Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

High Frequency Earthquake Ground Motion Research - Selection of Equipment for Seismic Fragility Test

In-Kil Choi [a*], Seunghyun Eem [a]
[a]*Korea Atomic Energy Research Institute, Daejeon, Korea*
[*]*Corresponding author: cik@kaeri.re.kr*

1. Introduction

Recently, strong earthquakes that affect the operation of close nuclear power plants occurred in Korea. Gyeongju earthquake, M5.8, occurred in 2016, and followed by Pohang earthquake, M 5.4, in 2017. The recorded earthquake ground motion shows the typical characteristics of a high frequency ground motion which is different from that of the response spectrum used for the seismic design of Korean nuclear power plants. The high frequency ground motion was also issue in CEUS. To resolve the high frequency issue, a series of seismic fragility test was planned. In this paper, the procedure to select the equipment for seismic fragility test is introduced.

2. High Frequency Ground Motion Research Program

Due to the Gyeongju earthquake, 4 units of Wolsung nuclear power plants were manually shut down. The recorded acceleration at the plant site was less than the OBE (Operating Basis Earthquake) level. The OBE level of Wolsung plants is 0.1g. However, the spectral acceleration at some high frequencies exceed the OBE spectral acceleration. The recorded earthquakes show typical characteristics of high frequency ground motion [1]. The frequency content of the Gyeongju earthquake is very similar to that of a typical CEUS (Central and Eastern United States) site earthquake ground motion [2].

The high frequency research project which is similar to the high frequency program in US [3-5] was organized by KETEP. The main goal of the research project is to resolve the high frequency issue in Korean nuclear power plants, and to secure the seismic safety of nuclear facilities. This project include the following tasks.

- Soil-structure interaction effect considering the high frequency ground motions
- Ground motion development for tests and analyses considering Gyeongju earthquake
- Experimental study on the seismic capacity of safety related equipment
- High frequency ground motion effect to the reinforced concrete shear wall structures and anchorage

In this paper, the selection procedure for equipment tests will be introduced. The equipment selection was performed based on the three basic consideration, high frequency sensitivity, seismic risk contribution, and capacity of test facility. In the US high frequency program, most of the tests was performed for relays. Relay is known as a very sensitive component, and the functional failure of the relay governs the failure of electrical components.

3. Selection of Test Equipment

3.1. High frequency sensitive equipment

The earthquake response of an equipment is very much related to the fundamental frequency of the equipment. High frequency component can be significantly affected by the high frequency ground motions. The selected components and their fundamental frequency are listed in Table 1. Some components shows that the fundamental frequency is not higher than 10Hz, but those components contains various relays. The high frequency ground motion affects the functional failure of the electrical component due to the malfunction of the relays.

Table I: Preliminary Selection of High Frequency Sensitive Components

No	Component Name	Frequency (Hz)			
		NPP A	NPP B	NPP C	NPP D
1	Emergency DG	10.0	-	>33	>33
2	4.16kV SWGR	6.0	6.2	6.0	6.0
3	Regulating Transformer	16.16	9.49	9.9	9.9
4	125V DC Control Center	15.08	6.14	8.0	8.0
5	SI Inverter	14.07	-	13.8	13.8
6	120V AC Inverter(VBPSS)	15.57	-	13.8	-
7	CCW Heat Exchanger	20.0	10.97	21.0	21.0
8	Battery Rack	-	-	23.0	23.0
9	Battery Charger	-	-	11.5	11.5
10	ECW Compression Tank	-	-	>33	>33
11	ESW Pump	-	-	33.98	>33

3.2. Seismic risk contribution

The seismic probabilistic risk assessment is conducted to identify the risk contribution of the equipment. The Seismic-Induced Loss of Essential Power Event (LEP) is primary event which affects the core damage failure to nuclear power plants. The LEP is the event of failures that cause the safety-related system loss and the essential power loss of the equipment in the event of the station blackout. Therefore, the sensitivity analysis of the equipment for the LEP was performed. Table 2 listed the equipment which are related to the LEP.

Table II: Component of Loss of Essential Power Event

No	Component Name	HCLPF	Failure Modes
1	Diesel Generator	0.38	Concrete Coning
2	Battery Charger	0.41	Generic Function
3	4.16kV SWGR	0.48	Generic Structure
4	Battery Rack	0.51	Generic Function
5	480V Load Center	0.54	Generic Structure
6	125V DC Control Center	0.57	Generic Function
7	HVAC Ducting and Supports	0.62	Generic Structure
8	Switches	0.55	Generic Function
9	Auxiliary Building	0.62	Generic Structure
10	Inverter	0.49	Generic Function
11	Regulating Transformer	0.69	Generic Function

After constructing the event tree and fault tree of the LEP, an importance analysis is performed. Importance analyses, Fussel-Vesely, Risk Reduction Worth, and Risk Achievement Worth, are performed for the peak ground acceleration at 0.3g level for the LEP initiating event. Figure 1 shows the results of the Fussel-Vesely important measure of equipment for LEP. It is confirmed that the failure of the diesel generator greatly affect the risk of the nuclear power plant. The battery charger, 125V DC Control center 4.16kV SWGR, 480V LCC, Inverter and Regulating Transformer are electrical cabinets which will possibly be affected by the high-frequency earthquake.

3.3. Selection of Equipment

Considering the limited project period and budget, the test equipment was selected from the seismic risk point of view. The candidate equipment is the components included in the seismic PSA model. It means that the considered equipment has contribution to the seismic risk of a plant. The test equipment was finally selected from the point of view of seismic risk contribution, high-frequency sensitivity and the capacity of test facility. The selected test equipment are shown in Table III.

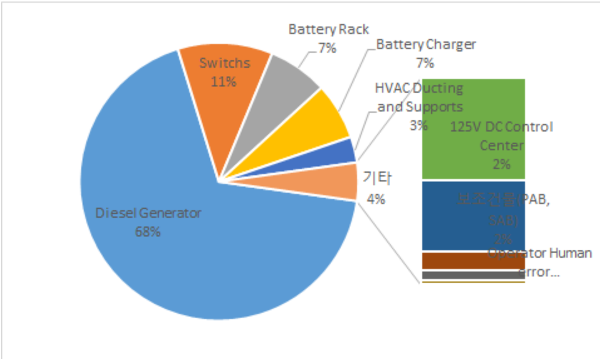

Figure 1: Fussel-Vesely Importance measure of Equipment for Loss of Essential Power Event

Table III: Selection of components for the High Frequency Ground Motion Research Program

No	Component Name	Selection Basis	
		Risk	High freq.
1	Diesel Generator	○	-
2	Battery Charger	△	○
3	125V DC Control center	△	○
4	4.16kV SWGR	△	○
5	Relays & Switches	○	○

4. Summary and Conclusion

The recent recorded ground motions of the Gyeongju and the Pohang earthquakes in Korea show typical characteristics of high frequency ground motion. The high-frequency research project is organized and the main goal of the research project is to resolve the high-frequency issue in Korean nuclear power plants. In this study, the selection of the equipment was performed for the high-frequency experimental study. The test equipment was selected from the point of view of seismic risk contribution, high-frequency sensitivity and capacity of the test facility.

Acknowledgment

This work was supported by the KETEP(Korea Institute of Energy Technology Evaluation and Planning) grant funded by the Korea government(MOTIE) (No. 20171510101910)

REFERENCES

[1] In-Kil Choi, Junghan Kim, Jinhee Park, Minkyu Kim, and Jaeho Jeon, "Seismic Fragility Reevaluation of SSCs in NPP with Site-specific Response Spectrum," Trans. Of Korean Nuclear Society Spring Meeting, May 18-19, 2017.

[2] K. Merz, and W. R. Schmidt, Program on Technology Innovation: Seismic Screening of Components Sensitive to High-Frequency Vibratiory Motions, EPRI 1015109, 2007.

[3] K. Merz, High Frequency Program : Phase 1 Seismic Test Summary, EPRI 3002000706, 2012.

[4] K. Merz, High Frequency Program : High Frequency Testing Summary, EPRI 3002002997, 2014.

[5] K. Merz, G. Hardy, F. Grant, and E. Keldrauk, High Frequency Program : Application Guidance for Functional Confirmation and Fragility Evaluation, EPRI 3002004396, 2015.