Transactions of the Korean Nuclear Society Autumn Meeting
Goyang, Korea, October 24-25, 2019

Analysis of setting the ground motion level in seismic probabilistic safety assessment

Jisuk Kim [a], Man Cheol Kim [a*]
[a]*Department of Energy Engineering, Chung-Ang University, 84 Heukseok-ro, Dongjak-gu, Seoul, Korea*
[*]*Corresponding author: charleskim@cau.ac.kr*

1. Introduction

Seismic probabilistic safety assessment(SPSA) is a method of quantitatively evaluating the risk of nuclear power plants due to the earthquake by deriving core damage frequency. In general, SPSA should be performed by the hazard analysis, fragility analysis, system modeling, and quantification.[1] The core damage frequency, which is the result of SPSA, is derived by convolution integrations of the hazard curve and fragility curve. However, an approximate method which is discretization of the ground motion level can be applied instead of convolution integrations. This method is a convenient way to derive the core damage frequency because it can overcome the difficulty of the convolution integrations and limitation of the calculation. It is important how the ground motion levels are divided in this method. If the intervals of the ground motion level are divided too roughly, it may be difficult to examine the impacts of core damage on the ground motion level. This paper analyzes the impacts of the number of the ground motion level intervals using SPSA example model.

2. Results of SPSA example model

2.1 SPSA example model

This paper assumes a simple example model of SPSA. In this example, only the primary seismic event tree is considered whose sequence states are mostly core damage. The seismically induced initiating events requiring detailed analysis is connected to the secondary seismic event tree, which is not considered in this analysis. The primary seismic event tree consists of the ruptures and failures of structure, system, and component(SSCs) which are not considered during internal events but are considered to be significant in seismic events.[2] The list of the SSCs in the primary seismic event tree and the fragility data of them are presented in Table I.[3] The event tree and fault tree for the example model are shown in Fig. 1. and Fig. 2. During the quantification, instead of the convolution integrations, the fragility is calculated by the representative value of each interval using two computer codes, iPro-Seis and PRASSE0.

Table I: Fragility data of example model

Event Name	Description	A_m	β_r	β_u
SEIS-125DC	Failure of 125V DC'	0.50	0.30	0.35
SEIS-120AC	Failure of 120V AC	0.50	0.30	0.35
SEIS-480AC	Failure of 480V AC	0.50	0.30	0.35
SEIS-CTMT	Rupture of containment building	2.00	0.30	0.35
SEIS-AUXBLD	Rupture of Auxiliary building	1.50	0.30	0.35
SEIS-LOOP	Loss of Offsite power	0.30	0.30	0.45

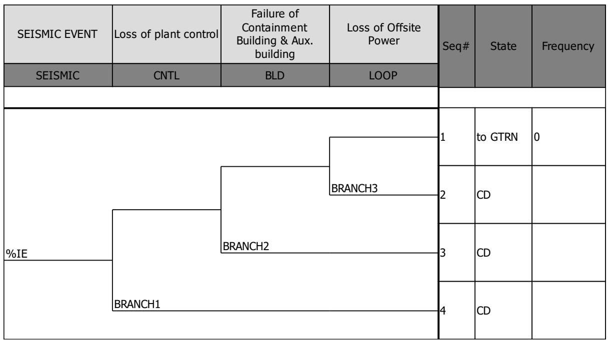

Fig. 1 Event tree of example model

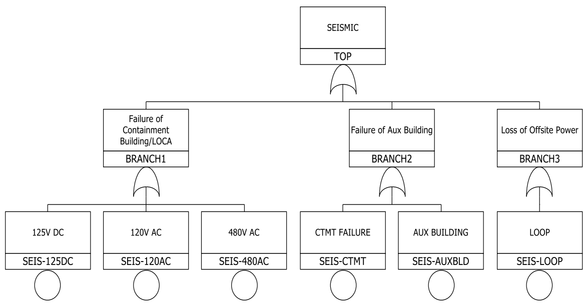

Fig. 2 Fault tree of example model

2.2 The results of example model

We compare the core damage frequencies from Sequences 2, 3, and 4 of SPSA example model depending on the number of the ground motion level intervals. For this reason, all other conditions except the number of ground motion level intervals, such as hazard curve and fragility data, are assumed to be same. The ground motion level analyzed in this analysis is between

0.1g and 1.0g. There ground motion level is divided into four cases, Case 1, Case 2, Case 3, and Case 4 with one, two, five, and nine intervals, respectively. The ground motion level, the representative level, and initial event frequency for each interval are shown in Table Ⅱ.

Table Ⅱ: The ground motion level and initial event frequency for each interval

	Ground motion level(g)			Frequency of Initiating event(/yr)
	Min	Max	Representative level	
Case 1	0.1	1.0	0.55	5.304E-04
Case 2	0.1	0.5	0.30	5.225E-04
	0.5	1.0	0.75	7.955E-06
Case 3	0.1	0.3	0.20	4.904E-04
	0.3	0.5	0.40	3.207E-05
	0.5	0.7	0.60	5.960E-06
	0.7	0.9	0.80	1.635E-06
	0.9	1.0	0.95	3.602E-07
Case 4	0.1	0.2	0.15	4.140E-04
	0.2	0.3	0.25	7.640E-05
	0.3	0.4	0.35	2.310E-05
	0.4	0.5	0.45	8.970E-06
	0.5	0.6	0.55	4.020E-06
	0.6	0.7	0.65	1.940E-06
	0.7	0.8	0.75	1.049E-06
	0.8	0.9	0.85	5.860E-07
	0.9	1.0	0.95	3.602E-07

Case 1 is interpreted as having a single value in all regions because it yields one result corresponding to 0.55g to represent the interval between 0.1g and 1.0g. If the interval is divided into two, the result is divided into two representative ground model levels, 0.3g for the interval from 0.1g to 0.5g and 0.75g for the interval from 0.5g to 1.0g. In this example, the core damage frequency is high in the low ground motion level, but the frequency is low in the high ground motion level. If we assume one ground motion level interval like Case 1, the core damage frequency is evaluated more conservatively than the actual value for the interval from 0.5g to 1.0g. In addition, it is impossible to have a good grasp the realistic tendency of the core damage frequency. In other words, the proportion of the core damage frequency in each interval can be examined if the ground motion level is divided into more intervals.

In addition, the results of the four cases are compared with the results of the convolution integrations using PRASSE, which is quantification code for SPSA developed by KAERI. Fig. 3. shows the relative error when the results are compared with that of convolution integrations. As the ground motion level is finely divided, the relative error is reduced.

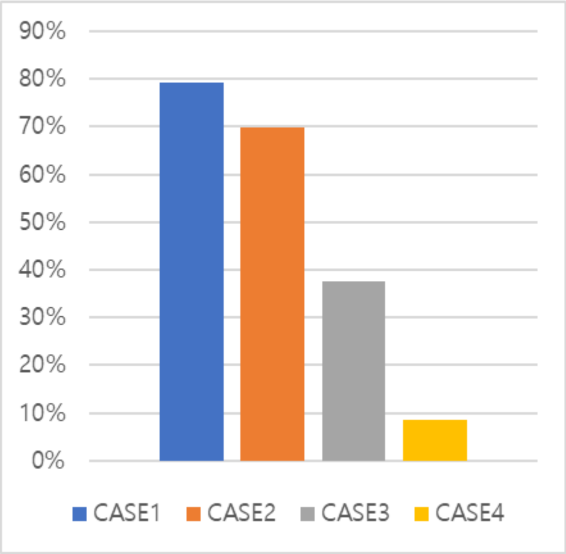

Fig. 3 Comparison of the results for each section and results of convolution integrations

3. Conclusions

In the SPSA, the core damage frequency is normally derived by convolution integration of the hazard curve and the fragility curve. This method has difficulties and limitation of convolution integration. In place of the method, the core damage frequency can be approximated by dividing the ground motion levels into multiple intervals. This method can produce the results more conveniently. It also has the advantage that it can analyze the impacts of the core damage frequency depending on the ground motion level.

It is necessary to divide the ground motion level into appropriate number of intervals. If the intervals of ground motion level are divided too roughly, the impacts of ground motion level on core damage frequency cannot be examined. On the other hand, it can be seen that the finer the intervals of the ground motion level can be divided, the smaller the error compared to the value from convolution integration can be achieved.

REFERENCES

[1] J. H. KIM, I. K. CHOI, M. K. KIM, S. H. HAN AND J. H. PARK, "KAERI/TR-4649/2012, Development and Validation of the Seismic Probabilistic Safety Assessment Software PRASSE", KAERI, Daejon, Korea 2012.
[2] International Atomic Energy Agency, "IAEA-TECDOC-724, Probabilistic safety assessment for seismic events", IAEA, Vienna, Austria 1993.
[3] Electric Power Research Institute, "EPRI 3002000709, Seismic Probabilistic Risk Assessment Implementation Guide", EPRI, 2013.