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ENHANCING RISK-INFORMED AND PERFORMANCE-BASED SEISMIC SAFETY FOR ADVANCED NON-LIGHT WATER REACTORS DAY 2

DIVISION OF ENGINEERING

RIPB Seismic Safety Approach (Integration of ASCE 43 Design Criteria with the LMP Framework)

SOUTHWEST RESEARCH INSTITUTE®

NRC Headquarters

Rockville, Maryland

September 2-3, 2020

Disclaimer

- This project was performed by the Southwest Research Institute for the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission (NRC).
- Reported results are preliminary, and part of an ongoing research program.
- The expressed views do not necessarily reflect the views or regulatory position of the U.S. Nuclear Regulatory Commission.

Part 3 – Questions and Challenges Related to Implementation

Objectives of Part 3

- Explore questions and challenges related to the various aspects of implementation, such as experience, regulatory and licensing impacts, and technical complexities
- Identify the questions and challenges to be evaluated in the next phase of the study
- Refine the proposed process to deal with these challenges as necessary

The current draft Phase 1 report contains only limited discussion of issues discussed in this presentation

How much experience do we have in using ASCE 43 and 4 processes?

- The proposed LMP/ASCE 43 Integration approach introduces a new consideration related to the selection of alternate SDC and LS categories instead of one single design category.
- If LS D is used and the deterministic analysis in ASCE 4 is implemented, the design process in the LMP/ASCE 43 Integration approach is basically the same as that used today.
- If the probabilistic response analysis option of ASCE 4 is used (in conjunction with LS D), LMP/ASCE 43 Integration does not add much more complexity.
- If LS C is chosen, there is no experience in using this approach in NPP design, although ASCE 43 does contain requirements for design.

Are there any regulatory challenges in using the proposed LMP/ASCE 43 Integration approach?

- The principal seismic regulations are GDC 2, 10 CFR Part 100.23, and Appendix S to Part 50. Currently, the seismic design basis is defined using the SDC-5 category of ASCE 43. Thus, the use of other ASCE 43 categories to define DBEs should also be permissible.
- Certain terminology such as “safe shutdown earthquake” and definition of SSE may not be the most optimal for non-LWR technologies, but this issue does not impede application of the LMP/ASCE 43 Integration approach.
- There is nothing in the regulation that forbids more than one safety classification of SSCs.
- Having more than one design basis is not an impediment in the current regulatory structure. Under the current Part 52 process, a plant will have CSDRS and GMRS as the design basis for the certified design and the site-specific portion of design, respectively

Are there any licensing challenges? Will the NRC review require more time and resources?

- The LMP/ASCE 43 Integration approach adds an option to select alternate SDC and LS categories, which may require separate review. The LMP framework includes SPRA as a part of the licensing and is anticipated to require more detailed review than that needed for the current process
- If the LS D is used in conjunction with the deterministic response analysis option in ASCE 4, no additional or different elements are added to the current design/review process
- If LS C is chosen
  - there will be a learning curve, which may impose additional review time initially,
  - implications for assuring defense-in-depth should be further explored
- Publication of a regulatory guide and associated SRP sections will facilitate and standardize the review

Technical Challenges

- The following technical questions are related to examination of complexity and new elements added by the LMP/ASCE 43 Integration process and issues related to seismic design

- These questions also apply to some extent to the general design process in the new LMP framework

How much extra complexity arises from embedding the SPRA in the design process?

- The use of PRA in the functional design and licensing is already integral to the LMP framework.

- SPRA is a mature methodology and is also a part of the Part 52 licensing process.

- However, broader application of SPRAs requires additional considerations.
  - For example, how to select hazard curves and fragilities for alternate SDCs and LSs for a generic design.

How detailed should a SPRA be, particularly for the design certification stage?

- The more detailed a SPRA, the better it is to support categorization of a larger number of SSCs in various design categories and to support more robust decisions

What are the challenges of using LS C and performing inelastic analyses?

- There will be a learning curve as LS C has not been used in nuclear facilities.
  - Design is anticipated to be more iterative.

- However, ASCE 43 provides detailed guidance for civil structural design.

- The combination of designs with LS C for structures and LS D for equipment should be further explored.

Besides design and licensing considerations, are there additional operational or general considerations?

- One example of such a consideration is shutdown and start-up if an earthquake event occurs at an operating plant that used the LMP/ASCE 43 Integration process for design
  - Current shutdown criteria are empirically based on the potential for an earthquake to cause damage to engineered structures at the site
  - The post-earthquake start-up depends on the extent of damage and the ability to restore a plant to its licensing conditions. This may require further exploration for LS C designs

Will some existing guidance have to be revised? Is new guidance needed? Do codes and standards need to be revised?

- One of the objectives of this project is to develop a technical basis for an NRC regulatory guide to implement the LMP/ASCE 43 Integration approach.
- It is also anticipated that extended SRP sections related to new elements of review, such as the process of selecting alternate SDC and LS categories and elements of inelastic design will have to be developed
- The LMP/ASCE 43 Integration process follows the ASCE 43 standard; therefore, no additional changes to codes and standards are needed. Other codes and standards (e.g., ACI and ASME Section III) also do not require any immediate revisions to implement the proposed process

How does the LMP/ASCE 43 Integration approach work for a generic design versus a site-specific design?

- The LMP/ASCE 43 Integration approach is applicable to both a generic and site-specific designs
  - This issue has been discussed in the draft report, and it will be further explored in Phase 2.
- A generic design will involve consideration of potential sites where the design is intended to be placed
- For a generic design it is important to have a clear interface with the site-specific application
- The LMP/ASCE 43 Integration is likely to be more easily implemented for a site-specific design and potentially provide more benefits

How can the LMP-ASCE approach be tailored to address diverse reactor designs (SMRs, sodium reactors, microreactors, etc.) with different degrees of risk?

- As shown through examples of an advanced non-LWR and LWR event sequence analysis, the LMP/ASCE 43 Integration approach is applicable to various types of reactor designs and associated risk metrics.

- ASCE 43 is a performance-based standard and can be used for any seismic design as the performance range covers occupant's safety to large radiological releases.

- Microreactors can be potentially designed to lower SDC categories than reactors with higher power ratings, considering the associated degree of risk.

Why should the LMP/ASCE 43 Integration process be used given the preceding challenges?

- The biggest motivation is that the proposed approach provides a flexibility that currently does not exist. The flexibility to choose design basis and design limits in accordance with risk-significance allows for more optimal safe design and cost savings.
- The proposed process integrates the seismic design in the risk-informed licensing framework
- Benefits of this flexibility go beyond the design, such as constructability through reduced steel and ease of inspections because of potentially less massive supports
- The proposed changes embedded in the LMP/ASCE 43 Integration approach, for the most part, are within the state-of-the-art and experience
- In our opinion, the LMP/ASCE 43 integration process does not require significant additional effort.

Summary

- There are no insurmountable challenges or impediments to implement the LMP/ASCE 43 Integration approach
- The proposed changes to the current process for seismic safety, for the most part, are within the state-of-the-art and experience
- Additional activities will provide further insights into some of the technical issues
- The demonstration and feasibility examples will more fully explore the implementation issues and will allow further refinements to the LMP/ASCE 43 Integration approach

Benefits are expected to outweigh any additional effort that may be needed for learning and applying the LMP/ASCE 43 Integration approach

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Part 4 – Phase 2 Activities and Scope

Objectives of Part 4

- To discuss objectives of Phase 2
- To discuss some proposed activities that are under consideration
- To identify any other activities or case studies with collaborative inputs

The feedback from this workshop will be used to develop a detailed plan for Phase 2 activities under an NRC project

Objectives of Phase 2

- Illustrate strengths and identify potential enhancements for the LMP/ASCE 43 Integration approach for seismic safety
- Expand Phase 1 case studies to take full advantage of flexibility afforded by ASCE 43
- Disseminate results and gather feedback
- Refine the LMP/ASCE 43 Integration approach as needed from the insights gained
- Provide a basis for development of guidance

Activities Under Consideration

- Evaluate the seismic design of a small stylized structural system (going beyond a single shear wall) and selected equipment to more fully understand how to implement the guidance in standards such as ASCE 43, 4, and 1 within the proposed new LMP/ASCE 43 Integration process. Explore the impact on responses and fragilities from the use of alternate SDC and LS categories.
- As case studies, use detailed SPRAs of a light water reactor and an advanced reactor design to implement the seven-step process to better assess feasibility and advantages and limitations of the LMP/ASCE 43 Integration approach to seismic safety.

Activities to Evaluate ASCE 43, 4 and 1 Guidance – 1

- The objectives of the following examples are not to evaluate the adequacy of the technical requirements of ASCE 43, 4 and 1. Instead the objectives are to identify important aspects to demonstrate feasibility and gain appreciation of the potential benefits and level of effort by implementers. It will also provide insights into issues related to guidance.
- Design and analyze the chosen structural system for both LS D and LS C cases and different SDC categories to better assess:
  - How much additional effort is involved in designing to LS C (for example, how iterative could this design process be)
  - For various types of SSCs, what are the reductions in structural loads and floor spectra for LS C compared to LS D
  - For various types of SSCs, how do the fragilities change for LS C design

Activities to Evaluate ASCE 43, 4 and 1 Guidance – 2

- Evaluate selected equipment (e.g., heat exchanger and tanks) for implication on designs and fragilities from the use of alternate design categories (that are based on an alternate SDC and/or an alternate LS). This will also support assessing the impact on anchorages.

Additional examples are under consideration and more may be developed based on feedback from this workshop and as we move forward in the next phase.

Activities Related to Demonstration of Feasibility

- Objective: explore the implementation of the seven-step process of the LMP/ASCE 43 Integration approach to demonstrate the overall feasibility of using alternate SDC and limit state categories from ASCE 43
  - Exploratory work will use one or more publicly available LWR and advanced reactor SPRAs
- Chapter 4 of the Phase 1 report includes discussion of an approach to demonstrate feasibility
- Develop effective implementation procedures

Yield information about the following aspects (relevant for feasibility demonstration)

- Generic vs. site-specific design
- Effects on individual event sequences and cumulative risk
- Changes in risk insights, such as changes in dominant sequences, dominant contributors, and the importance of non-seismic failures
- If a different design approach is used, evaluation of the potential that correlations among seismic failures of identical or similar equipment could change the “seismic risk profile” in an adverse way, and if so what steps would be required to limit risk increases
- Complex decisions and implementation challenges, such as when non-seismic loads play a major role, or when choices are required as to which SSCs to design using which Limit State or which Seismic Design Category
- Potential implementation challenge due to the necessity to assure that defense-in-depth criteria are met when using a different design approach than Seismic Design Category 5 with Limit State D
- Impact of other regulatory and technical considerations, such as maintenance or inspection considerations.

Why Use an LWR SPRA?

- The selection of existing recent LWR SPRAs that have been used to support a 50.69 application would facilitate the exploration of the implementation of the seven-step LMP/ASCE 43 Integration for the following reasons:
- The current SPRAs use the most recent seismic hazard information (i.e., PSHA and UHRS spectral shapes);
- Extensive and detailed seismic response and fragility analyses have been carried out for several SPRAs. Detailed fragilities would facilitate the process of adjusting them for a different SDC and LS design;
- These SPRAs include more accurate human error probabilities (HEPs) and non-seismic failures; and
- For the plants that have implemented the 50.69 process, the classification of SSCs in various risk-informed safety class (RISC) categories is already available.

Collaborative and Parallel Efforts

- Activities related to detailed execution of SPRAs can mostly be performed by owners and custodians of those SPRAs, providing opportunities for collaborative efforts.

- Industry and/or others (e.g., DOE) may undertake activities in parallel to further explore issues related to the use of ASCE 43 options.
  - For example, designing a complex structural system (e.g., non-symmetrical shear wall) to assess complexities, efforts, and benefits of LS C design.

Summary

- Insights from Phase 1 activities support further exploration through Phase 2 activities
- Feedback from practitioners and users is important to develop detailed plans for Phase 2
- Collaboration is desirable to gain broader and more useful insights

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GENERAL DISCUSSION AND FEEDBACK ON RIPB APPROACH

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Thanks you for participating in the "Enhancing Risk-Informed and Performance-Based Seismic Safety for Advanced Non-Light Water Reactors" Workshop !

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