

Sensitivity Analysis of Seismic Hazard for Domestic Nuclear Power Plant Sites Considering Double-Counting Corrections of Fault Sources

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1. Introduction

The consecutive occurrence of the 2016 Gyeongju and the 2017 Pohang earthquakes highlighted the need to identify seismic activity within the Korean Peninsula and to establish a national earthquake disaster preparedness system. Motivated by this, a government-led joint investigation of fault structures in the Korean Peninsula was initiated, and the first phase targeting the southeastern region was recently completed [1].

Probabilistic Seismic Hazard Analysis (PSHA), which is essential for determining the seismic safety and design ground motion of nuclear power plants (NPPs), utilizes various input variables such as seismic source models, seismicity parameters, and ground motion model (GMM). Historically, as the Korean Peninsula belongs to an intraplate region with low-to-moderate seismicity, the identification of individual fault sources has been limited. Consequently, previous PSHAs for domestic sites have primarily utilized Area Source models [2].

Modeling area sources and fault sources simultaneously within the same region can lead to a physical contradiction: exceeding the total seismic moment allocated to the local area. Simply adding newly identified fault structures to existing area source-based models results in a "double-counting" error [3], overestimating the released seismic energy. Ultimately, this can lead to an unrealistically increased assessment of site-specific seismic hazards.

This study examines seismic source correction methods to reasonably integrate new fault information into the previous PSHA model. To physically exclude the double-counting of seismic energy between area and fault sources, various PSHA cases were constructed. Through sensitivity analyses, the variations in Seismic Hazard Curves and Uniform Hazard Spectra (UHS) for domestic NPP sites were compared to preliminarily evaluate the impact of considering fault source parameters on seismic hazard estimation.

2. PSHA Model

2.1 Characterization of Fault Sources

This study utilized the location and geometry of fault segments identified during the Korean Peninsula fault

survey [1]. The average length of these segments was approximately 1–5 km. To estimate the maximum magnitude based on fault length, the empirical relationship [4] was applied, resulting in an average M_{\max} between 4 and 6. However, as this is a simplified estimation, further analysis of fault lengths and magnitudes is required.

2.2 PSHA Cases

The baseline PSHA model was based on the 2013 Korea Atomic Energy Research Institute (KAERI) seismic hazard input data for the Hanul NPP site [5]. It incorporated four area source models, a minimum magnitude M_{\min} of 5.0, and three GMMs. To address the double-counting issue, evaluation cases were configured under the assumption that the total seismic moment of the region remains constant.

- **Case 1 (A):** Existing Area sources only (Baseline).
- **Case 2 (F):** Fault sources only (M_{\max} 6.8).
- **Case 3 (A+F):** Simple summation of area and fault sources without correction (M_{\max} 6.8).
- **Case 4-1:** Area source seismicity rate reduced to 10% with fault sources added (M_{\max} 6.8).
- **Case 4-2:** Area source seismicity rate reduced to 10% with fault M_{\max} adjusted to 6.0.

3. Results of Sensitivity Analysis

3.1 Comparison of Seismic Hazard Curves

PSHA was performed for major domestic NPP sites to derive seismic hazard curves based on Peak Ground Acceleration (PGA). Results showed that for the Hanbit (HBN) site, which is relatively distant from the new fault sources, the change in hazard curves was negligible.

In contrast, the Wolsong (WSN) site, located near the additional faults, showed some variations. Case 3 (simple summation) yielded the higher hazard level, followed by Case 4-1. Notably, Case 4-2 showed hazard levels nearly identical to the baseline Case 1. Furthermore, safety shutdown earthquake (SSE) conservatism was reviewed per regulatory standards. The annual exceedance frequency for 0.2g was

confirmed to be below 10^{-3} per year across all sites and cases.

3.2 Comparison of Uniform Hazard Spectrum (UHS)

UHS were derived for an annual exceedance frequency of 10^{-4} per year. The spectra peaked in the 10–20 Hz range, indicating that high-frequency ground motion characteristics are dominant. Consistent with the hazard curves, the Hanbit site showed little change. For Wolsong, Case 3 showed the highest response, while Case 4-2 aligned closely with Case 1, clearly demonstrating the effectiveness of the double-counting correction. These spectral changes were most prominent in the 10–20 Hz high-frequency band.

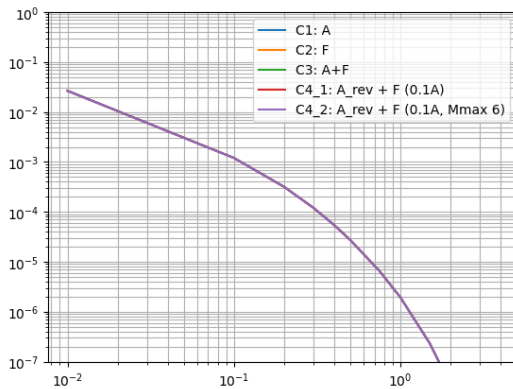


Fig. 1. Seismic Hazard Curves (HBN)

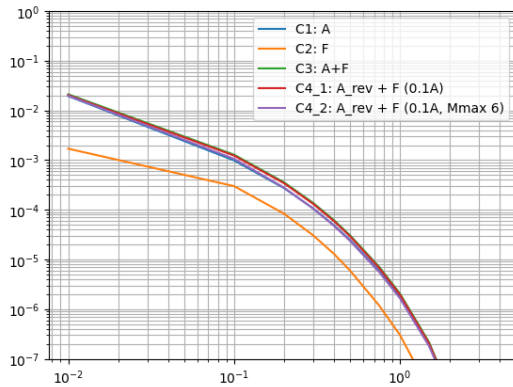


Fig. 2. Seismic Hazard Curves (WSN)

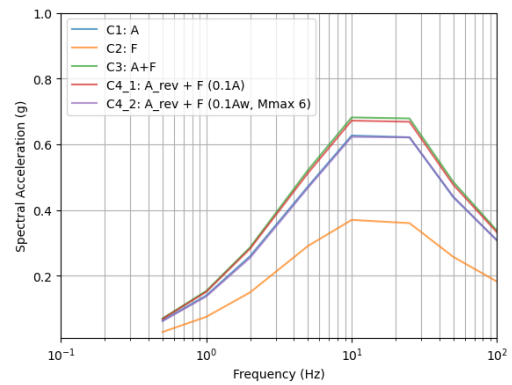


Fig. 3. Uniform Hazard Spectrum (WSN)

4. Conclusions

This study evaluated double-counting effects and correction methods for integrating fault data from the southeastern Korean Peninsula into existing area-source-based PSHA. The results indicate that the simple summation of new faults may lead to an overestimation of seismic hazards, with the degree of impact varying by distance to the NPP site. Consequently, applying appropriate corrections such as revising area seismicity rates is essential.

However, these findings entail significant uncertainties tied to the estimation of input parameters (e.g., M_{max} , seismicity rates, and GMM). To ensure applicability to actual NPP design and safety assessments, further field investigations of fault characteristics and rigorous parametric sensitivity studies are imperative.

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