Estimation of Internal Flooding Frequency for Screening Analysis of Flooding PSA by Using the Latest Generic Data and the Korean Plant Operation Data

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1. Introduction

The purpose of this paper is to estimate the internal flooding frequency for the quantitative screening analysis of the flooding PSA (Probabilistic Safety Assessment) with the extensive generic data including the recent operation experiences of U.S. NPPs (Nuclear Power Plant) and the Korean plant operation experience. For the existing flooding PSA of domestic NPPs, the plant area based flood frequency by MLE (Maximum Likelihood Estimation) method and the plant operation data before 1990 from U.S. NPE (Nuclear Plant Experience) data have been used for the quantitative screening analysis, while the component based flood frequency has been used for the detailed analysis [1]. Therefore with the NPE data occurred before 1990, it is not possible to reflect the current status related to the flooding event.

NUREG/CR-5750 suggested the Bayesian update method with Jeffrey's noninformative prior to estimate the initiating event frequency for a flood. It, however, calculates the initiating event frequency related to a flooding only. So the result can not be used for a screening analysis [2].

We proposed an internal flooding frequency to upgrade the existing flooding PSA quality by introducing domestic plant operation experience into the flooding frequency calculation [3]. Because the piping failures causing a flooding were sparse in domestic NPPs and we used the same generic data as the existing flooding PSA, it is required to use more recent generic data to reflect the latest trends.

Fleming and Lydell suggested an internal flooding frequency as a unit of the plant operation year-pipe length (in meter) by pipe size of each specific system which is susceptible to a flooding such as the service water system and the circulating water system [4].

Based on the research, EPRI (Electric Power Research Institute) proposed a more advanced internal flooding frequency by using the most extensive data and by reducing the data uncertainty. It recommended the flooding frequency by a system, pipe size, and failure mode as a good generic data [5].

In order to upgrade the internal flooding frequency for a screening analysis of a flooding PSA of domestic NPPs, we decided to use the EPRI result as generic data to reflect the latest trends in plant operations. However, there is a difference between flooding frequencies by EPRI and the existing flooding PSA of domestic NPPs. EPRI provided the component based flooding frequency by system, pipe size, and failure mode while a plant area based flooding frequency without respect to a system, pipe size, and failure mode has been used for the existing flooding PSA for domestic NPPs. Therefore we proposed a procedure to combine the flooding frequency by EPRI with the existing flooding PSA.

2. Methods and Results

2.1 Bayesian Analysis

There have been 30 piping failures related to safety class piping which may cause a flooding event in Korea.

Table 1. Piping Failures related to Flooding Event in Domestic NPPs

Failed System	Pipe Size (")	Failure Type	leak rate (gpm)	Source	# of events
AFWS	8	pinhole/leak	< 1	Demi Water	1
AFWS	10	pinhole/leak	< 1	Demi Water	2
ESWS	2	wall thinning (no leak)	0	Sea water	1
ESWS	6	pinhole/leak	< 1	Sea water	6
ESWS	8	wall thinning (leak)	< 1	Service Water	1
ESWS	10	pinhole/leak	0	Sea water	1
ESWS	20	pinhole/leak	< 1	Sea water	2
ESWS	28	wall thinning (no leak)	0	Service Water	2
ESWS	36	pinhole/leak	< 1	Service Water	1
MFWS	18	wall thinning (no leak)	0	Feedwater	12
MFWS	20	wall thinning (no leak)	0	Feedwater	1

With those evidences and the generic data provided by EPRI, we performed a Bayesian Analysis for a failure rate and a conditional rupture probability. There are few differences between the prior distribution and posterior distribution, because the dispersion of the prior distribution by EPRI is not wide and the evidences are sparse when the evidences are divided into a system and pipe size. Therefore we used the generic data by EPRI as a posterior distribution in this case.

2.2 Application of Component Based Frequency to Plant Area Based Frequency

As mentioned previously, EPRI provided the flooding frequency (per feet-critical year) by system, pipe size, and failure mode. On the other hand, the existing flooding PSA for domestic NPPs has used a plant area based flooding frequency (per critical year) which does not consider a system, pipe size, and failure mode. To solve this problem, we propose the following procedures.

1. Measure the length of each spool of each plant area considered in the existing flooding PSA with isometric drawings.
2. With the spool length and the posterior distribution for its failure rate and a conditional rupture probability, calculate the flooding frequency of each spool with respect to a system, pipe size, and failure mode in each plant area to change the frequency unit by EPRI (/feet-critical year) into the frequency unit for the domestic flooding PSA (/critical year).
3. Calculate the flooding frequency for each spool by summing the flooding frequency for all kinds of failure modes.
4. Calculate the plant area based flooding frequency by summing all of the spool's flooding frequency in each plant area considered in the existing flooding PSA

Table 2 explains the example of computing a plant area based flooding frequency with the posterior distribution results (*) from generic data by EPRI and domestic piping failures and each spool length (**). From Table 2, the flooding frequency of room 047-A01A becomes 3.59E-05.

3. Conclusions

The purpose of this paper was to upgrade the data quality for a domestic flooding PSA. In this research, we selected the recent EPRI's output as generic data because it used the extensive U.S. plant operation experience reflecting the latest trends. With the generic data and piping failures related to flooding events in domestic NPPs we performed the Bayesian analysis for a piping failure rate and a conditional rupture probability. We proposed a procedure for changing the component based flooding frequency by a system, piping size, and failure mode into the plant area based flooding frequency to apply it to the existing flooding PSA for domestic NPPs.

REFERENCES

[1] KHNP, 98NJ14, "Probabilistic Safety Assessment for UCN 5&6: External Event Analysis, " 2002.
[2] J. P. Poloski et al, NUREG/CR-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants: 1987-1995, " 1999.
[3] S. Y. Choi and E. J Yang, "Estimation of Internal Flooding Frequency for Screening Analysis of Flooding PSA," KNS, 2005.
[4] Karl N. Fleming and Bengt O.Y. Lydell, "Reliability Engineering and System Safety, Vol. 86, Database Development and Uncertainty Treatment for Estimating Pipe Failure Rates and Rupture Frequencies, " 2004.
[5] EPRI-1013141, "Pipe Rupture Frequencies for Internal Flooding PRAs, Rev. 1," EPRI, 2006.

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Table 2. Procedure for Plant Area Based Flooding Frequency from Component Based Flooding Frequency

Room ID	Line Number	Segment ID	**Length (Ft)	*FR-spray (/Ft-CrYr)	FR-spray (/CrYr)	*FR-flooding (/Ft-CrYr)	FR-flooding (/CrYr)	*FR-major flooding (/Ft-CrYr)	FR-major flooding (/CrYr)	FR-total (/CrYr)
047-A01A	SI023AA-14	CS-109	1.83	2.41E-7	4.42E-7	7.35E-8	1.35E-7	9.14E-9	1.68E-8	5.93E-7
	SI032AA-10	CS-111	5.42	1.60E-8	8.67E-8	4.17E-9	2.26E-8	4.97E-10	2.69E-9	1.12E-7
	SI012AA-10	LS-053	86.58	1.60E-8	1.39E-6	4.17E-9	3.61E-7	4.97E-10	4.30E-8	1.79E-6
	SI002AA-8	LS-059	1.67	1.60E-8	2.67E-8	4.17E-9	6.95E-9	4.97E-10	8.28E-10	3.44E-8
	SI021AA-4	LS-061	37.17	5.30E-8	1.97E-6	1.42E-8	5.28E-7	1.71E-9	6.36E-8	2.56E-6
	SI002AA-8	LS-071	1.67	1.60E-8	2.67E-8	4.17E-9	6.95E-9	4.97E-10	8.28E-10	3.44E-8
	SI001BA-20	LS-109	26.25	2.41E-7	6.33E-6	7.35E-8	1.93E-6	9.14E-9	2.40E-7	8.50E-6
	SI001BA-20	LS-111	20.42	2.41E-7	4.92E-6	7.35E-8	1.50E-6	9.14E-9	1.87E-7	6.61E-6
	SI022AA-18	CS-105	8.67	2.41E-7	2.09E-6	7.35E-8	6.37E-7	9.14E-9	7.92E-8	2.80E-6
	CS012AA-14	CS-107	36.33	2.41E-7	8.76E-6	7.35E-8	2.67E-6	9.14E-9	3.32E-7	1.18E-5
	SI002BA-10	LS-049	14.75	1.60E-8	2.36E-7	4.17E-9	6.15E-8	4.97E-10	7.33E-9	3.05E-7
	SI001CA-14	LS-089	2.25	2.41E-7	5.42E-7	7.35E-8	1.65E-7	9.14E-9	2.06E-8	7.28E-7
	Total				2.68E-5		8.02E-6		9.94E-7	3.59E-5