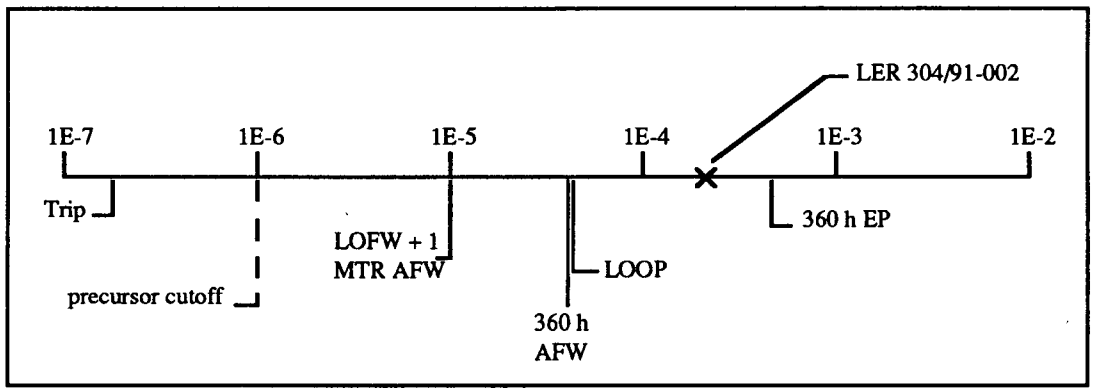
ACCIDENT SEQUENCE PRECURSOR PROGRAM EVENT ANALYSIS

LER No.: 304/91-002
Event Description: Loss of offsite power with one diesel generator out of service
Date of Event: March 21, 1991
Plant: Zion 2

Summary

Multiple inadvertent deluge system actuations sprayed the station auxiliary transformer (SAT) at Zion 2 and resulted in a loss of offsite power (LOOP). One emergency diesel generator (EDG) was out of service for maintenance at the time of the event. Equipment rendered unavailable by the LOOP complicated recovery from the event. The conditional core damage probability for this event, based on the current Accident Sequence Precursor (ASP) models, is estimated to be 2.1 x 10^{-4}. The relative significance of this event as compared to other postulated events at Zion 2 is shown below.



Event Description

On March 21, 1991, Zion 2 was operating at full power. EDG 0, the common swing diesel for the two Zion units, was out of service to repair a jacket water leak. Surveillance testing of the Unit 2 EDGs was in progress, as was Performance Test (PT)-211, "Wet Pipe Sprinkler Test."

During the morning, three inadvertent deluges occurred on the main power transformer (MPT)/unit auxiliary transformer (UAT) and SAT. In each case, the operators confirmed that no fire had occurred. After the second deluge, the deluge isolation valve for the MPT/UAT was closed. A third deluge occurred while the operators were trying to reset the deluge valve and reopen the isolation valve.

At 1307 hours in the afternoon, another inadvertent deluge of the Unit 2 SAT occurred. While the deluge flow was being isolated, the SAT tripped because of a phase-to-ground fault. Buses 243 and 244 supplied by the SAT were automatically transferred to the UAT, which is powered by the main generator. An arc strike was subsequently found on the C phase transformer bushing, and the deluge system spray nozzles were found to have been incorrectly aligned and tested.

Feedwater for Unit 2 was being supplied by one turbine-driven pump and the motor-driven main feedwater (MFW) pump; the second turbine-driven pump was out of service for maintenance. When the SAT tripped, the motor-driven feedwater pump lost power. Unavailability of the motor-driven feedwater pump caused a reduction in feedwater flow to the steam generators (SGs) and a consequent reduction in SG level, since steam flow had not changed. A lo-lo SG level reactor trip occurred at 1310 hours. Following the reactor trip, the UAT tripped as expected, resulting in a LOOP.

At the time of the SAT trip, surveillance testing was in progress on EDG 2A. The generator was running, paralleled to bus 248, and loaded to 1 MW. At the time of the UAT trip, EDG 2A output breaker tripped on reverse power but closed again on the LOOP undervoltage signal and repowered bus 248. EDG 2B automatically started and reenergized bus 249 essential loads. Since EDG 0 was out of service for maintenance, bus 247 was not repowered until the operators manually transferred it at 1405 hours (approximately 1 h after the LOOP) to Unit 1 vital bus 141, which is the backup emergency power source for the Unit 2 vital buses.

A number of other problems occurred during and following the LOOP that affected plant and operator response to the event.

1. The sequence of events recorder was powered from a nonvital bus that was lost following the LOOP. Because of this, events that occurred immediately following the reactor trip were not recorded. This lack of information complicated diagnosis of the event.

2. Prior to Unit 2 entering cold shutdown, both power-operated relief valves (PORVs) were stroke-tested to confirm operability for low-temperature overpressure protection. PORV 455C failed to open because of a failed air line. Inoperability of this valve impacted the unit's ability to remove decay heat using bleed and feed, if that had been required.

3. Component cooling water (CCW) pump 0A was tripped by an operator after it was observed that there was no oil in the pump. The CCW system is a shared system between the two units, and four CCW pumps remained operable.

4. Following a loss of nonvital AC power at Zion, the SG relief valve controls fail as is. The valves were nearly full-open at the time of the LOOP because the operators were attempting to match feed and steam flow following loss of the motor-driven MFW pump. The valves had to be closed locally by bleeding control air. One of the relief valves failed open and the associated isolation valve had to be closed to terminate flow.

5. Some doors between the power block and the service buildings failed closed when power was apparently lost from the security inverter (reason unspecified). This delayed personnel outside the power block in responding to the event. Personnel inside the power block were not affected. Security personnel responded to the failure in an uncoordinated manner, and station personnel were unaware of which doors would be manned by security personnel in such a situation.

Additional Event-Related Information

The Zion 2 emergency power system consists of three buses (247, 248, and 249), which provide essential AC power to safety-related equipment. EDGs 2A and 2B provide emergency power to buses 248 and 249, and swing EDG 0 provides power to bus 247 or Unit 1 bus 147. In addition, power from the Unit 1 SAT can be manually aligned to supply power to Unit 2. In a similar manner, three batteries provide backup DC power for Unit 2. The two batteries that only provide power to Unit 2 are capable of supplying loads for at least 3 h.

If secondary-side cooling is unavailable, feed and bleed can provide decay heat removal at Zion. Based on the information provided in the NUREG-1150 analysis for Zion (NUREG/CR-4550, Vol. 7, Rev. 1), feed and bleed success requires one-of-two safety injection (SI) pumps and two PORVs or one-of-two charging pumps and one PORV.

ASP Modeling Assumptions and Approach

The event has been modeled as a plant-centered LOOP with one EDG unavailable. Unavailability of EDG 0 resulted in unavailability of one charging, service water, SI, and containment spray pump. Manual connection of the emergency buses to the Unit 1 feeder bus was not addressed, and therefore the analysis is somewhat conservative. Nonrecovery probabilities for LOOP (short-term), electric power prior to battery depletion or core uncovery following a reactor coolant pump (RCP) seal loss-of-coolant accident (LOCA), and the probability of an RCP seal LOCA, were revised to reflect the observed plant-centered LOOP (see ORNL/NRC/LTR-89/11, *Revised LOOP Recovery and PWR Seal LOCA Models*, August 1989).

The current ASP models do not address the use of the charging pumps as an alternate to

the SI pumps for high-pressure injection (HPI) and feed and bleed. The branch probabilities for HPI and feed and bleed were modified to reflect the potential use of the charging pumps, and these probabilities were used in a sensitivity analysis.

Because of the unavailability of EDG 0 and PORV 455C, only one charging pump, one SI pump, and one PORV were available for HPI and feed and bleed. Using the train-level screening probabilities typically employed in ASP calculations results in the following branch estimates for these functions:

Branch	Current ASP models	SI or charging pumps provide success
HPI	~8.4×10^{-3}*	~8.4×10^{-5}*
Feed and bleed	1.0*	~2.8×10^{-2}*

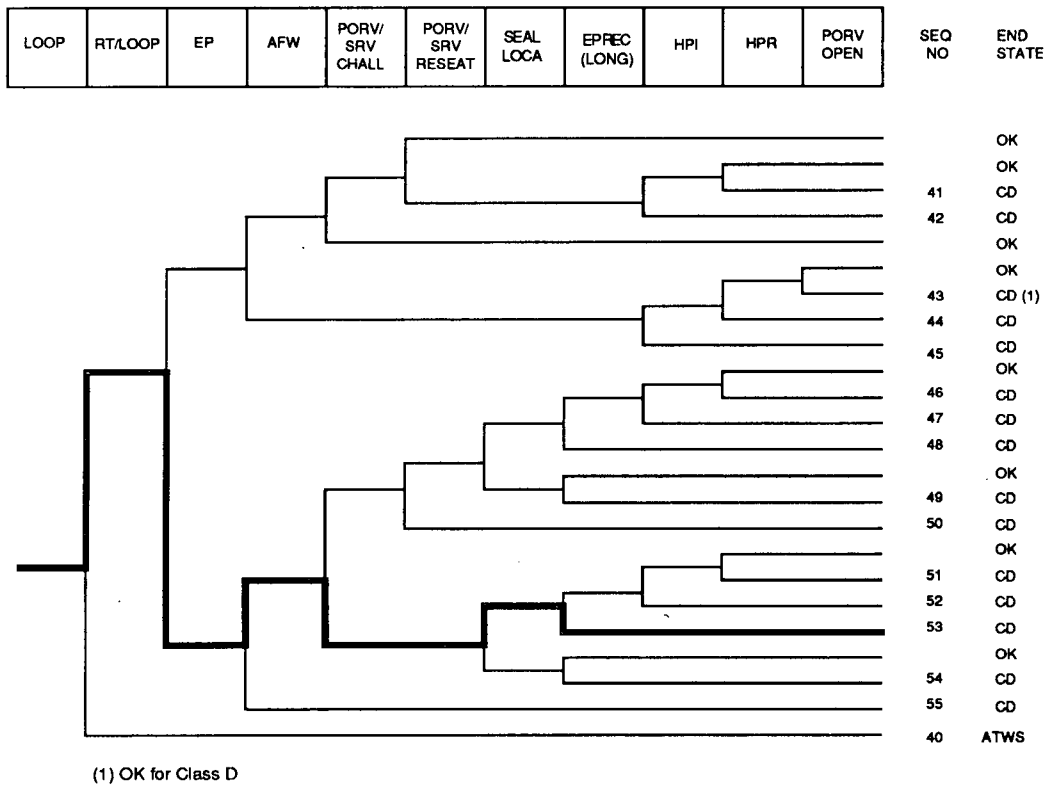
*conditional on unavailability of EDG 0 and PORV 455C

Analysis Results

The conditional core damage probability for this event, based on the current ASP models, is estimated to be 2.1×10^{-4}. The dominant core damage sequence, highlighted on the following event tree, involves a LOOP with emergency power failure, a resulting RCP seal LOCA, and failure to recover AC power prior to core uncovery.

The second most dominant sequence involves a postulated failure of auxiliary feedwater (AFW) and feed and bleed following emergency power success. The probability of this sequence is affected by assumptions concerning those systems that can provide HPI and feed and bleed, as discussed earlier. Considering the charging pumps as an alternate high-pressure source reduces the core damage frequency estimate for this event to 1.6×10^{-4}.

Additional information concerning this event is included in Region III AIT inspection team report 50-304/91006 (DRP), dated April 17, 1991.



Dominant core damage sequence for LER 304/91-002

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 304/91-002
Event Description: LOOP with one EDG out of service (only SI for HPI)
Event Date: 03/21/91
Plant: Zion 2

INITIATING EVENT

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

LOOP	5.0E-01

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOOP	2.1E-04
Total	2.1E-04
ATWS	
LOOP	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
53	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall SEAL.LOCA EP.REC(SL)	CD	1.2E-04	4.0E-01
43	LOOP -rt/loop -EMERG.POWER afw -HPI(F/B) -HPR/-HPI PORV.OPEN	CD	4.8E-05	1.3E-01
55	LOOP -rt/loop EMERG.POWER afw/emerg.power	CD	1.9E-05	1.4E-01
54	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall - SEAL.LOCA EP.REC	CD	7.9E-06	4.0E-01
48	LOOP -rt/loop EMERG.POWER -afw/emerg.power porv.or.srv.chall - porv.or.srv.reseat/emerg.power SEAL.LOCA EP.REC(SL)	CD	5.1E-06	4.0E-01

** non-recovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
43	LOOP -rt/loop -EMERG.POWER afw -HPI(F/B) -HPR/-HPI PORV.OPEN	CD	4.8E-05	1.3E-01
48	LOOP -rt/loop EMERG.POWER -afw/emerg.power porv.or.srv.chall - porv.or.srv.reseat/emerg.power SEAL.LOCA EP.REC(SL)	CD	5.1E-06	4.0E-01
53	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall SEAL.LOCA EP.REC(SL)	CD	1.2E-04	4.0E-01
54	LOOP -rt/loop EMERG.POWER -afw/emerg.power -porv.or.srv.chall - SEAL.LOCA EP.REC	CD	7.9E-06	4.0E-01
55	LOOP -rt/loop EMERG.POWER afw/emerg.power	CD	1.9E-05	1.4E-01

** non-recovery credit for edited case

SEQUENCE MODEL: c:\asp\1989\pwrbseal.cmp

Event Identifier: 304/91-002

BRANCH MODEL: c:\asp\1989\zion.sl1
PROBABILITY FILE: c:\asp\1989\pwr_bsl1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	1.5E-04	1.0E+00	
LOOP	1.6E-05 > 1.6E-05	5.3E-01 > 5.0E-01	
Branch Model: INITOR			
Initiator Freq:	1.6E-05		
loca	2.4E-06	4.3E-01	
rt	2.8E-04	1.2E-01	
rt/loop	0.0E+00	1.0E+00	
EMERG.POWER	5.4E-04 > 2.9E-03	8.0E-01	
Branch Model: 1.OF.3			
Train 1 Cond Prob:	5.0E-02		
Train 2 Cond Prob:	5.7E-02		
Train 3 Cond Prob:	1.9E-01 > Unavailable		
afw	3.8E-04	2.6E-01	
afw/emerg.power	5.0E-02	3.4E-01	
mfw	2.0E-01	3.4E-01	
porv.or.srv.chall	4.0E-02	1.0E+00	
porv.or.srv.reseat	2.0E-02	1.1E-02	
porv.or.srv.reseat/emerg.power	2.0E-02	1.0E+00	
SEAL.LOCA	2.7E-01 > 2.4E-01	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.7E-01 > 2.4E-01		
EP.REC(SL)	5.7E-01 > 4.8E-01	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	5.7E-01 > 4.8E-01		
EP.REC	3.1E-02 > 9.7E-03	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	3.1E-02 > 9.7E-03		
HPI	1.0E-03 > 1.0E-02	8.4E-01	
Branch Model: 1.OF.2			
Train 1 Cond Prob:	1.0E-02		
Train 2 Cond Prob:	1.0E-01 > Unavailable		
HPI(F/B)	1.0E-03 > 1.0E-02	8.4E-01	1.0E-02
Branch Model: 1.OF.2+opr			
Train 1 Cond Prob:	1.0E-02		
Train 2 Cond Prob:	1.0E-01 > Unavailable		
HPR/-HPI	1.5E-04 > 1.0E-02	1.0E+00	1.0E-03
Branch Model: 1.OF.2+opr			
Train 1 Cond Prob:	1.0E-02		
Train 2 Cond Prob:	1.5E-02 > Unavailable		
PORV.OPEN	1.0E-02 > 1.0E+00	1.0E+00	4.0E-04
Branch Model: 1.OF.1+opr			
Train 1 Cond Prob:	1.0E-02 > Failed		

* branch model file
** forced

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