Final Precursor Analysis

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research

Oyster Creek	Loss of Offsite Power due to Lightning Strike	
Event Date: 07/12/2009	**LER:** 219/09-005 **IR:** 50-219/09-09	**CCDP =** 5×10^{-5}

EVENT SUMMARY

Event Description. At 1:31 am on July 12, 2009, a lightning strike on the 34.5 kV Whiting Line near the Oyster Creek switchyard, caused the pilot wire to break and fall across the suspended wire conductors. This caused both a phase to phase and a phase to ground short circuit. The generator responded to the fault on the Whiting line as an additional load and the generator automatic voltage regulator increased excitation to the generator field to match the load. The generator protection relays sensed a valid over-excitation condition, and after an appropriate time delay, caused the generator output breakers to open. This initiated a signal to remove steam from the turbine, which resulted in a fast closure of the turbine control valves. The fast closure of the turbine control valves initiated the reactor scram, as designed.

Following the generator trip and reactor scram, the safety-related 4 kV busses were de-energized. The maximum reactor coolant system (RCS) pressure during the transient was 1066 psig, which caused the 'A' and 'D' electromatic relief valves (EMRVs) to open, as designed, to limit the pressure increase. Both isolation condensers (ICs) initiated at an RCS pressure of 1051 psig, as designed. To limit the RCS cooldown and depressurization the operators secured both ICs by closing their condensate return valves. The main feed pumps, powered from non-safety-related busses, tripped on loss of power and could not be restarted until offsite power was restored.

Both emergency diesel generators (EDGs) started on their respective bus under-voltage relay signals. EDG 2 breaker closed within the required design basis time period; while EDG 1 output breaker did not close within the design basis time period. EDG 1 output breaker closed in about 91 seconds.[1] In the time that the 4 kV safety busses were de-energized, the reactor protection system (RPS) motor generator sets lost power until the EDGs started and repowered the busses. This loss of RPS power caused primary and secondary containment isolations due to a loss of power, including closure of the main steam isolation valves.

Once the EDGs repowered the safety-related busses, the operators started a second control rod drive pump and used that system to feed cooling water to the RCS to restore reactor pressure vessel water level.

The operators cycled the IC condensate return valves, as needed, to control RCS pressure and temperature. After the initial operation, the third time that the 'B' IC was initiated its shell side water level indication decreased to zero. Operators noted the decrease and removed the 'B' IC from further service.

[1] The loads supplied by EDG 1 were automatically powered in sufficient time to perform their safety function.

Operators unsuccessfully attempted to restore offsite power to the 1C Safety Bus at 3:08 am. EDG 1 would not automatically synchronize with offsite power and operators could not complete the manual synchronization given the procedures in place at the time. Although offsite power was available to the bus, EDG 1 continued to power the bus until July 13, 2009. Offsite power was restored to Safety Bus 1D at 3:14 am and EDG 2 was secured and placed in a standby status.

Additional information is provided in References 1 and 2.

Cause. The cause of the LOOP was a lightning strike that broke the carrier/static line, resulting in a three-phase-to-ground fault. The Q-121 line breaker at Oyster Creek failed to open on the line fault resulting in the generator feeding the fault until backup line breakers opened and isolated the line. These grid disturbances caused voltage swings and when the backup line breakers eventually isolated the Q-121 fault, switchyard voltage increased rapidly and the generator tripped on over-excitation. The turbine-generator trip resulted in an automatic reactor scram.

Recovery Opportunities. Offsite power was restored to the first safety bus (Bus 1D) 1 hour and 43 minutes after the LOOP occurred. Offsite power was available in switchyard 9 minutes earlier. See Appendix C for further details.

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.

Two GREEN (i.e., very low safety significance) findings have been identified for this event and are described in Reference 2. Therefore, this analysis focuses solely on the risk of the loss of offsite power to the safety buses and subsequent reactor trip that occurred.

ANALYSIS RESULTS

Conditional Core Damage Probability. The point estimate conditional core damage probability (CCDP) value for this event is 4.1×10^{-5}. The results of an uncertainty assessment on the event CCDP are summarized below.

	5%	Mean	95%
CCDP	8.8×10^{-8}	4.8×10^{-5}	2.0×10^{-4}

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 Oyster Creek is 2×10^{-5}.

Dominant Sequence. The dominant accident sequence, LOOP Sequence 25 (CCDP = 2.3×10^{-5}) contributes 56% of the total internal events CCDP. Additional sequences that contribute greater than 1% of the total internal events CCDP are provided in Appendix A.

The dominant sequence is shown graphically in Figure B-1 in Appendix B. The events and important component failures in LOOP Sequence 25 are:

- LOOP occurs,
- reactor scram succeeds,
- EDGs succeed,
- safety relief valves (SRVs) successfully close (if opened),
- IC fails, and
- operators fail to depressurize the RCS.

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 3.50 of the Oyster Creek SPAR model (Reference 3) created in November 2009 was used for this event analysis. This event was modeled as a LOOP initiating event.

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

- This analysis models the July 12, 2009 reactor trip at Oyster Creek as a LOOP initiating event.

- Offsite power recovery to a safety bus was possible 94 minutes after the LOOP occurred.

- Recovery of the ‘B’ IC was possible within 1 hour of the initiating event occurrence.

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

- Two basic events were added to the ISO-B and ISO-HW fault trees. A basic event (ISO-TRNB-SD) to account for the operators securing the ‘B’ IC due to low level and a basic event (ISO-XHE-TRNB-LEVEL) representing the non-recovery probability of the ‘B’ IC were inserted under an ‘AND’ gate. See Figures B-2 and B-3 in Appendix B for the modified isolation condenser fault trees.

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

- The LOOP initiating event frequency (IE-LOOPSC) was set 1.0 to represent the operational event that occurred at Oyster Creek on July 12, 2009. All other initiating events frequencies were set to zero.

- The 'A' IC condensate return valve was cycled 67 times by operators during the event. Therefore, the failure probability for basic event ISO-MOV-CC-V1434 was changed to 6.3×10^{-2} (binomial expansion) to account for increased chance that this motor-operated valve would fail to open on demand.

- The basic event ISO-TRNB-SD was set to TRUE because operators secured the 'B' IC due to low indicated level.

- The non-recovery probability for basic event ISO-XHE-TRNB-LEVEL was set to 0.5 using the SPAR-H method (Reference 4). The performance shaping factor (PSF) for diagnosis ergonomics/human machine interface was set to 'missing/misleading' due to erroneous level indication caused by the foreign material present in the instrument line. All other PSFs were set to nominal.

- The non-recovery probability for basic event OEP-XHE-XL-NR30MSC was set to TRUE because offsite power was unavailable in the switchyard until 94 minutes after the LOOP occurred.

- The non-recovery probability for basic event OEP-XHE-XL-NR01HSC was set to TRUE because offsite power was unavailable in the switchyard until 94 minutes after the LOOP occurred.

- The non-recovery probability for basic event OEP-XHE-XL-NR03HSC was changed to 2.4×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR04HSC was changed to 2.4×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR08HSC was changed to 2.4×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR10HSC was changed to 2.4×10^{-3}. See Appendix C for further details.

- There were five openings of EMRVs: The 'A' and 'D' EMRVs opened at their set points (1066 psig) to limit pressure after the reactor and turbine trips and operators manually opened a EMRV three times to lower RCS pressure and vessel level. Therefore, the failure probability for basic event PPR-SRV-OO-1VLV was changed to 4×10^{-3} (binomial expansion) to account for the increased probability that one the EMRVs could stick open.

- The default diesel generator mission times were changed to reflect the actual time offsite power was restored to the first vital 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 = 1 hour.

REFERENCES

1. Oyster Creek Generating Station, "LER 219/09-005– Reactor Scram Following a Transmission Line Lightning Strike" dated September 9, 2009.

2. U.S. Nuclear Regulatory Commission, "Oyster Creek Generating Plant Special Inspection Report 05000219/2009009," dated September 26, 2009.

3. Idaho National Laboratory, "Standardized Plant Analysis Risk Model for Oyster Creek," 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 1.03, dated August 2009.

Appendix A
GEM Worksheet

SAPHIRE Code Version:	7.27.0.41
SPAR Model Version:	Oyster Creek 3.45 (June 2008)
Analysis Type:	Initiating Event Assessment
Event Description:	LOOP with Offsite Power Recovery Possible 94 Minutes after Event Occurrence
Total CCDP:	4.1E-5 (*Point Estimate*) 4.8E-5 *(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 IE 2-MOV RHR Interface	4.0E-006	0.0E+000
IE-LLOCA	Large LOCA	1.0E-005	0.0E+000
IE-LO1C	Loss of 4160 V AC Bus 1C	4.5E-003	0.0E+000
IE-LO1D	Loss of 4160 V AC Bus 1D	4.5E-003	0.0E+000
IE-LOCHS	Loss of Condenser Heat Sink	2.0E-001	0.0E+000
IE-LOCW	Loss of Circulating Water	4.0E-004	0.0E+000
IE-LODCB	Loss of Vital DC Bus	1.2E-003	0.0E+000
IE-LOFC	Loss of Feedwater Control	1.7E-001	0.0E+000
IE-LOIAS	Loss of Instrument Air	1.0E-002	0.0E+000
IE-LOIS	Loss of Intake Structure	7.5E-003	0.0E+000
IE-LOMFW	Loss of Feedwater	1.0E-001	0.0E+000
IE-LOOPGR	Loss of Offsite Power (Grid-Related)	1.9E-002	0.0E+000
IE-LOOPPC	Loss of Offsite Power (Plant-Centered)	2.1E-003	0.0E+000
IE-LOOPSC	Loss of Offsite Power (Switchyard-Centered)	1.0E-002	1.0E+000
IE-LOOPWR	Loss of Offsite Power (Weather-Related)	4.8E-003	0.0E+000
IE-LOSWS	Loss of Service Water	4.0E-004	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
ISO-MOV-CC-V1434	Train ‘A’ Injection Valve EC-14-34 Fails to Open	1.0E-003	6.3E-002
ISO-TRNB-SD	Operators Shutdown Train ‘B’ IC Due to Level	0.0E+000	TRUE
ISO-XHE-TRNB-LEVEL	Operators Fail to Restore Level in Train ‘B’	0.0E+000	5.0E-001
OEP-XHE-XL-NR01HSC	Operator Fails to Recover Offsite Power in 1hr	0.0E+000	TRUE
OEP-XHE-XL-NR03HSC	Operator Fails to Recover Offsite Power in 3hrs	0.0E+000	2.4E-003
OEP-XHE-XL-NR04HSC	Operator Fails to Recover Offsite Power in 4hrs	0.0E+000	2.4E-003
OEP-XHE-XL-NR08HSC	Operator Fails to Recover Offsite Power in 8hrs	0.0E+000	2.4E-003
OEP-XHE-XL-NR10HSC	Operator Fails to Recover Offsite Power in 10hrs	0.0E+000	2.4E-003
OEP-XHE-XL-NR30MSC	Operator Fails to Recover Offsite Power in 30m	0.0E+000	TRUE
PPR-SRV-OO-1VLV	One SRV Sticks Open	8.0E-004	4.0E-003
ZT-DGN-FR-L	Emergency Diesel Generator (Fail-to-Run Late)	1.8E-002	8.0E-004

DOMINANT SEQUENCES

Event Tree	Sequence	CCDP	% Contribution
LOOPSC	25	2.3E-005	56.1
LOOPSC	24	6.1E-006	14.9
LOOPSC	29-37	4.9E-006	12.0
LOOPSC	29-50	2.6E-006	6.3

LOOPSC	29-44	2.3E-006	5.6

SEQUENCE LOGIC

Event Tree	Sequence Name	Logic
LOOPSC	25	/RPS, /EPS, /SRV, ISO-HW, DEP
LOOPSC	24	/RPS, /EPS, /SRV, ISO-HW, /DEP, LCI
LOOPSC	29-37	/RPS, EPS, /SRV, /ISO1, CTG, SEALS, /DEP1, FWS, OPR-30M, DGR-30M
LOOPSC	29-50	/RPS, EPS, P1, /ISO1, OPR-01H, DGR-01H
LOOPSC	29-44	/RPS, EPS, /SRV, ISO1, CTG1, /SEALS, OPR-01H, DGR-01H

FAULT TREE DESCRIPTIONS

Fault Tree Name	Description
CTG	Forked River Combustion Turbines
CTG1	Oyster Creek Forked River Combustion Turbines (Early)
DEP	Manual Reactor Depressurization
DEP1	Manual Reactor Depressurization
DGR-01H	Operator Fails To Recover Emergency Diesel in 1 Hour
DGR-30M	Operator Fails To Recover Emergency Diesel in 30 Minutes
EPS	Emergency Power
FWS	Firewater Injection
ISO-HW	Isolation Condenser
ISO1	Isolation Condenser
LCI	Low-Pressure Injection
OPR-01H	Offsite Power Recovery in 1 Hour
OPR-30M	Offsite Power Recovery in 30 Minutes
P1	One Stuck Open SRV
RPS	Reactor Protection System
SEALS	Recirculation Pump Seals Survive
SRV	SRV Are Closed

SEQUENCE CUTSETS

Sequence: LOOP 25 **CCDP**: 2.3E-005

CCDP	% Cutset	Cutset Events
1.6E-005	68.33	ISO-MOV-CC-V1434, ADS-XHE-XM-MDEPR, ISO-XHE-TRNB-LEVEL

Sequence: LOOP 24 **CCDP**: 6.4E-006

CCDP	% Cutset	Cutset Events
3.2E-006	51.49	ISO-MOV-CC-V1434, LCS-XHE-XM-ERROR, ISO-XHE-TRNB-LEVEL
3.1E-007	5.06	ISO-MOV-CC-V1434, LCS-MDP-CF-BSTART, ISO-XHE-TRNB-LEVEL
3.1E-007	5.06	ISO-MOV-CC-V1434, LCS-MDP-CF-START, ISO-XHE-TRNB-LEVEL
1.5E-007	2.50	ISO-MOV-CF-INJEC, LCS-XHE-XM-ERROR

<u>Sequence</u>: LOOP 29-37 **<u>CCDP</u>**: 4.9E-006

CCDP	**% Cutset**	**Cutset Events**
5.8E-007	11.83	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-CF-RUN, EPS-CTG-OP-BOTH
4.1E-007	8.20	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-FR-DG1, EPS-DGN-TM-DG2, EPS-CTG-OP-BOTH
4.1E-007	8.20	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-TM-DG1, EPS-DGN-FR-DG2, EPS-CTG-OP-BOTH
3.3E-007	6.60	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-CF-START, EPS-CTG-OP-BOTH
3.0E-007	6.04	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-TM-DG1, EPS-DGN-FS-DG2, EPS-CTG-OP-BOTH
3.0E-007	6.04	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-FS-DG1, EPS-DGN-TM-DG2, EPS-CTG-OP-BOTH
2.3E-007	4.64	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-FR-DG1, EPS-DGN-FR-DG2, EPS-CTG-OP-BOTH
1.7E-007	3.42	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-FS-DG1, EPS-DGN-FR-DG2, EPS-CTG-OP-BOTH
1.7E-007	3.42	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-FR-DG1, EPS-DGN-FS-DG2, EPS-CTG-OP-BOTH
1.5E-007	3.02	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-TM-DG2, ACP-CRB-CC-M1C, EPS-CTG-OP-BOTH
1.5E-007	3.02	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-TM-DG1, ACP-CRB-CC-M1B, EPS-CTG-OP-BOTH
1.5E-007	3.02	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-TM-DG1, ACP-CRB-OO-DG2, EPS-CTG-OP-BOTH
1.2E-007	2.52	RRS-MDP-LK-SEALS, EPS-XHE-XL-NR30M, EPS-DGN-FS-DG1, EPS-DGN-FS-DG2, EPS-CTG-OP-BOTH

<u>Sequence</u>: LOOP 29-50 **<u>CCDP</u>**: 2.6E-006

CCDP	**% Cutset**	**Cutset Events**
3.6E-007	14.22	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-CF-RUN
2.5E-007	9.86	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-FR-DG1, EPS-DGN-TM-DG2
2.5E-007	9.86	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-TM-DG1, EPS-DGN-FR-DG2
2.0E-007	7.93	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-CF-START
1.9E-007	7.27	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-FS-DG1, EPS-DGN-TM-DG2
1.9E-007	7.27	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-TM-DG1, EPS-DGN-FS-DG2
1.4E-007	5.58	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-FR-DG1, EPS-DGN-FR-DG2
1.1E-007	4.11	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-FR-DG1, EPS-DGN-FS-DG2
1.1E-007	4.11	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-FS-DG1, EPS-DGN-FR-DG2
9.3E-008	3.63	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-TM-DG1, ACP-CRB-OO-DG2
9.3E-008	3.63	EPS-XHE-XL-NR01H, PPR-SRV-OO-1VLV, EPS-DGN-TM-DG1, ACP-CRB-CC-M1B

Sequence: LOOP 29-44 **CCDP**: 2.3E-006

CCDP	% Cutset	Cutset Events
1.7E-007	7.33	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-CF-RUN, EPS-CTG-OP-BOTH
1.2E-007	5.08	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-FR-DG1, EPS-DGN-TM-DG2, EPS-CTG-OP-BOTH
1.2E-007	5.08	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-TM-DG1, EPS-DGN-FR-DG2, EPS-CTG-OP-BOTH
9.2E-008	4.09	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-CF-START, EPS-CTG-OP-BOTH
8.5E-008	3.74	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-TM-DG1, EPS-DGN-FS-DG2, EPS-CTG-OP-BOTH
8.5E-008	3.74	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-FS-DG1, EPS-DGN-TM-DG2, EPS-CTG-OP-BOTH
6.5E-008	2.87	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-FR-DG1, EPS-DGN-FR-DG2, EPS-CTG-OP-BOTH
5.7E-008	2.53	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-CF-RUN, EPS-XHE-XM-CTG1
4.8E-008	2.12	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-FR-DG1, EPS-DGN-FS-DG2, EPS-CTG-OP-BOTH
4.8E-00	2.12	EPS-XHE-XL-NR01H, ISO-XHE-TRNB-LEVEL, ISO-MOV-CC-V1434, EPS-DGN-FS-DG1, EPS-DGN-FR-DG2

BASIC EVENTS (cutsets only)

Event Name	Description	Probability
ACP-CRB-CC-M1B	Main Generator Circuit Breaker 1b Fails To Open	2.5E-003
ACP-CRB-CC-M1C	Main Generator Circuit Breaker 1c Fails To Open	2.5E-003
ACP-CRB-OO-DG2	Dg2 Breaker Fails To Remain Close (PRA)	2.5E-003
ADS-XHE-XM-MDEPR	Fail To Depressurize Given Transient Plant	5.0E-004
EPS-CTG-LP-XSW	Extreme Weather Event Conditional Probability	4.8E-003
EPS-CTG-OP-BOTH	Both CTGs Initially Operating	5.8E-002
EPS-DGN-CF-RUN	Diesel Fail from Common Cause to Run	1.2E-004
EPS-DGN-CF-START	Diesels Fail from Common Cause to Start	6.6E-005
EPS-DGN-FR-DG1	Diesel Generator DG1 Fails to Run	6.8E-003
EPS-DGN-FR-DG2	Diesel Generator DG2 Fails to Run	6.8E-003
EPS-DGN-FS-DG1	Diesel Generator DG1 Fails to Start	5.0E-003
EPS-DGN-FS-DG2	Diesel Generator DG2 Fails to Start	5.0E-003
EPS-DGN-TM-DG1	DG1 Is Unavailable Due To Test or Maintenance	1.2E-002
EPS-DGN-TM-DG2	DG2 Is Unavailable Due To Test or Maintenance	1.2E-002
EPS-XHE-XL-NR01H	Operator Fails To Recover Emergency Diesel in 1H	7.7E-001
EPS-XHE-XL-NR30M	Operator Fails To Recover Emergency Diesel in 30M	8.6E-001
EPS-XHE-XM-CTG1	Failure to Align Forked River CTGs	2.0E-002
ISO-MOV-CC-V1434	Train A Injection Valve EC-14-34 Fails To Open	6.3E-002
ISO-MOV-CF-INJEC	Common Cause Failure of Injection Valves	1.5E-003
ISO-XHE-TRNB-LEVEL	Operators Fail To Restore Level in Train B	5.0E-001
LCS-MDP-CF-BSTART	Core Spray Booster Pumps Fail from Common Cause	9.8E-006
LCS-MDP-CF-START	Core Spray Pumps Fail from Common Cause to Start	9.8E-006
LCS-XHE-XM-ERROR	Operator Fails to Start/Control Core Spray	1.0E-004
PPR-SRV-OO-1VLV	One SRV Sticks Open	4.0E-003
RRS-MDP-LK-SEALS	Recirculation Pump Seals Fail during SBO	1.0E-001

Appendix B
Key Event Trees and Modified Fault Trees

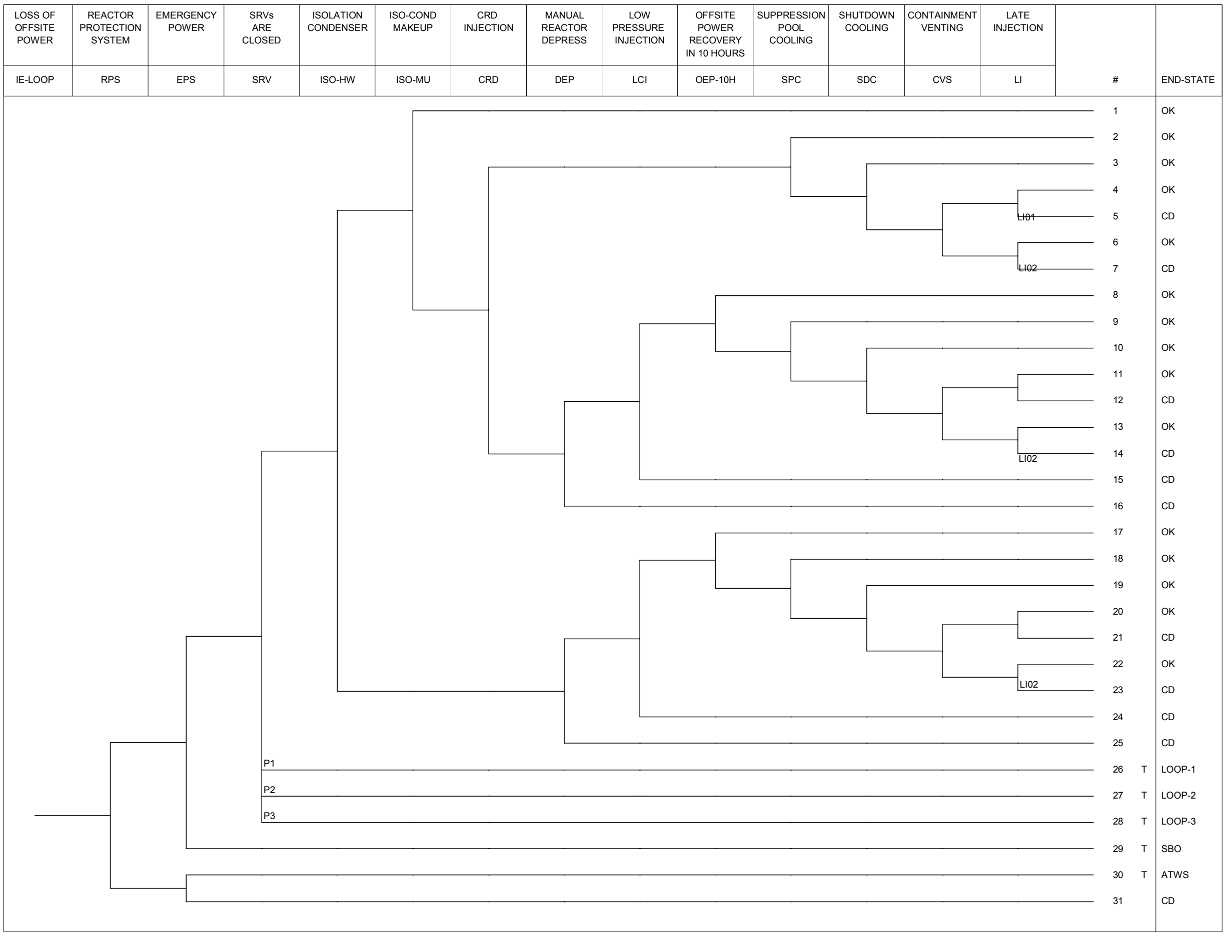

Figure B-1. Oyster Creek LOOP event tree.

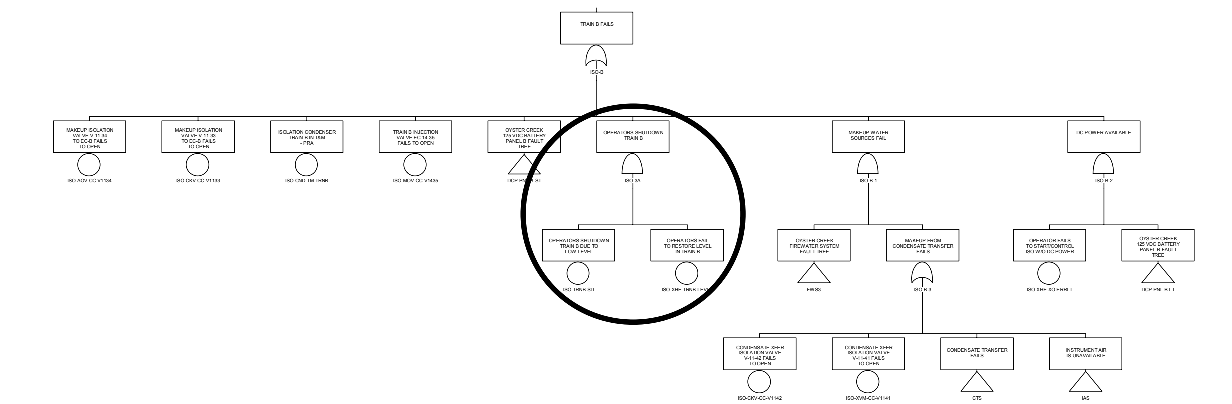

Figure B-2. Oyster Creek modified ISO-B fault tree.

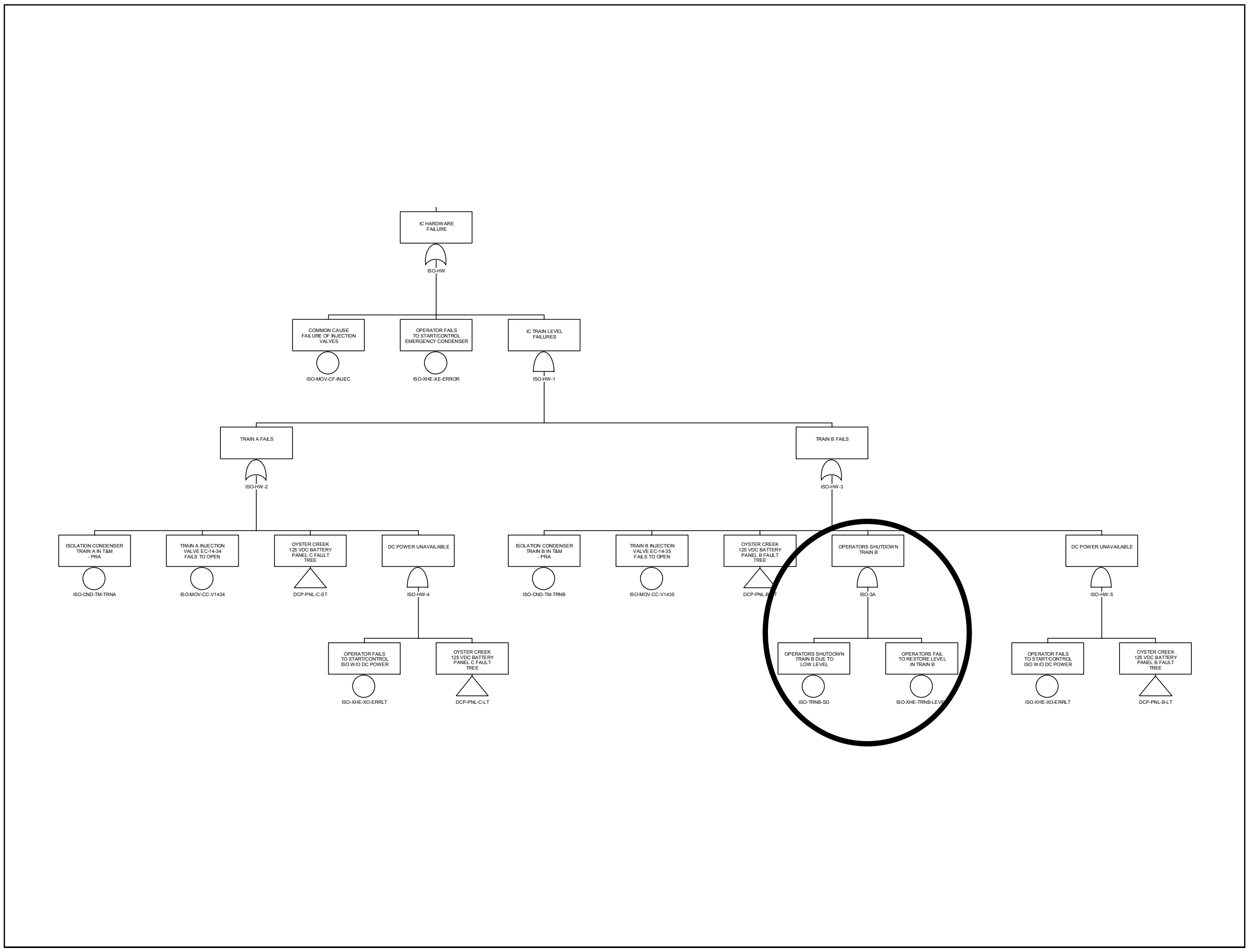

Figure B-3. Oyster Creek modified ISO-HW fault tree.

Appendix C
Offsite Power Recovery Modeling

Background and Modeling Details of Offsite Power Recovery[2]

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, approximately 1 hour 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 References 1 and 2. Offsite power was restored to the first safety bus (Bus 1D) 1 hour and 43 minutes after the LOOP occurred. Offsite power was available in switchyard 9 minutes earlier. In the event of a blackout condition, operators would not be able to recover offsite power until 94 minutes after the LOOP occurred. Therefore, the recovery actions OEP-XHE-XL-NR30M and OEP-XHE-XL-NR01H are set to TRUE for this analysis.

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-H Human Reliability Analysis Method (Ref. 4) was used to estimate non-recovery probabilities as a function of time following restoration of offsite power to the switchyard.

Diagnosis, Action, and Dependency

The SPAR Human Reliability Analysis Method considers the following three factors:

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

This analysis considers the probability of failure to diagnose the need for action and the probability of failure to successfully perform the desired action. However, dependency between operator power recovery tasks and any other operator tasks is not considered. Dependency is considered only when multiple operator actions are present in the same cutset. This analysis does not have any cutsets containing multiple human error basic events.

[2] This section provides background information and details involving recovery of offsite power for this event. In an ASP analysis, offsite power recovery constitutes the recovery of power to the unit vital busses once power has been restored to the switchyard. ASP analyses do not deal with offsite recovery actions outside the switchyard.

Performance Shaping Factors

The probability of failure to perform an action is the product of a nominal failure probability (1×10^{-3}) and the following eight performance shaping factors (PSFs):

- Available Time
- Stress
- Complexity
- Experience/Training
- Procedures
- Ergonomics
- Fitness for Duty
- Work Processes

Time

New human reliability analysis (HRA) guidance currently being developed directs the analyst to determine if time is available to perform the action. If sufficient time is available to perform the action, the time available (best estimate) for operators to perform to action is subtracted from the total time available for the recovery action, with the remainder of the time being available for diagnosis activities. Under this new guidance, the time available PSF for action is not modified unless sufficient time to perform the operator action is not available.

Diagnosis. If the EDGs failed (postulated failure) during this event, operators would have approximately 90 minutes to recover offsite power prior to the first possible recovery action (OEP-XHE-XL-NR03H). The time required for the action component (i.e., breaker(s) manipulation) of recovery of offsite power to a vital bus is minimal (< 5 minutes). Therefore, expansive time (i.e., 2× nominal and > 30 minutes) is used for the time available PSF for all recovery actions greater than or equal to three hours.

Action. The PSF for time available for action is set to nominal for the possible AC power recovery actions.

Stress

Diagnosis and Action. The PSF for diagnosis and action stress is assigned a value of 2 (i.e., High Stress) for all possible AC power recovery actions. Factors considered in assigning this PSF level "higher than nominal level" include sudden onset of the LOOP initiating event, multiple alarms/annunciators, actual and/or postulated compounding equipment failures, and resulting core uncovery and eminent core damage.

Complexity

Diagnosis and Action. The PSF for diagnosis complexity is assigned a value of 2 (i.e., Moderately Complex) for all possible AC power recovery actions. Factors considered in assigning this PSF level include multiple equipment unavailabilities, communications with grid-operators to ensure offsite power is stable, and the concurrent actions/multiple procedures used during a station blackout.

Action. The PSF for action complexity is set to nominal for all possible AC power recovery actions.

All Other PSFs

Diagnosis and Action. For all possible AC power recovery actions, the diagnosis and action PSFs for experience/training, procedures, ergonomics, fitness for duty, and work processes are set to nominal (i.e., are assigned values of 1.0). Details of the event, plant response, and crew performance did not warrant a change from nominal for these PSFs.

Tables C-1 though C-4 contain the PSF adjustments and non-recovery probabilities for all possible AC power recovery actions.

Table C-1. PSF adjustments for operator recovery actions of offsite power.

	DIAGNOSIS				ACTION	
Recovery Basic Event	**Time**	**Stress**	**Complexity**	**All Other PSFs**	**Stress**	**All Other PSFs**
OEP-XHE-XL-NR03H	Expansive Time	High	Moderate	Nominal	High	Nominal
OEP-XHE-XL-NR04H	Expansive Time	High	Moderate	Nominal	High	Nominal
OEP-XHE-XL-NR08H	Expansive Time	High	Moderate	Nominal	High	Nominal
OEP-XHE-XL-NR10H	Expansive Time	High	Moderate	Nominal	High	Nominal

Table C-2. Diagnosis non-recovery probabilities for operator recovery actions of offsite power.

Recovery Basic Event	Base Probability	Time	Stress	Complexity	All Other PSFs	Diagnosis Probability
OEP-XHE-XL-NR03H	1×10^{-2}	×0.01	×2	×2	×1	4×10^{-4}
OEP-XHE-XL-NR04H	1×10^{-2}	×0.01	×2	×2	×1	4×10^{-4}
OEP-XHE-XL-NR08H	1×10^{-2}	×0.01	×2	×2	×1	4×10^{-4}
OEP-XHE-XL-NR10H	1×10^{-2}	×0.01	×2	×2	×1	4×10^{-4}

Table C-3. Action non-recovery probabilities for operator recovery actions of offsite power.

Recovery Basic Event	Base Probability	Stress	All Other PSFs	Action Probability
OEP-XHE-XL-NR03H	1×10^{-3}	×2	×1	2×10^{-3}
OEP-XHE-XL-NR04H	1×10^{-3}	×2	×1	2×10^{-3}
OEP-XHE-XL-NR08H	1×10^{-3}	×2	×1	2×10^{-3}
OEP-XHE-XL-NR10H	1×10^{-3}	×2	×1	2×10^{-3}

Table C-4. Total non-recovery probabilities for operator recovery actions of offsite power.

Recovery Basic Event	Diagnosis Probability	Action Probability	Final Probability
OEP-XHE-XL-NR03H	4×10^{-4}	2×10^{-3}	2.4×10^{-3}
OEP-XHE-XL-NR04H	4×10^{-4}	2×10^{-3}	2.4×10^{-3}
OEP-XHE-XL-NR08H	4×10^{-4}	2×10^{-3}	2.4×10^{-3}
OEP-XHE-XL-NR10H	4×10^{-4}	2×10^{-3}	2.4×10^{-3}