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Seismic Performance Evaluation of Electrical Cabinet

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1. Introduction

Various type of equipment is installed at a nuclear power plant (NPP). An electrical cabinet is especially important because it generally contains various electrical devices and electric control equipments. So the safety of NPP should be secured against gravity and seismic loads.

Previous methods for calculating in-cabinet response spectrum (ICRS) are mainly used to evaluate dynamic properties based on analytical method[1-3]. In this study the response from finite element method was compared with that from table test to verify the accuracy of analysis result. Fragility analysis was also conducted to evaluate seismic performance of electrical cabinet.

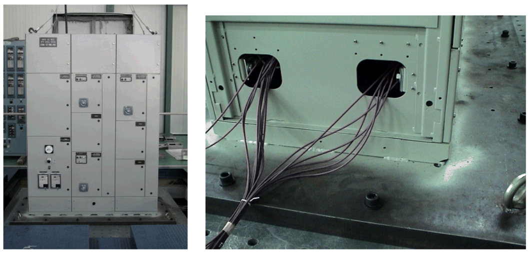
According to the result it can be concluded that the 480V Motor Control Centers (MCCs) in nuclear power plant (NPP) sites have sufficient seismic capacity.

2. Seismic testing of cabinet

2.1 *Test setup and failure mode*

A MCC Cabinet is one of the major equipment systems in a NPP. For the shaking table test, a real MCC cabinet was rented from a manufacturing company. Test setup is shown in Fig. 1(a).

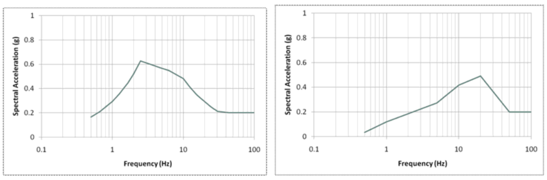
The failure occurred in the side panel of MCC cabinet system at 2.5g of peak ground acceleration (PGA) during the shaking table test (Fig. 1(b)).



(a) Setup (b) Failure part
Fig. 1. Test setup and failure part of the MCC

2.2 *Ground motion*

For the shaking table test, three kinds of seismic input motions were used. One is an artificial record based on the design spectrum of NRC Reg. guide 1.60 and the second is also an artificial seismic wave based on site specific Uniform Hazard Spectrum (UHS) for the Korean NPP. The UHS motion was selected for evaluation of a high frequency effect on the electric equipment in a NPP. The target input spectra are depicted in Figure 2.



(a) US NRC (b) UHS
Fig. 2. Seismic Motion for Shaking Table Test

3. Analysis of cabinet

3.1 *Analysis model*

The linear dynamic analyses of the model structures were carried out using the program code MIDAS [4].

The location of mass in cabinet can't be determined properly due to irregular installation of electrical components. Therefore it is assumed in this study that the mass is uniform over the cabinet height.

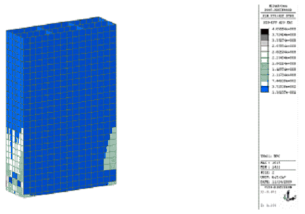
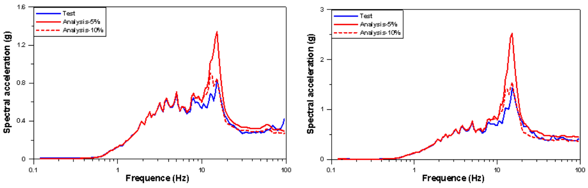


Fig. 3. Von mises stress at PGA 2.5g(NRC)

The support condition at the base of MCC is assumed to be fixed, but on the other hand, the doors of cabinet are assumed to have hinge and free boundary conditions. The plate elements were used for modeling of MCC. The plates are made of SS400 steel. According to the modal analysis, the frequencies for longitudinal and transverse directions are about 73Hz and 15Hz, respectively. Figure 3 shows stress of MCC at 2.5g of PGA. The results showed that dynamic properties of MCC obtained from analysis and test are similar.

It is difficult to calculate the exact damping ratio of MCC because of friction of equipments in the cabinet. The floor response spectrum of MCC is shown in Fig. 4. According 10% of damping ratio is adequate for MCC.

Fig. 5 shows the maximum stress of MCC applying NRC ground motion. The maximum stress in MCC exceeds the limit state (4500kgf/cm^2) when PGA exceeds 2.5g as shown in Fig. 5.



(a) Middle (b) Top

Fig. 4. Floor response spectrum of MCC

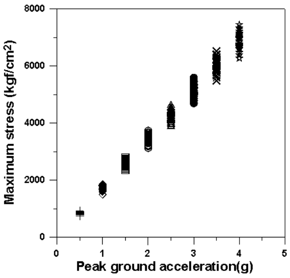


Fig. 5. Maximum stress at bottom (NRC)

3.2 Fragility analysis

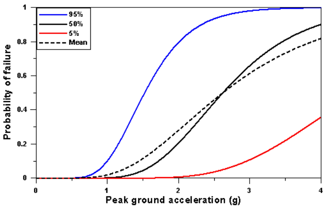
The seismic fragility of a structure represents probabilistically the capability of a ground motion to cause structural damage. The probability of a failure of a structure $P_f(a)$ at any non-exceedence probability level Q can be obtained from the following equation.

$$P_f(a) = \phi\left(\frac{\ln(S_m(a)/C_m)+\beta_U\phi^{-1}(Q)}{\beta_R}\right) \qquad (1)$$

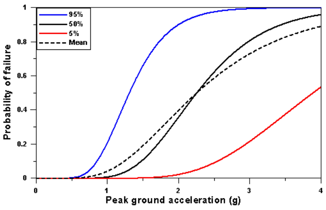
Where $\phi(\bullet)$ is the standard Gaussian cumulative distribution function, a is a peak ground motion as a ground motion parameter, $\phi^{-1}(\bullet)$ is the inverse of the standard Gaussian cumulative distribution function, $S_m(a)$ and C_m are the median seismic response at a given ground acceleration a, and the median seismic capacity, respectively, and β_R and β_U are the lognormal standard deviations of the randomness and uncertainty of $S_m(a)$ and C_m respectively.

For the fragility analysis, definition of failure mode and criteria are very important. According to the test result, the failure mode divides into functional and structural mode. In this study the failure of MCC is defined as when the plate of MCC reaches the ultimate stress.

Fig. 6 shows a fragility curve of MCC for the NRC and UHS ground motions. The high confidential and low probability of failure(HCLPF) capacity for the NRC is 0.88g and the HCLPF capacity for the UHS is 0.75g.



(a) NRC



(b) UHS

Fig. 6. Fragility curve on input ground motion

4. Conclusion

A finite element analysis to evaluate seismic performance of electrical cabinet systems in an NPP was implemented. The results show that the MCC has a sufficient seismic resistant capacity for a safe shutdown earthquake(SSE) level earthquake.

According to the analysis results, the response of the NRC turned out to be relatively smaller than that of the UHS. In this study seismic performance of MCC was evaluated using linear analysis. If nonlinear behavior of MCC is considered, the capacity of MCC will be low compared with the capacity of the linear analysis.

Acknowledgement

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