

## Development of a Preliminary Organization for i-SMR Operation and Maintenance

Jihyeon Kim \*, Taecheol Park, Sanggyu Lim, Hangan Kim  
Innovative Small Modular Reactor Development Agency  
1, Expo-ro, Yuseong-gu, Daejeon, Republic of Korea  
\*Corresponding author: jhk@ismr.or.kr

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### 1. Introduction

Unlike conventional large nuclear power plants (NPPs), the i-SMR incorporates an integral reactor vessel design, boron-free operation, an innovative instrumentation and control (I&C) system, a multi-module and passive safety systems that requires no operation action during the first 72 hours following a design-basis accident (DBA). Applying the operation organization model of existing large NPPs to i-SMR without modification risks unnecessary staffing levels that erode the economic competitiveness that SMRs are expected to deliver. This paper examines the operation organization structure of traditional domestic NPPs and reviews the staffing plans of representative near term deployed SMR designs, including NuScale and BWRX-300. Based on this comparative case study, a stepwise methodology for optimizing the i-SMR operation organization is proposed, incorporating task-based workforce restructuring. The results are intended to provide a technical basis for establishing an economically optimized operation organization for i-SMR.

### 2. Comparative Review of Staffing and Preliminary Organization Development of i-SMR

The operation organization of existing domestic NPPs — including shift crew composition, licensed operator staffing levels, and job classifications — was established under the operating paradigm of single- or dual-unit, large-capacity plants. Applying this legacy organizational model directly to multi-module, passive NPPs such as i-SMR is likely to result in staffing levels that do not reflect the plant's actual risk and workload profile, thereby undermining the labor-cost advantage that is essential to SMR economic competitiveness, given the smaller electrical output per unit of staff. In accordance with the purpose stated above, this section compares the staffing composition of domestic NPPs and SMRs.

#### 2.1 Domestic NPP

The operating organization of the domestic APR1400, selected as the reference large nuclear power plant, has been established and refined based on accumulated operating experience and is structured as shown in Table I.

Table I: Staffing Composition of Domestic NPP [1]

| Job Positions                     | Ratio(%) |
|-----------------------------------|----------|
| Plant Manager                     | 0.8      |
| Department Managers               | 2.9      |
| Management, Support               | 12.5     |
| Operations                        | 35       |
| Radiation                         | 5        |
| Chemistry                         | 4.4      |
| Program Engineering               | 4.4      |
| System Engineering                | 4.7      |
| Component Engineering             | 10.4     |
| Design Engineering                | 3.9      |
| Maintenance Management            | 8.4      |
| Control Engineering               | 5.5      |
| Civil & Architectural Engineering | 2.1      |

#### 2.2 Near term deployed SMR

The staffing plans proposed for near term deployed SMRs require fewer personnel than those of large nuclear power plants; Although the absolute staffing levels proposed for near term deployed SMRs are lower than those of large NPP sites, the number of personnel required per unit of electrical output is higher. The NuScale VOYGR-12 plant(US600), with a total electrical output of 600 MWe, is expected to employ approximately 270 personnel.[2] For the BWRX-300, approximately 150 personnel are expected to be assigned to plant operation, maintenance and other supporting functions.[3]

These examples demonstrate that SMR staffing levels vary depending on the reactor design, plant capacity, scope of onsite functions and maintenance strategy.

#### 2.3 Development of a Preliminary Organization Model Based on Design Differences

Building on the domestic NPP staffing structure examined in Section 2.1, a preliminary personnel composition for i-SMR is derived by considering how i-SMR's specific design characteristics affect the Table I baseline. The following design characteristics and their corresponding impacts on staffing were identified.

Table II: Expected Staffing Impacts of i-SMR Design Characteristics [4] [5] [6] [7]

| Design Characteristics                                                                                                                                 | Effect on Staffing                                                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Passive safety systems (reduced number of safety-related components)                                                                                   | Reduction in maintenance personnel                                   |
| Integrated Reactor Vessel Steel Containment Vessel (reduced testing, equipment condition monitoring)                                                   | Reduction in maintenance personnel                                   |
| Boron-free operation (reduced chemistry sampling/testing workload)                                                                                     | Reduction in chemistry & maintenance personnel                       |
| Elimination of safety-related (Class 1E) electrical power system required for active safety functions (reduced inspection, testing, qualification etc) | Reduction in maintenance personnel                                   |
| Reduced radioactive waste generation                                                                                                                   | Reduction in radiation protection personnel                          |
| No operator action required within 72 hours following a design-basis accident & Integrated Control Room                                                | Reduction operator workload during accident response                 |
| Increased number of turbines and reactor modules (NPP 2 unit → i-SMR 4 module)                                                                         | Increase in turbine maintenance and preventive maintenance personnel |
| Multi-module standardization with shared/consolidated support functions                                                                                | Merging departments and reduction in support personnel               |
| Automated load following and advanced operation                                                                                                        | Reduction in status monitoring and operation personnel               |

Based on these impacts, an initial round of interviews with experts experienced in nuclear power plant operation indicated that the onsite operating workforce for i-SMR would be approximately 129 personnel. Section 3 presents a data-driven methodology to be applied in subsequent work to systematically quantify and validate the preliminary staffing composition.

### 3. Optimization Methodology

Based on the case study findings, this paper proposes a three-step, data-driven methodology that screens the reference plant's operating data against the i-SMR design basis to identify tasks that are deleted, changed, or added, and converts the resulting workload change into a task-based staffing plan.

#### Step 1 — Baseline Organization and Data Collection

Using the APR1400 as the reference plant, four types of operating data — corrective maintenance work orders, operating and maintenance procedures, equipment reliability records, and maintenance regulations — will be collected and mapped to each job classification in Table I, forming a baseline task and workload inventory (corrective maintenance counts, procedure counts, Preventive Maintenance(PM) man-hours, failure cause etc).

#### Step 2 — Detailed Analysis of Design-Characteristic Impacts

Based on the preliminary staffing impacts identified in Section 2.3, the differences between the APR1400 and i-SMR designs will be analyzed in detail at the system and task levels. The analysis will examine how major i-SMR design characteristics—including boron-free operation, passive safety systems, the integral reactor vessel, the steel containment vessel, the elimination of safety-related electrical power systems, the integrated control room, and the multi-module configuration—affect the scope, frequency, and complexity of operation and maintenance activities.

The operating data collected in Step 1 will be used to evaluate the effects of these design differences on the workload of each job classification, including operations, maintenance, chemistry, radiation protection, engineering, and supporting functions. The results will provide a systematic basis for refining the preliminary personnel composition presented in Section 2.3 and developing the optimized operation organization in Step 3.

#### Step 3 — Development and Validation of the Operation Organization

Based on the workload analysis results obtained in the previous step, the appropriate personnel distribution for each i-SMR job classification will be estimated, and an efficient operation organization model will be developed. Expert reviews involving specialists in nuclear power plant operation, maintenance, and organizational design will then be conducted to assess the adequacy and applicability of the proposed staffing levels and organizational structure.

### 4. Further Study

This paper derived a preliminary i-SMR operation organization of approximately 129 personnel based on the design-characteristic impacts identified in Section 2.3 and an initial round of expert interviews. Further study will apply the three-step, data-driven methodology presented in Section 3 to the complete large NPP operating dataset — corrective maintenance records, operating and maintenance procedures, equipment reliability records, and maintenance regulations — to systematically quantify the deleted, changed, and added tasks by job classification and to refine and validate the resulting i-SMR staffing plan.

The refined and validated organization model, along with the underlying task-level analysis, will be presented in a follow-up paper. The finalized staffing plan will be used as the standard organization for i-SMR operation.

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