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Experimental Evaluation of In-cabinet Responses to High-Frequency Earthquakes

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1. Introduction

Following the 2011 Fukushima nuclear accident in Japan, the U.S. Nuclear Regulatory Commission (NRC) mandated the development of site-specific ground motion response spectra (GMRS) across the United States [1]. In the central and eastern regions, GMRS of some nuclear power plants were found to exceed the existing design-basis response spectra at the high-frequency range. Consequently, the U.S. Electric Power Research Institute (EPRI) investigated the effects of high-frequency earthquakes on structures and components in nuclear power plants, concluding that electrical components may be sensitive to such excitations [2].

Safety-related electrical components in nuclear power plants are typically installed inside cabinets. The cabinet exterior consists of steel frames and doors, while the interior is partitioned by steel panels of various shapes. Electrical components are mounted on these interior panels or doors. Since the steel panels and doors are relatively thin, they are structurally vulnerable to seismic excitation in the out-of-plane direction. The vibration of these panels, in particular, may adversely affect the functionality of sensitive electrical components under high-frequency seismic inputs.

The present study evaluates the influence of high-frequency earthquakes on in-cabinet responses using shaking table tests. The objective is to identify vulnerable structural elements and critical locations that may amplify seismic demands on electrical components.

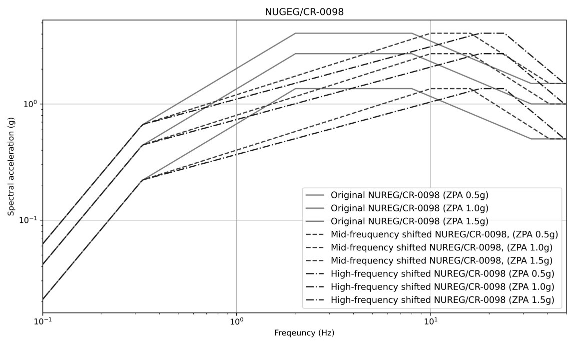
2. Methods and Results

2.1 Shaking Table

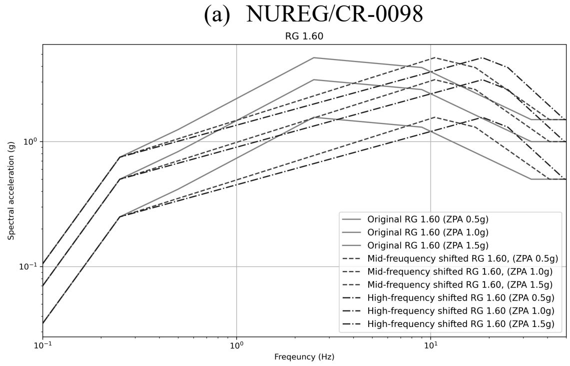
Earthquake loading was simulated using the multi-axial shake table facility at the Central Research Institute, Korea Hydro & Nuclear Power (KHNP). The table has an operational frequency range of 0.5 Hz - 100 Hz and supports a maximum payload of 2 tons with a peak acceleration capacity of approximately 14 g. This specification enables applying high-frequency earthquakes to NPP cabinets. Before the seismic test, the natural frequency search tests were performed in three directions to estimate cabinet stiffness. A uniaxial seismic test was then conducted in the direction corresponding to the lowest stiffness.

2.2 Input Ground Motions

High-frequency input motions were generated by modifying the design response spectra of the Regulatory Guide (RG) 1.60 [3] and NUREG/CR-0098 [4]. Fig. 1 compares the original and the modified spectra. In the modified spectra, the frequency band corresponding to the peak spectral acceleration was shifted toward the high-frequency range. Additionally, the zero-period acceleration (ZPA) was also amplified to 0.5 g, 1.0 g, and 1.5 g, yielding a total of 18 artificially generated response spectra.



(a) NUREG/CR-0098



(b) RG 1.60

Fig. 1. Original and modified design response spectra.

2.3 Test Cabinet and Instrumentation

The test cabinet has dimensions of 1800 mm × 800 mm × 900 mm, as shown in Fig. 2. The input ground motion was applied uniaxially in the front-to-back horizontal direction, corresponding to the weakest stiffness of the cabinet. To verify the accuracy of input reproduction, one accelerometer (Accelerometer 1) was mounted on the cabinet fixture. Another (Accelerometer 5) was attached to the cabinet frame to measure the natural frequency of the cabinet. For the in-cabinet response, three representative measurement locations were selected: one on the top horizontal panel (Accelerometer 4), one on the bottom horizontal panel (Accelerometer 2), and one on the mid-height vertical panel (Accelerometer 3).

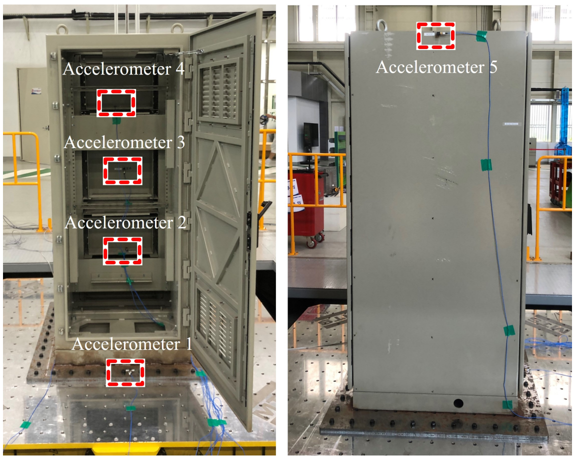


Fig. 2. Cabinet and accelerometer instrumentation.

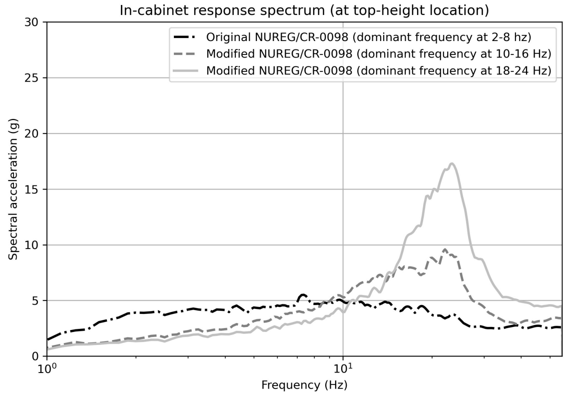
2.4 In-cabinet Response Spectrum

It is generally expected that seismic responses increase with height, with maximum demands occurring at the highest location. However, due to the complex interior configuration of the cabinet, the location of the maximum response is unpredictable in the cabinet. Fig. 3 presents the in-cabinet response spectra (ICRS) at different measurement locations under NUREG/CR-0098 input. Interestingly, the most intensive response occurred not at the top panel but at the mid-height panel.

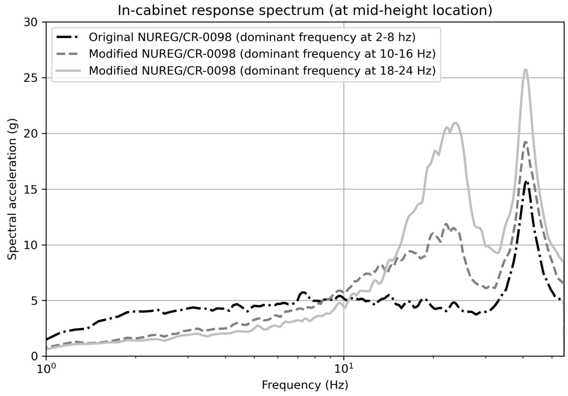
As the dominant frequency of the input ground motion was shifted to the high-frequency range, the ICRS at the horizontal panels (top and bottom) exhibited a corresponding shift in the peak frequency. In contrast, the vertical mid-height panel did not exhibit this frequency shift. Instead, an additional vibration mode emerged, manifested as a distinct peak in the ICRS.

3. Conclusions

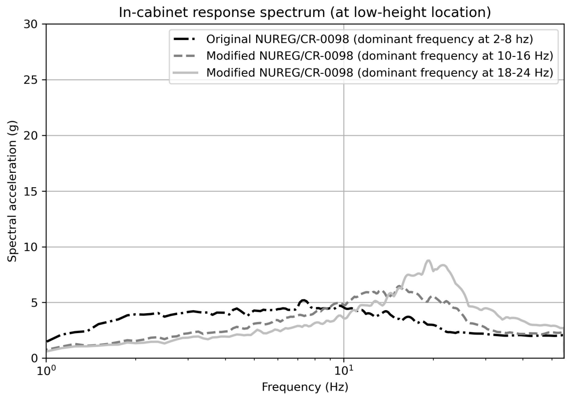
Shaking table tests demonstrated that high-frequency earthquakes significantly influence in-cabinet responses, particularly at mid-height vertical panels where additional vibration modes were identified. These insights not only clarify the amplification mechanisms within electrical cabinets but also provide valuable guidance for improving seismic qualification practices. By highlighting critical response locations and vulnerable structural elements, the findings support the development of more robust design and evaluation methods for safety-related components and cabinets in nuclear power plants.



(a) Top-height horizontal panel (Acc. 4)



(b) Mid-height vertical panel (Acc. 3)



(c) Low-height horizontal panel (Acc. 2)

Fig. 3. Comparison of in-cabinet response spectra at different location under original and modified NUREG/CR-0098.

REFERENCES

[1] USNRC/ USDOE/ EPRI. Central and Eastern United States Seismic Source Characterization for Nuclear Facilities Report (NUREG-2115, DOE/NE-0140/1021097), 2013.
[2] EPRI. Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near Term Task Force Recommendation 2.1 (Seismic, Report 1025287), February 2013.
[3] USNRC, Development of Criteria for Seismic Review of Selected Nuclear Power Plants, (NUREG/CR-0098), 1978.
[4] USNRC, Design Response Spectra for Seismic Design of Nuclear Power Plants (Regulatory Guide 1.60), 2014.