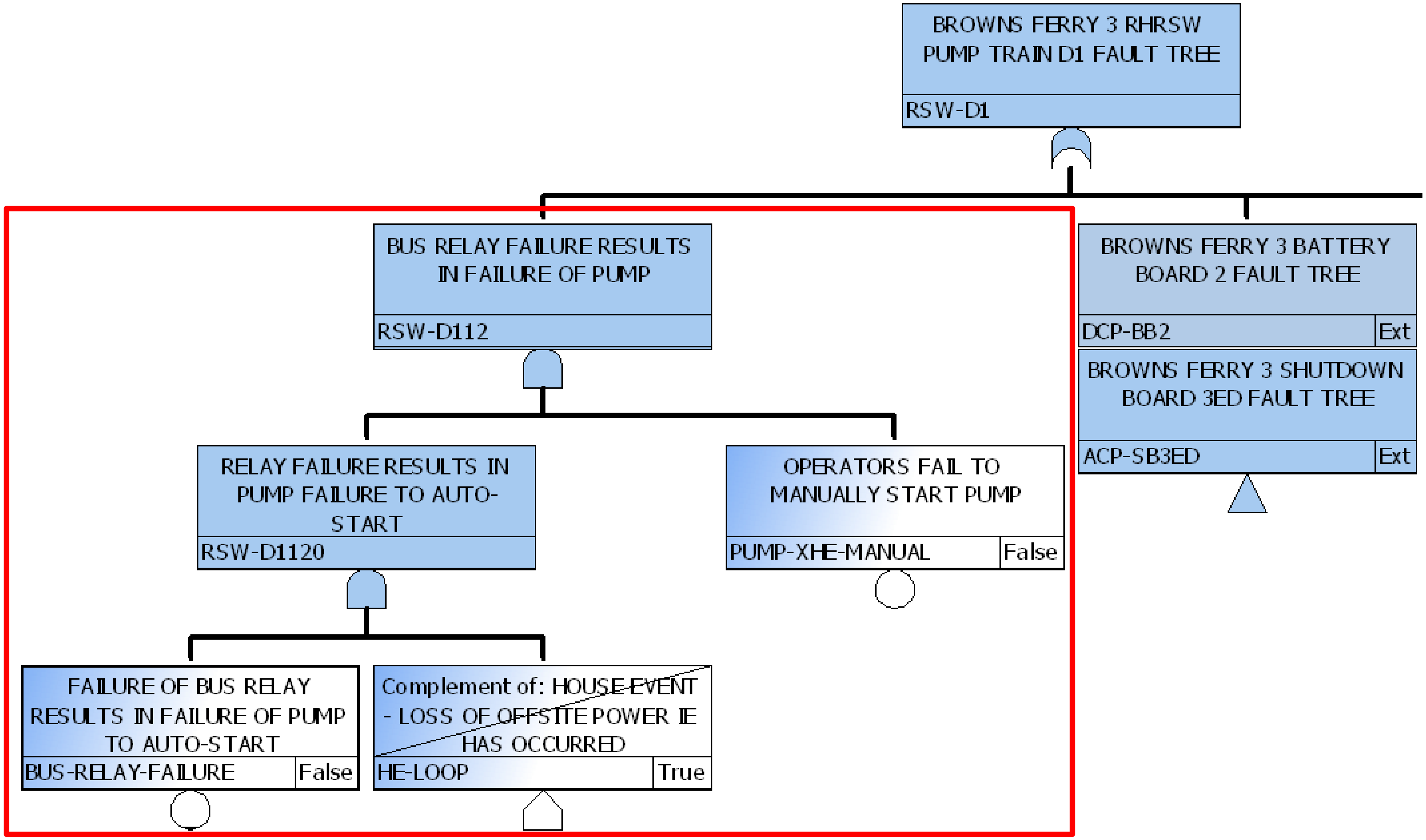

Figure 4: RHRSW Pump Train D1 Fault Tree Modification