*Transactions of the Korean Nuclear Society Autumn Meeting*
*Changwon, Korea, October 20-21, 2022*

# Development of Core Simulator for PWRs Startup Physics Tests Training

*Seo-Jeong Lee [a*], Sang-Rae Moon [a], Ho-Cheol Shin [a] and Jung-Hoon Choi [b]*
*[a] Korea Hydro & Nuclear Power Co. Ltd., 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon, Korea*
*[b] USERS Co. Ltd., HanshinS-MECA 530Room, 65, Techno 3-ro, Yuseong-gu, Daejeon, Korea*
*[*]Corresponding author: s.jeong2@khnp.co.kr*

## 1. Introduction

For pressurized water reactors, after reload each cycle or when a significant change occurs in the reactor, the reactor physics tests should be performed to ensure that the core characteristics meet the safety limits and follow the design value predicted by the core calculation. During the tests, changes in thermal power, coolant temperature, control rod position, boron concentration, etc. occur, so it must be managed so as not to violate the relevant technical specifications. In addition, it should be reviewed whether the operational behavior of operators or staff that can change the reactivity (for example, dilution or control rod withdrawal) is appropriate. In particular, it is necessary to be proficient the response methods for abnormal situations during the test such as control rod stuck. However, because the tests are generally performed once about every 20 months for each power plant, it is difficult for test staff to skilful the tests procedure or emergency action. And due to the generational change of manpower in this field, human error may occur more frequently as expertise decreases. In order to solve these problems, the core simulator (COSI) was developed, and it is contributing the improvement of a core management ability of the staff through training using the equipment before the tests or from time to time.

## 2. Development Contents

The simulator program was developed for every type of domestic nuclear power plant (Framatome, Westinghouse, OPR1000, APR1400), and the equipment was placed at each plant site to enable training of field staff at any time.

It was developed to be able to simulate initial criticality approach, determination testing range of the power, and all reactor physics tests required for core safety and design value verification such as measurement of critical boron concentration, control rod worth and isothermal temperature coefficient [1]. The advantage of this development is that it is possible to observe and understand the core phenomenon that occurs during actual testing in advance, and the most important part is to enable the simulation tests to be performed in accordance with the plant operation procedure.

### *2.1 Configuration*

The simulator includes one workstation for core calculation and input/output processing, four screens for monitoring and operation, and one control rod selection and manipulation instrument.

Figure 1 shows the appearance of the equipment. Inside the cabinet, there is also an analog signal generator that converts results calculated by the workstation into analog signals, allowing a digital reactivity computer system (DRCS) to be connected to this. The reactivity calculator is a device that can receive analog signals and digitally convert them to reactivity, power level, and coolant temperature in real-time.

Figure 2 shows its screen composition. Screen 1 and 2 are the parts that need to be monitored and operated for tests, and the reality is enhanced by modeling the actual operator control panel of main control room (MCR). Screen 3 is real-time chart that can monitor a current state of a core. Screen 4 is user tools that can various settings for user convenience and testing.

Fig. 1. Core Simulator Appearance

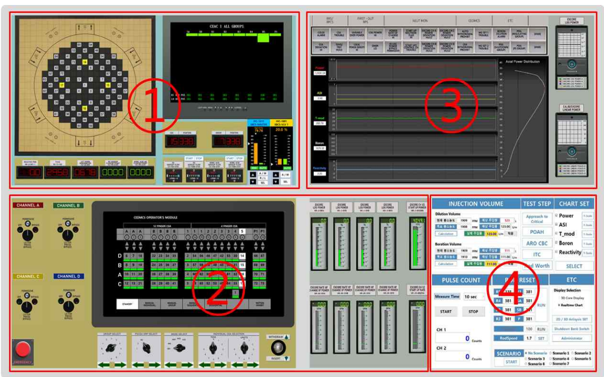



Fig. 2. Screen Layout of OPR1000 Type Simulator

### *2.2 Core Calculation Tool*

In order to simulate real-time core behavior, core calculation must be possible within a very short time. To this end, nuclear reaction cross-section was produced in advance for each burnup step in a nuclear design report, and the simulator allowed the core calculation to be performed within one second with the RAST-Q. It is a light version of RAST-K, the in-house code for research and verification of a core design.

Figure 3 is a schematic diagram of the input/output flow of the simulator. The current core state such as control rod position and boron concentration is accepted as input, and the core calculation is performed by RAST-Q, and the new core state is shown on the screens.

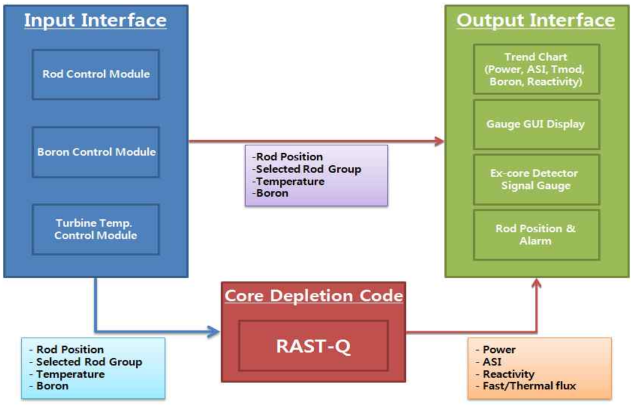


Fig. 3. Schematic Diagram of the Simulator

### *2.3 Monitoring and Control Function*

It is possible to monitor core parameters such as control rod position, boron concentration, coolant temperature, etc., and neutron flux of ex-core neutron detectors and startup rate. Control rod movement, dilution/boration, and steam bypass control system can be operated almost similarly to the actual operation. In addition, when the power level reaches the pre-trip setpoint, alarm light and sound are generated. At this time, if the trip bypass action is not performed, the trip occurs when it reaches the setpoint. By experiencing realistic warnings and actions, the training effect can be maximized.

### *2.4 Real-Time Chart*

Reactor power, axial shape index (axial offset), coolant temperature, boron concentration, and reactivity can be monitored in real time. The unit of the power can be selected as log power (%), neutron counting rate (cps), and current value (Amp) reflecting all domestic plant types. And it is possible to monitor only the necessary parameters and adjust the monitoring range.

### *2.5 User Tool*

For a user's convenience, the amount of the water to reach the target boron concentration is automatically calculated by entering the target. And the injection rate of dilution/boration and control rod movement speed can be adjusted for faster simulation than the actual test. There is also a neutron counter for inverse counting rate ratio (ICRR) measurement during initial critical approach, and various setpoints are set in this tool. In addition, when only one subgroup of a shutdown bank needs to be controlled, a window as shown in figure 4 can be displayed to adjust the switch as in operation procedure.

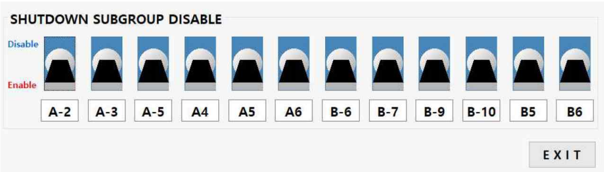


Fig. 4. Shutdown Bank Subgroup Selection Window

### *2.6 Abnormal Scenarios*

It can be selected in the user tool, and is marked only with numbers so that trainees do not know the scenarios in advance. These include a control rod slip down, rod stuck, rod drop, deviation of rod position, and opposite phenomenon of dilution/boration.

## 3. Conclusions

By developing the screen of the monitoring/operation and operation method of the simulator very similar to the field environment, the training effect can be enhanced by minimizing the gap between the actual and the simulator. By using this equipment, it is possible to improve the understanding of the phenomenon in the core and reactivity management. Thus, it can have the effect of increasing the plant capacity factor by preventing human error in actual tests and shortening the test period.

## REFERENCES

[1] American Nuclear Society, Reload Startup Physics Tests for Pressurized Water Reactors, ANSI/ANS-19.6.1-2011, 2011