Estimation of Equipment Fragility Curve of Nonlinear Nuclear Power Plant Structures

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Abstract

Fragility analysis is priorly conducted for probabilistic seismic risk assessment of nuclear power plants (NPPs). In this research, a sample-based method is used to estimate equipment fragility curves more realistically. A numerical model representing an auxiliary building of NPP is used for probabilistic seismic analysis. The structural nonlinearity comes from the hysteretic behaviour of shear walls, which is a dominant structural component affecting the structural behaviour under earthquakes. Uncertainties from ground motions, structural and equipment properties are considered. To generate simulation cases, an advanced Latin Hypercube sampling approach with sequential sampling capability is adopted. The response distribution are utilized for calculating fragility curves, and the effects of each uncertainty sources on fragility curves are evaluated and compared.

Keywords: fragility analysis; seismic analysis; nonlinear structures; equipment; uncertainty.

1 Introduction

Seismic risk of nuclear power plants (NPPs) are quantified following the probabilistic procedure, which includes seismic hazard analysis, seismic fragility analysis, and system analysis. Conventionally, the safety factor method is used for assessing the fragility curves of NPP structures and components. The method makes it simple to consider uncertainties from various sources by using safety factors and their logarithmic standard deviation. However, the method could be not appropriate for the case where the structure exhibits considerable nonlinear behaviour; the structural nonlinearity has different affects on a fragility curve along with different ground motion intensities. Especially, spectral acceleration value of an equipment can change substantially when the fundamental frequency of the equipment is changed. This cannot be considered with the safety factor method, but the sample-based approach can capture the variation of the equipment response. In this research, probabilistic analysis is conducted to consider the uncertainties in the input ground motions, structural and equipment properties. The simulation cases are generated using an advanced Latin Hypercube sampling method for the efficient calculation of the response distribution. The failure probability is calculated from the obtained response distribution and the fragility curves are estimated using the lognormal assumption of the fragility curves. The fragility curves with different uncertainty factors will be compared.

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