The Seismic Fragility Evaluation of an Offsite Transformer according to Aging Effects

Min Kyu Kim, In Kil Choi
Integrated Risk Assessment Center, Korea Atomic Energy Research Institute, Youseong, Daejeon, minkyu@kaeri.re.kr

1. Introduction

A seismic fragility analysis was performed, especially for an aged electric power transmission system, in this study. A real electric transformer system for Korean Nuclear Power Plants was selected for the seismic fragility evaluation. In the case of a seismic fragility analysis we should use design material properties and conditions. However material properties and environmental conditions of most structures and equipments are changed according to a lapse of time. Aging conditions greatly affect the integrity of the structures and equipments at NPP sites, but it is very difficult to estimate them qualitatively. Integrity of an anchor bolt system was considered with the aging conditions for an electric transformer system. At first, a seismic fragility analysis was performed for a fine condition for an electric transformer system. After that, a seismic fragility analysis according to the fastener of an anchor bolt system was conducted. This study showed that a looser anchor bolt creates seismic responses and seismic fragility changes of more 10%.

2. Evaluation of Anchorage Force

A nominal strength of an anchor bolt can be determined using eq. (1). (ACI 318)

$$N_s = nA_{se}f_{ut} \qquad (1)$$

where,

N_s : nominal strength of anchor bolt

n : number of anchor bolt

A_{se} : cross-sectional area of anchor bolt

f_{ut} : tensile strength of anchor steel

Using the equation (1), we can determine an ideal nominal strength of an anchor bolt. In the case of an aging condition, the nominal strength is decreased as 90% to 50%.

3. Seismic Response Analysis

The drawing of a target transformer is shown in Fig. 1. This transformer is located in the Ulchin units 5&6 NPP site. The dimensions of the transformer are summarized in Table 1.

For the numerical analysis, a commercial computer program SAP2000 was used and a numerical model was constructed as shown in Fig. 2. The transformer body was modeled as a steel frame structure and the two bushings were modeled as ceramic pipes. The analyses were performed about a fixed boundary condition, considered as an anchor bolt axial force condition and aging conditions. In the case of the aging conditions, a decrease of a fastening force of an anchor was considered as 90%, 80%, 70%, 60% and 50%. The fastening force of an anchor was calculated by using equation (1).

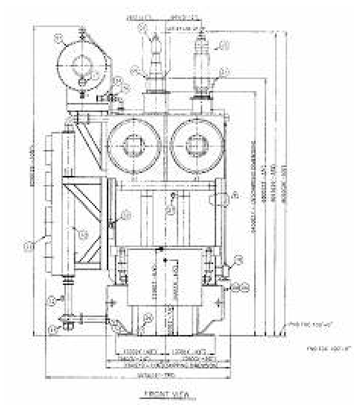


Fig. 1 The Offsite Transformer of Ulchin 56 NPP Site

Table 1. Description of Offsite Transformer

Dimension(mm)	Width	6,980
	Depth	5,075
	Height	8,055
Weight (tf)	Transportation	145
	Total	186

Fig. 2 The Numerical Model of Offsite Transformer

For the seismic response analysis, a US NRC design spectrum is used. The maximum acceleration responses according to the boundary conditions are summarized in Table 2. These results present a case of 0.2g peak ground acceleration. As shown in Table 2, the maximum accelerations at specific points were compared according to the boundary conditions. These results show that the decrease of the nominal strength of the anchor bolt forces create larger acceleration responses. As shown in Table 2, the maximum acceleration responses increase almost 5% where we only consider the nominal strength of an anchor bolt.

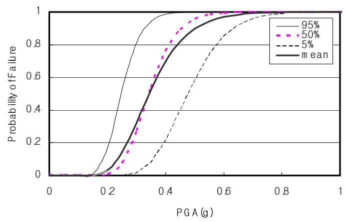
Table. 2 The Peak ground Accelerations according to the boundary condition of Target Transformer

		Maximum Acceleration (g)	
		Top of Bushing	Connection of Bushing
Fix		0.405	0.351
Anchor		0.430	0.370
Decrease of Fasten Anchor Force	90%	0.425	0.361
	80%	0.448	0.379
	70%	0.474	0.393
	60%	0.481	0.391
	50%	0.473	0.412

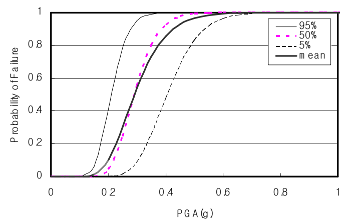
4. Seismic Fragility Analysis according to the Aging Condition

The seismic fragility was evaluated according to the anchorage conditions. The failure modes of the Transformer were a sliding, overturning and failure of a bushing. In this study, the failure of a bushing was selected for the evaluation of the seismic fragility of the Transformer. That is because, in the case of a previous earthquake, the governing failure mode of the Transformer system was revealed as a failure of a bushing (FEMA, 1990). The failure criteria can be decided by using the seismic PSA manual from the Japan Society of Nuclear Engineering (2006). The failure criterion was decided as the maximum response acceleration at the connection point between a bushing and the transformer body which was 0.6g. This criterion follows the seismic PSA manual in Japan. As a result, the seismic fragility curves in the case of a fixed condition and a 50% decrease of the nominal strength cases are shown in Fig. 3. But in this figure, it is very difficult elucidated the variation of the seismic fragility.

The HCLPF values according to the aging conditions are summarized in Table 3. As shown in Table 3, the HCLPF values are decreased according to the progress of an aging. Actually, when only considering the anchorage nominal strength instead of fixed boundary condition, the HCLPF values change from 0.171g to 0.162g. They decrease more according to the progress of an aging condition. Finally, if the nominal strength of anchorage decreases by 50%, the HCLPF decreases by almost 10%. Finally, it can be concluded that the aging condition of an anchorage system can greatly affect to the seismic safety of the Transformer.



(a) Fixed Condition



(b) Aging condition(50%)

Fig. 3 The Seismic Fragility Curves According to the Aging Conditions of Offsite Transformer

Table 3. The HCLPF Values according to the aging condition of Offsite Transformer

	fix	anchor	90	80	70	60	50
HCLPF(g)	0.171	0.162	0.166	0.158	0.153	0.153	0.146

5. Conclusion

A seismic fragility analysis performed according to the aging condition. Aging conditions greatly affect the integrity of the structures and equipments at NPP sites, but it is very difficult to estimate them qualitatively. Integrity of an anchor bolt system was considered with the aging conditions for an electric transformer system. At first, the seismic fragility analysis was performed for a fine condition for an electric transformer system. After that, a seismic fragility analysis according to the fastener of an anchor bolt system was conducted. This study showed that a looser anchor bolt creates seismic responses and seismic fragility changes of about more 10%.

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