Effect of Seismic Hazard Curves on Seismic Probabilistic Safety Assessment of a NPP

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1. Introduction

After Fukushima nuclear accident, safety of nuclear power plant become more important. Although, nuclear power plants are designed to be safer to earthquakes than other structures, safety assessment is important because of the severe damage impact. Legal requirements have been made in Korea to evaluate the safety of nuclear power plants against earthquakes, and seismic hazard analysis that reflects the latest earthquake data (Pohang and Gyeongju earthquakes) is required.

In this paper, we performed the seismic probabilistic safety assessment (SPSA) of a nuclear power plant (NPP) using standardized method, and analyzed the effect of seismic hazard curves to the safety assessment of a NPP.

2. Methods and Results

Seismic probabilistic safety assessment (SPSA) of nuclear power plants (NPP) is basically performed to integrate the seismic hazard curve and fragility of equipment. After the frequency of initial events (IE) has been determined, if the mitigation of core damage is possible, the final core damage frequency (CDF) can be reduced from the IE frequency. Fig 1. shows the SPSA process of NPPs [1].

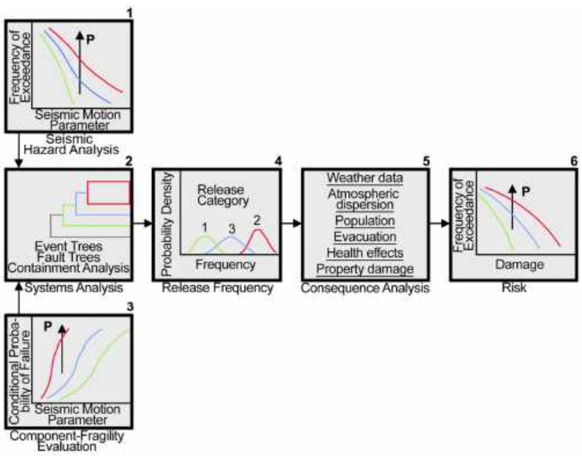

Fig. 1. SPSA process of NPPs

2.1 Probabilistic Seismic Hazard Analysis

NPPs are designed and built to withstand strong earthquake based on their location and nearby earthquake activity. This seismic design basis is established before a plant is built, using site-specific seismic hazard assessments. Each NPP determined its expected ground motions independently with site-specific information from historical earthquakes and examination of local geology. The regulations and guidance suggest the probabilistic seismic hazard analysis (PSHA) as the favored assessment process. Seismic hazards are determined by combining knowledge of seismic sources surrounding a site, how often those sources generate earthquake and how ground motions change based on a quake's magnitude and distance from the site.

Fig. 2 demonstrates the seismic hazard curves at a NPP site calculated from various experts. They used different seismic sources, magnitude-recurrence rate models, and attenuation relationships.

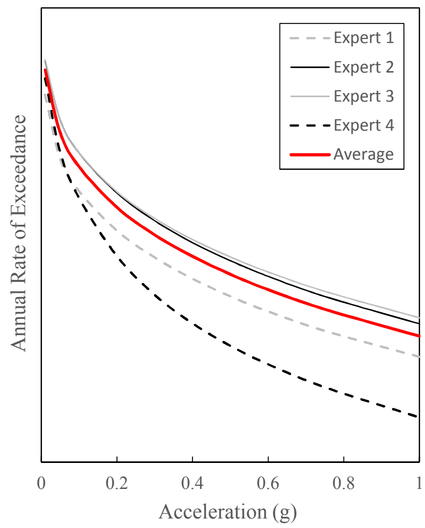

Fig. 2. Probabilistic seismic hazard curves

2.2 Seismic Fragilities of Structures and Equipment

Safety–related SSCs (structure, system, or components) are designed to withstand the SSE (safe shutdown earthquake). There are intentional conservatisms introduced in the design, analysis, qualification testing, and construction of these SSCs to provide high confidence that they will not fail to perform their intended function of earthquakes moderately larger than a SSE occur.

Seismic capacity of SSCs is represented by seismic fragility. Fragility is the conditional probability of failure as a function of earthquake motion level for any SSC that might contribute to seismic risk. The earthquake motion level parameter could be peak ground acceleration (PGA). Seismic fragility typically uses a double lognormal model with three parameters: the median acceleration capacity (A_m), the logarithmic standard deviation of randomness (β_r), and the logarithmic standard deviation of uncertainty (β_u).

In this SPSA model, structures and equipment with median capacity greater 1.5g are screened out and other equipment are modeled. Table I summarizes the modeled components and its median capacities.

Table I: Seismic Fragilities of Component

Components	Median (g)
Off-Site Power	0.3
Emergency Diesel Generator	1.4
4.16kV MCSG	1.33
Instrumentation Tube	1.5
Safety Injection Tank	1.26

2.3 Seismic Induced Initiating Event

Total five events are selected to the seismic induced initiating events: seismic induced station blackout (SBO), small loss-of-coolant accident (SLOCA), large loss-of-coolant accident (LLOCA), loss of offsite power (LOOP), general transient (GTRN). These events are expected to occur during earthquakes, and caused by components vulnerable to earthquakes. Fig. 3 demonstrates the primary seismic event tree for seismic initial events. The frequencies of initiating events are estimated by using S/W of EQESRA [2]. As a base case, we used the average hazard curve in Fig. 2.

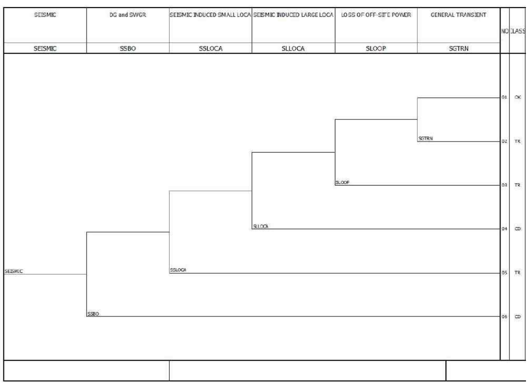

Fig. 3. Primary seismic event tree

2.4 Seismic Core Damage Frequency

Of the five initial events, SBO and LLOCA are directly progressed to core damage. The other events can be mitigated using safety related equipment. In case of non-direct core damage, the core damage frequency (CDF) is calculated by modeling second-order event trees and fault trees. The frequencies of seismic induced events are calculated by using S/W of SAREX. Fig 4 shows the calculated CDF results of all events. In this case, SBO event have the greatest effect on total CDF (69%). LOOP and GTRN events account for 27% and 4%, respectively. On the other hand, the effect core damage caused by SLOCA and LLOCA can be negligible.

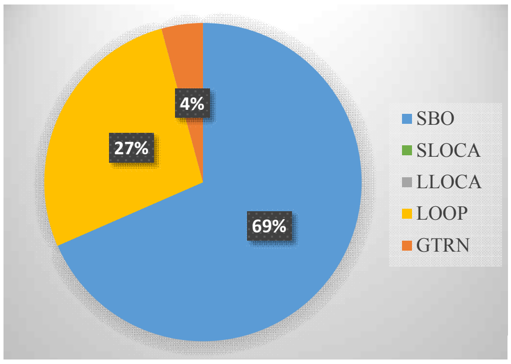

Fig. 4. Core damage frequency results

2.5 Sensitivity Analysis of Hazard Curves

Fig. 5 compares the CDF results for various cases using different seismic hazard curves. According to the PSHA results, the CDF value increased to 1.78 times higher than the base case. If the seismic hazard rate is low, the CDF decreased by one six. When quantitatively compared, the ratio of the hazard value at 0.3g is analyzed to be similar to the ratio of the final CDF value.

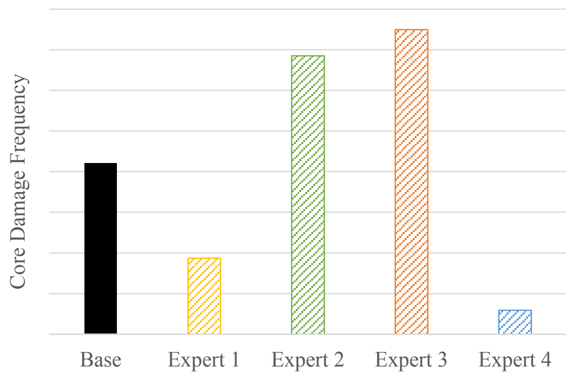

Fig. 5. Sensitivity analysis results

3. Conclusions

In this study, we performed the seismic probabilistic analysis and sensitivity analysis for seismic hazard curves. In this nuclear power plant, the station blackout event caused by earthquake is considered to have the highest risk than other seismic induced events.

The probabilistic seismic hazard curve integrated with the system fragility for initial event frequency have great impact on the estimation of core damage and risk frequency. It is also analyzed that the CDF increases or decreases by the ratio of the hazard value. Therefore, it is very important to calculate the accurate seismic hazard level in addition to model the event trees and fault trees in seismic PSA.

REFERENCES

[1] EPRI, Seismic Fragility and Seismic Margin Guidance for Seismic Probabilistic Risk Assessments, EPRI TR-3002012994, p. 732, 2018.
[2] Reference Document fir EQESRA Seismic Risk Analysis Code, EQE International Inc., 1995.