An Improved Hybrid Method to Develop Seismic Fragilities for Seismic Probabilistic Risk Assessments

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Seismic fragility evaluations of structures, systems, and components (SSCs) are often performed in seismic probabilistic risk assessments (SPRAs) using one of the two methods described in Electric Power Research Institute (EPRI) 3002012994: the Separation of Variables (SOV) approach, and the Hybrid Method (HM). The SOV approach is more rigorous and highly detailed, requiring considerably more effort. The HM is significantly more simple to use since it is closer to conventional civil design evaluations familiar to engineers, enabling rapid development of seismic fragilities for a large number of SSCs. As a practical matter, most SSC seismic fragilities in typical SPRAs are developed using the HM, with the more detailed SOV approach reserved for SSCs with significant risk contributions. This represents an efficient and cost-effective strategy for seismic fragility development in typical SPRAs.

The HM aims to compute the SSC's $C_{1\%}$ seismic capacity that has a 1% non-exceedance probability using a set of deterministic rules. The $C_{1\%}$ is intended to approximate the high confidence of low probability of failure (HCLPF), which is the 95% confidence estimate of 5% probability of failure and is most rigorously computed using the SOV approach. With the HCLPF capacity approximated by $C_{1\%}$, the HM uses generic conservative aleatory and epistemic variabilities to estimate the median seismic capacity. The set of deterministic rules followed in the HM to compute $C_{1\%}$ are calibrated to provide sufficiently accurate estimates of $C_{1\%}$ in most cases. However, in certain cases where the variability in the seismic demand is much greater than the variability in the SSC capacity, the HM can result in unconservative and inaccurate estimates of $C_{1\%}$ and by extension, the HCLPF capacity.

We present an Improved Hybrid Method (IHM) which is more significantly more accurate and requires only marginally more computations. The median seismic capacity is calculated explicitly following the guidance in EPRI 3002012994, in addition to $C_{1\%}$. The aleatory and epistemic variabilities are computed from the median seismic capacity and $C_{1\%}$. A minimum

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variability check for consistency is performed to preclude the cases where HM may yield unconservative results. This improved method was successfully implemented in a recent SPRA of a commercial nuclear power plant.