Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Seismic Isolation of an Emergency Diesel Generator by a Coil Spring-Viscous Damper System

Young-Sun Choun, Min-Kyu Kim
Korea Atomic Energy Research Institute, Integrated Safety Assessment Division, P.O. Box 105, Yuseong, Daejeon, Korea, sunchun@kaeri.re.kr

1. Introduction

Recent studies have shown that the use of base isolators instead of anchor bolts for an Emergency Diesel Generator (EDG) can remarkably increase the seismic capacity of the EDG and finally reduce the core damage frequency (CDF) in nuclear power plants [1,2].

This study demonstrates the effectiveness of an isolation system for the EDG by shaking table tests. An EDG model was built with concrete and steel blocks, and a coil spring-viscous damper system was used as an isolation system. The dynamic characteristics of the coil spring-viscous damper system were obtained by cyclic tests and the seismic responses of the EDG model were obtained by shaking table tests.

2. Model Tests

A test model was designed to represent the seismic behavior of a prototype of the EDG set installed in nuclear power plants. An EDG set with a HANJUNG-SEMT Pielstick Engine 16PC2-5V 400, which is installed in Younggwang 5&6, Ulchin 3&4 and 5&6, and Wolsung 3&4 Units, was chosen as the prototype.

2.1 EDG Model

The prototype of the EDG set consists of an engine unit, a generator unit, and a concrete mat. Net weights of the engine unit, the generator unit, and the concrete mat are 912 kN, 392 kN, and 2,474 kN, respectively, and the total weight is 3,779 kN. A 6-DOF seismic simulator with a table dimension of 2.5 m × 2.5 m was used for the model test. Test model was designed by considering the size of the shaking table of the simulator as shown in Figure 1, which consists of a concrete block of 2,300 mm × 800 mm × 450 mm, four steel blocks of 600 mm × 600 mm × 140 mm, and two steel plates of 1,500 mm × 300 mm × 30 mm. Total weight of the test model is 39 kN and the steel blocks were placed to have an equivalent mass center of the prototype.

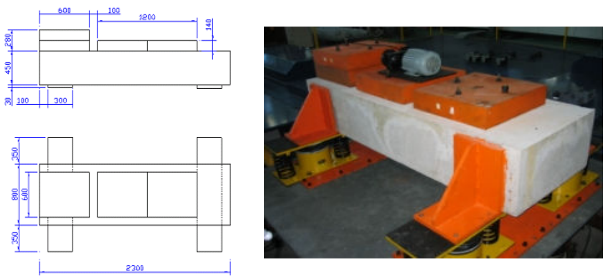


Figure 1. EDG model for shaking table tests.

2.2 Coil Spring-Viscous Damper

For the seismic isolation of the EDG, a coil spring-viscous damper system was adapted because it is able to effectively reduce the mechanical vibration during an operation as well as the seismic force during earthquake. The stiffnesses of the coil-spring and the damping coefficients of the viscous damper for the vertical and horizontal directions were determined by the seismic responses of the EDG test model for the design input motion. The coil spring-viscous damper system was designed and manufactured by GERB as shown in Figure 2.

Item		Properties
Stiffness	Vert.	0.144 kN/mm
	Hor.	0.04 kN/mm
Damping Coef.	Vert.	3.5 kNs/m
	Hor.	4.0 kNs/m

Figure 2. Coil spring-viscous damper system.

2.3 Input Motions

Three input motions representing the scenario earthquake, USNRC spectrum, and uniform hazard spectrum shown in Figure 3 were used for the shake tests, and three peak acceleration levels 0.1g, 0.2g, and 0.3g were applied for each input motion. Identical input motions and peak acceleration levels were used in the horizontal and vertical directions.

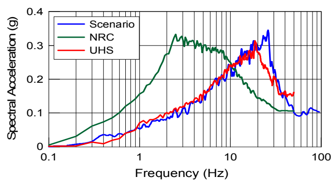


Figure 3. Input motions used for model tests.

2.4 Test Methods

Shaking table tests were carried out for one and three directional excitations with three acceleration levels. The acceleration and displacement responses were measured by using two accelerometers (A1 & A2) and eight LVDTs (D1-D8) as shown in Figure 4.

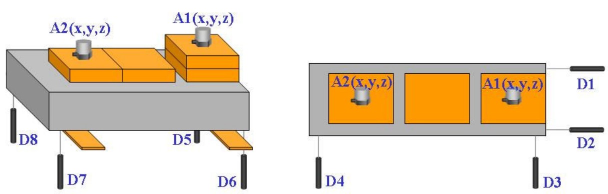


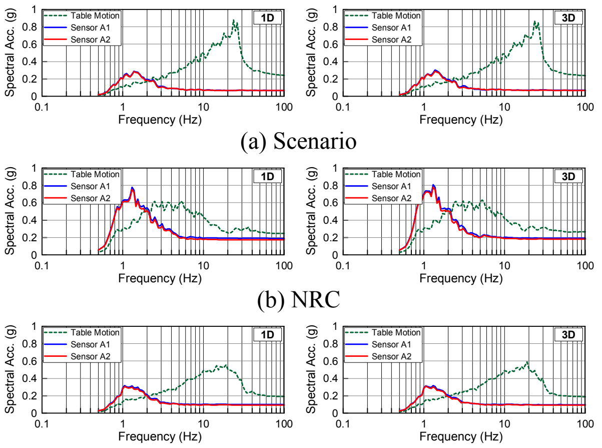
Figure 4. Arrangement of accelerometers and LVDTs.

3. Test Results and Discussions

In this section some of the test results are briefly reviewed and the effectiveness of the isolation system is discussed.

3.1 Acceleration Responses

Figure 5 shows the acceleration responses for the peak acceleration level 0.2g during one and three directional excitations together with the table motions. Maximum spectral accelerations appear at around 1.3Hz for all the cases. The spectral accelerations decrease significantly under the Scenario and UHS motions but increase under the NRC motion. The differences between the acceleration responses for the 1D and 3D excitations are very small.



(a) Scenario

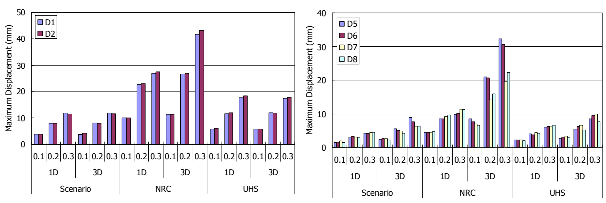
(b) NRC

(c) UHS

Figure 5. Acceleration responses for different input motions.

3.2 Displacement Responses

Figure 6 shows the displacement responses in the horizontal and vertical directions for three input motions with different acceleration levels at different measuring points. The largest displacements were measured in the 3D-NRC excitation. For the horizontal and vertical direction, maximum displacements of about 40 mm and 30 mm are obtained, respectively. For the Scenario and UHS excitations, maximum displacements of less than 20 mm in the horizontal direction and 10 mm in the vertical direction are obtained. There is a great difference between the maximum displacements during the 1D and 3D excitations, especially, in the vertical direction.

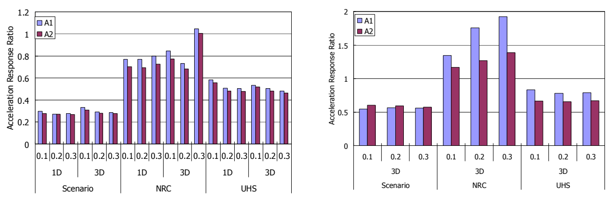


(a) Horizontal direction (b) Vertical direction

Figure 6. Comparisons of displacement responses for the isolated EDG.

3.3 Effectiveness of Seismic Isolation

Figure 7 shows the acceleration response ratios for different input motions and acceleration levels. The acceleration response ratio is determined as the ratio of the peak acceleration response at the test model to the peak acceleration of the shaking table. From the figure, the effectiveness of the isolation systems can be found. Roughly speaking, the isolation system used in this study can reduce the seismic force transmitted to the EDG by about 70 and 50 percent for the Scenario and UHS input motions respectively. For the NRC input motion, since the spectral acceleration is significant in the frequency range of 1-10Hz, a 20 percent reduction of the seismic force is obtained. Therefore, in order to reduce the seismic response significantly under the NRC input motion, the horizontal and vertical natural frequencies of the isolated EDG should be less than 1Hz.



(a) Horizontal direction (b) Vertical direction

Figure 7. Comparisons of acceleration response ratios for the isolated EDG.

4. Conclusion

Seismic responses of an isolated EDG with a coil spring-viscous damper system are demonstrated through the shaking table tests and the effectiveness of the isolation system is discussed. It is found that the coil spring-viscous damper system is a very effective seismic isolation system for an EDG installed in NPPs. Generally speaking, the isolation system can reduce the seismic force transmitted to the EDG by up to 70 percent for the scenario earthquake and UHS input motion. For the NRC input motion, the horizontal and vertical natural frequencies of the isolated EDG should be less than 1Hz. For the design of an effective three-dimensional isolation system, careful attention must be paid to reduce the vertical responses.

ACKNOWLEDGEMENT

This study was supported by the Mid- and Long-Term Nuclear Research and Development Program of the Ministry of Science & Technology, Korea.

REFERENCES

[1] Y.S, Choun and I.K. Choi, Effect of Seismic Isolation of Nuclear Plant Equipment on Core Damage Frequency, Proceedings of the KNS Autumn Meeting, 2002.

[2] Y.S, Choun and I.K. Choi, Seismic Safety Improvement of Yonggwang Nuclear Units 5&6 by Increase of Equipment Seismic Capacity, Proceedings of the KNS Spring Meeting, 2003.