Study on the Simplification of STC combination in Multi-unit PSA

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1. Introduction

Korea Hydro & Nuclear Power (KHNP) has started the project on Multi-Unit Probabilistic Safety Assessment (MUPSA), which is planned to be done by June 2020. This project consist of two phases. The first phase was to develop the overall framework of multi-unit PSA and to perform the preliminary assessment for pilot site with some limitations and assumptions and it was done on June 2018. Final phase will be done by June 2020. In this phase, multi-unit PSA model will be modified and updated to apply site-specific considerations in more detail. PSA scope is Level 1&2 PSA covering all operating modes (Full Power and Low Power & Shutdown condition).

In this paper, we introduced the multi-unit Level 2 PSA method used in the KHNP project. Especially, the focus is on simplifying the combination of Source Term Category (STC).

2. Multi-unit Level 2 in KHNP Multi-unit Project

Single-unit Level 2 PSA is the comprehensive process to address containment failure and the release of radioactive materials considering severe accident phenomena that can affect the integrity of containment. Generally, it consists of four steps as follows.

- Development of extended Level 1 ET (Plant Damage State Event Tree, PDS ET)
- Grouping and quantification of PDS ET into PDS
- Containment Event Tree (CET)/Decomposition Event Tree (DET) analyses
- Grouping and quantification of CET into STC

By performing this assessment, we can attain various results such as Large Early Release Frequency, Containment Failure Frequency, and STC. In the first phase of KHNP project, the method developed by Korea Atomic Energy Research Institute (KAERI) [1] was used for multi-unit Level 2 PSA. With regard to dependencies related to the containment integrity, we have assumed that they are independent of each other. Overall process was briefly summarized as follows.

- Extract the fraction between PDS and STC and the fraction between PDS and the end state of CET such as Early Containment Failure (ECF) and Late Containment Failure (LCF) according to the selected risk metrics in multi-unit Level 2 PSA (see Fig. 1)

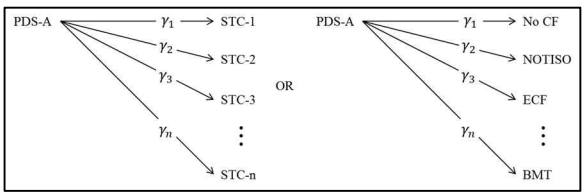

Fig. 1 Relations between PDS and STC

- Using single-unit PSA result, assign PDS of each units to correspond unit sequence which is included in multi-unit accident sequence quantified in multi-unit level 1 PSA. Each PDSs herein have the information of branch fraction to STC and the end state of CET (see Fig. 2)

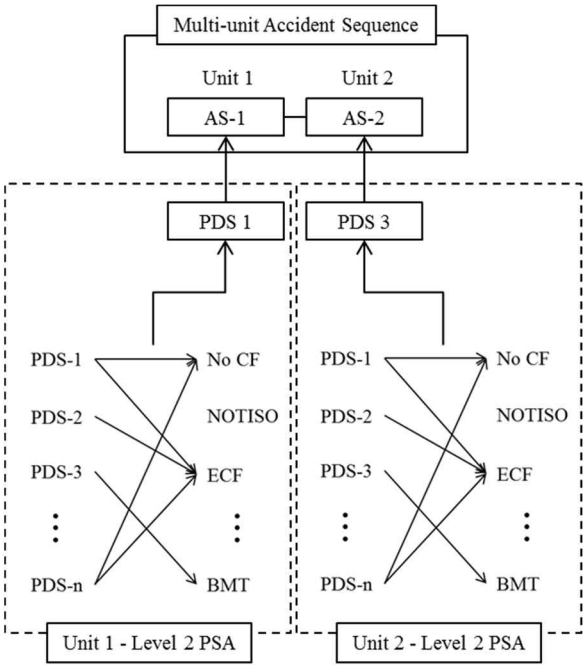

Fig. 2 Structure of Multi-unit Level 2 PSA

- Quantify multi-unit Level 2 risk metrics and multi-unit STCs using PDS-STC or PDS-LERF fraction

This method using the results of existing PSA could assess the selected risk metrics and multi-unit STCs without additional model development for Level 2 PSA.

3. Multi-unit Source Term Category (STC)

One of the results of KHNP project is the multi-unit STC. The basic concept of MUPSA is to assess the risk under the situation that all units on the same site are affected by the same hazard such as seismic. That is, the

nuclear power plant sites may have a possibilities of the release of radioactive materials from multiple units to the environment. These release can be expressed as a combination of STC of each units on the same site. This combination can be increased with the number of STCs of individual units, and if the different type of reactor are on the same site, the number will increase further. The pilot site considered in the preliminary assessment have three types of reactor. This can lead to an increase in STC combinations that are difficult to handle in the consequence assessment. Hence, the efficient method for grouping and quantifying the combination of STC is needed to be developed. Actually, authors already suggested the method [2] related to simplify the combination of STC (see Fig. 3). This method was to reduce the number of combinations using cut-off value.

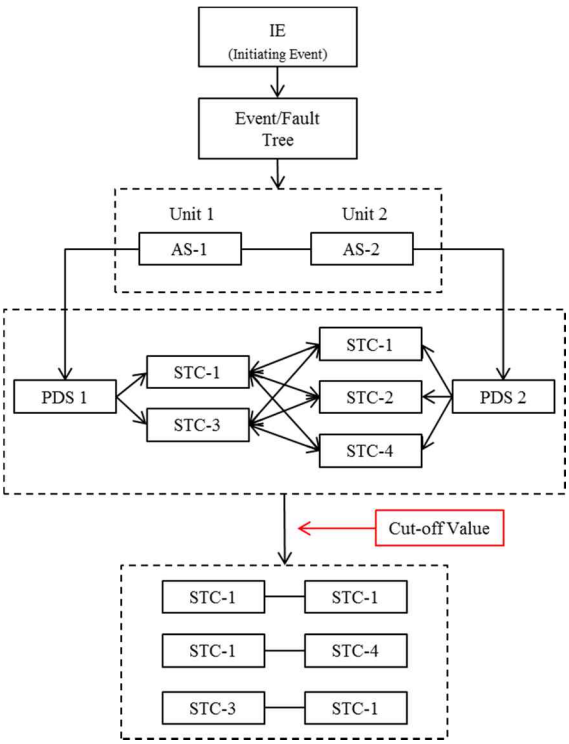

Fig. 3 Structure for quantifying multi-unit STC

In addition to above method, we are considering various approaches to simplify the combination of STCs for final phase of KHNP project.

1) Assume that one PDS assign to one STC
2) Consider all combinations applying the cut-off value
3) Restructure STC Logic Diagram to reduce the number of STCs

In case of first approach, it is assumed that one PDS will be branched to one representative STC. The major factor of the increase of STC combinations is that some PDS in single-unit PSA are branched to two or more STCs. So, some screening criteria is used in the first approach. This criterion can make the branch a one-to-one function. If multi-unit accident sequence includes a PDS that branches to more than two STC, we can know each branch fraction through single-unit Level 2 PSA. If one branch fraction is greater than 50% or more, the STC is selected as the representative STC. If all branch fractions are less than 50%, the amount of Cs-137 (or I-131) of each STC is compared with each other, then the STC having the largest Cs-137 (or I-131) is determined as the representative STC. Second approach is to consider all STC combinations using an adequate cut-off value. It is expected that second approach will have more STC combinations then first approach. Last is to restructure STC logic diagram of each units. In other words, it reduces the number of STCs considered in Level 2 PSA. One of the approaches will be chosen until the final phase, and it will be used as a method for STC quantification.

4. Conclusions

In this paper, we briefly introduced multi-unit Level 2 PSA method used in KHNP project. This method is based on the result of single-unit Level 2 PSA without additional model development. If single-unit Level 2 model and results for all units in the same site exist, this method is expected to be practical for multi-unit Level 2 PSA. In addition, we proposed three approaches to simplify the combination of STCs. One of them would be used in final phase and it may be used for the future research project related to the consequence analysis.

REFERENCES

[1] Jaehyun Cho, et al., “Multi-unit Level 2 Probabilistic Safety Assessment: Approaches and their Application to a six-unit Nuclear Power Plant Site”, Nuclear Engineering and Technology (NET), 2018

[2] Kyemin Oh, et al., “Simplified Method for Quantification of Multi-unit STC”, Transactions of the Korean Nuclear Society Spring Meeting, May 17-19, 2017