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Seismic Risk Analysis of an Isolated EDG Model

Min Kyu Kim, Yasuki Ohtori,[a] Young Sun Choun
Integrate Safety Assessment Division, Korea Atomic Energy Research Institute, Youseong, Daejeon, minkyu@kaeri.re.kr
a Central Research Institute of Electric Power Industry, Abiko, Japan, ootori@criepi.denken.or.jp

1. Introduction

An Emergency Diesel Generator (EDG) is one of the safety related equipments of a Nuclear Power Plant. The seismic capacity of an EDG in nuclear power plants influences the seismic safety of the plants significantly. A recent study showed that the increase of the seismic capacity of the EDG could reduce the core damage frequency (CDF) remarkably [1]. It is known that the major failure mode of the EDG is a concrete coning failure due to a pulling out of the anchor bolts [2]. The use of base isolators instead of anchor bolts can increase the seismic capacity of the EDG without any major problems. Choun, et al [3] studied the fragility analysis of a seismically isolated EDG system. This study introduces a seismic risk analysis method and presents sample results about the seismically isolated and conventional EDG system.

2. Annual Probability of Failure

2.1 Annual Probability of Failure

The annual probability of a failure of structures can be evaluated by using the hazard and the fragility results. The evaluation program is shown in Figure 1, which can be presented as the hazard curve, fragility curve and the quantitative value of an annual probability of a failure.

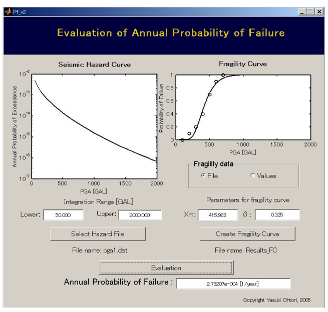


Figure 1. The Program for Calculation of Annual Probability of Failure

2.2 Fragility Analysis

In this study, the simple fragility analysis technique was introduced by using only one seismic input motion. The proposed method used the relation regarding the seismic response and input seismic motion. The structural probability of a failure regarding as the input seismic motion is defined the equation (1).

$$F_A(A) = \int_0^{\infty} f_R(A, x_R)\left[\int_0^{x_R} f_C(x)dx\right]dx_R \quad (1)$$

Where, f_R is a probability density function of a seismic response, f_C is that of the capacity.

3. Numerical Example

3.1 Numerical Model of EDG System

The analytical model for the base-isolated EDG is shown in Figure 2. This model was already used in a previous study [3]. The failure criterion for the fragility analyses are assumed as a maximum acceleration response of 1.2g and a maximum displacement limit of 5cm.

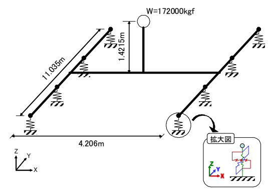
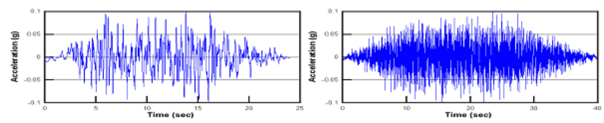


Figure 2. The Numerical Model of EDG System

3.2 Input Seismic Motion

For the seismic analysis, two kinds of seismic input motion were selected. Those are the artificial seismic motions which are generated based on NRC and UHS spectrum. The time history of an input motion is shown in figure 3. The seismic response analyses were performed at 0.2g to 3g.



(a) NRC (b) UHS

Figure 3. The Time History of Input Seismic Motion

3.3 Fragility Results

The fragility analysis was performed as an isolation and non-isolation EDG system. Figure 4 shows the fragility analysis results according to the input seismic motion and the damping coefficient. And the HCLPF values of the EDG systems are determined with the same parameters as shown in Figure 5. As shown in the Figure, in the case of the NRC wave, it is very difficult to decrease the HCLPF because of the limited displacement.

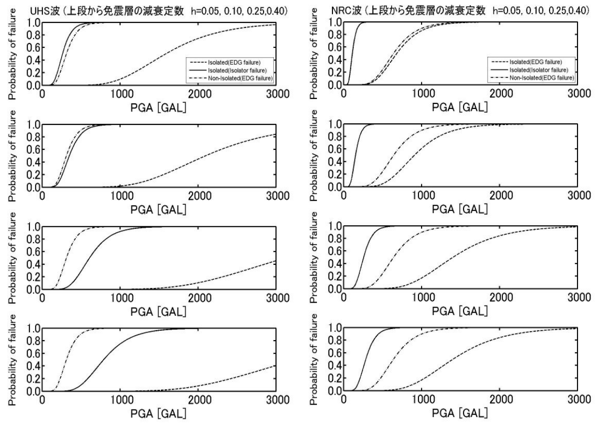


Figure 4. The Fragility Results according to the Input Seismic Motion and Damping Coefficient

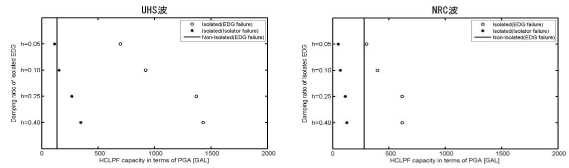


Figure 5. The HCLPF Value of EDG System

3.5 Seismic Hazard Curves

The hazard curves which are used in this study are developed for the Wolsung NPP site(129.4773°, 35.7127°). Two kinds of attenuation equations were used for this analysis [4]. The maximum magnitudes were determined as 6.3-7. 0. The hazard curves which were used in this study are shown in the Figure 7.

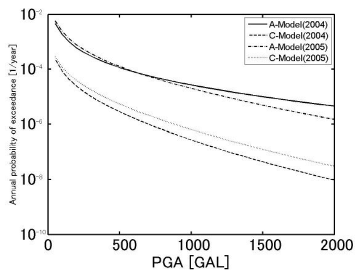


Figure 6. The Hazard Curves for Analysis

3.5 Annual Probability of a Failure

The annual probabilities of a failure are determined and tabulated by using the previous fragility and hazard results as shown in Table 1. As shown in Table 1, in the case of a UHS wave, the annual probability of a failure decreases by 1/3.4-1/4.9 according to the isolation system. But in the case of the NRC wave, the annual probability of a failure increases by 5.2-8.5times according to the isolation system. These results are caused by the maximum displacement limit which governs the failure criteria. If the maximum displacement limit increase, the annual probability of a failure decreases for an isolation system.

Table 1. The Annual probability of Failure of EDG

Seismic Hazard Curves		Annual Probability of Failure			
Attenuation Equation	Source Model	UHS		NRC	
		Non-isolated EDG	Isolated EDG	Non-isolated EDG	Isolated EDG
2004	A-Model	3.329E-04	9.799E-05	8.831E-05	4.650E-04
	C-Model	1.209E-05	2.457E-06	2.125E-06	1.807E-05
2005	A-Model	4.144E-04	1.067E-04	9.456E-05	5.893E-04
	C-Model	2.005E-05	4.645E-06	4.063E-06	2.888E-05

4. Conclusion

A risk analysis method for an isolated EDG is developed. Using the method, the annual probabilities of a failure were determined for the conventional and isolated EDG system. Through this study, the seismic risk of an EDG system can be determined quantitatively and it is possible to establish the effectiveness of an isolation system.

ACKNOWLEDGEMENT

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