

A Study on the Frequency of Initiating Event of OPR-1000 during Outage Periods

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1. Introduction

The frequency of initiating event for OPR-1000 was evaluated using NUREG/CR-6144, generic data, and domestic operating experiences as a result of low power and shutdown(LPSD) PSA that is conducted as built from 2005 to 2008. NUREG/CR-6144 and the operating experiences were used to evaluate loss of shutdown cooling(LOSDC) and loss of off-site power(LOOP). However, these sources of data did not reflect the latest event data which have occurred during the PWR outage to the frequencies of initiating event Electric Power Research Institute(EPRI) in USA collected the data of loss of decay heat removal during outage from 1989 to 2009 and published technical report[1,3]. Domestic operating experiences for LOOP is gathered in Operational Performance Information System for Nuclear Power Plant(OPIS). To reduce conservatism and obtain completeness for LPSD PSA, those data should be collected and used to update the frequencies. The frequencies of LOSDC and LOOP are reevaluated using the data of EPRI and OPIS in this paper. Quantification is conducted to recalculate core damage frequency(CDF), since the rate is changed. The results are discussed below.

2. Methods and Results

In this section some of the techniques used to evaluate the frequency. Bayesian approach was used for LOSDC and SAREX was used to estimate CDF.

2.1 Data Collection and Classification

LOSDC event which had occurred during outage was collected and classified using EPRI technical report[1,3]. Because Loss of residual heat removal(RHR) event data recorded NUREG/CR-6144 from 1973 to 1989 is not enough to calculate the frequency. Shutdown cooling system in OPR-1000 is the same function as RHR System. These data is presented in Table 1.

Operating time provided by NRC homepage was used to determine the shutdown year. The amount of

shutdown year is approximately 219.17 years or 1.92 million hours.

Table 1: The number of LOSDC events

Category	Number
Overdraining Event(SO)	10
Failure to maintain low level Event(SL)	18
Recoverable Loss of SDC(S1)	5
Loss of operating train of SDC(S2)	1

OPIS was used to estimate the domestic operating experiences for LOOP event. This event had occurred 7 times during 1978-2009. Critical year given by 2009 Annals of Nuclear Power is approximately 241.3 years.

2.2 Frequency of Loss of SDC Events

Table 2 summarizes the estimated failure rate and failure probability for the loss of SDC categories using Bayesian approach. Data from NUREG/CR-6144 are used to derive a prior distribution. It is assumed that the prior distribution is a lognormal and the number of demand between 1990 and 2009 is increased by the factor of two compared to the demand data in NUREG/CR-6144.

Table 2: LOSDC frequency

Category	Mean	5%	95%	EF
SO	3.99E-03 /demand	2.22E-03	6.16E-03	1.73
SL	8.11E-02 /year	5.24E-02	1.14E-01	1.51
S1	2.88E-02 /year	1.39E-02	4.83E-02	1.97
S2	7.71E-03 /year	1.73E-03	1.77E-02	3.74

2.3 Frequency of Loss of Off-Site Power Events

Domestic operating experiences are applied to the LOOP frequency at power and evaluate using equation (1). The value is used to calculate the frequency for each plant operating state(POS).

$$\text{LOOP frequency} = \text{LOOPc} + \text{LOOPm} \times \text{LOOPa} \quad (1)$$

- LOOPc : LOOP due to CCF[†]
- LOOPm : Loss of Main Switchyard except CCF[†]
- LOOPa : Loss of Auxiliary Switchyard except CCF[†]
- †: Common Cause Failure

The estimated failure rate is 1.47E-02/yr from equation (1). To evaluate this rate, 2.90E-02/yr (7/241.3) or 3.31E-06/hr is used, which is the result of domestic operating experience described in subsection 2.1.

2.4 Quantification

The initiating event frequency is quantified for each POS using the LPSD PSA model. SAREX is used for quantification. CDF for the events presented in table 3 is estimated. Total CDF is decreased from 8.26E-06 to 4.96E-06 due to the rate changes of LOSDC and LOOP. Δ CDF is roughly -40% and pressurizer PSV stuck open event is evaluated as the dominant contributor from the quantification results.

3. Conclusions

To make an accurate estimate of the initiating events of LPSD PSA, the event data were collected and the frequencies of initiating events were updated using Bayesian approach. CDF was evaluated through quantification. Δ CDF is -40% and the dominant contributor is pressurizer PSV stuck open event.

The most of the event data in EPRI TR were collected from US nuclear power plant industry. Those data are not enough to evaluate outage risk precisely. Therefore, to reduce conservatism and obtain completeness for LPSD PSA, the licensee event report and domestic data should be collected and reflected to the frequencies of the initiating events during outage.

REFERENCES

- [1] EPRI TR-1021176, "An Analysis of Loss of Decay Heat Removal and Loss of Inventory Event Trend (1990-2009)", EPRI, 2010.
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- [4] T. L. Chu, Etc, "Evaluation of Potential Severe Accident During Low Power and Shutdown Operations at Surry, Unit 1", NUREG/CR-6144, Vol. 2, Part 1A, NRC, 1994.
- [5] "SAREX User Manual", Version 1.2, KEPKO E&C, 2011.

Table 3: CDF as Initiating Events

Initiating Event	CDF (/year)	Contribution (%)
Recoverable Loss of SDC	1.12.E-07	2.25
Loss of Operating Train of SDC	6.55.E-08	1.32
Overdraining Event	5.57.E-07	11.23
Failure to maintain Low Level Event	1.54.E-07	3.10
Large LOCA	3.11.E-09	0.06
Medium LOCA	2.04.E-09	0.04
Small LOCA	7.00.E-09	0.14
SGTR	2.01.E-09	0.04
Recoverable LOCA	7.13.E-09	0.14
Non-recoverable LOCA	7.64.E-08	1.54
Pressurizer PSV stuck open	2.98.E-06	60.14
LTOP stuck open	3.36.E-08	0.68
LOOP	1.75.E-07	3.54
SBO	5.96.E-08	1.20
Loss of 1E 4.16kV AC Bus	1.97.E-08	0.40
Loss of 1E 125V Dc Bus	2.20.E-09	0.04
Loss of component cooling	6.88.E-07	13.88
General Transient	1.18.E-08	0.24
Total CDF	4.96E-06	100