Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 24-25, 2024

Analysis of Regulatory Issues in the Electric Power System of i-SMR

Yongsun Choi[a], Jaehyun Cho[a*]
[a]*Chung-Ang University., 84, Heukseok-ro, Dongjak-gu, Seoul, Republic of Korea*
[*]*Corresponding author: jcho@cau.ac.kr*

***Keywords :** Small Modular Reactor, i-SMR, Electric Power Systems, Safety class, SBO, VRLA

1. Introduction

Currently, many SMRs around the world are being developed by country. Korea is developing I-SMR and is aiming for standard design approval in 2028. Since the current regulatory guidelines were made in accordance with large commercial nuclear power plants, they are not suitable for the standard design approval review for I-SMR, a light water reactor type SMR. Therefore, many regulatory issues arise. Preparation is necessary to ensure that there is no problem in the standard design approval stage in 2028. Considering the design goals of I-SMR, there are three major regulatory issues related to the electric electric power system.
I. AC/DC electric power system non-safety class, II. SBO coping ability evaluation, III. It is a DC electric power system that guarantees high reliability. Regulatory research is currently underway because it is necessary to prepare for three regulatory issues in advance. For regulatory research, it is important to know about current electric power system regulatory issues and analyze Regulations on Technical Standards for Nuclear Reactor Facilities, Article 24 of the Reactor Regulations related to them. Through this study, we plan to develop an evaluation guideline for the domestic SMR electric power system so that KINS, a regulatory agency, can understand the three current electric power system regulatory issues and use them during regulatory activities in the future. Therefore, this paper will be the basis for the analysis of electric power system regulatory issues and the development of domestic SMR electric power system evaluation guidelines to be developed later through the technical background of Regulations on Technical Standards for Nuclear Reactor Facilities, Article 24 of the Reactor Regulations.

2. Electric Power System of Regulatory Issues

The electric power system regulatory issues can be classified into three categories

2.1 AC/DC electric power system non-safety class

The safety-class is a system that classifies structures, systems, and components (SSC) in a nuclear electric power plant according to their importance in order to ensure the safe operation of the nuclear electric power plant and the safety in the event of an accident. SSC is determined by its impact on the safety of a nuclear electric power plant and the necessity of performing functions in the event of an accident. There are many safety class classification methodologies worldwide, and for this part, refer to Table 1. i-SMR aims to make the AC/DC electric power system non-safety-class in order to simplify the design and ensure economic feasibility. According to the existing LWR, the electric power system supporting the safety system is classified as Safety-class. Safety-class includes emergency electric power system, emergency AC electric power system, emergency DC electric power system, and emergency diesel generator. i-SMR is designed with passive safety system that does not require operator's operation. Therefore, it can be designed at a non-safety class because the passive safety function operates even in case of AC/DC electric power loss.
This is because the safety function reduces dependence on the electric power system and enables cooling through natural phenomena.

Table 1. Safety-class methodology

Classification	Name
IAEA	SSR-2/1
	SSG-30
	TECDOC-1787
ANS	ANSI/ANS-51.1
	ANSI/ANS-58.14
US.NRC	RG 1.26
	RG 1.201
NSSC	Regulations on the Safety Classification of Nuclear Reactor Facilities and the Specifications for Each Classification

2.2 SBO coping ability evaluation

According to Regulations on Technical Standards for Nuclear Reactor Facilities, Article 24 (Electric Power System) Paragraph 6 of the Regulations on Technical Standards for Reactor Facilities, etc., if there is no ability to cope with the SBO, an alternative AC electric power (AAC) should be installed. However, I-SMR is in the process of not installing AAC due to the introduction of the passive safety system. Therefore, it is necessary to prove the safety of whether the safety function operates by the operation of the passive safety system in the event of an SBO without installing AAC. It is necessary to develop an evaluation methodology to confirm such safety.

2.3 A DC electric power system that guarantees high reliability

The I-SMR requires high-reliability DC electric power from safety-related systems (e.g., post-accident monitoring systems, etc.). The DC electric power system is classified as a non-safety class, but it is designing a reinforced DC electric power system that reinforces the design, interior environment, seismic verification and quality assurance according to the reinforced requirements. In particular, it is planned to use VRLA, Valve Regulated Lead Acid. Therefore, the safety evaluation of the electric power system including the design of the DC electric power system includes the suitability of classifying the safety grade of the electric power system, the suitability of the DC electric power system reliability, and the suitability of applying the VRLA storage battery.

Table 2. Comparison of electric power systems Regulatory Issues for APR1400, i-SMR

Regulatory Issues	**APR1400**	**i-SMR**
Safety-class of electric power systems	Existing Safety-class Classification Methodology	All Non-Class 1E
Storage battery	Lead-acid	Valve Regulated Lead Acid
Coping with SBO	AAC	Passive safety systmes

3. Regulations on Technical Standards for Nuclear Reactor Facilities, Article 24

Regulatory standards exist for electric power facilities in Korea. It is Regulations on Technical Standards for Nuclear Reactor Facilities, Article 24. Article 24 (Electric Power System) of the Regulations on Technical Standards for Nuclear Electric power Plants stipulates in detail the requirements that electric power facilities must meet to ensure the safety of nuclear electric power plants. This provision requires the electric power systems inside and outside the electric power plant to be designed, installed, and operated to maintain safety functions in the event of an accident. In order to understand Article 24, it is helpful to know the technical background first.

Table 3. Electric systems comparison of the Regulations

Regulations on Technical Standards for Nuclear Reactor Facilities, Etc	**General Design Criteria (GDC)**	**IAEA**
Article 24 Electric power system	GDC 17—Electric power systems.	INSAG-3 4.2.3.12 Sataion black out

The i-SMR is designed for non-safety class in the electric power system. There are many things to consider when designing for non-safety class in Article 24 of the Regulations on Technical Standards for Reactor Facilities.

Table 4. Consideration in Article 24 of the Regulations on Technical Standards for Nuclear Reactor Facilities, etc. when designing a non-safety class

Regulations on Technical Standards for Nuclear Reactor Facilities, Article 24	**Considerations for designing non-safety class electric power systems**
① Onsite and offsite electric power systems necessary for the performance of the functions of the structures, systems, and components important to safety shall be provided to nuclear reactor facility to meet the following requirements: 1. In the event of a loss of either onsite or offsite electric power systems, the remaining available system shall have sufficient capacity and capability to prevent the specified acceptable fuel design limits and the design conditions of reactor coolant pressure boundary from being exceeded in anticipated operational occurrences and to maintain the safety 2. The systems shall have sufficient capacity and capability to maintain reactor core cooling, containment structural integrity, and other essential functions in the design basis accidents.	No review of capacity and capabilities required to maintain safety is required as no power system is required for safety functions
② The onsite electric	Since all sources of electric power in the plant

power system, including the batteries, and onsite electric distributions system shall have sufficient independency, redundancy, and testability necessary to maintain their safety functions assuming a single failure.	are non-safety class, it is necessary to review whether matters regarding independence, redundancy, and testability should be taken as obligatory.
③ Electric power from power transmission network to the onsite electric distribution system shall be supplied by two physically and electrically independent circuits to minimize the likelihood of their simultaneous failure under normal operation conditions, design basis accidents, and all environmental conditions. And it shall be designed to meet each of the following requirements: 1. Each circuit shall be available immediately following a loss of all the onsite alternating current power supply and the other offsite electric power circuit 2. One of the two independent circuits shall be available within a few seconds following loss of coolant accidents.	Even if the onsite electric power system fails, assistance from the offsite electric power source is not necessarily required as shown in 1 and 2 because the safety function operates passively.
④ The stability analysis of the electric grid shall assure that the probability of losing any of the remaining power sources as a result of the loss of at least one among the electric power sources by the nuclear power unit, from the transmission network, or from the onsite electric power sources including emergency power sources is extremely low	-
⑤ Safety-related electric power systems shall be designed to allow periodic tests and inspections in order to check the continuity of such systems and the states of their components.	Since the electric power system is all non-safety class, it is necessary to review whether the matters for the periodic test and inspection should be taken as obligatory.
⑥ An alternative alternating current power source with necessary capacity and reliability shall be provided to prepare for the cases of total loss of alternating current power and no capability to cope with the such loss. The performance of the alternative alternating current power source shall be demonstrated through tests.	It is necessary to check the safety of the passive safety system without the AAC

4. Conclusions

In this study, the regulatory issues related to the electric power system of i-SMR are analyzed in depth, and this is considered in connection with the technical background of Article 24 of the Regulations on Technical Standards for Nuclear Facilities etc. It is confirmed that the electric power system design of i-SMR requires a regulatory approach different from that of large commercial nuclear power plants due to the introduction of passive safety systems and innovative technologies. In addition, the safety of i-SMR is the top priority and additional technical review is required to increase the reliability of the power system. It is expected that it can be used as important basic data for safe and efficient operation of SMR based on this to deep understanding of the current issues of power system regulation of i-SMR.

5. Acknowledgements

This work was supported by the Nuclear Safety Research Program through the Regulatory Research Management Agency for SMRS (RMAS) and the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea (No. 1500-1501-409).

REFERENCES

[1] US NRC, 10 CFR 50 Appendix A, 2002
[2] IAEA, Basic Safety Principles for Nuclear Power Plants 75-INSAG-3 Rev. 1, 1999
[3] NSSC, Regulations on the Safety Classification of Nuclear Reactor Facilities and the Specifications for Each Classification, 2024
[4] KINS, Development of General Safety Criteria for Korean Next Genera(III), 2001
[5] KINS, Technical Background Document for the Proposed

Revision of Regulations on Technical Standards for Nuclear Facilities and Related Facilities, 2017
[6] KINS, Case Study on the Standard Design Approval for the Innovative System of the Light Water Reactor Type SMR, 2023
[7] KHNP, APR1400 Design Control Document Tier 2 Chapter 8 Electric Power, 2018