A Proposed Alternative Risk-Informed and Performance-Based Regulatory Framework for Seismic Safety at NRC-Regulated Facilities

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This paper describes the concept and preliminary results of a research project funded by the Office of Nuclear Research (RES) of the US Nuclear Regulatory Commission (NRC). This project aims at appropriately integrating the licensing modernization project (LMP) risk-informed and performance-based (RIPB) framework and the American Society of Civil Engineers (ASCE) Standard ASCE 43 performance-based seismic design criteria into a technology inclusive (TI) and RIPB seismic safety of NRC-regulated facilities. This approach can be also used for advanced non-light water reactor designs. The LMP has been a multi-year cost-shared initiative led by nuclear utilities and supported by the U.S. Department of Energy (DOE) and the Nuclear Energy Institute (NEI). It was established to enhance the risk-informed and performance-based (RIPB) regulatory basis for licensing and regulating the safety of advanced nuclear power reactors, as documented in NEI 18-04. In Regulatory Guide 1.233, the U.S. Nuclear Regulatory Commission (NRC) has endorsed recommendations in NEI 18-04 implementing the LMP. Although the NEI 18-04 contains details about how LMP concepts should work for many aspects of design to realize an acceptable level of reactor safety, including those for external hazards, it does not yet explicitly address how to incorporate seismic performance criteria into the physical design of structures, systems, and components (SSCs). The seismic design under the LMP framework is also a novel challenge for advanced reactor designs that rely on passive safety controls, have significantly different facility footprints, or involve different structures and structural elements than are typical of the large light water reactors.

Our proposed approach to seismic design aligns the LMP concepts with criteria in the American Society of Civil Engineers (ASCE) Standard ASCE 43. We have developed the LMP/ASCE 43 Integration Approach, in which seismic probabilistic risk assessments (SPRAs) and seismic design are interrelated in a way that uses the SPRAs to both inform licensing decisions and aid the design process. The underlying strategy of our approach is to consider the performance of individual SSCs as well as the role they play in an event sequence, in contrast to current regulations, in which every individual safety-related SSC is designed to the same seismic criteria with the most stringent design limit state (LS) criterion, irrespective of the role the SSC plays in the overall system performance. In our approach, the design process may be iterative, such that seismic design levels and LS criteria are adjusted to meet SSC-level risk targets, which are then examined within the SPRA to evaluate their contributions to system-level and plant-level performance. Our approach also considers defense-in-depth and safety margins to allow the engineering design to be tailored to meet the desired performance goal by concentrating on the relevant event sequences. The approach allows nuclear plant designers and operators greater flexibility for the overall seismic design to meet SSC-level, system-level, and plant-level acceptability criteria, and it further enables allocating resources where they matter the most for safety. In the presentation, several stylized and illustrative examples will be described that evaluate the potential regulatory and safety benefits of the LMP/ASCE 43 Integration Approach