Final ASP Analysis–Reject

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research		
Fermi 2 Power Plant	Concurrent Failures of the Division ‘II’ EDG Load Sequencer, Battery Charger, and HPCI	
Event Date: 8/22/2021	**LER:** 341-21-002 **IR:** TBD	**ΔCDP =** 4×10^{-7}
Plant Type:	General Electric Type 4 Boiling-Water Reactor (BWR) with a Mark I Containment	
Plant Operating Mode (Reactor Power Level):	Mode 1 (100% Reactor Power)	
Analyst: Christopher Hunter	**Reviewer:** Dale Yeilding	**Completion Date:** 6/7/2022

1 EVENT DETAILS

1.1 Event Description

On August 22, 2021, main control room (MCR) alarms occurred for the division ‘II’ emergency diesel generator (EDG) load sequencer and the high-pressure coolant injection (HPCI) inverter circuit. These issues led to division ‘II’ EDGs and HPCI being declared inoperable per Technical Specification (TS) 3.8.1, “Alternating Current (AC) Sources – Operating,” Required Action B.4 and TS 3.5.1, “Emergency Core Cooling Systems (ECCS) – Operating,” Condition E.1, respectively.

The initial licensee investigation identified blown fuses associated with the power supplies of both the division ‘II’ EDG load sequencer and HPCI. Licensee personnel replaced the fuses; however, the fuses failed again. The blown replacement fuses were removed, and additional troubleshooting activities were performed. During these troubleshooting activities, a direct current (DC) low voltage alarm was received in the MCR, which alerted operators that division ‘II’ battery charger 2B-2 had failed. The division ‘II’ battery charger was declared inoperable, and TS 3.8.4, “DC Sources – Operating,” Condition A was entered. In addition, the division ‘II’ DC electrical power distribution subsystem was also declared inoperable due to low voltage and TS 3.8.7, “Distribution Systems – Operating,” Condition B was entered.

The failed battery charger was replaced with an available spare and, therefore, the division ‘II’ battery charger was restored to an operable status on August 23rd and TS 3.8.4, Condition A was exited. In addition, replacement of the battery charger with the spare also stabilized voltage on the division ‘II’ DC electrical power distribution subsystem such that TS 3.8.7, Condition B was exited.

Following replacement of the division ‘II’ battery charger, the power supplies for the division ‘II’ EDG load sequencer and HPCI Inverter were replaced. The division ‘II’ EDG load sequencer was restored to service and the EDGs were declared operable on August 23rd. HPCI was restored to service and declared operable on August 24th. Additional information is provided in licensee event report (LER) 341-21-002, “Unplanned Inoperability of High-Pressure Coolant Injection System Due to an Inverter Circuit Failure,” (ML21294A060).

Cause. The causes of the failures of the HPCI, Division 'II' EDG Sequencer, and Division 'II' battery charger are currently unknow and are still under investigation. See LER 341-21-002 for additional information.

2 MODELING

2.1 SDP Results/Basis for ASP Analysis

The ASP Program uses SDP results for degraded conditions when available (and applicable). To date, issued inspection reports for Fermi 2 Power Plant do not provide additional information on this event. Discussions with Region 3 staff indicated that no performance deficiency has been identified to date; however, the LER remains open. An independent ASP analysis was performed because there was no performance deficiency identified and there were concurrent degraded conditions. A search of additional Fermi LERs did not reveal any additional "windowed" events.

2.2 Analysis Type

A condition analysis was performed using a test and limited use revision of the standardized plant analysis risk (SPAR) model for Fermi 2 Power Plant (Version 8.62) created in April 2022. This SPAR model includes the following hazards:

- Internal events,
- Internal floods,
- Internal fires,
- Seismic, and
- High winds (including tornados).

2.3 SPAR Model Modifications

The following modifications were made to the SPAR model for this analysis:

- *Crediting FLEX Strategies*. The probability of basic event FLX-XHE-XE-ELAP (*operators fail to declare ELAP when beneficial*) was set to its nominal value of 10^{-2} to activate the credit for FLEX mitigation strategies for postulated station blackout (SBO) scenarios for which an extended loss of AC power (ELAP) is declared.

- *Removal of Credit for Redundant FLEX N+1 Train*. The base SPAR models credit both the FLEX N and N+1 trains of equipment. It is unknown whether Fermi operators would have sufficient time to move and connect the N+1 redundant train equipment prior to battery depletion given a postulated failure of the N train equipment. Therefore, the credit for the FLEX N+1 train equipment was eliminated for this analysis, which is potentially conservative. A review of the results indicate that this potential conservatism has a negligible effect on the results of this analysis.

- *FLEX Reliability Parameters*. The base SPAR models currently use the reliability parameters of permanently installed equipment as placeholders for FLEX equipment because FLEX-specific reliability parameters were not available when the FLEX logic was incorporated into the SPAR models. The FLEX reliability parameters used in this analysis were updated based on the generic values provided in PWROG-18043-NP, "FLEX Equipment Data Collection and Analysis," (ML22123A259).

- *Removal of EDG Repair Credit for ELAP Scenarios*. The base SPAR model provides credit for repair of postulated EDG failures for SBO scenarios. However, this potential credit is not applicable for scenarios where ELAP will be declared because (a.) operators will be focused on implementing the FLEX mitigation strategies and (b.) the DC load shedding activities could preclude recovery of EDGs. Therefore, credit for EDG repair credit was removed from the sequences if it is included after ELAP is likely declared (i.e., 1 hour).

- *72-Hour AC Power Recovery Requirement*. The base SPAR model requires AC power recovery within 72 hours for a safe/stable end state for ELAP scenarios with successful FLEX implementation. If AC power is not recovered in these scenarios, the SPAR models assume core damage. The American Society of Mechanical Engineers/American Nuclear Society probabilistic risk assessment standard definition for safe/stable end state does not require AC power recovery. Because of the large uncertainty in modeling assumptions related to availability and reliability of components and strategies for mission times that are well beyond 24 hours and the unclear basis for requiring AC power recovery within 72 hours, the 72-hour AC power requirement was eliminated in this analysis. As part of this change, the FTR events for FLEX diesel generators and pumps have a 72-hour mission time in the base SPAR model. These mission times were reset to be consistent with the 24-hour mission time used in the SPAR model.

- *SPAR Model Quantification Issues.* A review of preliminary analysis results revealed some additional SPAR model issues that required changes. First, the RCIC fault tree transfer was eliminated from the FLEX-TDP fault tree. Second, basic event FLX-XHE-XL-RECOSP (*operator fails to restore offsite power following flex operation (ELAP)*) was set to FALSE.

2.4 Exposure Time

The following table provides the key dates and times associated with the failures of the division 'II' EDG load sequencer, HPCI, and division 'II' battery charger 2B-2.

Table 1. Failure Dates and Times

Date	Time	Description
August 22, 2021	0529	MCR alarms indicate that the division 'II' EDG load sequencer and HPCI power supplies fuses had failed.
August 22, 2021	2223	DC low voltage alarm indicated that division 'II' battery charger 2B-2 had failed.
August 23, 2021	0046	Division 'II' battery charger was replaced.
August 23, 2021	2132	Division 'II' EDG load sequencer power supply fuses were replaced.
August 24, 2021	0956	HPCI power supply fuses were replaced.

Based on this information, the following four exposure times were identified for this condition analysis:

- *Exposure Time 1*. This period represents the time of when the division 'II' EDG load sequencer, HPCI, and division 'II' battery charger 2B-2 were failed concurrently from August 22nd at 2223 until August 23rd at 0046 (i.e., 2 hours and 23 minutes).

- *Exposure Time 2*. This period represents the time of when the division 'II' EDG load sequencer and HPCI were failed concurrently from August 22nd at 0529 until August 23rd at 2132 minus Exposure Time 1 (i.e., 37 hours and 37 minutes).

- *Exposure Time 3*. This period represents the time of when HPCI was failed by itself from August 23rd at 2132 until August 24th at 0956 (i.e., 12 hours and 24 minutes).

2.5 Analysis Assumptions

The following assumptions were determined to be significant to the modeling of this condition assessment:

- Basic event DCP-BCH-LP-2B2 (*division II battery charger 2B-2 fails*) was set to TRUE for Exposure Time 1.

- Basic event DCP-BCH-TM-2B12 (*division II spare battery charger is unavailable*) was set to TRUE for Exposure Times 2 and 3 because the division 'II' spare battery charger was not available after being put into service.

- The failed HPCI power supply is assumed to be within the HPCI pump component boundary. Therefore, basic event HCI-TDP-FS-TRAIN (*HPCI pump fails to start*) was set to TRUE for all three exposure times.

- The failure division 'II' EDG load sequencer power supply is assumed to be within the EDG sequencer component boundary. Therefore, basic event EPS-SEQ-FO-DIVII (d*ivision II DG load sequencer fails to operate*) was set to TRUE for Exposure Times 1 and 2.

- During a postulated loss of offsite power (LOOP) to the division 'II' safety buses, EDGs '13' and '14' would have started automatically, and their respective loads would have been properly shed. However, the failed sequencer would have prevented the loads from being automatically sequenced back on to the buses. Plant procedures and training direct MCR operators to manually add these loads if automatic function fails. Therefore, the human error probability (HEP) for existing human failure event EPS-XHE-XL-SEQDIVII (*operator fails to recover division II DG load sequencer*) was set to 1×10^{-2} based on an evaluation using IDHEAS-ECA for Exposure Times 1 and 2. Details regarding this evaluation are provided in the following table.

Table 2. IDHEAS-ECA Evaluation of EPS-XHE-XL-SEQDIVII

Name	EPS-XHE-XL-SEQDIVII
Definition	Operator fails to recover division 'II' EDG load sequencer. The starting point for this task is when the LOOP to the division 'II' safety buses occur (i.e., T = 0). The ending point for this task is when operators completed sequence all required loads onto the division 'II' EDGs with the associated EDG service water pumps the most time critical.

Description/ Event Context	Consistent with this degraded condition, the division ‘II’ EDG load sequencer failure occurred prior to any postulated initiating event. Therefore, operators were aware of the need to manually sequence loads due to the fault alarm associated with the sequencer circuit. If offsite power is lost to the division ‘II’ safety buses, the division ‘II’ EDGs (i.e., EDGs ‘13’ and ‘14’) will start on undervoltage. Given the observed failure of the division ‘II’ EDG sequencer, the division ‘II’ EDGs would still successfully start, their associated loads of the safety buses would be shed, and the output breakers would close. However, operators would need to manually sequence the required loads onto the safety buses. Since this ASP analysis is of concurrent degraded conditions, a range of initiating events from internal event, internal flood, internal fire, high wind, and seismic hazards is considered. The dominant risk contributors are internal fires and internal events. Therefore, the most complex initiating event context from the dominant accident sequences was assumed for the evaluation of the cognitive failure modes (CFMs) and performance influencing factors (PIFs) below. Specifically, this evaluation focused on dominant internal fire scenarios. However, based on the review of the dominant internal fire accident sequences, this task would occur very early in the scenario and, therefore, any of the dominant fire events would not be expected to negatively affected operator performance.
Success Criteria	Operator successfully sequences necessary loads onto the division ‘II’ safety buses given a demand of the division ‘II’ EDGs in time to prevent damage to the diesels.
Key Cue(s)	• Sequencer fault alarm • LOOP to the division ‘II’ safety buses and associated annunciators • Start of division ‘II’ EDGs and associated annunciators
Procedural Guidance	• AOPs 20.300.65E and 20.300.65F, “Loss of Bus 65E” and “Loss of Bus 65F” provide notes on the requirement to restore service water to the EDGs within 3 minutes to prevent damage to the diesels. However, explicit guidance to start the EDG service water pump is not provided. Operators were aware that sequencer was failed and that a service water pump must be started quickly given a demand.
Critical Task(s)	Operator manually sequences loads onto the division ‘II’ EDGs.
Task Analysis	**Detection –** This task requires the operators to detect the key alarms and annunciators given the various initiating events that could occur. **Understanding –** This task requires the operators to integrate the various cues to determine that a LOOP to the division ‘II’ safety buses occurred and that loads must be manually sequenced onto the division ‘II’ EDGs. **Decisionmaking –** Decisionmaking is not required for this task because with correct understanding of the event, operators would have an obvious decision to manually sequence loads for the division ‘II’ EDGs. Therefore, this CFM is not applicable for this task. **Action Execution –** This task requires the operators to manually sequence loads for the division ‘II’ EDGs. **Interteam Coordination –** Interteam coordination is not required for this task because multiple teams would not be involved. Therefore, this CFM is not applicable for this task. The applicable CFMs are: *CFM1 – Failure of Detection* *CFM2 – Failure of Understanding* *CFM4 – Failure of Action Execution*

Evaluation of PIFs for the Applicable CFMs	**Detection (*P_{CFM1} = 3×10^{-3}*)** • Scenario Familiarity – No impact because operators are routinely trained in LOOP scenarios and the expected cues. • Task Complexity – *C1: Detection overload with multiple competing signals (1: Few < 7); Multiple annunciators associated with postulated initiating events that result in LOOP to division 'II' safety buses.* • The other PIFs were evaluated to not have a significant impact on this task. **Understanding (*P_{CFM2} = 1×10^{-3}*)** • Scenario Familiarity – No impact because the LOOP cues along with the sequencer fault alarm received prior to the LOOP alerted operators to the need to manually sequence associated division 'II' EDG loads, especially the service water pumps. • Information Completeness and Reliability – No impact because the MCR alarms and annunciators are sufficient to diagnose the LOOP and the division 'II' EDG sequencer failure. • Task Complexity – *No impact; Although there was no specific procedure path to manually sequencer division 'II" loads if a postulated LOOP were to occur, operators (due to their training and the sequencer fault alarm prior to the postulated initiating event) were already aware of the need to manually sequence loads for the division 'II' EDGs.* • The other PIFs were evaluated to not have a significant impact on this task. **Action Execution (*P_{CFM4} = 2.2×10^{-4}*)** • Scenario Familiarity – No impact because operators are trained on the need of having service water to cool the EDGs. • Task Complexity – No impact because the actions are relatively simple for operators (e.g., manipulation of a few switches). • Procedures and Guidance – *PG3: Procedure lacks details; this PIF was selected given the lack of clear procedure path to manually sequence loads for the division 'II' EDGs.* • The other PIFs were evaluated to not have a significant impact on this task. Using these assumptions, P_c was calculated as 4×10^{-3}.
Timing Evaluation	Operators would need to start a service water pump to both division 'II EDGs within 3 minutes to prevent damage to the diesels. Other loads would need to be restored as well, but operators would have at least 30 minutes to complete the other actions. Based on conversations with NRC inspectors, it would be expected that it would take operators approximately 1 minute to get through the reactor trip immediate actions before acting to manually sequence the division 'II' EDG loads. It would take operators approximately 30 seconds to initiate the EDG service water pumps for EDGs '13' and '14'. Additional loads would need to be manually sequenced; however, operators would have at least 30 minutes to complete this action. Therefore, the T_{reqd} = 1.5 minutes (median) and the T_{avail} = 3 minutes (single value). The current IDHEAS-ECA guidance recommends using a lognormal distribution for the time values that use a distribution; however, the current IDHEAS-ECA software does not have this capability yet. So, P_t was calculated using an OpenBUGS script using lognormal distribution parameters recommended by PNNL-32384 for T_{reqd} (σ = 0.28 and μ = 0.41). Using these assumptions, P_t was calculated as 7×10^{-3}. Note that the P_t would have been higher if a T_{avail} was considered as a distribution as well; however, there was no information available that damage the EDGs would occur prior to 3 minutes.
Recovery	Recovery credit is not provided for this task.
Calculated HEP	HEP = $1 - (1 - P_c)(1 - P_t) = 1 - (1 - 4\times10^{-3})(1 - 7\times10^{-3}) = 1\times10^{-2}$

3 ANALYSIS RESULTS

3.1 Results

The overall mean ΔCDP for this analysis is calculated to be 4×10^{-7}, which is the sum of the three exposure times. The ASP Program threshold is 1×10^{-6} for degraded conditions; therefore, this event is not a precursor. The parameter uncertainty results for each exposure time are provided below:

Table 3. Parameter Uncertainty Results (ΔCDP) for Exposure Times 1, 2, and 3

Exposure Time	5%	Median	Point Estimate	Mean	95%
1	1.1×10^{-8}	8.1×10^{-8}	1.5×10^{-7}	1.6×10^{-7}	5.8×10^{-7}
2	3.5×10^{-8}	1.4×10^{-7}	1.8×10^{-7}	1.8×10^{-7}	4.5×10^{-7}
3	1.0×10^{-10}	7.0×10^{-9}	1.1×10^{-8}	1.1×10^{-8}	4.0×10^{-8}

3.2 Dominant Hazards[1]

The dominant hazards for this analysis are internal fires (ΔCDP = 1.7×10^{-7}) and internal events (ΔCDP = 1.7×10^{-7}), which contribute approximately 51 percent and 49 percent of the total ΔCDP, respectively. Internal flooding, seismic hazards, and high winds (including tornadoes) are negligible contributors to the overall ΔCDP for this analysis.

3.3 Dominant Sequences

The dominant accident sequence is TRANS sequence 60 (ΔCDP = 6.6×10^{-8}), which contributes approximately 19 percent of the total ΔCDP. The dominant sequence is shown in the table below and graphically in Figure A-1 in Appendix A. Accident sequences that contribute at least 5 percent of the total ΔCDP are also included in the table.

Table 4. Dominant Sequences

Sequence	ΔCDP	%	Description
TRANS 60	6.6×10^{-8}	19.2%	A general transient initiating event occurs; HPCI is unavailable due to its failed power supply; postulated common-cause failure of the battery chargers results in a loss of all DC power that causes the failure of standby feedwater (SFW), reactor core isolation cooling (RCIC), and reactor depressurization resulting in core damage.
FRI-AB11E-4 2-59	3.1×10^{-8}	9.0%	A fire in miscellaneous room AB11E results in loss of condenser heat sink and a failure division 'I' DC power results in the failure of SFW and RCIC; HPCI is unavailable due to its failed power supply; postulated DC electrical failures or operator error leads to the failure of reactor depressurization resulting in core damage.
FRI-AB04N-2 2-61	2.7×10^{-8}	7.7%	A fire in division '1' switchgear room results in a LOOP and a failure of a division 'I' AC safety bus; the failed division 'II' EDG sequencer with operators failing to manually sequence loads results in the loss of both division 'II' safety buses; additional electrical failures result in the subsequent loss of DC power results in the failure of SFW and RCIC (HPCI is unavailable due to its failed power supply); operators successfully depressurize the reactor; low-pressure coolant injection (LPCI) and low-pressure core spray (LPCS) are unavailable; alternate injection is successful, but containment venting fails due to the lack of DC power resulting in core damage.

1 The ΔCDP presented in Sections 3.2 and 3.3 are point estimates.

Sequence	ΔCDP	%	Description
FRI-AB04N-2 2-20[2]	2.0×10^{-8}	5.9%	A fire in division '1' switchgear room results in a LOOP and a failure of a division 'I' AC safety bus; the failed division 'II' EDG sequencer with operators failing to manually sequence loads results in the loss of both division 'II' safety buses; additional electrical failures result in the subsequent loss of DC power results in the failure of SFW (HPCI is unavailable due to its failed power supply), but RCIC is successful; suppression pool cooling is unavailable; operators successfully depressurize the reactor; shutdown cooling, alternate injection, and containment venting are unavailable resulting in core damage.
FRI-MCR-SF 2-66-07	1.9×10^{-8}	5.6%	Fire in MCR results in a LOOP and a failure of the division 'I' safety buses; the failed division 'II' EDG sequencer with operators failing to manually sequence loads results in the loss of both division 'II' safety buses and a subsequent SBO; RCIC fails (HPCI is unavailable due to its failed power supply); operators fail to restore AC power within 30 minutes results in core damage.

3.4 Key Uncertainties

It is believed that results from internal fire hazards are likely conservative due to the vintage of the fire modeling in the Fermi SPAR model, which is largely based on the results of the individual plant examinations of external events (IPEEEs) that was completed in 1996 for Fermi. Observations from NRC analysts indicate that the SPAR models overall internal fire core damage frequency (CDF) can often be relatively close to the CDF of updated licensee fire models. However, the risk of individual fire scenarios can often be significantly different. It is unknown how these potential conservatisms affected the results of this analysis. However, since the results are believed to be conservative and the overall ΔCDP was less that the precursor threshold, no further evaluation was performed.

2 The cut sets for this sequence are identical to those in sequence FRI-AB04N-2 2-61; however, this error does not have a significant effect on the overall results of this analysis. Idaho National Laboratory is investigating this issue.

Appendix A: Key Event Tree

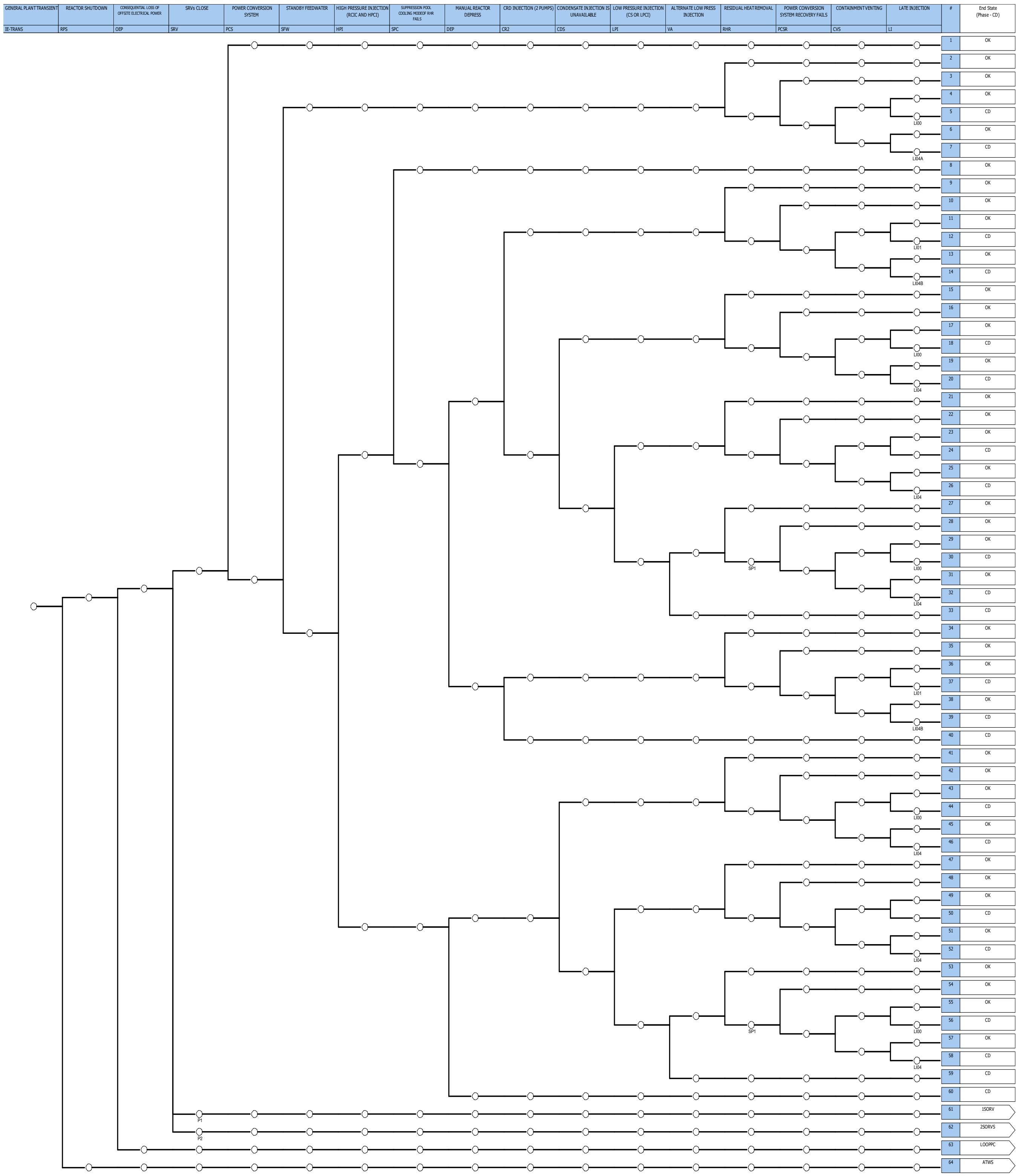

Figure A-1. Fermi General Transient Event Tree