Cost- and Risk-Based Design Optimization of Safety-Related Nuclear Structures

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The nuclear industry is currently at a severe economic disadvantage, mainly due to the extremely large capital costs involved constructing in new nuclear power plants. In addition, recent nuclear constructions have seen large cost overruns and schedule delays, contributing to a further loss of confidence in the nuclear sector amongst investors. Advanced reactors are designed with newer, safer reactor technologies like passive and 'walk-away' safe systems. However, the design procedures for the balance of plant (BoP) of advanced reactors are similar to those used in existing nuclear power plants, and without swift and aggressive innovation in design procedures and construction technologies aimed towards reducing capital costs, advanced reactors are at a risk of running into cost overruns. The risk reduction from advanced reactor technologies, apart from increasing safety, provides a unique opportunity to reduce capital costs, especially in the BoP. The risk-based design paradigm aims to use this opportunity to translate the risk reductions into cost reductions by designing the various SSCs based on their relative risk contributions. Nuclear power plants in the past have been designed using essentially deterministic, non-iterative methods that result in highly conservative and expensive designs. This study proposes a more iterative risk- and cost-based design process where the seismic design is optimized to both meet safety performance goals, as well as minimize the total capital cost. This design process is termed as risk- and cost-based design optimization.

This presentation demonstrates the risk- and cost-based seismic design optimization of an idealized but representative safety system in a nuclear facility, referred to as the generic nuclear facility (GNF). The GNF is assumed to be sited in the boundaries of the Idaho National Laboratory (INL), which has a low to moderate seismic hazard. The design of the safety system in GNF is defined by seismic fragilities of the SSCs of the safety system. The goal of the design optimization process presented here is to minimize the total capital cost of the GNF while meeting performance goals, i.e., staying below a user-specified seismic risk. This is an optimization problem involving capital cost and risk calculation. The risk calculation here involves probabilistic risk assessment and is performed using MASTODON (Veeraraghavan *et al.*, 2020), which is an open-source seismic analysis and risk assessment software being developed at Idaho National Laboratory. The optimization is performed using Dakota (Adams *et al.*, 2014), which is another open-source software for optimization and uncertainty quantification developed at Sandia National Laboratory. The presentation includes a description of the design optimization process and results of the design optimization of the GNF safety system with and without component seismic isolation.

References

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