Final ASP Program Analysis - Reject

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research			
Susquehanna Steam Electric Station, Unit 2	HPCI Manually Overridden Prior to a Manual Scram During a Plant Transient		
Event Date: 5/13/2016	**LER(s):** 388-2016-005 and 388-2016-004-01 **IR(s):** 05000387/2016002		**CCDP =** 4×10^{-7}
Plant Type: General Electric, BWR-4 with a Wet Mark II Containment			
Plant Operating Mode (Reactor Power Level): Mode 1 (69% Reactor Power)			
Analyst: David Aird	**Reviewer:** Keith Tetter	**Contributors:** N/A	**BC Approved Date:** 12/6/2016

EVENT DETAILS

Event Description. At 11:55 pm on May 12, 2016, Susquehanna Steam Electric Station (SSES) Unit 2 experienced an electrical transient resulting in a loss of 2B246 Reactor Building Engineered Safeguard System Division 2 480V Motor Control Center (MCC) and 2Y246 208/120V Alternate Current Instrument Panel. With the loss of the MCC, several drywell cooling fans were lost leading to an increase in drywell pressure. Operators reduced reactor power by reducing reactor recirculation flow. Maintenance personnel reported that the 2B246 bus faulted and was not able to be re-energized. Operators determined that a manual scram was required based upon a loss of drywell cooling.

On May 13, 2016 at 12:55 am, the High Pressure Coolant Injection (HPCI) system was overridden (placed in manual) prior to the manual scram to prevent the trip of all feedwater pumps on reactor pressure vessel high water level alarm. Although HPCI is not normally expected to initiate during a reactor scram if the non-safety related integrated control system (ICS) responds appropriately to control reactor water level, taking HPCI out of automatic mode rendered the system incapable of automatic initiation in the event of a failure of the ICS. Technical Specification 3.5.1 was entered for HPCI inoperable due to manual override.

At 1:10 am, with drywell pressure increasing to 1.3 psig, operators placed the mode switch in the shutdown position to manually scram the reactor. All control rods inserted as expected. Reactor water level lowered and was immediately restored by normal feedwater level control. Primary Containment Isolation System isolations occurred, along with an initiation of the Reactor Core Isolation Cooling (RCIC) system. Once adequate level was verified, RCIC was overridden. Reactor pressure was controlled with turbine bypass valves, and subsequently main steam line drains. HPCI was restored to automatic mode at 1:22 am. All other safety systems functioned as expected. Additional information related to the override of HPCI and the electrical transient is available in licensee event reports (LERs) 388-2016-005 (Ref. 1), 388-2016-004-01 (Ref.2), and Inspection Report (IR) 05000387/2016002 (Ref. 3).

Causes. The direct cause of the transient was found to be a phase to ground short between a cable and a protruding screw in the MCC. The protruding screw damaged and/or abraded the wire insulation until the short occurred.

There were two contributing causes to the incorrect override of HPCI prior to the manual reactor scram. First, the Unit Supervisor made a decision to prematurely override HPCI to minimize distractions later in the shutdown without procedural guidance to do so. Second, weaknesses in teamwork and oversight prevented the mistake from being corrected by the crew. A crew update was not conducted to announce the placing of HPCI in manual override, preventing the crew from providing a peer check of the Unit Supervisor's decision.

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 addressed and evaluated in IR 05000387/2016002 (Ref. 3). Inspectors identified a performance deficiency for the licensee's failure to implement procedures for controlling the HPCI system. A detailed risk evaluation (condition assessment) was performed that resulted in a change in core damage frequency per year of less than 1×10^{-9}. Therefore, the issue was determined to be of very low safety significance (Green).

An independent ASP analysis is required because this is an initiating event with a concurrent unavailability of a safety-related system designed to mitigate the consequences of an accident. The analysis performed in support of the SDP was not an initiating event analysis and only analyzed the performance deficiency for the short duration that HPCI was not in automatic mode.

Analysis Type. An initiating event analysis was performed using the SSES Unit 2 Standardized Plant Analysis Risk (SPAR) model Revision 8.21, created in May 2014.

SPAR Model Modifications. No SPAR model modifications were required as part of this analysis.

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

- This event is modeled as a transient initiating event. Therefore, the probability of IE-TRANS (*General Plant Transient*) was set to 1.0. All other initiating event probabilities were set to zero.
- Basic event HCI-XHE-XO-ERROR (*Operator fails to start/control HPCI injection*) was set to TRUE. This is a conservative assumption because 1) operators could have assumed manual control of HPCI at any time if needed, and 2) HPCI was restored to automatic mode 27 minutes into the event.
- All other safety systems responded as designed.

[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.

ANALYSIS RESULTS

CCDP/Rejection Basis. The point estimate conditional core damage probability (CCDP) for this event is 4.2×10^{-7}. The ASP Program acceptance threshold is a CCDP of 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 TRANS Sequence 49 (CCDP = 3.4×10^{-7}) that contributes approximately 81% 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 49 are:

- Reactor shutdown success,
- Safety relief valve close if opened,
- Power conversion system (condenser) is unavailable,
- High pressure injection sources (HPCI and RCIC) are unavailable, and
- Manual reactor depressurization fails.

REFERENCES

1. Susquehanna Nuclear, LLC, "LER 388-2016-005 – Susquehanna Steam Electric Station Unit 2 HPCI Manually Overridden Prior to a Manual Scram During a Plant Transient," dated July 12, 2016 (ML16194A251).

2. Susquehanna Nuclear, LLC, "LER 388-2016-004-01 – Susquehanna Steam Electric Station Unit 2 experienced an electrical transient resulting in a manual SCRAM," dated September 29, 2016 (ML16273A157).

3. U.S. Nuclear Regulatory Commission, "Susquehanna Steam Electric Station – NRC Integrated Inspection Report 05000387/2016002 and 05000388/2016002, dated August 11, 2016 (ML16225A000).

Appendix A: SAPHIRE 8 Worksheet

Summary of Conditional Event Changes

Event	Description	Cond Value	Nominal Value
HCI-XHE-XO-ERROR	OPERATOR FAILS TO START/CONTROL HPCI INJECTION	True	1.00E-3
IE-TRANS	GENERAL PLANT TRANSIENT	1.00E+0[a]	7.62E-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	49	3.39E-7	81.4%	/RPS, /SRV, PCS, HPI, DEP
TRANS	34	4.54E-8	10.9%	/RPS, /SRV, PCS, /HPI, SPC, DEP, /CRD, RHR, PCSR, CVS, LI08
TRANS	52-10	1.19E-8	2.8%	RPS, /PPR, RRS
TRANS	09	5.96E-9	1.4%	/RPS, /SRV, PCS, /HPI, SPC, /DEP, /CRD, RHR, PCSR, CVS, LI08
TRANS	52-05	5.10E-9	1.2%	RPS, /PPR, /RRS, /PCS1, SLC
Total		**4.17E-7**	**100.0%**	

Referenced Fault Trees

Fault Tree	Description
CVS	CONTAINMENT VENTING
DEP	MANUAL REACTOR DEPRESS
HPI	HIGH PRESSURE INJECTION (HPCI or RCIC)
LI08	LATE INJECTION
PCS	POWER CONVERSION SYSTEM
PCSR	POWER CONVERSION SYSTEM RECOVERY
RHR	RESIDUAL HEAT REMOVAL
RPS	REACTOR SHUTDOWN
RRS	RECIRC PUMP TRIP
SLC	STANDBY LIQUID CONTROL
SPC	SUPPRESSION POOL COOLING

Cut Set Report - TRANS 49

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

#	CCDP	Total%	Cut Set
	3.39E-7	100	Displaying 108 Cut Sets. (108 Original)
1	8.30E-8	24.45	IE-TRANS,ADS-XHE-XM-MDEPR,MSS-TBV-CC-BYPAS,RCI-TDP-FR-TRAIN
2	3.98E-8	11.72	IE-TRANS,DCP-BDC-CF-ALL
3	2.30E-8	6.78	IE-TRANS,ADS-XHE-XM-MDEPR,MSS-TBV-CC-BYPAS,RCI-TDP-TM-TRAIN
4	1.98E-8	5.82	IE-TRANS,ADS-XHE-XM-MDEPR,MFW-XHE-XO-ERROR,RCI-TDP-FR-TRAIN
5	1.98E-8	5.82	IE-TRANS,ADS-XHE-XM-MDEPR,RCI-TDP-FR-TRAIN,SWS-XHE-XO-ERROR
6	1.88E-8	5.54	IE-TRANS,ADS-XHE-XM-MDEPR,MFW-AOV-CC-START,RCI-TDP-FR-TRAIN
7	1.88E-8	5.54	IE-TRANS,ADS-XHE-XM-MDEPR,CDS-AOV-CC-MKUP1,RCI-TDP-FR-TRAIN
8	1.88E-8	5.54	IE-TRANS,ADS-XHE-XM-MDEPR,CDS-AOV-CC-MKUP2,RCI-TDP-FR-TRAIN
9	1.36E-8	4.02	IE-TRANS,ADS-XHE-XM-MDEPR,MSS-TBV-CC-BYPAS,RCI-TDP-FS-TRAIN
10	1.19E-8	3.51	IE-TRANS,DCP-BCH-CF-CHRS,RCI-TDP-FR-TRAIN
11	6.30E-9	1.86	IE-TRANS,ADS-XHE-XM-MDEPR,MSS-TBV-CC-BYPAS,RCI-RESTART,RCI-TDP-FS-RSTRT,RCI-XHE-XL-RSTRT
12	5.48E-9	1.61	IE-TRANS,ADS-XHE-XM-MDEPR,MFW-XHE-XO-ERROR,RCI-TDP-TM-TRAIN
13	5.48E-9	1.61	IE-TRANS,ADS-XHE-XM-MDEPR,RCI-TDP-TM-TRAIN,SWS-XHE-XO-ERROR
14	5.21E-9	1.53	IE-TRANS,ADS-XHE-XM-MDEPR,MFW-AOV-CC-START,RCI-TDP-TM-TRAIN
15	5.21E-9	1.53	IE-TRANS,ADS-XHE-XM-MDEPR,CDS-AOV-CC-MKUP1,RCI-TDP-TM-TRAIN
16	5.21E-9	1.53	IE-TRANS,ADS-XHE-XM-MDEPR,CDS-AOV-CC-MKUP2,RCI-TDP-TM-TRAIN

Cut Set Report - TRANS 34

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

#	CCDP	Total%	Cut Set
	4.54E-8	100	Displaying 2 Cut Sets. (2 Original)
1	4.52E-8	99.67	IE-TRANS,CFAILED,CVS-XHE-XM-VENTL,DCP-BCH-CF-CHRS

Cut Set Report - TRANS 52-10

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

#	CCDP	Total%	Cut Set
	1.19E-8	100	Displaying 10 Cut Sets. (10 Original)
1	4.07E-9	34.30	IE-TRANS,RPS-SYS-FC-PSOVS,RRS-CRB-CC-PUMP1
2	4.07E-9	34.30	IE-TRANS,RPS-SYS-FC-PSOVS,RRS-CRB-CC-PUMP2
3	9.09E-10	7.67	IE-TRANS,RPS-SYS-FC-RELAY,RRS-CRB-CC-PUMP1
4	9.09E-10	7.67	IE-TRANS,RPS-SYS-FC-RELAY,RRS-CRB-CC-PUMP2
5	5.98E-10	5.04	IE-TRANS,RPS-SYS-FC-CRD,RRS-CRB-CC-PUMP2
6	5.98E-10	5.04	IE-TRANS,RPS-SYS-FC-CRD,RRS-CRB-CC-PUMP1
7	2.63E-10	2.22	IE-TRANS,RPS-SYS-FC-HCU,RRS-CRB-CC-PUMP1
8	2.63E-10	2.22	IE-TRANS,RPS-SYS-FC-HCU,RRS-CRB-CC-PUMP2

Cut Set Report - TRANS 09

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

#	CCDP	Total%	Cut Set
	5.97E-9	100	Displaying 31 Cut Sets. (31 Original)
1	1.05E-9	17.60	IE-TRANS,CFAILED,CVS-XHE-XM-VENT,MSS-TBV-CC-BYPAS,RHR-XHE-XM-ERROR
2	5.50E-10	9.21	IE-TRANS,ACP-BAC-LP-2A202,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RHR-XHE-XM-ERROR
3	5.50E-10	9.21	IE-TRANS,ACP-BAC-LP-2A201,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RHR-XHE-XM-ERROR
4	3.60E-10	6.03	IE-TRANS,ACP-BAC-LP-2A202,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RHR-MOV-OO-HXBPA,RSW-XHE-XL-SPVB
5	3.60E-10	6.03	IE-TRANS,ACP-BAC-LP-2A201,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RHR-MOV-OO-HXBPB,RSW-XHE-XL-SPVA
6	3.60E-10	6.03	IE-TRANS,ACP-BAC-LP-2A202,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RSW-MOV-OO-1222A,RSW-XHE-XL-SPVB
7	3.60E-10	6.03	IE-TRANS,ACP-BAC-LP-2A201,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RSW-MOV-OO-1222B,RSW-XHE-XL-SPVA
8	3.48E-10	5.84	IE-TRANS,CFAILED,CVS-XHE-XM-VENTL,ESW-MDP-CF-RUN,SWS-XHE-XO-ERROR
9	2.92E-10	4.90	IE-TRANS,CFAILED,CVS-XHE-XM-VENTL,ESW-MDP-CF-START,SWS-XHE-XO-ERROR
10	2.50E-10	4.19	IE-TRANS,CFAILED,CVS-XHE-XM-VENT,MFW-XHE-XO-ERROR,RHR-XHE-XM-ERROR
11	2.50E-10	4.19	IE-TRANS,CFAILED,CVS-XHE-XM-VENT,RHR-XHE-XM-ERROR,SWS-XHE-XO-ERROR
12	2.38E-10	3.99	IE-TRANS,CDS-AOV-CC-MKUP1,CFAILED,CVS-XHE-XM-VENT,RHR-XHE-XM-ERROR
13	2.38E-10	3.99	IE-TRANS,CDS-AOV-CC-MKUP2,CFAILED,CVS-XHE-XM-VENT,RHR-XHE-XM-ERROR
14	2.38E-10	3.99	IE-TRANS,CFAILED,CVS-XHE-XM-VENT,MFW-AOV-CC-START,RHR-XHE-XM-ERROR
15	1.11E-10	1.86	IE-TRANS,CFAILED,CVS-XHE-XM-VENTL,RHR-XHE-XM-ERROR,TBC-MDP-CF-RUN,TBC-MDP-FC-ARUN
16	1.11E-10	1.86	IE-TRANS,CFAILED,CVS-XHE-XM-VENTL,RHR-XHE-XM-ERROR,TBC-MDP-CF-RUN,TBC-MDP-FC-BRUN
17	6.55E-11	1.10	IE-TRANS,ACP-BAC-LP-2A201,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RSW-MDP-TM-PUMP1B,RSW-MDP-TM-PUMP2B,RSW-XHE-XL-SPVA

18	6.55E-11	1.10	IE-TRANS,ACP-BAC-LP-2A202,CFAILED,CVS-XHE-XM-VENTL,IAS-XHE-XM-IACIG,RSW-MDP-TM-PUMP1A,RSW-MDP-TM-PUMP2A,RSW-XHE-XL-SPVB

Cut Set Report - TRANS 52-05

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

#	CCDP	Total%	Cut Set
	5.10E-9	100	Displaying 11 Cut Sets. (11 Original)
1	3.40E-9	66.63	IE-TRANS,RPS-SYS-FC-PSOVS,SLC-XHE-XM-ERROR
2	7.60E-10	14.89	IE-TRANS,RPS-SYS-FC-RELAY,SLC-XHE-XM-ERROR
3	5.00E-10	9.80	IE-TRANS,RPS-SYS-FC-CRD,SLC-XHE-XM-ERROR
4	2.20E-10	4.31	IE-TRANS,RPS-SYS-FC-HCU,SLC-XHE-XM-ERROR
5	1.09E-10	2.14	IE-TRANS,RPS-SYS-FC-PSOVS,SLC-EPV-CF-VALVS

Referenced Events

Event	Description	Probability
ACP-BAC-LP-2A201	DIVISION I AC POWER BUS 2A201 FAILS	3.33E-5
ACP-BAC-LP-2A202	DIVISION II AC POWER BUS 2A202 FAILS	3.33E-5
ADS-XHE-XM-MDEPR	OPERATOR FAILS TO MANUALLY DEPRESSURIZE THE REACTOR	5.00E-4
CDS-AOV-CC-MKUP1	HOTWELL MAKEUP VALVE FAILS TO OPEN	9.51E-4
CDS-AOV-CC-MKUP2	HOTWELL MAKEUP VALVE FAILS TO OPEN	9.51E-4
CFAILED	CONTAINMENT FAILURE CAUSES LOSS OF ALL INJECTION	5.00E-1
CVS-XHE-XM-VENT	OPERATOR FAILS TO VENT CONTAINMENT	1.00E-3
CVS-XHE-XM-VENTL	OPERATOR FAILS TO VENT CONTAINMENT LOCALLY	3.00E-1
DCP-BCH-CF-CHRS	BATTERY CHARGERS FAIL FROM COMMON CAUSE	3.02E-7
DCP-BDC-CF-ALL	4-OF-4 125 VDC BUSES FAIL FROM COMMON CAUSE	3.98E-8
ESW-MDP-CF-RUN	ESW PUMPS FAIL FROM COMMON CAUSE TO RUN	2.32E-6
ESW-MDP-CF-START	ESW PUMPS FAIL FROM COMMON CAUSE TO START	1.95E-6
IAS-XHE-XM-IACIG	OPERATOR FAILS TO OPEN IA-CIG CROSSTIE VALVES (PSA VALUE)	2.20E-1
IE-TRANS	GENERAL PLANT TRANSIENT	1.00E+0
MFW-AOV-CC-START	FEEDWATER STARTUP VALVE FAILS TO OPERATE	9.51E-4
MFW-XHE-XO-ERROR	OPERATOR FAILS TO START/CONTROL FEEDWATER	1.00E-3
MSS-TBV-CC-BYPAS	TURBINE BYPASS VALVES FAIL TO OPEN	4.20E-3
RCI-RESTART	RESTART OF RCIC IS REQUIRED	1.50E-1
RCI-TDP-FR-TRAIN	RCIC PUMP FAILS TO RUN GIVEN THAT IT STARTED	3.95E-2
RCI-TDP-FS-RSTRT	RCIC FAILS TO RESTART GIVEN START AND SHORT-TERM RUN	8.00E-2
RCI-TDP-FS-TRAIN	RCIC PUMP FAILS TO START	6.49E-3
RCI-TDP-TM-TRAIN	RCIC TRAIN IS UNAVAILABLE BECAUSE OF MAINTENANCE	1.09E-2
RCI-XHE-XL-RSTRT	OPERATOR FAILS TO RECOVER RCIC FAILURE TO RESTART	2.50E-1
RHR-MOV-OO-HXBPA	RHR LOOP A HTX BYPASS MOV F048A FAILS TO CLOSE	9.63E-4
RHR-MOV-OO-HXBPB	RHR LOOP B HTX BYPASS MOV F048B FAILS TO CLOSE	9.63E-4
RHR-XHE-XM-ERROR	OPERATOR FAILS TO START/CONTROL RHR	5.00E-4
RPS-SYS-FC-CRD	CONTROL ROD DRIVE MECHANICAL FAILURE	2.50E-7
RPS-SYS-FC-HCU	HCU COMPONENTS FAIL	1.10E-7
RPS-SYS-FC-PSOVS	HCU SCRAM PILOT SOVS FAIL	1.70E-6
RPS-SYS-FC-RELAY	TRIP SYSTEM RELAYS FAIL	3.80E-7
RRS-CRB-CC-PUMP1	RECIRC PUMP 1 FIELD BREAKER FAILS TO OPEN	2.39E-3
RRS-CRB-CC-PUMP2	RECIRC PUMP 2 FIELD BREAKER FAILS TO OPEN	2.39E-3
RSW-MDP-TM-PUMP1A	RHRSW PUMP TRAIN 1A IS IN TEST OR MAINT	1.32E-2
RSW-MDP-TM-PUMP1B	RHRSW PUMP TRAIN 1B IS IN TEST OR MAINT	1.32E-2
RSW-MDP-TM-PUMP2A	RHRSW PUMP TRAIN 2A IS IN TEST OR MAINT	1.32E-2
RSW-MDP-TM-PUMP2B	RHRSW PUMP TRAIN 2B IS IN TEST OR MAINT	1.32E-2

RSW-MOV-OO-1222A	RHRSW/ESW SPRAY POND VALVE HV-01222A FAILS TO CLOSE	9.63E-4
RSW-MOV-OO-1222B	RHRSW/ESW SPRAY POND VALVE HV-01222B FAILS TO CLOSE	9.63E-4
RSW-XHE-XL-SPVA	OPERATOR FAILS TO MANUALLY STROKE SPRAY POND NETWORK A VLVS	3.40E-1
RSW-XHE-XL-SPVB	OPERATOR FAILS TO MANUALLY STROKE SPRAY POND NETWORK B VLVS	3.40E-1
SLC-EPV-CF-VALVS	SLC SQUIB VALVES FAIL FROM COMMON CAUSE	6.42E-5
SLC-XHE-XM-ERROR	OPERATOR FAILS TO START/CONTROL SLC	2.00E-3
SWS-XHE-XO-ERROR	OPERATOR FAILS TO MAINTAIN SERVICE WATER FLOW	1.00E-3
TBC-MDP-CF-RUN	TBCCW PUMPS FAIL FROM COMMON CAUSE TO RUN	2.95E-6
TBC-MDP-FC-ARUN	TBCCW PUMP A IS RUNNING, PUMP B IS IN STANDBY	5.00E-1
TBC-MDP-FC-BRUN	TBCCW PUMP B IS RUNNING, PUMP A IS IN STANDBY	5.00E-1

Appendix B: Key Event Tree

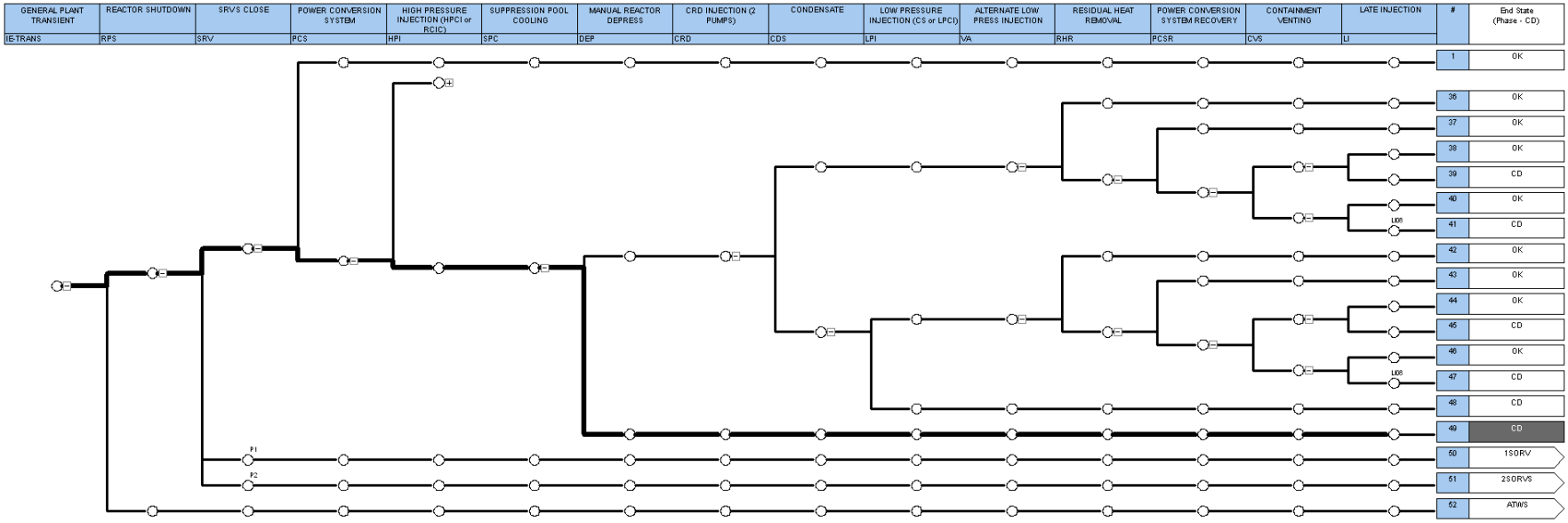

Figure 1: Transient Event Tree (Sequence 49 in bold)