Over View of Development of PRASSE: Probabilistic Risk Assessment of Systems for Seismic Events

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1. Introduction

The purpose of a seismic Probabilistic Safety Analysis (PSA) is to determine the probability distribution of core damage due to the potential effects of earthquakes. The seismic PSA is performed based on four steps, seismic hazard analysis, component fragility evaluation, plant system and accident sequence analysis, and consequence analysis [1]. In this study, a computer program PRASSE (Probabilistic Risk Assessment of Systems for Seismic Events) was developed for calculating an initiating event frequency and a failure probability of equipment.

2. Development of Seismic PSA Module

2.1 Initiating Event Frequency Calculation Module

The procedure of the code for calculating initiating event frequency caused by seismic accident is depicted in Fig. 1. For easy use and a reduction in the input errors, a GUI system was developed. In the GUI, a user can check the input parameters, such as seismic hazard curves and component fragility data, with a graphical output. In the accident sequence analysis, the input in the form of text format of Boolean equations with predefined rules or subroutines are required. These types of input rules can cause an error during the generation of Boolean equations or a program coding error. To prevent this error from complex rules or program coding, Event Tree (ET) and Fault Tree (FT) editor was introduced in this code. From ET/FT editors, Boolean expressions are generated automatically for each release category as shown in Fig. 2.

Plant level fragility curves are obtained by combing the fragilities of individual components according to Boolean expressions. This system fragility includes uncertainty because of the existence of component uncertainties. However it cannot be estimated directly from the deviation of component uncertainties. Therefore uncertainty analysis should be applied for calculating system uncertainty. A straightforward method is to estimate system uncertainty from the outcome of system fragilities calculated by numerous samples of component. In this code, Monte Carlo simulation method and Latin Hypercube sampling method were adopted for sampling based uncertainty analysis [2]. Uncertainty of plant level fragility is represented by 5% and 95% system fragility curves. In this code, the two methods can be selected with various sample sizes and the system fragility curve of each confidence level is plotted with the mean curve.

The plant damage state frequency is obtained by convolving plant level fragilities with the seismic hazard curves. The uncertainty of the event frequency is also represented by 5% and 95% confidence levels. The uncertainty of hazard is also reflected in the uncertainty of the event frequency.

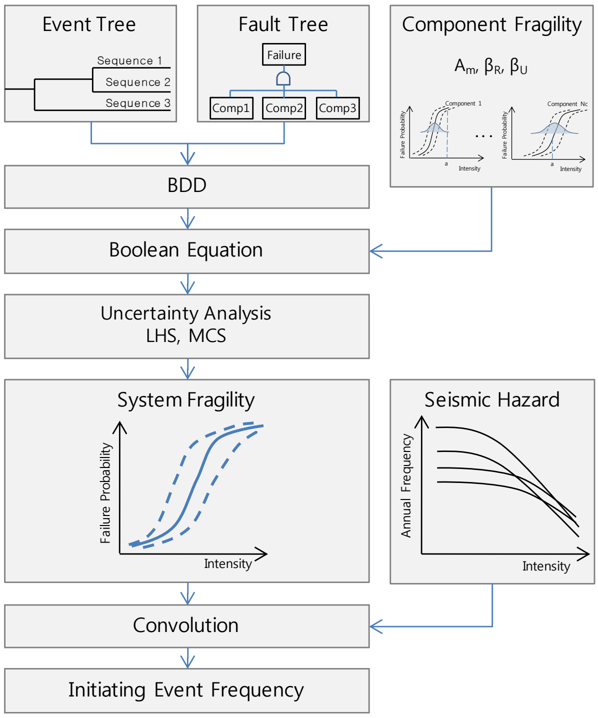

Fig. 1. Procedure of Seismic Initiating Event Frequency Calculation

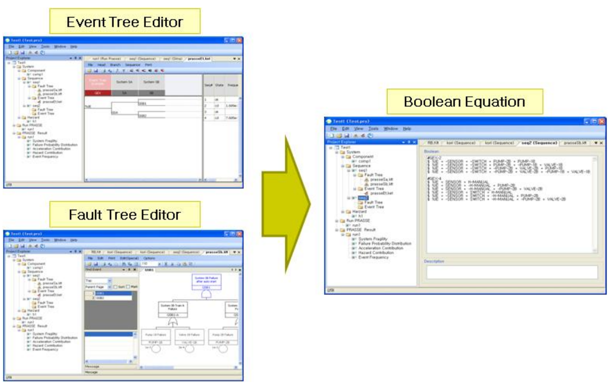

Fig. 2. Automatic generation of Boolean equations by ET/FT editor

2.2 Component Failure Probability Calculation Module

The conditional probability of a failure of important structures and equipment is necessary for the detailed plant level seismic PSA. The component failure probability is usually defined by fragility curve parameters, which are median capacity and variations of randomness and uncertainty. Sometimes the data of a failure probability versus a seismic intensity is given by an experiment or a seismic analysis. In this case, the regression analysis is performed to find optimal fragility parameters. The failure probability of components at the given acceleration level is calculated from these fragility parameters by the lognormal distribution function. For the component inducing random failure, the failure probability is calculated using a mean failure rate and an error factor.

3. Evaluation of Seismic PSA

ET represents the general event scenario initiated by a seismic accident and FTs are usually attached to the branches of ET to define the cause of sub-system failures. For the simplified seismic PSA, only these initiating event are used. But there could be a basic event whose failure probability can be affected by a seismic accident. Therefore the basic event which is not related to the seismic initiating event should be considered. In this full seismic PSA, an earthquake level, which is usually defined as an acceleration range, is determined first. Then the PRASSE IE (Initiating Event) module calculates the initiating event frequencies using the seismic hazard curves in the given acceleration range and the PRASSE component module calculates the failure probability of basic events at the representative acceleration level of the given range as shown in Fig. 3. The result from each module is saved as the table format with IE and component information and the uncertainty value as shown in Fig. 4. These results are used as the input of main PSA program to evaluate the core damage frequency and radioactive release caused by earthquake accident.

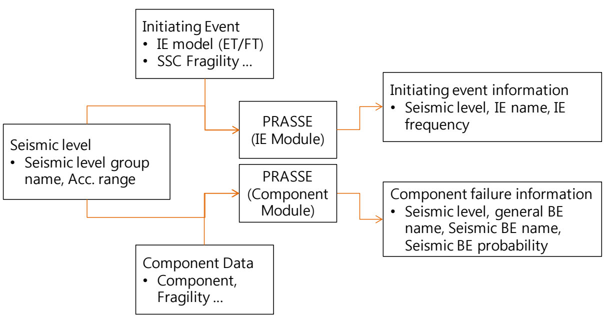

Fig. 3. Procedure of IE and Component modules

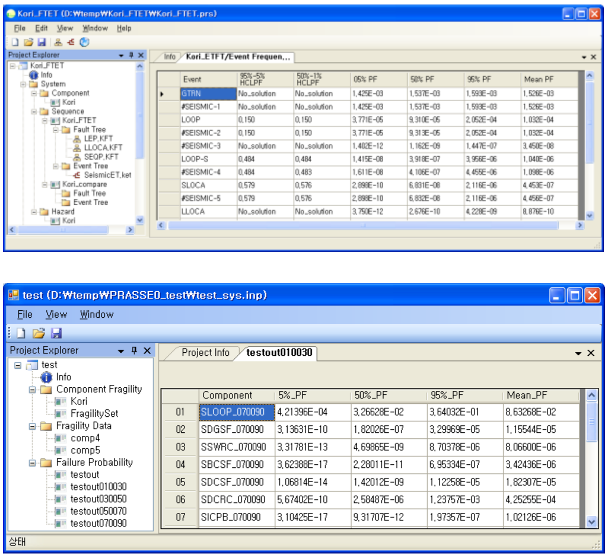

Fig. 4. Output data from the PRASSE.

4. Conclusions

In this study, the seismic PSA program was developed for advanced evaluation of an earthquake accident. The initiating event frequency calculation module and the component failure probability calculation module were developed and integrated. The GUI system such as the ET/FT editor for the accident sequence analysis was adjusted in this program.

ACKNOWLEDGEMENT

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[2] J. H. Kim, I. Choi and J. Park, Uncertainty Analysis of System Fragility for Seismic Safety Evaluation of NPP, Nuclear Engineering and Design, Vol. 241, pp.2570-2579, 2011.