Final Precursor Analysis

Accident Sequence Precursor Program --- Office of Nuclear Regulatory Research

Perry	Automatic Reactor Trip and Loss of Offsite Power Due to the August 14, 2003, Transmission Grid Blackout	
Event Date 8/14/2003	LER: 440/03-002	CCDP[1] = 3×10⁻⁵

December 17, 2004

Event Summary

At 1610 hours on August 14, 2003, Perry experienced a disturbance on the electrical grid and a subsequent main generator trip followed by a turbine trip and a reactor trip while operating at 100% power. Plant emergency diesel generators (EDGs) started and supplied power to safety-related plant loads until offsite power was restored. Attachment A is a timeline of significant events. (Refs. 1 and 2).

Cause.   The reactor trip and loss of offsite power (LOOP) were caused by grid instability associated with the regional transmission system blackout that occurred on August 14, 2003.

Other conditions, failures, and unavailable equipment. Residual heat removal (RHR) train A was inoperable for approximately 6 hours because of air binding in the keep-fill system pump. The low-pressure core spray (LCS) system was also affected by the air binding in the keep-fill system pump, but the LCS system was recoverable from the start of the LOOP (Refs. 3 and 4). Approximately 3 hours into the event, the reactor core isolation cooling (RCIC) turbine-driven pump was manually secured to prevent an automatic shutdown on high steam tunnel temperature. The steam tunnel temperature was caused by a loss of ventilation.

The Division 1 EDG tripped on reverse power while being removed from service. This had no effect on the conditional core damage probability (CCDP) for this event; it will be analyzed as a separate Accident Sequence Precursor (ASP) analysis.

Recovery opportunities. Offsite power was first available at 1737 hours when one transmission yard breaker was closed. Offsite power was restored to the Division 1 emergency bus at 1813 hours on August 14, to the Division 3 emergency bus at 1214 hours on August 15, and to the Division 2 emergency bus at 1548 hours on August 15.

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[1] For the initiating event assessment, the parameter of interest is the measure of the CCDP. This is the value obtained when calculating the probability of core damage for an initiating event with subsequent failure of one or more components following the initiating event. The value reported here is the mean.

Analysis Results

- **Conditional Core Damage Probability (CCDP)**

  The CCDP for this event is 3×10^{-5}. The acceptance threshold for the ASP Program is a CCDP of 1×10^{-6}. This event is a precursor.

	Mean	5%	95%
Best estimate	**3×10^{-5}**	1×10^{-6}	1×10^{-4}

- **Dominant Sequences**

  The dominant core damage sequences for this assessment are LOOP sequences 30 (44.4% of the total CCDP) and LOOP sequence 21 (30.7% of the total CCDP). The LOOP event tree is shown in Figure 1.

  The events and important component failures in LOOP Sequence 30 are:

  – loss of offsite power occurs,
  – reactor shutdown succeeds,
  – emergency power is available,
  – safety relief valves (SRVs) reclose after opening
  – high-pressure core spray (HPCS) fails,
  – reactor core isolation cooling (RCIC) fails,
  – manual depressurization succeeds, and
  – low pressure injection fails.

  The events and important component failures in LOOP Sequence 21 are:

  – loss of offsite power occurs,
  – reactor shutdown succeeds,
  – emergency power is available,
  – SRVs reclose after opening,
  – HPCS fails,
  – RCIC succeeds,
  – suppression pool cooling (SPC) fails,
  – manual depressurization succeeds,
  – low pressure injection fails, and
  – alternate low pressure injection fails.

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● **Results Tables**

–   The CCDP values for the dominant sequences are shown in Table 1.
–   The event tree sequence logic for the dominant sequences is presented in Table 2a.
–   Table 2b defines the nomenclature used in Table 2a.
–   The most important cut sets for the dominant sequences are listed in Table 3.
–   Table 4 presents names, definitions, and probabilities of (1) basic events whose probabilities were changed to update the referenced SPAR model, (2) basic events whose probabilities were changed to model this event, and (3) basic events that are important to the CCDP result.

Modeling Assumptions

● **Assessment Summary**

This event was modeled as a LOOP initiating event. Rev. 3.10 (SAPHIRE 7) of the Perry SPAR model (Ref. 5) was used for this assessment. The specific model version used as a starting point for this analysis is dated December 10, 2004.

RHR Train A, LCS, and RCIC were inoperable at various times during the LOOP. Since this event involves a LOOP of significant duration, probabilities of nonrecovery of offsite power at different times following the LOOP are important factors in the estimation of the CCDP.

Best Estimate: Offsite power was available in the switchyard approximately 90 minutes after the LOOP. The first safety bus was returned to offsite power at 1813 (2 hours after the LOOP). Failure to recover offsite power to plant safety-related loads (if needed because EDGs fail to supply the loads), given recovery of power to the switchyard, could result from (1) operators failing to restore proper breaker line-ups, (2) breakers failing to close on demand, or (3) a combination of operator and breaker failures. The dominant contributor to failure to recover offsite power to plant safety-related loads in this situation is operators failing to restore proper breaker line-ups. This analysis assumed that at least 30 minutes are necessary to restore power to an emergency bus given that offsite power is available in the switchyard. The time available for operators to restore proper breaker line-ups to prevent core damage is dependent on specific accident sequences and is modeled as such using the SPAR human reliability model (Ref. 6). Assumptions described below, combined with the assumption of offsite power restoration described above, form the bases for the LOOP nonrecovery probabilities.

● **Important Assumptions**

Important assumptions regarding power recovery modeling include the following:

–   No opportunity for the recovery of offsite power to safety-related loads is considered for any time prior to power being available in the switchyard.
–   At least 30 minutes are required to restore power to emergency loads after power is available in the switchyard.
–   SPAR models do not credit offsite power recovery following battery depletion.

The GEM program used to determine the CCDP for this analysis will calculate probabilities of recovering offsite power at various time points of importance to the analysis based on historical data for grid-related LOOPs. In this analysis, this feature was overridden; offsite power recovery probabilities were based on (1) known information about when power was restored to the switchyard and (2) use of the SPAR human error model to estimate probabilities of failing to realign power to emergency buses for times after power was restored to the switchyard.

Attachment B is a procedure for analysis of LOOP events in the ASP Program. Attachment C is a description of the approach to estimating offsite power recovery probabilities.

- **Event Tree and Fault Tree Modifications**

  Train A of RHR (RHR-A) was inoperable for the first 6 hours of the event because of air binding in the keep-fill system pump. After 6 hours, RHR-A was operable. Failure of the keep-fill system is not modeled in the RHR-A fault tree of the base SPAR model; therefore, the RHR-A fault tree was updated to include this failure mode. The updated RHR-A fault tree is shown in Figure 2. For this analysis, the recovery of train A of RHR was credited for long-term LOOP sequences. The following project rules were created to apply the recovery to long-term LOOP sequences:

  > *if INIT(IE-LOOP) * system(CVS) * RHR-A-KEEP-FILL then*
  >   *DeleteEvent = RHR-A-KEEP-FILL;*
  >   *AddEvent = RHR-A-KEEP-FILL-REC;*
  > *elsif INIT(IE-LOOP) * system(CSS) * RHR-A-KEEP-FILL then*
  >   *DeleteEvent = RHR-A-KEEP-FILL;*
  >   *AddEvent = RHR-A-KEEP-FILL-REC;*
  > *endif*

  Additionally, the LCS pump train was affected by the failure of the keep-fill system; however the LCS pump train was immediately recoverable. Like RHR-A, failure of the keep-fill system is not modeled in the LCS fault tree of the base SPAR model; therefore, the LCS fault tree was updated to include this failure mode. The updated LCS fault tree is shown in Figure 3. The three basic events involved in the these two changes are included in the basic event probability changes section.

- **Basic Event Probability Changes**

  Table 4 includes basic events whose probabilities were changed to reflect the event being analyzed. The bases for these changes are as follows:

  – ***LCS pump train is unavailable because of keep-fill system failure (LCS-KEEP-FILL).*** This event represents the failure of the LCS pump train due to the keep-fill system failures. Since the LCS pump train was immediately recoverable, recovery of the system was credited. Using the SPAR human error model to determine the value (see Attachment D), LCS-KEEP-FILL was set to 2.1×10^{-1}. This is assumed to be the mean of a constrained noninformative distribution.

  – ***Probability of failure to recover offsite power in 30 minutes (OEP-XHE-XL-NR30M).*** During the event, offsite power was not available in the switchyard until

1.5 hours after the LOOP. Therefore, there was no opportunity to recover offsite power in 30 minutes and OEP-XHE-XL-NR30M was set to TRUE.

– **_Probability of failure to recover offsite power in 1 hour (OEP-XHE-XL-NR01H)._** During the event, offsite power was not available in the switchyard until 1.5 hours after the LOOP. Therefore, there was no opportunity to recover offsite power in 1 hour and OEP-XHE-XL-NR01H was set to TRUE.

– **_Probability of failure to recover offsite power in 3 hours (OEP-XHE-XL-NR03H)._** During the event, offsite power was not available in the switchyard until 1.5 hours after the LOOP. Therefore, the operators had approximately 1.5 hours to recover offsite power to the vital safety buses. Using the SPAR human error model to determine the value (see Attachment C), OEP-XHE-XL-NR03H was set to 1.0×10^{-2}.

– **_Probability of failure to recover offsite power in 7 hours (OEP-XHE-XL-NR07H)._** During the event, offsite power was not available in the switchyard until 1.5 hours after the LOOP. Therefore, the operators had approximately 6.5 hours to recover offsite power to the vital safety buses. Using the SPAR human error model to determine the value (see Attachment C), OEP-XHE-XL-NR07H was set to 1.0×10^{-3}.

– **_Probability of failure to recover offsite power in 16 hours (OEP-XHE-XL-NR016H)._** During the event, offsite power was not available in the switchyard until 1.5 hours after the LOOP. Therefore, the operators had approximately 14.5 hours to recover offsite power to the vital safety buses. Using the SPAR human error model to determine the value (see Attachment C), OEP-XHE-XL-NR16H was set to 1.0×10^{-3}.

– **_Probability that restart of RCI is required (RCI-RESTART)._** During the event, RCI and HPCS automatically started to provide flow to the reactor vessel. Upon reaching level 8 in the reactor, both systems were isolated. RCIC was later used to provide makeup inventory to the reactor. Since RCI restart occurred, RCI-RESTART was set to TRUE.

– **_Probability of RCI TDP failing to run (RCI-TDP-FR-TRAIN)._** Approximately 5 hours into the event, the RCIC turbine-driven pump was automatically isolated because of high steam tunnel temperature due to a loss of ventilation. Therefore, RCI-TDP-FR-TRAIN was set to TRUE.

– **_Probability of operator failing to recover failure of RCI to run (RCI-XHE-XL-RUN)._** This event represents the probability that an operator fails to recover the failure of the RCI TDP to run. During this event, the RCI TDP was taken offline, not because of mechanical failure, but because of an inhospitable plant environment (high steam tunnel temperature). Therefore, for this analysis, RCI-XHE-XL-RUN was updated to represent a composite of two distinct failure modes, mechanical failure and inhospitable plant environment. The mechanical failure portion was calculated by multiplying the probability of mechanical failure (1.2×10^{-2}) by the probability of operator recovery of mechanical failure (5.0×10^{-1}), yielding an overall mechanical failure probability of 6.0×10^{-3}. The probability of the operator failing to recover the RCI TDP from the inhospitable plant environment was calculated using

the SPAR human error model to determine the diagnosis and recovery value, 5.5×10^{-3} (see Attachment C). RCI-XHE-XL-RUN was set to the sum of the two probabilities, 1.15×10^{-2}.

– ***RHR-A is unavailable because of keep-fill system failures (RHR-A-KEEP-FILL).***
This event represents the short-term failure-to-run (< 6 hours) of the RHR train A. Since the pump was unavailable for the first 6 hours, RHR-A-KEEP-FILL was set to 1.0. (Note: Due to the way that the GEM program applies recovery rules, RHR-A-KEEP-FILL must be set to 1.0, not TRUE.)

– ***RHR-A train keep-fill nonrecovery after 6 hours (RHR-A-KEEP-FILL-REC).*** This event represents the long-term (> 6 hours) failure-to-recover the keep-fill system. Since the RHR system was available after the first 6 hours, long-term recovery of the system was credited. Using the SPAR human error model to determine the value (see Attachment D), RHR-A-KEEP-FILL-REC was set to 2.1×10^{-1}. This is assumed to be the mean of a constrained noninformative distribution.

– ***Probability of diesel generators failing to run (ZT-DGN-FR-L).*** The default diesel generator mission times were changed to reflect the actual time to recover power to the first safety bus (approximately 2 hours). Since the overall fail-to-run is made up of two separate factors, the mission times for the factors were set to the following: ZT-DGN-FR-E = 1 hour (base case value) and ZT-DGN-FR-L = 8.75 hours.

References

1. Licensee Event Report 440/03-002, Revision 1, *Reactor Scram Due to Electric Grid Disturbance*, event date December 2, 2003 (ADAMS Accession No. ML033530117).

2. NRC Region 1 Grid Special Report, October 15, 2003 (ADAMS Accession No. ML0324102160).

3. NRC Special Inspection Report 440/03-009, October 10, 2003 (ADAMS Accession No. ML032880107).

4. Licensee Event Report 440/03-005, Revision 1, *Technical Specification Violation/Loss of Safety Function due to Air Bound Water-leg Pump*, event date October 31, 2003 (ADAMS Accession No. ML040070073).

5. J. A. Schroeder, *Standardized Plant Analysis Risk Model for Nine Mile Point 2 (ASP BWR C)*, Revision 3.10, December 2004.

6. D. Gertman, et al., *SPAR-H Method*, INEEL/EXT-02-10307, Draft for Comment, November 2002 (ADAMS Accession No. ML0315400840).

Table 1. Conditional probabilities associated with the highest probability sequences.

Event tree name	Sequence no.	Conditional core damage probability (CCDP)[1]	Percentage contribution
LOOP	30	1.2×10^{-5}	44.4%
LOOP	21	8.3×10^{-6}	30.7%
Total (all sequences)[2]		**2.7×10^{-5}**	

1. Values are point estimates. (File name: GEM 440-03-002 12-13-2004.wpd)
2. Total CCDP includes all sequences (including those not shown in this table).

Table 2a. Event tree sequence logic for the dominant sequences.

Event tree name	Sequence no.	Logic ("/" denotes success; see Table 2b for top event names)
LOOP	30	/RPS, /EPS, /SRV, HCS, RCI, /DEP, LPI
LOOP	21	/RPS, /EPS, /SRV, HCS, /RCI, SPC, /DEP, LPI, VA

Table 2b. Definitions of fault trees listed in Table 2a.

DEP	MANUAL DEPRESSURIZATION FAILS
EPS	LOSS OF ONSITE EMERGENCY POWER
HCS	HPCS FAILS TO PROVIDE SUFFICIENT FLOW TO REACTOR VESSEL
LPI	LOW-PRESSURE INJECTION IS UNAVAILABLE
RCI	RCIC FAILS TO PROVIDE SUFFICIENT FLOW TO REACTOR VESSEL
RPS	REACTOR SHUTDOWN FAILS
SPC	SUPPRESSION COOLING MODE OF RHR FAILS
SRV	ONE OR MORE SRVS FAIL TO CLOSE
VA	ALTERNATE LOW-PRESSURE INJECTION FAILS

Table 3. Conditional cut sets for dominant sequences.

CCDP[1]	Percent contribution	Minimal cut sets[2]	
Event Tree: LOOP, Sequence 30			
5.0×10^{-7}	4.1	SSW-MDP-TM-TRNC EPS-DGN-FR-DGB RCI-XHE-XL-RUN	RHR-A-KEEP-FILL LCS-KEEP-FILL
2.9×10^{-7}	2.4	RCI-XHE-XO-ERROR EPS-DGN-FR-DGB RHR-A-KEEP-FILL	LCS-KEEP-FILL HCS-XHE-XO-ERROR1
2.5×10^{-7}	2.1	ECW-MDP-TM-C001B SSW-MDP-TM-TRNC RCI-XHE-XL-RUN	RHR-A-KEEP-FILL LCS-KEEP-FILL
2.5×10^{-7}	2.1	SSW-MDP-TM-TRNC EPS-DGN-FR-DGB RCI-TDP-FS-RSTRT	RCI-XHE-XL-RSTRT RHR-A-KEEP-FILL LCS-KEEP-FILL
1.2×10^{-5}	**Total (all cut sets)[3]**		
Event Tree: LOOP, Sequence 21			
4.2×10^{-7}	5.1	OPR-XHE-XM-ALPI SSW-MDP-TM-TRNC EPS-DGN-FR-DGB	RHR-A-KEEP-FILL LCS-KEEP-FILL
2.1×10^{-7}	2.5	OPR-XHE-XM-ALPI ECW-MDP-TM-C001B SSW-MDP-TM-TRNC	RHR-A-KEEP-FILL LCS-KEEP-FILL
2.1×10^{-7}	2.5	FWS-EDP-TM-TRN SPCAI SSW-MDP-TM-TRNC	EPS-DGN-FR-DGB RHR-A-KEEP-FILL LCS-KEEP-FILL
2.1×10^{-7}	2.5	OPR-XHE-XM-ALPI EPS-DGN-FR-DGB EPS-DGN-FR-DGC	RHR-A-KEEP-FILL LCS-KEEP-FILL
8.3×10^{-6}	**Total (all cut sets)[3]**		

1. Values are point estimates.
2. See Table 4 for definitions and probabilities for the basic events.
3. Totals include all cut sets (including those not shown in this table).

Table 4. Definitions and probabilities for modified or dominant basic events.

Event name	Description	Probability/ frequency	Modified
ECW-MDP-TM-C001B	ECW PUMP 1B IS IN TEST OR MAINTENANCE	5.0×10^{-3}	No
EPS-DGN-FR-DGB	EDG B FAILS TO RUN	1.0×10^{-2}	No
EPS-DGN-FR-DGC	EDG C FAILS TO RUN	1.0×10^{-2}	No
FWS-EDP-TM-TRAIN	DIESEL FIREWATER PUMP UNAVAILABLE BECAUSE OF TEST AND MAINTENANCE	5.0×10^{-3}	No
HCS-XHE-XO-ERROR1	OPERATOR FAILS TO START/CONTROL HPCS INJECTION	1.4×10^{-1}	No
IE-LOOP	LOSS OF OFFSITE POWER INITIATING EVENT	1.0	Yes[1]
LCS-KEEP-FILL	LCS PUMP TRAIN IS UNAVAILABLE BECAUSE OF KEEP-FILL SYSTEM FAILURES (OPERATOR FAILURE TO RECOVER)	2.1×10^{-1}	Yes[2]
OEP-XHE-XL-NR30M	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 30 MINUTES	TRUE	Yes[3]
OEP-XHE-XL-NR01H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 1 HOUR	TRUE	Yes[3]
OEP-XHE-XL-NR03H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 3 HOURS	1.0×10^{-2}	Yes[3]
OEP-XHE-XL-NR07H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 7 HOURS	1.0×10^{-3}	Yes[3]
OEP-XHE-XL-NR16H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 16 HOURS	1.0×10^{-3}	Yes[3]
OPR-XHE-XM-ALPI	OPERATOR FAILS TO ALIGN ALTERNATE LOW PRESSURE INJECTION	1.0×10^{-2}	No
RCI-RESTART	RESTART OF RCIC IS REQUIRED	TRUE	Yes[2]
RCI-TDP-FR-TRAIN	RCIC FAILS TO RUN GIVEN THAT IT STARTED	TRUE	Yes[2]
RCI-TDP-FS-RSTRT	RCIC FAILS TO RESTART GIVEN START AND SHORT-TERM RUN	1.2×10^{-2}	No
RCI-XHE-XL-RSTRT	OPERATOR FAILS TO RECOVER RCIC FAILURE TO RESTART	5.0×10^{-1}	No
RCI-XHE-XL-RUN	OPERATOR FAILS TO RECOVER RCIC FAILURE TO RUN	1.2×10^{-2}	Yes[2]
RCI-XHE-XO-ERROR	OPERATOR FAILS TO START/CONTROL RCIC INJECTION	1.0×10^{-3}	No
RHR-A-KEEP-FILL	RHR-A TRAIN IS UNAVAILABLE BECAUSE OF KEEP-FILL SYSTEM FAILURES	1.0	Yes[2]

Event name	Description	Probability/ frequency	Modified
RHR-A-KEEP-FILL-REC	RHR TRAIN A KEEP-FILL NONRECOVERY AFTER 6 HOURS	2.1×10^{-1}	Yes[2]
SPCAI	SUPPRESSION POOL CLEANUP ALTERNATE INJECTION FAILS	1.0	No
SSW-MDP-TM-TRNC	SSW PUMP C IS UNAVAILABLE BECAUSE OF MAINTENANCE	2.0×10^{-2}	No
ZT-DGN-FR-L	EDG FAILS TO RUN (LATE)	7.0×10^{-3}	Yes[4]

1. Initiating event assessment– all other initiating event frequencies set zero.
2. Changed to reflect to the event being analyzed. See report and Basic Event Probability Changes for further details.
3. Evaluated per the SPAR-H method (Ref. 4). See report and Attachment C for further details.
4. Changed mission times to correspond to the time offsite power was restored to the first vital bus. See report and Basic Event Probability Changes for further details.

Attachment A
Event Timeline

Table A.1 Timeline of significant events.

Date	Time	Event
8/14/03	1610	Generator, turbine, and reactor trip due to grid instability
	1737	Offsite power is restored to the switchyard
	1813	Division 1 emergency bus is switched to offsite power source
37847	1214	Division 3 emergency bus is switched to offsite power source
	1548	Division 2 emergency bus is switched to offsite power source

Attachment B
LOOP Analysis Procedure

This procedure is not intended to stand alone; instead it is intended to augment *ASP Guideline A: Detailed Analysis*[2]. LOOP event analyses are a type of initiating event assessment as described in ASP Guideline A. Specific analysis steps that are unique to ASP analysis of LOOP events are included here.

1.   Determine significant facts associated with the event.

1.1   Determine when the LOOP occurred.
1.2   Determine when stable offsite power was first available in the switchyard.
1.3   Determine when offsite power was first restored to an emergency bus.
1.4   Determine when offsite power was fully restored (all emergency buses powered from offsite, EDGs secured).
1.5   Identify any other significant conditions, failures, or unavailabilities that coincided with the LOOP.

2.   Model power recovery factors associated with the best estimate case and any defined sensitivity cases.

2.1   For the best estimate case, the LOOP duration is the time between the occurrence of the LOOP and the time when stable power was available in the switchyard plus the assumed time required to restore power from the switchyard to emergency buses. Attachment C documents the probabilistic analysis of power recovery factors for the best estimate case analysis.

2.2   If EDGs successfully start and supply emergency loads, plant operators do not typically rush to restore offsite power to emergency buses, preferring to wait until grid stability is more certain. Therefore, a typical upper bound sensitivity case considers the LOOP duration as the time between the occurrence of the LOOP and the time when offsite power was first restored to an emergency bus. Attachment C documents the probabilistic analysis of power recovery factors for the sensitivity case analysis.

3.   Model event-specific mission durations for critical equipment for the best estimate case and any defined sensitivity cases. (For most equipment, SPAR model failure probabilities are not functions of defined mission durations and are therefore not affected by this analysis step. Notable exceptions include EDGs and, for PWRs, turbine-driven auxiliary feedwater pumps.)

3.1   For the best estimate case, mission durations are set equal to the assumed LOOP duration as defined in Step 2.1 above.

3.2   For a typical upper bound sensitivity case, mission durations are set equal to the time between the occurrence of the LOOP and the time when offsite power was fully restored to all emergency buses. (Note these mission durations are longer than the assumed LOOP duration defined in Step 2.2 above; they are intended to represent the longest possible mission duration for any critical equipment item.)

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[2] ASP Guideline A: Detailed Analysis, U.S. Nuclear Regulatory Commission.

Attachment C
Power Recovery Modeling

● **Background**

The time required to restore offsite power to plant emergency equipment is a significant factor in modeling the CCDP given a LOOP. SPAR LOOP/SBO models include various sequence-specific ac power recovery factors that are based on the time available to recover power to prevent core damage. For a sequence involving failure of all of the cooling sources, only about 30 minutes would be available to recover power to help avoid core damage. On the other hand, sequences involving successful early inventory control and decay heat removal, but failure of long-term decay heat removal, would accommodate several hours to recover ac power prior to core damage.

In this analysis, offsite power recovery probabilities are based on (1) known information about when power was restored to the switchyard and (2) estimated probabilities of failing to realign power to emergency buses for times after offsite power was restored to the switchyard. Power restoration times were reported by the licensee in the LER and in response to the questionnaire that was conducted by the NRC Regional Office. The time used is the time at which the grid operator informed the plant that power was available to the switchyard (with a load limit). This ASP analysis does not consider the possibility that grid power would have been unreliable if that power were immediately used.

Failure to recover offsite power to plant safety-related loads (if needed because EDGs fail to supply the loads), given recovery of power to the switchyard, could result from (1) operators failing to restore proper breaker line-ups, (2) breakers failing to close on demand, or (3) a combination of operator and breaker failures. The dominant contributor to failure to recover offsite power to plant safety-related loads in this situation is operators failing to restore proper breaker line-ups. The SPAR human error model (ref.) was used to estimate nonrecovery probabilities as a function of time following restoration of offsite power to the switchyard. The best estimate analysis assumes that at least 30 minutes are necessary to restore offsite power to emergency buses given offsite power is available in the switchyard.

● **Human Error Modeling**

The SPAR human error model generally considers the following three factors:

– Probability of failure to diagnose the need for action
– Probability of failure to successfully perform the desired action
– Dependency on other operator actions involved in the specific sequence of interest

This analysis assumes no probability of failure to diagnose the need to recover ac power and no dependency between operator performance of the power recovery task and any other task the operators may need to perform. Thus, each estimated ac power nonrecovery probability is based solely on the probability of failure to successfully perform the desired action.

The probability of failure to perform an action is the product of a nominal failure probability (1.0×10^{-3}) and the following eight performance shaping factors (PSFs):

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- – Available time
- – Stress
- – Complexity
- – Experience/training
- – Procedures
- – Ergonomics
- – Fitness for duty
- – Work processes

For each ac power nonrecovery probability, the PSF for available time is assigned a value of 10 if the time available to perform the action is approximately equal to the time required to perform the action, 1.0 if the time available is between 2 and 4 times the time required, and 0.1 if the time available is greater than or equal to 5 times the time required. If the time available is inadequate (i.e., less than the time to restoration of power to the switchyard plus 30 minutes for the best estimate), the ac power nonrecovery probability is 1.0 (TRUE).

The PSF for stress is assigned a value of 5 (corresponding to extreme stress) for all ac power nonrecovery probabilities. Factors considered in assigning this PSF include the sudden onset of the LOOP initiating event, the duration of the event, the existence of compounding equipment failures (ac power recovery is needed only if one or more emergency buses are not powered by EDGs), and the existence of a direct threat to the plant.

For all of the ac power nonrecovery probabilities, the PSF for complexity is assigned a value of 2 (corresponding to moderately complex) based on the need for multiple breaker alignments and verifications.

For all of the ac power nonrecovery probabilities, the PSFs for experience/training, procedures, ergonomics, fitness for duty, and work processes are assumed to be nominal (i.e., are assigned values of 1.0).

- **Results**

    Table C.1 presents the calculated values for the ac power nonrecovery probabilities used in the best estimate analysis.

Table C.1 AC Power Nonrecovery Probabilities

| Nonrecovery Factor | Nominal Value | PSF | | Nonrecovery Probability |
		Time Available	Product of All Others	
OEP-XHE-XL-NR30M	1.0×10^{-3}	Inadequate	10	TRUE
OEP-XHE-XL-NR01H	1.0×10^{-3}	Inadequate	10	TRUE
OEP-XHE-XL-NR03H	1.0×10^{-3}	1	10	1.0×10^{-2}
OEP-XHE-XL-NR07H	1.0×10^{-3}	0.1	10	1.0×10^{-3}
OEP-XHE-XL-NR16H	1.0×10^{-3}	0.1	10	1.0×10^{-2}

Attachment D
Modified Human Error Events

For this analysis, the values of two operator recovery events, LCS-KEEP-FILL and RHR-A-KEEP-FILL-REC, were updated using the standard SPAR Model Human Error Worksheet. A summary of the worksheet results are provided by table D.1.

Table D.1 Human Error Basic Event Probabilities

Nonrecovery Factor	Nominal Value	Time	Stress	Complexity	Training	Procedures	Nonrecovery Probability	
LCS-KEEP-FILL (Diagnosis)	1.0×10^{-2}	.1	2	2	1	50	2.0×10^{-1}	**2.1×10^{-1} (Total)**
LCS-KEEP-FILL (Action)	1.0×10^{-3}	.1	2	1	1	50	1.0×10^{-2}	
RHR-A-KEEP-FILL-REC (Diagnosis)	1.0×10^{-2}	.1	2	2	1	50	2.0×10^{-1}	**2.1×10^{-1} (Total)**
RHR-A-KEEP-FILL-REC (Action)	1.0×10^{-3}	.1	2	1	1	50	1.0×10^{-2}	

1. All other PSFs were set to nominal (i.e., 1.0).

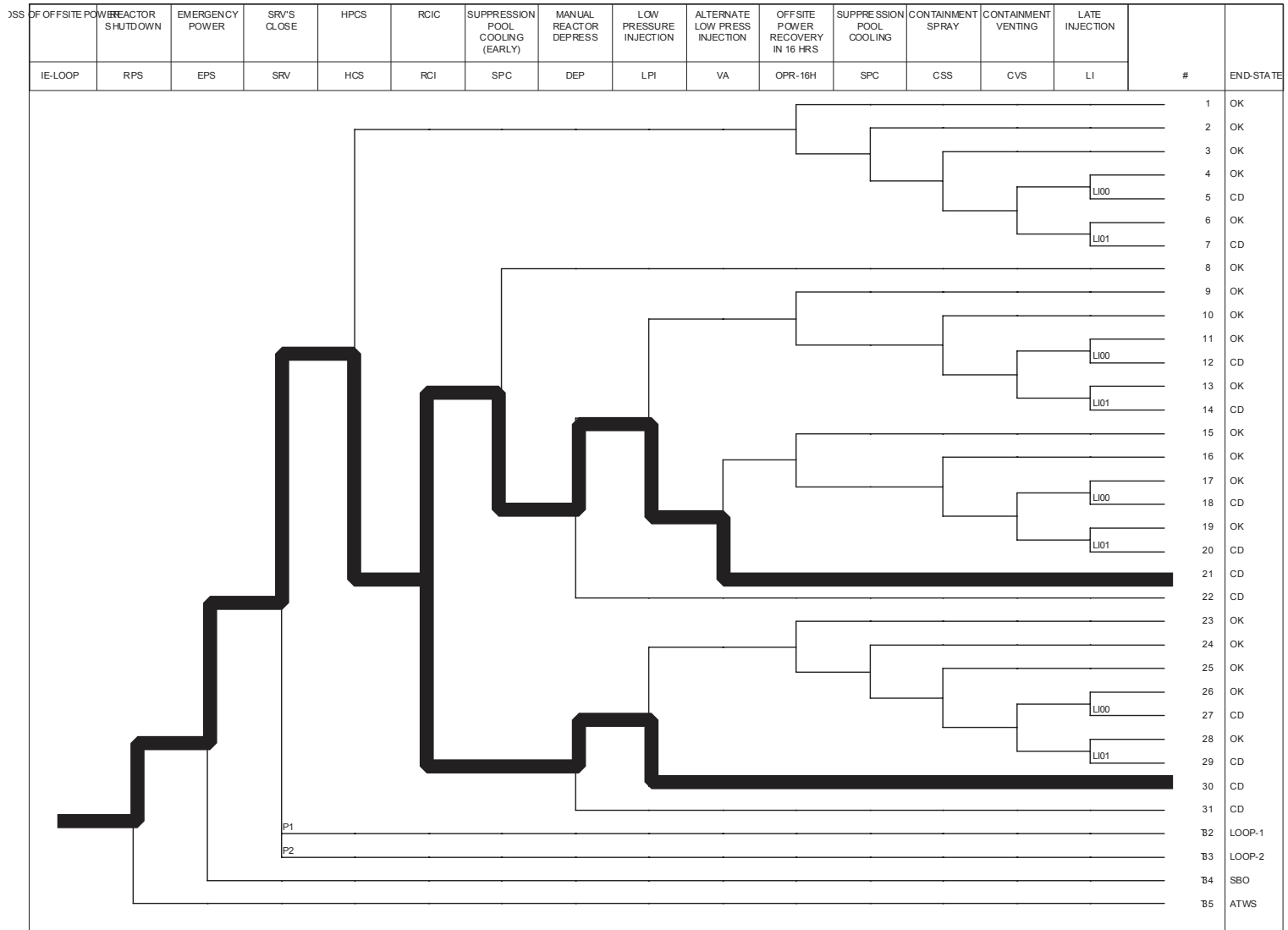| LOSS OF OFFSITE POWER	REACTOR SHUTDOWN	EMERGENCY POWER	SRV'S CLOSE	HPCS	RCIC	SUPPRESSION POOL COOLING (EARLY)	MANUAL REACTOR DEPRESS	LOW PRESSURE INJECTION	ALTERNATE LOW PRESS INJECTION	OFFSITE POWER RECOVERY IN 16 HRS	SUPPRESSION POOL COOLING	CONTAINMENT SPRAY	CONTAINMENT VENTING	LATE INJECTION		
IE-LOOP	RPS	EPS	SRV	HCS	RCI	SPC	DEP	LPI	VA	OPR-16H	SPC	CSS	CVS	LI	#	END-STATE
															1	OK
															2	OK
															3	OK
															4	OK
														LI00	5	CD
															6	OK
														LI01	7	CD
															8	OK
															9	OK
															10	OK
															11	OK
														LI00	12	CD
															13	OK
														LI01	14	CD
															15	OK
															16	OK
															17	OK
														LI00	18	CD
															19	OK
														LI01	20	CD
															21	CD
															22	CD
															23	OK
															24	OK
															25	OK
															26	OK
														LI00	27	CD
															28	OK
														LI01	29	CD
															30	CD
															31	CD
P1															T2	LOOP-1
P2															T3	LOOP-2
															T4	SBO
															T5	ATWS

Figure 1: Perry LOOP event tree with dominant sequences highlighted.
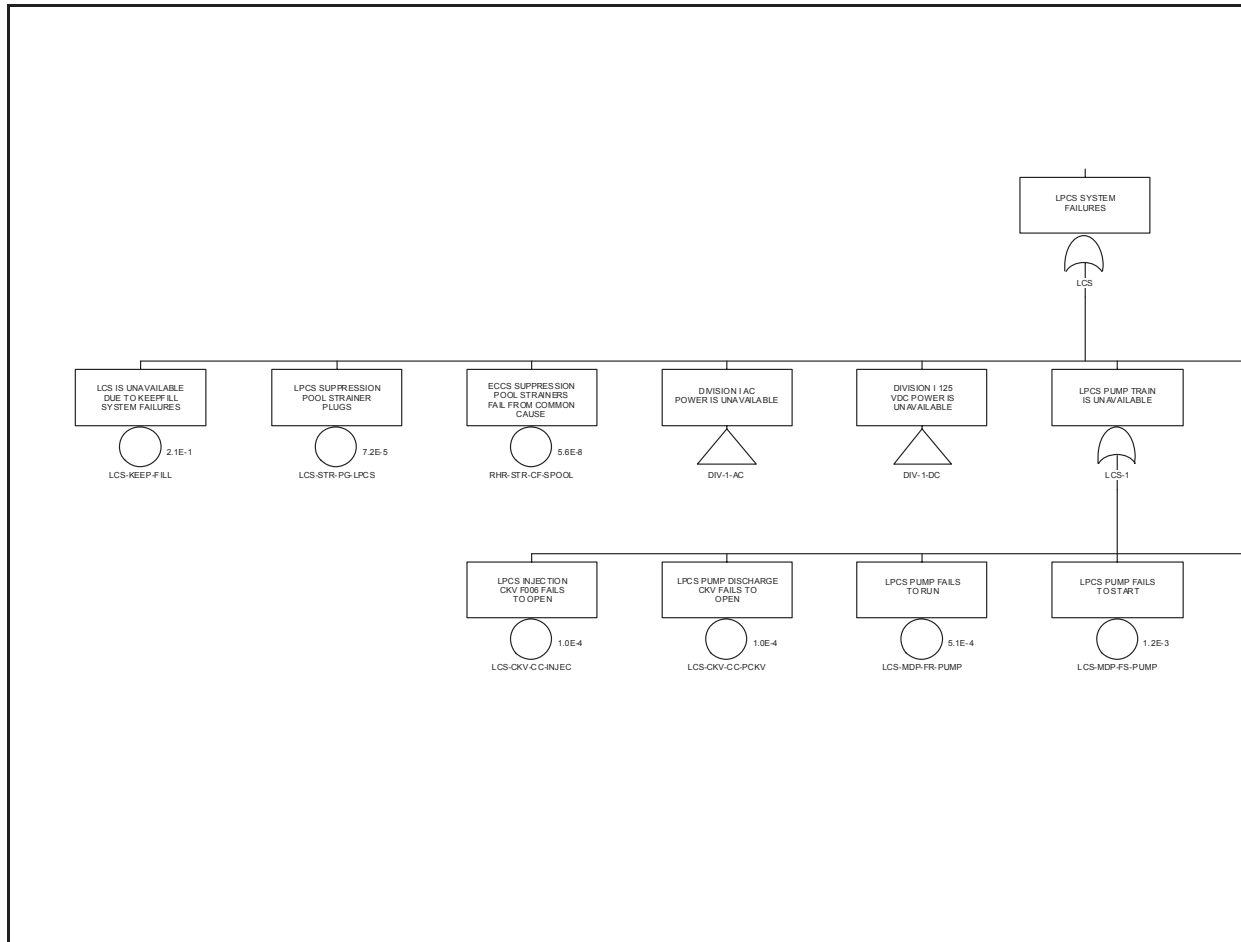
Figure 2: Perry LCS Fault Tree (The figure is cropped to show event modification)

RHR PUMP TRAIN
A IS UNAVAILABLE

RHR-A

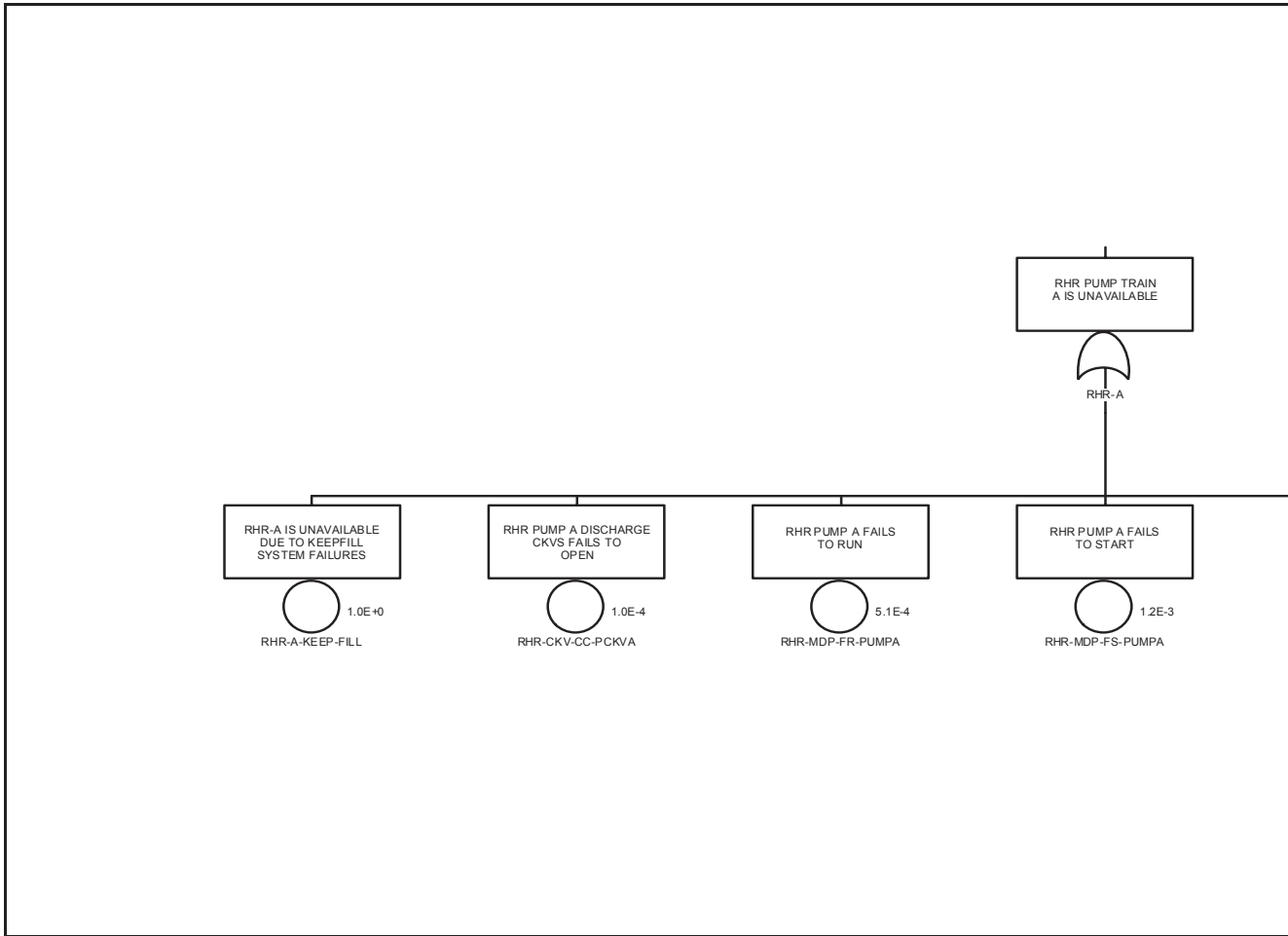| RHR-A IS UNAVAILABLE DUE TO KEEPFILL SYSTEM FAILURES	RHR PUMP A DISCHARGE CKVS FAILS TO OPEN	RHR PUMP A FAILS TO RUN	RHR PUMP A FAILS TO START
1.0E+0	1.0E-4	5.1E-4	1.2E-3
RHR-A-KEEP-FILL	RHR-CKV-CC-PCKVA	RHR-MDP-FR-PUMPA	RHR-MDP-FS-PUMPA

Figure 3: Perry RHR-A Fault Tree (The figure is cropped to show event modification)