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Modelling Approaches in KHNP Multi-unit PSA Project

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1. Introduction

Site safety assessment (or Multi-unit PSA) was highlighted as one of the important issues after Fukushima accident. Most nuclear sites in the world have two or more reactor units. However, there were no methodologies to comprehensively assess the site safety. So, many research projects related to multi-unit PSA have lunched in many countries.

In case of Korea, all nuclear sites have six or more reactor units on the same site. In addition, multi-unit PSA was issued in the construction licensing process of Shin-Kori unit 5&6. For this reason, Korea Hydro & Nuclear Power (KHNP) lunched multi-unit PSA project on July 2016. The purpose of this paper is to briefly introduce KHNP project and describe several assumptions and modelling approaches to consider multi-unit aspect.

2. Scope of KHNP Project

The purpose of KHNP multi-unit PSA project is to develop the methodology and to apply it to a pilot site. This project consists of two phases. The first phase is to perform the preliminary assessment and it was done on June 2018. Final phase will be done by June 2020. In the preliminary phase, we focused on making overall framework and modeling approaches addressing technical issues such as multi-unit Common Cause Failure (CCF). PSA scopes of this project is Level 1&2 PSA considering the operating modes (Full power and Low Power & Shutdown). Level 3 PSA is not considered in this project.

In addition, the case study for a pilot site is performed based on developed methodology. The pilot site has nine operating units and one permanent shutdown unit. Each units have one Spent Fuel Pool (SFP). For permanent shutdown unit, we will consider the SFP only. Expected results are multi-unit Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) of n units. Also, we consider increased risk resulting from adding new nuclear power plants in the existing site and risk insights in multi-unit aspect. Table 1 shows the overall scope of KHNP MUPSA project.

3. Modeling Approach on Multi-unit Dependencies

Currently, there are a number of technical issues in performing MUPSA. One of them is that how to apply multi-unit dependencies to the models. These multi-unit dependencies include:

- Initiating events (e.g. seismic)
- CCF
- External hazards correlation (e.g. seismic)
- Shared and Common SSCs
- Etc.

As most of MUPSA projects in the world are now at the beginning stage, there are no methods to properly address multi-unit dependencies. So, we considered several assumptions for above them in multi-unit aspect.

3.1 Multi-unit Initiating Events

Multi-Unit Initiating Event (MUIE) could be defined as internal and external hazards that affect more than two units concurrently. Since 1978, a few events which cause the trip of multiple units happened in Korea. To identify these initiating events, we reviewed the experience data of domestic NPPs and lesson learned from Fukushima. Through this, we identified and determined five MUIEs as shown in Table 1. Most of MUIE in Korea had been occurred by external causes such as typhoon, heavy snowstorm, and massive influx of marine lives.

Table 1 Overall Scope of KHNP MUPSA Project

Operation Mode	Initiating Events	Level 1	Level 2	Preliminary	Final
Full power & Low power and Shutdown	LOOP (due to Typhoon, Heavy snow, Fire, etc.)				
	LOCV (due to marine lives)				
	GTRN (due to Typhoon, Lightening)				
	Seismic Event				
	Tsunami Event				

3.2 Multi-unit Common Cause Failure (CCF)

In single-unit PSA, CCF was known as one of the significant risk contributors. This is also valid in multi-unit aspect. So, many researches related to MUPSA have considered inter-unit CCF as an important issue. To apply inter-unit CCF to MUPSA model, we considered two kinds of aspects as follows:

- What kinds of equipment we consider for inter-unit CCF
- How to apply inter-unit CCF to MUPSA models including various type of nuclear power plants such as Westinghouse and OPR-1000

To determine an equipment for inter-unit CCF, we reviewed the PSA results of each units at the pilot site and then identified the list of equipment which had more than 0.005 of the Fussell-Vesely (F-V) importance. In the list, a few equipment have been identified due to the design differences between NPPs. For identified above, several equipment which was considered as major contributor to the risk in single unit PSA results were added in the list through the expert judgment. In aspect of modeling of inter-unit CCF, it can be considered as a three kinds of types as follow.

- between twin unit (e.g., Kori unit 3&4)
- between similar units (e.g., Shin Kori unit 3&4 and Shin Kori unit 5&6)
- across site

For each types, we considered one CCF events representing all equipment failure (n out of n) and assumed that the failure probabilities of CCF events have the values of 0.5, 0.25, and 0.1 of single-unit CCF events.

3.3 Operator Action

Korea NPPs does not share the safety related SSCs excepting switchyard, intake structure, and AAC D/G. In addition, it does not share the operators between units. In other word, most of operator actions have no interactions when the multi-unit accidents occur. In general, it is known that these features are more beneficial in terms of the multi-unit safety. So, we developed all operator actions to be independent excepting off-site power recovery action. Multi-unit LOOP in Korea have been occurred by external hazards such as typhoon and heavy snow. Although the operators who perform recovery action are different in each units, they have same stress level, harsh environment, and so on. So, we considered off-site power recovery action to be fully dependent.

4. Modeling Approach on Other Considerations

4.1 Unit Combinations considering operating modes

One of the most important challenges on MUPSA is the modelling complexity due to the large number of reactor units. In addition, to consider the operating modes of all reactor units, the number of combinations of reactor units increases a lot. In this regard, it was presented at a previous conference [1].

4.2 Seismic

In existing PSA, seismic models of each units in a pilot site had one group regardless of magnitude of seismic. In addition, each units considered different seismically induced initiating events due to the design characteristics. In multi-unit model, we divided five seismic groups according to the magnitude (i.e., peak ground acceleration: 0.1g, 0.3g, 0.5g, 0.7g, and 0.9g) [2]. For each seismic group, MUPSA model have been developed. In addition, we identified same seismically induced initiating events in all units at a pilot site. In case of HRA, we used the concept of Performance Shaping Factor (PSF) as function of the magnitude based on engineering judgement in preliminary phase. Three PSF values have been used as follow. 3, 5, and 10.

- 0.1g ~ 0.3g: PSF 3
- 0.3g ~ 0.7g: PSF 5
- 0.7g ~ 1.0g: PSF 10

5. Conclusions

In this paper, we briefly introduced KHNP project and described several assumptions and modelling approaches to be used in multi-unit model. Currently, there are no methods to properly address technical issues such as inter-unit CCF, seismic correlation and so on. Hence, we used simple approaches based on several assumptions and engineering judgements in the preliminary phase. To cope with these technical issues, we make an efforts to find the proper methods and to apply it to the models in the final phase.

REFERENCES

[1] H.J. Jeon, et al., “Evaluation Plan for Multi-unit PSA Considering Operating Modes in a reference site”, Transactions of the Korean Nuclear Society Spring Meeting, May 17-19, 2017

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