

## Study on Fuel Handling System in innovative Small Modular Reactor

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### 1. Introduction

Conventional nuclear power plants have primarily served as stable baseload electricity sources, with design strategies primarily focused on enhancing economic viability through large-scale reactors that exploit economies of scale. However, the recent developments including the strengthening of international nuclear safety standards, the emergence of new countries adopting nuclear energy, and evolving energy demand patterns have shifted priorities toward enhanced safety, improved investment feasibility, and greater operational flexibility [1]. These attributes are increasingly recognized as distinct from, and in some cases superseding, the conventional emphasis on cost reduction via reactor scaling.

Aligned with this global trend, ROK is actively advancing the development of an Innovative Small Modular Reactor (i-SMR), designed to integrate enhanced safety features, economic competitiveness, and operational flexibility. A critical aspect of this development is the optimization of fuel loading and discharge strategies, for which a robust and efficient fuel handling procedure is inevitable.

Accordingly, this study aims to develop the layout of the fuel handling area for the i-SMR, along with the associated fuel handling equipment and fuel handling procedures, to support safe, reliable, and efficient fuel management operations.

### 2. Methods and Results

#### 2.1 General Arrangement

The general arrangement of the fuel handling area of i-SMR as conceptual design comprises four principal zones. Four independent refueling pools (first zone) are connected to a single, elongated refueling canal (second zone) via individual gates. The refueling canal provides access to the spent fuel storage pool (third zone) and other pits (fourth zone) enabling consecutive transfer of fuel assemblies between key handling and storage areas.

#### 2.2 Fuel Handling Equipment

The primary fuel handling equipment as conceptual design includes the refueling machine (RM), the spent fuel handling machine (SFHM), the new fuel elevator (NFE), and the spent fuel transfer device (SFTD). The RM consists of a bridge, trolley, and hoisting system

equipped with a grappling device. It operates within the refueling pools to insert or remove a fuel assembly from the reactor core and transfer them to the SFTD in the refueling canal. The SFHM comprises a bridge, trolley, and fuel handling tools. It takes to transport a new fuel assembly between the new fuel storage rack and the cavity of the NFE, as well as transferring the fuel assembly between the cavity of the NFE and the spent fuel storage rack or the cavity of the SFTD. The NFE lowers a new fuel assembly from the operating floor to the bottom of the refueling canal, where they are retrieved in the water by the SFHM. The SFTD, located within the refueling canal, receives a fuel assembly from either the SFHM or the RM and transports them to a position accessible by the other machine, thereby enabling bidirectional fuel transfer.

#### 2.3 Operating Zones of Fuel handling Equipment

The operating envelope of the RM encompasses reactor vessels 1 to 4, as well as a portion of the SFTD's operational zone. The SFHM is capable of traversing between the spent fuel storage pool and the new fuel storage racks via a designated segment of the refueling canal. The SFTD is designed to operate along the full length of the canal, enabling it to receive and deliver a fuel assembly to and from both the RM and the SFHM, thus facilitating the transfer of both new and spent fuel assemblies. The NFE is installed in the refueling canal, allowing the SFHM to access the NFE zone, the spent fuel storage pool, and the cask loading pit. Additionally, the SFHM can be repositioned to the new fuel inspection area and the new fuel storage area when required, ensuring comprehensive coverage across all fuel handling functions.

#### 2.4 Fuel Handling Procedures

The conceptual procedure for new fuel transfer is being considered as follows. New fuel shipping containers are transported from the loading and unloading area to a designated laydown area, where they are secured on the designated location. A new fuel handling tool, attached to the crane, is engaged with the fuel assembly. The fuel assembly is extracted from the container. The fuel assembly is transferred to the new fuel storage racks for placement in its designated cavity. Prior to storage, each fuel assembly undergoes inspection using a dedicated new fuel inspection system to verify dimensional integrity, structural soundness,

and cleanliness. This process is repeated iteratively until all fuel assemblies have been safely received and stored.

Prior to refueling operations, selected a new fuel assembly is retrieved from the new fuel storage area using the SFHM and the tool. A fuel assembly is then transferred to the cavity of the NFE, which lower them to the accessible position using the equipment. The SFHM with the other tool retrieves the fuel assembly and delivers it to the spent fuel storage pool. For new fuel assembly loading, the new fuel assembly is loaded into the cavity of the SFTD and conveyed along the refueling canal to a position adjacent to the target reactor core gate. The RM then retrieves the fuel assembly from the SFTD and inserts it into the reactor core in the refueling pool.

The conceptual procedure for spent fuel transfer is being considered as follows. Prior to refueling, all equipment and instrumentation are removed from the reactor vessel head, internal regions, and containment vessel to provide unobstructed access. The RM is then positioned above the designated core location. The grappling device are lowered into the reactor cavity, and secures the fuel assembly. Upon successful engagement, the spent fuel assembly is withdrawn from the core and transported underwater to the refueling canal. The fuel assembly is then lowered into the cavity of the SFTD. The SFTD traverses from the refueling pool gate to the spent fuel storage pool gate, enabling transfer of the fuel assembly to the storage area. The SFHM retrieves the spent fuel assembly from the SFTD and transports it to a designated position within the spent fuel storage pool.

If required, the SFHM may also transfer a spent fuel assembly from the spent fuel storage rack to a transport cask located in the spent fuel cask loading pit. This operation is initiated once the cask loading pit is flooded with water from the spent fuel storage pool and the isolation gates between the spent fuel storage pool, refueling canal, and loading pit are opened. Once the assemblies are loaded into the cask, it is sealed under water, and the cask handling hoist lifts it to the cask decontamination pit. There, the external surfaces are decontaminated, and the cask is subsequently transferred to the truck loading/unloading area.

### **3. Conclusions**

This study presents the conceptual design of the fuel handling layout for the i-SMR, with particular emphasis on fuel handling equipment and associated fuel handling procedures. Key equipment including the RM, SFHM, NFE, and SFTD are strategically designed to support safe, efficient, and flexible fuel management across fuel handling scenarios. The defined fuel handling procedures ensure systematic handling of new and spent fuel assemblies, incorporating inspection, storage, transfer, and cask loading operations within a fully underwater environment to maintain radiological safety. The modular and scalable nature of the layout

supports future adaptation to multi-unit SMR deployments.

Moreover, further in-depth research is required to address specific engineering challenges, including the optimization of fuel handling depth, integration of remote handling and automation systems, and verification of equipment reliability under extended operational and unexpected conditions. Additionally, human factors, maintenance accessibility, and interface compatibility with other systems warrant detailed investigation in subsequent design phases.

### **REFERENCES**

- [1] Kyungmin Kim, Chanho Sung, Jooyoul Lee, Development status of the Simulator for i-SMR, Transactions of the KNS spring meeting, May.9-10, 2024, Jeju, Korea.