Effect on the Updated PSHA to Seismic PRA

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1. Introduction

Seismic PRA analysis consists of seismic hazard, seismic fragility and seismic response analysis. Among them, seismic fragility is considerably dependent on the structural seismic response spectrum. This response spectrum in the most of the NPPs had been determined based on its geological condition. In accordance with history, the seismic fragility were developed by the target response spectrum or site-specific response spectrum. The response spectrum for seismic fragility should de consider with care when the site hazard is changed. Recently, the new active faults were discovered and it pushed to update the seismic hazard. When there are significant changes in the seismic hazard then the fragility effect on the site-specific response spectrum have to be considered. In this paper, the fragility effect from changing the seismic hazard would be deal with to have the insight on the plant damage state risk.

2. Probabilistic from Seismic Fragility Analysis

There are two types of analysis method to calculate HCLPF which stands for seismic capacity.

- First, HCLPF calculated by the Conservative Deterministic Failure Method (CDFM) is used for the Seismic Margin Assessment and it is based on target response spectrum.
- Second, HCLPF calculated by separate of variables which is for the seismic probabilistic safety assessment.

The methodology above had been adopted with different purpose for Korea NPP. HCLPF from CDFM were developed for the seismic margin assessment. The latter were for the SPRA. However, the current HCLPF methodology provide the efficient way of conversion CDFM HCLPF to median acceleration capacity (Am) with variables which is called the hybrid method. When HCLPF were converted to Am, the effect on the reference spectrum needs to be ensured that have the similar seismic energy. When there are differences between them, the effect from site-specific response spectrum should be identified.

2.1 Probability from HCLPF

The entire family of fragility curves for an element corresponding to a particular failure mode can be expressed in terms of the best estimate of the median ground acceleration capacity, Am, and two variables. Thus, the ground acceleration capacity, A, is given by:

$$A=A_m e_R e_U \quad (1)$$

At each acceleration value, the fragility f can be represented by a subjective probability density function. The subjective probability, Q (confidence) of not exceeding a fragility f' is related to f':

$$f' = \Phi\left[\frac{\ln\left(\frac{a}{A_m}\right)+\beta_U\Phi^{-1}(Q)}{\beta_R}\right] \quad (2)$$

2.2 HCLPF from CDFM

In accordance with EPRI 30021002994 [1], CDFM methodology based on EPRI NP-6041-SLR1 [2] is considered as the 1% failure probability capacity.

$$HCLPF_{CDFM} = A_{1\%} = \text{CDFM Capacity} \quad (3)$$

When the CDFM HCLPF was calculated, a smooth target spectrum had been usually NUREG/CR-0098[3]. Recent studies [4] show that the target response spectrum such as NUREG/CR-0098 response spectrum is often different from the site-specific response spectrum. When the differences were identified then the HCLPF capacity should be modified based on the new UHRS which is developed from site-specific probabilistic seismic hazard analysis. However it is not significant then the effect can be negligible for SPRA.

2.3 Reasonable Plant Damage State Risk

The plant damage state risk is developed by convolving with seismic fragility and seismic hazard curves like as followings:

$$f_{ij} = -\int_0^{\infty} f_i(a)\frac{dH_j}{da}da \quad (4)$$

Where,
H_j = J_{th} Hazard Curve
F_i = i_{th} plant damage fragility curve

The general SPRA had been convolving with both of PGA or SA based HCLPF and corresponding PSHA. To take into consideration of more rigorous risk without recalculating HCLPF after updating PSHA, the most of the frequency range need to be considered to have the plant damage state risk. The HCLPF usually defined in terms of a peak ground acceleration (PGA) capacity but the structure and component could be affected by 2.5 to 10 Hz range. Therefore, the risk based on the frequency range could affect the total plant damage state risk, so it have to take into consideration when the PSHA is updated.

To take into consideration of interesting spectrum acceleration, a more rigorous approach needs to be adopted in term of 1Hz, 2.5Hz, 5Hz, 10Hz, and 25Hz spectral acceleration capacities, as well as the PGA capacity based on the spectral shape used in the HCLPF calculations. Each of these HCLPF capacities are convolved with the corresponding hazard curve to obtain failure probabilities P_1, $P_{2.5}$, P_{10}, P_{25}, and P_{PGA}. The best estimate of the mean seismic risk P_F is given by

$$P_F = \frac{F_1 \cdot P_{F1} + F_{2.5} \cdot P_{F2.5} + F_5 \cdot P_{F5} + F_{10} \cdot P_{F10} + F_{25} \cdot P_{F25} + F_{PGA} \cdot P_{FPGA}}{\sum F} \qquad (5)$$

Where,
F_i = Judgement based weighting factor on important

In accordance with EPRI [1], ratio of weighting factor is judged to be 65 % to 70% between 2.5Hz and 10Hz.

In this paper, the effect from the differences in each frequency of PSHA were studied to have the insights. For this work, the PSHA from Surry NPP site [5] was selected and the fragility was also assumed.

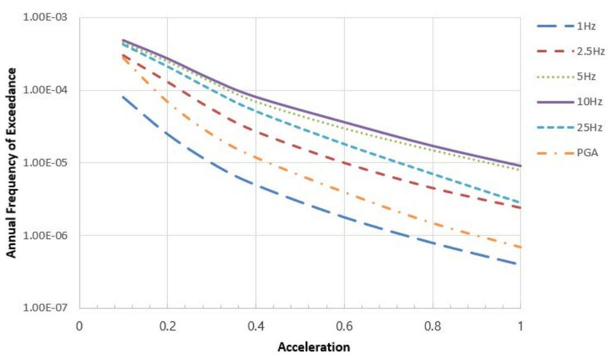

Figure 1. PSHA from Surry [5]

HCLPF for each frequency was estimated based on the UHS for 1E-4/yr. The risk for each frequency were convolved with each PSHA and fragility. The result of each frequency contents shows that there are quite differences from each other. Based on equation (5), the effect is easily demonstrated to have the insight for the change of reference earthquake. Contrary to traditional belief, the risk based on each frequency is differently calculated. This is because of different annual frequency of exceedance in PSHA. Even if the result show the differences in each frequency range, the most of them is not important since the structure and component could be affect from 2.5Hz to 10Hz. Based on the recommendation to use the weighting factor, the plant damage state risk is fluctuated. Table 1 shows the differences between conventionally calculated risk and weighted result.

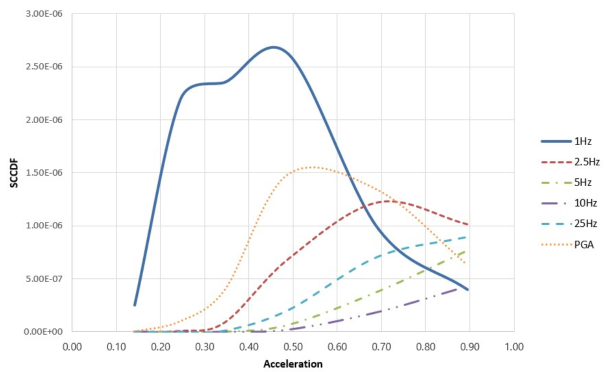

Figure 2. Calculated Plant Damage Risk for Each Frequency Range based on Surry PSHA and assumed fragility

Table 1. Case Study of the risk effect on PSHA

Cases	Risk	Differences
Base Case	3.96E-06	-
Equally Weighting	3.24E-06	-18%
65% Weighting	2.52E-06	-36%

From the result, the new plant damage state risk without recalculating HCLPF could provide the unreasonable result. Consequently, HCLPF should be properly modified when the site specific PSHA is updated. That is, if the original target spectrum such as NUREG/CR-0098 is changed due to the newly developed PSHA, the updated risk results could be affected by the differences. Consequently, the UHS need to be used to have the reasonable fragility for the plant damage state risk when PSHA is newly developed and significantly changed.

3. Conclusions

The recent study often requires to update the site specific PSHA due to newly discovered geological data, so the fragility for SPRA also have to be modified with that changes. The case study in this paper is based on the simple HCLPF, so the plant damage state risk is easily developed. However, when there are various SSCs need to be combined with various scenario for the risk after the updating the PSHA, the equation might be impractical. Therefore, the UHS based on the new PSHA have to be developed and all of the fragilities for SSCs need to be also updated with new structural response analysis result unless effect on PSHA is negligible.

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