Nuclear Control Regulatory Issues for SMR Developments

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1. Introduction

As the advantage of nuclear power, which does not emit greenhouse gases, is re-emerged, SMR development is being promoted worldwide and is expected to lead the nuclear power generation market in the future. As a way to overcome the limitations of existing large LWRs, SMR pursues technological innovation, safety, and flexibility, and the need to develop procedures and standards that are different from the existing nuclear regulatory system arises. The ROK is also developing an innovative SMR, so it is necessary to take a preemptive action at the design stage, such as applying safeguards measures, physical protection, and cyber security regulatory requirements.

2. Status of SMR Development and Common Characteristics

SMR developments are actively underway in major countries such as the ROK, the United States, China, Canada, and Russia. In addition to the existing LWR types, about 70 various models such as high-temperature gas reactors, high-speed reactors, and molten salt reactors have been proposed and developed for SMR. It has the characteristics of pursuing technological innovation such as modularization and sharing the main control room, etc. Most SMR models under development have some common characteristics: reduced electrical output compared to large LWRs, inherent passive safety to prevent severe accidents, modularization. The IAEA Regulators Forum presents the characteristics of SMR as follows.

Table I: Common Characteristics of SMRs under Development

● Reduced Facility Size - Reduced site area compared to existing NPPs - Downscaling the core output
● Technological innovation - Passive Cooling Mechanism - Integrated Design and New Fuel Concepts
● Modular Design and Assembling - Assembling and testing at the facility manufacturing site - Multi-module Facility
● Construction / installation / transportation - Expansion to areas other than land (sea, underwater, etc.) - Module transport and construction

The IAEA published a book introducing most of the SMRs being developed around the world in 2020 which presents more than 70 different models including SMART and i-SMR in the ROK, and LWR types are more than 30 among them.

3. International Activities for Solving SMR Regulatory Issues

The leading countries like the United States, Canada are providing aggressive support for SMR development. It is noteworthy that the US has prepared a government support program for licensing regulations as well as support for research funds required for development. It is anticipated that SMR will become the mainstream in the future nuclear power generation market, so most of the major nuclear countries are seeking ways to streamline and accelerate the licensing process for SMR as a strategy to occupy a preemptive position in the future market. The case of NuScale SMR of the US is particularly noteworthy, which is currently in the final stage of design certification. The USNRC recognized the limitations of applying the current licensing process prepared for large LWRs, and adopted a new approach in consideration of the unique characteristics of SMR. This will increase the degree of freedom to apply new technologies from the point of view of developers, and at the same time, from the point of view of regulatory agencies, it will be possible to alleviate the burden of rigid regulatory procedures. The USNRC published a Design Specific Review Standard (DSRS) corresponding to SRP of light water reactors for NuScale SMR in 2016. Another noteworthy point is that developers are actively requesting exemption from licensing standards for technologies that are difficult to meet the existing licensing standards. If the SMR design concept conflicts with the existing laws or technical standards, it is difficult to obtain permission itself, so it is highly recommended that the developers aggressively utilize the TRs (topical report) as a way to solve these kinds of problems in advance.

As the necessity of an international forum to discuss the issues of SMR regulation was raised by some major countries, the SMR Regulators Forum was organized in 2015, which is being led by the IAEA. The Regulator Forum started with a total of seven countries including the ROK, the United States, China, France, Canada, Finland, and Russia. Phase 3 is currently in progress,

and the main common issues that have been dealt with are as follows.

■ Phase 1
- Graded Approach
- Defence-in-depth
- Emergency Planning Zone

■ Phase 2
- Licensing Issues
- Design and Safety Analysis
- Manufacturing, Commissioning and Operations

4. Regulatory Issues in Nuclear Control Regulation

A traditional NPP generally goes through seven stages suggested by IAEA SSG-12 during its life cycle. During this period, nuclear control regulatory activities are as follows:

Table II. Nuclear Regulatory Activities during NPP Life Cycle

IAEA SSG-12 Licensing Stages	Nuclear Control Regulatory Activities
⓪ Standard design certification	N/A
① Site selection and evaluation	○ Preliminary design information
② Design	○ Safeguards by Design ○ Security by Design ○ Safety analysis report ○ Final design information
③ Construction	○ Nuclear Material Accounting Regulations ○ Physical protection operating system ○ Physical protection regulations ○ Protection emergency plan ○ Information Security Regulations ○ Design information book/design information verification ○ Facility Attachments
④ Commissioning	○ Pre-inspection before Fuel Bring-in ○ Initial inspection
⑤ Operation	○ Safeguards National Inspection ○ Physical Inventory Verification, Interim inspection ○ Physical protection national inspection ○ Physical protection training
⑥ Dismantling	○ Revision of facility attachments
⑦ Deregulation	○ Revision of facility attachments

Although the SMR regulatory forum has a position that regulations on SMR should start from the existing LWR-based regulatory system, they agree that a new approach should be prepared in consideration of the characteristics of SMR. As it is not easy to derive specific regulatory measures for systems or facilities whose design has not been finalized, it is necessary to first examine the differences between the SMR characteristics identified so far compared to large-scale light water nuclear power plants and the life cycle licensing stage. Since SMR basically adopts module unit design and facility expansion as a basic concept, the steps that may cause regulatory intervention in the licensing stage should be added as follows:

- Manufacturing and assembling major modules in manufacturing facilities
- Testing and commissioning of major modules and components in manufacturing facilities
- Nuclear fuel loading in manufacturing facilities
- Module transfer from manufacturing facility to SMR site, integration testing and commissioning
- Dismantling after module unit off-site transport

The steps describe above will have some impacts on nuclear control regulation for SMR, so it is necessary to find ways to avoid expected obstacles through SSBD (Safeguards/Security by Design) or revision of related laws to adopt SMR's innovative design concepts. The regulatory points which should be dealt with from the perspective of nuclear control are as follows:

Table III: SMR Regulatory Points of Nuclear Control Regulation

Safeguards	Structural Design	MBA, Diversion Paths, SFP location, Surveillance
	Operating Period	Frequency of regular and interim inspections
	Nuclear Fuel Type and Enrichment	NDA
	Fuel loading in Manufacturing Facility	Specifying Manufacturing Facility as MBA
Physical Protection	Structural Design	Vital Area, DBT
	Site location	Physical Protection Measures
	Reduced Operator	Sabotage, Emergency Preparedness
	Radiation Inventory	Graded Approach
Cyber Security	Sharing Digital Equipment	Cyber security vulnerability,
	Integrated Design	Module inside I&C calibration
	Optimized Spatial Design	Increased I&C device complexity

5. Conclusions

The ROK is also promoting the development of innovative SMR based on the knowledge and experience acquired in the development of SMART.

However, it is difficult to effectively respond to SMR licensing, which introduces various innovative technologies, with the current regulatory system focused on LWRs, and it is necessary to prepare a new regulatory approach that considers SMR's unique design and operation concepts. It should be considered that the current ROK regulatory system for nuclear control be adjusted and well-prepared for SMR regulation as well as other future regulatory issues such as drone, cyber security, etc. For this, the enactment and revision of related laws is essential, and cooperation with SMR developers is very important. In addition, the development of independent regulatory technology that can enhance the efficiency of the regulatory system should also be promoted.

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