PERSPECTIVES OF SEISMIC PROBABILISTIC RISK ASSESSMENT AND SEISMIC MARGIN ASSESSMENT TO ENHANCE SEISMIC SAFETY FOR NEW REACTORS IN THE UNITED STATES

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In the late 1970s and early1980s, the U.S. Nuclear Regulatory Commission (NRC) sponsored the Seismic Safety Margin Research Program (SSMRP) to develop a seismic probabilistic risk assessment (SPRA) method and to systematically ascertain the level of conservatisms in various steps of seismic design. The industry also developed a similar SPRA approach and performed SPRAs for several plants in 1980s. Since then, many SPRAs have been performed worldwide.

After the development of the SSMRP approach, the NRC established an expert panel to address the issue of seismic margin beyond the design basis. The expert panel established the seismic margin assessment (SMA) approach based on the fault-space event/fault trees plant logic approach similar to the SPRAs; however, instead of quantifying the core-damage frequency to establish the plant-level seismic margin, the NRC expert panel introduced the concept of plant-level seismic capacity based on the high confidence (95 percent) of low probability (5 percent) of failure value on the fragility curve. In the 1980s, the Electric Power Research Institute, Inc. (EPRI) developed a deterministic seismic margin assessment methodology. EPRI based this methodology on a success path approach rather than the fault-space based approach.

The following describes how the SPRA and SMA concepts have been used in new reactor licensing.

For licensing generation III/III+ reactors (new reactors) in the United States., the NRC established Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” which provides requirements for early site permit, standard design certification (DC), and combined license (COL) applications. In this process, an application for a COL may incorporate by reference a design certification, an early site permit, both, or neither. This approach allows for the early resolution of safety and environmental issues. A COL review does not reconsider the safety issues that the design certification and early site permit processes have resolved. However, a COL application that incorporates a design certification by reference must demonstrate that pertinent site-specific parameters are confined within the envelopes established by the design certification. Although the NRC increasingly uses risk information and performance requirements to develop regulatory requirements and guidance, the agency recognizes that the design process of nuclear facilities is still inherently deterministic. To evaluate the robustness of new reactor designs, an assessment, such as SPRA/SMA, can enhance the safety performance of the design for new reactors.

In addressing severe accident prevention and mitigation for new reactors, 10 CFR 52.47(a)(27) requires that the final safety analysis report for a design certification application describe the design-specific probabilistic risk assessment (PRA) and its results. NRC’s Regulatory Guide 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” issued June 2007, further states that the scope of this assessment should be a Level 1 and Level 2 PRA that includes internal and external hazards and that addresses all plant operating modes. However, the staff recognized that it is not practical for a design certification applicant to perform a site-specific seismic PRA because a design certification application would not contain site-specific seismic hazard information. As an alternative

approach to a seismic PRA, the NRC staff proposed a PRA-based seismic margin analysis as described in NRC paper SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," dated April 2, 1993, the Commission approved this PRA-based seismic margin analysis in the corresponding staff requirements memorandum dated July 21, 1993. This analysis preserves key elements of a seismic PRA to the maximum extent applicable and estimates the design-specific plant seismic capacity in terms of high confidence of low probability of failure capacity. The goal is to demonstrate that this capacity is at least 1.67 times the ground motion acceleration of the design-basis safe-shutdown earthquake. Using this approach, the analysis can be used to evaluate the seismic risk for a design certification to show that it is acceptably low.

Accordingly, the NRC developed Interim Staff Guidance DC/COL ISG-020, "Interim Staff Guidance on Implementation of a Probabilistic Risk Assessment-Based Seismic Margin Analysis for New Reactors," dated March 22, 2010, to provide a clear process for the implementation and the safety review of PRA-based SMA. The NRC based ISG-020 on the PRA standard jointly developed by the American Society of Mechanical Engineers, the American Nuclear Society, and the applicable provisions of the NRC's Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities." The ISG-020 includes detailed elements with respect to the PRA-based SMA implementation in design certification applications and post-design certification updating activities, including COL updates to incorporate site and plant-specific features and post-COL verifications.