Flooding PSA for System Integrated Modular Advanced Reactor

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1. Introduction

The Korean Atomic Energy Research Institute (KAERI) launched a project to develop a small and medium sized reactor (SMR) which is an integral type pressurized water reactor (PWR) with a rated thermal power of 330 MWt and electrical power of 100 MWe in 1996. This reactor is called the System Integrated Modular Advanced Reactor (SMART).

KAERI performed a level 1 probabilistic safety assessment (PSA) including fire PSA and internal flooding PSA (IFPSA) for SMART.

The purpose of this paper is to describe the IFPSA method and results for SMART and to draw some insights from the results. In this paper, we applied a modified IFPSA method compared with the existing one for domestic nuclear power plants (NPPs) [1][2].

2. Internal Flooding PSA Method and Results

The objective of the IFPSA is to estimate the contribution of internal floods due to failures of equipment that contains inventories of water to a core damage frequency (CDF) and to identify any plant design or operational vulnerabilities attributable to internal flooding potential. For an IFPSA, a qualitative screening analysis to screen out flooding areas that does not affect plant trip with qualitative screening criteria is performed firstly and a quantitative screening analysis to calculate a CDF of each flooding area not screened out for the previous stage is performed. Finally a detailed analysis is performed to calculate a refined CDF by considering more detailed piping rupture frequency or a barrier failure probability.

2.1 Qualitative Screening Analysis

For the qualitative screening analysis, SMART was divided into broad areas generally corresponding to those major plant buildings and each broad area were defined as smaller areas (flooding areas) within a larger independent area. We selected 213 flooding areas from 6 broad areas, auxiliary building, turbine building, component cooling water heat exchanger building, emergency diesel generator building, sea water intake building and circulating water intake building. We identified flooding sources, equipment in each flooding area, and flood propagation path. We performed qualitative screening analysis to remove less significant flood areas based on the screening criteria. The screening criteria for the qualitative analysis consider the potential for flood initiation and propagation, potential for a need for immediate plant shutdown, and damage to equipments that may be needed to prevent core damage in response to the plant shutdown. Therefore 152 flooding areas of the total 213 areas were screened out and 61 flooding areas are remained for the quantitative screening analysis.

2.2 Quantitative Results

In this stage, we modified the existing IFPSA method for domestic NPPs to correct some habitual practices.

Firstly, we modified the flooding frequency calculation method because the flooding frequencies used for the existing flooding PSA were calculated inappropriately. We used the same data, US Nuclear Power Experience (NPE) data, as the existing IFPSA for domestic NPPs but we analyzed them again to link a flooding occurrence location with a plant building appropriately.

Secondly, we revised potential initiating events due to flood. In the case of the level 1 PSA for SMART, a rupture on downstream piping of a main steam isolation valve (MSIV) and a rupture on upstream piping of main feedwater isolation valve (MFIV) are included in large secondary side break (LSSB), while a rupture on upstream piping of a MSIV and a rupture on downstream piping of MFIV are included in steam line break MSIV upstream (SLBU) initiating event. For the flooding areas in which MFIV and MSIV are placed together, we did not consider any initiating event that can be caused by a flooding since the LSSB and SLBU due to the related piping rupture by flooding in the flooding areas were already comprised in SMART level 1 PSA. Therefore we excluded the flooding areas from the quantitative screening analysis. However, the existing IFPSA for domestic NPPs considered the general transient for the flooding areas conventionally even though the related initiating events (i.e. LSSB and loss of feedwater (LOFW)) due to piping rupture about MSIV and MFIV were also included in the level 1 PSA.

Thirdly, we changed human error probability due to internal flooding since operation environment after the occurrence of internal flooding will be harsher than normal operation environment. We considered that an execution error probability will be affected by an internal flooding accident, while diagnosis error probability will be left intact. So we changed execution error probability inside and outside main control room (MCR) respectively.

With the flooding frequency, initiating events selected for IFPSA, barrier failure probability and increased human error probability, CDFs for each flooding area were calculated and compared to the screening criteria (1.0E-8/Yr). As a result, 61 flooding areas not screened out at the previous stage were screened out on the quantitative screening analysis stage.

3. Conclusions

In this paper, we described the IFPSA method and results for SMART. We modified the existing IFPSA method for domestic NPPs to correct some habitual practices. They are flooding frequency calculation, selection of the potential initiating events due to flooding, and human error probability estimation.

The results show that all flooding areas not screened out on qualitative screening analysis stage were screened out on quantitative screening analysis stage since the CDFs for each flooding area were lower than screening criteria. Therefore there is no need for detailed analysis. Since SMART design has not been developed completely we only considered a door for flooding barrier. When we consider other barrier such as watertight door, the CDF for each flooding area can de reduced.

REFERENCES

[1] KHNP 98NJ14, "Probabilistic Safety Assessment for Ulchin Units 5&6 (Phase II): External Event Analysis (Final Report)," KHNP (2002).

[2] 916-NS301-036, "SMART Internal Flooding Event Analysis (Level 1 PSA) ," KAERI (2011).