Final Precursor Analysis

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research

Monticello	Partial Loss Of Offsite Power Event With HPCI High Level Instrument Trip Failures	
Event Date: 09/11/2008	***LER:*** 263/2008-005	***CCDP =*** 1×10^{-5}

EVENT SUMMARY

Event Description. On September 11, 2008, Monticello Nuclear Generating Plant experienced a line fault on the supply line to the 2R Transformer. The 1R Transformer was out-of-service for planned maintenance when the event started. With both the 1R and 2R Transformers unavailable, the offsite electrical power supply to the non-safety buses was lost, resulting in a reactor scram with loss of the normal heat sink. The unit also experienced Group 1, 2 and 3 isolations of containment and the reactor pressure vessel. The 1AR Transformer remained available and the safety buses automatically transferred to that source as designed. Both emergency diesel generators (EDGs) started and were running, but did not load as offsite power was available to the safety buses.

Since the normal heat sink was lost as a result of main steam isolation valve (MSIV) closure and loss of electrical power to support equipment, operators used the reactor core isolation cooling system (RCIC), the high pressure coolant injection (HPCI), the safety relief valves (SRVs) and the torus cooling system for pressure and level control. The licensee decided to place the plant in Mode 4 (Cold Shutdown) pending assessment of the transient. Subsequently, the licensee restored the 1R Transformer and returned power to the non-safety buses.

The licensee documented their event details in Reference 1. NRC conducted a special inspection of the event; inspection findings are documented in Reference 2.

Cause. The root cause of the event was the A and B phase conductors supplying power to the 2R Transformer faulted to ground, resulting in the 34.5 kV breaker opening as designed to protect equipment from fault current damage. The opening of the 34.5 kV Breaker with the 1R Transformer out of service resulted in a loss of normal offsite power and a reactor scram. Due to the destruction of the failed insulation (splice and cable), the exact failure mechanism was not determined.

Additional Event Details. The HPCI turbine failed to trip at the +48 inch reactor vessel level signal. Operators manually isolated the steam line for the turbine. HPCI was declared inoperable. An investigation determined the failure of the HPCI to trip was due to three effects: (1) the trip solenoid valve had been misassembled, (2) no periodic maintenance on the valve, and a battery voltage well above the minimum required, but slightly below the normally observed voltage.

In addition, Division I of Residual Heat Removal Service Water (RHRSW) was out of service for maintenance at the onset of the reactor trip and during event recovery.

Recovery Opportunities. The licensee determined that recovery of the 1R Transformer was possible within 6 hours (Reference 1).

Analysis Rules. The ASP program uses Significance Determination Process (SDP) results for degraded conditions when available. However, the ASP program performs independent initiating event analysis when an initiator occurs and a condition analysis when there are no performance deficiencies identified for a particular event. In addition, the ASP program analyzes separate degraded conditions that were present during the same period and similar degraded conditions on an individual system or component that had different performance deficiencies.

Five GREEN findings have been identified for this event and are described in Reference 2. Therefore, this analysis focuses solely on the risk of the reactor trip and loss of offsite power to the non-safety buses that occurred.

ANALYSIS RESULTS

Conditional Core Damage Probability. The point estimate conditional core damage probability (CCDP) value for this event is 1.4×10^{-6}. The results of an uncertainty assessment on the event CCDP are summarized below.

	5%	Mean	95%
CCDP	1.9×10^{-6}	1.4×10^{-5}	4.5×10^{-5}

The Accident Sequence Precursor Program acceptance threshold is a CCDP of 1×10^{-6} or the CCDP equivalent of an uncomplicated reactor trip with a non-recoverable loss of secondary plant systems (e.g., feed water and condensate), whichever is greater. This CCDP equivalent for Monticello is 2×10^{-6}.

Dominant Sequence. The dominant accident sequence, Loss of Condenser Heat Sink (LOCHS) Sequence 62 (CCDP = 1.1×10^{-5}) contributes 78.6% of the total internal events CCDP. Additional sequences that contribute at least 1% of the total internal events CCDP are provided in Appendix A (GEM Worksheet).

The dominant sequence is shown graphically in Figure B-1 (Appendix B). The events and important component failures in LOCHS Sequence 62 are:

- LOCHS occurs due to loss of offsite power to the non-safety buses,
- reactor scram succeeds,
- SRVs successfully close (if opened),
- main feedwater fails,
- high-pressure injection (HPCI/RCIC) fails,
- manual reactor depressurization succeeds,
- condensate injection fails,
- low-pressure injection (LPCI/CS) fails, and
- alternate low-pressure injection fails.

GEM Worksheet. The GEM analysis worksheet contained in Appendix A provides the following:

- Modified basic events and initiating event frequencies, including base and change case probabilities/frequencies.
- Dominant sequences (including CCDPs).
- Sequence logic for all dominant sequences.
- Fault tree definitions.
- Sequence cutsets.
- Definitions and probabilities for key basic events.

MODELING ASSUMPTIONS

Analysis Type. The Revision 3-Plus (Change 3.45) of the Monticello Standardized Plant Analysis Risk (SPAR) model (Reference 3) created in June 2008 was used for this event analysis. This event was modeled as a loss of condenser heat sink initiating event with the unavailability of offsite power to the non-safety buses.

Unique Design Features. Monticello has the following unique design features that are pertinent to this event assessment:

- ***Reserve Auxiliary Transformer 1AR.*** Auxiliary power is supplied by the Station Auxiliary Transformer 2R during normal power operation. However, provisions are made for an automatic, fast transfer of the auxiliary load to the Reserve Transformer 1R. In the event Reserve Transformer 1R is unable to accept load, the essential buses are automatically transferred to the Reserve Auxiliary Transformer 1AR. Reserve Auxiliary Transformer 1AR is sized to provide only the plant's essential 4160 V buses and connected loads.

- ***Control Rod Drive System.*** Modifications made to the control rod drive (CRD) return flow required analysis and testing to ensure this source of high-pressure water flow was not reduced below a water boil-off rate due to decay heat generation 40 minutes following shutdown from rated power and the maximum leakage rate from the primary system. The analysis was redone using up-to-date thermal power and decay heat curve. This analysis indicates that a flow rate of 100.9 gpm is required to maintain the water level above the top of the active fuel. Additional flow to the vessel can be obtained by opening the two outboard isolation valves to the reactor water cleanup return line. In this mode of operation, one CRD pump can be used to add as much as 150 gpm to reactor vessel.

Modeling Assumptions. The following modeling assumptions were determined to be vital to this event analysis:

- ***Loss of Condenser Heat Sink Initiating Event.*** This analysis models the September 11, 2008 reactor scram at Monticello as a loss of condenser heat sink initiating event. A loss of offsite power to the non-safety buses resulted in the unavailability of the feedwater, condensate, recirculation, and circulating water systems. In addition, the unavailability of both the 1R and 2R Transformers caused a Group 1 isolation (i.e., the MSIVs automatically closed).

- ***Power Recovery to Non-Safety Bus.*** Offsite power recovery to a non-safety bus was possible six hours after the initiating event occurred. To reenergize a non-safety bus, Reserve Transformer 1R would need to be placed back into service from the ongoing maintenance activity. In this analysis, time for recovery is assumed to be available if high-pressure injection (HPCI/RCIC) is successful.

- ***Failure of HPCI/RCIC High Reactor Vessel Level Trip.*** The high reactor vessel level automatic trip for HPCI/RCIC failed during event recovery. Operator action was required to prevent over-filling the reactor vessel and prevent the unavailability and potential damage to RCIC and HPCI turbine-driven pumps.

- ***Division I RHRSW Unavailable.*** Division I of RHRSW was unavailable due to maintenance and was assumed to be non-recoverable during the event.

Fault Tree Modifications. The following fault tree modifications were necessary to perform this event analysis:

- ***Condensate.*** The condensate pumps fault tree (CDS-PMPS) was modified to account for initial loss of the condensate system (i.e., it balance-of-plant function) due to the loss of power to the non-safety buses. However, if HPCI and/or RCIC were initially available, condensate could be available later. The 'AND' Gate CDS-LOOP1 and the subsequent logic (including basic event (OPR-XHE-XL-NONVITAL) were added to model the initial loss of condensate and the potential recovery of the low-pressure injection function of the condensate system. See Figure C-1 (Appendix C) for modified CDS-PMPS fault tree.

- ***HPCI and RCIC.*** The basic event TDP-XHE-XL-LEVEL was added to the HPCI and RCIC turbine-driven pump faults trees to account for the required operator action to secure the pumps due to the failure of the automatic high reactor vessel level trip. See Figure C-2 (HCI-TDP) and Figure C-3 (RCI-TDP) in Appendix C for the modified HPCI and RCIC fault trees.

Basic Event Probability Changes. The following initiating event frequencies and basic event probabilities were modified for this event analysis:

- ***IE-LOCHS set to 1.0.*** The loss of condenser heat sink (LOCHS) initiating event frequency was set 1.0 to represent the operational event that occurred at Monticello on September 11, 2008. All other initiating events frequencies were set to zero.

- ***LOOP-NONVITAL was set to TRUE.*** This event was set to TRUE because Monticello experienced a loss of offsite power to the non-safety buses during the event.

- ***OPR-XHE-XL-NONVITAL.*** This event represents the probability of operators failing to restore power to a non-safety bus given successful high-pressure injection (HPCI/RCIC). This event was evaluated using the SPAR-H Method (Reference 4). It was determined that this human failure event required diagnostic activity. All diagnostic performance shaping factors were determined to be nominal; therefore, the failure probability was calculated as 1.0×10^{-2}.

- ***RSW-MDP-TM-TRNA and RSW-MDP-TM-TRNC were set to TRUE.*** These basic events were set to TRUE because Division I RHRSW was unavailable due to maintenance

- ***TDP-XHE-XL-LEVEL was set to 1.0×10^{-2}.*** This event represents the probability of operators failing to terminate HPCI/RCIC flow prior to overfilling the reactor vessel into the steam piping and potentially damaging the pumps. This event was evaluated using the SPAR-H Method (Reference 4). It was determined that this human failure event required diagnostic activity. All diagnostic performance shaping factors were determined to be nominal; therefore, the failure probability was calculated as 1.0×10^{-2}.

REFERENCES

1. Xcel Energy, "LER 263-2008-005, Rev. 0, Reactor Scram due to Loss of Normal Offsite Power, Event Date of September 11, 2008," dated November 07, 2008.

2. U.S. Nuclear Regulatory Commission, "Monticello Nuclear Generating Plant Special Inspection Report 05000263/2008009," dated December 16, 2008.

3. Idaho National Laboratory, "Standardized Plant Analysis Risk Model for Monticello," Revision 3.45, dated June 2008.

4. Idaho National Laboratory, "NUREG/CR-6883: The SPAR-H Human Reliability Analysis Method," dated August 2005.

5. U.S. Nuclear Regulatory Commission, "RASP Handbook: Internal Events," Revision 1.01, dated January 2008.

APPENDIX A
GEM WORKSHEET

SAPHIRE Code Version: 7.27.0.41
SPAR Model Version: Monticello 3.45 (June 2008)

Analysis Type: Initiating Event Assessment
Event Description: Loss of Condenser Heat Sink (LOCHS) With Loss of Offsite Power to the Non-Safety Buses.

Total CCDP: 1.4E-5 (Point Estimate & Mean)

Basic Event Changes

Event Name	Description	Base Probability	Current Probability
IE-IORV	Inadvertent Open Relief Valve	2.0E-002	0.0E+000
IE-ISL-RHR	ISLOCA (2-MOV RHR Interface)	4.0E-006	0.0E+000
IE-LLOCA	Large LOCA	1.0E-005	0.0E+000
IE-LOACB-A	Loss of Vital Bus A	4.5E-003	0.0E+000
IE-LOACB-B	Loss of Vital Bus B	4.5E-003	0.0E+000
IE-LOCHS	Loss of Condenser Heat Sink	2.0E-001	1.0E+000
IE-LODCB-A	Loss of Vital DC Bus A	6.0E-004	0.0E+000
IE-LODCB-B	Loss of Vital DC Bus B	6.0E-004	0.0E+000
IE-LOIAS	Loss of Instrument Air	1.0E-002	0.0E+000
IE-LOMFW	Loss of Feedwater	1.0E-001	0.0E+000
IE-LOOP	Loss of Service Water	4.0E-004	0.0E+000
IE-MANSD	Manual Shutdown	1.7E+000	0.0E+000
IE-MLOCA	Medium LOCA	1.0E-004	0.0E+000
IE-SLOCA	Small LOCA	6.0E-004	0.0E+000
IE-TRANS	General Plant Transient	8.0E-001	0.0E+000
IE-XLOCA	Excessive LOCA (Vessel Rupture)	1.0E-007	0.0E+000
LOOP-NONVITAL	Loss of Offsite Power to Non-Safety Buses	0.0E+000	TRUE
OPR-XHE-XL-NONVITAL	Operator Fails to Restore Power to a Non-Safety Bus	IGNORE	1.0E-002
RSW-MDP-TM-TRNA	RHRSW Train A Is Unavailable Due to Maintenance	0.0E+000	TRUE
RSW-MDP-TM-TRNC	RHRSW Train C Is Unavailable Due to Maintenance	0.0E+000	TRUE
TDP-XHE-XL-LEVEL	Operator Fails To Secure TDPs Prior to Water Induction	0.0E+000	1.0E-002

Dominant Sequences

Event Tree	Sequence	CCDP	% Contribution
LOCHS	62	1.1E-005	78.6
LOCHS	19	1.8E-006	12.9
LOCHS	39	3.9E-007	2.8
LOCHS	69	3.1E-007	2.2

Sequence Logic

Event Tree	Sequence	Logic
LOCHS	62	/RPS /SRV MFW HPI /DEP CDS LPI VA
LOCHS	19	/RPS /SRV MFW /HPI SPC /DEP /CDS SDC CSS PCSR CVS LI01
LOCHS	39	/RPS /SRV MFW /HPI SPC DEP CRD
LOCHS	69	/RPS /SRV MFW HPI DEP CRD

Fault Tree Descriptions

Fault Tree	Description
CDS	Condensate
CRD	CRD Injection (2 Pumps)
CSS	Containment Spray
CVS	Containment Venting
DEP	Manual Reactor Depress
HPI	High Pressure Injection (RCIC or HPCI)
LI01	Monticello Late Injection Fails
LPI	Low Pressure Injection (CS or LPCI)
MFW	Main Feedwater
PCSR	Power Conversion System Recovery
RPS	Reactor Shutdown
SDC	Shutdown Cooling
SPC	Suppression Pool Cooling
SRV	SRVs Close
VA	Alternate Low Press Injection

Sequence Cutsets

Sequence: LOCHS 62 **CCDP:** 1.1E-005

CCDP	% Cutset	Cutset Events		
1.0E-005	88.45	LPI-XHE-XO-LVLCTL	TDP-XHE-XL-LEVEL	
1.8E-007	1.59	HCI-MOV-CC-IVFRO	HCI-MULTIPLE-INJECT	HCI-XHE-XL-INJECT
		LPI-XHE-XO-LVLCTL	RCI-TDP-TM-TRAIN	
1.3E-007	1.11	HCI-MOV-CC-IVFRO	HCI-MULTIPLE-INJECT	HCI-XHE-XL-INJECT
		LPI-XHE-XO-LVLCTL	RCI-TDP-FS-TRAIN	
8.4E-008	0.74	LPI-XHE-XO-LVLCTL	HCI-TDP-TM-TRAIN	RCI-TDP-FS-TRAIN
7.4E-008	0.65	HCI-MOV-CC-IVFRO	HCI-MULTIPLE-INJECT	HCI-XHE-XL-INJECT
		LPI-XHE-XO-LVLCTL	RCI-TDP-FR-TRAIN	
7.0E-008	0.62	LPI-XHE-XO-LVLCTL	RCI-TDP-TM-TRAIN	HCI-TDP-FS-TRAIN

Sequence: LOCHS 19 **CCDP:** 1.8E-006

CCDP	% Cutset	Cutset Events		
1.0E-006	55.96	RHR-XHE-XO-CHR		
5.5E-007	30.78	CVS-XHE-XM-RVENT	PCS-XHE-XL-LTLCHS	CFAILED
		OPR-XHE-XE-IDSHED	CFAILED1	
1.3E-007	7.39	HCI-MOV-CC-IVFRO	CVS-XHE-XM-RVENT	HCI-XHE-XL-INJECT
		PCS-XHE-XL-LTLCHS	OPR-XHE-XE-IDSHED	CFAILED1

Sequence: LOCHS 39 **CCDP:** 3.9E-007

CCDP	% Cutset	Cutset Events		
1.1E-007	28.41	OPR-XHE-XM-INJEC	OPR-XHE-XE-IDSHED	
6.1E-008	15.63	ADS-XHE-XM-MDEPR	OPR-XHE-XE-IDSHED	CRD-XHE-XM-BRKRS
4.4E-008	11.36	ADS-XHE-XM-MDEPR	CRD-MDP-TM-TRNA	OPR-XHE-XE-IDSHED
4.4E-008	11.36	ADS-XHE-XM-MDEPR	CRD-MDP-TM-TRNB	OPR-XHE-XE-IDSHED
2.0E-008	5.16	SPC-MOV-CC-LOOPB	OPR-XHE-XM-INJEC	
1.1E-008	2.84	ADS-XHE-XM-MDEPR	CRD-MDP-FS-TRNB	OPR-XHE-XE-IDSHED

Sequence: LOCHS 69 **CCDP:** 3.1E-007

CCDP	% Cutset	Cutset Events		
1.0E-007	31.97	OPR-XHE-XM-INJEC	TDP-XHE-XL-LEVEL	
5.5E-008	17.58	ADS-XHE-XM-MDEPR	TDP-XHE-XL-LEVEL	CRD-XHE-XM-BRKRS
4.0E-008	12.79	ADS-XHE-XM-MDEPR	CRD-MDP-TM-TRNB	TDP-XHE-XL-LEVEL
4.0E-008	12.79	ADS-XHE-XM-MDEPR	CRD-MDP-TM-TRNA	TDP-XHE-XL-LEVEL
1.0E-008	3.20	ADS-XHE-XM-MDEPR	CRD-MDP-FS-TRNA	TDP-XHE-XL-LEVEL
1.0E-008	3.20	ADS-XHE-XM-MDEPR	CRD-MDP-FS-TRNB	TDP-XHE-XL-LEVEL
1.0E-008	3.20	ESF-ACT-FC-LEVEL	OPR-XHE-XM-INJEC	
5.0E-009	1.60	ADS-XHE-XM-MDEPR	RBC-MOV-OO-ISOL	TDP-XHE-XL-LEVEL
5.0E-009	1.60	ADS-XHE-XM-MDEPR	TDP-XHE-XL-LEVEL	CRD-XHE-XM-PUMP

Basic Events (Cutsets Only)

Event Name	Description	Current Probability
ACP-BAC-LP-DII	Division II AC Power Buses Fail	9.6E-006
ADS-XHE-XM-MDEPR	Operator Fails To Depressurize the Reactor	5.0E-004
CFAILED	Containment Failure Causes Loss of All Low-Pressure Injection	5.0E-001
CFAILED1	Containment Failure Causes Loss of CRD/FW Injection	1.0E-001
CRD-MDP-FS-TRNA	CRD Pump P-201A Fails To Start	2.0E-003
CRD-MDP-FS-TRNB	CRD Pump P-201B Fails To Start	2.0E-003
CRD-MDP-TM-TRNA	CRD Train A Is Unavailable Because Of Maintenance	8.0E-003
CRD-MDP-TM-TRNB	CRD Train B Is Unavailable Because Of Maintenance	8.0E-003
CRD-XHE-XM-BRKRS	Operator Fails To Close CRD-RBCW Breakers	1.1E-002
CRD-XHE-XM-PUMP	Operator Fails To Start the Standby CRD Pump	1.0E-003
CVS-XHE-XM-RVENT	Operator Fails To Vent Containment (Remote Operation)	1.0E-003
DCP-BAT-LP-BATTB	Division II Battery Fails	4.8E-005
DCP-XHE-XL-BRKRS	Operator Fails To Close DC Powered Breakers Locally	3.4E-001
ESF-ACT-FC-LEVEL	ESF Actuation Fails	1.0E-003
HCI-MOV-CC-IVFRO	HPCI Injection Valve (MOV HPCI-2061) Fails To Reopen	1.5E-001
HCI-MULTIPLE-INJECT	Probability of Multiple HPCI Injections	1.5E-001
HCI-TDP-FS-TRAIN	HPCI Pump P-209 Fails To Start	7.0E-003
HCI-TDP-TM-TRAIN	HPCI Train Is Unavailable Because Of Maintenance	1.2E-002
HCI-XHE-XL-INJECT	Operator Fails To Recover HPCI Injection Valve Reopening	8.0E-001
LPI-XHE-XO-LVLCTL	Operator Fails to Control Level Using Low-Pressure Injection	1.0E-003
OPR-XHE-XE-IDSHED	Operator Fails To Identify Load Shedding As Cause of Failure	1.1E-002
OPR-XHE-XM-INJEC	Operator Fails To Detect Need for Injection within 45 Minutes	1.0E-005
PCS-XHE-XL-LTLCHS	Operator Fails To Recover the PCS in the Long Term	1.0E+000
RBC-MOV-OO-ISOl	RBCCW Isolation Valve Fails To Close	1.0E-003
RCI-TDP-FR-TRAIN	RCIC Pump P-207 Fails To Run Given That It Started	4.1E-003
RCI-TDP-FS-TRAIN	RCIC Pump P-207 Fails To Start	7.0E-003
RCI-TDP-TM-TRAIN	RCIC Pump Train Is Unavailable Because Of Maintenance	1.0E-002
RHR-XHE-XO-CHR	Operator Fails To Start/Control RHR (Dependent Event)	1.0E-006
RHR-XHE-XO-ERROR	Operator Fails To Start/Control RHR	5.0E-004
SPC-MOV-CC-LOOPB	SPC Injection Valves LPCI-2007 and LPCI-2009 Fail To Open	2.0E-003
TDP-XHE-XL-LEVEL	Operator Fails To Secure Pumps Prior To Water	1.0E-002

APPENDIX B
EVENT TREE WITH DOMINANT SEQUENCE HIGHLIGHTED

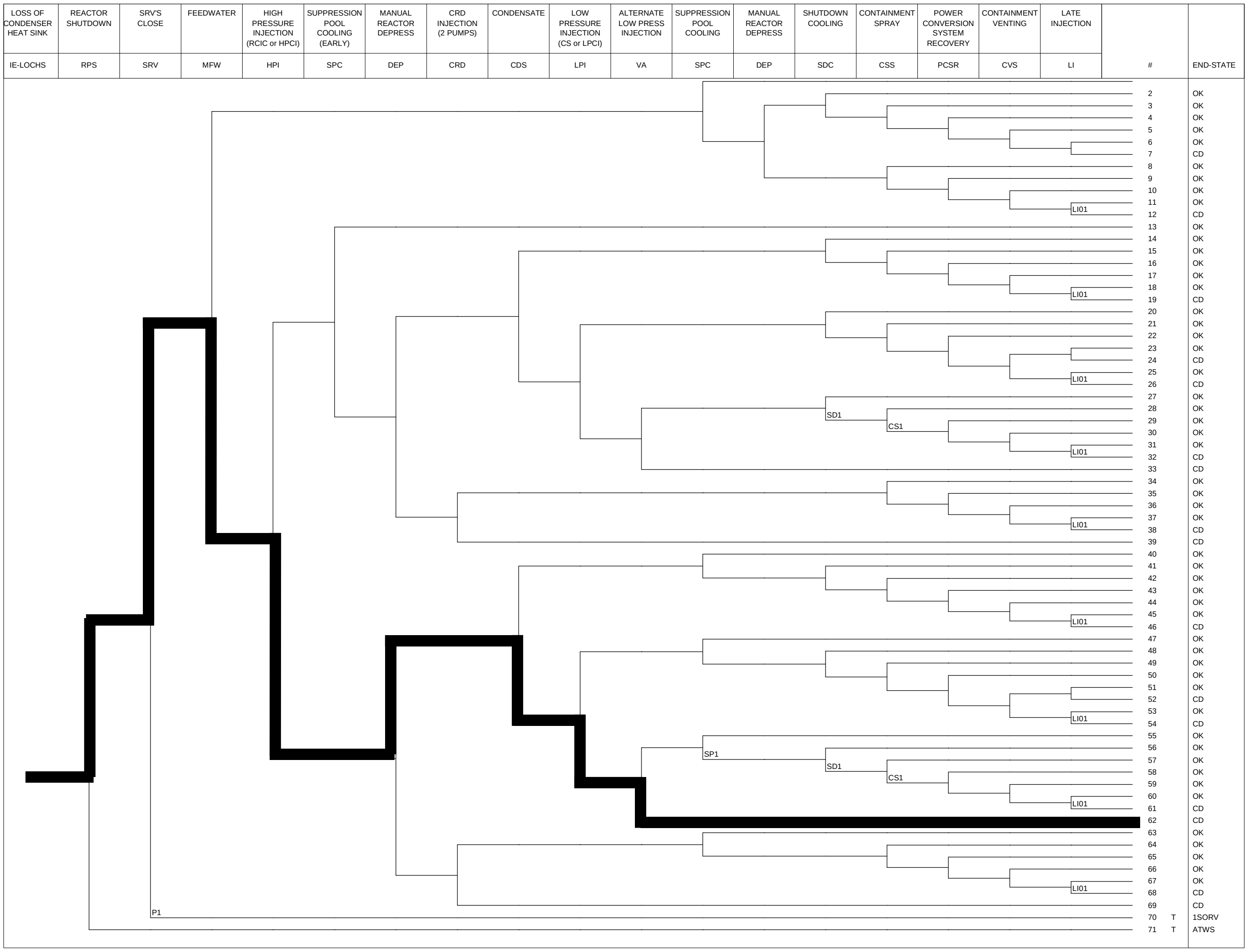

Figure B-1: Loss of Condenser Heat Sink Event Tree (w/ Dominant Sequence Highlighted).

APPENDIX C
MODIFIED FAULT TREES

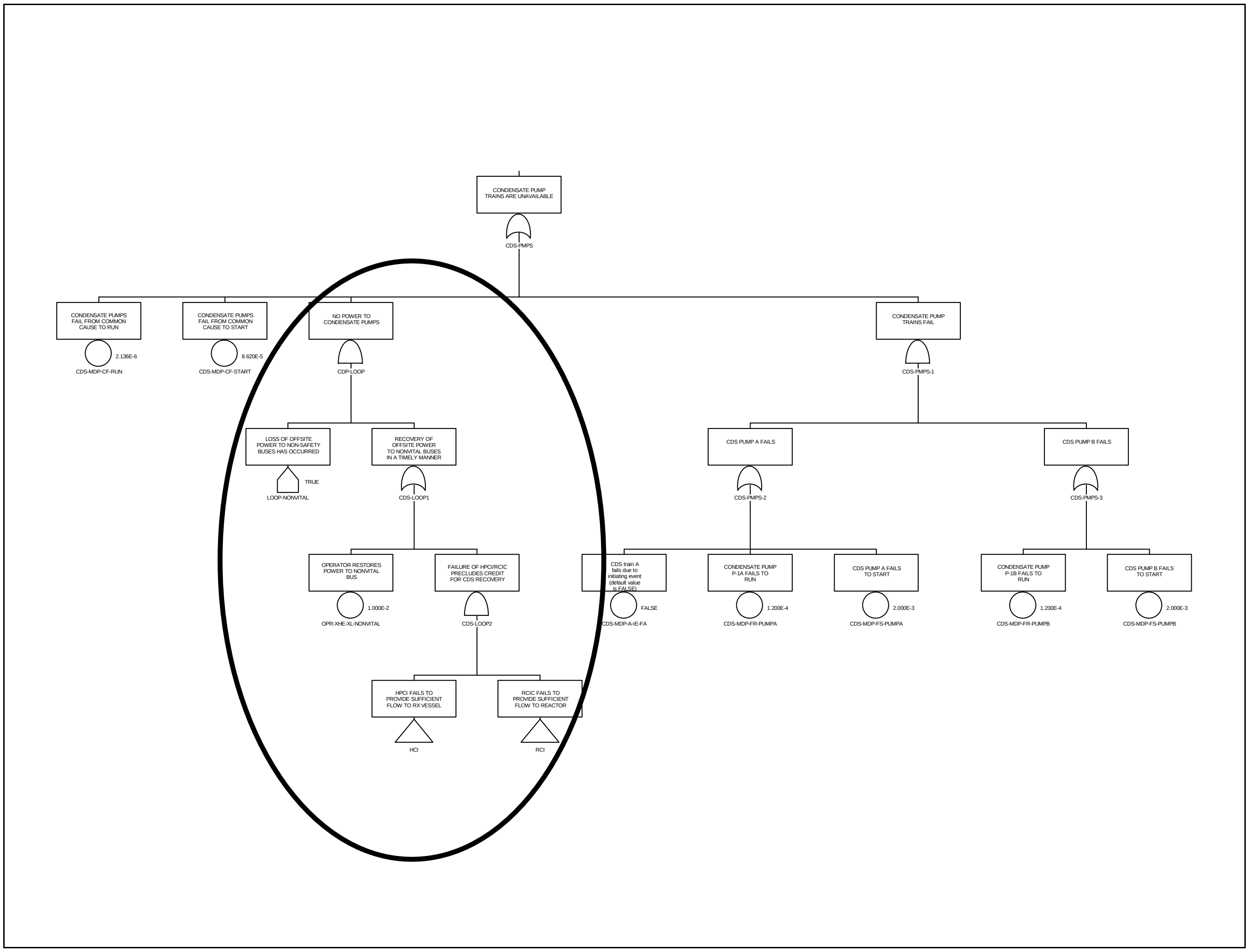

Figure C-1: Modified CDS-PMPS Fault Tree.

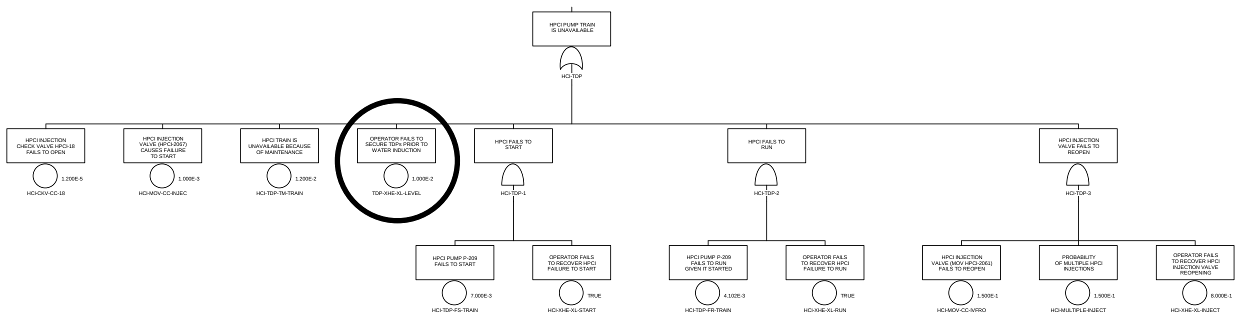

Figure C-2: Modified HCI-TDP Fault Tree.

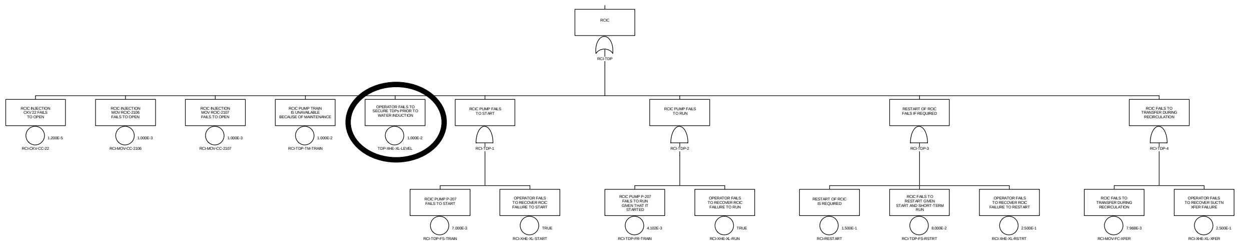

Figure C-3: Modified RCI-TDP Fault Tree.