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Development of Virtual Nuclear Reactor for Design and Demonstration of SMRs

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1. Introduction

Recently, Korea Atomic Energy Research Institute (KAERI) initiated the Global Top Strategic Research Group project whose title is 'Virtual Reactor Platform Development for SMRs'. The purpose of this project is to develop a multi-scale and multi-physics (MSMP) simulation platform entitled 'Virtual SMR (V-SMR)', which will play an essential role in advancing SMR technology. This paper will provide a brief overview of the virtual reactor being developed in the project.

2. Outline of V-SMR Project

The V-SMR project constitutes three government-funded research institutes, 19 universities, and four companies as illustrated in Fig. 1. The participating government-funded institutions include KAERI, KISTI (Korea Institute of Science and Technology Information), and ETRI (Electronics and Telecommunications Research Institute). KAERI oversees the overall project management and the development of software relevant to the nuclear field. KISTI supports the utilization of national supercomputers and performs optimization tasks for simulation codes, taking into consideration GPU architectures. ETRI is developing the integrated platform and managing 3D design software, very fast visualization methods, and pre- and post-processing functions.

Fig. 1. Organization of participating institution

3. Technical Composition of V-SMR

Figure 2 illustrates the schematic of the technical composition of V-SMR. V-SMR integrates high-fidelity and real-time analysis capabilities. For high-fidelity analysis, we are developing cutting-edge technologies including Monte Carlo neutron transport simulations [1], LES/DNS-based thermo-fluid simulations [2], AI-powered MD analysis codes, and FEM-based structural simulations. These advanced tools will be critical for validating numerical designs for SMR demonstration. Additionally, we aim to develop a real-time simulator that combines system analysis codes such as MARS, AI-enhanced models, and simplified BOP models. This real-time platform will be pivotal for creating autonomous operation models for SMRs and facilitating rapid accident prediction and response technologies.

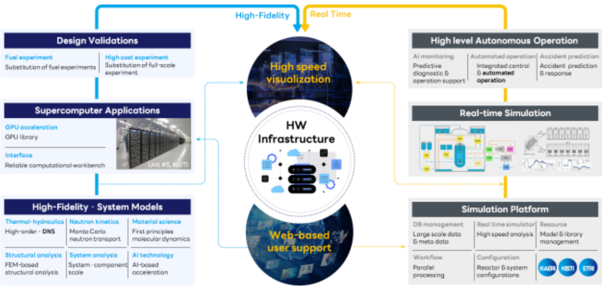

Fig. 2. Schematic of V-SMR

V-SMR leverages the preCICE (Precise Code Interaction Coupling Environment) open-source tool [3], as illustrated in Fig. 3. preCICE facilitates the coupling of different solvers by employing adapters. It also offers multiple data mapping methods, such as nearest neighbor, nearest projection, and radial-basis function-based methods. This feature enables the MSMP coupling of various codes included within V-SMR.

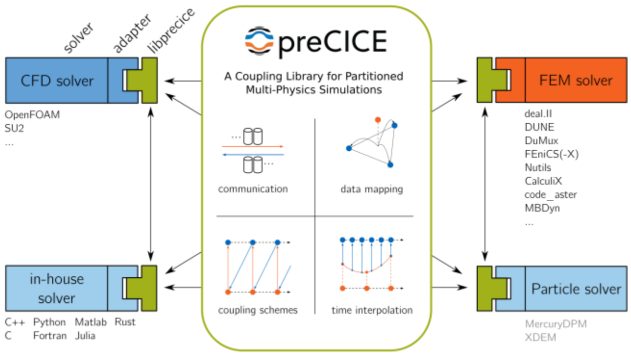

Fig 3. Overview of preCICE [4]

3. Conclusions

The V-SMR project is currently focusing on achieving high-fidelity simulations to validate the designs of SMRs being actively developed globally.

Maximizing high-fidelity simulation technologies, such as MC neutron transport codes, LES/DNS scale thermal-fluid codes along with supercomputing capabilities, is essential for making these technologies practically applicable to SMR development. To achieve this goal, efforts are ongoing to convert the developed codes into GPU-compatible formats and to establish HPC systems comprising GPUs. In the future, collaborative research will facilitate the comparison and validation of these technologies with platforms such as MOOSE in INL

REFERENCES

[1] Choi N.J. et. Al, “Domain decomposition for GPU-based continuous energy Monte-Carlo power reactor calculation,’ Nuclear Engineering and Technology, 52. 2000.
[2] You Ho. et al., “Deneb: open-source high-perfomance multi-physical flow solver based on high-order DRM-DG method,” Computer Physics Communications, 286, 108672. 2023.
[3] Chourdakis, G., Davis, K., Rodenberg, B., Schulte, M., Simonis, F., Uekermann, B., et al., "preCICE v2: A sustainable and user-friendly coupling library," Open Research Europe, 2, 2022.
[4] www.precice.org