Seismic Behavior Analysis of Electrical Cabinets due to Rocking in Shaking Table Test

Sung-Wan Kim*, Da-Woon Yun, Bub-Gyu Jeon, Dong-Uk Park
Seismic Research and Test Center, Pusan National University, Yangsan, Korea
**Corresponding author: swkim09@pusan.ac.kr*

1. Introduction

Generally, the seismic performance evaluation of electrical cabinets is conducted through the shaking table test or finite element analysis. Seismic performance evaluation through finite element analysis generally assumes that the electrical cabinet is firmly secured to the floor or foundation. Depending on the electrical cabinet fixing method, however, such boundary condition assumption in finite element analysis may not be valid as the bolted electrical cabinet bottom may experience rocking or uplifting. Therefore, this study conducted a shaking table test to analyze the effects of such rocking or uplifting on the dynamic behavior of electrical cabinets.

2. Methods and Results

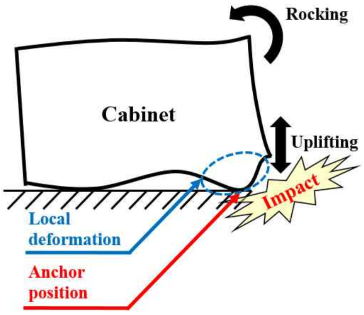


Fig. 1. Uplifting and rocking of the electrical cabinet

In finite element analysis, it is generally assumed that the boundary conditions of the bottom foundation of an electrical cabinet are secured to the floor. The thin plate of an electrical cabinet, however, can occur local deformation around the anchor bolts due to strong seismic motion. Thus, as shown in Fig. 1, the floor plate (except the anchors) occurs uplifting, thereby causing the electrical cabinet to rock. When this happens, the electrical cabinet may impact with the uplifted electrical cabinet floor, possibly amplifying the cabinet acceleration response. Thus, this study sought to examine the impact of rocking on the earthquake response of the electrical cabinet through the shaking table test.

To analyze the rocking and uplifting behaviors of the electrical cabinet using the shaking table test, an electrical cabinet was installed in a shaking table, as shown in Fig. 1. The size of the electrical cabinet was 800 mm (length) × 800 mm (width) × 2,350 mm (height), and weighed 480 kg. It was fixed to the shaking table using the steel frame. The electrical cabinet and the steel frame were connected using 8 M16 bolts, and as shown in Fig. 3, ring-type load cells were installed to measure the load of each anchor bolt.

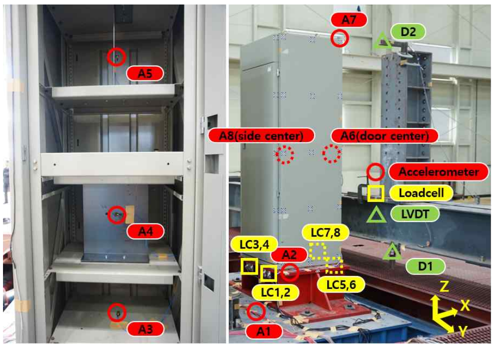


Fig. 2. Sensor installation location

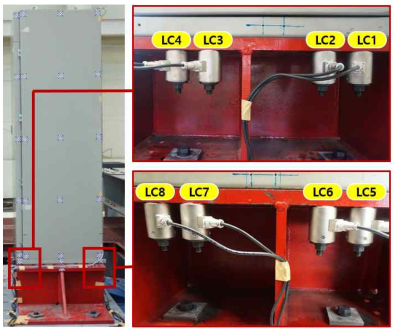
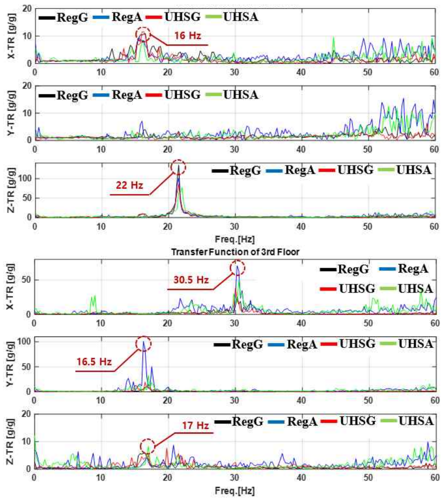


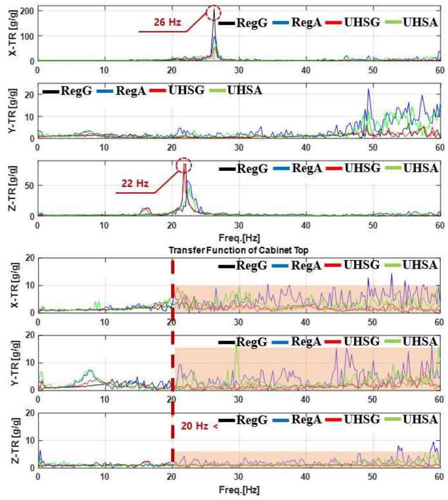
Fig. 3. Ring-type load cells installed in the anchor bolts

It was assumed that the target electrical cabinet was located at 165 feet of the auxiliary building of the nuclear power plant (OPR1000) in Uljin, South Korea. Most of the nuclear power plants in South Korea have a seismic design based on the design response spectrum of Regulatory Guide (Reg) 1.60, and the uniform hazard spectrum (UHS) is used in the evaluation of the earthquake safety of nuclear power plants. The peak ground acceleration was adjusted to 0.2 g, and RegA, the floor response spectrum at 165 feet of the auxiliary building when RegG is given as the input seismic motion. UHSG is the UHS in the Uljin area [2] while UHSA is the floor response spectrum for UHSG at 165 feet of the auxiliary building.

In this study, a transfer function was used to examine the acceleration amplification of the electrical cabinet due to the input earthquake. Fig. 4 shows the transfer function calculated from the acceleration response in the time history test. In Fig. 4, the black and blue lines are RegG and RegA, respectively, and the red and green lines are the transfer functions of UHSG and UHSA, respectively.



<First floor>



<Second floor>

Fig. 4. Transfer function of the acceleration response

Here, the case where rocking occurred is RegA, and UHSA is the case where the largest vertical input acceleration occurred. The frequency where the largest transfer function, measured in each floor inside the electrical cabinet, occurred was found to be similar to the result of the resonance search test. Fig. 4 shows that there was no difference in rocking-caused response amplification in the first and second floors inside the electrical cabinet. Compared to the other test response results, the third floor showed a big horizontal transfer function amplification due to the excitation of RegA. Particularly, the lateral transfer function was more than twice greater. RegA, where rocking occurred in the top measured signal, was found to tend to have a higher transfer function amplification rate at 20 Hz or higher compared to where rocking did not occur. This is because it is deemed that the shock, caused by the impact of the electrical cabinet floor and the steel jig due to rocking, was transmitted to the top of the electrical cabinet via the frame of the electrical cabinet, thereby contributing to the amplification of the internal-floor response.

Table 1 shows the maximum acceleration values of RegA and UHSA. In the case of the time history tests of RegA and UHSA, where the earthquake motion in the ground was the input seismic motion with the floor response amplified by the structure, due to the electrical cabinet door rattling and the local-mode amplification caused by the high earthquake acceleration, the maximum acceleration was found to have been considerably high than those of RegG and UHSG. The shock caused by the impact between the electrical cabinet floor and the steel frame was transmitted to the top via the electrical cabinet frame.

Table I: Peak acceleration of RG$_A$ and UHS$_A$

Position	Peak ground acceleration (g)					
	RegA			UHSA		
	X	Y	Z	X	Y	Z
A2	2.0	1.9	1.6	2.0	1.4	2.0
A3	5.9	9.5	23.9	6.1	8.1	27.6
A4	10.7	7.4	9.3	9.5	7.7	10.1
A5	21.1	16.0	24.6	17.3	19.3	10.9
A6	9.7	17.0	8.6	8.7	19.2	10.9
A7	17.7	12.3	7.7	16.4	25.2	9.5
A8	6.2	21.5	9.7	5.9	12.1	7.8

3. Conclusions

It is estimated that shocks caused by rocking are transmitted to the top via the electrical-cabinet frame. RegA, where rocking occurred, was found to be great in all directions compared to UHSA, where the maximum acceleration value, measured at the top of the electrical cabinet, was the highest. The shocks caused by the electrical-cabinet rocking were found to have significantly increased the transfer function value in the 20 Hz or higher frequency range at the top of the electrical cabinet. The transfer function of the third floor inside the electrical cabinet was confirmed to have greatly increased due to the impact of rocking. The response of the first and second floors of the electrical cabinet, however, was not greatly affected. Thus, it is estimated that the impact of shocks accompanied by rocking or uplifting was concentrated on the top of the electrical cabinet.

Acknowledgment

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[1] H. M. Rhee, M. K. Kim, D. H. Sheen, I. K. Choi, Analysis of Uniform Hazard Spectra for Metropolises in the Korean Peninsula, Journal of the Earthquake Engineering Society of Korea, Vol. 17, p. 71, 2013.