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Limit State Evaluation of 1000kW Emergency Diesel Generator Using Shaking Table Test

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1. Introduction

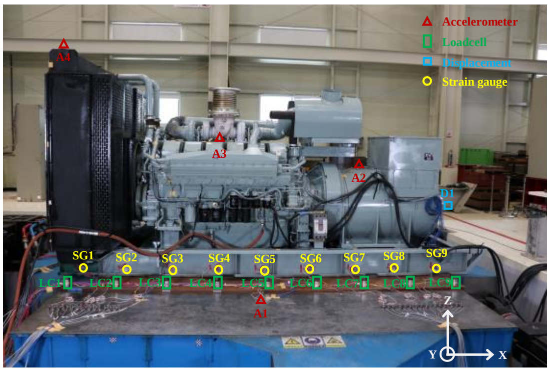
Recently, large-scale earthquakes have been occurring all over the world, and damage caused by earthquakes is increasing. The magnitude and frequency of occurrence and felt earthquakes are increasing in the earthquake data of KMA (Korea Meteorological Administration). The 5.8-maginitude earthquake in September 2016 caused the greatest damage since the observation in Korea. In November 2017, the 5.4-magnitude earthquake in Pohang was the second largest after the Gyeong-ju earthquake [1].

Generally, nuclear power plants in Korea are designed according to the design response spectrum of RG (Regulatory Guide) 1.60 or an independent spectrum in other regions in the frequency range of 2 to 10 Hz. However, the recently constructed ground response spectrum of CEUS (Central and Eastern United States) represents the spectrum over 10 Hz, which exceeds the design response spectrum. The standard seismic design response spectrum of RG 1.60 does not fully reflect the high-frequency vibration of earthquake motions occurring in Korea. Also, the ground response spectrum based on risk analysis can exceed the standard seismic design spectrum in the high frequency vibration. Therefore, it is necessary to evaluate the response behavior and the failure modes for high frequency earthquake environments for the components of nuclear power plants. In this study, the failure behavior and the functional evaluation of a 1000 kW emergency diesel generator using a shaking table test were carried out in the high frequency vibration.

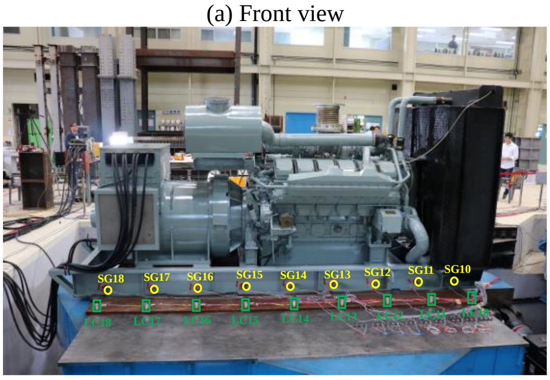
2. Methods and Results

The input seismic wave is the design spectrum of RG 1.60 which is used as a design earthquake of nuclear power plant and the artificial earthquake by UHS (Uniform Hazard Spectrum) in Uljin. The damping ratio was set to 5%, and the seismic waves satisfying the RRS (Required Response Spectrum) were excited in three axial directions. The frequency range is from 1.0 Hz to 60.0 Hz. The vibration duration is 30 seconds and the duration of the strong motion is 20 seconds. The seismic performance test of the emergency diesel generator was carried out in accordance with IEEE 323 [2] and IEEE 344 [3].

The location of the sensor is shown in Fig. 1. In the shaking table test, four 3-axis accelerometers were used. In addition, a wire displacement sensor was installed to measure the displacement response in the horizontal direction. eight ring type load cells were installed on M30 bolts for fastening jig and shaking table to measure pullout force. 18 three-axis strain gages were installed on the common bed of the diesel generator to measure the response.



(a) Front view



(b) Rear view

Fig. 1 Sensor installation location

Fig. 2 shows the acceleration response in each axis direction for the UHS 200% seismic wave in the shaking table test. The shaking table test was performed using the artificial seismic waves generated. The TRS (Tested Response Spectrum) of the acceleration response measured at the bottom of the shaking table was well enveloped in RRS, as shown in Fig. 3. In Fig. 3, the black dashed line is RRS, the red solid line is TRS, and 90% and 150% lines of RRS are indicated by blue dotted lines. The test results are shown in Table I. Test results show that after the RG 1.60 350%, leakage was observed on the fuel filter connection. It was confirmed that leakage of fuel filter connection, fuel injection port, and fuselage connection was observed after UHS 325%. Also, the function check of the emergency diesel generator was performed. The possibility of operation for more than 5 minutes was confirmed, and no abnormality of the output signal due to the excitation of the seismic wave was found.

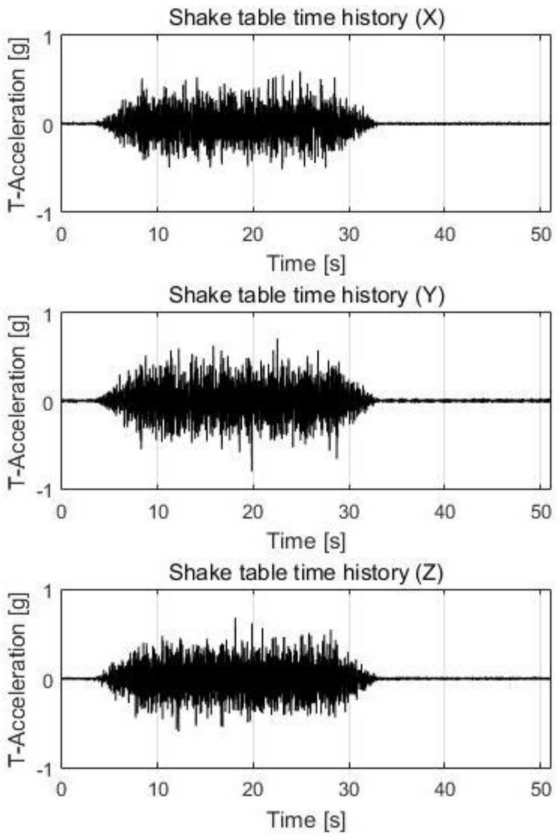


Fig. 2 Input seismic wave (UHS 200%)

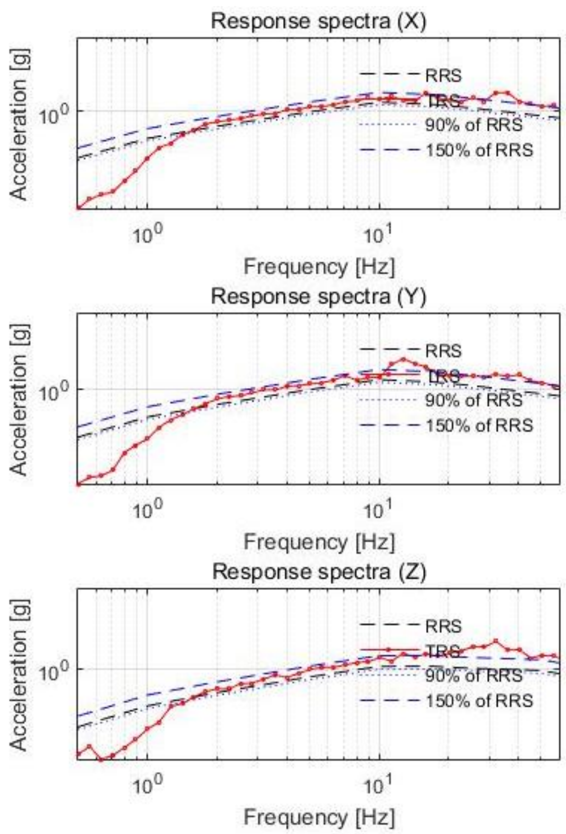


Fig. 3 TRS and RRS

Table I: Results of function and visual inspection

Seismic	Reference	Results	
		Function	Inspection
RG	200%	O.K.	O.K
	225%	O.K	O.K
	250%	O.K	O.K
	275%	O.K	O.K
	300%	O.K	O.K
	325%	O.K	O.K
	350%	O.K	Leakage
UHS	200%	O.K	O.K
	225%	O.K	O.K
	250%	O.K	O.K
	275%	O.K	O.K
	300%	O.K	O.K
	325%	O.K	Leakage
	350%	O.K	Leakage

3. Conclusions

Generally, fuel storage tanks are based on supplying enough fuel to operate two emergency diesel generators for seven days. One daily storage tank has a fuel capable of operating for 60 minutes at the rated output of one emergency generator. However, such leakage of fuel and lubricating oil may not meet the fuel requirements for emergency diesel generator operation due to the shutdown of the external power supply of the nuclear power plant. Therefore, due to the characteristic of the emergency diesel generator being operational until the external power is restored, this leakage may affect the performance requirements for continued operation of the diesel generator. In order to secure the emergency power supply capability of the emergency diesel generator, it is necessary to consider the bolt connections of the anchor bolts of the foundation, generators, and engine parts to the inspection items.

Acknowledgements

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[2] IEEE 323, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generation Stations, 2010.
[3] IEEE 344, IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations, 2013.