Seismic Response Analysis of an Electrical Cabinet for Scenario Earthquakes

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1. Introduction

A safety-related equipment in a NPP (Nuclear Power Plant), like the containment building, plays very important role in the importance and safety requirements. In the case that the equipment looses its function due to the earthquakes, a reactor core of a NPP is damaged, thus, the entire NPP system can be damaged significantly. This has a harmful effect on the environment, too.

GIP[1] assumes that there is no problem in the seismic capacity of most equipment if the joints of the equipment are sound. However, the failure-pattern of the relay is not a structural one but a functional one by chatter. So, it is necessary to estimate the seismic response of an instrument mounted on a cabinet for the assessment of the seismic safety of a relay. This means the assessment of the ICRS (In-cabinet Response Spectrum) and cabinet amplification factor that depends on the dynamic properties of a cabinet, the location of the instrument, and so on.

Therefore, this study measured the ICRS and amplification factor of a cabinet subjected to various input motions and assessed its seismic capacity.

2. Modeling and Input Motions

2.1 Characteristics of Electrical Cabinet

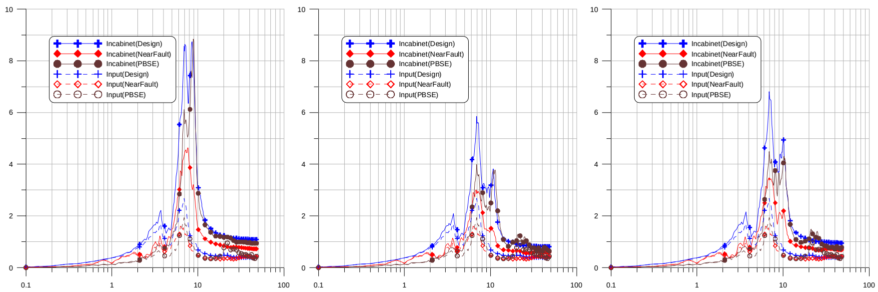
Generally, electrical cabinet has the form of an in-closer door and its function is to mount, support and protect the electrical instruments. The instrument mounted on the cabinet are assigned according to their functional conditions. Generally, the heavier instruments are put near the base, the lighter ones on the top. The instruments range from the simple small, electronic ones to the complicated large, mechanical ones. There are also complex wire bundles, which connect several instruments, inside the cabinet. This study sets the box type cabinet with a fixed floor, and assumes that the instruments are mounted on the front door, inner frame and back panel.

2.2 Dynamic Characteristics

In this study, an eigenvalue analysis for a 3D finite element model is conducted to evaluate the dynamic properties. At this time, the frequencies and the mode shapes of each local mode are analyzed to evaluate the ICRS for the instruments located on the front door, back panel and inner frame. As a result, the frequency of the front door, which is also the first cabinet mode, is 8.65Hz, the frequency of the back panel, which is the third cabinet mode, is 10.12Hz, the frequency of the inner frame, which is the forth cabinet mode, is 10.74Hz. The mode shapes of each mode show that the motions are a front-back direction. On the other hand, a global bending electrical cabinet mode for this box type cabinet does not exist in the nonrigid frequency region.

2.3 Input Motions

Because the cabinet is usually installed inside the structures, the response of floor located the cabinet should be input for the base of the cabinet. This study used the floor responses at 30.19m as the input of the cabinet after performing a seismic analysis of the Wolsung containment building with the input of a design earthquake, PBSE (Probability Based Scenario Earthquake), and near-fault earthquake which have different frequency characteristics, by scaling the PGA to 0.2g. Here, the design earthquake means the acceleration time history involving the design response spectra of the US NRC NRC Regulatory Guide 1.60[2], the PBSE means the probability earthquake made based on the result of the probabilistic seismic hazard analysis of NPP sites in Korea[3], and the near-fault earthquake means the earthquake that has response spectrum looked alike the mean response spectrum of 30 near-fault earthquake records.



(a) Front Door (b) Inner Frame (c) Back Panel

Fig1. In-cabinet response spectrum subjected to various ground motions

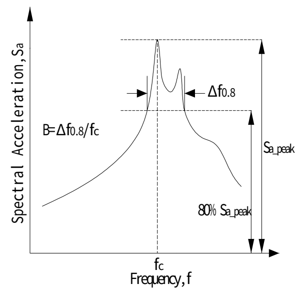


Fig2. Example for clipping of the response spectrum

3. Seismic Response of Electrical Cabinet

3.1 ICRS

Fig1 shows the response spectrum of the front door, the inner frame and back panel subjected to the design earthquake, PBSE and near-fault earthquake, respectively. On the whole, the response to the near-fault earthquake is the smallest, and that to the design earthquake is the largest. But, it shows that the amplification ratio is larger in the PBSE rather than the design earthquake on the local frequency of the instruments. This is due to the rich high frequency contents of the PBSE. This means that such the input motion with an obvious rich high frequency contents like the PBSE has a great effect on the seismic safety of the important equipment inside the structure.

3.2 Cabinet Amplification Factor

The in-cabinet RRS (Required Response Spectrum) often has a highly amplified narrow frequency content. Experimental observations by Merz[4] and by others as well, indicate that a narrow frequency input spectrum must be scaled to a higher level than a broad frequency input spectrum in order to produce relay chatter or structural damage. Therefore, in this study, the RRS_c (Clipped RRS) is calculated by using the clipping factors c_c. Then the effective amplification factor AF_c is evaluated.

RRS_c is defined as

$$RRS_c = c_c \times RRS \tag{1}$$

where, c_c is defined as[5]

$$\begin{aligned} c_c &= 0.55 && B \le 0.2 \\ c_c &= 0.4 + 0.75B && 0.2 \le B \le 0.8 \\ c_c &= 1.0 && B \ge 0.8 \end{aligned} \tag{2}$$

where, B is a function of the bandwidth to the central frequency ratio as represented in Fig2. $\Delta f_{0.8}$ is the total frequency range over which the spectral amplitudes exceed 80% of the peak spectral amplitude and f_c is a central frequency for the frequencies which exceed 80% of the peak amplitude.

AF_c is defined as

$$AF_c = \frac{RRS_{c-ICRS}}{RRS_{c-FRS}} \tag{3}$$

Table 1 shows the amplification factors (AF), over the original or clipped spectral accelerations for the various input motions. This shows that the cabinet has a lesser amplification on the peak value when compared with each value at the natural frequencies. Among the input motions, the amplification subjected to PBSE is largely evaluated at the front door when compared with the result at the GIP; amplification factor proposed by GIP is 3.0.

Table 1. Electrical cabinet amplification factors

		No clipped			Clipped		
		Front Door	Inner Frame	Back Panel	Front Door	Inner Frame	Back Panel
Peak	Design Eq.	3.260	2.180	2.540	3.261	2.183	2.537
	PBSE	4.590	2.060	2.330	4.584	2.067	2.331
	Near-Fault Eq.	2.890	1.880	2.170	2.935	1.972	2.273
At Frequency	Design Eq.	9.352	6.099	7.136	5.163	5.157	5.444
	PBSE	9.238	8.337	8.645	6.032	5.141	5.222
	Near-Fault Eq.	4.679	3.209	4.478	3.962	3.209	4.065

4. Conclusion

1. A global bending cabinet mode for the box type cabinet does not exist in the non-rigid frequency region. This means that the significant mode in such cabinet is a local mode of the cabinet component (front door, inner frame, back frame) on which the instrument is mounted. Therefore it must know the dynamic properties about them. The dynamic properties for the cabinet can be summarized as follows: the frequencies of front door, back panel and inner frame are 8.65Hz, 10.12Hz and 10.74Hz. The mode shapes of each mode show that the motions are front-back direction.
2. For an instrument location on the front door of cabinet, the maximum amplification occurs at the first frequency. But, for the instrument location on the inner frame and back panel of cabinet, the maximum amplification occurs at the third and fourth frequencies and not at the first frequency. This shows that the local modes of the cabinet component contribute significantly to the response at a given instrument location in the cabinet.
3. The amplification subjected to PBSE is evaluated as the largest when compared with the other. This is due to the rich high frequency contents of the PBSE. This supports the fact that such input motion with the obvious high frequency contents like the PBSE has a great effect on the seismic capacity of the important equipment inside the structure.

ACKNOWLEDGEMENT

This research was supported by the Mid- and Long-Term Nuclear Research & Development Program of the Ministry of Science and Technology, Korea.

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