Determination of the Effective HCLPF Values for Improving the Seismic Safety of Yonggwang Nuclear Units 5&6

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1. Introduction

All of the safety-related structures, systems and components in a nuclear power plant should be designed to have a sufficient seismic capacity. However, even though the facilities in the plant are designed to be safe for a design basis earthquake, they may be damaged or failed by strong ground motions greater than the design basis earthquake as well as a particular earthquake of which the frequency contents are different from those of the design ground motions. Due to these uncertainties in the seismic design, it is necessary to improve the seismic capacities of the safety facilities to ensure the seismic safety of a plant during earthquakes.

Recently, the applicability of a seismic isolation system to nuclear equipment or components has been investigated for improving their seismic capacities. Choun and Choi [1,2] and Kim, et al. [3] evaluated the effectiveness and performance of seismic isolation systems for nuclear equipment and components. It was found that the seismic isolation system can reduce the transmitted seismic force to the equipment or components by up to 70%. Therefore, they concluded that the seismic isolation system is more effective in increasing the seismic safety of the existing nuclear power plants.

This study evaluates the seismic safety of the Yonggwang Nuclear Units 5&6 in the case that the seismic capacities of the components are increased, and then suggests the effective seismic capacities of the components for the plants.

2. Contribution of Components for Core Damage

Figure 1 shows the contribution of an equipment or component failure for a core damage in Yonggwang Nuclear Units 5&6 [4]. Based on the contribution shown in Figure 1, four high contribution components - Diesel Generator (29.8%), Offsite Power (18.3%), Condensate Storage Tank (17.7%), and Battery Rack (9.3%) - are selected for a detailed investigation. The contribution of the failure of the four selected components and the General Transient event occupies about 90% for the earthquake-induced core damage. The failure modes of the four selected components are summarized in Table 1. The failure mode of the Diesel Generator is known as a concrete coning by pulling it out of its anchor bolts, and the HCLPF (High Confidence and Low Probability of Failure) value of the Offsite Power is the lowest.

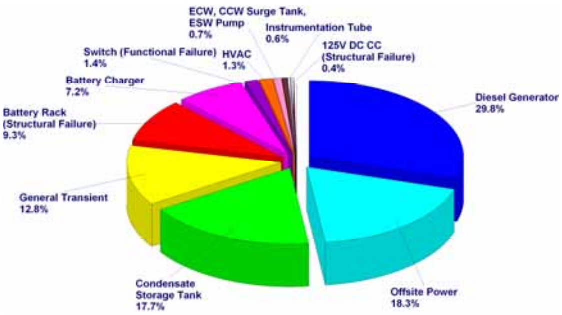


Figure 1 Contribution of components for core damage

Table 1 Failure modes of selected components

Components	Failure mode	Mean frequency of failure	HCLPF (g)
Diesel Generator	Concrete coning	1.95E-06	0.38
Offsite Power	Functional failure	1.12E-04	0.15
Condensate Storage Tank	Structural failure (Sliding)	1.16E-06	0.41
Battery Rack	Structural failure	6.11E-07	0.51

3. Effect of the Seismic Capacities of Components on Core Damage Frequency

The seismic capacities of the components have a significant influence on the core damage frequency (CDF) according to the peak ground acceleration (PGA) as shown in Figure 2. The effect of the seismic capacities of the components on the CDF is remarkable in the PGA range of 0.3g to 0.5g. If the seismic capacities of all the selected components are improved, the CDF may be decreased by about 5% and 30% at 0.2g and 0.3g, respectively. At 0.4g, increasing the

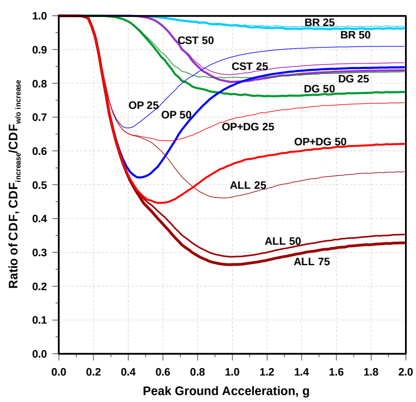
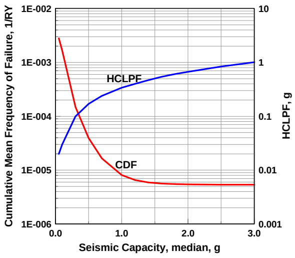


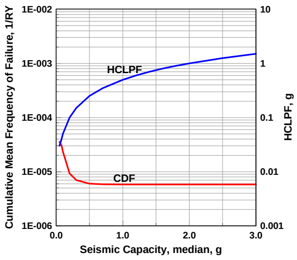
Figure 2 CDF ratios with increase of the seismic capacity of selected components

seismic capacity of the Offsite Power will be more effective, and, under 0.6g, increasing both the seismic capacities of the Offsite Power and the Diesel Generator will be more effective. In the case of the Offsite Power, at 0.4g, an increase of its seismic capacity of 25% and 50% leads to a reduction of 33% and 45% in the CDF, respectively.

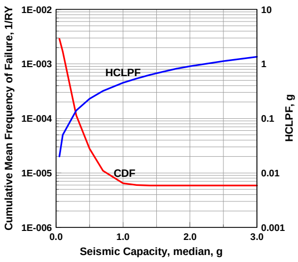
Figure 3 shows the relations between the HCLPF of the component and the CDF according to the median value of the seismic capacity, and Table 2 summarizes the CDF for the different HCLPF values of the selected components. From Figure 3 and Table 2, the effective HCLPF values for the Diesel Generator, Offsite Power, Condensate Storage Tank, and Battery Rack are determined as 0.84g, 0.35g, 0.63g, and 0.63g, respectively. For the larger HCLPF values than the effective value, even though the seismic capacity increases, the CDF does not decrease any more. In the case that all the four selected components have an increased seismic capacity, the CDF decreases to 2.30E-06 from 6.96E-06.



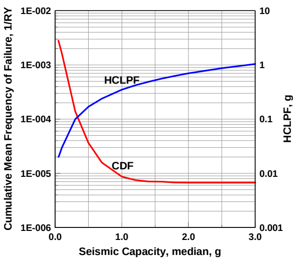
(a) Diesel Generator



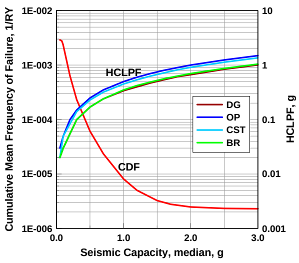
(b) Offsite Power



c) Condensate Storage Tank



(d) Battery Rack



(e) All

Fig. 3 Relations between the HCLPF of the components and the core damage frequency

Table 2 Variation of the core damage frequency for different HCLPF of the components

Diesel Generator		Offsite Power		Condensate Storage Tank		Battery Rack	
HCLPF	CDF	HCLPF	CDF	HCLPF	CDF	HCLPF	CDF
0.02	2.79E-03	0.03	3.58E-05	0.02	2.89E-03	0.02	2.82E-03
0.03	1.67E-03	0.05	2.38E-05	0.05	1.68E-03	0.03	1.66E-03
0.10	1.49E-04	0.15	6.98E-06	0.14	1.14E-04	0.10	1.39E-04
0.17	3.94E-05	0.25	6.04E-06	0.23	2.78E-05	0.17	3.65E-05
0.24	1.65E-05	0.35	5.86E-06	0.32	1.10E-05	0.24	1.58E-05
0.34	8.13E-06	0.50	5.82E-06	0.45	6.44E-06	0.35	8.67E-06
0.40	6.59E-06	0.60	5.82E-06	0.54	5.99E-06	0.42	7.50E-06
0.47	5.95E-06	0.70	5.82E-06	0.63	5.88E-06	0.49	7.06E-06
0.54	5.65E-06	0.80	5.82E-06	0.72	5.86E-06	0.56	7.02E-06
0.61	5.52E-06	0.90	5.82E-06	0.82	5.86E-06	0.63	6.79E-06
0.67	5.45E-06	1.00	5.82E-06	0.91	5.85E-06	0.70	6.76E-06
0.84	5.39E-06	1.25	5.82E-06	1.13	5.85E-06	0.87	6.73E-06
1.01	5.38E-06	1.50	5.82E-06	1.36	5.85E-06	1.04	6.72E-06

4. Conclusion

For the Yonggwang Nuclear Units 5&6, the Diesel Generator, Offsite Power, Condensate Storage Tank, and Battery Rack contribute to the CDF remarkably. When the Diesel Generator or Condensate Storage Tank has an increased seismic capacity, the CDF will be decreased significantly, while in the case of the Battery Rack the CDF does not decrease significantly. Increasing the seismic capacities of the Diesel Generator by more than 25% can improve the seismic safety of the plant by more than 16%. In the case of increasing the seismic capacities of the components which exert a high contribution to a core damage, the CDF may be decreased by more than 50%. In the case that all the four selected components have an increased seismic capacity, the CDF decreases to 2.30E-06 from 6.96E-06.

The effective HCLPF values for the Diesel Generator, Offsite Power, Condensate Storage Tank, and Battery Rack are determined as 0.84g, 0.35g, 0.63g, and 0.63g, respectively.

Acknowledgement

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REFERENCES

[1] Y.S. Choun and I.K. Choi, “Effect of Seismic Isolation of Nuclear Plant Equipment on Core Damage Frequency,” *Proceedings of the Korean Nuclear Society 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 Korean Nuclear Society Spring Meeting*, 2003.

[3] M.K. Kim, Y.S. Choun, I.K. Choi, and J.M. Seo, A Study of Seismic Capacity of Nuclear Equipment with Seismic Isolation System, KAERI/TR-2765/2004, Korea Atomic Energy Research Institute, 2004.

[4] Korea Electric Power Company, External event analysis for Yonggwang Units 5&6 PSA, 2001.