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Flooding PSA with Plant Specific Operating Experiences of Korean PWRs

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1. Introduction

The purpose of this paper is to update the flooding PSA with Korean plant specific operating experience data and the appropriate estimation method for the flooding frequency to improve the PSA quality. The existing flooding PSA used the NPE (Nuclear Power Experience) database up to 1985 for the flooding frequency [1][2][3]. They are all USA plant operating experiences. So an upgraded flooding frequency with Korean specific plant operation experience is required. We also propose a method of only using the PWR (Pressurized Water Reactor) data for the flooding frequency estimation in the case of the flooding area in the primary building even though the existing flooding PSA used both PWR and BWR (Boiled Water Reactor) data for all kinds of plant areas. We evaluate the CDF (Core Damage Frequency) with the modified flooding frequency and compare the results with that of the existing flooding PSA method.

2. Estimation of the Internal Flooding Frequency for the Screening Analysis

The existing flooding PSA calculates the flooding frequency with the restricted NPE data and the MLE method for a screening analysis [1][2][3]. As mentioned previously, the NPE data does not include the Korean specific plant operation status. In this study, we utilize the NuPIPE data and the NPE data for an estimation of the flooding frequency as an alternative method. The NPE data has merits in that the data analysis was performed by experts and the NuPIPE data can reflect the plant operation experience of domestic NPPs.

We use the three-stage Bayesian analysis to estimate the flooding frequency by considering both the NPE data and the NuPIPE data. Like an evaluation of the initiating event frequencies by U.S. NRC (Nuclear Regulation Committee), when the number of available data is not enough for a frequency evaluation, the Bayesian estimation is preferred [4][5].

Table 1 shows a summary of the flooding frequencies of the flooding areas by the three-stage Bayesian analysis. We estimate the flooding frequency for four flooding areas, namely the HPSI pump room, the LPSI pump room, the general area, and the turbine building in this paper. We adopt the PWR data and BWR data for flooding frequencies of the turbine building, but only the PWR data for the primary building – the HPSI pump room, the LPSI pump room, and the general area when we use the NPE data.

In Table 1, reference value 1 is the flooding frequency used for the existing flooding PSA which use the PWR and BWR data from the NPE database and the MLE method. And reference value 2 is that calculated by using the PWR and BWR data for all the flooding areas from the NPE database, NuPIPE database, and the three-stage Bayesian method.

Table 1 shows that the ratio between the mean flooding frequency and reference value 2 ranges from 0.3 to 1.5, while the ratio between reference 1 and reference 2 ranges from 0.8 to 1.11. The result shows that the difference of the flooding frequencies between using all kinds of LWR data and using PWR data from the NPE database when the NPE database and the NuPIPE database are used for the flooding frequency is larger than one between using only the NPE database (PWR data and BWR data) and adding the NuPIPE data to the NPE database regardless of the parameter estimation method.

Table 1. Flooding Frequency for Quantitative Screening Analysis

Flood Area	Mean Flooding Frequency	Percentile		Reference Value 1	Reference Value 2
		5%	95%		
Turbine BLDG	5.4E-3	2.2E-3	9.6E-3	6.0E-3	5.4E-3
General Area	2.2E-3	2.6E-4	5.7E-3	1.2E-3	1.5E-3
HPSI PP Rm.	3.7E-4	1.4E-6	1.4E-3	1.2E-3	1.2E-3
LPSI PP Rm.	1.8E-3	4.2E-4	4.0E-3	2.4E-3	2.2E-3

3. Calculation of the Core Damage Frequency

The risk contribution from a flooding is evaluated by requantifying the appropriate core melt sequences developed in the internal event study, by taking into account equipment failures due to flood damage as well as random equipment failures. With the updated flooding frequencies, we calculate the new CDF by considering a flooding event. For those flooding areas singled out for the qualitative screening analysis, the sub flooding areas were defined to be independent with respect to an internal flooding by safety significant component [1][2][3]. We compute the CDF for the flooding events occurring in those sub flooding areas with the CCDP (Conditional Core Damage Probability), flooding frequency and the possibility of a flood barrier failure based on expression (3). We used the same value for the possibility of a flood barrier failure and for the designation of the flooding area as the analysis of the UCN (Ulchin) 3&4 flooding PSA [1].

The procedural guidance for performing an IPEEE (Individual Plant Examination of External Events) for severe accident vulnerabilities provided in NUREG-1407 indicates that any external event with an estimated CDF of less than 1.06E-6/yr may be not considered further [6]. However, since the UCN 3,4 flooding PSA, 1.0E-7/yr has been used as a screening criterion. Because the plants have a new design, a conservative value is considered [1].

The CDF evaluation result in this paper is that sixteen flooding events in the nine sub areas of the primary auxiliary building according to the screening criterion. We summarize the sixteen flooding events in Table 2. Reference CDF 1 shows the CDF calculated by using the flooding frequency of the existing flooding PSA, which is reference value 1 in the Table 1. Reference CDF 2 shows the CDF calculated by using the flooding frequency of reference value 2 in Table 1. Both reference CDF 1 and reference CDF 2 are based on the upgraded KSNP internal full-power PSA model.

Table 2. Flooding Events and Sub Areas Singled Out with Quantitative Screening Analysis

Area	Flooding Frequency	Propagation Area	CDF	Reference CDF 1	Reference CDF 2
A-29	2.2E-3	A-27	2.0E-7	5.9E-8	7.4E-8
A-34	2.2E-3	A-27	1.1E-7	5.9E-8	7.4E-8
	2.2E-3	A-30	3.8E-7	2.1E-7	2.6E-7
	2.2E-3	A-31	3.8E-7	2.1E-7	2.6E-7
A-37	2.2E-3	None	1.3E-7	7.3E-8	9.1E-8
	2.2E-3	A-23	2.8E-7	1.5E-7	1.9E-7
A-38	2.2E-3	None	1.3E-7	7.3E-8	9.1E-8
	2.2E-3	A-24	2.8E-7	1.5E-7	1.9E-7
A-45	2.2E-3	A-37	2.9E-7	1.6E-7	2.0E-7
	2.2E-3	A-38	2.9E-7	1.6E-7	2.0E-7
A-51	2.2E-3	A-48	2.2E-4	1.2E-4	1.5E-4
	2.2E-3	A-53	2.1E-6	1.1E-6	1.4E-6
A-52	2.2E-3	A-48	2.2E-4	1.2E-4	1.5E-4
	2.2E-3	A-54	4.5E-7	2.4E-7	3.1E-7
A-55	2.2E-3	A-53	2.1E-6	1.1E-6	1.4E-6
A-56	2.2E-3	A-54	4.5E-7	2.5E-7	3.2E-7

Based on reference CDF 1 and reference CDF 2, both results show that twelve flooding events in the eight sub areas are singled out and these values in the two columns show a very slight difference. From this, we conclude that the effect of the Korean plant operation experience does not show a big difference in the CDF values while the effect of only using the PWR data for the primary building brings about the additional flooding events exceeding the screening criterion.

4. Conclusion

We used the Korean specific plant operation experience data and an appropriate flooding frequency estimation method to improve the flooding PSA quality of domestic NPPs and then we requantified the CDF based on the upgraded KSNP internal full power model. In doing so, the flooding PSA quality can be improved from ASME Standard Capability Category *I* to *II* for a requisite related to a plant specific operation experience [7].

For the flooding frequency of flooding area in the primary building, we proposed to use only the PWR data while the existing flooding PSA uses the PWR and BWR data for all kinds of flooding area. We suggested the three-stage Bayesian analysis to estimate the flooding frequency by considering both the NPE data and NuPIPE data. Based on the recalculated flooding frequency, we estimated the CDF. With this procedure, we found that thirteen flooding events in nine sub areas are additionally singled out in a comparison with the existing domestic flooding PSA of UCN 5&6 in which three events in two sub areas were singled out for a further analysis.

We compared the CDF results with the results of two cases which are (1) the PWR and BWR data from the NPE database with the MLE method (2) the PWR and BWR data from the NPE and NuPIPE data with the three-stage Bayesian method. From the comparison, we found that the effect of the Korean plant operation experience does not show a big difference in the CDF values while the effect of only using the PWR data for the primary building brings about a remarkable variation in the CDF values. Therefore a further analysis is required for the thirteen additional flooding areas.

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