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Estimation of Internal Flooding Frequency for Screening Analysis of Flooding PSA

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1. Introduction

The purpose of this paper is to estimate the internal frequency for the quantitative screening analysis of the flooding PSA (Probabilistic Safety Assessment) with the appropriate data and estimation method.

In the case of the existing flood PSA for domestic NPPs (Nuclear Power Plant), the screening analysis was performed firstly and then detailed analysis was performed for the area not screened out. For the quantitative screening analysis, the plant area based flood frequency by MLE (Maximum Likelihood Estimation) method was used, while the component based flood frequency is used for the detailed analysis. [1]

The existing quantitative screening analysis for domestic NPPs have used data from all LWRs (Light Water Reactor), namely PWR (Pressurized Water Reactor) and BWR (Boiling Water Reactor) for the internal flood frequency of the auxiliary building and turbine building. However, in the case of the primary auxiliary building, the applicability of the data from all LWRs needs to be examined carefully because of the significant difference in equipments between the PWR and BWR structure.

NUREG/CR-5750 suggested the Bayesian update method with Jeffrey's noninformative prior to estimate the initiating event frequency for the flood. It, however, did not describe any procedure of the flood PSA. [2]

Recently, Fleming and Lydell suggested the internal flooding frequency in the unit of the plant operation year-pipe length (in meter) by pipe size of each specific system which is susceptible to the flooding such as the service water system and the circulating water system. They used the failure rate, the rupture conditional probability given the failure to estimate the internal flooding frequency, and the Bayesian update to reduce uncertainties. To perform the quantitative screening analysis with the method, it requires pipe length by each pipe size of the specific system per each divided area to change the concept of the component based frequency to the concept of the plant area based frequency. [3]

2. Comparison of Database for Quantitative Screening Analysis

We considered the three kinds of databases which are applicable to the quantitative screening analysis and compared their advantages and disadvantages. They are NPE (Nuclear Plant Experience) data, NuPIPE (Korea Nuclear Pipe Failure Database) data, and OPDE (OECD/NEA Pipe Failure Data Exchange) data.

Flooding narrative and root causes were described in detail in the NPE data. In addition, the flooding occurrence area and the degree of the flooding were already analyzed for flooding PSA of some of the U.S. NPPs including Surry plant. Therefore it can be a good data sources. However, with the NPE data, it is not possible to reflect the current status related to the flooding event, because the data after 1987, July is unavailable. [4]

The NuPIPE data is a collection of pipe failures of Korean NPPs from the first operation date of each plant. The NuPIPE data has a great advantage that it reflects the real world about pipe failures occurred in domestic NPPs. However, the internal flooding frequency from the NuPIPE data can be a little bit optimistic because there is no history of the flooding event in Korea. [5]

The OPDE project have developed a well structured, comprehensive database on pipe failure events based on the SKI-PIPE database, the result of 1994-1998 R&D project by SKI. Therefore the OPDE DB consists of selected records with validation from the SKI-PIPE and new records added by the OPDE project. To utilize the OPDE data for the quantitative screening analysis of the flooding PSA, the data analysis such as which event is the flood event, where is the area flood occurred and so on is required, even though there is a column from which we can understand if each pipe failure resulted from a flooding. In addition, the OPDE data needs to be examined carefully to be used for the quantitative screening analysis, since the work scope between the SKI-PIPE project and the OPDE project such as nations and the duration for data collecting are different. [6]

3. Estimation of Internal Flooding Frequency for Screening Analysis

In this paper, we use two kinds of method to estimate the internal flooding frequency. They are MLE with the three kinds of data sources previously mentioned and the two stage Bayesian analysis with the NPE data and the domestic data from the NuPIPE DB

3.1 Maximum Likelihood Estimation

Table 1 and 2 show the results of the MLE for the internal flooding frequency of the turbine building and the auxiliary building respectively. When there is no flooding event, the Chi-square approach is applied. Plant operation years from the NuPIPE data and the OPDE data are calculated up to 2003, while that from the NPE data is calculated up to 1985, July.

Table 1. Internal Flooding Frequency for Screening Analysis by MLE (Turbine BLDG)

Data	Number of Flooding	Plant Operation Year	Internal Flooding Frequency (/yr)
NPE (PWR+BWR)	5	829	6.0E-03
NuPIPE DB (PWR)	0	174.6	1.3E-03
OPDE DB (PWR+BWR)	5	6304.6	7.9E-04

Table 2. Internal Flooding Analysis for Screening Analysis by MLE (Aux. BLDG)

Data	Flood Area	Number of Flooding	Plant Operation Year	Internal Flooding Frequency (/yr)
NPE (PWR)	HPSI PP Rm.	0	968	2.4E-04
	LPSI PP Rm.	2	968	2.1E-03
	General Area	1	484	2.1E-03
NuPIPE DB (PWR)	HPSI PP Rm.	0	349.2	6.5E-04
	LPSI PP Rm.	0	349.2	6.5E-04
	General Area	0	174.6	1.3E-03
OPDE DB (PWR)	HPSI PP Rm.	0	8708	2.6E-05
	LPSI PP Rm.	0	8708	2.6E-05
	General Area	0	4354	5.2E-05

From the Table 1 and 2, internal flooding frequencies from the OPDE data are lower than the others with the NPE and NuPIPE data, since the plant operating year from the OPDE data is larger than the others. Results from the NuPIPE which reflects the domestic plant specific characteristics are lower than those from the NPE due to no flooding history in Korea.

3.2 Two Stage Bayesian Analysis

In this paper, we suggested the two stage Bayesian updates for the estimation of the internal flooding frequency. The NPE database is well analyzed to apply for the estimation of the flooding frequency except that data after 1987, July are unavailable. Therefore, in the first stage Bayesian analysis, we obtained the Gamma distribution, the prior of the second stage, with the NPE data and the Jeffrey's noninformative prior.

Then we calculated the posterior of the second stage Bayesian analysis with the Korean specific data that reflects characteristics of Korean NPPs. Table 3 shows the two stage Bayesian analysis.

In the two stage Bayesian analysis, the OPDE data is excluded because it needs more detailed analysis for the each record.

There is not a big difference between results from the Table 3 and results with NPE data from the Table 2. However, it could be evaluated that the two stage Bayesian analysis is reasonable to apply for the estimation of the internal flooding frequency for the quantitative screening analysis from the point of that it utilize the NPE data well analyzed and the NuPIPE data reflecting the characteristics of Korean NPPs

Table 3. Internal Flooding Frequency by Two Stage Bayesian Analysis

Flood Area	Mean Frequency of Prior & Distribution.	Mean Frequency of Posterior & Distribution
Turbine BLDG	6.6E-03, Gamma(5.5, 829)	5.4E-03, Gamma(5.5,1003.6)
General Area (Aux. BLDG)	3.1E-03, Gamma(1.5, 484)	2.3E-03, Gamma(1.5, 658.6)
HPSI PP Room.	5.2E-04, Gamma(0.5, 968)	3.8E-04, Gamma(0.5,1317.2)
LPSI PP Room.	2.6E-03, Gamma(2.5, 968)	1.9E-03, Gamma(2.5,1317.2)

4. Conclusion

We survey the several estimation methods and databases for the estimation of the internal flooding frequency for the quantitative screening analysis. We compare their advantages and disadvantages and examine their applicability to the flooding PSA for domestic NPPs.

We estimate the plant area based internal flooding frequency by using the three kinds of data with the MLE. And then we calculated the frequency by using the two stage Bayesian Analysis with the NPE and NuPIPE data.

We evaluate that the two stage Bayesian analysis is reasonable to apply for the estimation of the internal flooding frequency for the quantitative screening analysis from the point of that it utilizes the NPE data well analyzed and the NuPIPE data reflecting the characteristics of Korean NPPs.

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