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Quantitative Screening Analysis of Internal Flooding PSA Using the EPRI Methodology For Kori 2 Nuclear Power Plant

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1. Introduction

The flooding probabilistic safety assessment (PSA) [1] was used to measure the frequency of internal flooding events reported to the Nuclear Power Experience (NPE) database. Existing methods did not take into consideration the individual characteristics of the systems and piping present in the flood areas. A quantitative analysis was selected only using the frequency of the flood incident reported to NPE for auxiliary buildings, turbine buildings, etc.

In this paper, we performed a preliminary quantitative screening analysis for the systems and piping in the flood areas of the Kori Unit 2 Nuclear Power Plant (herein called 'Kori Unit 2') of Westinghouse design by applying the methodology described in EPRI 300200079, Pipe Rupture Frequencies for Internal Flooding Probabilistic Risk Assessments. 2013[2].

2. Methods and Results

A quantitative analysis performed by calculating the scenario core damage frequency (CDF) as a function of time, in this case, year, for all flood areas. Then, the area CDF can be obtained by summing the scenario CDF of each flood area. The equation to obtain the scenario CDF is the following:

Scenario CDF = (frequency of flooding events) * (flood protection failure rate) * (conditional CDF) (1)

In this paper, we changed the flood frequency calculation method used for obtaining the scenario CDF from the one listed in NPE database to the methodology described in EPRI [2]. Using the new scenario CDF, a preliminary quantitative screening analysis was performed.

2.1 Existing methodology

Existing Kori Unit 2 PSA involving the frequency of flooding incidents assumed the frequency of flooding events reported in NPE for the BWRs and PWRs located in the US. Table 1 shows the flood event frequency of auxiliary buildings.

Table 1. An example of auxiliary building flooding event frequency

Flood area	Number of Event	Event	Operating Year	frequency (/yr)
		BWR		
HPSI Pp Rm	2	1,3	690	2.90E-03
LPSI Pp Rm	2	2,4	690	2.90E-03
General area	0		345	0
		PWR		
HPSI Pp Rm	0		968	0
LPSI Pp Rm	2	6,7	968	2.10E-03
General area	1	5	484	2.10E-03
		Total of BWR & PWR		
HPSI Pp Rm	2	1,3	1658	**1.20E-03**
LPSI Pp Rm	4	2,4,6,7	1658	**2.40E-03**
General area	1	5	829	**1.20E-03**

2.2 Assumption

The following assumption is made prior to performing the preliminary screening quantitative analysis using the methodology described in EPRI [2]:

Existing values for flood protection failure rate and conditional CDF are applied for calculating the scenario CDF in performing the preliminary quantitative screening analysis.

2.3 Definition and the calculation of flood frequency using the EPRI[2] methodology

The frequency of flooding events calculated in the EPRI[2] is based on the frequency of flood modes and the pipe diameter per foot. The flood mode is classified as spray, flood, and major flood. In each flood mode, the pipe rupture frequency is varied. In this paper, we used conservative values which combine all flood modes for frequency of flooding events in the flood areas.

In order to apply the EPRI[2] flood area frequency, we investigated the pipe size and length of each system. We used isometric drawings, piping & instrument diagram drawings and piping drawings for a comprehensive pipe survey. The pipe survey investigated almost all areas outside of the containment because it is a reasonable to assume that the containment building was designed against a LOCA. The survey is limited to the PSA system of the Kori Unit 2 and is shown in Table 2.

Table 2. PSA System Kori Unit 2

System	System Code
Safety Injection	SI
Pressure Relief Valve	RC
Chemical & Volume Control	CS
Containment Spray	CI
Auxiliary Feed Water	AF
Component Cooling Water	CC
Essential Service Water	SW
Main Feed Water	FW
Main Steam	MS
Auxiliary Cooling Water	TC
Circulating Water	CW
Essential Chilled Water	CZ
Fire Protection	FP
Spent Fuel Pool	SF

Table 3 shows the system piping characteristics for the flood areas.

Table 3. An example of select pipe information by flood area

Flood area	Sys	Pipe Diameter (inch)	Total Length (ft)
General Access Area - 94.21 m (HAB094-4)	CC	3	26.50
	CC	4	176.17
	CC	6	65.14
	CC	10	23.48
	CS	0.75	54.71
	CS	1	3.97
	CS	1.5	1.12
	CS	2	78.82
	CS	3	105.32
	CS	4	48.45
	FP	2	74.59
	FP	2.5	26.40
	FP	4	74.59
	FP	6	71.41
	SI	1	17.55
	SI	2	58.68
Safety Injection Pp Rm A (HAB094-1A)	SI	6	11.97
	SI	10	26.01
	CI	0.375	0.49
Health Physics Area (HAB100-1)	FP	3	40.29
Steam Header Area (HIB107-1)	MS	14	61.20

Using the surveyed pipe length and frequency of flood recorded in EPRI[2], frequency of flood for each flood area is obtained. The flood area conditional core damage probability (CCDP) is defined below:

Flood area CCDP =

$$\sum_{M=1}^{n} (MPFR)_n * (\text{Pipe Length})_n \quad (2),$$

Where,

$(MPFR)_n$ is defined as the n^{th} system mean pipe failure rates, and
$(\text{Pipe Length})_n$ is defined as the n^{th} pipe length.

Table 4 shows the quantitative screening analysis by applying the methodology described in EPRI[2].

Table 4. An example of quantitative screening analysis by applying the methodology EPRI[2]

Description	The preliminary quantitative screening analysis		The quantitative screening analysis	
	Frequency (/yr)	Area CDF (/yr)	Frequency (/yr)	Area CDF (/yr)
General Access Area - 82.85 m	8.26E-04	3.83E-08	2.40E-03	1.11E-07
SI Pp Rm A	6.36E-05	3.40E-09	2.40E-03	1.31E-07
SI Pp Rm B	6.95E-05	3.54E-09	2.40E-03	1.22E-07
General Access Area - 94.21 m	3.51E-03	2.44E-06	1.20E-03	6.06E-07
CCW Pump Area	9.38E-03	5.86E-04	1.20E-03	7.49E-05
Chilled Water Pp Room A	4.33E-05	2.92E-08	1.20E-03	8.09E-07
CW Pp house	8.18E-04	5.96E-09	1.20E-03	8.73E-09
EDG Room A	4.33E-04	3.15E-09	1.20E-03	8.73E-09
General Access Area - 100.3 m	5.40E-03	5.58E-06	1.20E-03	6.23E-07
Fuel Handling BLDG	7.44E-04	3.04E-07	1.20E-03	4.90E-07
AFW & HVAC Equipment Area	1.12E-02	3.40E-03	1.20E-03	3.64E-04
Steam Header Area	2.15E-02	6.02E-06	1.20E-03	1.93E-07
MCR/CB Electrical Room AHU Area	5.33E-04	2.79E-08	1.20E-03	6.28E-08
General Access Area - 107.1 m	3.40E-03	1.84E-06	1.20E-03	6.23E-07
ESW Pp Area	5.26E-03	3.36E-04	1.20E-03	7.67E-05
Turbine BLDG	3.12E-03	7.86E-06	6.00E-03	1.51E-05

There are currently 4 existing detailed analysis areas, which have a higher than quantitative screening value of 1.0E-06/yr, in Kori Unit 2. However, the following areas are expected to be added to the list: General Access Area - 94.21 m, General Access Area - 100.3 m, General Access Area - 107.1 m, and Steam Header Area. This is because the frequency of flood events described by the methodology of EPRI[2] is higher than the ones listed the NPE database.

3. Conclusions

A preliminary quantitative screening analysis of internal flooding PSA is performed according to the methodology of EPRI[2]. Switching from using the NPE database to the methodology in EPRI[2], it is expected more areas will be added to the list of detailed analysis areas. The scenario CDF, which influences area CDF, increases more as flood frequency is increased by using EPRI[2] instead of using the database of NPE.

Further research is scheduled in order to calculate more accurate area CDF by changing conditional CDF in near future.

REFERENCES

[1] KHNP, Probabilistic Safety Assessment for Shin-Kori Unit 2 Level 1 PSA for Internal Events, Korea Hydro & Nuclear Power Co., Ltd., 2003.
[2] EPRI 300200079, Pipe Rupture Frequencies for Internal Flooding Probabilistic Risk Assessments. 2013
[3] Nuclear Power Experience (NPE)
[4] General Arrangement Drawing for Kori Unit 2

[5] Piping & Instrument Diagram for Kori Unit 2
[6] Plumbing Drawing for Kori Unit 2
[7] Drainage Drawing for Kori Unit 2
[8] Isometric Drawing for Kori Unit 2