# Final ASP Program Analysis – Reject

| Accident Sequence Precursor Program – Office of Nuclear Regulatory Research | | | |
|---|---|---|---|
| **Joseph M. Farley Nuclear Plant, Units 1 and 2** | Turbine Driven Auxiliary Feedwater Pump Design Issue Resulted in a Degraded Condition in both Units | | |
| **Event Date:** 11/22/2015 | **LER:** 348-2015-005-01<br>**IR:** 05000348/2016002 | **ΔCDP =** $2\times10^{-7}$ | |
| **Plant Type:** Westinghouse 3-Loop PWR with a dry, ambient pressure containment | | | |
| **Plant Operating Mode (Reactor Power Level):** Mode 1 (100% Reactor Power) | | | |
| **Analyst:**<br>David Aird | **Reviewer:**<br>Ian Gifford | **Contributors:**<br>N/A | **BC Review Date:**<br>12/23/2016 |

## EVENT DETAILS

**Event Description.** On November 20, 2015, the Farley Unit 1 turbine-driven auxiliary feedwater (TDAFW) pump over sped and tripped on startup during surveillance testing. The TDAFW pump tripped on overspeed due to a design change which allowed the governor valve to admit excess steam at startup. This error made both Unit 1 and Unit 2 TDAFW pumps vulnerable to an overspeed trip since the design changes were made in April 2015 and January 2015, respectively. However, there were no actual automatic start demands on the Unit 1 or Unit 2 TDAFW systems for the duration of this degraded condition.

After the incorrect modification was made on each unit, several successful starts were performed to validate the set point adjustment before the pumps were returned to service. Additionally, the TDAFW pumps successfully started 19 times on Unit 1 and 15 times on Unit 2 for surveillances, post-maintenance testing, and troubleshooting while the degraded condition existed. Once discovered, the licensee implemented another design change to adjust the low idle speed set point to minimize the potential for turbine speed overshoot on startup. Additional event information is available in licensee event report (LER) 348-2015-005-01 (Ref. 1).

**Causes.** The licensee determined that a previous design change to adjust the Magnetic Pick Up (MPU) override timer setting from 10 seconds to 600 seconds resulted in a governor controller speed set point conflict that revealed itself during performance of the Unit 1 surveillance test. The licensee implemented the set point change after consulting with the vendor to address previous issues with the MPU override timer setting. This new failure mode was not anticipated when the TDAFW pump governor controller MPU timer set point was changed on Units 1 and 2.

## 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]

This event was evaluated in inspection report (IR) 05000348/2016002 (Ref. 2). Farley Unit 1 and 2 Technical Specification (TS) limiting condition for operation (LCO) 3.7.5, "Auxiliary Feedwater (AFW) System," requires three operable AFW trains while the unit is in Modes 1, 2 or 3. With one AFW pump train inoperable, LCO 3.7.5. Condition B requires restoration of the AFW train to operable status within 72 hours. Contrary to this requirement, Unit 1 operated from May 3, 2015, until November 22, 2015, with the Unit 1 TDAFW inoperable. Unit 2 operated from January 10, 2015, until November 22, 2015, with the Unit 2 TDAFW inoperable. There were instances when each unit was unknowingly in a more restrictive LCO due to the inoperability of more than one AFW train (e.g. a motor-driven AFW pump in planned maintenance).

As a result of this TS violation, a detailed risk evaluation (condition assessment) as part of the SDP was performed for Unit 1 that resulted in a change in core damage frequency per year of less than $1\times10^{-6}$. Therefore, the issue was determined to be of very low safety significance (Green). The major analysis assumptions for Unit 1 included a 200-day exposure interval, recovery credit for local manual overspeed trip reset evaluated using the NRC SPAR-H human reliability analysis method, and an overspeed trip startup failure probability determined from plant specific data. The SDP analysis for Unit 1 meets the requirements of the ASP Program and the LER is closed.

An analysis of Unit 2 was not performed under the SDP because no actual failure occurred on Unit 2 and, therefore, an independent ASP analysis is required to address the impact of this degraded condition.

**Analysis Type.** A condition assessment was performed using the Farley Standardized Plant Analysis Risk (SPAR) model Revision 8.21, created in May 2014.

**SPAR Model Modifications.** In order to provide operator recovery credit for the failure to start of the TDAFW pump due to excess steam, two basic events were created and added to the model. A new AND gate was added in the AFW-TDP fault tree. New basic events AFW-TDP-FS-XSS (*TDAFW Pump Fails to Start due to Excess Steam at Startup*) and AFW-XHE-XM-RESET (*Operator Fails to Reset Overspeed Trip*) were added under the AND gate and set to IGNORE. An illustration of this SPAR model change is depicted in Figure 2 of Appendix C. The Bayesian inference method was used to evaluate the failure probability of new basic event AFW-TDP-FS-XSS. The SPAR-H method was used to evaluate the failure probability of new basic event AFW-XHE-XM-RESET. These evaluations are described in the Key Modeling Assumptions section.

**Key Modeling Assumptions.** The following assumptions were determined to be significant to the modeling of this event[2]:

- The condition duration was set to 317 days.

[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.

[2] In the base model, main feedwater is not credited and the service water system is assumed unrecoverable if lost.

- The SPAR model accounts for other random failures of components and equipment that may be unavailable due to test and maintenance for the duration of the degraded condition. These events were unchanged from their nominal values.
- The probability of new basic event AFW-TDP-FS-XSS was set to $4.2\times10^{-2}$. The Bayesian inference method, specifically, the Jeffreys prior approach ($\alpha_{prior} = 5\times10^{-1}$ and $\beta_{prior} = 5\times10^{-1}$) was used to calculate the increased failure-to-start probability of the TDAFW pump based on the observed data. Between Unit 1 and Unit 2, there was 1 observed failure in 35 attempted starts of the TDAFW pumps while this degraded condition existed. The Bayesian method is described in more detail in Section 3.2 of Reference 3.
- New basic event AFW-XHE-XM-RESET was created to model the recovery of the TDAFW pump by the operators. This human failure event (HFE) was evaluated using SPAR-H (Ref. 4 and Ref. 5). Table 1 and Table 2 provide the key qualitative information for this HFE and the performance shaping factor (PSF) adjustments required for the quantification of the human error probability (HEP) using SPAR-H.

**Table 1. Qualitative Evaluation of HFE for Recovery of TDAFW Pump**

| | |
|---|---|
| **Definition** | The definition for this HFE is the operators failing recover the TDAFW pump within 1.6 hours assuming a loss of all AFW pumps. |
| **Description and Event Context** | This recovery action is only applicable to the failure to start of the TDAFW pump due to excess steam at initial startup. This condition would trip the pump. However, operators would be able to manually reset this trip and return the TDAFW to operable status from the control room. The TDAFW pump is required for core cooling during scenarios when the motor-driven AFW pumps are unavailable. |
| **Operator Action Success Criteria** | Recover the TDAFW pump to operable status within the specified timeframe. Specifically, this scenario requires operators to manually reset the TDAFW pump trip signal from the control room. |
| **Nominal Cues** | Indications and alarms in the control room would alert operators to the inoperable TDAFW system. |
| **Procedural Guidance** | The analyst assumed that there are alarm response procedures that operators would use to restore the TDAFW pump. |
| **Diagnosis/Action** | This HFE contains sufficient diagnosis and action components. |

**Table 2. SPAR-H Evaluation of HFE for Recovery of EDG in Four Hours**

| PSF | Diagnosis/ Action Multiplier | Notes |
|---|---|---|
| Time Available | 1 / 1 | The analyst conservatively assumed that operators would need approximately 20 minutes to perform the action component of resetting the pump trip logic and initiating the TDAFW pump. The time for diagnosis was estimated to be 20 minutes. Therefore, the available time (i.e., 96 minutes) for the diagnosis component for this operator action is assigned as *Nominal Time* (i.e., ×1). Since sufficient time was available for the diagnosis component, the available time for the action component for this operator action is evaluated as *Nominal* (i.e., ×1). See Reference 5 for guidance on apportioning time between the diagnosis and action components of an HFE. |

| PSF | Diagnosis/ Action Multiplier | Notes |
|---|---|---|
| Stress | 2 / 2 | The PSF for diagnosis and action stress is assigned a value of *High Stress* (i.e., ×2) due to the plant being in a tripped condition and the postulated failures of other systems. This is a conservative assumption. |
| Complexity | 1 / 1 | The PSF for diagnosis complexity is assigned a value of *Nominal* (i.e., ×1) because of the multiple indications available that would indicate a failure of core cooling. The PSF for action complexity is also assigned a value of *Nominal* (i.e., ×1) because the actions required can be accomplished in the control room. |
| Procedures Experience/Training Ergonomics/HMI Fitness-for-Duty Work Processes | 1 / 1 | No event information is available to warrant a change in these PSFs (for diagnosis and action) from *Nominal* for these HFEs. |

The following formula is used to calculate the HEP for an event evaluated through SPAR-H:

*Calculated HEP = (Product of Diagnosis PSFs × 0.01) + (Product of Action PSFs × 0.001)*

Therefore, the probability of new basic event AFW-XHE-XM-RESET was set to $2\times10^{-2}$.

## ANALYSIS RESULTS

**ΔCDP/Rejection Basis.** The point estimate increase in core damage probability (ΔCDP) for this event is $2.1\times10^{-7}$. The calculated risk is below the ASP precursor threshold of $1\times10^{-6}$; therefore, this event is not considered a precursor under the ASP Program.

**Dominant Sequence.** The dominant accident sequence is loss of service water system (LOSWS) Sequence 26 (ΔCDP = $1.74\times10^{-7}$) that contributes approximately 83% of the total internal events ΔCDP. Figure 1 in Appendix B illustrates this sequence. The cut sets/sequences that contribute to the top 95% and/or at least 1% of the total internal events ΔCDP are provided in Appendix A.

The events and important component/system failures in LOSWS Sequence 26 are:

- A loss of service water occurs (initiating event),
- Reactor trip is successful, and
- The TDAFW pump is unavailable.[3]

[3] The motor-driven AFW pumps were unavailable in this sequence because of the lack of service water cooling.

## REFERENCES

1. Southern Nuclear Operating Company, Inc., "Joseph M. Farley Nuclear Plant – Units 1 and 2, Licensee Event Report 2015-005-01, Condition Prohibited by Technical Specifications Due to Turbine Driven Auxiliary Feedwater Design Issue," dated July 1, 2016 (ML16183A339).
2. U.S. Nuclear Regulatory Commission, "Joseph M. Farley Nuclear Plant – NRC Integrated Inspection Report 05000348/2016002; and 05000364/2016002 and Exercise of Enforcement Discretion," dated August 12, 2016 (ML16225A407).
3. Kelly, D. & Smith, C., "Bayesian Inference for Probabilistic Risk Assessment: A Practitioner's Guidebook," Springer, 2011.
4. Idaho National Laboratory, NUREG/CR-6883, "The SPAR-H Human Reliability Analysis Method," August 2005 (ML051950061).
5. Idaho National Laboratory, "INL/EXT-10-18533, SPAR-H Step-by-Step Guidance," May 2011 (ML112060305).

# Appendix A: SAPHIRE 8 Worksheet

## Condition Assessment Summary

| | |
|---|---|
| Duration | 317 days |
| CCDP | 2.10E-5 |
| CDP | 2.08E-5 |
| **ΔCDP** | **2.10E-7** |

## Summary of Conditional Event Changes

| Event | Description | Cond Value | Nominal Value |
|---|---|---|---|
| AFW-TDP-FS-XSS | TDAFW Pump fails to start due to excess steam at startup | 4.20E-2 | 0.00E+0 |
| AFW-XHE-XM-RESET | Operator fails to reset overspeed trip | 2.00E-2 | 0.00E+0 |

## Event Tree Dominant Results

*Only items contributing at least 1.0% to the total CCDP are displayed.*

| Event Tree | CCDP | CDP | ΔCDP | Description |
|---|---|---|---|---|
| LOSWS | 1.38E-5 | 1.36E-5 | 1.74E-7 | FARLEY TOTAL LOSS OF SERVICE WATER |
| LOSWSA | 8.09E-7 | 7.95E-7 | 1.30E-8 | FARLEY LOSS OF SERVICE WATER TRAIN A (A ON SERVICE) |
| LOSWSB | 8.14E-7 | 8.01E-7 | 1.30E-8 | FARLEY LOSS OF SERVICE WATER TRAIN B (A ON SERVICE) |
| TRANS | 1.00E-6 | 9.97E-7 | 5.22E-9 | FARLEY GENERAL TRANSIENT |
| **Total** | **2.10E-5** | **2.08E-5** | **2.10E-7** | |

## Dominant Sequence Results

*Only items contributing at least 1.0% to the total CCDP are displayed.*

| Event Tree | Sequence | CCDP | CDP | ΔCDP | Description |
|---|---|---|---|---|---|
| LOSWS | 26 | 1.33E-5 | 1.31E-5 | 1.74E-7 | IEFT-LOSWS, /RPS, AFW-S, MFW, REC-SWS |
| LOSWSA | 26 | 7.96E-7 | 7.83E-7 | 1.30E-8 | IEFT-LOSWSA, /RPS, AFW-SA, MFW, REC-SWS |
| LOSWSB | 26 | 8.03E-7 | 7.90E-7 | 1.30E-8 | IEFT-LOSWSB, /RPS, AFW-SB, MFW, REC-SWS |
| TRANS | 21-15 | 2.22E-7 | 2.20E-7 | 2.61E-9 | RPS, /RCSPRESS, MFW, AFW-A |
| TRANS | 20 | 1.67E-7 | 1.64E-7 | 2.43E-9 | /RPS, AFW, MFW, FAB |
| **Total** | | **2.10E-5** | **2.08E-5** | **2.10E-7** | |

## Referenced Fault Trees

| Fault Tree | Description |
|---|---|
| AFW | AUXILIARY FEEDWATER |
| AFW-A | AUXILIARY FEEDWATER SYSTEM |
| AFW-S | AUXILIARY FEEDWATER |
| AFW-SA | AUXILIARY FEEDWATER |
| AFW-SB | AUXILIARY FEEDWATER |
| FAB | FEED AND BLEED |
| IEFT-LOSWS | TOTAL LOSS OF SERVICE WATER IE FAULT TREE |
| IEFT-LOSWSA | LOSS OF SERVICE WATER TRAIN A IE FAULT TREE |
| IEFT-LOSWSB | LOSS OF SERVICE WATER TRAIN B IE FAULT TREE |
| MFW | MAIN FEEDWATER |
| REC-SWS | SWS RECOVERED |
| RPS | REACTOR TRIP |

## Cut Set Report - LOSWS 26

*Only items contributing at least 1% to the total are displayed.*

| # | CCDF | Total% | Cut Set |
|---|---|---|---|
| | 1.53E-5 | 100 | Displaying 134 Cut Sets. (134 Original) |
| 1 | 9.72E-6 | 63.48 | IE-LOSWS,AFW-TDP-FR-P02 |
| 2 | 1.74E-6 | 11.38 | IE-LOSWS,IAS-XHE-XM-2CTOU1-DEP,IAS-XHE-XM-EAS |
| 3 | 1.60E-6 | 10.43 | IE-LOSWS,AFW-TDP-FS-P02 |
| 4 | 1.33E-6 | 8.67 | IE-LOSWS,AFW-TDP-TM-P02 |
| 5 | 2.34E-7 | 1.53 | IE-LOSWS,AFW-AOV-CC-HV3226 |

| | | | |
|---|---|---|---|
| 6 | 2.07E-7 | 1.35 | IE-LOSWS,AFW-TDP-FS-XSS,AFW-XHE-XM-RESET |
| 7 | 1.87E-7 | 1.22 | IE-LOSWS,IAS-SYS-FC-2CTOU2,IAS-XHE-XM-EAS |
| 8 | 1.68E-7 | 1.10 | IE-LOSWS,IAS-MDC-FS-C002C,IAS-XHE-XM-EAS |

### Cut Set Report - LOSWSA 26

*Only items contributing at least 1% to the total are displayed.*

| # | CCDF | Total% | Cut Set |
|---|---|---|---|
| | 9.17E-7 | 100 | Displaying 164 Cut Sets. (164 Original) |
| 1 | 3.14E-7 | 34.26 | IE-LOSWSA,AFW-MDP-TM-P1B,AFW-TDP-FR-P02 |
| 2 | 2.05E-7 | 22.31 | IE-LOSWSA,AFW-ACX-FR-MDPB,AFW-TDP-FR-P02 |
| 3 | 7.49E-8 | 8.16 | IE-LOSWSA,AFW-MDP-FS-P1B,AFW-TDP-FR-P02 |
| 4 | 6.32E-8 | 6.89 | IE-LOSWSA,AFW-ACX-FS-MDPB,AFW-TDP-FR-P02 |
| 5 | 5.16E-8 | 5.63 | IE-LOSWSA,AFW-MDP-TM-P1B,AFW-TDP-FS-P02 |
| 6 | 3.36E-8 | 3.67 | IE-LOSWSA,AFW-ACX-FR-MDPB,AFW-TDP-FS-P02 |
| 7 | 2.86E-8 | 3.12 | IE-LOSWSA,AFW-MDP-FR-P1B,AFW-TDP-FR-P02 |
| 8 | 2.79E-8 | 3.05 | IE-LOSWSA,AFW-ACX-FR-MDPB,AFW-TDP-TM-P02 |
| 9 | 1.23E-8 | 1.34 | IE-LOSWSA,AFW-MDP-FS-P1B,AFW-TDP-FS-P02 |
| 10 | 1.04E-8 | 1.13 | IE-LOSWSA,AFW-ACX-FS-MDPB,AFW-TDP-FS-P02 |
| 11 | 1.02E-8 | 1.11 | IE-LOSWSA,AFW-MDP-FS-P1B,AFW-TDP-TM-P02 |

### Cut Set Report - LOSWSB 26

*Only items contributing at least 1% to the total are displayed.*

| # | CCDF | Total% | Cut Set |
|---|---|---|---|
| | 9.25E-7 | 100 | Displaying 157 Cut Sets. (157 Original) |
| 1 | 3.14E-7 | 33.96 | IE-LOSWSB,AFW-MDP-TM-P1A,AFW-TDP-FR-P02 |
| 2 | 2.05E-7 | 22.12 | IE-LOSWSB,AFW-ACX-FR-MDPA,AFW-TDP-FR-P02 |
| 3 | 7.49E-8 | 8.09 | IE-LOSWSB,AFW-MDP-FS-P1A,AFW-TDP-FR-P02 |
| 4 | 6.32E-8 | 6.83 | IE-LOSWSB,AFW-ACX-FS-MDPA,AFW-TDP-FR-P02 |
| 5 | 5.16E-8 | 5.58 | IE-LOSWSB,AFW-MDP-TM-P1A,AFW-TDP-FS-P02 |
| 6 | 3.36E-8 | 3.63 | IE-LOSWSB,AFW-ACX-FR-MDPA,AFW-TDP-FS-P02 |
| 7 | 2.86E-8 | 3.10 | IE-LOSWSB,AFW-MDP-FR-P1A,AFW-TDP-FR-P02 |
| 8 | 2.79E-8 | 3.02 | IE-LOSWSB,AFW-ACX-FR-MDPA,AFW-TDP-TM-P02 |
| 9 | 1.23E-8 | 1.33 | IE-LOSWSB,AFW-MDP-FS-P1A,AFW-TDP-FS-P02 |
| 10 | 1.04E-8 | 1.12 | IE-LOSWSB,AFW-ACX-FS-MDPA,AFW-TDP-FS-P02 |
| 11 | 1.02E-8 | 1.11 | IE-LOSWSB,AFW-MDP-FS-P1A,AFW-TDP-TM-P02 |

### Cut Set Report - TRANS 21-15

*Only items contributing at least 1% to the total are displayed.*

| # | CCDF | Total% | Cut Set |
|---|---|---|---|
| | 2.56E-7 | 100 | Displaying 174 Cut Sets. (174 Original) |
| 1 | 4.39E-8 | 17.14 | IE-TRANS,AFW-TDP-FR-P02,RPS-BME-CF-RTBAB |
| 2 | 3.66E-8 | 14.30 | IE-TRANS,AFW-TDP-FR-P02,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL |
| 3 | 3.30E-8 | 12.88 | IE-TRANS,AFW-TDP-FR-P02,RPS-ROD-CF-RCCAS |
| 4 | 2.48E-8 | 9.69 | IE-TRANS,AFW-TDP-FR-P02,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL |
| 5 | 7.21E-9 | 2.82 | IE-TRANS,AFW-TDP-FS-P02,RPS-BME-CF-RTBAB |
| 6 | 6.02E-9 | 2.35 | IE-TRANS,AFW-TDP-FS-P02,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL |
| 7 | 5.99E-9 | 2.34 | IE-TRANS,AFW-TDP-TM-P02,RPS-BME-CF-RTBAB |
| 8 | 5.42E-9 | 2.12 | IE-TRANS,AFW-TDP-FS-P02,RPS-ROD-CF-RCCAS |
| 9 | 5.00E-9 | 1.95 | IE-TRANS,AFW-TDP-TM-P02,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL |
| 10 | 4.50E-9 | 1.76 | IE-TRANS,AFW-TDP-TM-P02,RPS-ROD-CF-RCCAS |
| 11 | 4.42E-9 | 1.73 | IE-TRANS,AFW-MDP-TM-P1B,RPS-BME-CF-RTBAB |
| 12 | 4.42E-9 | 1.73 | IE-TRANS,AFW-MDP-TM-P1A,RPS-BME-CF-RTBAB |
| 13 | 4.08E-9 | 1.59 | IE-TRANS,AFW-TDP-FS-P02,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL |

| | | | |
|---|---|---|---|
| 14 | 3.69E-9 | 1.44 | IE-TRANS,AFW-MDP-TM-P1B,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL |
| 15 | 3.69E-9 | 1.44 | IE-TRANS,AFW-MDP-TM-P1A,/RPS-CCP-TM-CHA,RPS-TXX-CF-6OF8,RPS-XHE-XE-NSGNL |
| 16 | 3.39E-9 | 1.32 | IE-TRANS,AFW-TDP-TM-P02,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL |
| 17 | 3.32E-9 | 1.30 | IE-TRANS,AFW-MDP-TM-P1B,RPS-ROD-CF-RCCAS |
| 18 | 3.32E-9 | 1.30 | IE-TRANS,AFW-MDP-TM-P1A,RPS-ROD-CF-RCCAS |
| 19 | 2.88E-9 | 1.12 | IE-TRANS,AFW-ACX-FR-MDPB,RPS-BME-CF-RTBAB |
| 20 | 2.88E-9 | 1.12 | IE-TRANS,AFW-ACX-FR-MDPA,RPS-BME-CF-RTBAB |
| 21 | 2.83E-9 | 1.11 | IE-TRANS,AFW-TDP-FR-P02,RPS-UVL-CF-UVDAB,RPS-XHE-XE-SIGNL |

## Cut Set Report - TRANS 20

*Only items contributing at least 1% to the total are displayed.*

| # | CCDF | Total% | Cut Set |
|---|---|---|---|
| | 1.92E-7 | 100 | Displaying 298 Cut Sets. (298 Original) |
| 1 | 5.18E-8 | 26.97 | IE-TRANS,AFW-ACX-CF-MDPABR,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 2 | 2.59E-8 | 13.50 | IE-TRANS,AFW-MDP-CF-START,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 3 | 1.09E-8 | 5.68 | IE-TRANS,AFW-ACX-CF-MDPABS,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 4 | 8.51E-9 | 4.43 | IE-TRANS,AFW-ACX-CF-MDPABR,AFW-TDP-FS-P02,HPI-XHE-XM-FB |
| 5 | 7.07E-9 | 3.68 | IE-TRANS,AFW-ACX-CF-MDPABR,AFW-TDP-TM-P02,HPI-XHE-XM-FB |
| 6 | 6.03E-9 | 3.14 | IE-TRANS,AFW-TNK-FC-CST,HPI-XHE-XM-FB |
| 7 | 5.61E-9 | 2.92 | IE-TRANS,AFW-ACX-FR-MDPA,AFW-MDP-TM-P1B,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 8 | 5.61E-9 | 2.92 | IE-TRANS,AFW-ACX-FR-MDPB,AFW-MDP-TM-P1A,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 9 | 4.48E-9 | 2.33 | IE-TRANS,AFW-TDP-FR-P02,SWS-MDP-CF-RUN |
| 10 | 4.26E-9 | 2.22 | IE-TRANS,AFW-MDP-CF-START,AFW-TDP-FS-P02,HPI-XHE-XM-FB |
| 11 | 4.07E-9 | 2.12 | IE-TRANS,AFW-PMP-CF-RUN,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 12 | 3.65E-9 | 1.90 | IE-TRANS,AFW-ACX-FR-MDPA,AFW-ACX-FR-MDPB,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 13 | 3.54E-9 | 1.84 | IE-TRANS,AFW-MDP-CF-START,AFW-TDP-TM-P02,HPI-XHE-XM-FB |
| 14 | 2.05E-9 | 1.07 | IE-TRANS,AFW-MDP-FS-P1A,AFW-MDP-TM-P1B,AFW-TDP-FR-P02,HPI-XHE-XM-FB |
| 15 | 2.05E-9 | 1.07 | IE-TRANS,AFW-MDP-FS-P1B,AFW-MDP-TM-P1A,AFW-TDP-FR-P02,HPI-XHE-XM-FB |

## Referenced Events

| Event | Description | Probability |
|---|---|---|
| AFW-ACX-CF-MDPABR | MDAFW PUMP A & B ROOM COOLER FTR DUE TO COMMON CAUSE | 9.50E-5 |
| AFW-ACX-CF-MDPABS | MDAFW PUMP A & B ROOM COOLER FTS DUE TO COMMON CAUSE | 2.00E-5 |
| AFW-ACX-FR-MDPA | MDAFW PUMP A ROOM COOLER FTR DUE TO RANDOM FAULTS | 2.59E-3 |
| AFW-ACX-FR-MDPB | MDAFW PUMP B ROOM COOLER FTR DUE TO RANDOM FAULTS | 2.59E-3 |
| AFW-ACX-FS-MDPA | MDAFW PUMP A ROOM COOLER FTS DUE TO RANDOM FAULTS | 8.00E-4 |
| AFW-ACX-FS-MDPB | MDAFW PUMP B ROOM COOLER FTS DUE TO RANDOM FAULTS | 8.00E-4 |
| AFW-AOV-CC-HV3226 | STEAM SUPPLY VALVE HV3226 FAILS TO OPEN | 9.51E-4 |
| AFW-MDP-CF-START | CCF OF AFW MDPS TO START | 4.76E-5 |
| AFW-MDP-FR-P1A | AFW MOTOR-DRIVEN PUMP P1A FAILS TO RUN | 3.62E-4 |
| AFW-MDP-FR-P1B | AFW MOTOR-DRIVEN PUMP P1B FAILS TO RUN | 3.62E-4 |
| AFW-MDP-FS-P1A | AFW MOTOR-DRIVEN PUMP P1A FAILS TO START | 9.47E-4 |
| AFW-MDP-FS-P1B | AFW MOTOR-DRIVEN PUMP P1B FAILS TO START | 9.47E-4 |
| AFW-MDP-TM-P1A | AFW MDP UNAVAILABLE DUE TO TEST AND MAINTENANCE | 3.98E-3 |
| AFW-MDP-TM-P1B | AFW MDP UNAVAILABLE DUE TO TEST AND MAINTENANCE | 3.98E-3 |
| AFW-PMP-CF-RUN | CCF OF AFW PUMPS TO RUN (EXCLUDING DRIVER) | 7.47E-6 |
| AFW-TDP-FR-P02 | TURBINE DRIVEN FEED PUMP P02 FAILS TO RUN | 3.95E-2 |
| AFW-TDP-FS-P02 | TURBINE DRIVEN FEED PUMP P02 FAILS TO START | 6.49E-3 |
| AFW-TDP-FS-XSS | TDAFW Pump fails to start due to excess steam at startup | 4.20E-2 |

| | | |
|---|---|---|
| AFW-TDP-TM-P02 | FEED PUMP P02 IS IN TEST OR MAINTENANCE | 5.39E-3 |
| AFW-TNK-FC-CST | CST OR PUMP SUCTION PATH IS UNAVAILABLE | 4.37E-7 |
| AFW-XHE-XM-RESET | Operator fails to reset overspeed trip | 2.00E-2 |
| HPI-XHE-XM-FB | OPERATOR FAILS TO INITIATE FEED AND BLEED COOLING | 2.00E-2 |
| IAS-MDC-FS-C002C | Instrument Air Compressor C002C Fails to Start | 1.71E-2 |
| IAS-SYS-FC-2CTOU2 | 2C AIR COMP NEEDED FOR UNIT 2 DUE TO LOSS OF COMPRESSORS 2A AND 2B | 1.90E-2 |
| IAS-XHE-XM-2CTOU1-DEP | OPERATOR FAILS TO ALIGN & START COMPRESSOR 2C ON UNIT 1 (DEPENDENT) | 1.77E-1 |
| IAS-XHE-XM-EAS | OPERATOR FAILS TO ALIGN EMERGENCY AIR SYSTEM | 4.00E-2 |
| IE-LOSWS | TOTAL LOSS OF SERVICE WATER | 2.46E-4 |
| IE-LOSWSA | LOSS OF SERVICE WATER TRAIN A (A ON SERVICE) | 2.00E-3 |
| IE-LOSWSB | LOSS OF SERVICE WATER TRAIN B (A ON SERVICE) | 2.00E-3 |
| IE-TRANS | TRANSIENT | 6.90E-1 |
| RPS-BME-CF-RTBAB | CCF OF RTB-A AND RTB-B (MECHANICAL) | 1.61E-6 |
| RPS-CCX-CF-6OF8 | CCF 6 ANALOG PROCESS LOGIC MODULES IN 3 OF 4 CHANNELS | 1.83E-6 |
| RPS-ROD-CF-RCCAS | CCF 10 OR MORE RCCAS FAIL TO DROP | 1.21E-6 |
| RPS-TXX-CF-6OF8 | CCF 6 BISTABLES IN 3 OF 4 CHANNELS | 2.70E-6 |
| RPS-UVL-CF-UVDAB | CCF UV DRIVERS TRAINS A AND B (2 0F 2) | 1.04E-5 |
| RPS-XHE-XE-NSGNL | OPERATOR FAILS TO RESPOND WITH NO RPS SIGNAL PRESENT | 5.00E-1 |
| RPS-XHE-XE-SIGNL | OPERATOR FAILS TO RESPOND WITH RPS SIGNAL PRESENT | 1.00E-2 |
| SWS-MDP-CF-RUN | SWS PUMPS FAIL FROM COMMON CAUSE TO RUN | 1.64E-7 |

# Appendix B: Key Event Tree

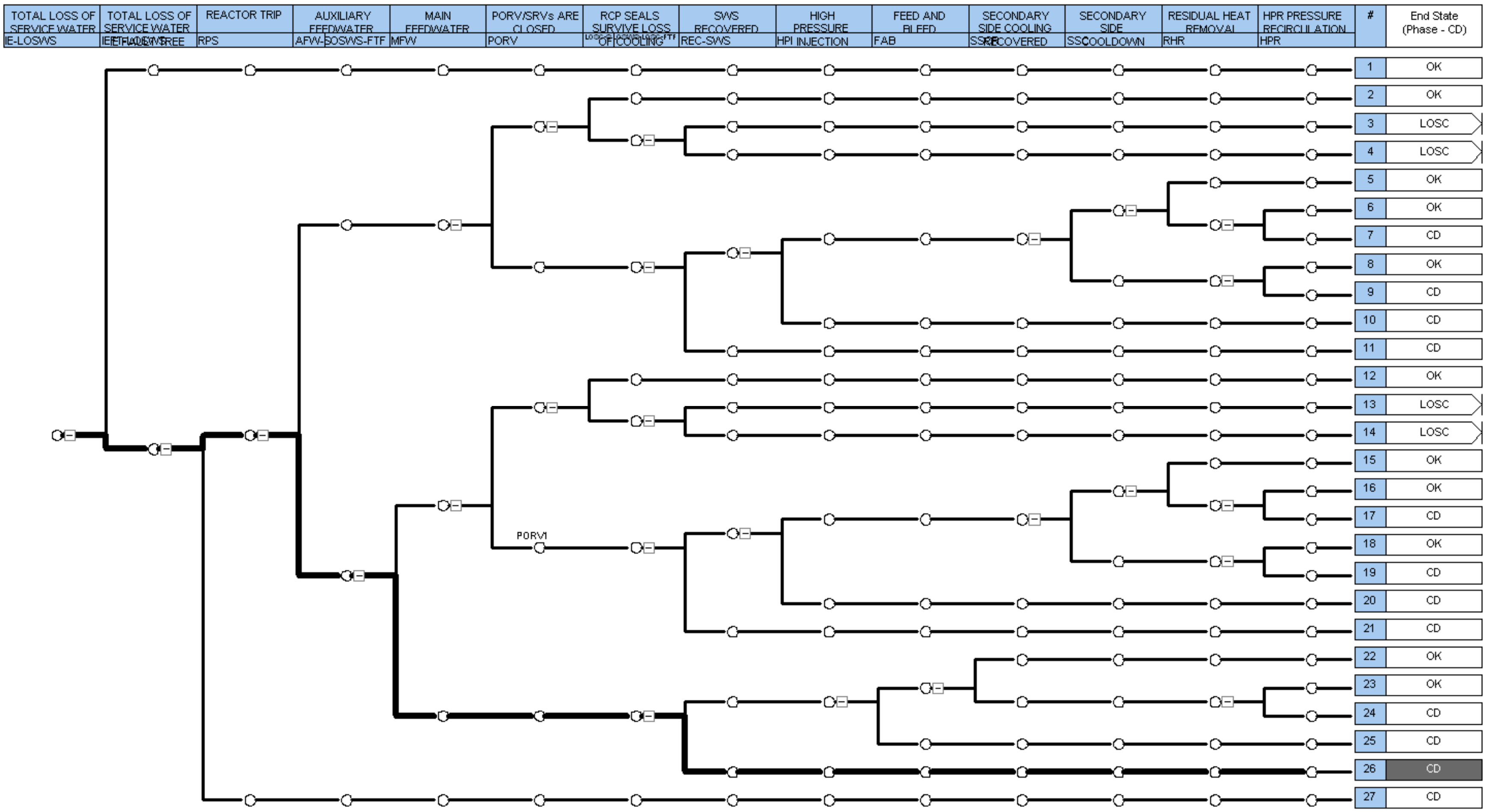


**Figure 1: LOSWS Event Tree (Sequence 26 in Bold)**

# Appendix C: SPAR Model Modifications

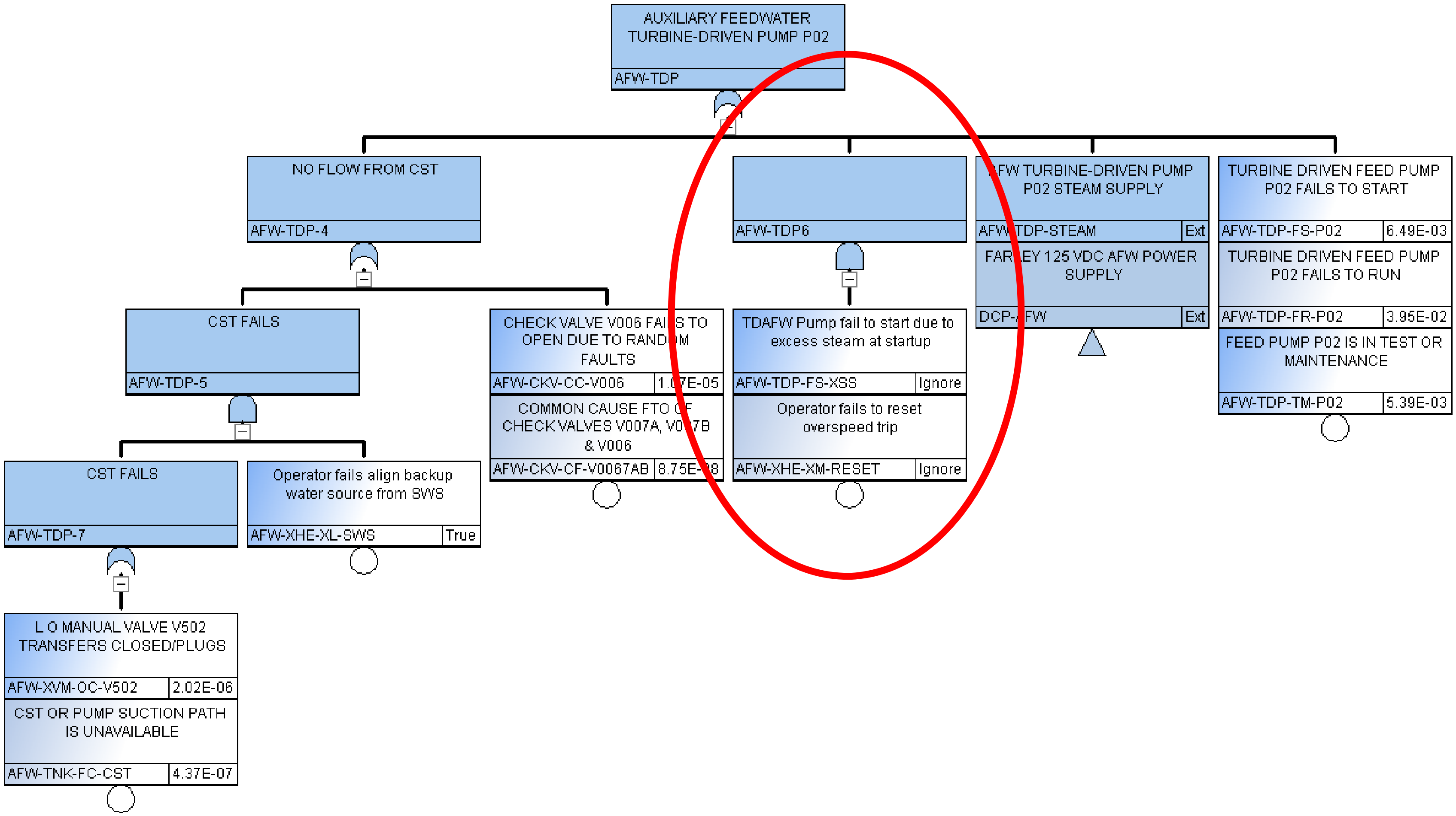


**Figure 2: AFW-TDP Fault Tree Modification**