A Methodology for Staffing Plan Validation in aspect of Human Performance in Integrated Control Room of Multi-Module Reactors

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1. Introduction

The domestic innovative Small Modular Reactor (SMR) is being developed with a strategic goal to secure a competitive edge in the global market in terms of safety, economy, and flexibility as shown in Figure 1. We aim to achieve the safety goal through the development of a simple and excellent passive safety systems. Through simplification, modularization, standardization, and advanced manufacturing technology, it intends to secure economic feasibility comparable to that of large nuclear power plants. It is intended to secure energy flexibility by supplementing the intermittent nature of renewable energy and securing various uses such as hydrogen production activities or distributed power sources in remote areas.

Figure 1. Development Strategy of Innovative SMR
(Excerpted from the 3rd Innovative SMR Congress Forum)

This domestic innovative SMR has an operation concept that safely and efficiently operates at least four reactor modules with a minimum of three operators in one integrated main control room. This innovative concept of operation is positioned as an advantageous design characteristic for preoccupation of the global market by securing a clear competitive advantage among over 50 types of SMRs being developed at home and abroad. In the case of SMR, compared to large nuclear power plants such as the domestic APR1400 nuclear power plant, the proportion of construction costs is lower, but the proportion of operation and maintenance costs is expected to increase [6]. This is a natural phenomenon according to the principle of economies of scale, but it has the duality of being both a crisis and an opportunity in the development of domestic innovative SMR. The cost of operation and maintenance of a large nuclear power plant accounts for approximately 10% of the total nuclear power plant cost, but economic analysis experts predict that it will account for around 25% in the case of SMR including Gen IV typed nuclear power plants (see Table 1) [1, 2, 3, 4, 5, 7]. Therefore, technology that optimizes operation and maintenance costs can have an absolute impact on SMR's global market competitiveness.

Table 1. Life Cycle Costs of NPP

Costs	Gen II [1)]	Gen IV [2)]	Remark
Capital	67.4%	48.7%	
O&M	10.9%	23.25%	
Fuel	17.4	27.22%	
Decommissioning	4.3%	0.84%	

[1)] Gallanti and Parozzi, 2006; US Congress/EIA, 1993; EIA, 2005; Mackerron et al., 2006
[2)] Williams and Miller, 2006

2. Research Method and Content

The operation and maintenance cost of the innovative SMR and the staffing plan in the integrated main control room are closely related. This is because the operation of the nuclear power plant is carried out with the operation-related activities such as normal, abnormal, emergency, test and periodic inspection centered on the main control room. Therefore, in the development of innovative SMR, the problem of optimizing the staffing plan of the integrated main control room operator considering the double-edged sword of safety and economy is a matter that needs to be carefully considered from the developer's point of view. Moreover, it is difficult to apply the current regulatory position to the SMR in the same way as the domestic and foreign regulatory positions regarding staffing plan of the main control room operators of nuclear power plants are optimized for large nuclear power plants. Table 2 shows the minimum requirements per shift for on-site staffing of nuclear power units by operators and senior operators licensed under US NRC 10 CFR Part 55. Therefore, it is also necessary to prepare a balanced regulatory plan through continuous technical discussions between regulators and developers.

Table 2. Minimum licensed operator staffing requirements under US NRC 10 CFR 50.54(m)

Number of Nuclear Power Units Operating[(2)]	Position	One Unit	Two Units		Three Units	
		One Control Room	One Control Room	Two Control Rooms	Two Control Rooms	Three Control Rooms
None	Senior Operator	1	1	1	1	1
	Operator	1	2	2	3	3
One	Senior Operator	2	2	2	2	2
	Operator	2	3	3	4	4
Two	Senior Operator		2	3	3[(3)]	3
	Operator		3	4	5[(3)]	5
Three	Senior Operator				3	4
	Operator				5	6

1 Temporary deviations from the numbers required by this table shall be in accordance with criteria established in the unit's technical specifications.

2 For the purpose of this table, a nuclear power unit is considered to be operating when it is in a mode other than cold shutdown or refueling, as defined by the unit's technical specifications.

3 The number of required licensed personnel when the operating nuclear power units are controlled from a common control room is two senior operators and four operators.

In particular, in the case of the innovative SMR, the verification method to ensure the human factors suitability of staffing plan in the integrated main control room is emerging as an important safety issue. This study proposes a rational methodology to verify the human factors suitability of a new staffing plan for integrated main control room of Korea innovative SMR in a perspective of human performance. We tried to propose a reasonable methodology suitable for domestic situations by analyzing domestic and foreign regulatory positions and analyzing similar cases. Detailed information on this will be proposed and discussed.

3. Conclusion

The suitability of human performance should be validated from the viewpoint of human factors regulation in staffing plan of the new integrated main control room operator applied to the domestic innovative SMR. Therefore, a staffing plan validation methodology to evaluate human factors suitability is proposed through this presentation. It is hoped that this presentation will serve as a starting point for forming a rational consensus on the relevant safety issue.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) funded by the Korea Government (Ministry of Science and ICT) (NRF-2020M2D7A1079181).

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