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The Preliminary Seismic Probabilistic Safety Assessment for Fuel Examination Facility

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1. Introduction

According to the requirements of the Citizen Verification Team (2018.3 ~ 2019.4), a research project was launched in 2019 to prove that the operating research facilities are fully satisfied with the domestic nuclear safety goals (e.g., less than 0.1% of individual risks) through the risk profile assessment of the research site. Generally speaking, a seismic event is the most important contributor for the site risk assessment.

This study focuses on the preliminary seismic probabilistic safety assessment (PSA) for Post Irradiation Examination Facility (PIEF) in the research site, which is the only research facility for inspections and examination of the commercial spent fuels in the country.

2. Model and Quantification for PIEF Seismic PSA

Generally, a seismic PSA consists of four steps; 1) seismic hazard analysis, 2) seismic fragility analysis, 3) plant response analysis (event tree and fault tree analysis), and 4) core damage frequency (CDF) quantification. In this study, however, a preliminary seismic PSA for PIEF of 0.2g SSE (Safe Shutdown Earthquake) is conservatively quantified with an assumption that PIEF building collapse due to an earthquake leads to spent fuel damage in the pool of PIEF directly. In other words, the spent fuel damage frequency in the pool of PIEF due to seismic event is simply quantified by the multiplication of the seismic event frequency and the corresponding PIEF building collapse probability.

2.1 Seismic event frequency

The seismic event frequency for a specific peak ground acceleration(PGA) are obtained from a seismic hazard curve, which presents the annual exceedance frequency for a selected PGA value. A site-specific seismic hazard curve was developed for KAERI site as shown in Fig. 1 [1]. As the results of the sensitivity study on the number of bins (e.g., 3, 4 or 5 bins), the most appropriate number of bins is determined for the preliminary seismic PSA for PIEF. The final binning information and the corresponding seismic event frequencies are summarized in Table 1.

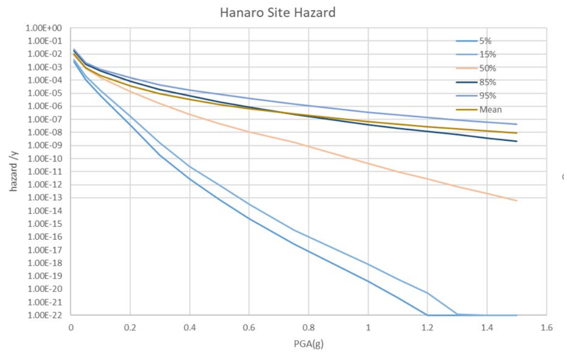

Fig. 1. Seismic hazard curve for KAERI site

Table 1. Seismic event frequency for each bin

Case	Range (PGA)	Representative PGA	IE. Freq
Bin 1	0.1-0.3	0.173	2.20E-04
Bin 2	0.3-0.5	0.387	8.20E-06
Bin 3	0.5-1.0	0.707	1.36E-06

2.2 PIEF building collapse probability

The fragility curves of a SSC (Structure, System and Component) is defined as conditional failure probabilities for a given PGA level, that is expressed as the formula below, where ϕ is the standard Gaussian cumulative distribution function. [2]

$$f' = P(A < a) \quad , (\text{Capacity} < \text{Response})$$
$$f' = \emptyset\left(\frac{\ln\left(\frac{a}{A_m}\right) + \beta_U \emptyset^{-1}(Q)}{\beta_R}\right) \text{ with Q uncertainty level, or} \qquad (1)$$
$$f' = \emptyset\left(\frac{\ln\left(\frac{a}{A_m}\right)}{\beta_C}\right), \text{ with composite uncertainty } \beta_C = (\beta_R^{\,2} + \beta_U^{\,2})^{1/2}$$

The seismic fragility of the PIEF building structure is evaluated as shown in Table 2.

Table 2: Fragility data for each SSC

Failure Mode	Am	Br	Bu	Bc
North-side wall	0.53g	0.24	0.26	0.35

Note that the probability of gross structure collapse for PIEF building is estimated conservatively due to major two points; 1) use of generic ground response spectrum (NUREG/CR-0098) with even more conservatism (NH84.1 in Fig. 2), instead of site-specific uniform hazard response spectrum(UHRS) as shown in Fig. 2, 2) the use of hybrid approach based on a conservative deterministic failure margin (CDFM) method for seismic margin analysis (SMA) due to the lack of design information.

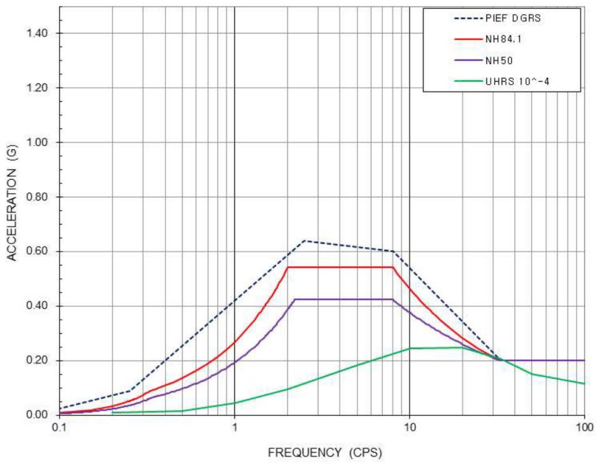

Fig.2. Comparison on generic GRS and site-specific UHRS

The collapse probabilities of PIEF building for the representative values for each bin is calculated by equation (1), as summarized in Table 3.

Table 3. Seismic failure probability for SSC in each bin

SSC	Bin1	Bin2	Bin3
Building Structure	7.31E-04	1.82E-01	7.86E-01

2.3 Quantification

As the previous definition, the preliminary seismic spent fuel damage frequency can be estimated as 2.72e-6/year (=2.20E-04 x 7.31E-04 + 8.20E-06 x 0.182 + 1.36E-06 x 0.786). As mentioned before, note that it is the preliminary result based on the very conservative assumptions and ground-rules.

3. Summary and Conclusion

The preliminary seismic level 1 PSA was performed on Post Irradiation Examination Facility (PIEF). In the study, the damage frequency of spent fuels in the pool of PIEF due to seismic event is simply evaluated as 2.72e-6/year by the multiplication of the seismic event frequency and the corresponding PIEF building collapse probability. However, note that it is close to the bounding analysis for PIEF seismic PSA due to very conservative assumptions and ground-rules. In addition, it should be considered that fuel failure induced by cladding oxidation will not occur for the spent fuel cooled for more than 17 months, because of the low decay heat [3].

Acknowledgements

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