Seismic Analysis of an Emergency Diesel Generator with Coil Spring-Viscous damper

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1. Introduction

Seismic isolation, which is now recognized as a mature and efficient technology, can be adopted to improve the seismic performance of strategically important buildings such as schools, hospitals, industrial structures etc., in addition to the places where sensitive equipment are intended to protect from hazardous effects during earthquakes [1-3]. Because the damage of important structures such as nuclear power plants (NPPs) are related to the safety of life and the cost of risk, the NPPs must retain an adequate seismic performance.

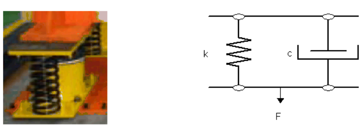
The Emergency Diesel Generator (EDG) is a very important piece of equipment in NPPs. Recent studies have shown that the use of base isolators instead of anchor bolts for an EDG can remarkably increase the seismic capacity of the EDG [4, 5].

In this study analytical model were compared with test model to verify analytical model. The seismic analysis of the actual EDG with an isolator was performed.

2. Verification of analytical model

2.1 Modeling of isolator

For the seismic isolation of the test model, the coil spring-viscous damper system was adapted. Fig 1 shows test and analytical model. As shown in Fig 1 b), the isolators were modeled using Kelvin-voigt model. The spring constants and damping coefficients are equal to test specimen.



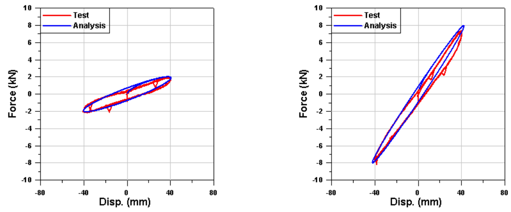
a) Test model b) Analytical model
Fig. 1. Test and analytical model

2.2 Result of test model

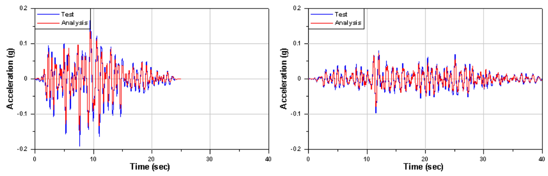
To verify an analytical model, the test results of Kim et al.[6] were used. The acceleration and displacement responses of the analysis model were compared with responses of the test model.

The force-displacement curves of the model are shown in Fig 2. Because the stiffness and damping of model were designed differently depending on the direction, the horizontal and vertical behavior of isolator was different from each other.

Fig 3 shows the acceleration of the test and analytical model at the top of analytical model for the input motion. The analysis results are very similar to the test result for input ground motion.



a) Horizontal b) Vertical
Fig. 2. Force-displacement curves of model



a) NRC b) UHS
Fig. 3. Acceleration of model

3. Seismic analysis of actual EDG

3.1 Input motion

In this study two kinds of seismic input motions were used. The first input motion is the floor response spectrum of the Yonggwang 5 unit EDG building based on the design spectrum of NRC Reg. guide 1.60. The second is also an artificial seismic wave based on site specific Uniform Hazard Spectrum (UHS) for the Korean NPP. The UHS motion was selected for evaluation of a high frequency effect on the electric equipment in a NPP. To generate acceleration time histories the normalized spectral accelerations were used. The predominant frequency of the first input motion is from 2Hz to 10 Hz. While the predominant frequency of the second input motion is 20Hz.

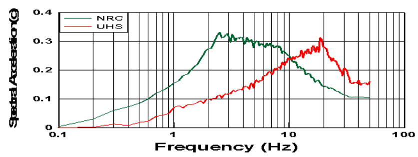


Fig. 4. Spectral acceleration of input motion

3.2 Analytical model of the EDG

An EDG set with a HANJUNG-SEMT Pielstick Engine 16PC2-5V 400 was chosen in this analysis. The horizontal stiffness and damping coefficients are 30kN/cm and 200 kNs/m. The vertical stiffness and damping coefficients is 80kN/cm and 200 kNs/m.

Fig 5 shows analytical model of the EDG. The total weight of the analytical model is 380ton including the weight of engine, generator and base mat. The mass was uniformly placed to consider the weight of the engine, generator. The thickness of base mat was assumed to be 2.4m. The bottom of EDG consists of 16 isolators with spring element integrated viscous damper.

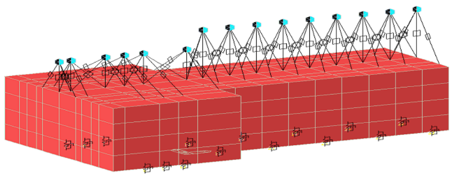


Fig. 5. Analytical model of EDG

4. Results and Discussions

4.1 Nonlinear dynamic analysis result

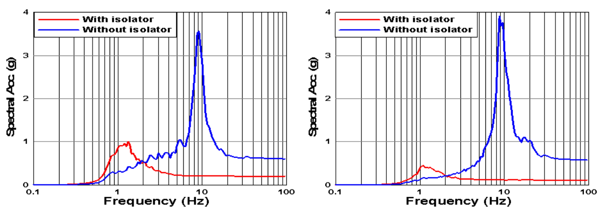
According to the modal analysis the natural frequency of the EDG on the horizontal direction and vertical direction is 1.1Hz and 2.6Hz.

Fig 6 shows the acceleration response of horizontal direction at top of EDG. The predominant frequency of the EDG was shifted by the isolator from 13Hz to 1.1Hz. Fig 7 and 8 shows the response of EDG.

In the NRC input motion, an acceleration of EDG with isolator was reduced by minimum 31%. In the UHS input motion, it was reduced by minimum 79%.

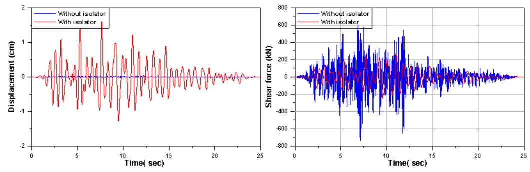
Because the displacement at the bottom of EDG was designed to satisfy limit state, It was observed that the maximum displacement of EDG by the nonlinear analysis ranged 0.82 ~ 1.75cm. Considering that the limit state is to 4cm it was showed that the isolated EDG retain highly seismic capacity.

Because the seismic energy was mainly dissipated by isolator, the shear force at the bottom of the EDG with isolator was lower than that of the EDG without isolator.



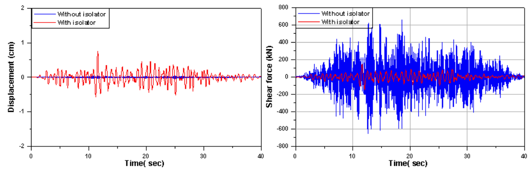
a) NRC b) UHS

Fig. 6. Response spectrum at the top of EDG



a) Displacement b) Shear force

Fig. 7. Response of EDG (NRC-0.2g)



a) Displacement b) Shear force

Fig. 8. Response of EDG (UHS-0.2g)

5. Conclusion

In this study the seismic analysis of the conventional and isolated EDG system was carried out. The response of the EDG was obtained using nonlinear time history analysis.

Prior to seismic analysis of actual EDG, analytical model of isolator was compared with test model. According to the result, the response of EDG with isolator in the UHS input motion was more highly reductive than that in the NRC input motion.

Acknowledgement

This work was supported by Nuclear Research & Development Program of the National Research Foundation (NRF) grant funded by the Korean government (MEST). The authors appreciate this financial support.

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