Response Amplification of MCC Cabinets Induced by High Frequency Earthquakes

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1. Introduction

It was concerned for the public with the safety of nuclear power plants due to the Gyeongju earthquake which occurred in September 2016 in Korea. The observed Gyeongju earthquake showed relatively high frequency components. High-frequency earthquakes affect not only the structure but also the equipment of the nuclear power plant. The structures of nuclear power plants should be safe from earthquakes, as well as functional units, which are equipments. In this study, it is investigated the amplification of earthquake response of an electrical cabinet by high frequency earthquakes.

2. Seismic Analysis and Results

2.1 Input Earthquakes

In order to confirm the amplification of the cabinet response due to the high frequency earthquake, the input earthquake was generated and the seismic response analyses were performed according to the Uniform Hazard Spectrum and the Regulatory Guide 1.60 spectrum [1]. Relatively, the Uniform Hazard Spectrum contains much higher frequency components than the Regulatory Guide 1.60 spectrum. The Fig. 1 shows the Uniform Hazard Spectrum and the Regulatory Guide 1.60 spectrum which is anchored to PGA 0.2g.

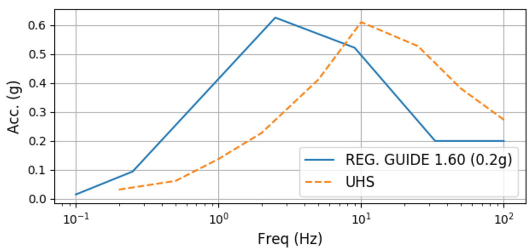


Fig. 1. The Uniform Hazard Spectrum and the Regulatory Guide 1.60 spectrum

As shown in the Fig. 1, it can be seen that the high frequency component of the Uniform Hazard Spectrum is larger than that of the Regulatory Guide 1.60 spectrum. The 5 sets of seismic time history were generated to corresponding to the each spectrum for the seismic response analysis.

2.2 Auxiliary Building of OPR1000

The floor response spectrum at the position of the cabinet is required to investigate the seismic response amplification effect of the cabinet. A nuclear power plant model was constructed using Opensees to create the floor response spectrum. The target structure is an Auxiliary building of OPR1000, a Korean nuclear power plant, and modeled with a lumped-stick model. The Auxiliary building is a reinforced concrete shearwall structure and the Auxiliary building is connected to the Turbine building and the Access control building. The lumped-stick model of the Auxiliary building is shown in Fig. 2.

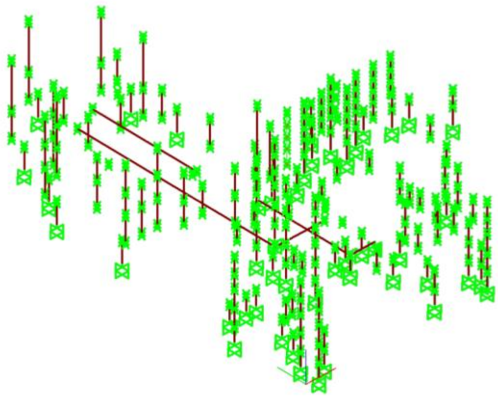


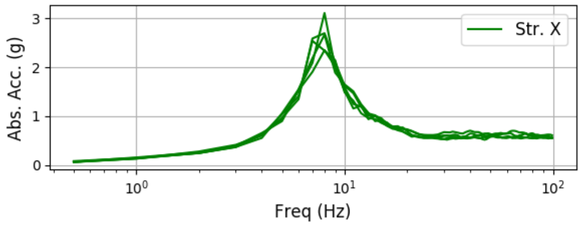
Fig. 2. The lumped-stick model of an Auxiliary building

The eigenvalue analysis was performed on the lumped-stick model, and the results are shown in the table 1.

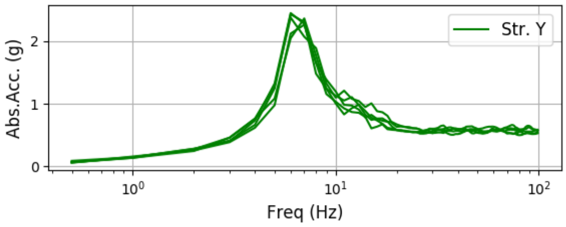
Table I: Modal Frequencies

Mode	Frequency (c/s)
1	1.815
2	1.851
3	2.368
4	3.053
5	3.305
6	4.470
7	5.181
8	5.247
9	6.437
10	6.791
11	7.506
12	8.628

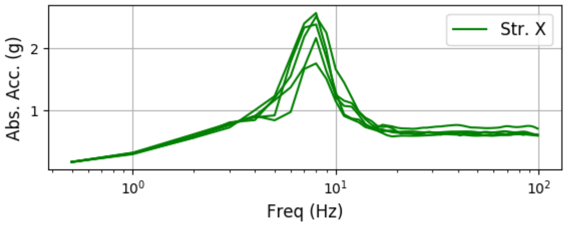
The natural frequencies of a 6.437 *Hz* and a 7.506 *Hz* will have a great effect on the seismic response of the auxiliary building. The Fig. 3 shows the floor response spectrum of the Auxiliary building at 165 *ft*.



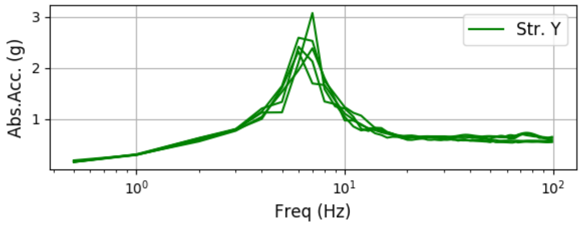
(a) FRS-X direction with UHS input



(b) FRS-Y direction with UHS input



(c) FRS-X direction with Regulatory guide 1.60 spectrum

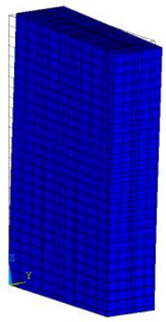


(d) FRS-Y direction with Regulatory guide 1.60 spectrum

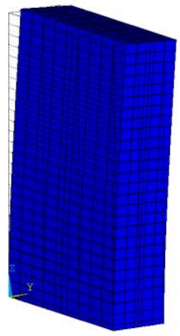
Fig. 3. The floor response spectrum of the Auxiliary building at 165 *ft*

2.3 Electrical Cabinet

The electrical cabinet is that used for the seismic test analysis in "Seismic Performance Evaluation of Electrical Cabinet" [2]. The electrical cabinets is “480V AC MCC” and it is assumed to be located at 165 *ft* of an Auxiliary building. The Fig. 4 shows the natural frequency and natural mode of the cabinet which is calculated with computer program ANSYS.



(a) Mode shape-X direction (74 Hz)



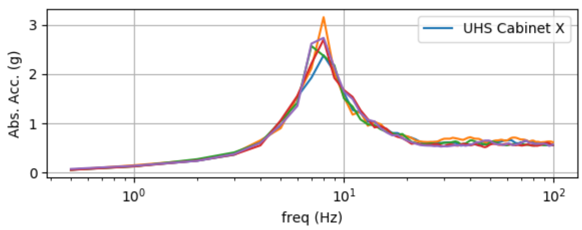
(b) Mode shape-Y direction (13 Hz)

Fig. 4. The natural frequency and the natural mode of the cabinet

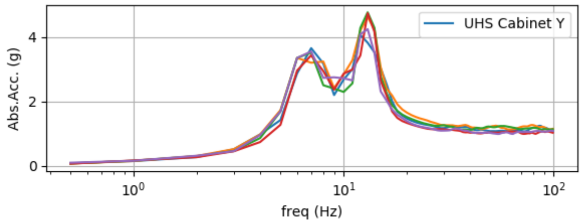
The natural frequencies of the cabinet were found to be in good agreement with the test results [2]. The input earthquakes of the cabinet are utilized with the seismic time history which are calculated from the 5th floor of the auxiliary building (165 *ft*). In this study, it is assumed that seismic amplification occurs by the global mode of the cabinet.

2.4 Results

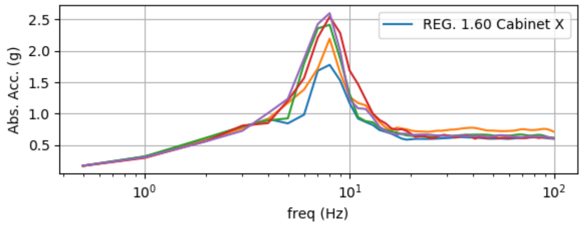
The Fig. 5 shows the seismic response spectrum at the top of the cabinet for the damping ratio of 5% for each earthquake inputs.



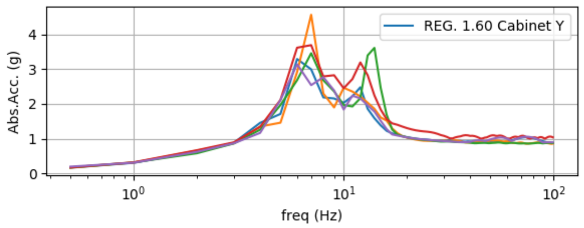
(a) Response spectrum of cabinet-X direction with UHS input



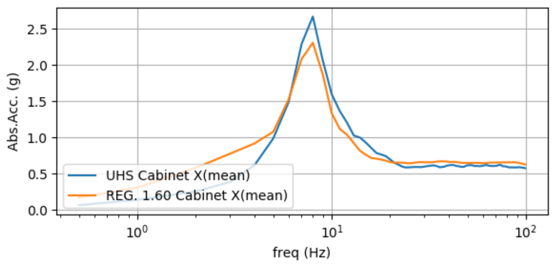
(b) Response spectrum of cabinet-Y direction with UHS input



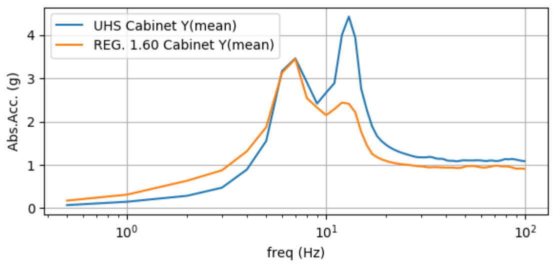
(c) Response spectrum of cabinet-X direction with Regulatory guide 1.60 spectrum



(d) Response spectrum of cabinet-Y direction with Regulatory guide 1.60 spectrum



(e) Mean response spectrum of cabinet-X direction



(f) Mean response spectrum of cabinet-Y direction

Fig. 5. The response spectrum of the cabinet

The response spectrum of X-direction is similar, comparing with the results of the Uniform Hazard spectrum and the Regulatory Guide 1.60 spectrum, due to the high stiffness. However the response spectrum in Y-direction is different. The results show that the response spectrum in Y-direction, which is calculated by Uniform Hazard Spectrum, is higher than which is calculated by the Regulatory guide 1.60 spectrum. Because the Uniform Hazard Spectrum contains more high frequency components compared to the Regulatory guide 1.60 spectrum.

3. Conclusions

In this study, seismic response analyses were performed to investigate the response amplification of cabinet due to high frequency earthquakes. The uniform hazard spectrum as seismic input, relatively has high frequency components than the Regulatory Guide 1.60 spectra, confirmed that the seismic response of the electrical cabinet becomes larger in high frequency range. It is necessary to evaluate the characteristics of earthquakes to confirm seismic performance of electrical cabinets.

ACKNOWLEDGMENTS

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[1] USNRC, Regulatory Guide 1.60, United States Nuclear Regulatory Commission, Washington, DC, 2014.
[2] J. H. Park, M.K. Kim, and I.K. Choi, Seismic Performance Evaluation of Electrical Cabinet, Transactions of Korean Nuclear Society Spring Meeting, Pyeongchang, Korea, 2010.