Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Application Methods for added Requirement in ASME/ANS RA-Sb-2013 to Internal Flooding PRA

Hyun-Joon Son [a*] and Jin-Sik Son [a]
[a] *Integrated Safety Assessment Department, Power Engineering Research Institute, KEPCO E&C*
[*] *Corresponding author: june3820@kepco-enc.com*

1. Introduction

PRA (Probabilistic Risk Assessment) of NPP (Nuclear Power Plant) has been performed for both operating and constructing from a variety of perspectives and applied to design. For the requirement of PRA acceptance, ASME/ANS RA-Sb-2013 [1] was published on July 1, 2013 and provided detailed support requirement for PRA. This document describes supporting for applying requirements for specific applications. Compared to the requirement of previous version [2] which was published 2009, much has changed in current version which was published 2013. Therefore, research of new requirement is needed to meet regulatory in addition to successive PRA acceptance.

The object of this paper is suggestion of measures to meet added requirements of ASME/ANS RA-Sb-2013 for internal flooding PRA.

2. Method and Results

In this chapter, some of principal requirements of ASME/ANS RA-Sb-2013 with respect to flooding PRA are reviewed, including difference with ASME 2009. Comparison analysis is performed using these results and critical issues to be considered in assessment are described. Finally, methodology for the flooding PRA are derived and suggested to meet the regulatory criteria and PRA acceptance from the comparison analysis of ASME/ANS requirements between the two versions. Flooding requirement for ASME/ANS is divided into:

- IFPP : Internal Flood Plant Partitioning
- IFSO : Internal Flood Source Identification and Characterization
- IFSN : Internal Flood Scenarios
- IFEV : Internal Flood-Induced Initiating Events
- IFQU : Internal Flood Accident Sequences and Quantification

3.1 Requirement for Internal Flood Plant Partitioning

IFPP defines the physical boundaries and divides the various volume of the building in NPP as a flood area. Flood areas are normally defined in terms of types of or location within a building and the physical barriers that delay, restrict, or prevent the propagation of floods to adjacent areas.

In relation to the requirements of this element, identification of the plant partitioning uncertainty and assumption are added in 2013 as compared to 2009. When define the flood area, uncertainty is possible due to complex structure of the plant. In addition, if the plant is under the construction, it is difficult to define a precise flood area because the P&ID (Piping and Instrumentation Drawing) and Room number drawing will be changed frequently and designs of SSC (Structure, System and Component) are not completed yet. In order to meet for identification of the plant partitioning uncertainty and assumption, site walkdown should be conducted in detail. During the walkdown, flood area boundary, barriers, propagation path, assumption and other checklist have to be verified. These check list will be utilized in qualitative and quantitative analysis. Therefore, performing detailed walkdown can meet the added requirement.

3.2 Requirement for Internal Flood Source Identification and Characterization

IFSO is related to identification and characterization of internal flood source. All flood sources have a potential to cause flooding impact, then the various potential sources of flood and equipment spray within the plant have to be identified along with the mechanisms resulting in flood. In relation to the requirements of this element, identification of HEL (High Energy Line), assumptions and sources of uncertainty associated with flood source identification and characterization are added in 2013 as compared to 2009.

HELB (High Energy Line Break) events can produce a variety of impacts that will affect both local and global in nature. Therefore, it is necessary to identify HEL, HELB area and qualitative assessment. Confirmation of HEL and HELB area are possible through piping information. Once, collection of HELB area information is complete, have to review the impact of failing all components in each HELB area. And then, examine the initiating event frequency to prioritize areas susceptible to HELB and examine propagation. The potential flood scenario propagation pathway for a HELB event can be defined in the same manner as any other liquid flood source. A detailed description of the HELB scenario is given in section 3.3.

It can be possible inconsistencies between flood source information and construction because there many rooms and piping in NPP. Thus, detailed walkdown is needed to remove uncertainty of flood source. The method of walkdown is same as plant partitioning.

3.3 Requirement for Internal Flood Scenario

IFSN means development of internal flood scenarios. In the requirement of IFSN, HELB scenario analysis is added in 2013 as compared to 2009. HELB scenario analysis includes impact of jet impingement, pipe whip, temperature, and pressure failure mechanisms. Also, when develop HELB scenarios, HELB analysis includes flood area, flood source, flood rate, flood propagation path, flood impact on plant SSCs, and human actions considered in flood initiation, mitigation, and termination.

To meet requirement for IFSN, it is necessary to develop HELB scenarios. Due to the large impact of HELB, it is assumed that all components will fail in corresponding area. All equipment and component in the flood area which are defined as flood susceptible (to steam, spray, and flood accumulation) are failed with the frequency of the HELB event. HELB scenarios can be classified into three categories. One is HELB in flood areas with barriers. In this case, flood area is equipped with HELB Barriers which prevent propagation out of the HELB area. Another is HELB in flood areas without barriers and with additional piping but no SSCs. In this case this flood area is subject to impacts from pipe whip, jet impingement, humidity, condensation, and temperature with the potential for propagation of humidity and temperature impacts through penetrations to directly adjacent flood areas. But, there are no pipes and cable tray related to the mitigation function and reactor trip in this flood area. Thus, the potential pipe whip and jet impingement cannot be happened in this flood area. The other is HELB in areas without barriers and with additional piping and SSCs. In this case, this flood area is subject to impacts from pipe whip, jet impingement, humidity, condensation, and temperature with the potential for propagation of humidity and temperature impacts through penetrations to directly adjacent flood areas.

3.4 Requirement for Internal Flood-Induced Initiating Event

The purpose of IFEV is to identify the flooding induced initiating events and estimate their frequencies. In relation to the requirements of this element, estimate the frequency of human-induced flooding through plant-specific data or engineering judgment, assumptions and source of uncertainty associated with flood-induced initiating-event analysis are added in requirement.

Human-induced (also called as maintenance-induced) internal flooding is caused by an incorrectly-performed surveillance, testing or maintenance activity. Errors during these activities have the potential to lead an increased probability of flooding.

In order to estimate for human-induced flood through plant specific data, the following process can be used in IFEV analysis. First step is identification of human-induced flooding accident. The identification of human-induced flooding can be accomplished considering plant-specific data. Second step is screening of human-induced flooding accident. EPRI TR-1019194[3] provides high-level, general guidance for screening maintenance activities as potential flood sources. Each of the screening considerations is based on a plant-specific practice. EPRI screening criteria is presented in Table I.

Table I: EPRI Screening Criteria

No.	Criteria
1	No plant trip would occur from flood
2	The frequency of occurrence can be subsumed by a non-flood initiating event and no resulting damage occurs to PRA SSCs due to the flood.
3	The opening is isolated by two or more means
4	The opening is isolated by a blind flange or manual valve because of low transfer open probability
5	The maintenance can be shown to be unlikely or very infrequent during full-power operation
6	Failure of additional equipment such as sump pumps would be required in addition to isolations to result in damaging flood
7	A flood would be readily detected by roving operations or security personnel well before PRA SSCs would be affected.

Last step is quantification of human-induced flooding accident. Data that are not screed out are used for quantification by considering operation period and fuel cycle. The results can be used for human-induced initiating event.

For the requirement of assumptions and source of uncertainty associated with flood-induced initiating-event, EF (Error Factor) can be used in initiating event analysis. Each flood frequency is a statistical estimate with an associated uncertainty, which is typically characterized by its error factor. The EF is an appropriate risk metrics for failure rates, which often have a log-normal distribution. The EF is similar to the standard deviation for normally distributed data. The error factors are identified as RF (Range Factor). The RF is calculated as the square root of the ratio of the 95th and 5th percentiles of the break frequency point estimate [4]:

$$RF = \sqrt{[\text{ninety-fifth percentile/fifth percentile}]}$$

The result of RF can support assumptions and source of uncertainty.

3.5 Requirement for Internal Flood Accident Sequences and Quantification

IFQU means internal flood accident sequences and quantification. The internal flood plant response model is used to quantify and results derived as CDF (Core Damage Frequency) and LERF (Large Early Release Frequency) contain some uncertainties in the calculated for the flooding scenarios. Because the uncertainties in the parameters and assumptions used in the characterization of the flood scenarios, time available for flood isolation/mitigation, impact of the flood on plant equipment, and the response of the plant to the flooding events make some inaccuracy of results.

To solve the inaccuracy related to uncertainties, sensitivity and uncertainty analysis can be used after quantification. Sensitivity analysis can be performed to evaluate the impact to the results of principal assumptions used in the flooding PRA. Thus, characterization and estimation of the uncertainty interval of the CDF results for flood-induced accident sequences can support for requirement.

3. Conclusions

In this paper, presented methodologies can meet the changed requirements in ASME/ANS related to flooding PRA. These methodologies are useful to develop flooding PRA model and quantification.

a) Detailed walkdown for IFPP, IFSO
b) HELB Scenario Analysis for IFSO and IFSN
c) Human-induced internal flooding through plant-specific data for IFEV
d) Uncertainty and sensitivity analysis for IFPP, IFEV and IFQU

REFERENCES

[1] ASME/ANS RA-Sb-2013, Addenda to ASME/ANS RA-S– 2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, ASME/ANS, 2013.

[2] ASME/ANS RA-Sa-2009, Addenda to ASME/ANS RA-S– 2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, ASME/ANS, 2009.

[3] Guidelines for Performance of Internal Flooding Probabilistic Risk Assessment, pp 5.28, EPRI, 2009.

[4] Pipe Rupture Frequencies for Internal Flooding Probabilistic Risk Assessments, pp 3.21-3.22, EPRI, 2013.