B.13 LER Number 269/92-018

Event Description: Both Keowee Emergency Power Hydro Units Potentially Unavailable

Date of Event: December 2, 1992

Plant: Oconee 1, 2, and 3

B.13.1 Summary

With all three Oconee units at 100% power, both emergency power sources, Keowee Hydro Units 1 and 2 (Keowee 1 and 2), were determined to be inoperable. A modification to the antipump relays in the Westinghouse (type DB) breakers at Keowee did not consider the reduced control circuit dc voltage which would exist following a loss of offsite power (LOOP), when the battery chargers are not supplying the dc buses. During emergency start testing 6 d after completion of the modification (which simulated a LOOP) and in subsequent testing, certain Keowee breakers did not close when required. Both Keowee units were potentially unavailable for 15 d. The conditional core damage probability estimated for this event is 3.2×10^{-5}. This estimate is a bounding estimate that assumes all impacted breakers fail following an actual LOOP and may be conservative for the observed event. The relative significance of this event compared to other postulated events at Oconee is shown in Fig. B.20.

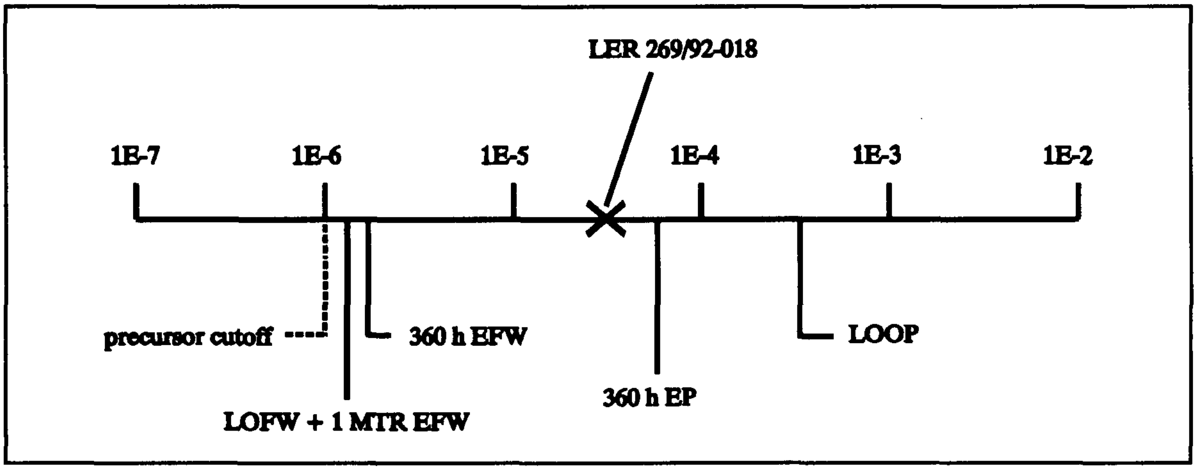

Fig. B.20. Relative event significance of LER 269/92-018 compared with other potential events at Oconee.

B.13.2 Event Description

On January 29, 1992, Keowee 2 failed to start during a routine attempt to supply power to the grid. The failure to start was caused by a mechanical failure of the "X" relay (antipump relay) in a Westinghouse

(type DB) circuit breaker. Corrective actions included the replacement of the existing electromechanical antipump scheme with an electrical antipump scheme in a number of breakers. During the design review prior to the modification, Westinghouse expressed a concern that the closing coil could be damaged if it remained energized for too long a period of time. Because of this concern, each type-DB breaker was individually time-tested before and after the modification to ensure that the new antipump scheme would keep the closing coil energized for the same time as the old antipump scheme. The modification was completed for Keowee 1 on July 19, 1992, and for Keowee 2 on November 18, 1992.

On November 24, 1992, the annual Keowee emergency start test was performed for both units. This test differed from the postmodification testing described above in that a loss of auxiliary ac power was also simulated. With no output from the battery charger because of the unavailability of auxiliary ac power, dc voltage (supplied only by the battery) was lower than during the post-modification testing. During attempts to tie Keowee 2 to the overhead path (one of the two power paths from Keowee to Oconee), the Keowee 2 auxiliary power alternate feeder breaker (ACB-8) could not be closed after the normal feeder breaker (ACB-6) was opened. The auxiliaries for both units were placed in a dedicated alignment which would not require breaker operation during an emergency, pending further breaker testing. On December 1, 1992, voltage regulator problems required Keowee 1 to be shut down and declared inoperable. Testing later in the day demonstrated that the Keowee 1 auxiliary power alternate feeder breaker (ACB-7) failed to close at low dc voltages.

The standby buses were energized from a Lee gas turbine on December 2, 1992 around 1000 hours, and testing of the control circuitry for the type-DB circuit breakers was completed later that day at about 1605 hours. The testing indicated that the available dc voltage was inadequate to ensure closure of the breakers. Keowee 2 was declared inoperable.

The utility stated that, under reduced dc voltage situations, the closing mechanism moves more slowly and therefore has less momentum. This reduced momentum was inadequate to complete the breaker travel for the actual dc voltage. In addition to the auxiliary power breakers, the problem affected the field and field supply breakers, which made both units inoperable. The problem was corrected by increasing the time that the closing coils were energized.

Keowee 1 was restored to an operable status at 0835 hours on December 3, 1992, following the modification to increase the time that the type-DB breaker closing coils are energized. On December 4, 1992, modifications to increase the time that the Keowee 2 closing coils are energized were completed and Keowee 2 was returned to service just before midnight.

B.13.3 Additional Event-Related Information

The Keowee Station, located approximately 0.75 mile east-northeast of the Oconee Nuclear Station, it consists of two hydroelectric generators that generate at 13.8 kV. The two units serve the dual functions of generating commercial power to the Duke Power system grid through the Oconee 230-kV switchyard and providing emergency power to the Oconee Station. When a Keowee unit is generating to the grid and an emergency start occurs, it is separated from the 230-kV switchyard and continues to run in standby until needed. Upon loss of power from an Oconee generating unit and 230-kV switchyard,

power is supplied from both Keowee units through two separate and independent paths. One path is a 4000-ft underground 13.8-kV cable feeder to transformer CT-4, which supplies power to the 4160-V standby buses. The underground power path is connected at all times to one hydro unit on a predetermined basis through locked-closed breakers. The underground power path and associated transformer are sized to carry full engineered safeguards auxiliaries of one Oconee unit plus auxiliaries for safe shutdown of the other two units. If a Keowee unit is to provide power to an Oconee unit through the underground power path (required by Technical Specifications if one of the Keowee units is out of service), then due to the limited capacity of CT-4, loadshed of non-essential loads occurs. The second path from Keowee is a 230-kV transmission line through breakers ACB-1 or ACB-2, via the yellow bus, to each Oconee unit's startup transformer.

Keowee auxiliary power is required for the ac hydraulic oil pumps, which are used to pressurize the air preloaded accumulators that provide hydraulic oil pressure to the governor which controls the position (depending on load) of the wicket gates on the Keowee water turbine. The length of time that the Keowee units can run without ac auxiliaries is limited by the changing load to which the governor must respond. The utility has indicated in several LERs that 1 h is the expected maximum time period of Keowee operation without ac auxiliaries.

A standby shutdown facility (SSF) is located in a separate building on the Oconee site. This facility, which is not normally manned, is capable of providing limited high-pressure injection for reactor coolant system (RCS) makeup and reactor coolant pump (RCP) seal cooling [provided an RCP seal loss-of-coolant accident (LOCA) does not occur]. It can also supply limited steam generator makeup. The facility includes a separate diesel generator which can power SSF loads in the event of a station blackout. SSF systems consist of single trains and are therefore not single-failure-proof.

A more detailed description of the Oconee emergency power system is included in the precursor analysis for LER 270/92-004, *Loss of Offsite Power with Failed Emergency Power*.

B.13.4 Modeling Assumptions

The event was modeled as a postulated LOOP from the time the Keowee units became unavailable (November 18, 1992) until the standby buses were energized from the Lee gas turbine (December 2, 1992), approximately 360 h. Since the breakers that failed were found in different tests (some breakers apparently worked correctly during some tests and not for others), it is not possible to conclude that all breakers would have failed to function during an actual LOOP. Because of this, a bounding analysis was performed, with the assumption that, given a LOOP, the Keowee auxiliary power and field breakers would have failed to function. Such an analysis may be conservative, but provides insight into the potential significance of the event.

Potential sequences associated with the event are described in Appendix A, Sect. A.3.1, PWR Loss of Offsite Power. These sequences were modified to address the Oconee-specific SSF, as described later in this section, and are shown on the event tree included with this analysis documentation. The plant response observed during the event impacted the following branch on the event tree:

Emergency Power. The Keowee hydro units were assumed to fail because of the postulated inoperability of the auxiliary power and field breakers, a result of reduced dc voltage following the LOOP.

Recovery from the event was assumed to be sufficiently complex that an on-call technician would have to be called to the site during off-hours. The probability of the on-call technician failing to arrive on-site and recover Keowee Hydro prior to the loss of wicket gate control was estimated to be 0.64, as described under Modeling Assumptions for the precursor analysis for LER 270/92-004. While procedures at Keowee had been revised after the LOOP, the method used to notify the on-call technician (a phone call) had not been changed. (Depending on the specifics of an event, the Keowee operator may be remotely instructed to close the breakers manually. The potential effectiveness of such an action was not addressed in this analysis.)

Use of an on-call technician was assumed to be required except for the day shift, when adequate support was assumed available on-site to quickly correct the breaker problem and recover Keowee, if needed. This assumption results in a revised estimate for failing to recover Keowee of (16h/24h) × 0.64 = 0.43.

The Central Switchyard was also assumed available as an alternate source of power to the Standby Buses for plant-centered LOOPs. A probability of 0.12 (ASP nonrecovery class R3, see Appendix A, section A.1) was assumed for failing to recover power from the Central Switchyard via transformer CT-5. This value was chosen because recovery appeared possible in the required time period from the control room. However, during a postulated LOOP with problems at Keowee, this recovery would be considered to be non-routine and burdened. During a postulated grid- or severe weather-related LOOP, the Central Switchyard was assumed to be unavailable. However, during a postulated grid-related LOOP, ac power was assumed to be recoverable in approximately 1 h using the Lee combustion turbines. A nonrecovery probability of 0.12 was also assumed for this action, for the same reasons.

The frequency of LOOP and the probability of not recovering offsite power was estimated as described in ORNL/NRC/LTR-89/11, *Revised LOOP and PWR Seal LOCA Models*, August 1989. The frequencies and probability values used in the calculations follow:

	LOOP Type		
	Plant-Centered	Grid-Related	Severe Weather-Related
LOOP frequency	1.3×10^{-5}/h	1.6×10^{-6}/h	1.1×10^{-6}/h
P_{nrec} (LOOP)	0.15	0.48	0.93
P_{nrec} (emergency power)	0.43 × 0.12	0.43	0.43
P_{nrec} (ac power prior to battery depletion)	0.23	0.44 × 0.12	0.86

The use of the SSF as an alternate source of reactor coolant system (RCS) and steam generator (SG) makeup was also addressed in the analysis. This was done by identifying core damage sequences that could be recovered through the use of the SSF (sequences with failed SG makeup or RCP seal cooling and without loss of inventory), and modifying the event tree model described in Appendix A to include its consideration. The revised event tree for Oconee is included with this analysis. A combined operator and equipment failure probability of 0.2 was used for the SSF. This probability is consistent with values developed in the Oconee PRA (NSAC-60) and in licensee analyses of this event.

B.13.5 Analysis Results

The conditional core damage probability estimated for the event is 3.2×10^{-5}. This conditional probability is applicable to each of the three Oconee units. The dominant core damage sequence, highlighted on the event tree in Fig. B.21, involves a postulated weather related LOOP with failure of emergency power, failure of the SSF, and failure to recover ac power before battery depletion. The conditional probability estimate is strongly influenced by assumptions concerning the potential for recovery of the Keowee units.

As described in Sect. B.13.4, this analysis is a bounding analysis that addresses the potential impact of multiple breaker inoperability over the entire exposure period. As such, this analysis may be conservative.

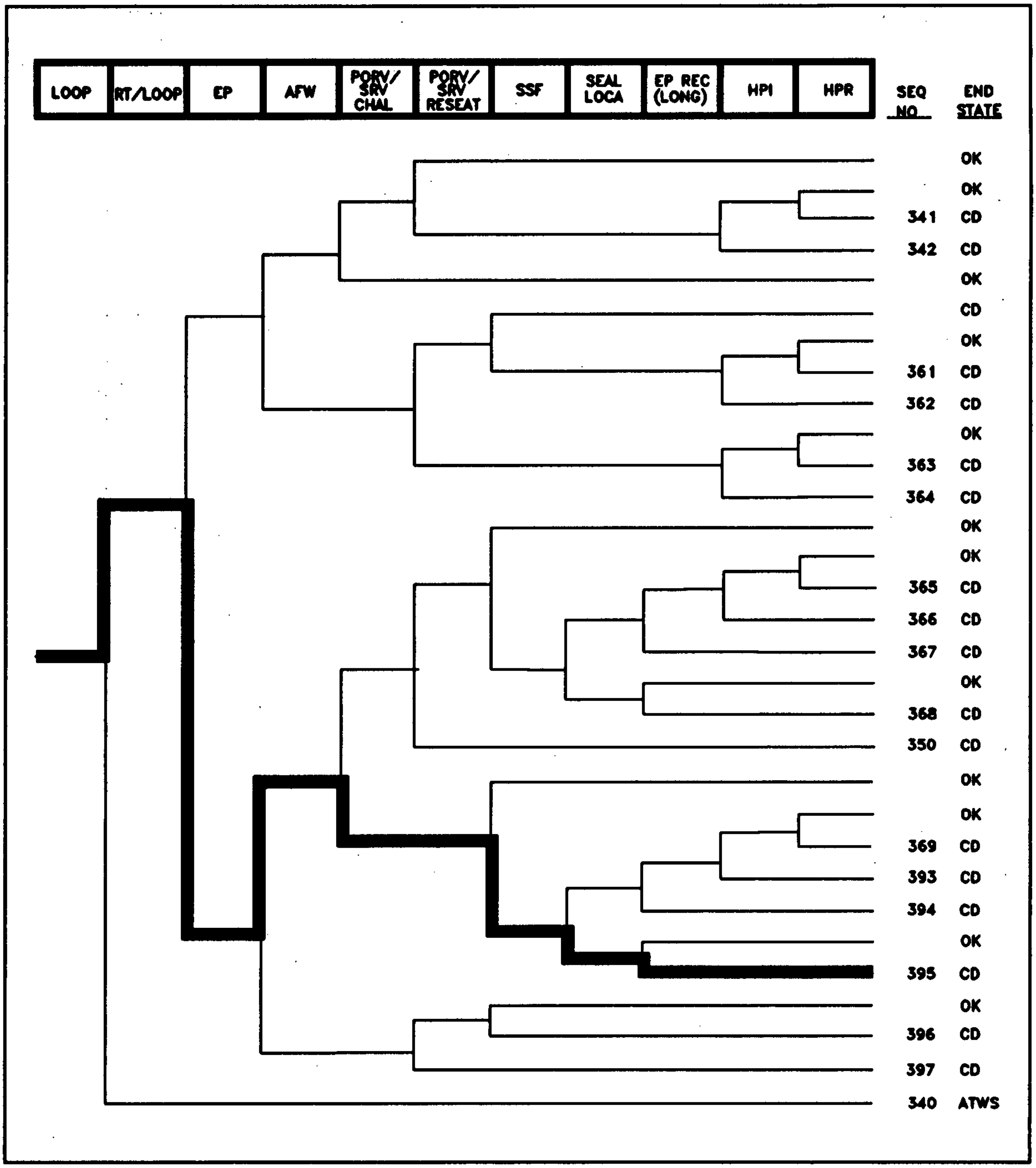

Fig. B.21. Dominant core damage sequences for LER 269/92-018.

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 269/92-018
Event Description: Both Keowee hydro units potentially unavailable
Event Date: 12/02/92
Plant: Oconee 1

UNAVAILABILITY, DURATION= 360

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

LOOP(PLANT_CENT)	7.0E-04
LOOP(GRID)	2.8E-04
LOOP(WEATHER)	3.8E-04

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOOP(PLANT_CENT)	1.8E-06
LOOP(GRID)	1.8E-06
LOOP(WEATHER)	2.8E-05
Total	3.2E-05
ATWS	
LOOP(PLANT_CENT)	0.0E+00
LOOP(GRID)	0.0E+00
LOOP(WEATHER)	0.0E+00
Total	0.0E+00

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
395	loop(weather) -rt/loop EMERG.POWER(WEATHER) -afw/emerg.power -porv.or.srv.chall(loop) ssf -seal.loca(weather) ep.rec(weather)	CD	2.5E-05	4.0E-01
368	loop(weather) -rt/loop EMERG.POWER(WEATHER) -afw/emerg.power porv.or.srv.chall(loop) -porv.or.srv.reseat/emerg.power ssf -seal.loca(weather) ep.rec(weather)	CD	2.2E-06	4.0E-01
195	loop(plant_cent) -rt/loop EMERG.POWER(PLANT_CENT) -afw/emerg.power -porv.or.srv.chall(loop) ssf -seal.loca(plant_cent) ep.rec(plant_cent)	CD	1.5E-06	6.4E-02
295	loop(grid) -rt/loop EMERG.POWER(GRID) -afw/emerg.power -porv.or.srv.chall(loop) ssf -seal.loca(grid) ep.rec(grid)	CD	1.2E-06	2.0E-01

** non-recovery credit for edited case

Event Identifier: 269/92-018

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
195	loop(plant_cent) -rt/loop EMERG.POWER(PLANT_CENT) -afw/emerg.power -porv.or.srv.chall(loop) ssf -seal.loca(plant_cent) ep.rec(plant_cent)	CD	1.5E-06	6.4E-02
295	loop(grid) -rt/loop EMERG.POWER(GRID) -afw/emerg.power -porv.or.srv.chall(loop) ssf -seal.loca(grid) ep.rec(grid)	CD	1.2E-06	2.0E-01
368	loop(weather) -rt/loop EMERG.POWER(WEATHER) -afw/emerg.power porv.or.srv.chall(loop) -porv.or.srv.reseat/emerg.power ssf -seal.loca(weather) ep.rec(weather)	CD	2.2E-06	4.0E-01
395	loop(weather) -rt/loop EMERG.POWER(WEATHER) -afw/emerg.power -porv.or.srv.chall(loop) ssf -seal.loca(weather) ep.rec(weather)	CD	2.5E-05	4.0E-01

** non-recovery credit for edited case

Note: For unavailabilities, conditional probability values are differential values which reflect the added risk due to failures associated with an event. Parenthetical values indicate a reduction in risk compared to a similar period without the existing failures.

SEQUENCE MODEL: c:\asp\1989\oconseal.cmp
BRANCH MODEL: c:\asp\1989\oconee1.ssf
PROBABILITY FILE: c:\asp\1989\pwr_bsl1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	6.4E-05	1.0E+00	
loop(plant_cent)	1.3E-05	1.5E-01	
loop(grid)	1.6E-06	4.8E-01	
loop(weather)	1.1E-06	9.3E-01	
loca	2.4E-06	4.3E-01	
rt	2.8E-04	1.2E-01	
rt/loop	0.0E+00	1.0E+00	
EMERG.POWER(PLANT_CENT)	3.0E-04 > 1.2E-01[1]	8.0E-01 > 4.3E-01[1]	
Branch Model: 1.OF.3			
Train 1 Cond Prob:	5.0E-02 > Failed		
Train 2 Cond Prob:	5.0E-02 > Failed		
Train 3 Cond Prob:	1.2E-01		
EMERG.POWER(GRID)	2.5E-03 > 1.0E+00[1]	8.0E-01 > 4.3E-01[1]	
Branch Model: 1.OF.2			
Train 1 Cond Prob:	5.0E-02 > Failed		
Train 2 Cond Prob:	5.0E-02 > Failed		
EMERG.POWER(WEATHER)	2.5E-03 > 1.0E+00[1]	8.0E-01 > 4.3E-01[1]	
Branch Model: 1.OF.2			
Train 1 Cond Prob:	5.0E-02 > Failed		
Train 2 Cond Prob:	5.0E-02 > Failed		
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	8.0E-02	1.0E+00	

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porv.or.srv.chall(loop)	8.0E-02	1.0E+00	
porv.or.srv.reseat	1.0E-02	1.1E-02	
porv.or.srv.reseat/emerg.power	1.0E-02	1.0E+00	
ssf	2.0E-01	1.0E+00	
seal.loca(plant_cent)	0.0E+00	1.0E+00	
seal.loca(grid)	0.0E+00	1.0E+00	
seal.loca(weather)	0.0E+00	1.0E+00	
ep.rec(sl)(plant_cent)	0.0E+00	1.0E+00	
ep.rec(sl)(grid)	0.0E+00	1.0E+00	
ep.rec(sl)(weather)	0.0E+00	1.0E+00	
ep.rec(plant_cent)	2.3E-01	1.0E+00	
ep.rec(grid)	5.3E-02	1.0E+00	
ep.rec(weather)	8.6E-01	1.0E+00	
hpi	3.0E-04	8.4E-01	
hpi(f/b)	3.0E-04	8.4E-01	1.0E-02
hpr/-hpi	1.5E-04	1.0E+00	1.0E-03

* branch model file
** forced

Notes:

[1] See Modeling Assumptions for the development of this probability value

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