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Reconciliation of Dynamic Characteristics of Electrical Double Door Cabinet based on Experimental and Numerical Analysis

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ABSTRACT

The electrical cabinet system related to safety shutdown operational functionality requires the seismic qualification under high frequency ground motions that have been emerging a key issue in the area of nuclear power plant in Korea. Consequently, in order to understand the dynamic characteristics of double door electrical cabinet including Metering Out Fit (MOF), the search resonant test of the double door cabinet was conducted on a shaking table with sweep rate 2 *Octave/min*. Then, the dynamic properties of the electrical double door cabinet system were detected with the global and local modes. Based on the data obtained from the experimental test, the high fidelity simulation finite element (FE) model was developed in this study. Finally, reconciliation of the results between the experimental and analytical model was also significantly identified in this study.

INTRODUCTION

The electrical cabinet was one of essential components to maintain the function and operation in nuclear and nonnuclear power plants. However, the earthquake damage of the electrical cabinet such as sliding or overturning by inadequately anchored conditions and failure of in-cabinet equipment has been often reported during and after a strong earthquake (Lim et al. 2016). For example, overturned electrical equipment and damage of electrical cabinet system due to unanchored geometric conditions was observed in 1985 Mexico Earthquake, 1999 Izmit Earthquake, Turkey and 2010 Haiti Earthquake (FEMA E-74 2012). In order to mitigate such non-structural earthquake damage such as electrical equipment and cabinets, in recent years, many researches have been conducted. Gupta et al.(2019) studied in-cabinet response spectra using Ritz vector based on artificial earthquakes and GyeongJu earthquake represented a high frequency earthquake and it was shown that the amplification factor under the high frequency earthquake can be significantly increased by local modes in the cabinet. In addition, Cho and Salman (2021) developed the electrical cabinet-anchor interaction model using experimental data and the seismic fragility considering the interaction model was constructed. Therefore, the electrical equipment showed the complicated dynamic behaviour based on the boundary conditions, electrical cabinet models, and ground motions. In order to understand the dynamic characteristics of the electrical cabinet subjected to a strong ground motion, the experimental test and numerical analysis must be conducted. This study presented the dynamic characteristics of electrical double door cabinet system by a shaking table test and the high fidelity FE simulation model was developed based on the data obtained from the experimental test because the local mode of the electrical cabinet can be sensitive to the high frequency earthquake.

EXPERIMENTAL TEST

An existing electrical double door cabinet system was selected and the shaking table test has been conducted in this study. The cabinet was composed of vertical and horizontal main frame, strut and panels. Metering Out Fit (MOF) and switch box were installed in the cabinet system, as can be seen in Figure 1. The member and frame in the cabinet system was coupled by bolts and welds, and then the reinforced plate was connected by bolts, in order to reduce the experimental error due to local excessive deformation. Finally, a jig-plate on the shaking tale was welded with the cabinet system at the bottom area. The dimensions of electrical double door cabinet were1200 mm (width), 600 mm(depth) and 2350 mm(height) and the total mass of the cabinet was 549 kg. To measure the acceleration response in resonance search tests, the accelerometers were attached to the top of the shaking table (A1), the top of the jig (A2), the MOF (A3), the switch box (A4), the center of the door (A5) and the top edge (A6), as shown in Figure 1.

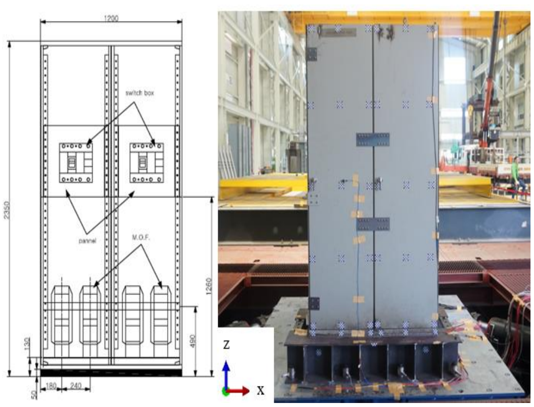


Figure 1. Schematic design of electrical double door cabinet

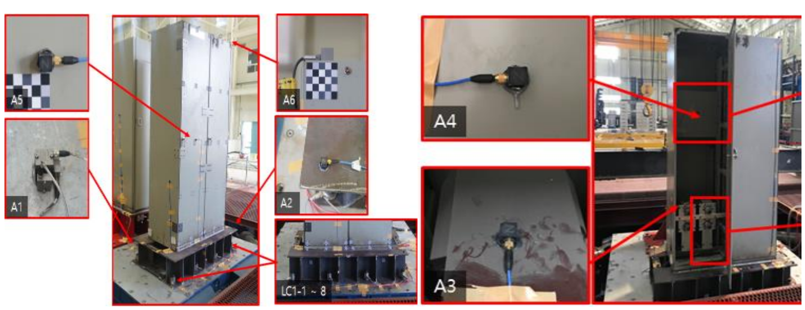
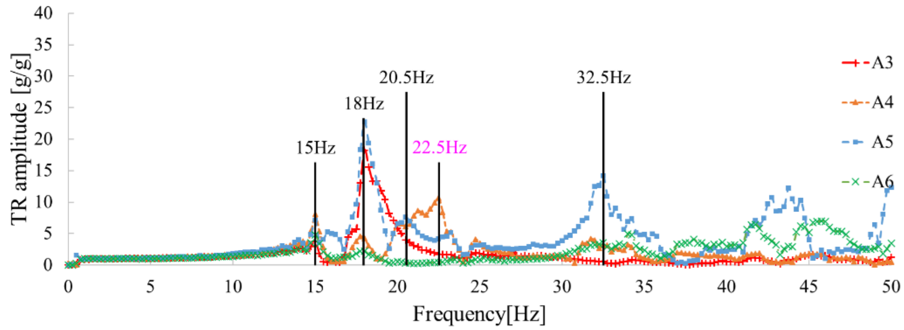
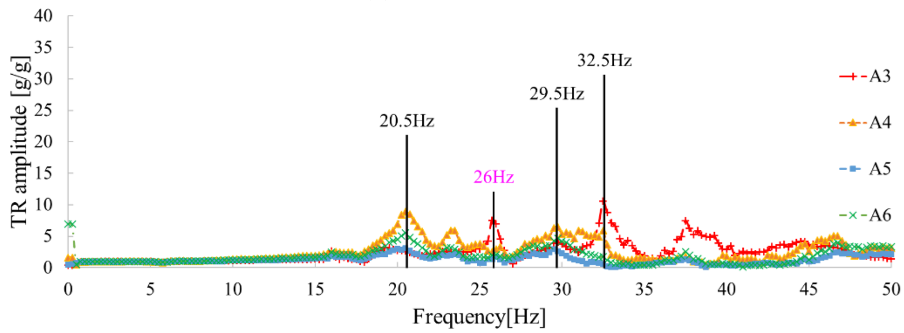


Figure 1. Experimental tests of electrical double door cabinet

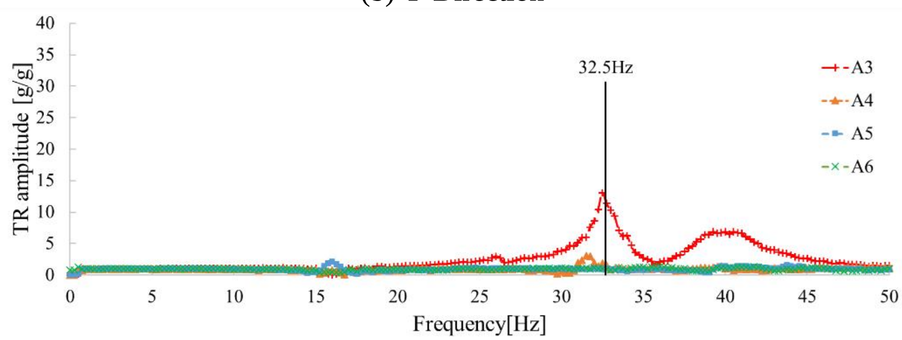
Next, for the resonance search test, the test was performed using a shaking table with a maximum load of 6000kg and the shaking table considering the frequency range from 0.1Hz to 60 Hz was consisted of 6-DOF. Sinusoidal sweep wave for the resonance search test was applied with the rate of 2 Oct/min and the test included the frequency range from 1.3 Hz to 33.3 Hz with the acceleration $0.1g \pm 0.05g$. As a result, based on the experimental test the natural frequencies of the electrical double door cabinet was targeted and it was illustrated in table 1 and Figure 2.



(a) X-Direction



(b) Y-Direction



(c) Z-Direction

Figure 2. The frequencies of electrical double door cabinet of the experimental test

VALIDATION OF NUMERICAL MODEL

There was no excessive deformation and local buckling in the electrical double door cabinet from the experimental test. Therefore, in order to build the FE model of the cabinet, the linear elastic model was assumed in this study. The high fidelity simulation model of the electrical double door cabinet was conducted in ABAQUS platform.

Table 1: Dynamic characteristics of the double door cabinet

	1^{st} global	2^{nd} global	3^{rd} global	4^{th} global	5^{th} global	1^{st} local	2^{nd} local
Experimental	15.00Hz	18.00Hz	20.50Hz	29.50Hz	32.50Hz	22.50Hz	26.00Hz
Numerical	14.55Hz	18.0Hz	21.85Hz	30.27Hz	33.29Hz	23.17Hz	26.14Hz

In the HF FE model, the main frame, panel and jig plat was modelled by 3D 4-node reduced integration shell element (S4R) in ABAQUS and then 3D 8-node reduced integration solid element (C3D8R) was used for M.O.F and switch box in the cabinet. Figure 3 showed the HF FE model of the existing electrical cabinet system in ABQAUS platform, and the natural frequencies obtained from the HF simulation model was extremely identical to the data from the experimental test. The error was less than only 7%, which indicated that the high fidelity simulation model can be reliable. Furthermore, the FE model was validated and verified with the data obtained from the experimental test both in global and local modes of the cabinet system, as shown in Figure 5 and Table 1.

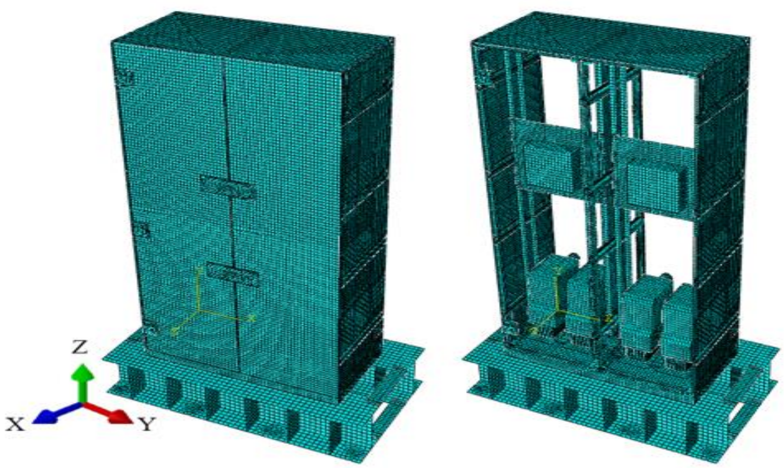
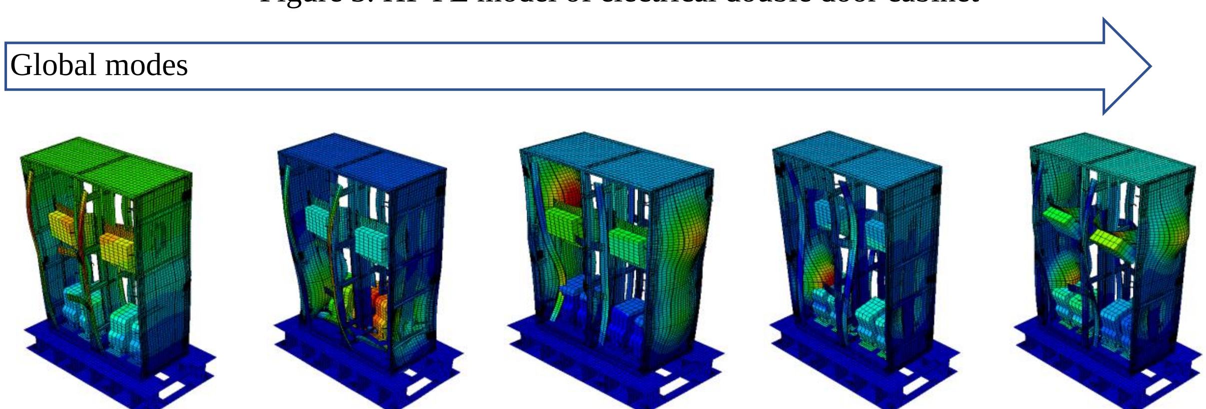
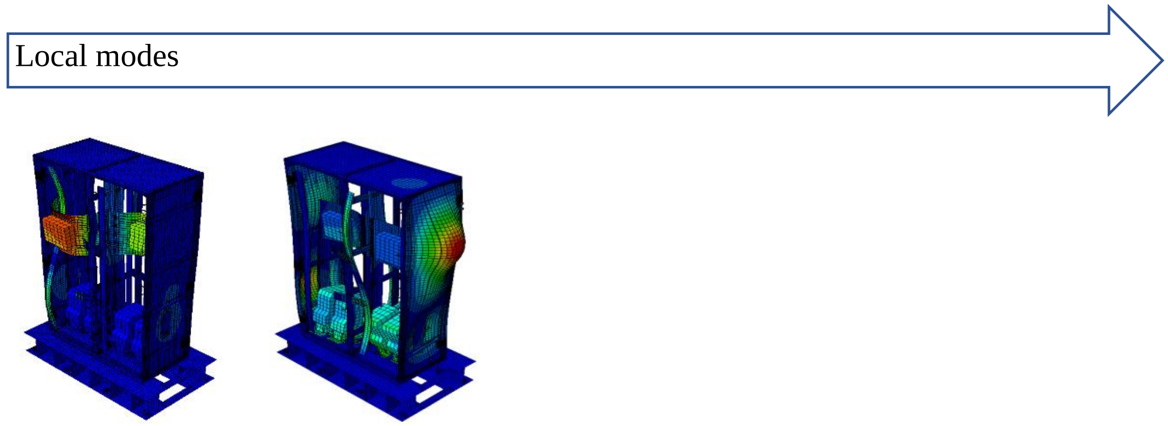


Figure 3. HF FE model of electrical double door cabinet



(a) 1^{st} mode (b) 2^{nd} mode (c) 3^{rd} mode (d) 4^{th} mode (e) 5^{th} mode



(f) 1st mode (g) 2nd mode

Figure 4. Mode shapes of HF FE model of double door cabinet

CONCLUSION

This study showed the dynamic characteristics of the electrical double door cabinet system subjected to a shaking table test. In addition, the high fidelity simulation finite model of the cabinet was developed in this study and then the validation of the numerical model of the cabinet was significantly identified with the results of the experimental test both in global and local modes. More specifically, further can be used to obtain accurate ICRS of the cabinet in this study.

ACKNOWLEDGEMENT

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