Vector intensity measures for a more accurate reliability assessment of NPP sub-systems

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Within the European-funded H2020 NARSIS project (New Approach to Reactor Safety ImprovementS, http://narsis.brgm.fr), one of the main challenges pertains to the development of innovative methods for the numerical derivation of fragility function for systems, structures or components (SSCs) within nuclear power plants (NPPs). In this context, the present study investigates the effect of integrating secondary seismic intensity measures when assessing the reliability of SSCs, with the objective of better identifying or even reducing the uncertainties due to record-to-record variability. While such an approach has already been applied to common reinforced-concrete or masonry buildings in previous studies, it is proposed here to consider an industrial structure containing a set of components at various locations of the building. We propose to treat the problem of station blackout following an earthquake (an accident event which is of primary importance as exemplified by the Fukushima Dai-Ichi event). Here the internal equipment is supposed to perform a given function (e.g., generation of emergency on-site power) and it may therefore be considered as a sub-system, for which a functionality assessment may be required within a probabilistic safety analysis.

The studied sub-system comprises various types of components, whose failure modes are susceptible to either floor acceleration spectra or inter-story drift (e.g., failure of anchor bolts, excessive stress in pipeline segments, etc.). Such engineering demand parameters at various floor locations are not evenly correlated with the same intensity measures (e.g., spectral accelerations at different periods), thus highlighting the need for vector intensity measures that are able to capture a wide range of potential failure modes. Finally, the vector-based fragility functions derived at the component level are assembled in order to quantify the probability of the sub-system losing its function, for various levels of seismic loading. The statistical dependence between component failure events is taken into account thanks to the matrix-based system reliability method. A parametric study is then performed in order to evaluate the sensitivity of the sub-system‘s reliability with respect to various assumptions (e.g., correlation between failure events, correlation between intensity measures, etc.).