Final Precursor Analysis

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research

Wolf Creek Generating Station	Loss of Offsite Power due to Lightning Strike Near Transmission Lines	
Event Date: 08/19/2009	**LER:** 482/09-002 **IR:** 50-482/09-07	**CCDP =** 9×10^{-6}

EVENT SUMMARY

Event Description. On August 19, 2009, Wolf Creek Generating Station experienced a complete loss of offsite power (LOOP) to the two essential 4 kV Bus Transformers, XNB01 and XNB02, for about 49 seconds. This condition resulted from a lightning strike causing a fault four miles to the east of the plant on the tie-line to La Cygne 345 kV Substation. Wave trap and tuning circuitry damage caused carrier system signal failures which prevented the feeder breakers from two other substations, Rose Hill and Benton, from getting 'block' signals. Thus, these substation feeds were also rendered unavailable to Wolf Creek. The Wolf Creek main generator experienced a load change from approximately 1220 MW to 100 MW. This resulted in a turbine trip and subsequent reactor trip. All reactor coolant pump (RCP) motors tripped on under-frequency.

The main generator protection lockout Relay 386-2G actuated, opening the main generator output breakers. At 49.6 seconds after the initiating event, the feeder breakers to 4 kV Busses NB01 and NB02 were tripped open by loss of voltage relays. At 55.2 seconds after the initiating event, the transmission system operator closed the Wolf Creek–Rose Hill transmission network line Breaker 345-50. This restored one transmission line, supporting offsite power to Wolf Creek's essential 4 kV bus transformers. At 56.5 seconds, the emergency diesel generator (EDG) output Breakers NE001 and NE002 closed onto safety-related 4 kV Busses NB01 and NB02. At 12 minutes, the Wolf Creek–Benton 345 kV network line Breaker 345-120 was closed by the transmission operator, restoring a second transmission line supporting offsite power. At 13 minutes and 6 seconds, the transmission system operator restored the third transmission line.

One hour and 50 minutes after the event, offsite power was restored to Safety Bus NB02. Two hours and 54 minutes after the event, offsite power was restored to Safety Bus NB01. This was the second loss of offsite power event at Wolf Creek in less than 18 months. The first occurred on April 7, 2008, during a refueling outage. For both of the LOOP events, damage requiring repairs occurred within the essential service water (ESW) system. In this event, a 3/8-inch hole developed in the licensee's service water system.

Additional information is provided in References 1 and 2.

Cause. The cause of the LOOP was a lightning strike on LaCygne line which caused the loss of the LaCygne line and loss of the carrier function on Rose Hill line, causing line operation (opening of switchyard breakers) and subsequent loss of the Benton line due to a 3-phase impedance swing resulting in loss of offsite power.

Additional Event Details. The ESW system experienced a pressure surge (i.e., water hammer) when the ESW pumps restarted after the LOOP. The water hammer created a ⅜ inch diameter hole (~20 gpm) in essential service water piping on the 1988' elevation of the Auxiliary Building. However, the ESW system did not lose safety function and the leakage was bounded by maximum allowable ESW leakage (140 gpm) from the ultimate heat sink system. Therefore, the water hammer event and subsequent leakage is not modeled in this event analysis.

Recovery Opportunities. Offsite power was restored to the first safety bus (NB02) 1 hour and 50 minutes after the LOOP occurred. However, offsite power was available in switchyard within one minute after the event occurred. Therefore, in the event of a postulated core uncovery sequence (i.e., a SBO condition), operators had approximately 59 minutes to close the one of the supply feeder breakers to restore offsite power to a vital bus. 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.

Seven 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 9×10^{-6}. The results of an uncertainty assessment on the event CCDP are summarized below.

	5%	Mean	95%
CCDP	2×10^{-6}	9×10^{-6}	2×10^{-5}

The Accident Sequence Precursor Program acceptance threshold is a CCDP of 1×10^{-6} or the CCDP equivalent of an uncomplicated reactor trip with a non-recoverable loss of secondary plant systems (e.g., feed water and condensate), whichever is greater. This CCDP equivalent for Wolf Creek is 6×10^{-7}.

Dominant Sequence. The dominant accident sequence, LOOP/SBO Sequence 16-03-10 (CCDP = 2.5×10^{-6}) contributes 27% 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 Figures B-1 and B-2 in Appendix B. The events and important component failures in LOOP/SBO Sequence 16-03-10 are:

- LOOP occurs,
- reactor scram succeeds,
- EDGs fail,

- auxiliary feedwater (AFW) succeeds,
- power-operated relief valves (PORVs) successfully close (if opened),
- rapid secondary depressurization succeeds,
- RCP Seal 1 integrity is maintained,
- RCP Seal 2 integrity is maintained,
- operators fail to restore offsite power within 8 hours,
- operators fail to recover an EDG within 8 hours,
- operators fail to manual control AFW, and
- steam generator (SG) depressurization fails.

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

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

MODELING ASSUMPTIONS

Analysis Type. The Revision 3.51 of the Wolf Creek SPAR model (Reference 3) created in May 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 August 19, 2009 reactor trip at Wolf Creek as a LOOP initiating event.

- Offsite power recovery to a safety bus was possible one minute after the LOOP occurred.

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-LOOP) was set 1.0 to represent the operational event that occurred at Wolf Creek on August 19, 2009. All other initiating events frequencies were set to zero.

- The non-recovery probability for basic event OEP-XHE-XL-NR01H was changed to 6.0×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR02H was changed to 2.4×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR03H was changed to 2.4×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR04H was changed to 2.4×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR06H was changed to 2.4×10^{-3}. See Appendix C for further details.

- The non-recovery probability for basic event OEP-XHE-XL-NR08H was changed to 2.4×10^{-3}. See Appendix C for further details.

- 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.

- Since the turbine-driven AFW pump is the only alternate current (AC) power-independent pump in the AFW system, the turbine-driven AFW pump mission time was set to the actual time that offsite power was restored to the second vital bus (approximately 3 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-TDP-FR-E = 1 hour (base case value) and ZT-TDP-FR-L = 2 hours.

Sensitivity Case. Potential recovery for LOOP Sequence 15 was analyzed based on a reviewer comment as a sensitivity case. For this recovery to be successful, operators would have to recovery offsite power and restore feed to the steam generators via the condensate pumps within one hour. In addition, the support systems (e.g., instrument air, cooling water) for the condensate pumps would need to be restored as well. A non-recovery probability of 0.5 was used for total non-recovery probability for LOOP Sequence 15 in this case. Applying this recovery decreases the sequence CCDP and total CCDP by approximately 6×10^{-7} (i.e., less than 7%).

REFERENCES

1. Wolf Creek Nuclear Operating Corporation, "LER 482/09-002– Loss of Offsite Power Due to Lightning" dated October 17, 2009.

2. U.S. Nuclear Regulatory Commission, "Wolf Creek Generating Plant Special Inspection Report 05000482/2009007," dated February 2, 2010.

3. Idaho National Laboratory, "Standardized Plant Analysis Risk Model for Wolf Creek," Revision 3.51, dated May 2009.

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: Wolf Creek 3.51 (May 2009)

Analysis Type: Initiating Event Assessment
Event Description: LOOP with Offsite Power Recovery Possible within 1 Minute of Event Occurrence

Total CCDP: 9E-6 (*Point Estimate and Mean*)

BASIC EVENT CHANGES

Event Name	Description	Base Probability	Current Probability
IE-ISL-HPI	ISLOCA IE 2-CKV HPI Interface	9.2E-006	+0.0E+000
IE-ISL-LPI	ISLOCA IE 2-CKV LPI Interface	4.6E-006	+0.0E+000
IE-ISL-RHR	RHR Pipe Ruptures	7.9E-006	+0.0E+000
IE-LLOCA	Large LOCA	2.5E-006	+0.0E+000
IE-LOCCW	Loss of Component Cooling Water	4.0E-004	+0.0E+000
IE-LOCHS	Loss of Condenser Heat Sink	8.0E-002	+0.0E+000
IE-LODCNK01	Loss of DC Bus NK01	6.0E-004	+0.0E+000
IE-LODCNK04	Loss of DC Bus NK04	6.0E-004	+0.0E+000
IE-LOMFW	Loss of Main Feedwater	1.0E-001	+0.0E+000
IE-LOOP	Loss of Offsite Power	+0.0E+000	1.0E+000
IE-LOSWS	Loss of Service Water	4.0E-004	+0.0E+000
IE-MLOCA	Medium LOCA	2.0E-004	+0.0E+000
IE-SGTR	Steam Generator Tube Ruptures	4.0E-003	+0.0E+000
IE-SLOCA	Small LOCA	6.0E-004	+0.0E+000
IE-TRANS	Transient	8.0E-001	+0.0E+000
IE-VSLOCA	Very Small LOCA	2.0E-003	+0.0E+000
IE-XLOCA	Reactor Vessel Ruptures	1.0E-007	+0.0E+000
OEP-XHE-XL-NR01H	Operator Fails to Recover Offsite Power (1hr)	+0.0E+000	6.0E-003
OEP-XHE-XL-NR02H	Operator Fails to Recover Offsite Power (2hrs)	+0.0E+000	2.4E-003
OEP-XHE-XL-NR03H	Operator Fails to Recover Offsite Power (3hrs)	+0.0E+000	2.4E-003
OEP-XHE-XL-NR04H	Operator Fails to Recover Offsite Power (4hrs)	+0.0E+000	2.4E-003
OEP-XHE-XL-NR06H	Operator Fails to Recover Offsite Power (6hrs)	+0.0E+000	2.4E-003
OEP-XHE-XL-NR08H	Operator Fails to Recover Offsite Power (8hrs)	+0.0E+000	2.4E-003
ZT-DGN-FR-L	Emergency Diesel Generator (Standby)	1.8E-002	8.0E-004
ZT-TDP-FR-L	Turbine-Driven Pump (Standby)	1.6E-003	1.4E-004

DOMINANT SEQUENCES

Event Tree	Sequence	CCDP	% Contribution
LOOP	16-03-10	2.5E-006	27.2%
LOOP	16-04-2	1.9E-006	20.7%
LOOP	15	1.1E-006	12.0%
LOOP	16-06	8.8E-007	9.6%
LOOP	02-02-04	6.2E-007	6.7%
LOOP	02-04	5.7E-007	6.2%
LOOP	16-45	3.5E-007	3.8%
LOOP	16-04-7	2.9E-007	3.2%

SEQUENCE LOGIC

Event Tree	Sequence Name	Logic
LOOP	16-03-10	/RPS EPS /AFW-B /PORV-B /RSD-B /BP1 /BP2 OPR-08H DGR-08H AFW-MAN SG-DEP-LT1
LOOP	16-04-2	/RPS EPS /AFW-B /PORV-B /RSD-B /BP1 BP2 /OPR-04H /HPI /SSC LPR
LOOP	15	/RPS /EPS AFW-L FAB-L
LOOP	16-06	/RPS EPS /AFW-B /PORV-B /RSD-B /BP1 BP2 OPR-04H DGR-04H
LOOP	02-02-04	/RPS /EPS /AFW-L /PORV-L LOSC-L /RSD-L /BP1 BP2 /OPR-02H /FW /HPI /SSC RHR HPR LPR
LOOP	02-04	/RPS /EPS /AFW-L /PORV-L LOSC-L /RSD-L /BP1 BP2 OPR-02H /HPI-L HPR-L
LOOP	16-45	/RPS EPS AFW-B OPR-01H DGR-01H
LOOP	16-04-7	/RPS EPS /AFW-B /PORV-B /RSD-B /BP1 BP2 /OPR-04H HPI /SSC LPI

FAULT TREE DESCRIPTIONS

Fault Tree Name	Description
AFW-B	Auxiliary Feedwater
AFW-L	Auxiliary Feedwater during LOOP
AFW-MAN	Manual Control AFW
BP1	RCP Seal Stage 1 Integrity
BP2	RCP Seal Stage 2 Integrity
DGR-01H	Operator Fails To Recover Emergency Diesel in 1 Hour
DGR-04H	Operator Fails To Recover Emergency Diesel in 4 Hours
DGR-08H	Operator Fails To Recover Emergency Diesel in 8 Hours
EPS	Emergency Power
FAB-L	Feed And Bleed during LOOP
FW	Feedwater (AFW or MFW)
HPI	High Pressure Injection
HPI-L	High Pressure Injection during LOOP
HPR	High Pressure Recirculation
HPR-L	High Pressure Recirculation during LOOP
LOSC-L	RCP Seals Survive Loss of Cooling during LOOP
LPI	Low Pressure Injection
LPR	Low Pressure Recirculation
OPR-01H	Operator Fails To Recover Offsite Power in 1 Hour
OPR-02H	Operator Fails To Recover Offsite Power in 2 Hours
OPR-04H	Operator Fails To Recover Offsite Power in 4 Hours
OPR-08H	Operator Fails To Recover Offsite Power in 8 Hours
PORV-B	PORVs Are Closed during SBO
PORV-L	PORVs Are Closed during LOOP
RHR	Residual Heat Removal
RPS	Reactor Shutdown
RSD-B	Rapid Secondary Depressurization
RSD-L	Rapid Secondary Depressurization during LOOP
SG-DEP-LT1	Depressurize SGs (Dependent)
SSC	Cooldown (Primary and Secondary)

SEQUENCE CUTSETS

Sequence: LOOP 16-03-10 **CCDP:** 2.5E-006

CCDP	% Cutset	Cutset Events
1.4E-007	5.53	EPS-XHE-XL-NR08H, OEP-XHE-XL-NR08H, /RCS-MDP-LK-BP2, ESW-FAN-CF-GDFANR
9.6E-008	3.79	EPS-XHE-XL-NR08H, OEP-XHE-XL-NR08H, /RCS-MDP-LK-BP2, ESW-FAN-CF-GDFANS
8.1E-008	3.21	EPS-DGN-CF-NE012R, EPS-XHE-XL-NR08H, OEP-XHE-XL-NR08H, /RCS-MDP-LK-BP2
6.3E-008	2.49	EPS-XHE-XL-NR08H, OEP-XHE-XL-NR08H, /RCS-MDP-LK-BP2, EPS-DGN-FR-NE01, EPS-DGN-TM-NE02
6.3E-008	2.49	EPS-XHE-XL-NR08H, OEP-XHE-XL-NR08H, /RCS-MDP-LK-BP2, EPS-DGN-TM-NE01, EPS-DGN-FR-NE02
6.3E-008	2.49	EPS-XHE-XL-NR08H, OEP-XHE-XL-NR08H, /RCS-MDP-LK-BP2, EPS-DGN-FR-NE02, ESW-MDP-TM-1A
6.3E-008	2.49	EPS-XHE-XL-NR08H, OEP-XHE-XL-NR08H, /RCS-MDP-LK-BP2, ESW-MDP-TM-1B, EPS-DGN-FR-NE01

Sequence: LOOP 16-04-2 **CCDP:** 1.9E-006

CCDP	% Cutset	Cutset Events
7.2E-008	3.72	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, LPR-XHE-XM-RECIRC, ESW-FAN-CF-GDFANR
5.0E-008	2.55	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, LPR-XHE-XM-RECIRC, ESW-FAN-CF-GDFANS
4.2E-008	2.16	EPS-DGN-CF-NE012R, /OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, LPR-XHE-XM-RECIRC
3.3E-008	1.67	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, ESW-MDP-TM-1B, EPS-DGN-FR-NE01, LPR-XHE-XM-RECIRC
3.3E-008	1.67	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-FR-NE02, ESW-MDP-TM-1A, LPR-XHE-XM-RECIRC
3.3E-008	1.67	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-FR-NE01, EPS-DGN-TM-NE02, LPR-XHE-XM-RECIRC
3.3E-008	1.67	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-TM-NE01, EPS-DGN-FR-NE02, LPR-XHE-XM-RECIRC

Sequence: LOOP 15 **CCDP:** 1.1E-006

CCDP	% Cutset	Cutset Events
1.2E-008	1.04	HPI-XHE-XM-FB, AFW-TDP-FS-PAL02, AFW-MDP-CF-START
1.0E-008	0.92	HPI-XHE-XM-FB, AFW-TDP-FS-PAL02, AFW-ACX-CF-GF02ABR
8.3E-009	0.74	HPI-XHE-XM-FB, AFW-TDP-TM-PAL02, AFW-MDP-CF-START
8.3E-009	0.74	AFW-XHE-XE-SGOVERFILL, HPI-XHE-XM-FB, AFW-MDP-CF-START
7.3E-009	0.66	HPI-XHE-XM-FB, AFW-TDP-TM-PAL02, AFW-ACX-CF-GF02ABR
7.3E-009	0.66	AFW-XHE-XE-SGOVERFILL, HPI-XHE-XM-FB, AFW-ACX-CF-GF02ABR

Sequence: LOOP 16-06 **CCDP:** 8.8E-007

CCDP	% Cutset	Cutset Events
4.8E-008	5.53	EPS-XHE-XL-NR04H, OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, ESW-FAN-CF-GDFANR
3.3E-008	3.79	EPS-XHE-XL-NR04H, OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2,

		ESW-FAN-CF-GDFANS
2.8E-008	3.21	EPS-DGN-CF-NE012R, EPS-XHE-XL-NR04H, OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2
2.2E-008	2.49	EPS-XHE-XL-NR04H, OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, ESW-MDP-TM-1B, EPS-DGN-FR-NE01
2.2E-008	2.49	EPS-XHE-XL-NR04H, OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-FR-NE01, EPS-DGN-TM-NE02
2.2E-008	2.49	EPS-XHE-XL-NR04H, OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-TM-NE01, EPS-DGN-FR-NE02
2.2E-008	2.49	EPS-XHE-XL-NR04H, OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-FR-NE02, ESW-MDP-TM-1A

Sequence: LOOP 02-02-04 **CCDP:** 6.7E-007

CCDP	% Cutset	Cutset Events
2.7E-007	43.13	/OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-HTX-CF-ALL
5.9E-008	9.53	/OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-MDP-CF-RUN
3.8E-008	6.14	/OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-XHE-XM-ISOLATE, ACP-BAC-LP-NB01
3.8E-008	6.14	/OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-XHE-XM-ISOLATE, ACP-BAC-LP-NG03

Sequence: LOOP 02-04 **CCDP:** 6.2E-007

CCDP	% Cutset	Cutset Events
1.2E-007	20.07	OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-XHE-XM-ISOLATE, ESW-MDP-TM-1A
1.2E-007	20.07	OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, EPS-DGN-TM-NE01, CCW-XHE-XM-ISOLATE
6.5E-008	11.35	OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, EPS-DGN-FR-NE01, CCW-XHE-XM-ISOLATE
4.8E-008	8.36	OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, EPS-DGN-FS-NE01, CCW-XHE-XM-ISOLATE
4.6E-008	7.95	OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-XHE-XM-ISOLATE, ESW-FAN-FR-CGD01A
2.9E-008	5.02	OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-XHE-XM-ISOLATE, ESW-FAN-FS-CGD01A
2.4E-008	4.18	ACP-CRB-CC-NB0112, OEP-XHE-XL-NR02H, RCS-MDP-LK-BP2, CCW-XHE-XM-ISOLATE

Sequence: LOOP 16-45 **CCDP:** 3.8E-007

CCDP	% Cutset	Cutset Events
6.4E-008	18.34	DCP-BAT-CF-ALL
6.0E-009	1.70	EPS-XHE-XL-NR01H, OEP-XHE-XL-NR01H, AFW-TDP-FS-PAL02, ESW-FAN-CF-GDFANR
4.3E-009	1.22	EPS-XHE-XL-NR01H, AFW-TDP-TM-PAL02, OEP-XHE-XL-NR01H, ESW-FAN-CF-GDFANR
4.3E-009	1.22	AFW-XHE-XE-SGOVERFILL, EPS-XHE-XL-NR01H, OEP-XHE-XL-NR01H, ESW-FAN-CF-GDFANR
4.1E-009	1.17	EPS-XHE-XL-NR01H, OEP-XHE-XL-NR01H, AFW-TDP-FS-PAL02, ESW-FAN-CF-GDFANS

Sequence: LOOP 16-04-7 **CCDP:** 3.2E-007

CCDP	% Cutset	Cutset Events
1.6E-008	5.53	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, ESW-FAN-CF-GDFANR, HPI-SYS-FC-RWSTLLO
1.1E-008	3.79	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, HPI-SYS-FC-RWSTLLO, ESW-FAN-CF-GDFANS
9.2E-009	3.21	EPS-DGN-CF-NE012R, /OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, HPI-SYS-FC-RWSTLLO
7.2E-009	2.48	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-FR-NE02, ESW-MDP-TM-1A, HPI-SYS-FC-RWSTLLO
7.2E-009	2.48	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-FR-NE01, EPS-DGN-TM-NE02, HPI-SYS-FC-RWSTLLO
7.2E-009	2.48	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, EPS-DGN-TM-NE01, EPS-DGN-FR-NE02, HPI-SYS-FC-RWSTLLO
7.2E-009	2.48	/OEP-XHE-XL-NR04H, RCS-MDP-LK-BP2, ESW-MDP-TM-1B, EPS-DGN-FR-NE01, HPI-SYS-FC-RWSTLLO

BASIC EVENTS (cutsets only)

Event Name	Description	Probability
ACP-BAC-LP-NB01	4160 VAC BUS NB01 Fails	9.6E-006
ACP-BAC-LP-NG03	480 VAC BUS NG03 Fails	9.6E-006
ACP-CRB-CC-NB0112	ESF Transformer XNB01 Breaker Fails to Open	2.5E-003
AFW-TDP-FR-PAL02	TDP PAL02 Fails to Run	4.1E-003
AFW-TDP-FS-PAL02	TDP PAL02 Fails to Start	7.0E-003
AFW-TDP-TM-PAL02	TDP PAL02 Unavailable Due to T&M	5.0E-003
AFW-XHE-XE-SGOVERFILL	Failure to Maintain SG Levels	5.0E-003
CCW-HTX-CF-ALL	CCF of CCW Heat Exchangers	1.4E-006
CCW-MDP-CF-RUN	CCW Pumps Fail from Common Cause to Run	3.0E-007
CCW-XHE-XM-ISOLATE	Operator Fails to Isolate Idle CCW Loop	2.0E-002
DCP-BCH-TM-BC21	Battery Charger BC-21 Unavailable Due T&M	2.0E-003
EPS-DGN-CF-NE012R	CCF of EDGs to Run	3.7E-004
EPS-DGN-FR-NE01	EDG NE01 Fails to Run	2.4E-002
EPS-DGN-FR-NE02	EDG NE02 Fails to Run	2.4E-002
EPS-DGN-FS-NE01	EDG NE01 Fails to Start	5.0E-003
EPS-DGN-FS-NE02	EDG NE02 Fails to Start	5.0E-003
EPS-DGN-TM-NE01	EDG NE01 Unavailable Due to T&M	1.2E-002
EPS-DGN-TM-NE02	EDG NE02 Unavailable Due to T&M	1.2E-002
EPS-XHE-XL-NR01H	Operator Fails to Recover EDG in 1 Hour	7.9E-001
EPS-XHE-XL-NR04H	Operator Fails to Recover EDG in 4 Hours	5.6E-001
EPS-XHE-XL-NR08H	Operator Fails to Recover EDG in 8 Hours	4.0E-001
ESW-FAN-CF-GDFANR	ESW Room HVAC Fans CGD01A & 1B Fail to Run	1.8E-004
ESW-FAN-CF-GDFANS	ESW Room HVAC Fans CGD01A & 1B Fail to Start	1.2E-004
ESW-FAN-FR-CGD01A	ESW Train A HVAC Fan CGD01A Fails to Run	4.8E-003
ESW-FAN-FS-CGD01A	ESW Train A HVAC Fan CGD01A Fails to Start	3.0E-003
ESW-MDP-FS-1A	ESW Train A MDP 1A Fails to Start	2.0E-003
ESW-MDP-TM-1A	ESW Train A MDP 1A Unavailable Due to T&M	1.2E-002
ESW-MDP-TM-1B	ESW Train A MDP 1B Unavailable Due to T&M	1.2E-002
HPI-SYS-FC-RWSTLLO	Failure of RWST Level Lo 2/4 Instrumentation	4.4E-004
LPR-XHE-XM-RECIRC	Operator Fails to Initiate Low Pressure Recirculation	2.0E-003
OEP-XHE-XL-NR01H	Operator Fails to Recover Offsite Power in 1 Hour	6.0E-003
OEP-XHE-XL-NR02H	Operator Fails to Recover Offsite Power in 2 Hours	2.4E-003
OEP-XHE-XL-NR04H	Operator Fails to Recover Offsite Power in 4 Hours	2.4E-003
OEP-XHE-XL-NR08H	Operator Fails to Recover Offsite Power in 8 Hours	2.4E-003
RCS-MDP-LK-BP2	RCP Seal Stage 2 Integrity (Binding/Popping)	2.0E-001

Appendix B
LOOP and SBO Event Trees

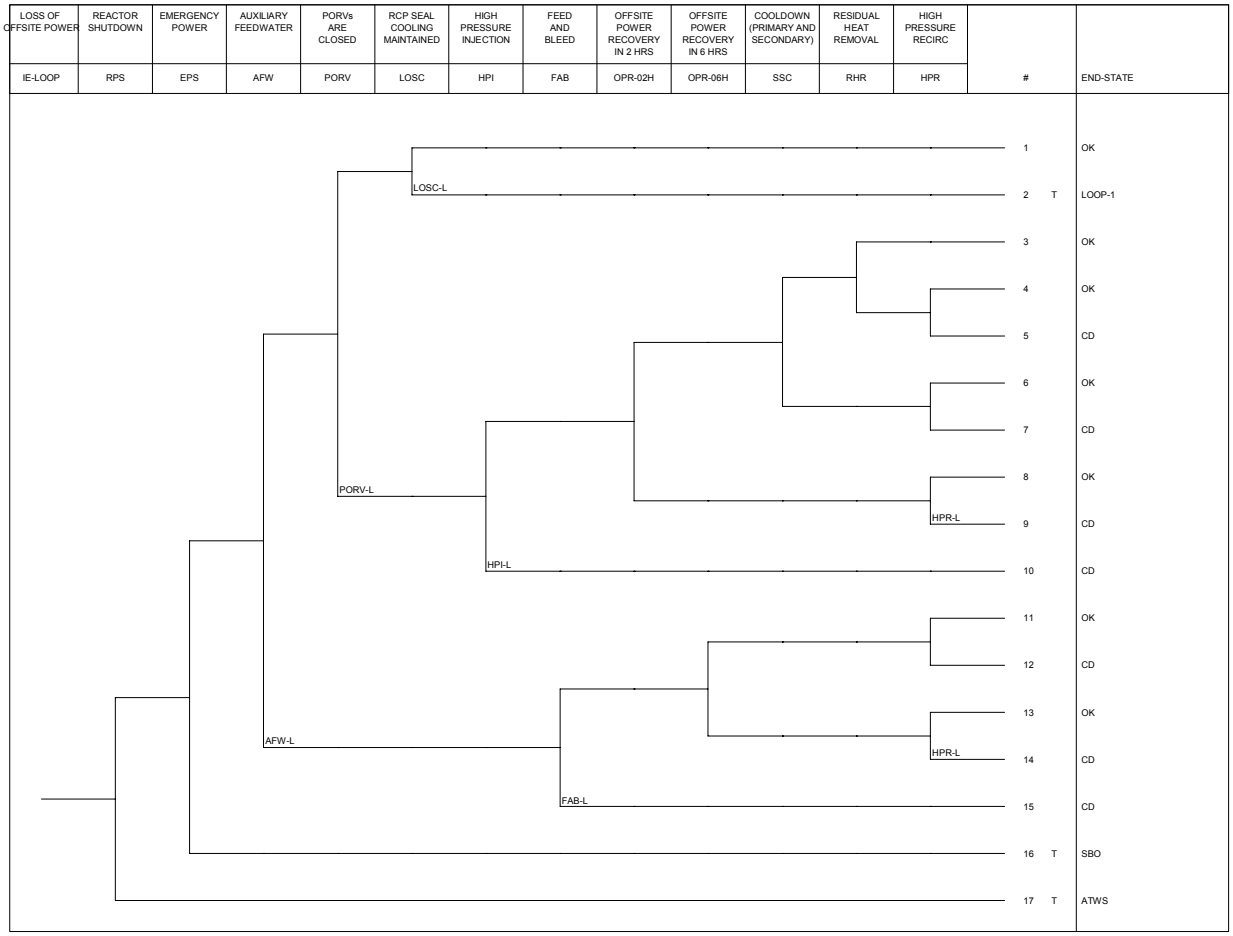

Figure B-1. Wolf Creek LOOP event tree.

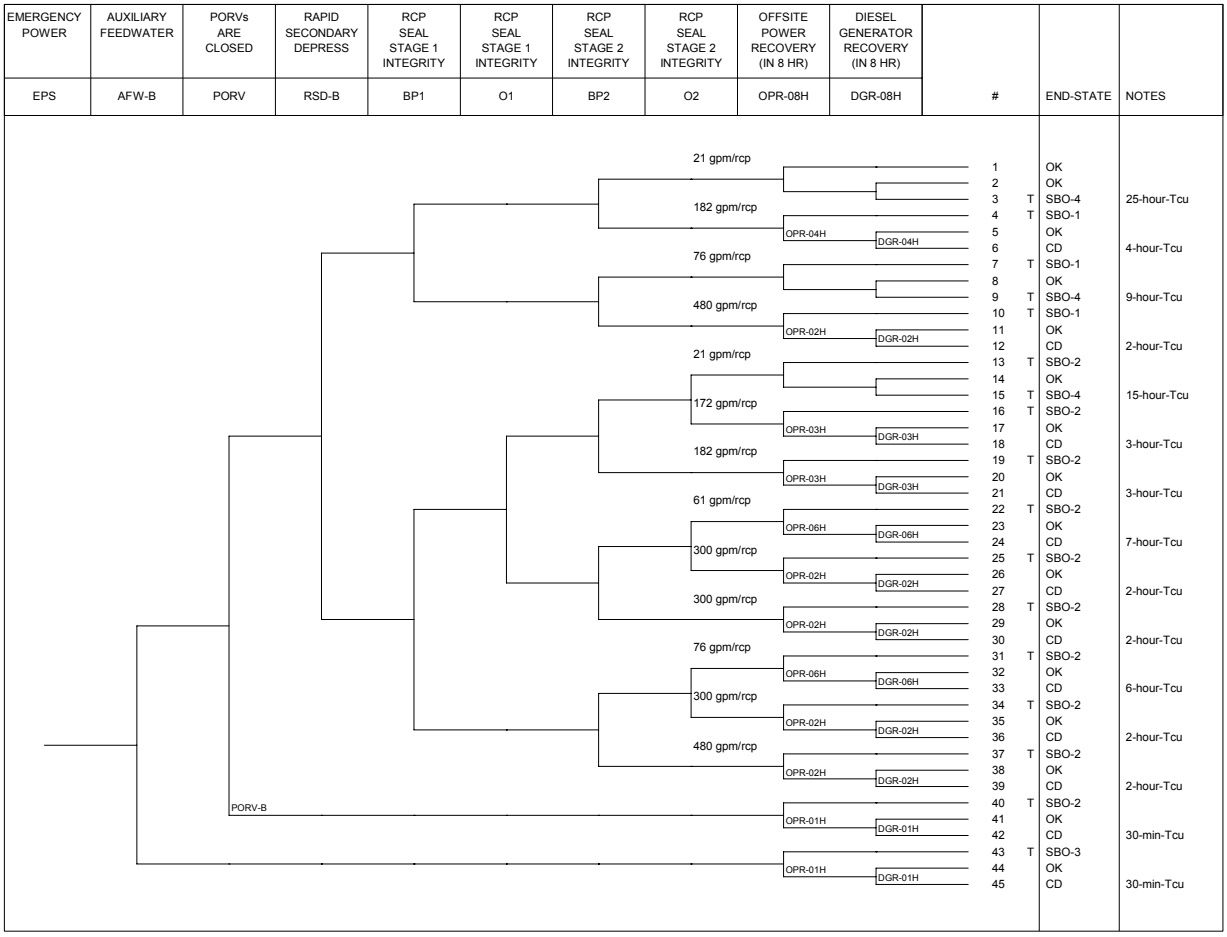

Figure B-2. Wolf Creek SBO event tree.

Appendix C
Offsite Power Recovery Modeling

Background and Modeling Details of Offsite Power Recovery[1]

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. Within one minute of the LOOP, the transmission system operator closed the Wolf Creek–Rose Hill transmission network line Breaker 345-50. This restored offsite power to Wolf Creek's switchyard. After the power was restored to the switchyard bus, operators would need to close one of the supply feeder breakers to supply offsite power to a vital bus (NB01 or NB02). In the event of a blackout condition, operators would have sufficient time (approximately 59 minutes) to shut the one breaker to restore AC power to a vital bus.

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.

[1] 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. Operators would have a minimum of 59 minutes available to restore offsite during a postulated blackout event. If the EDGs failed (postulated failure) during this event, operators would have a minimum of 45 pages of procedures to go through before the steps to close the feeder supply breakers to one of the vital busses (NB01 or NB02) are reached. Therefore, this analysis uses an estimation of 45 minutes (i.e., nominal time) for operators to go through the correct procedures to 'diagnose' the need to restore power to a vital bus. With only one breaker needing to be shut, the action portion time for recovery of offsite power to a vital bus is minimal (< 1 minute). Therefore, the 1-hour recovery action (OEP-XHE-XL-NR01H) PSF for time available is set to extra time (i.e., 1 to 2× nominal and > 30 minutes). 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 two hours.

Action. The PSF for time available for action is set to nominal for all 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 AC power non-recovery probabilities. 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 non-recovery probabilities. 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 recovery actions.

All Other PSFs

Diagnosis and Action. For all of the AC power non-recovery probabilities, 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 of the offsite power recovery operator 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-NR01H	Extra Time	High	Moderate	Nominal	High	Nominal
OEP-XHE-XL-NR02H	Expansive Time	High	Moderate	Nominal	High	Nominal
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-NR06H	Expansive Time	High	Moderate	Nominal	High	Nominal
OEP-XHE-XL-NR08H	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-NR01H	1×10^{-2}	×0.1	×2	×2	×1	4×10^{-3}
OEP-XHE-XL-NR02H	1×10^{-2}	×0.01	×2	×2	×1	4×10^{-4}
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-NR06H	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}

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-NR01H	1×10^{-3}	×2	×1	2×10^{-3}
OEP-XHE-XL-NR02H	1×10^{-3}	×2	×1	2×10^{-3}
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-NR06H	1×10^{-3}	×2	×1	2×10^{-3}
OEP-XHE-XL-NR08H	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-NR01H	4×10^{-3}	2×10^{-3}	6.0×10^{-3}
OEP-XHE-XL-NR02H	4×10^{-4}	2×10^{-3}	2.4×10^{-3}
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-NR06H	4×10^{-4}	2×10^{-3}	2.4×10^{-3}
OEP-XHE-XL-NR08H	4×10^{-4}	2×10^{-3}	2.4×10^{-3}