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

Preliminary Research on the Quantification of Failure Frequency by Multi-Hazard

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1. Introduction

As the demand of safety for nuclear power plant increases, the risk assessment of the events which were not considered in the past is required. Multi-hazard is one of them to be considered. For the risk assessment of multi-hazard, the identification of multi-hazard and the fundamental method to estimate the failure frequency need to be established. Recently, the research for the multi-hazard risk assessment has started around the world. This study is the preliminary research for multi-hazard assessment. This study does not suggest general framework yet, but it can be a starting point for future research work.

2. Categorization of Multi-hazard

For the risk assessment of multi external event, the combination of multi event and multi hazard were categorized by the number of events and hazards. The multi event was classified into three types as independent, simultaneous, and sequential event in detail.

2.1 Definition and categorization

The general methodology for multi-hazard risk assessment has not been developed yet. Furthermore, the studies about multi-hazard event used to be in non-nuclear area [1-2]. So, we need to clarify the definition of multi-hazard and its characteristics first. The basic terminology related to the multi-hazard are summarized in Table I.

Table I: Terminology of multi-hazard

Term	Definition	Example
Event	Natural and human oriented event which can affect the safety of nuclear power plants	Earthquake, tsunami, typhoon
Hazard	Phenomena that cause the damage of nuclear power plants	Vibration, inundation, wind
Hazard Parameter	Parameters which quantifies the hazard	Ground motion acceleration, water height, wind speed
Secondary Event	A event which is triggered by another event	Landslide after earthquake
Multi-Event	Two or more event occurrence	Earthquake and typhoon
Multi-Hazard	Two or more hazard occurrence	Ground vibration and inundation
Multi-Hazard Risk Assessments	Quantification of multi-hazard risk	

Table II is the categorization of multi-hazard. It can be divided by two criteria such as the number of event or hazard and the order of the event.

Table II: Categorization of multi-hazard

categorization		explanation
Number of event and hazard	Number of event	Single event: one event one hazard Multi-event: two or more event including secondary event
	Number of hazard	Single hazard: one hazard (even it caused by multi event) Multi-hazard: two or more hazard (even in one event)
Order of event	Independent event	Two or more event which is not related each other (ex. Earthquake and typhoon)
	Simultaneous event	Two or more event caused by single source (ex. Earthquake and tsunami)
	Sequential event	Occurred by secondary event· (ex. Landslide caused by earthquake vibration)

2.2 Multi-hazard expression

A hazard curve is used to express the frequencies of the occurrences with regard to the different levels of intensity. This intensity can be ground motion parameters such as peak ground acceleration, peak ground velocity, spectral acceleration, etc. for earthquake vibration hazard, or water height, hydraulic pressure for tsunami hazard. The multi-hazard curve for two hazards can be expressed as Fig. 1. Each horizontal axis represent the hazard parameters and z-axis represent the non-exceedance frequency with regard to the each hazards.

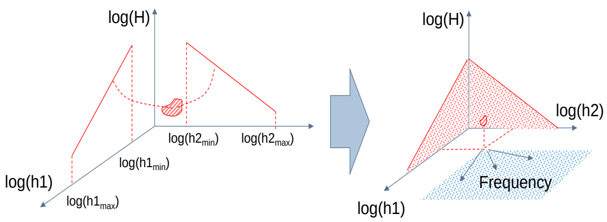

Fig. 1. Expression of multi-hazard curve

Fig. 2 shows the typical hazard curve shape we can introduce. The independent case can be about no correlated event such as earthquake vibration and high wind speed. Dependent can be expressed as the volume of three dimensional hazard curve. Secondary effect can increases the frequency of hazard each other. Even by the multi-hazard, hazard can be one parameter.

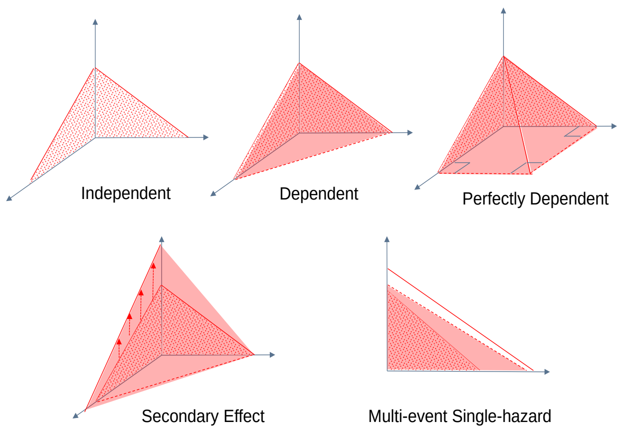

Fig. 2. Type of multi-hazard curve

3. Mathematical Expression for the Multi-hazard Risk Assessment

The plant damage state frequency is obtained by convolving plant level fragilities with the hazard curves. If we construct the hazard curve and fragility curve with regard to the two or more hazard intensity variable, the convolution equation may derived as Eq. (1).

$$\text{Risk} = \int_0^\infty \int_0^\infty F(p,q)\frac{dH(p,q)}{dpdq}dp\,dq$$
$$= \sum_{k=1}^{n-1}\sum_{j=1}^{m-1}\frac{F(p_k,q_j)+F(p_{k+1},q_{j+1})}{2}$$
$$\left(H(p_k,q_j)-H(p_{k+1},q_j)-H(p_k,q_{j+1})+H(p_{k+1},q_{j+1})\right) \quad (1)$$

Applying this equation for failure frequency by multi-hazard, multi-fragility curve and multi-hazard curve need to be assessed. The dependency of each hazard in hazard curve and fragility curve can affect the result of frequency.

4. Conclusions

In this research, the mathematical expression for the multi hazard curve and the multi fragility curve was developed and the convolution equation composed of these two curves was derived. The effect of the correlation relation between each hazard and each fragility on the estimated risk was studied quantitatively. The quantification of failure frequency by multi-hazard was performed.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIP) (No. 2017M2A8A4015290)

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