Internal Flooding Probabilistic Safety Assessment of an OPR-1000 Plant during Low Power and Shutdown Operation

Yoon-Hwan Lee, Jin-Hee Park and Ho-Gon Lim

Korea Atomic Energy Research Institute, Integrated Safety Assessment Div., Daejon, Yuseong, Daeduck-daero 1045, Korea, 305-353
Corresponding author: yhlee3@kaeri.re.kr

1. Introduction

This document is intended to evaluate an internal flooding probabilistic safety assessment (PSA) for a Korean nuclear power plant (NPP) as a part of efforts to develop a Korean site risk profile (KSRP) based on all-mode, all hazard level 1/2/3 PSA including the extreme risk factors. This IF-PSA was performed for low power and shutdown (LPSD) state of the OPR-1000 using a part of the EPRI draft guidance report.

In 2009, the electric power research institute (EPRI) published a guideline for the development of IF-PRA that addresses the requirements of the ASME/ANS RA-Sa-2009 PRA consensus standard. The EPRI guideline delineates a level of detail and assessment complexity that has been significantly increased with respect to the guidance for IF assessment performed for the individual plant examination (IPE) to address Generic Letter 88-20 [1]. The main differences include:

- A more systematic approach to the definition of flood area
- The identification, screening and analysis of flooding sources and scenarios
- The calculation of the initiating-event frequency (IEF) based on the actual length and characteristics of the piping
- The inclusion of spatial effects such as spray from pipe leaks
- The specific documentation associated with the plant walkdowns

Among these differences, this research focused on the third and fourth items when performing the internal flooding PSA. This is done by identifying the pipe and fluid characteristics, assessing the pipe pressure, characterizing the pipe (i.e., pipe diameter, length, etc.) and determining the pressure boundary failure frequency. The results were summed for the various piping systems within a given flood area to arrive at an overall internal flood initiating frequency for a given flood mode (i.e., spray, general flood, or major flood) for that particular area by each POS (Plant Operational State). In this initiating event frequency evaluations, the POS duration time is especially considered to get the real values for LPSD state. Characterizations of spray scenarios were evaluated to determine their impact on plant risk caused by internal flooding events [2].

This paper summarizes the results and highlights of the internal flood analysis performed for the OPR-1000 plant during the low power and shutdown operation.

2. Analytical Methods

IF-PSA guidelines have been organized into three major phases of the analysis in Figure 1 [3].

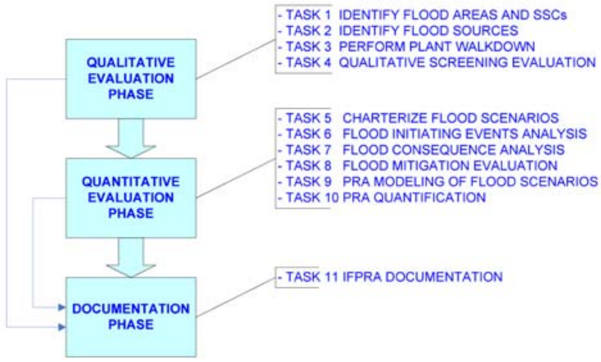

Figure 1. Major Phases and Tasks of IF-PSA

2.1. Qualitative Evaluation Phase

In the first phase of IF-PSA, Qualitative Analysis, the information that is needed for the IF-PSA is collected and the initial qualitative analysis tasks are performed. The major outputs of this phase include the screening out of plant flood areas based on criteria associated with flood sources, flood propagation pathways, and potential impacts of floods on SSCs and the selection of flood areas for quantitative evaluation. There are four key tasks that are completed in this phase for the identification of flood areas and SSCs, identification of flood sources, performance of a plant walkdown, and completion of a qualitative screening evaluation of plant locations [3].

2.2. Quantitative Evaluation Phase

Quantitative evaluations plant locations, which have not been screened out are addressed in six separate tasks that comprise the quantitative evaluation phase of IFPRA. These tasks are organized around the key steps in defining flood scenarios and quantifying their impacts in the PRA model in terms of their contributions to core damage frequency (CDF) and large early release frequency (LERF). These steps include the definition of flood scenarios in terms of flood initiating events, the consequences of the flood on SSCs, human actions to mitigate the consequences of the flood and to control the plant, and the interfacing of the flood scenario with the PRA event tree/fault tree logic. Once the scenarios have been properly characterized, this phase also addresses the quantification of the flood initiating event frequency, CDF, and LERF [3].

3. Quantification Results

3.1 Screening Analysis

To incorporate flooding event characteristics into flooding event PSA model, a new initiating event such as a loss of power control (LOPC) due to a MCR flooding was considered, and a risk assessment was performed based on fault trees and event trees developed for internal event PSA.

To screen out a flood area, a quantitative screening analysis is conducted by each POS if the sum of the product of the frequencies of the flood scenarios for the area and the conditional core damage probability (CCDP) is less than 1.0E-07. In the screening analysis, the human failure events (HFEs) for IF-PSA were five times higher than internal Level 1 scenarios. Flooding scenarios were identified and quantified by each POS using the AIMS-PSA (Advanced Information Management System for PSA). Of them, POS 02, 03, 04A, 10, 11, 12B, 13 and 14 were screened out with 1.0E-07 of cut-off value. Two flooding areas, D058-A00A for POS 4B, 5, 6 and D058-A00B for POS 12A were necessary for detailed analysis to know more realistic risk.

3.2 Detailed Analysis

Two flooding areas, D058-A00A and D058-A00B for total 4 POSs were identified and quantified with more realistic pipe rupture frequencies for the flood areas and the additional human failure event analysis. The major reason why the risk due to the flooding was higher than 1.0E-07/yr of screening criteria is that the train A and B of the shutdown cooling system are flood-damaged due to an EOL (Emergency Overflow Line) installed between Div. A and Div. B in 55 ft of primary auxiliary building. In this detailed analysis, insulated and lagged pipes were not considered to be significant spray sources and as such were not included in the calculation of the spray frequency.

Table 1. Contribution to CDF by POSs

POS	Area	CDF (/yr)
POS 4B	D058-A00A - Div. A	1.67E-09
POS 5	D058-A00A - Div. A	8.49E-09
POS 6	D058-A00A - Div. A	6.92E-10
POS 12A	D058-A00B - Div. B	9.90E-11
SUM		2.72E-09

Each contribution to the overall internal flooding induced CDF was obtained by combining the values of flood scenario frequency, flood barrier failure probability and CCDP as shown in Table 1.

4. Conclusions

According to the results of flooding event analysis during low power and shutdown operation, a risk was assessed to be 2.72E-09/yr. The core damage frequencies for POS 02, 03, 04A, 10, 11, 12B, 13 and 14 were lower than the 1.0E-07/yr of screening criteria. Two flooding areas, D058-A00A and D058-A00B of each POS 4B, 5, 6 and 12A were necessary for detailed analysis to know more realistic risk. The major reason why the risk due to the flooding was higher than 1.0E-07/yr of screening criteria is that the train A and B of the shutdown cooling system are flood-damaged due to an EOL installed between Div. A and B in 55 ft of primary auxiliary building. Through the detailed analysis, the uncertainty caused by risk increase due to the EOL installed between Div. A and Div. B could be reduced, and more realistic results were obtained.

This study shows that the CDF due to internal flooding events during LPSD operation is lower by about two orders to magnitude than that of power operation. This is mainly due to the much smaller fraction of time that the plant is at low power and shutdown state.

To extend the applicability of this study results, more efforts are needed for conducting additional detailed analysis according to the variation of the cut-off condition based on the risk of flooding area.

ACKNOWLEDGMENT

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