Final ASP Program Analysis - Reject

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research			
Callaway Plant, Unit 1	Auxiliary Feedwater Control Valves in Motor Driven Pump Train Inoperable due to Faulty Electronic Positioner Cards		
Event Date: 8/11/2015	**LERs:** 483-2015-003 and 483-2015-004 **IR:** 50-483/2015-009	**CCDP=** 1.1×10^{-6}	
Plant Type: Westinghouse 4-Loop PWR with Large Dry Containment			
Plant Operating Mode (Reactor Power Level): Mode 3 (0 Percent Reactor Power)			
Analyst: David Aird	**Reviewer:** Keith Tetter	**Contributors:** N/A	**BC Approved Date:** 6/7/2016

EVENT DETAILS

Event Description. On August 11, 2015, while operating in Mode 1, an unexpected turbine trip and reactor trip occurred at Callaway Unit 1 due to an offsite transmission line fault. The fault was later attributed to an unrecognized electrical jumper in the main transformer. See Licensee Event Report (LER) 483-2015-003 (Ref. 1) for more details regarding the transmission line fault. All control rods fully inserted and decay heat was removed through the steam dumps to the main condenser. The turbine-driven auxiliary feedwater (TDAFW) pump and both motor-driven auxiliary feedwater (MDAFW) pumps started, with the TDAFW pump primarily satisfying the water level requirements of the steam generators.

As part of the trip response, all four flow control valves (FCVs) in the two MDAFW pump trains closed as a result of the adequate flow supplied by the TDAFW pump. Approximately 300 gpm is required for each steam generator (SG) in this operating mode. The TDAFW pump can provide adequate flow for all of the SGs. See Figure 2 in Appendix C for a diagram of the MDAFW pump trains.

In accordance with normal operating procedures, operator action was later initiated to transfer flow to the MDAFW pumps in order to secure the TDAFW pump. In preparation for securing the TDAFW pump, the operator was unable to reopen MDAFW FCV ALHV0007 from the main control room. A technician was dispatched and partially opened the valve using the handwheel; however, the control room operator was still unable to regain remote electrical control of the valve. The valve was manually closed and declared inoperable. Additional information is provided in LER 483-2015-004 (Ref. 2). Flow to the SGs was maintained by the TDAFW pump. The plant was stabilized in Mode 3 (Hot Standby).

Cause. In 2014, the electronic positioner cards for the four MDAFW FCVs were reverse-engineered for Callaway by a vendor due to obsolescence issues. The electronic positioner cards in the 'B' train MDAFW FCVs (ALHV0005 and ALHV0007) were replaced in late October and early November 2014 with the new reverse-engineered circuit cards. The 'A' train MDAFW FCVs were not modified. It was later identified that the new reverse-engineered circuit cards used bridge rectifiers with a lower than required current rating for the operating conditions. Overloading of the bridge rectifier was experienced. Without the bridge rectifier in the circuit card, remote control of the valve is not possible.

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]

Soon after this event occurred, Management Directive 8.3, "NRC Incident Investigation Program," was used to evaluate the potential need for an increased level of NRC response. The preliminary estimated conditional core damage probability (CCDP) was determined to be 2.4×10^{-5}, which necessitated a Special Inspection.

In Special Inspection Report 05000483/2015009 (Ref. 3), inspectors identified several Green findings related to FCV malfunction. The most relevant was a non-cited violation of 10 CFR Part 50, Appendix B, Criterion III, "Design Control," for the licensee's failure to assure that the design of the replacement reverse-engineered circuit cards for the MDAFW FCVs were suitable for their application. The vendor modified the circuit cards with higher rated bridge rectifiers and showed, through various tests, that the "hybrid" cards were able to perform their design function across all anticipated operating conditions. The licensee replaced the faulty circuit cards with the new "hybrid" cards. It was later determined that these new cards were still degraded, but operable because additional controller card components might also be undersized.

The Region IV senior reactor analyst performed a detailed risk evaluation (condition assessment) of the violation described above. The internal events incremental conditional core damage probability was 8.17×10^{-7} (Green). This LER is not yet closed.

An independent ASP analysis is required because this was an initiating event (reactor trip due to transmission line fault) with multiple equipment failures.

Analysis Type. An initiating event analysis was performed using the Callaway Standardized Plant Analysis Risk (SPAR) model Revision 8.25, created in May 2014.

SPAR Model Modifications. A new basic event was added to the model and inserted into two fault trees. New basic event AFW-XHE-XM-AOV (*Operator Fails to Manually Open FCV*) was created and set to IGNORE. In the AFW-TRANS-SG1A fault tree, the new basic event AFW-XHE-XM-AOV was inserted under a new AND gate with existing basic event AFW-FCV-FC-HV07 (*SG A Control AOV HV07 From MDP Fails*). Similarly, in the AFW-TRANS-SG1D fault tree, the new basic event AFW-XHE-XM-AOV was inserted under a new AND gate with existing basic event AFW-FCV-FC-HV05 (*SG D Control AOV HV05 From MDP Fails*). Figures 3 and 4 in Appendix D illustrate these changes.

This SPAR model change was required to provide operator recovery credit to manually open and throttle the MDAFW 'B' train FCVs in order to provide flow to SGs 'A' and 'D' if flow from the TDAFW pump is or becomes unavailable. Under the most limiting scenario (design basis accident occurring immediately after plant shutdown when core decay heat is at its peak), operators would have over 45 minutes to open the MDAFW FCV before reaching a critical level in the SG. Procedure OTN-AL-00001, for manually starting the AFW pumps, directs the

[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.

operators to "OPEN discharge control valves as needed." Other commonly used post-trip procedures (e.g., E-0, ES-0.1, FR-H.1, etc.) direct the operators to "align AFW valves as necessary." During an event that occurred at Callaway on July 23, 2015, local manual operator action was successfully used to actuate MDAFW FCV ALHV0011 following procedural guidance when it failed to remotely open from the control room. In this instance, the action was completed successfully within 8.5 minutes – well under the maximum allowed completion time of 45 minutes.

Given that procedural guidance exists for manual operation of the MDAFW FCVs and that the licensee recently demonstrated successful completion of this operator action, the analyst determined that operator recovery credit should be allowed.

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

- The probability of IE-TRANS (*General Transient Initiating Event*) was set to 1.0; all other initiating event probabilities were set to zero.

- The probability of basic events AFW-FCV-FC-HV05 (*SG D Control AOV HV05 from MDP Fails*) and AFW-FCV-FC-HV07 (*SG A Control AOV HV07 from MDP Fails*) were set to 1.0 from their nominal values. Since the faulty circuit cards were only installed on these two valves, common cause failure affecting the two FCVs in the other MDAFW train (i.e., ALHV0009 and ALHV0011) was discredited. Although ALHV0005 did not fail during the August 11th event, there was a high likelihood that it could have failed given that the same circuit card with the underrated bridge rectifier was installed with similar operating conditions.

- The probability of new basic event AFW-XHE-XM-AOV (*Operator Fails to Manually Open FCV*) was set to a screening value of 5×10^{-1} (50% chance of operator failure). Recovery credit must be given to the operators for local/manual control of the FCVs if the TDAFW system is unavailable. The failure mode of the TDAFW pump dictates the initial position of the MDAFW FCVs. Specifically, if the TDAFW pump fails-to-start, the MDAFW FCVs would be in a throttled/open position requiring action from operators to throttle to obtain necessary flow. If the TDAFW pump fails-to-run, the MDAFW FCVs would be in a closed position requiring action from operators to open and throttle to obtain necessary flow. As documented in the Special Inspection Report, using the SPAR-H method, the calculated human error probabilities for these two scenarios were 1.21×10^{-3} and 9.37×10^{-2}, respectively. A screening value of 5×10^{-1} was used for this bounding analysis.

- All other safety systems responded as designed.

ANALYSIS RESULTS

CCDP/Rejection Basis. The CCDP for this analysis is 1.1×10^{-6}. The ASP Program threshold is a CCDP of 1×10^{-6} or the CCDP equivalent of a reactor trip and non-recoverable loss of main feedwater or condenser heat sink, whichever is greater. The CCDP for a loss of condenser heat sink at Callaway is 1.1×10^{-6}. Therefore, this event is not a precursor and is screened out of the ASP Program.

Dominant Sequence. The dominant accident sequence is Transient (TRANS) Sequence 20 (CCDP = 6.8×10^{-7}) that contributes approximately 65% of the total internal events CCDP. 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 CCDP are provided in Appendix A.

The events and important component/system failures in TRANS Sequence 20 are:

- A plant transient occurs,
- Reactor protection system succeeds,
- Auxiliary feedwater system fails,
- Main feedwater system fails,
- Feed and bleed fails.

REFERENCES

1. Callaway Nuclear Power Plant, "LER 483-2015-003-01 – Reactor Trip Caused by Transmission Line Fault," dated January 21, 2016 (ML16021A443).

2. Callaway Nuclear Power Plant, "LER 483-2015-004 – Auxiliary Feedwater Control Valve Inoperable Due to Faulty Electronic Positioner Card," dated October 12, 2015 (ML15285A019).

3. U.S. Nuclear Regulatory Commission, "Callaway Plant – NRC Special Inspection Report 05000483/2015009," dated January 13, 2016 (ML16013A021).

Appendix A: SAPHIRE 8 Worksheet

Summary of Conditional Event Changes

Event	Description	Cond Value	Nominal Value
AFW-FCV-FC-HV05	SG D CONTROL AOV HV05 FROM MDP FAILS	1.00E+0	5.97E-6
AFW-FCV-FC-HV07	SG A CONTROL AOV HV07 FROM MDP FAILS	1.00E+0	5.97E-6
AFW-XHE-XM-AOV	OPERATOR FAILS TO MANUALLY OPEN FCV	5.00E-1	0.00E+0
IE-TRANS	TRANSIENT INITIATING EVENT	1.00E+0[a]	6.90E-1

a. All other initiating event probabilities were set to zero.

Dominant Sequence Results

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

EVENT TREE	SEQUENCE	CCDP	% CONTRIBUTION	DESCRIPTION
TRANS	20	6.84E-7	65.2%	/RPS, AFW, MFW, FAB
TRANS	21-9	1.45E-7	13.8%	RPS, RCSPRESS
TRANS	19	1.05E-7	10.0%	/RPS, AFW, MFW, /FAB, SSCR, HPR
TRANS	21-7	1.04E-7	9.9%	RPS, /RCSPRESS, /FW, BORATION
Total		**1.05E-6**	**100.0%**	

Referenced Fault Trees

Fault Tree	Description
AFW	AUXILIARY FEEDWATER
BORATION	EMERGENCY BORATION
FAB	FEED AND BLEED
HPR	HIGH PRESSURE RECIRC
MFW	MAIN FEEDWATER
RCSPRESS	RCS PRESSURE LIMITED
RPS	REACTOR TRIP
SSCR	SECONDARY SIDE COOLING RECOVERED

Cut Set Report - TRANS 20

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

#	CCDP	TOTAL%	CUT SET
	6.84E-7	100	Displaying 1327 Cut Sets. (1327 Original)
1	1.11E-7	16.29	IE-TRANS,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,DCP-BDC-LP-NK01
2	5.73E-8	8.38	IE-TRANS,AFW-MDP-TM-PAL01A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
3	4.09E-8	5.98	IE-TRANS,AFW-ACX-FR-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
4	3.95E-8	5.78	IE-TRANS,AFW-ACX-TM-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
5	1.83E-8	2.68	IE-TRANS,AFW-TDP-FS-PAL02,AFW-XHE-XM-AOV,DCP-BDC-LP-NK01
6	1.58E-8	2.31	IE-TRANS,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,AFW-XHE-XR-SGF02A,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
7	1.50E-8	2.20	IE-TRANS,AFW-AOV-OO-BMHV2,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
8	1.50E-8	2.20	IE-TRANS,AFW-AOV-OO-BMHV3,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
9	1.50E-8	2.20	IE-TRANS,AFW-TDP-TM-PAL02,AFW-XHE-XM-AOV,DCP-BDC-LP-NK01
10	1.50E-8	2.19	IE-TRANS,AFW-MDP-FS-PAL01A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
11	1.26E-8	1.85	IE-TRANS,AFW-ACX-FS-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
12	1.13E-8	1.65	IE-TRANS,AFW-XHE-XM-AOV,AFW-XHE-XM-SGLEVEL,DCP-BDC-LP-NK01

#	CCDP	TOTAL%	CUT SET
13	1.01E-8	1.48	IE-TRANS,AFW-MDP-TM-PAL01A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,MFW-XHE-XM-FLOW,PPR-SRV-CC-V456A
14	1.01E-8	1.48	IE-TRANS,AFW-MDP-TM-PAL01A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,MFW-XHE-XM-FLOW,PPR-SRV-CC-V455A
15	9.42E-9	1.38	IE-TRANS,AFW-MDP-TM-PAL01A,AFW-TDP-FS-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-FB,MFW-XHE-XM-FLOW
16	7.24E-9	1.06	IE-TRANS,AFW-ACX-FR-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,MFW-XHE-XM-FLOW,PPR-SRV-CC-V456A
17	7.24E-9	1.06	IE-TRANS,AFW-ACX-FR-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,MFW-XHE-XM-FLOW,PPR-SRV-CC-V455A
18	6.99E-9	1.02	IE-TRANS,AFW-ACX-TM-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,MFW-XHE-XM-FLOW,PPR-SRV-CC-V456A
19	6.99E-9	1.02	IE-TRANS,AFW-ACX-TM-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,MFW-XHE-XM-FLOW,PPR-SRV-CC-V455A

Cut Set Report - TRANS 21-9

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

#	CCDP	TOTAL%	CUT SET
	1.45E-7	100	Displaying 61 Cut Sets. (61 Original)
1	2.03E-8	14.02	IE-TRANS,RCS-PHN-MODPOOR,RCS-PHN-PL,RPS-BME-CF-RTBAB
2	1.69E-8	11.70	IE-TRANS,RCS-PHN-MODPOOR,RCS-PHN-PL,RPS-CBI-CF-6OF8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
3	1.52E-8	10.54	IE-TRANS,RCS-PHN-MODPOOR,RCS-PHN-PL,RPS-ROD-CF-RCCAS
4	1.15E-8	7.93	IE-TRANS,RCS-PHN-MODPOOR,RCS-PHN-PL,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
5	5.70E-9	3.94	IE-TRANS,PPR-SRV-CC-V456A,RPS-BME-CF-RTBAB
6	5.70E-9	3.94	IE-TRANS,PPR-SRV-CC-V455A,RPS-BME-CF-RTBAB
7	4.76E-9	3.29	IE-TRANS,PPR-SRV-CC-V455A,RPS-CBI-CF-6OF8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
8	4.76E-9	3.29	IE-TRANS,PPR-SRV-CC-V456A,RPS-CBI-CF-6OF8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
9	4.56E-9	3.15	IE-TRANS,PPR-MOV-FC-HV8000A,RPS-BME-CF-RTBAB
10	4.56E-9	3.15	IE-TRANS,PPR-MOV-FC-HV8000B,RPS-BME-CF-RTBAB
11	4.28E-9	2.96	IE-TRANS,PPR-SRV-CC-V456A,RPS-ROD-CF-RCCAS
12	4.28E-9	2.96	IE-TRANS,PPR-SRV-CC-V455A,RPS-ROD-CF-RCCAS
13	3.80E-9	2.63	IE-TRANS,PPR-MOV-FC-HV8000A,RPS-CBI-CF-6OF8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
14	3.80E-9	2.63	IE-TRANS,PPR-MOV-FC-HV8000B,RPS-CBI-CF-6OF8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
15	3.42E-9	2.37	IE-TRANS,PPR-MOV-FC-HV8000A,RPS-ROD-CF-RCCAS
16	3.42E-9	2.37	IE-TRANS,PPR-MOV-FC-HV8000B,RPS-ROD-CF-RCCAS
17	3.22E-9	2.23	IE-TRANS,PPR-SRV-CC-V455A,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
18	3.22E-9	2.23	IE-TRANS,PPR-SRV-CC-V456A,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
19	2.58E-9	1.78	IE-TRANS,PPR-MOV-FC-HV8000A,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
20	2.58E-9	1.78	IE-TRANS,PPR-MOV-FC-HV8000B,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL

Cut Set Report - TRANS 19

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

#	CCDP	TOTAL%	CUT SET
	1.05E-7	100	Displaying 1082 Cut Sets. (1082 Original)
1	5.73E-9	5.46	IE-TRANS,AFW-MDP-TM-PAL01A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW
2	4.09E-9	3.90	IE-TRANS,AFW-ACX-FR-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW
3	3.95E-9	3.76	IE-TRANS,AFW-ACX-TM-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW
4	2.90E-9	2.76	IE-TRANS,ACP-BAC-LP-SL31,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,ESW-MDP-TM-1A,SWS-CFG-AP-1CRUN
5	2.90E-9	2.76	IE-TRANS,ACP-BAC-LP-SL31,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,ESW-MDP-TM-1A,SWS-CFG-AP-1BRUN
6	2.90E-9	2.76	IE-TRANS,ACP-BAC-LP-SL31,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,ESW-MDP-TM-1A,SWS-CFG-AP-1ARUN
7	1.97E-9	1.88	IE-TRANS,ACP-TFM-FC-SL31,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,ESW-MDP-TM-1A,SWS-CFG-AP-1CRUN
8	1.97E-9	1.88	IE-TRANS,ACP-TFM-FC-SL31,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,ESW-MDP-TM-1A,SWS-CFG-AP-1BRUN
9	1.97E-9	1.88	IE-TRANS,ACP-TFM-FC-SL31,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,ESW-MDP-TM-1A,SWS-CFG-AP-1ARUN
10	1.58E-9	1.51	IE-TRANS,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,AFW-XHE-XR-SGF02A,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW
11	1.50E-9	1.43	IE-TRANS,AFW-AOV-OO-BMHV3,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW
12	1.50E-9	1.43	IE-TRANS,AFW-AOV-OO-BMHV2,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW
13	1.50E-9	1.43	IE-TRANS,AFW-MDP-FS-PAL01A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW
14	1.43E-9	1.36	IE-TRANS,AFW-MDP-TM-PAL01A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XO-RWST,MFW-XHE-XM-FLOW
15	1.26E-9	1.20	IE-TRANS,AFW-ACX-FS-SGF02A,AFW-TDP-FR-PAL02,AFW-XHE-XM-AOV,HPI-XHE-XM-RECIRC,MFW-XHE-XM-FLOW

Cut Set Report - TRANS 21-7

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

#	CCDP	TOTAL%	CUT SET
	1.04E-7	100	Displaying 7 Cut Sets. (7 Original)
1	3.22E-8	30.88	IE-TRANS,CVC-XHE-XM-BOR,RPS-BME-CF-RTBAB
2	2.69E-8	25.76	IE-TRANS,CVC-XHE-XM-BOR,RPS-CBI-CF-6OF8,/RPS-CCP-TM-CHA,RPS-XHE-XE-NSGNL
3	2.42E-8	23.21	IE-TRANS,CVC-XHE-XM-BOR,RPS-ROD-CF-RCCAS
4	1.82E-8	17.46	IE-TRANS,CVC-XHE-XM-BOR,/RPS-CCP-TM-CHA,RPS-CCX-CF-6OF8,RPS-XHE-XE-NSGNL
5	2.08E-9	1.99	IE-TRANS,CVC-XHE-XM-BOR,RPS-UVL-CF-UVDAB,RPS-XHE-XE-SIGNL

Referenced Events

Event	Description	Probability
ACP-BAC-LP-SL31	4.16 KV Bus SL31 FAILS	3.33E-5
ACP-TFM-FC-SL31	FAILURE OF 13.8-4.16 KV AUX TRANSFORMER XSL31	2.27E-5
AFW-ACX-FR-SGF02A	AFW MDP A ROOM COOLER SGF02A FAILS TO RUN	2.59E-3
AFW-ACX-FS-SGF02A	AFW MDP A ROOM COOLER SGF02A FAILS TO START	8.00E-4
AFW-ACX-TM-SGF02A	AFW MDP A ROOM COOLER SGF02A UNAVAILABLE DUE TO T&M	2.50E-3
AFW-AOV-OO-BMHV2	BLOWDOWN ISOLATION AOV HV0002 FAILS TO CLOSE	9.51E-4
AFW-AOV-OO-BMHV3	BLOWDOWN ISOLATION AOV HV0003 FAILS TO CLOSE	9.51E-4
AFW-MDP-FS-PAL01A	AFW MOTOR-DRIVEN PUMP PAL01A FAILS TO START	9.47E-4

AFW-MDP-TM-PAL01A	AFW MDP PAL01A UNAVAILABLE DUE TO TEST AND MAINTENANCE	3.63E-3
AFW-TDP-FR-PAL02	TURBINE DRIVEN FEED PUMP PAL02 FAILS TO RUN	3.95E-2
AFW-TDP-FS-PAL02	TURBINE DRIVEN FEED PUMP PAL02 FAILS TO START	6.49E-3
AFW-TDP-TM-PAL02	FEED PUMP PAL02 IS IN TEST OR MAINTENANCE	5.33E-3
AFW-XHE-XM-AOV	OPERATOR FAILS TO MANUALLY OPEN FCV	5.00E-1
AFW-XHE-XM-SGLEVEL	OPERATOR FAILS TO CONTROL STEAM GENERATOR LEVELS	4.00E-3
AFW-XHE-XR-SGF02A	OP FAILS TO RESTORE AFW MDP A ROOM COOLER SGF02A AFTER T&M	1.00E-3
CVC-XHE-XM-BOR	OPERATOR FAILS TO INITIATE EMERGENCY BORATION	2.00E-2
DCP-BDC-LP-NK01	125 VDC PANEL DP-NK01 FAILS	5.64E-6
ESW-MDP-TM-1A	ESW TRAIN A MDP 1A UNAVAILABLE DUE TO TEST AND MAINTENANCE	1.32E-2
HPI-XHE-XM-FB	OPERATOR FAILS TO INITIATE FEED AND BLEED COOLING	2.00E-2
HPI-XHE-XM-RECIRC	OPERATOR FAILS TO START HIGH PRESSURE RECIRC	2.00E-3
HPI-XHE-XO-RWST	MISCALIBRATION OF ALL RWST LEVEL CHANNELS (TOO LOW)	5.00E-4
IE-TRANS	TRANSIENT INITIATING EVENT	1.00E+0
MFW-XHE-XM-FLOW	OPERATOR FAILS TO RESTORE MFW FLOW	4.00E-2
PPR-MOV-FC-HV8000A	PORV 455A BLOCK VALVE CLOSED DURING POWER	2.83E-3
PPR-MOV-FC-HV8000B	PORV 456A BLOCK VALVE CLOSED DURING POWER	2.83E-3
PPR-SRV-CC-V455A	PORV V455A FAILS TO OPEN ON DEMAND	3.54E-3
PPR-SRV-CC-V456A	PORV V456A FAILS TO OPEN ON DEMAND	3.54E-3
RCS-PHN-MODPOOR	MODERATOR TEMP COEFFICIENT NOT ENOUGH NEGATIVE	1.40E-2
RCS-PHN-PL	POWER AT HIGH LEVEL	9.00E-1
RPS-BME-CF-RTBAB	CCF OF RTB-A AND RTB-B (MECHANICAL)	1.61E-6
RPS-CBI-CF-6OF8	CCF 6 BISTABLES IN 3 OF 4 CHANNELS	2.70E-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-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-CFG-AP-1ARUN	SWS PUMP 1A RUNNING	3.33E-1
SWS-CFG-AP-1BRUN	SWS PUMP 1B RUNNING	3.33E-1
SWS-CFG-AP-1CRUN	SWS PUMP 1C RUNNING	3.33E-1

Appendix B: Key Event Tree

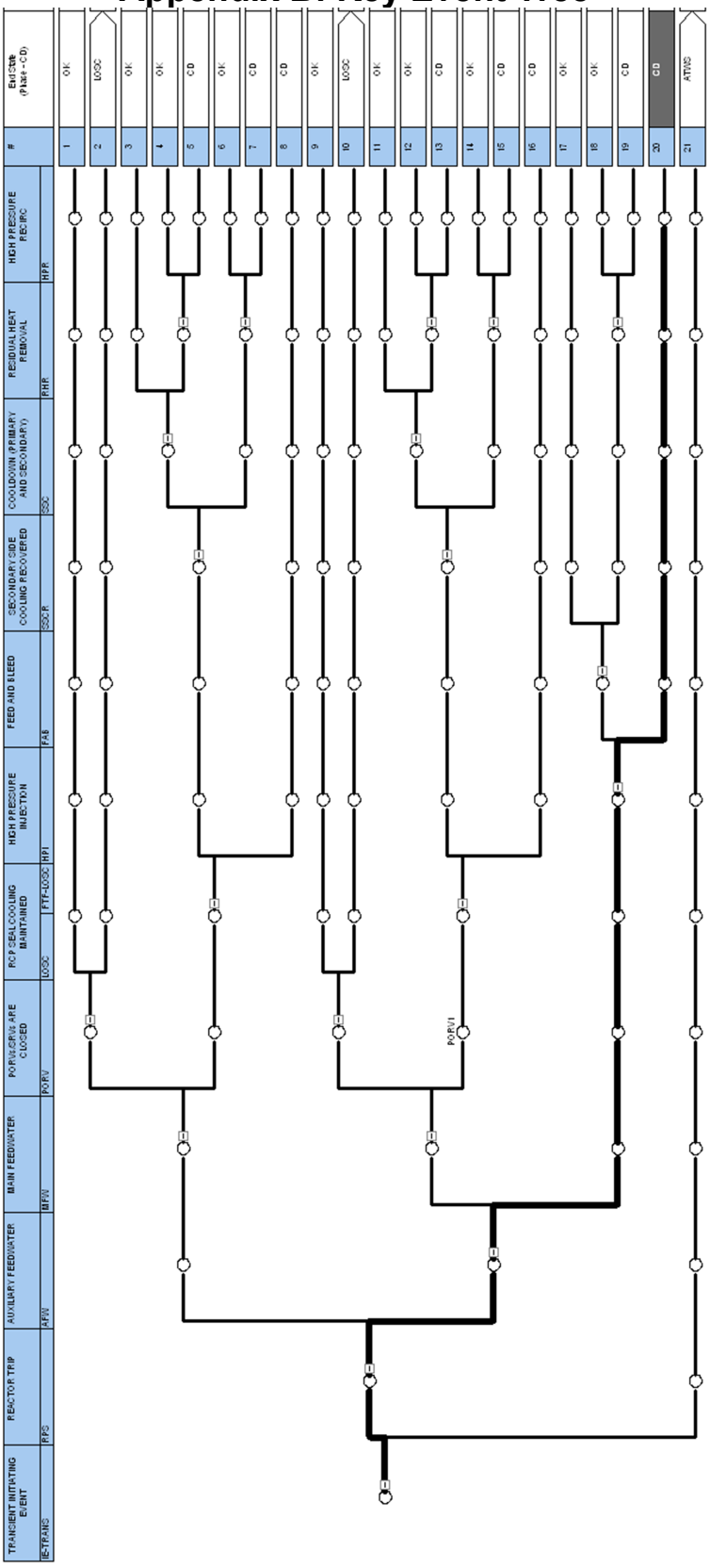

Figure 1: Callaway General Plant Transient Event Tree (Sequence 20 Bolded)

Appendix C: System Drawing

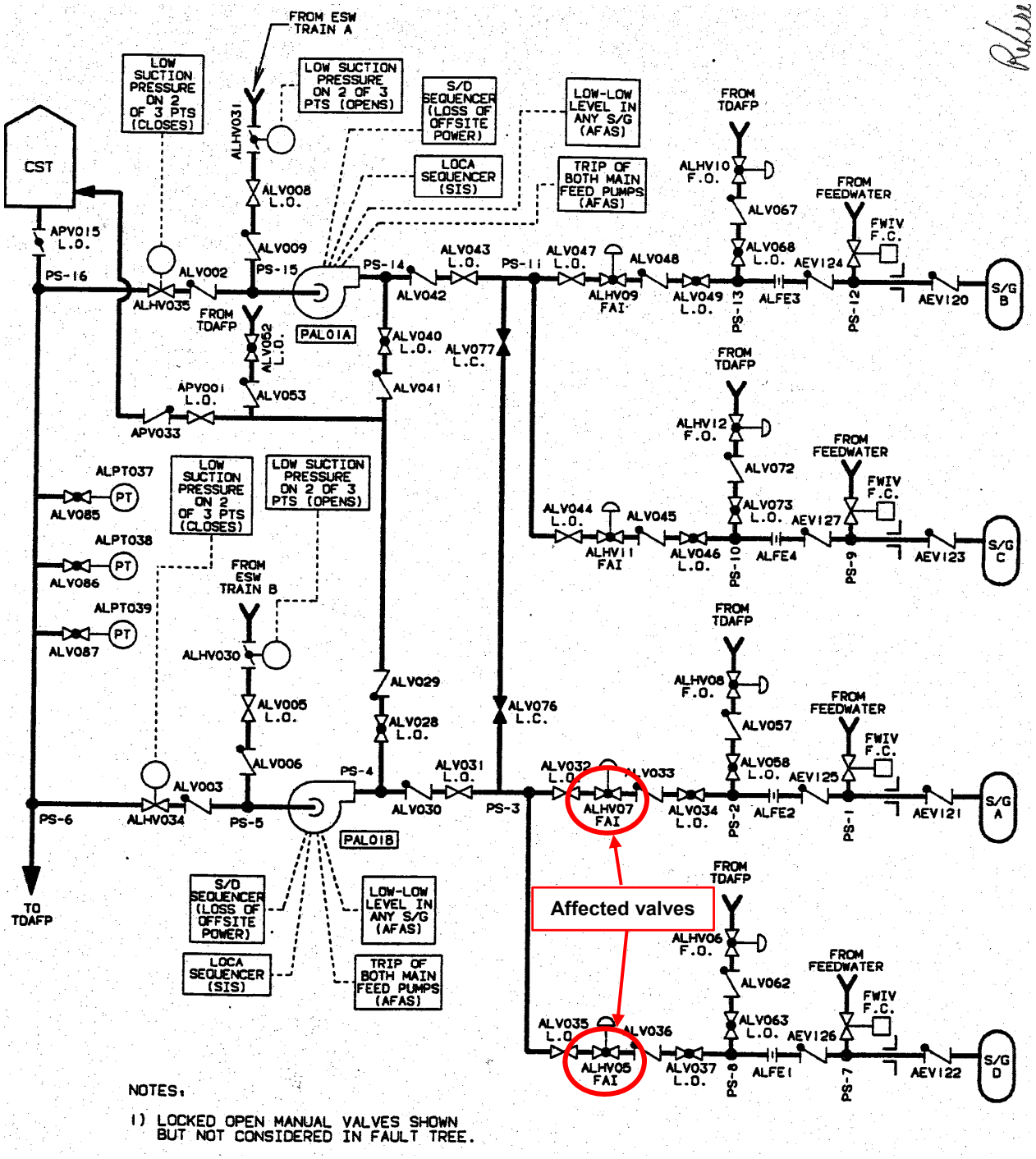

Figure 2: Drawing of Motor-Driven Auxiliary Feedwater Pump Trains for Callaway

Appendix D: SPAR Model Modifications

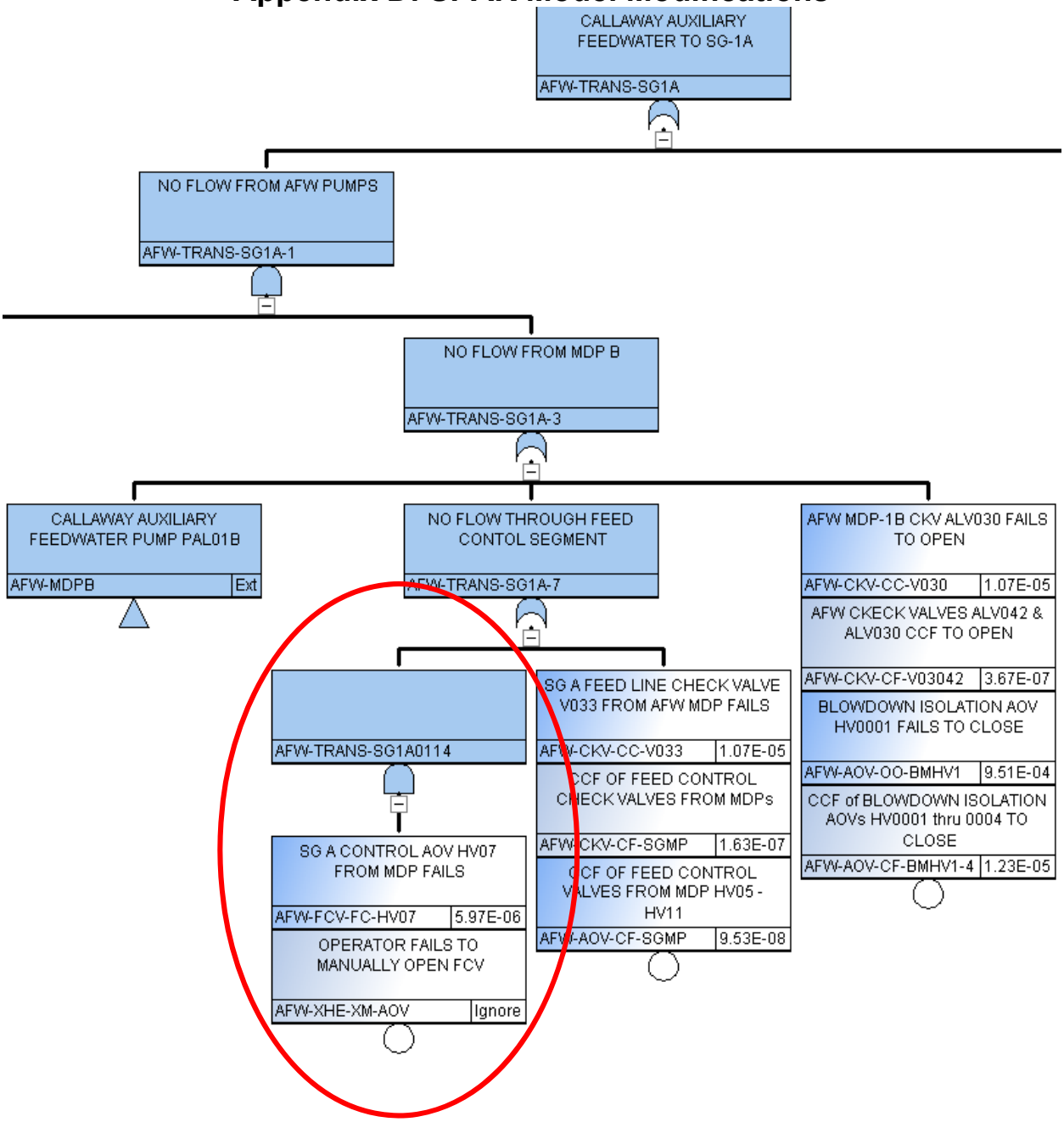

Figure 3: Change to AFW-TRANS-SG1A Fault Tree

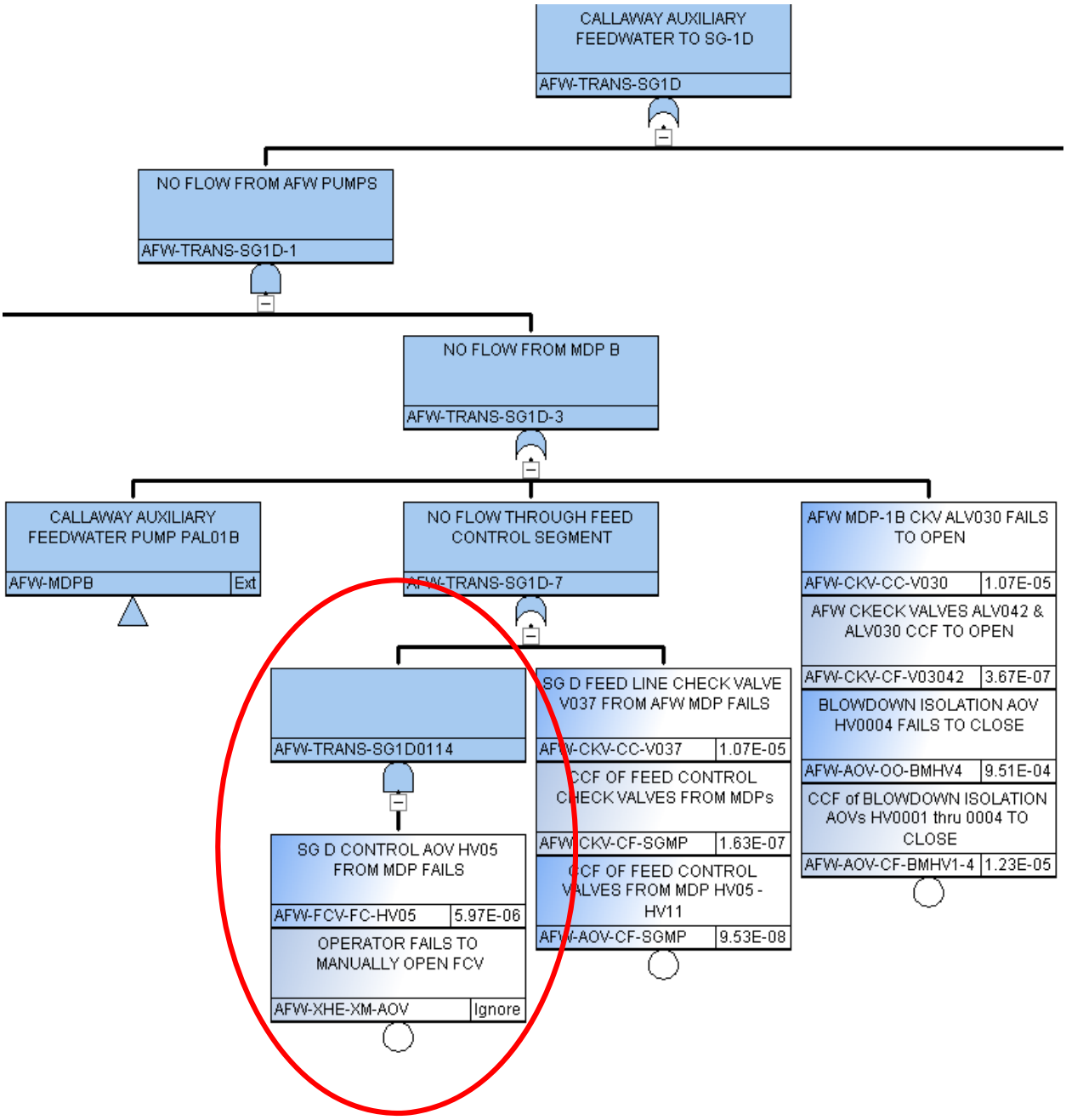

Figure 4: Change to AFW-TRANS-SG1D Fault Tree