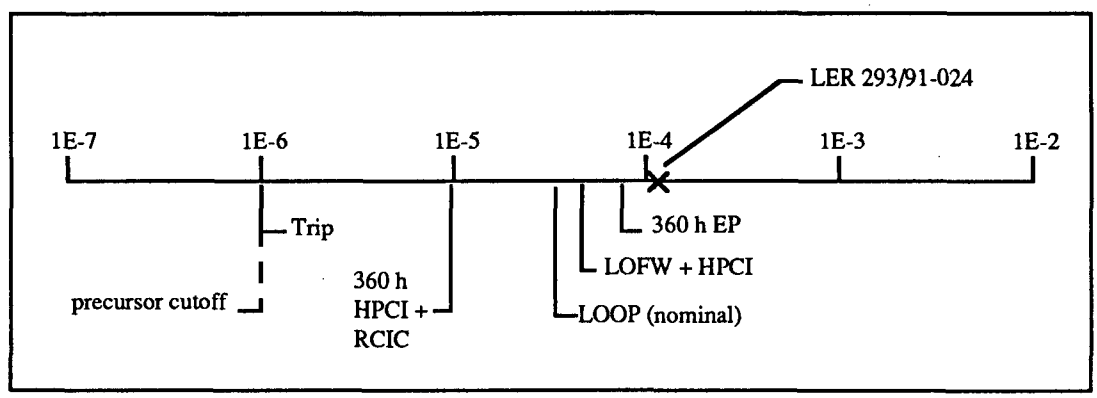
ACCIDENT SEQUENCE PRECURSOR PROGRAM EVENT ANALYSIS

LER No.: 293/91-024, 293/91-006, 293/91-021, 293/91-025
Event Description: Loss of offsite power and RCIC trip
Date of Event: October 30, 1991
Plant: Pilgrim

Summary

A loss of offsite power (LOOP) occurred at Pilgrim 2-1/2 h after the plant was shut down during a storm. Both emergency diesel generators (EDGs) started and powered the safety-related buses. Reactor core isolation cooling (RCIC) was manually started but tripped on overspeed when opening of the discharge isolation valve was delayed. Four min later, the RCIC inverter tripped because of a voltage transient caused by the start of a residual heat removal (RHR) pump. The inverter was reset in the control room, and RCIC operability was restored.

The conditional core damage probability estimated for this event is 1.2×10^{-4}. The relative significance of this event compared to other postulated events at Pilgrim is shown below.



Event Description

The reactor was shut down in response to severe storm conditions at 1710 hours on October 30, 1991. The main condenser vacuum had become degraded due to the storm wind and tide conditions in which seaweed was carried over from the intake structure onto the main condenser tubesheets. Reactor power was reduced to backwash the main condenser.

At 1942 hours, preferred offsite 345-kV power was lost, resulting in loss of the station startup transformer. A flashover had occurred on an insulator column on air circuit breaker (ACB) 104 due to salt deposit buildup on the insulator (see Fig.1). This caused ACBs 103, 104, and 105 to trip open, thereby deenergizing one of the two lines providing preferred offsite power. The second line was deenergized when ACB 102 tripped open in response to operation of relay 62/5, which is a time delay relay designed to respond to a stuck ACB 105. The operation of relay 62/5 was false since ACB 105 had opened as required by design. The cause of the ACB 105 stuck-breaker relay operation is unknown but is speculated to be either a random signal or self-excitation of the breaker through electrical noise coupling.

EDGs A and B started automatically following the loss of preferred power and successfully reenergized emergency buses and related AC-powered load center buses, motor control centers, and distribution panels. Eleven minutes after the loss of preferred offsite power, the secondary source of offsite power was lost when a storm-damaged tree fell onto the 23-kV line serving the shutdown transformer.

Following the loss of preferred offsite power, the RCIC turbine pump tripped due to mechanical overspeed. This resulted when the operator failed to open the RCIC injection valve promptly following the opening of the turbine steam inlet valve. Without a coolant flowpath for the RCIC, the turbine tripped within 4 s of actuation. The operator initially started to open the full flow test valve, realized this mistake, and closed the valve. This delayed the manual opening of the injection valve. In addition, the simulator allows ~15 s to open the valve before RCIC trip compared to 4 s on the plant.

The operator reset the turbine trip and manually restarted the RCIC. Four minutes after the initial RCIC trip, start of an RHR pump resulted in an overvoltage trip of the RCIC system inverter. The RHR pump start caused an AC voltage transient, which caused a DC voltage transient of 152.5-VDC on the 125-VDC system. This exceeded the inverter overvoltage setpoint of 150-VDC and tripped the inverter. Inability of the 125-VDC battery chargers to adequately regulate DC output under AC transient conditions resulted in the output overvoltage. The inverter trip prevented RCIC from attaining rated flow. The operators responded by manually shutting down the RCIC, resetting the inverter, and successfully restarting the system. The duration from the initial overspeed trip to successful resumption of the RCIC function was 5 min.

Two hours after the loss of preferred offsite power, the startup transformer was returned to service when ACB 102 was manually closed following a switchyard inspection and re-energization of a 345-kV line. The shutdown transformer was restored about 2.25 h after initial loss of secondary offsite power.

Additional Event-Related Information

Pilgrim 1 is a BWR with a Mark I pressure suppression containment. The unit has two dedicated diesel generators, two 125-V and one 250-V batteries. Fig. 1 shows the preferred offsite 345-kV power distribution system at Pilgrim.

The RCIC mission is to provide reactor coolant makeup during vessel isolation. The RCIC inverter converts 125-VDC to 120 VAC to power the RCIC flow control circuit and the test circuit power supply. With the inverter tripped, the RCIC can both start and continue to operate, but at minimum speed. The RCIC inverter can be reset and RCIC restored from the control room.

The source 125-VDC bus for the inverter is energized by a 125-VDC battery in parallel with a backup battery charger. The main battery charger, at the time of the event, was inoperable. The backup charger, by design, is required only to maintain the charging voltage within 0.5% from no load to full load with an AC supply voltage variation of 10%. The transient conditions encountered in the event were not addressed in the design specifications.

LER 293/91-006 reports a combined RCIC and HPCI trip due to inverter trips during a recirculation pump start. The pump was being started after an earlier lockout of one of the 4160-VAC emergency buses (see LER 293/91-005). Both inverters were reset in 9 min from the control room.

LER 293/91-021 described a change to an alarm response procedure, which specified required operator actions if the RCIC inverter trips. An extension of the 7-d RCIC system Limiting Condition for Operation (LCO) to 97 d had been requested by the utility on October 24, 1991, to allow testing to be conducted and modifications to be implemented to address the inverter problem. However, as a result of the October 30, 1991, event, RCIC inverter problems were to be resolved prior to startup.

Experience of multiple RCIC overspeed trips in transient conditions exists also at Pilgrim (see LER 293/90-013).

ASP Modeling Assumptions and Approach

The event has been modeled as a severe weather-related LOOP with RCIC unavailable but recoverable from the control room. A nonrecovery probability of 0.08 was assigned to RCIC. This addressed the potential for in-control-room recovery [p(nonrecovery = 0.04)] from the two separate and unrelated RCIC unavailabilities that occurred during the event. The probabilities used for LOOP nonrecovery in the short-term and LOOP nonrecovery prior to battery depletion were also revised to reflect values associated with a

severe weather-related LOOP (see ORNL/NRC/LTR-89/11, *Revised LOOP Recovery and PWR Seal LOCA Models*, August 1989).

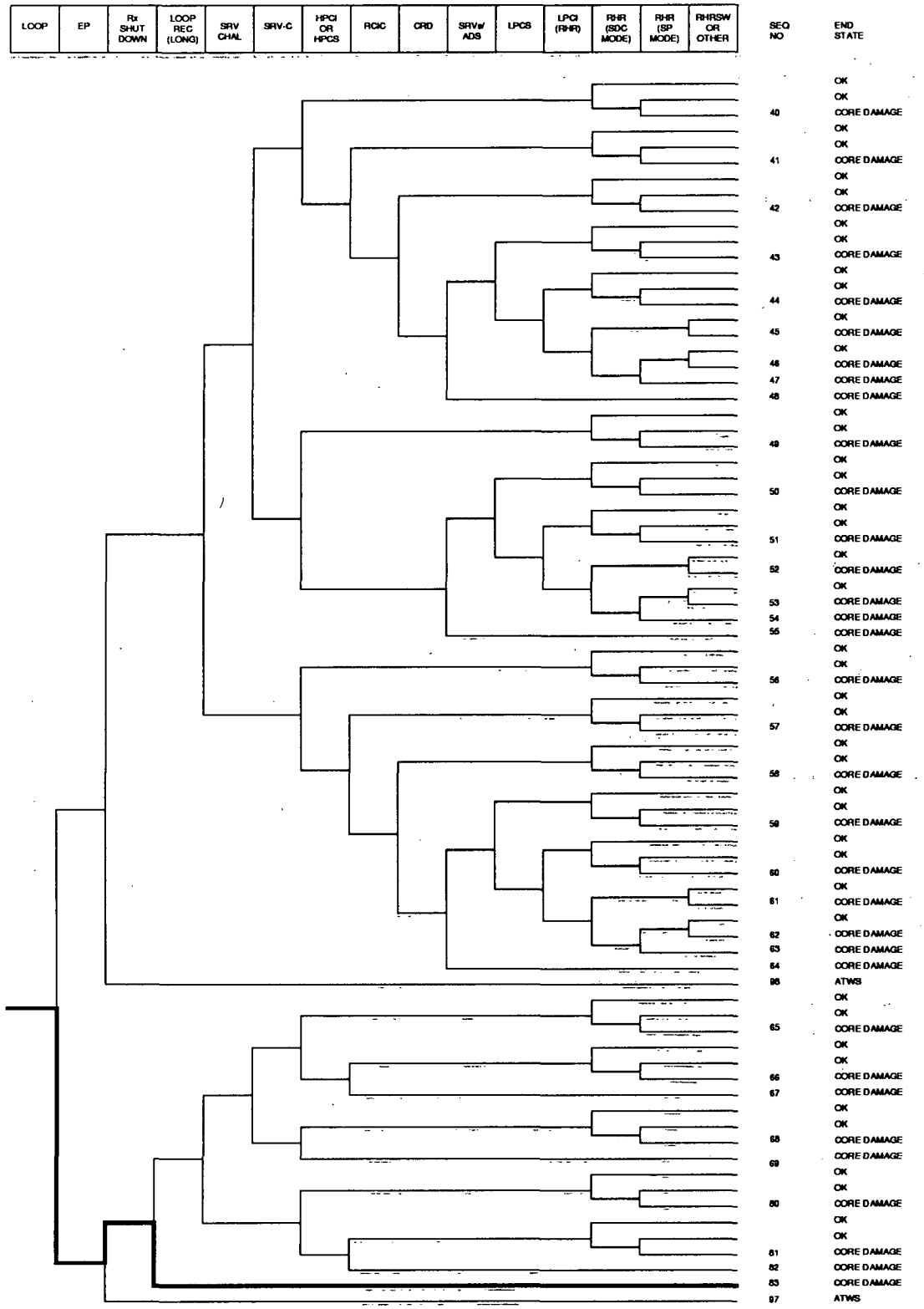
Analysis Results

The conditional core damage probability estimated for the event is 1.2×10^{-4}. The dominant sequence, highlighted on the following event tree, involves a LOOP with failure of emergency power and failure to recover AC power prior to battery depletion. The recoverable unavailability of RCIC did not significantly contribute to the core damage probability associated with the event.

Additional information concerning an associated event is included in LER 293/90-013 (see NUREG/CR-4674, Vol. 13).

Figure removed during SUNSI review.

Fig. 1. Pilgrim 345-kV distribution system



Dominant core damage sequence for LER 293/91-024

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 293/91-024
Event Description: Loss of Offsite Power and RCIC trip
Event Date: 10/30/91
Plant: Pilgrim 1

INITIATING EVENT

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

LOOP	9.0E-01

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
LOOP	1.2E-04
Total	1.2E-04
ATWS	
LOOP	2.7E-05
Total	2.7E-05

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
83	LOOP emerg.power -rx.shutdown/ep EP.REC	CD	1.1E-04	7.2E-01
40	LOOP -emerg.power -rx.shutdown srv.chall/loop.-scram -srv.close -hpci rhr(sdc) rhr(spcool)/rhr(sdc)	CD	4.8E-06	1.0E-01
98	LOOP -emerg.power rx.shutdown	ATWS	2.7E-05	9.0E-01

** non-recovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
40	LOOP -emerg.power -rx.shutdown srv.chall/loop.-scram -srv.close -hpci rhr(sdc) rhr(spcool)/rhr(sdc)	CD	4.8E-06	1.0E-01
98	LOOP -emerg.power rx.shutdown	ATWS	2.7E-05	9.0E-01
83	LOOP emerg.power -rx.shutdown/ep EP.REC	CD	1.1E-04	7.2E-01

** non-recovery credit for edited case

SEQUENCE MODEL: c:\asp\1989\bwrcseal.cmp
BRANCH MODEL: c:\asp\1989\pilgrim.sll
PROBABILITY FILE: c:\asp\1989\bwr_csll.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail

Event Identifier: 293/91-024

trans	5.5E-04	1.0E+00	
LOOP	2.0E-05 > 2.0E-05	4.3E-01 > 9.0E-01	
Branch Model: INITOR			
Initiator Freq:	2.0E-05		
loca	3.3E-06	5.0E-01	
rx.shutdown	3.0E-05	1.0E+00	
rx.shutdown/ep	3.5E-04	1.0E+00	
pcs/trans	1.7E-01	1.0E+00	
srv.chall/trans.-scram	1.0E+00	1.0E+00	
srv.chall/loop.-scram	1.0E+00	1.0E+00	
srv.close	1.3E-02	1.0E+00	
emerg.power	2.9E-03	8.0E-01	
EP.REC	3.1E-02 > 5.5E-02	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	3.1E-02 > 5.5E-02		
fw/pcs.trans	2.9E-01	3.4E-01	
fw/pcs.loca	4.0E-02	3.4E-01	
hpci	2.9E-02	7.0E-01	
RCIC	6.0E-02 > 1.0E+00	7.0E-01 > 8.0E-02	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	6.0E-02 > Failed		
crd	1.0E-02	1.0E+00	1.0E-02
srv.ads	3.7E-03	7.1E-01	1.0E-02
lpcs	3.0E-03	3.4E-01	
lpci(rhr)/lpcs	1.0E-03	7.1E-01	
rhr(sdc)	2.1E-02	3.4E-01	1.0E-03
rhr(sdc)/-lpci	2.0E-02	3.4E-01	1.0E-03
rhr(sdc)/lpci	1.0E+00	1.0E+00	1.0E-03
rhr(spcool)/rhr(sdc)	2.0E-03	3.4E-01	
rhr(spcool)/-lpci.rhr(sdc)	2.0E-03	3.4E-01	
rhr(spcool)/lpci.rhr(sdc)	9.3E-02	1.0E+00	
rhrsw	2.0E-02	3.4E-01	2.0E-03

* branch model file
** forced

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Event Identifier: 293/91-024