Development of an Integrated Support Application for iSMR Flexible Operation

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***Keywords :** innovative small modular reactor (iSMR), reactor core design, visualization, flexible operation

1. Introduction

The flexible operation capability estimation of the innovative Small Modular Reactor (iSMR), a next-generation reactor technology, is a key characteristic and a critical issue in the iSMR research. Designers perform core analysis for the iSMR using existing core analysis codes. In this process, core integrity variables such as Axial Shape Index (ASI) and peak pin power change must be considered during load-following operation. These variables are present in existing core analysis results, but their text format makes it difficult for users to view them at the fuel rod and layer levels. Especially, variables like peak pin power change, mainly relevant to flexible operation, are secondary results requiring additional calculations from core analysis data.

In this study, a Windows application was developed to support core performance evaluation using existing core analysis codes. It includes a 3D visualization module for main input/output data and features specialized for flexible operation.

2. Application Features

The flexible operation support application in this study is an extended version of the previously developed Windows application iSMR Optimizer [1], featuring an improved user interface and enhanced flexible operation functions.

2.1 Flexible Operation Control Process

A predefined operation schedule is required to run the iSMR core analysis code for flexible operation. The iSMR Optimizer provides an editing interface for modifying and visualizing the schedule. iSMR Optimizer applies a load-following control algorithm [2] to adjust control rod positions under specific conditions. In this study, the algorithm minimizes boron adjustments to evaluate boron-free operation performance.

Fig. 1 shows a screen for inputting a flexible operation schedule, where the core power is reduced from 100% to 20% and restored to 100% after 2 hours, once per day for a total of one week."

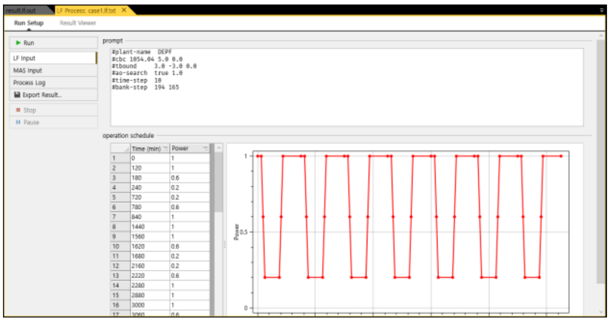

Fig. 1. The run setup screen for flexible operation control process.

2.2 Result Viewer

iSMR Optimizer retains core analysis results for each scheduled time step in the flexible operation process. Fig. 2 shows a summary graph with the schedule time on the X-axis and a visualization of core analysis results for a selected time step. The application allows users to monitor result variables such as power, rod position, inlet temperature, outlet temperature, coolant outlet, and axial shape index over time.

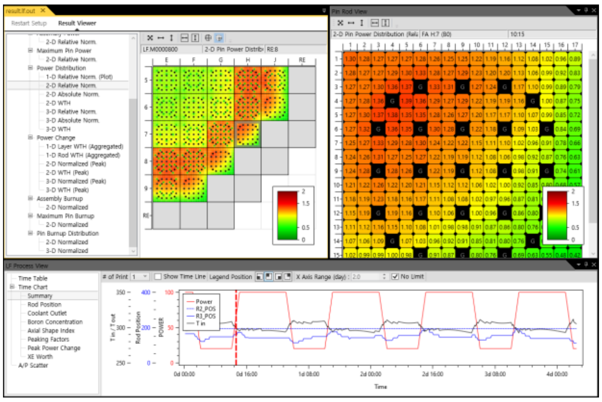

Fig. 2. The visualization screen of core analysis results for a selected time step and a summary graph.

2.3 Restart Setup

If users want to restart the flexible operation from a specific time step after the process is completed, they can do so in the Restart Setup screen. This screen allows rerunning the process with the original schedule or modification of the operation schedule.

3. Analysis Features

iSMR Optimizer organizes and analyzes core analysis code results, visualizing primary variables such as inlet temperature, outlet temperature, control rod positions, and coolant temperature. Additionally, it provides insights relevant to flexible operation performance and core integrity assessment.

A peak pin power change graph highlights the highest local power fluctuation among fuel rods within the fuel assembly. This helps evaluate the core integrity of the iSMR during flexible operation.

Fig. 3 displays a graph where control rod position and peak pin power change share the same Y-axis. Fig. 4 shows the fuel rod layer experiencing the highest local power change. The example in Fig. 3 indicates that significant local power variations occur when control rod positions change.

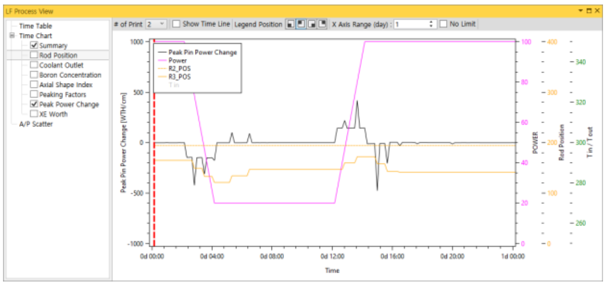

Fig. 3. The graph indicates that significant local power variations occur when control rod positions change.

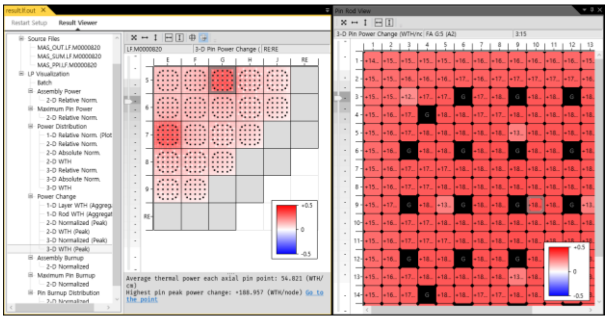

Fig. 4. The layer screen displaying the highest local power change.

4. Conclusions

iSMR Optimizer enables designers to instantly visualize core analysis results, and aiding in core evaluation. Additionally, it provides results related to flexible operation performance and core integrity, allowing for a reassessment of the suitability of the iSMR core design.

In this study, the iSMR Optimizer was developed with a flexible operation performance evaluation function for the core of primary system. If this function is extended to the secondary system, this application is expected to be useful for evaluating the flexible operation performance of the entire reactor system.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science and ICT) (No. RS-2024-00422848).

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