RISK-INFORMED AND PERFORMANCE-BASED LICENSING FOR SMRs

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1.0 INTRODUCTION

Under the current U.S. Nuclear Regulatory Commission (NRC) licensing schemes, small modular reactor developers lack a predictable and technology-sensitive licensing process for Small and Medium Sized Reactor (SMR) designs. The standard Design Certification (DC) process under 10 CFR 52 (Ref. 1) is too time-consuming to fit within the targeted development time frames for SMRs. A new set of licensing regulations incorporating risk-informed and performance-based criteria, as has been suggested, would likewise entail several years before enactment and implementation. The purpose of this paper is to evaluate the challenges to SMR development posed by the current licensing process and set forth both near-term and long-term approaches that could incorporate risk-informed and performance-based review criteria, resulting in significant licensing efficiencies for both the NRC as well the industry. This paper will discuss the background of NRC licensing approaches to advanced reactor technologies and the difficulties the existing licensing regime poses for SMR development. The paper will explain the use of licensing review basis documents and recommend their adoption in the near-term while new licensing regulations that incorporate risk-informed and performance-based review criteria are under consideration. The use of Licensing Basis Review (LRB) documents can facilitate timely SMR licensing within today's regulatory framework while placing more emphasis on risk-informed methods. Pursuing revisions to regulatory framework in parallel provides both a context for developing LBR documents and a solid foundation for future [Generation (GEN) IV] advanced reactor development.

2.0 BACKGROUND

A new class of SMRs has been specifically designed to meet the electrical power, water, hydrogen, and heat needs. In general, SMRs differ from current-generation light water reactors (LWRs) in many ways: size, moderator, coolant, fuel design, projected operation parameters, etc. These new reactors feature longer refueling intervals and simplified operations. Sized in the 10- to 50-MW(electric) range (very small and up to the 300-MW(electric) range (small to medium), these reactors are built through modularized factory production and designed for rapid site deployment and assembly. The anticipated fuel source is <20% ^{235}U uranium fuel with a nominal core life of 10+ years**.** Many SMRs have been designed to operate as multiunit integrated facilities with as many as 4 to 16 SMRs operating in unison.

SMRs also differ commercially from the current generation of LWRs. SMRs are factory built and may be fabricated entirely off-site. The fabricated reactors will be shipped to a site for installation, which may include locations overseas. As commercialization proceeds, SMR vendors may intend to fabricate SMRs without advanced long-term orders for installation.

For the near term, the preference is to rely on licensing advanced reactors under current regulations, where the experience base is robust and the review process is proven. Projects that largely rely on regulatory certainty prior to significant investment prefer use of the 10 CFR 52 one-step process; a more research-oriented project with funding less dependent on private investment may prefer use of the 10 CFR 50 (Ref. 2) two-step process for first-of-a-kind SMRs to advance construction of the first unit prior to completing design, while using 10 CFR 52 to license follow-on units that can incorporate design finalization work and operating experience from the first (or prototype) unit.

More emphasis on risk-informed and performance-based licensing for SMRs will bridge the gap between current, LWR-focused regulations and new review criteria specific to more advanced, smaller reactors. By focusing review and deterministic analysis on those aspects of SMR design that are most critical to safety, risk-informed methods will facilitate the use of much of today's regulatory framework for near-term construction and operation of SMRs.

3.0 PROBLEM/ISSUE STATEMENT

The DC process, typically lasting several years (and in many cases more than a decade) from preapplication meeting to eventual DC issuance, takes too long to be commercially viable for many SMR developers. However, to promulgate and rely on new regulations specifically tuned to SMRs may add uncertainty to licensing schedules, which would delay SMR construction in the United States.

It has been suggested that SMRs might be licensed more directly under new regulations that are more specifically tuned to the advances in technology that they represent, including the potential for mass production of reactor modules in a factory assembly line. Examples include the proposed 10 CFR 53 (Ref. 3), which would establish a new risk-informed and performance-based framework, or regulations that would focus on integral LWR systems, or gas-cooled or liquid metal reactor technology. However, unless there is a significant change in rulemaking methods for new regulations, establishing 10 CFR 53 or technology-specific rules would entail 5 to 10 years of concerted effort before the review of specific designs could begin. This would defer the potential benefits that SMRs can provide in the near term and delay their timely construction.

These issues are explored below in more detail.

4.0 DISCUSSION AND ACTUAL WORK

As established in NUREG-1368 (Ref. 4), General Design Criteria (GDC) that form the basis of Title 10 of *Code of Federal Regulations* (10 CFR 50, and, by extension, 10 CFR 52) are largely applicable to SMRs, despite their origin in operating LWRs. The exceptions are few and well defined, or focused on reactor core design, and do not represent an impediment to licensing, as pointed out directly in NUREG-1368 and NUREG-1338 (Ref. 5).

4.1 LICENSING REVIEW BASIS DOCUMENTS DEFINED

An LRB document is envisioned as an accord whereby the reactor design applicant and the NRC establish an agreed-upon licensing framework for proceeding in the absence of technology-specific regulations. LRB documents provide an interim means for conducting risk-informed and performance-based SMR design review that is consistent with both the industry's targeted development time frames and the NRC's regulatory goals. This device allows licensing to proceed now, but it does not preclude the pursuit of new regulations that may be of benefit in the longer term.

This is precisely the approach used to certify the first reactor designs [Advanced Boiling Water Reactor (ABWR), System 80+, AP600] under 10 CFR 52, where licensing review basis documents were negotiated to establish the framework for first-of-a-kind certification. This was before Chapter 18 "Human Factors Engineering," and Chapter 19, "PRA and Severe Accident Evaluation for New Reactors," were incorporated into NRC's Standard Review Plan, before NRC had completed its review of the Electric Power Research Institute (EPRI) Advanced Light Water Reactor (ALWR) Utility Requirements Document and before the closure of nearly 1,000 unresolved and generic safety issues, which the new regulations required.

4.2. FINALITY BENEFITS

A standard DC equips the developer with a substantial amount of regulatory certainty regarding future applications that incorporate the approved design. NRC regulations provide for finality of designs under 10 CFR 52.63 (Ref. 6), 10 CFR 52.135 (Ref. 7), or 10 CFR 52.171 (Ref. 8). For example, a certified design [10 CFR 52.63(a)] is not rescindable or modifiable except by notice-and-comment rulemaking on certain enumerated policy grounds. While a rulemaking specific to formalize LBR document approval may prove not timely, in like fashion, NRC policy statements can provide LRB documents a measure of finality, thus maximizing their value by ensuring future adherence to certain agreed-upon review criteria.

4.3 POLICY REASONS FOR NRC ADOPTION OF LICENSING REVIEW BASIS DOCUMENTS

4.3.1. Public Participation and Transparency

Implementation of LRB documents with the NRC on new DC applications would enable stakeholders to provide constructive input on new approaches to the DC process using their wealth of operating experience as well as their unique knowledge of the risk and performance features of proposed SMR designs. The industry would gain increased transparency on the regulatory side, thus facilitating interest

in SMR development, while the NRC would benefit from laudable public involvement consistent with its open government initiative.

4.3.2. Regulatory Certainty and Better Safety/Standardization

As the LRB document provides assurances of the terms on which the design is to be evaluated by NRC staff and would have enforceable finality provisions, LRB documents ensure stability of the review process where the current regime lacks regulatory certainty. Further, stakeholder and regulator collaboration on the licensing process may help to standardize the LRB document content and inform any subsequent rulemakings concerning new advanced-technology licensing regulations, as proposed below.

The use of risk insights to develop exemptions that reflect the safety characteristics of SMRs is consistent with NRC's Probabilistic Risk Assessment (PRA) Policy Statement. The process of conforming safety requirements to SMRs is analogous to the risk-informed assessment of changes to a plant's licensing basis, described in Regulatory Guide 1.174 (Ref. 9).

4.4. BEYOND LICENSING REVIEW BASIS DOCUMENTS

4.4.1. New Regulations

In addition to near-term implementation of a regulatory approach to license innovative modular reactors, it is equally important to establish a longer-term regulatory approach for nontraditional reactor technologies in parallel. Many new reactor technologies are being developed but suffer from a constrained regulatory process that is largely based on prescriptive regulations tuned to more traditional LWRs. This forces the developer to show that certain regulations do not apply or seek exemptions instead of focusing on making the safety case for the technology.

Innovation in the nuclear industry has suffered because of this regulatory constraint, which does not incentivize developers to implement design features that would be given safety credit in the regulatory review. While progress is being made using technology-neutral regulatory approaches, more effort is needed to finalize a new set of regulations for a regulatory process based on a risk-informed approach to "reasonable assurance" of public safety using safety goals as the controlling metric. It is understood that with new designs, the database for operational equipment would not be robust, but fundamental design principles in core design and safety are sufficiently developed to allow for a risk-informed decision on safety based on separate effects and integral tests. This approach has proved effective in the application process for designs that have already been certified. Performance-based approaches may also assist in the licensing of new designs with limited operational experience by establishing measurable objectives and required remedial actions if operational objectives are not achieved.

For a truly technology-neutral framework based on risk, it is important to take full advantage of risk analysis in safety assessments. The historical "defense-in-depth" strategy that relies on numbers of physical barriers as a criterion needs to be replaced with a firmer understanding of design features and processes that also serve to prevent and mitigate accidents. The single-failure criterion may not be appropriate to risk-informed safety assessments since it defeats the fundamental purpose of a risk analysis, given that all components, regardless of safety classification, have the opportunity to fail in a probabilistic assessment. Single-failure criteria can be used to assess the importance of components and

structures for design improvement, should the consequence be significant, but should not be mandatory.

By a rigorous application of risk analysis in a plant design, the important design-basis events can be deduced from the event and fault trees. In addition, safety classification of systems, structures, and components can be directly determined from the analysis, as can reliability requirements for component performance and the need for inspection, test, and surveillance based on component importance. The risk-informed assessment also allows for explicit treatment of uncertainties, which conventional deterministic analysis largely ignores by applying "margins" and "conservatisms" intended to bound these unknowns. The risk assessment methodology allows for a more transparent understanding of the safety basis of reactors.

A key element to development and implementation of innovative reactors is the use of a risk-informed framework, coupled with a demonstration test program upon which to issue DCs. Thus, the American Nuclear Society President's Special Committee on SMR Generic Licensing Issues (SMR Special Committee) recommends immediate development of a rulemaking to establish a new risk-informed, technology-neutral licensing process with a license-by-test element, to allow innovative designs to be developed and deployed more efficiently in the longer term.

5.0 CONCLUSIONS

Licensing Review Basis documents harmonize NRC licensing processes with SMR industry objectives on a temporary basis while new SMR-compatible regulations are under development. Near-term construction of SMRs can be realized by licensing under the current regulatory framework, while managing technology advances through the use of licensing review basis documents that include more direct use of risk-informed methods. This is an effective and proven approach to managing uncertainties in the licensing process for new technology, which in turn affect cost and schedule for a new generation of nuclear power reactors. New technology-neutral regulations should be pursued in parallel for longer-term benefits as technology continues to advance.

6.0 RECOMMENDATIONS

The SMR Special Committee recommends that the SMR community plan for the use of current regulations to license SMRs for near-term deployment, with licensing review basis documents negotiated to provide a framework for approval that will satisfy the regulator where current guidance may not apply. In order to compensate for the current absence of SMR-specific licensing criteria, the SMR Special Committee proposes (1) the incorporation of licensing review basis documents within the existing regulatory process and (2) the recommendation of new licensing criteria for advanced technology such as SMRs, to be implemented in the long term.

1. ***Interim Use of Licensing Review Basis Documents for SMR Design Review Process***. Utilizing licensing review basis documents enables SMR developers to reach agreement with the NRC on acceptable approaches to meeting the intent of current regulations (e.g., GDC) where new technology departs from that of operating LWRs. This approach provides regulatory certainty and standardization benefits to industry stakeholders while promoting the NRC policy goals of transparency and safety.

2. ***Initiation of Rulemaking for Risk-Informed, Technology-Neutral Licensing Process.*** A key element to development and implementation of innovative reactors is the use of a risk-informed framework, coupled with a demonstration test program upon which to issue DCs. Thus, the SMR Special Committee recommends immediate development of a rulemaking to establish a new risk-informed, technology-neutral licensing process with a license-by-test element, to allow innovative designs to be developed and deployed more efficiently in the longer term.

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