Software Development to Select and Scale Recorded Earthquake Compatible with Target Response Spectrum

Jeong-Gon Ha [a*], Tae-Hyun Kwon[a]
[a]*Structural Safety and Prognosis Research Division, Korea Atomic Energy Research Institute, 111, Daedeok-Daero 989 beon-gil, Yuseong-gu, Daejeon, Korea*
[*]*Corresponding author: jgha@kaeri.re.kr*

1. Introduction

Many factors such as the shape of the structure and material properties can affect the response of a structure to an earthquake, and in particular, the seismic excitation is one of the most critical input to dominate the response [1].

In a conventional evaluation of the seismic safety for an existing nuclear power plant structure, artificially simulated seismic waves were used, which is matched the design spectrum presented in U.S. NRC Regulatory Guide 1.60 [2] or the uniform hazard spectrum at a specific site [3].

This approach shows the possibility of conservative results because one seismic motion has energy over the entire frequency similar to the target spectrum. So, it is difficult to understand the behavior during a real earthquake motion accurately. To compensate for the shortcomings of the artificial seismic waves, various selection, and scaling methods for input excitations have been proposed [4]. And selecting and scaling a suit of recorded ground motion whose mean spectrum matches the target spectrum is an intuitive and efficient method.

However, several technical efforts are required to select the recorded earthquakes with some criteria, such as the construction of the database and the implementation of a selection algorithm. Therefore, in this study, the software was developed to select and scale recorded earthquakes compatible with the target spectrum. It is consisting of some modules to determine the criteria and also the graphical user.

2. Algorithm and Development of Software

2.1 Earthquake Selection Algorithm

In this software, the main algorithm for selecting seismic motions from the recorded earthquake motions database is the sequential selection method proposed by Ha et al. [5]. Selecting criteria is the difference between the mean spectrum of the chosen motions and the target spectrum in logarithmic scale. The determination method of the difference value is described in Fig. 1 and Equation (1-3). For selecting 1st to the nth earthquake, the earthquake motion with the minimum difference is selected in each iteration, and the selected one is excluded from the database. This method is not only intuitive but also efficient because it requires much less computation compared to considering all seismic motions combinations in the database.

$$SSE_s = \frac{1}{n_p}\sum_{i=1}^{n_p}[lnS_a^{target}(T_i) - \mu_{lnS_a(T_i)}]^2 \quad (1)$$

$$\mu_{lnS_a(T_i)} = \frac{1}{k}\sum_{j=1}^{k}[\ln s_j \times S_{aj}(T_i)] \quad (2)$$

$$s = \exp\left(\frac{1}{n_p}\sum_{i=1}^{n_p}[lnS_a^{target}(T_i) - lnS_a(T_i)]\right) \quad (3)$$

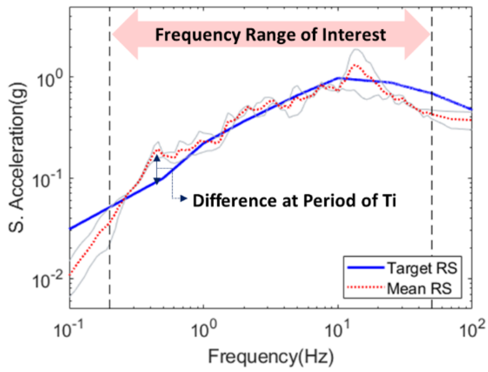

Fig. 1. Difference between mean spectrum of selected earthquake motions and target spectrum.

2.2 Process and Development Environment

Fig. 2 shows the flow chart of the entire program, with essential features and options to choose for each step. This software supports every procedure from creating an earthquake database library to finally selecting the desired number of seismic motions.

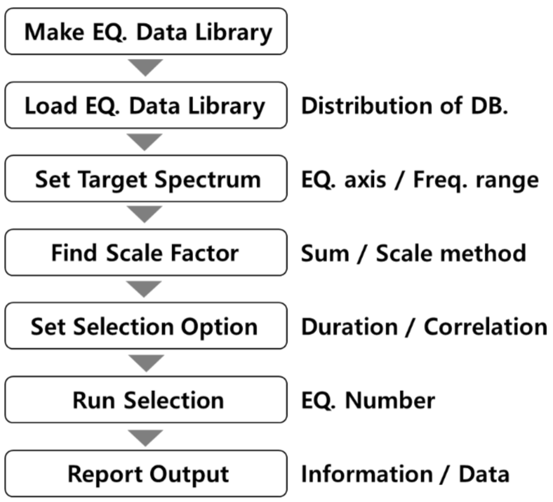

Fig. 2. Flow chart of software process.

In this study, Windows 10 and Python 3.7 were selected as the program development environment because there could be many restrictions on using a paid language such as MATLAB. Also, the final program is packaged as a stand-alone executables file so that it can be executed independently, even in an environment where Python is not installed.

3. Main Features in Program

3.1 Earthquake Database

The quality and quantity of the earthquake database are crucial when selecting a recorded seismic motion. There are many types of databases to provide recorded earthquake information in the world. This program is configured to efficiently utilize the NGA-WEST database provided by the U.S. Pacific Earthquake Engineering Research (PEER). Also, the user can construct the database separately if necessary. Fig. 3 describes the screenshot of the NGA-WEST1 earthquake database. At the bottom part, the distribution of data was summarized according to the seismic parameter, such as magnitude and distance.

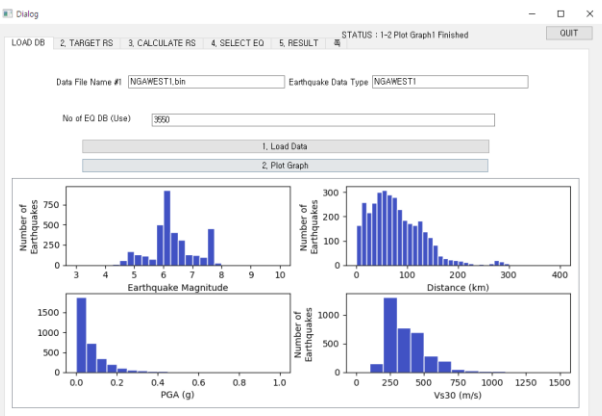

Fig. 3. Screenshot of Load Earthquake Database.

3.2 Selection of Ground Motion

Since this program prioritizes the application to nuclear facilities, the primary target spectrums are the design spectrum and the uniform hazard spectrum at the Uljin site. In addition, in the 'Set Selection Option' phase, limit values for the earthquake duration and correlation coefficient values can be set so that they could be reflected in the selection process. These options are to apply that the requirements of the input motions presented in Standard Review Plan 3.7.1 [6].

Fig. 4 describes the example of the selection result from the NGA-WEST1 database. The mean spectrum and the target spectrum were depicted together, and the difference between two was illustrated for user identification.

Fig. 4. Screenshot of setting selection option and final results of selected earthquake motions.

4. Conclusions

The recorded earthquake time histories were selected compatible with the uniform hazard spectrum for the (NPP) in Korea. The selection process was conducted based on the characteristics of the domestic NPP site and some criteria of standards. Still, additional considerations for various factors, such as frequency range and variation of the selected earthquake, are necessary.

Acknowledgement

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