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# Survey on Challenging Issues of Multi-Unit PSA

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## 1. Introduction

Fukushima Daiichi accident was the third core damage accident recorded since the birth of commercial nuclear power in the word. The impacts of this accident caused increase of public concern for nuclear safety and seriously considered the stop of operation of nuclear power plants in several countries. The major difference of Fukushima accident comparing with the other severe accidents is that this was the first event affecting multi-units by a single event. The consequences of the accident included core damage on three of the operating reactor units, containment breach on at least one of the reactors, and a large release of radioactive material. After this accident, multi-unit risk on site was highlighted and studied internationally. Most of nuclear power plant sites in the world have more than two reactor units. However, there are still no detailed guidelines and comprehensive methods for risk assessment for sites, especially those housing multi-unit nuclear power plants.

The purpose of this paper is to review two technical issues related with multi-unit PSA. First, multi-unit initiating events such as Fukushima Daiichi accident have been screened out due to low frequency. The other one is back-up or shared systems. In single-unit PSA, these systems had been considered to one of systems of single unit. However, dependencies and interaction between these systems should be considered to perform multi-unit PSA. These highlighted issues have not been addressed properly in existing PSA models.

## 2. Multi-Unit PSA

Typical results of risk quantification in single-unit PSA was Core Damage Frequency (CDF), Early Large Release Frequency (LERF). However, it is not sufficient for characterizing the total risk of a multi-unit [1]. These values are valid when PSA performed on one reactor unit at a time. So, new risk metrics needed to consider total risk for multi-unit PSA. Internationally, many studies had been suggested to modify risk metrics such as Site CDF (SCDF) and Site LERF (SLERF) for multi-unit PSA [2]. In order to calculate this metrics, new methodology must be developed. In this chapter, technical issues related with multi-unit PSA have been summarized.

### 2.1 Initiating event for multi-unit PSA

There are two ways to assess multi-unit risk. One way is to develop an entirely new multi-unit PSA, and the other is to modify the existing PSA model for a single-unit. Latter method is more feasible both practically and economically because of the ability to utilize existing data and models [3]. Existing PSA procedures could be divided with 4 steps [4].

- Initiating event identification
- Initiating event frequency estimation and screening out
- Determination of accident sequence
- Risk quantification

Initiating event identification considered internal/external hazard that have the attendant potential. In next step, frequency of each event considered in previous step was estimated. In this step, events that have low frequency were screened out. Fukushima Daiichi accident was typical event. Generally, it is difficult to visualize event such as Fukushima that is caused by two external hazards and affect one or more unit on site at the same time.

Initiating events for multi-unit PSA was divided with two classes [5]:

- Common-Cause initiators (CCIs): Initiators that simultaneously challenge all of the units at the site. CCIs include initiators that are caused by external hazards (e.g., earthquakes, severe weather).
- Single-Unit Initiators (SUIs): Initiators that occur at one unit, SUIs generally include initiators caused by internal hazards such as internal events (e.g., loss of main feedwater, loss of coolant accident), internal floods, and internal fires. SUIs may cause multi-unit accidents due to cross-unit dependencies such as shared support systems, spatial interactions (e.g., internal flood and internal fire propagation pathways), common-cause failure, or operator actions.

Most of external hazards may have potentials that these can affect both units concurrently. Internal flood and fire may have potentials to propagate to other units. Therefore, consideration of initiating events from event lists (internal & external) of the previous PSA should be required through adequate screening criteria for multi-unit PSA.

### 2.2 Dependencies and interactions between units

One of the key issues in multi-unit PSA was dependencies between the units. Generally, nuclear power plants shared identical electrical grid, ultimate heat sink and so on. Some cases shared safety systems

and structure. By these dependencies, multi-units were exposed by same hazards concurrently. Fig.1 shows risk of both units on site. The portion represented by $P(A \cap B)$ is multi-unit risk caused due to dependencies.

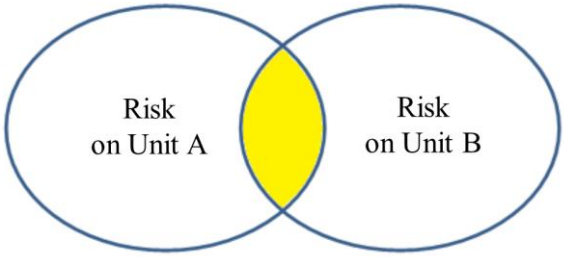


Fig.1 Hierarchy structure of Multi-unit dependencies

Those dependencies of adjacent units were followed [6]:

- Both units on the same site will be exposed to the same environmental stresses, particularly in terms of external hazards
- Systems may exist that are shared by both units
- There may be shared or inter-connecting rooms between the two units
- There may be shared resources in terms of operating and maintenance teams

Existing PSA have not considered these dependencies, and shared systems were assumed that include in one unit when single-unit PSA was performed. These things will increase multi-unit risk. To perform multi-unit PSA, dependencies and interaction between each unit must be considered properly.

## 3. Conclusions

In this paper, current technical issues for multi-unit PSA has been reviewed and summarized. Currently, there are still no detailed guideline and comprehensive method for multi-unit risk even though it is highlighted and studied internationally after Fukushima Daiichi accident.

Multi-unit risk issue is well-defined, but should be addressed many aspects of plant safety in the view point of multi-unit accident management such as potential source terms, impact of shared components and system dependencies, emergency planning against simultaneous multi-unit accidents, human and organizational factors, relationship between hazard intensity and design margin, and so on. Therefore, first of all, it is important to the understanding the potential risks associated with multi-unit event affected multi-units within a site.

In addition, the issue can have significant regulatory impact on current operating multi-unit sites and new plants, if it is proved that the multi-unit site operations have significant risk insights. It is reason that multi-unit sites have been licensed since the birth of commercial nuclear plant plants in the world.

## ACKNOWLEDGEMENT

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