Status of International Activities on Site Risk Assessment

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1. Introduction

Since the Fukushima accident in 2011, there has been growing attention on the safety of multiple NPPs located in a single site domestically and internationally. Korea currently has 25 operating NPP units in 4 sites (Kori, Wolsong, Hanbit and Hanul) and every site has at least 6 units in a single site. In addition, the population density near the site is higher than that of other NPP operating countries. Therefore, the public has concerns on the safety of multiple NPPs.

International agencies related with nuclear energy and several countries with multiple units in a single site are currently performing R&D projects on site risk. Currently, it is phase of establishing the concept on methodologies for assessment and regulation of site risk at both home and abroad. Therefore, there is need for investigating relevant international activities on site risk.

2. International Activities on Site Risk Assessment

2.1 IAEA

The IAEA started research for the development of multiple PSA methodologies under the realization that an assessment of the safety of multiple reactor plants existing at the same site after the Fukushima accident in Japan is required. Several interested countries have participated in these R&D and are being promoted as a form of international collaborative research. A number of IAEA members, including the United States, Canada, France, Britain, Japan, and Korea has dispatched relevant experts to carry out the international cooperative research.

IAEA's international joint study to develop PSA Phase I methodologies for safety assessment of multiple units of the same site in accordance with Article 54 of the safety resolution of the 60th conference in December 2016 was launched. The international joint study is a three-year plan from 2017 to 2019 aimed to publish IAEA technical documents on multiple PSA Phase 1 methodologies. The three-year planning is as follows:

- Step 1 (2017): Development of a draft model of the PSA phase 1 methodology
- Step 2 (2018): Case study based on the methodology developed in Step 1
- Step 3 (2019): Improvement in the PSA stage 1 methodology and publication of IAEA technical documents reflecting the results from Step 2.

Currently, a research startup meeting for international studies was held in December 2016, and three expert meetings were held in 2017. About 25 relevant experts from the United States, Canada, France, Britain, Germany, Japan, Czech Republic, Hungary, Slovakia, Romania and Belgium, among others, are participating in the study. In October 2017, the draft technical document is under review by participating experts, and it will be revised based on the ideas learned through the case study that will be performed in Step 2.

2.2 OECD/NEA

WGRISK (Working Group on Risk Assessment), one of the working group under the OECD / NEA, created a sub-practice-level group as a sub-practice-level (PSA) for the international joint study on site level PSA development. The peer review group is to prepare a report by examining what are the status of the multiple safety issues in the members with multiple nuclear power plants at the same site and how it is planned to resolve these issues. Three key areas associated with multi-unit PSA are:

- Key area 1: risk aggregation
- Key area 2: risk metrics and safety goals
- Key area 3: Multi-source interactions and/or dependencies between multiple sources of radiation

Currently, the countries involved in the group include Canada, France, Germany, the United States, Britain, the Czech Republic and Japan.

2.3 U.S.

The U.S. Nuclear Regulatory Commission (NRC) is conducting a Level 3 PSA for U.S. commercial nuclear power plants, and is considering the use of a particular PSA. The site level 3 PSA task is being performed for research purposes. Although potential future uses within the regulatory framework of some U.S. NRC, the Level 3 PSA tasks are not intended to support specific risk utilization regulations [1][2]. The basic purpose of this study is to:

1. Development of current Level 3 based on current methodology, models, data, and analysis tools
   - Reflecting the technical developments at Level 3 performed by the U.S. NRC as part of NUREG-0115
   - Considering risk contribution factors not previously considered, including those associated with the source of radiation at the same site
2. Determination of new risk points
   - Strengthen of regulatory decisions

- Helping concentrate limited resources on the issues most directly related to NRC's goals of protecting public health and safety

3. Advantage of the PSA capability and expertise of NRC staff

4. Improvement of PSA documentation for easier access and understanding of information

5. Development of an insight into technical feasibility and cost for developing a new Level 3 PSA

Although these Level 3 PSA studies are generally performed using the existing PSA techniques, they generally do not have enough experience in defining the current state and therefore require the development of several elements of methodology. One of these technical elements is the site PSA, or multi-unit PSA, technology element. The purpose of the site PSA technical elements is to:

1. Estimate the risks at the plant site

2. Determine the major factors of the site risks of the plant.

Once this basic study of the site risk assessment in progress in the United States is complete, it can be identified whether the proposed method is feasible. In particular, it is necessary to assess the technical feasibility of implementing the proposed method using existing analytical methods, and to identify and improve the difficulties in the implementation process.

2.4 Canada

Canada is a country that is interested in assessing the multi-unit risk. Canada's multi-unit site is all located in Ontario, Canada, and a CANDU type nuclear power plant. There are 3 site in Canada:

1. Bruce Power units are located on the Lake Huron site. There are two stations which has 4 plant. One plant has a power generation of 831 MWe.

2. The Ontario Power Generation units are located on the Darlington site. There is one station consist of 4 plant, and each plant with a power generation of 881 MWe.

3. Ontario Power Generation are located on the Lake Huron site. There is one station which has 6 plant. One plant has a power generation of 515 MWe. (Originally eight units, but two units were closed)

Canada's multi-unit design has evolved from the first one in its Pickering site to the last one in its Darlington site. In addition, many of the major features that affect PSA are similar at all. From a PSA perspective, the characteristics of Canada's many plant generators are shared among the different units of SSCs.

In addition, some systems have been connected between devices to enable one device to support the other. Due to this widespread sharing of safety-related SSCs, the Canada majority PSA has addressed the multi-unit effects from earlier years. In particular, the level of consideration for multi-unit effects has continued to increase, with the revision of PSA.

Canada's first multi-unit PSA is prepared to support the Darlington plant design. The Darlington Probabilistic Safety Evaluation (DPSE) completed in 1987 carried out a detailed level of all-power internal event level 1 PSA and a brief Level 2, 3 PSA. The PSA was then carried out at similar levels for other units until 2006. In 2005, the Canadian Nuclear Safety Commission (CNSC) released regulatory standards, Regulatory Standard S-488, where many changes are made associated with the PSA in Canada. As the S-488 became dependent on Canadian regulations, many efforts have been made to revise the existing PSA, from 2008 to 2014 [3][4].

From 2008 to 2014, PSA evaluated the Severe Core Damage Frequency (SCDF) and Large Release Frequency (LRF). Two risk indicators were calculated on the basis of accident by accident and accident, and compared to the safety goals by accident and by unit. The PSA was used to determine the important contributors to the risks and to create opportunities to increase the safety of the plant. In particular, the analysis was improved if the assessed risk indicators exceed the safety goals, and the plant was improved to lower than the safety goals.

After the Fukushima accident, the CNSC replaced S-488 with REGDOC-2.4.2, and for the new REGDOC-2.4.2, it also considered additional radiation sources, such as the spent fuel pool requirements. The current Canadian nuclear power project is committed to comply with the requirements of REGDOC-2.4.2.

2.5 France

French nuclear plants are currently operating at 58 and all are manufactured by the same manufacturer, AREVA and operated by the same operational sign EDF (Electricite de France). Although the assessment of plant safety is based on deterministic methods, the probabilistic methods are also being used in the safety-related decision making processes in recent years. In addition, risk information is used to complement the limited range of traditional deterministic methods. France's Nuclear Safety regulator ASN (ASN), which is the basis for the " probabilistic and safety assessment " requirement to clarify acceptable probabilistic methods. The minimum range of PSA developed by the EDF is a PSA phase that includes all internal initial events in all operating states, loss of ultimate heat sink, and loss of off-site power. The final heat sink loss and loss of off-site power are generally the initial events resulting from external hazards. In order to independently review the EDF's PSA model, a technical support organization for ASN developed its own PSA model.

2.6 Japan

After the Fukushima accident, Japan applied for restart by plant, and reviewed it before resuming it was

allowed for some units. It is decided that the five units are now restarted, the five units have completed the safety assessment, the 16 units are currently under consideration, and the 12 units are shut down.

Japanese regulatory agencies have gradually considered the PSA methodology established for their safety assessment reports, and considered the number of combination-induced accidents (seismic and tsunami) that occur in the spent fuel pools. In this regard, the Nuclear Risk Research Center (NRRC) in the Central Research Institute of Electric Power Industry (CRIEPI) in Japan has begun multi-unit PSA research. The purpose of the NRRC's majority of PSA studies is to develop procedures for multi-unit PSA for internal hazards and earthquakes for Japanese operators and to develop guidelines for performing PSA. In this study, a reasonable methodology for the Level 1 multi-unit PSA for internal events is developed, then extended to the Seismic Level 1 multi-unit PSA. (Level 2 will be carried out at the next stage.) The results of many of the PSA methodologies that this study is looking for are as follows:

- Consistency with the multi-unit PSA methodology and single-unit internal events PSA.
- Consider the effects of other accident sequences with shared facilities
- Major accident sequences
- Comparison of the development personnel and costs required to develop multi-unit PSA models with a single-unit PSA model

In addition, there are five major issues that are typical of the PSA selected in this study. Similar to the opinions of other countries, it is the risk index, the selection of the initial events of the multi-unit PSA, the methodology of the accident sequence analysis, the failure of the common causes per flight, and the analysis of human reliability. However, it is not easy to confirm the details as few Japanese studies are now available on the subject.

3. Conclusions

This paper presents an international survey of the development of site-level or multi-unit PSA methodologies and regulatory systems to address arriving concerns about the same site multi-unit being addressed following the Fukushima accident in Japan. The move is led by the international joint research center for nuclear energy, such as the International Atomic Energy Agency, and major nuclear plant operators including the United States and Canada. At this stage, there is no internationally established and recognized system of related assessment methods and regulations, and it is still at a research and development stage and needs time to be applied to reality.

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