Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2017

A Few Thoughts for Multi-unit Probabilistic Risk Assessment

Hak Kyu Lim
KEPCO International Nuclear Engineering Graduate School, Seosaeng-myon, Ulju-gun, Ulsan, Republic of Korea
hklim@kings.ac.kr

1. Introduction

The Fukushima Dai-ichi accident revealed the seriousness of multi-unit accidents at a site. Many countries have tried to develop multi-unit risk assessment methodology and to assess the multi-unit risk [1-3]. Most of the approaches are based on the technique of probabilistic safety assessment (PSA). PSA and the interpretation of its results have been widely accepted for single unit risk assessment [4].

Recently, in Korea, Nuclear Safety and Security Committee (NSSC) started an R&D project for development of multi-unit risk regulation. KHNP also started an R&D project for multi-unit probabilistic risk assessment (MUPRA) for Kori/Saewool site to submit the result as NSSC recommended for Shin-Kori 5&6 construction.

However, there has been no technically matured approach and results of MUPRA in the world, yet. To establish the practical and effective approach to resolve the anxiety of multi-unit risk, it is needed to look at multi-unit risk from basic perspectives.

This study proposes several thoughts which could be raised for effective and practical MUPRA studies.

2. Thoughts for MUPRA

Many countries have tries to assess the multi-unit risk of a site. The purposes of the trials are to identify the risk due to interaction between multi-units and to prove the safety of a site, based on licensing basis of each unit.

2.1 Why does multi-unit risk need to be assessed?

Regulatory authorities have reviewed applications for construction and operation of nuclear power plants based on a single unit. If the authorities approve the applications, it means the safety of a single unit is secured under the site condition. Then, if there is no unexpected (or undue) risk due to the interaction between multi-units, the multi-unit risk assessment would not be needed. The summation of risk assessed should be acceptable if any single unit in a site was licensed.

Let's introduce the following formulae.

Risk of Unit i = Risk assessed with risk measure (e.g. CDF) *for Unit i + Residual Risk for Unit i* ….(1)

$$Multi\text{-}unit\ Risk = \sum_i Risk\ for\ unit\ i \quad \text{….(2)}$$

$$= \sum_i Risk\ assessed\ for\ unit\ i + \sum_i Residual\ risk\ for\ unit\ i \quad \text{….(3)}$$

Under current licensing basis, Equation (1) shows that the risk assessed for single unit is sufficiently acceptable to the public. There is no technical rationale to concern the residual risk of single unit. If current licensing basis are correct even though the multi-unit risk have become an issue of nuclear power plant safety, Equation (2) should be correct. The summation of single unit risk should be multi-unit risk.

If the summation of residual risk is sufficiently small (or negligible) in Equation (3), multi-unit risk is same as the summation of risk assessed (e.g. CDFs) of each units. However, there is no evidence that the summation of residual risk is negligible under multi-unit condition because there are few studies for multi-unit risk and each site conditions are different. For example, the Fukushima Dai-ichi accident was not considered reasonably in PSA. Even though the tsunami hazard was considered, the intensity and frequency of hazard corresponding to the tsunami due to the great eastern Japan earthquake was not estimated rationally. In addition, the tsunami caused multi-unit severe accident. So, the assessment of the multi-unit risk is needed.

2.2 How could safety goal of a site be defined?

Current licensing basis of each nuclear power plant is based on single unit. The risk due to single nuclear power plant is sufficiently low enough to be negligible. However, the concept of safety for single unit cannot be applicable to a site risk (multi-unit risk). The summation of negligible risk of individual nuclear power plants in a site could not be negligible.

Two aspects of multi-unit risk could be considered. First, a consequence due to multi-unit accident should be higher than single unit accident. However, its frequency would be very small. Second, the frequency of a consequence should be higher than single unit accident, given the same consequence. The increase of consequence and frequency both should be considered compared to single unit consequence-frequency curve.

The multi-unit risk would not be a simple summation of risk due to individual nuclear power plants. The risk measures for multi-unit risk should be defined based on the consideration of frequency and consequence relation to cover integrated risk impact to population and area near nuclear a specific site. The quantitative societal risk concept could be effective to define the safety goal for a site. However, the quantitative societal risk of nuclear power plants is also difficult to be accepted to the public.

2.3 Do we have sufficient information for MUPRA?

There are many multi-unit sites in the world. Generally, single unit site is relatively small compared to

multi-unit sites. And since TMI-2 accident, the utilities and regulatory authorities have tried to apply operation experiences from a plant to their other plants

However, there is no data for multi-unit risk assessment. Only the single-unit-base data have been developed using the operating experiences because the single-unit-base safety and risk have been required by the regulatory authority.

To assess multi-unit risk, several data, such as common cause failure between units, frequencies of multi-unit initiators, human error dependencies between units, etc. need to be developed. Even though the data are not available currently, it could be developed using the accumulated operating experiences in each utilities and regulatory authorities.

3. Conclusions

Until now we have only one experience of multi-unit severe accident. The multi-unit risk studies are still pre-mature. Even though the necessity of MUPRA is generally accepted, the interpretation or application of the pre-matured results should be considerate. And site or country specific conditions should be considered as a key factor of MUPRA. The international cooperation helps to develop a specific technique for the MUPRA. But specific conditions of each site or country should be the starting point of the studies.

Acknowledgements

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety (KOFONS), granted financial resource from the Multi-Unit Risk Research Group (MURRG), Republic of Korea (No. 1705001).

REFERENCES

[1] Y. Ryu, et. al., A Study for Establishment of a Regulatory Guide on Multi-Unit Risk Assessment, KINS/RR-1426, December 2015.
[2] US NRC, Options for Proceeding with Future Level 3 Probabilistic Risk Assessment Activities, ADAMS Accession No. ML11090A039, 2011.
[3] CNSC, Safety Analysis, Probabilistic Safety Assessment for Nuclear Power Plants, REGDOC-2.4.2, May 2014.
[4] ASME/ANS RA-Sb-2013, Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, The American Society of Mechanical Engineers & American Nuclear Society, New York, U.S., 2013.
[5] Nuclear Safety Special Committee, Final Report for working Group on Shin-Gori 5, 6 Multi-unit Risk, April 2016.