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Development Study on Review Guidance for Cybersecurity Plan and Implementation Results of SMR in ROK

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1. Introduction

Nuclear energy has emerged as a crucial power source globally, constituting approximately 10% of the total energy sources. In the Republic of Korea (ROK), as of 2023, nuclear energy accounts for 32.9% of the total electricity generation [1]. However, there is a growing need to enhance nuclear safety post the Fukushima disaster and to consider improvements in nuclear energy utilization, such as accommodating the increasing coexistence of renewable energy sources. Therefore, attention has turned to Small Modular Reactor (SMR) technology.

To ensure the safe utilization of nuclear energy, regulatory measures for cybersecurity concerning of digital assets of nuclear facilities are being enforced. As part of these regulations, new nuclear facilities undergo on review of their cybersecurity plan and implementation results to ensure compliance. However, due to differences in design features between SMR and existing nuclear power plants, such as system simplification, there is a need to assess the applicability of existing review guidance

This study analyzes the feasibility of applying existing review guidance for cybersecurity plan and implementing results of SMR and proposes amendments to the guidance based on the analysis results.

2. Methods and Results

In this section, we analyze the distinctive features of SMR compared to existing nuclear power plants and assess the feasibility of applying existing review guidance to these features. Based on the result, we derive necessary improvements on review criteria for SMR.

2.1 SMR Technology and Differences from Conventional Nuclear Power Plants

While nuclear energy has emerged as a key energy source, conventional nuclear power plants are facing increasing initial investment costs. Additionally, there is a growing demand for alternative solutions for aging power plants, especially in developing countries where the demand for nuclear energy is rising. Furthermore, there is a need for low-carbon auxiliary power sources while also maintaining the nuclear energy ecosystem. In response to these, SMR technology has emerged.

SMR is characterized by integrating key components like steam generator and pressure vessels into a single container, typically with an output of less than 300MWe. There are over 70 types of SMR under development worldwide, including various designs being developed domestically in the ROK, such as the SMART100 and i-SMR. The main features of SMR are enhanced safety features, improved economic flexibility, and the adoption of innovative technologies [2].

2.1.1. Enhanced Safety Features

One of the most significant characteristics of SMR is the introduction of passive safety functions. This involves utilizing natural forces such as gravity instead of separate emergency power sources to ensure sufficient safety margins even during accidents. Additionally, SMR minimizes the intervention of operator during accidents and reduce the necessity for evacuation of nearby residents due to the reduced site. Moreover, SMR is designed with a focus on zero severe accident potential, significantly enhancing safety compared to conventional nuclear power plants.

2.1.2. Improved Economic Flexibility

SMR is manufactured in modular form, leading to relatively reduced construction costs and shortened construction period. Also, it is designed to utilize existing power grids, allowing for the reuse of established power infrastructure and enabling their deployment even in countries where establishing a single power grid is challenging. Furthermore, SMR features simplified system design and significantly reduced staffing requirements, leading to comparatively lower operating expenses. Since the SMR is designed to be smaller than conventional power plants, the components of SMR can be transported inland.

2.1.3. Adoption of Innovative Technologies

SMR incorporates innovative technologies such as autonomous operation and remote diagnostics. According to these technological advancements, facilities for SMR are designed with a single central control room for operation. Besides, SMR is designed to utilize multiple modules. It enables its power source to be utilized for various purposes, such as integration with renewable energy.

2.2 Existing Regulatory Review for Nuclear Facilities in ROK

To ensure the safe use of nuclear energy worldwide, nuclear facilities need to meet the cybersecurity regulatory requirements in nations. In ROK, the Nuclear Safety and Security Commission (NSSC), the government agency responsible for nuclear safety and security, evaluates and approves the cybersecurity plan (CSP) of nuclear facilities to provide high assurance of cyber security on the site. Especially, regulatory activity of review for CSP is delegated to and carried out the Korea Institute of Nuclear Nonproliferation and Control (KINAC).

Under the APPRE [5], which is a law related on the nuclear security in ROK, new nuclear facilities must establish and implement their own CSP to describe their cybersecurity program. Additionally, they must undergo the review of their CSP before operation to meet the cybersecurity regulatory requirements, with approval granted by the NSSC. KINAC evaluates the CSP of each facility according to APPRE and regulatory guidance, referencing the KINAC regulatory standard [6] and internal regulatory manual and procedure of review [7, 8].

SMR technology in ROK are currently in the development or conceptual design phase. However, once the development of SMR technology is completed, regulatory review in CSP must be implemented before operation. Nevertheless, due to differences in design features between SMR and conventional nuclear power plants, it is essential to evaluate the applicability of existing review guidance for SMR.

2.3 Analysis the Review Guidance for Applying to SMR

To assess the applicability of existing review guidance to SMR, we applied the characteristics of SMR analyzed in Section 2.1 to determine if they can be evaluated by the requirements of existing regulatory manual for review [7]. As the results, the features of SMR and corresponding considerations that are not sufficient for evaluation by current regulatory requirements have been identified and summarized in Table 1 as follows.

Table I: Analysis results of assessing the applicability of existing review guidance

No.	SMR feature	Considerations
1	Application of Passive Safety Functions	Reduction or elimination of protected area
		Difference in identifying critical digital asset (CDA) and establishing defense-in-depth protective strategy of SMR
		Difference in considerations for DBT
2	Reduction of Intervention of Operators and No Need for Evacuation of Residents in Accidents	Need Supplementary approach required for on-site Incident Response Security Team
		Difference in scope of site's emergency planning
3	Design for Zero Severe Accidents	Difference in considerations for DBT
4	Modularization and Simplified Design	Reduction of the number of on-site operators
		Being vulnerable in supply chain and design phases
		Difference in identifying CDA and establishing defense-in-depth protective strategy of SMR
		Existing regulation is excessive relative to the size of SMR.
5	Shortening Construction Period	Reformulation of regulatory review period
6	Inland Transportation Feasibility	Extend regulatory scope of adopted cyber security such as access control
7	Introduction of Innovative Technologies	Supplementing regulatory requirements of new technologies
		Including areas remotely controlled within the scope of cybersecurity program
8	Compatible with renewable Energy	Considering regulatory requirements for cyber security in renewable energy utilization

2.4 Development of Enhanced Review Guidance

Based on the considerations derived from Section 2.3, we derived the improvement strategy of review guidance. To induce the improvements, the considerations in Table 1 were linked to the categories of requirements in the KINAC regulatory manual for review [7] at first. And then, the improvements of the requirements are so proposed that enable them to adequately evaluate the considerations in Table 1. Moreover, the direction of guidance improvement is also suggested and categorized into establishment, revision, and additional consideration during review. The result of improvements and the direction of improvement are represented in Table 2.

Table II: Improvements of the review guidance

Relevant Requirement in [7]	Proposed Improvements (Relevant Consideration's Row #s in Table1)	Guidance Improvement Method*
Cyber Security Team	Revision of roles and responsibilities of cyber security team and incident response team due to reduction in on-site operating personnel (2, 4)	R
Identification of CDAs	Examining closely the identified CS and CDA lists during review due to differences in design features (1, 4)	AC
	Reviewing criteria for deciding addition or changes to existing criteria for identifying CS to consider changed protected scope (1, 7)	E, R
Defense-in-Depth Protective Strategy	Examining closely defense-in-depth protective strategy during review due to differences in design features (1, 4)	AC
Security Controls	Examining closely the scope of security measures considering to inland transportability and new technologies (6, 7)	AC
	Examining closely whether security measures for enhancing cyber security in supply chains and design phases (4)	AC
Continuous Monitoring and Assessment	Examining closely the analysis of vulnerability for DBT of site due to differences in design features (1, 3, 7)	AC
Incident Response and Contingency Planning	Revision of acceptance criteria to include alternative solutions for on-site incident response security team (2)	R
	Examining closely scope of emergency planning of site such as contact and reporting process during review due to unnecessary evacuation in accidents (2)	AC
Etc.	Re-establishment of review period due to shortened construction period (5)	R
	Find a way to relax the regulations to SMR due to the simplified design (4)	R, AC
	Considering cyber security guidance for renewable energy utilization and deciding the scope of review (8)	E

*** Guidance Improvement Method: Establishment (E) / Revision (R) / Additional Consideration during review (AC)**

The analyzed result in this section needs further evaluation based on the additional materials such as actual SMR design proposals, to identify detailed improvements in related regulatory requirements.

3. Conclusions

SMR represents a new generation of reactors that address the shortcomings of conventional nuclear power plants by implementing modular design, adopting passive safety concepts, and incorporating advanced technologies such as remote diagnostics and autonomous operation, thereby enhancing safety and improving economic flexibility. Recognizing the differences in SMR designs compared to conventional reactors, an analysis was conducted to assess the applicability of existing review criteria and identify potential gaps in the review process for SMR. Based on these findings, proposed improvements to the current regulatory guidance for review in SMR were formulated. It is anticipated that these proposed improvements will serve as a foundation for establishing revised review standard in advance, facilitating the implementation of evaluating the CSP of SMR in the future.

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