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Quantification of ISLOCA Frequency Using Plant Specific and NUREG/CR-6928 Reliability Data for Kori 3 and 4 Nuclear Power Plant

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1. Introduction

Interfacing System LOCA (ISLOCA), which is one of the initiating events for core damage, is used to estimate core damage frequency (CDF). ISLOCA is highly dependent on the component reliability data. The data from EPRI-URD, NSAC-154, and others have been used for calculating ISLOCA frequency. The reliability of ISLOCA frequency can be improved, using Bayesian updated data, which reflect domestic plant operation experience based on NUREG/CR-6928. In addition, if the data set from NUREG/CR-6928 is used, it is expected that the excessive leakage probability of the check valve, the rupture failure rate of MOV, etc. will improved. Therefore, it is expected ISLOCA frequency will also improve through the analysis. In this paper, calculations for the ISLOCA frequency for the Westinghouse-designed, Kori Unit 3 and 4 nuclear power plant, are compared to the frequency of ISLOCA of other plants in Korea.

2. Methods and Results

The study will examine the effect on ISLOCA frequency calculation due to the data selection change described in the introduction.

2.1 Selection criteria

ISLOCA occurs in piping connected to the external containment. In order to select the piping for the analysis, the following qualitative screening criteria are applied:

- The piping is connected to the reactor coolant system (RCS);
- The piping is passing through the containment building;
- The pressure boundary of the piping is extended to the outside of the containment;
- The piping whose design pressure of the lower pressure boundary is lower than the design pressure in the RCS;
- The piping that could create massive loss of coolant due to the overpressure generated, causing a block failure;
- The internal diameter of the pipe is bigger than 3/8 inch.

Pipes that do not meet the above criteria are a few; for example, Low Head SIS Cold Leg Injection, Low Head Hot Leg Recirculation, and RHR Pump Suction from RCS Hot Leg are the only ones.

2.2 Calculation methods

Calculation formulas are selected appropriately for the type of valves listed in Table I.

Table I: Failure mode corresponding to the types of valve

Valve Type	Failure Mode
Check Valve	Internal leak, Fail to close
Motor Operated Valve	Rupture, Operator fail to close, Mechanical error causing failure to close
Pressurizer Safety Valve	Fail to open

Description of variables and calculation formula are as follows:

- Low Head SIS Cold Leg Injection

$$= [H_{MOV}+\lambda_{MOV}]\times[3\ \lambda^2_{CRI}T+6\lambda_{CRI}P_{CL}D] \quad (1),$$

- Low Head Hot Leg Recirculation

$$= (1/3)\lambda^2_{CRI}\lambda_{MRT}T^2+\lambda_{CRI}P_{CL}D\lambda_{MRT}T \quad (2),$$

- RHR Pump Suction from RCS Hot Leg

$$= \lambda^2_{MRI}P(RV)T \quad (3),$$

Where,

λ_{CRI}: The failure rate of the check valve due to internal leak
P_{CL}: The excessive leakage probability of the check valve
P(RV): Open failure probability of the relief valve
λ_{MRT}: The failure rate due to the internal and external rupture of MOV
λ_{MRI}: Internal rupture failure rate of MOV
λ_{MOV}: The failure probability due to the closing malfunction of MOV(mechanical error)
H_{MOV}: The failure probability due to the closing malfunction of MOV (operator error)
D: The average number of valve operation
T: Refueling cycle

2.3 Data

The equipment reliability data have provided a decisive effect on calculating the ISLOCA frequency. Table II shows the data used in existing PSA reports and latest data for the update. The latest data set combines the set used in NUREG/CR-6928(2007) and the Bayesian updated data obtained from operating the domestic plants using the NUREG/CR-6928(2007) data set. Data for 'release valve is open fails' refers to NUREG/CR-6928(2010) because there are no data in NUREG/CR-6928(2007) for this category.

Table II: Comparative data sets used in this calculation

	Existing Data	Source	Latest Data	Source
λ_{CRI}	4.38E-5	EPRI-URD	2.59E-4	NUREG/CR-6928
P_{CL}	1.00E-3	EPRI-URD	1.19E-4	NUREG/CR-6928(Bayesian)
P(RV)	2.00E-5	EPRI-URD	2.69E-3	NUREG/CR-6928 (2010)
λ_{MRT}	2.37E-4	NSAC-154	3.79E-5	NUREG/CR-6928
λ_{MRI}	2.37E-4	NSAC-154	2.93E-5	NUREG/CR-6928
λ_{MOV}	2.54E-3	Plant date	1.40E-3	NUREG/CR-6928(Bayesian)
H_{MOV}	1.00E-1	Assumption	1.00E-1	Assumption
D	4	Assumption	4	Assumption
T	1.5	Assumption	1.5	Assumption

2.4 Results

The results of ISLOCA frequencies, obtained using Eqs. 1, 2, and 3 with the data from Table II, are shown in Table III. According to the Table III, most failure-prone pipe in Kori Unit 3 and 4 is the pipe for Low Head SIS Cold Leg Injection.

Table III: ISLOCA frequencies

Kori Unit 3,4(/YR)			
Pipe	Existing Data	Latest Data	Comparison
Low Head SIS Cold Leg Injection	1.09E-07	1.06E-07	0.97
Low Head Hot Leg Recirculation	6.26E-11	8.94E-12	0.14
RHR Pump Suction from RCS Hot Leg	1.69E-12	3.45E-12	2.05
Total	1.09E-07	1.06E-07	0.97

3. Conclusions

Using the Bayesian updated data, the reliability of ISLOCA frequency calculation for Kori 3 and 4 nuclear power plants has increased. ISLOCA frequencies of the pipe for RHR Pump Suction from RCS Hot Leg and Low Head Hot Leg Recirculation are increased to 2.05 and 0.14 times, respectively. However, ISLOCA frequencies of the pipe for Low Head Hot Leg Recirculation and RHR Pump Suction from RCS Hot Leg do not vary greatly. ISLOCA frequency of Low Head SIS Cold Leg Injection shows the largest value and reduced only 0.97 times from existing value. Compared to other values, the ISLOCA frequency for Low Head SIS Cold Leg Injection is approximately 4 orders of magnitude bigger than other pipes. Although ISLOCA frequency is changed very slightly, it is expected to provide higher reliability for the ISLOCA frequency calculation for Kori Unit 3 and 4 using the latest data.

REFERENCES

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