Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

Proposing a Draft Small Modular Reactor Regulatory Policy Direction for Korea

Young A Suh*, Kyuntae Kim, Keyyong Sung, Young-il Lee, Jinsu Kim, Youn young Jang
Korea Institute of Nuclear Safety
sya@kins.re.kr

1. Introduction

Countries with advanced nuclear power industries are accelerating the development of Small Modular Reactor (SMR) technology to meet energy demand, transition to clean energy and respond to climate change. Countries around the world are considering introducing SMRs into their electric power generation mix. SMR designs are small and modular, with multipurpose applications. SMRs involve new concept designs, new reactor types, dramatic improvements in safety, and a relaxation of site constraints.

To meet the challenges of regulating proposed SMR technologies, it is possible to build on the existing regulatory framework for large-scale pressurized water reactors. However regulatory agencies need to establish an effective and efficient SMR review framework through legal and institutional arrangements, and at the earliest stages, developers need predictability in regulatory compliance.

This study aims to investigate the United States (US) SMR policy trends, as influenced by SMR regulatory policy direction, in order to meet the demands of SMR developments.

2. US Case Studies of SMR Policy Direction

In 2008 the US Nuclear Regulatory Commission (NRC) issued the "Policy Statement on the Regulation of Advanced Reactors " [1]. The purpose of this policy statement is to facilitate early interaction with applicants and others involved in the design process of advanced reactors (ARs), provide NRC's opinion on the expected characteristics of advanced reactors, and express in a timely manner NRC's views on designs that could affect safety and regulatory procedures.

The NRC expects that early interaction during the design process of ARs will minimize licensing and regulatory complexity and contribute to the stability and predictability of the licensing process. The policy statement provides guidance on how to increase the acceptability and licensability of designs and includes a high-level technical perspective.

The NRC expects ARs to provide improved safety margins and achieve safety and security functions through simplified, inherent, passive, or other innovative methods. The policy statement consists of a preamble that provides background information, policy and regulatory direction, safety goals, and attributes to be considered during the design phase. The policy statement also aims to overcome potential inefficiencies in the regulation of non−light water reactor (non-LWR) technology, secure a state of readiness, and improve regulatory certainty for stakeholders.

The structure and key points of the NRC policy statement are shown in Table 1.

Table 1. NRC Policy Statement Structure and Key Points

Introduction (Background)	Keywords of NRC regulatory change: Modernization, Readiness
Policy Direction	Presenting considerations to increase the acceptability or licensability of designs, and promoting interaction with developers.
Safety Goals	Advanced nuclear power plants are expected to provide environmental protection, public health, safety, and security at least at the same level as the current generation of nuclear power plants.
Design Attributes to consider	Reliable reactor shutdown and decay heat removal systems, designs reflecting a defense-in-depth philosophy, use of equipment and parts that are easy to maintain, sufficient analysis of simple systems with reduced operator actions and safety shutdown components in extreme environments, and a design that minimizes the potential for significant accidents by providing inherent safety, reliability, redundancy, diversity, and independence.
Regulatory Direction	To provide timely and effective regulation for advanced nuclear power, encouraging early interaction with applicants/suppliers/other government agencies. Regulatory agencies develop appropriate evaluation and response capabilities for innovative design and advanced nuclear power design. The responsibility for documenting and researching necessary information to support applications rests with the applicant. In the early stages of advanced nuclear power development, encouraging design innovation that enhances safety, reliability, and security, and promoting design innovation that is easy to prove. Security considerations should be taken into account in the early stages of design.

The US NRC has announced its "Vision and Strategy: Safely Achieving Effective and Efficient Non−Light Water Reactor Mission Readiness" (2016) [2] to secure efficient and effective regulation readiness for licensing applications for non-LWRs, overcome potential inefficiencies of non-LWR regulations, and enhance regulatory certainty for stakeholders. The NRC's responsibility is to work effectively with stakeholders, clearly communicate requirements, and provide timely regulation information and feedback. Although the NRC's mission remains unchanged, efforts are being made to optimize the means to achieve the mission. The three main goals are to improve the technical readiness posture, optimize the regulatory readiness, and optimize communication. The strategy has been broken down into short- and long-term phases, The short-term strategy, within the next five years, includes the development of codes for advanced reactor licensing validation (neutronics, fuel performance, thermal-hydraulics, accident analysis, and material integrity evaluation); setting accident sets based on non-LWRs and analyzing gaps with existing requirements; assessing trends in industrial technical standards; developing a review process for flexible non-LWR regulation (including phased reviews); and developing a comprehensive and systematic strategy for communication with internal and external stakeholders.

The US organization NEI (Nuclear Energy Institute) has been modernizing technology requirements for advanced reactor licensing since 2016. The existing regulatory framework is based on large light water reactors, so there is a need to update it to a Technology-Inclusive (TI) Regulatory Framework to reduce uncertainty related to the development of non-LWRs.

The DOE initiated the Industry-led Licensing Modernization Project (LMP) in 2016 to improve the regulatory framework for advanced reactors. The LMP targets six advanced reactors: Sodium Fast Reactors (SFRs), Lead Fast Reactors, Gas-Cooled Fast Reactors, Modular High-Temperature Gas-Cooled Reactors (HTGRs), Fluoride High-Temperature Reactors, and Molten Salt Reactors. The LMP aims to provide developers with maximum licensing efficiency and to minimize unnecessary burdens; it also aims to promote NRC staff willingness to interact with stakeholders directly.

In this process, NEI proposed to the NRC the “Risk-Informed Performance-Based Technology Inclusive Guidance for Advanced Non-Light Water Reactor Licensing Basis Development” (2018-2019). The proposed TI perspective included the definition of licensing basis events, methods for defining and classifying Structure system components (SSCs), adequacy demonstration of Defense in Depth (DiD), and the applicability of PRA. Subsequently, the NRC endorsed the TI-Risk informed Performance Based (TI-RIPB) LMP methodology via a Notation Vote with SECY-19-0117 [3] and DG-1353 [4].

3. Implications of regulatory directions for SMRs and ARs in the United States

The United States has made efforts to establish in advance policy directions (declarations) containing the regulatory principles and philosophy of the NRC on AR, including SMRs. As AR development diversifies, companies propose LMP projects, and NEI develops guidelines and actively attempts to engage with regulatory agencies. The NRC also reviews NEI proposals and makes efforts to endorse developer proposals by creating SECY reports and Draft RGs. The fundamental background that made this possible was the existence of NRC's AR Policy Statement before the developer's LMP. Based on this policy direction, the AR Vision & Strategy was set, and a long-term pursuit was made to create a phased Action Item.

The US NRC's AR Policy Statement presents "considerations to enhance the acceptability or licensability of the design" and "interactions with developers," which differ from general statements. While regulation for existing large commercial reactors is based on demonstrating traditional safety principles using proven technology, AR has a low technology readiness level and lack of operational experience. This lack of experience requires that attributes be considered in the design from a technical perspective to reduce licensing uncertainty for developers and provide regulatory agencies with opportunities for efficient design review. These contents differ from general statements that provide only principled and declarative directions and act as evidence to verify design compliance. Also noteworthy is the declaration that encourages early interaction with developers in order to derive prior regulatory requirements.

The keywords for NRC regulatory change are modernization and readiness, which are considered in the 10CFR53 rulemaking. The NRC’s and NEI's efforts, which included the enactment of the Nuclear Energy Innovation and Modernization Act

(NEIMA) law by Congress, led to changes, improvements, and modernization of the existing NRC regulatory system and the establishment of a readiness strategy that encompasses efficient, effective, and timely regulatory requirements.

Lessons and implications from the analysis of US cases are as follows:

- Under the US AR approach, if a policy direction for SMRs is established, it is necessary to present policy and institutional improvement targets that encompass the currently developing various SMRs (i.e. LWR, non-LWR).
- If a policy direction for SMRs is declared domestically, it needs to promote changes (optimization, improvement, modernization, etc.) in the regulatory framework in a timely manner to meet the regulatory agency’s responsibilities and achieve its mission.

- The domestic SMR policy direction needs to suggest approaches that can increase licensing acceptability based on the improvement of the existing regulatory framework (e.g., pre-design review) and the application of new concepts by developers (e.g., minimum proof required to be recognized as an exception, technical principles to be followed when considering design).
- The foundation of the US regulatory framework improvement and strategies for ARs is the TI approach, which combines risk-informed regulation and comprehensive technology. The NRC analyzes the design issues of innovative concepts from a risk perspective and reflects them in rule-making. In the current the domestic market, attention needs to be paid to the exemption analysis and technical issue review based on the NuScale case.

4. A Draft of SMR Regulatory Policy Direction for the Republic of Korea

The regulatory policy direction can include the regulatory agency's role in SMR development, the purpose and effect of regulatory framework improvements, and high-level technical positions (design considerations and early interactions with developers) to resolve design and licensing uncertainties.

The Korean framework for regulating SMRs has the same regulatory purpose (Article 1 of the Nuclear Safety Law of the Republic of Korea) as the basis for regulatory policy direction, regulatory enforcement strategy, and response plan. The regulatory policy direction consists of ①compliance with basic principles (international norms, etc.), ②ensuring safety at a level at least equal to that of existing large-scale reactors, and ③flexible approach.

Three strategies are divided to implement the regulatory policy direction in detail and regulatory agency response plans for these strategies.

① SMRs must comply with international standards and principles, such as the IAEA Fundamental Safety Principles and the Nuclear Safety Convention, as well as rational safety regulations based on objective science and technology.

- SMRs, like existing nuclear power plants, should comply with the principles (such as IAEA SF-1) and current regulatory principles (independence, transparency, clarity, efficiency, and reliability) prescribed by international agreements and organizations such as the IAEA.
- As SMRs allow for the formation of new developers and operators, the "Responsibility for safety" should be emphasized, stating that the fundamental responsibility for safety lies with individuals or organizations responsible for facilities or activities that pose radiation hazards.

② SMRs must ensure safety at a level at least equal to that of existing large-scale reactors.

- (Safety objectives and principles) Regulatory agencies must declare unequivocally that their regulatory mission of "protecting citizens and the environment" remains unchanged by specifying the level of safety that developers must achieve at the design stage through safety objectives and principles and should promote securing a higher level of safety than the current generation of reactors. This means providing proactive regulatory guidance for new regulatory demands and promoting effective design reviews and standard development if designs that meet these demands are submitted.

③ SMRs require a flexible approach to the existing regulatory system due to the introduction of new technology.

- (Innovative Technology) Regulatory agencies acknowledge the need for various design innovations, such as system simplification and passive system applications, in the development of new reactors. However, innovative technologies must not compromise "high levels of safety assurance," and such technologies must be based on proven or demonstrated technologies through various means.
- Effective regulation through international cooperation with the IAEA and advanced countries in SMR based on regulatory capacity derived from domestic unique types (SMART, APR1400, etc.).
- Efforts to strengthen international cooperation and regulatory expertise to complete regulatory infrastructure development and regulatory technology development in a timely manner and to faithfully enforce regulations
- (Legal and Regulatory Framework) To prepare for potential issues in the current regulatory process resulting from innovative concepts that differ from existing design, production, and operation methods, the demand for legal revisions must be identified, and the system must be revised if necessary.
- (Regulatory Technology Development) Regulatory agencies make efforts to secure a continuous R&D budget for developing safety assessment and verification technologies to provide timely review and technical regulatory positions on innovative designs.

Acknowledgments

This work was supported by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety (KoFONS) using financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea.(No.2207005) .

REFERENCES

[1] Policy Statement on the Regulation of Advanced Reactors (73 FR 60612; October 14, 2008)

[2] NRC, "Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness."(2016)

[3] NRC, "Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors", SECY-19-0117 (2019)

[4] NRC, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors" working draft, DG-1353 (2019)

[5] Kyuntae Kim, et al., Establishment of Safety Philosophy for Generation IV Reactors, KINS/RR-902 (2011)