Model Updating of an Electric Cabinet using Shaking Table Test

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Key Words : shaking table test, modal test, electric cabinet, beam stick model.

ABSTRACT

This paper presents the procedure and the results of modal identification testing of a seismic monitoring system central processing unit cabinet for a nuclear power plant. This paper also provides a model updating for making effective analytical modeling of cabinet-type electrical equipment by comparing the test results with the analysis results. From the test results and their interpretation, modal properties (modal frequency, mode shape, and modal damping) of the specimen were satisfactorily identified. However, the analysis results may need to study further to find the effective and presentative model for the cabinet-type electrical equipment. This paper just presents the first stage of the research project "Development of dynamic behavior analysis technique of dynamic structure system" which is trying to build the lumped mass beam stick model even their results do not agree well with the test results.

1. Introduction

Safety-related equipment of nuclear power plants must be seismically qualified to demonstrate their ability to function as required during and/or after the time it is subjected to the forces resulting from an earthquake. The seismic qualification is usually achieved through testing or analysis, though qualification by experience data has also become recently acceptable. Specifically, for relatively complex equipment with small components or devices which are not easy to be mathematically modeled the testing method is preferably adopted for the qualification. In the course of a seismic qualification test program, an identification test for dynamic characteristics of the equipment, usually called exploratory test, is performed prior to a main seismic proof test to get useful information for determination of the optimum test method and interpretation of results of the qualification test. A modal identification test is also frequently used for the verification of analytical models used in seismic qualification by analysis.

This paper presents the procedure and the results of modal identification testing of a seismic monitoring system central processing unit cabinet for a nuclear power plant. For the test, a large-scale 6-degrees of freedom shaking table was used and the test results were recorded and evaluated, and the modal parameters, i.e. modal frequencies, damping factors, mode shapes were extracted through the polynomial curve-fitting technique. However, the analysis results may need to study further to find the effective and presentative model for the cabinet-type electrical equipment. This paper just presents the first stage of the research project "Development of dynamic behavior analysis technique of dynamic structure system" which is trying to build the lumped mass beam stick model even their results do not agree well with the test results.

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2. Test Setup

2.1 Test Equipment and Shaking Table

The test cabinet specimen is a seismic monitoring system central processing unit cabinet for a nuclear power plant. Its main function is alarming and monitoring seismic signals at the site of the plant. The specimen is a typical electrical cabinet of thin steel plate 650mm in width, 800mm deep, and 1550mm tall with front and rear entrance doors. Total weight of the cabinet is 317kg. The front view of the test cabinet is shown in Figure 1[1]. The righthand side cabinet of the two is the junction rack cabinet discussed in this study.

Figure 1. The test cabinet

The cabinet consists of an internal steel frame of channels and angles, 3.2mm thick steel plate covers the frame, with four intermediate diaphragms of thin steel plate inside. The cabinet has front and rear entrance doors and all structural components are inter-connected with each other by bolting or spot welding. The cabinet is expected to behave in a complex nonlinear manner with high damping characteristics under strong motion earthquake excitation. The specimen is bolted onto the prefabricated mounting fixtures which are connected with bolts to the shaking table. The shaking table has the capacity of maximum loading of 30 ton, and table size of 4.0m×4.0m. Maximum horizontal acceleration and displacement of the table are ±1.5g and ±100mm, respectively with a frequency range of 1~50Hz[2].

2.2 Instrumentation and Tests

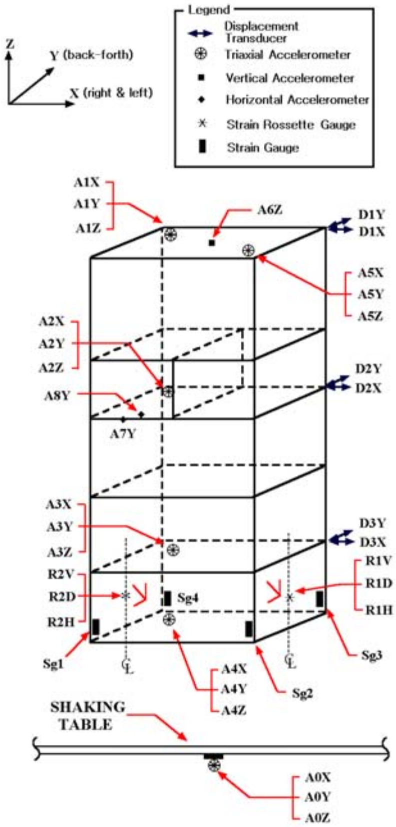


Figure 2. Instrumentation setup of the test

The modal test for this study was performed as a preliminary phase of the main seismic proof test to extract and evaluate the modal properties of the cabinet. For easier comparison and interpretation of directional effects and coupling, one directional test in one horizontal axis was conducted independently and repeated in the other two orthogonal directions with the same pattern of excitation. For the measurement and aquisition of the test motion and response signals, a number of instrument gauges were installed on the test specimen. The instrumentation system consisted of 16 signal sensors of three different kinds as shown in Figure 2.

2.3 Evaluation of the Test Data

A number of modal data sets have been extracted using the various measured data obtained from different sensors. The resulting modal data do not have unique values but varies from data to data depending on sensors, sensor locations, and excitation directions or levels. Typical values of the extracted modal frequencies and damping factors are summarized in Table 1 for the excitation level of 0.2g, representing linear and nonlinear behaviors, respectively. Figure 3 shows mode shapes corresponding to the case of 0.2g in Table 1. The values in Table 1 are from the acceleration measurements of the top floor and may give the most representative behavior. These values are averages of multiple estimations from different sensors.

Table 1. Typical natural frequencies and damping extracted from the test data

Direction	X−direction			Y−direction	
Mode No.	1	2	3	1	2
Frequency (Hz)	15.69	35.89	42.32	26.59	40.0
Damping (%)	11.79	1.71	1.34	5.48	2.94

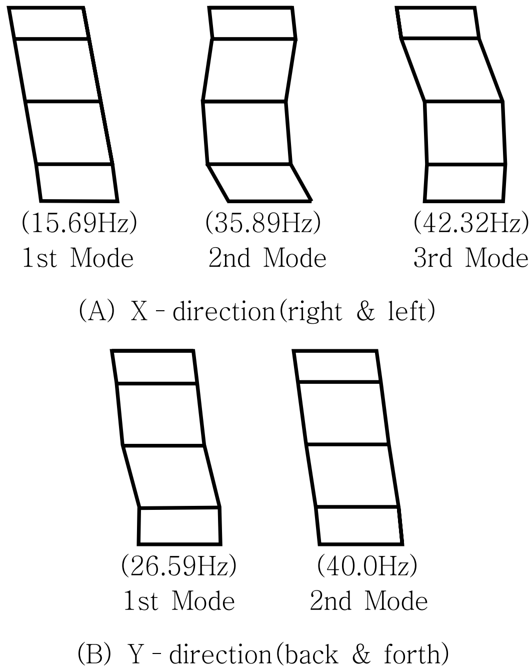
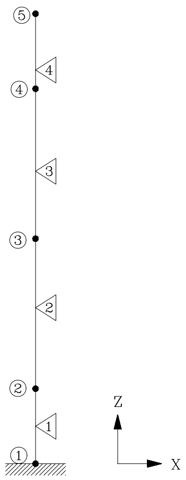


Figure 3. Schematic view of mode shapes of the cabinet

3. Modal Parameters by Analysis

For the comparison purposes of the test results, the modal properties of the tested cabinet have been also extracted through state−of−the−art modeling and analysis techniques. These analyses were also performed to check the availability of analysis technique to find modal properties of cabinet−type equipment with complex structural properties. For the analysis, the lumped mass beam stick model was prepared and modal analyses were performed using the computer program MATLAB[3] by performing the engin−value analysis and compared with test results. Figure 4 shows the schematic mathematical model for the lumped mass beam stick model. In the process of modeling, properties of the idealized members were prepared and calculated using the standard material properties of the steel (Young's Modulus $E = 2.1 \times 10^6 Kg/cm^2$ and Passion's ratio $\gamma = 0.3$). Table 2 shows the integrative mass which including the structure and equipments weights together and distributed to the points, that means the lumped masses at each point. Table 3 shows the section properties which were used to model the equivalent section for the beam stick model.



(12.08 Hz)

Figure 4. Lumped mass beam stick model

Table 2. Lumped mass for the stick model

Points No.	Lumped mass ($Kg \cdot sec^2/cm$)
2	78.111×10^{-3}
3	84.345×10^{-3}
4	68.045×10^{-3}
5	41.995×10^{-3}

Table 3. Section properties for the stick model

Area (cm^2)	Moment of inertia (cm^4)	
	I_{XX}	I_{YY}
91.52	379.34	796.32

The first natural frequency analyzed by the lumped mass beam stick model is about 12.08Hz, which is much different with the test results. It demonstrates that the beam stick model built now is not detailed and exact enough to be used as the presentative baseline model. The model needs to be identified and some model updating techniques are needed, such as the frequency relative errors and the modal assurance criterion (MAC) which are used as the popular measures of the correlation between two sets of structural dynamic data that can be used for model identification[4].

4. Conclusions

Modal parameters of a seismic monitoring system central processing unit cabinet have been satisfactorily extracted from large-scale shaking table excitation tests by using polynomial curve-fitting method. Those parameters also have been compared with the analyses which were performed by the lumped mass beam stick model. The stick model built now is verified and compared with the test results, which shows the necessity of model updating of the model. The final object of our research is to build the baseline model which can be used as the representative model to predict the structural performances of the cabinet-type electrical equipment under earthquakes. So further studies need to be done to update the FE model and find the effective and presentative model.

References

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