Fragility Curve Development of an Electric Cabinet for Isolated Nuclear Power Plants

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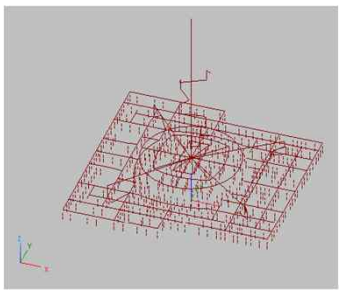
◆ Overview

- ✓ In case of isolated nuclear power plants, the components are subject to non-linearly behaving FRSs relative to the increasing PGA.
- ✓ Fragility parameters are estimated for each PGA level and the fragility curve of the cabinet in the isolated NPP was developed.

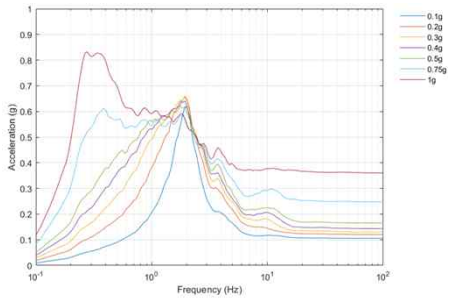
• Numerical Model



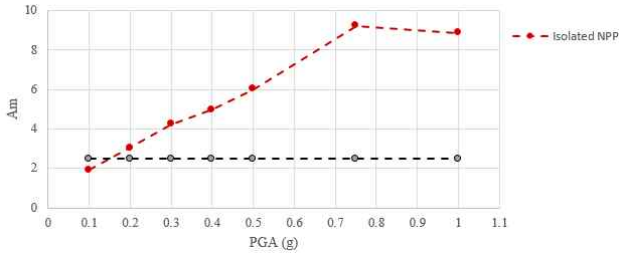
< Fig. 1. Numerical model of the isolated NPP >

- The Numerical model of the NPP, initially developed by KEPCO E&C, was converted into OpenSees model in collaboration with the University of California, Berkeley. Lead-Rubber-Bearing (LRB) model was implemented as the isolators of the base-isolated NPP. Total 486 isolators applied to the OpenSees model as shown in the figure.
- The numerical isolator model presents the LRB isolator in one horizontal direction only, based on the correlation results with full scale test.
- Twenty ground motions were used in this study which were scaled spectrally to match a 5% damped USNRC 1.60 target spectrum with the target PGA. The ground motions applied in X direction only for the numerical simulations.

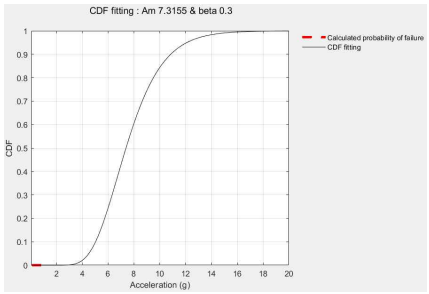
• Analysis Results



< Fig. 2. FRS on auxiliary building 78 ft. in the isolated NPP >



< Fig. 3. Median capacity factor of the battery charger in the isolated NPP (red points) >



< Fig. 4. Developed fragility curve of the battery charger in the isolated NPP (black line) >

- The FRS yielded from the numerical simulations are shown in Fig. 2. The FRSs were produced on the auxiliary building 78 ft. where the battery charger places. The PGA increased 0.1g to 1.0g, and the mean FRS was obtained at each PGA. The seismically isolated NPP shows nonlinear responses as the LRB isolators have the nonlinear characteristics.
- The Hybrid Method was applied for the seismic fragility evaluation of the battery charger in the isolated NPP. The hybrid method estimates the HCLPF capacity by the CDFM method, and approximately estimates the logarithmic standard deviation. The capacity factor at the each PGA was calculated from the FRSs of the isolated NPP and the cabinet test results as shown in Fig. 3. For non-isolated NPPs, general NPPs, the median capacity factor is a constant independent from the change of the PGA as shown in the gray points. The median capacity factor of the battery charger in the isolated NPP varies dependent on the PGA as the red points. As the median capacity factor is not a constant, the fragility curve of the battery charger cannot be produced by the established seismic fragility evaluation methodology.
- To develop the fragility curve of the component in the isolated NPP, the conditional probability of failure was calculated at the each PGA level. The conditional probability of failure was obtained from TRSc and RRSc. The conditional probability of failure can be calculated by below equation.

$$P_f(a) = \int_0^\infty f_D(x,a)\left(\int_0^x f_C(y)dy\right)dx$$

a : PGA level
$P_f(a)$: Probability of failure
f_c, f_D : Probability density function of capacity/demand

- By utilizing the derived conditional probability of failure corresponding to the each PGA level, the fragility curve of the battery charger can be develop. The fragility curve of the battery charger can be develop by fitting it into the derived conditional probability of failure. The fragility curve of the battery charger in the isolated NPP was obtained as shown in Fig. 4. The red dot line in Fig. 4 is the conditional probability of failure calculated by the TRSc and RRSc. And the black CDF line is the best fitting result to the red dot line. The developed fragility curve has the median capacity factor Am of 7.3155.

• Conclusion

- The components in isolated nuclear power plants experience the FRSs which behave nonlinearly relative to the change of the PGA. The median capacity factor of the battery charger in the isolated NPP varies dependent on the PGA. As the median capacity factor is not a constant, the fragility curve of the battery charger cannot be produced by the established seismic fragility evaluation methodology.
- We developed the fragility curve of the battery charger in the isolated NPP by applying the hybrid method and yielding the probability of failure at the PGA directly. And numerical models representing the NPP structure and seismic isolators were used to simulate the behavior of the isolated NPP and obtain the FRSs under seismic loads. The conditional probability of failure was calculated based on the FRSs and the battery charger test results. Then the fragility curve of the battery charger was developed by fitting it into the derived conditional probability of failure.