Simulation of irradiation rig loading/unloading in research reactor

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1. Introduction

Irradiation rigs are inserted into the reactor core of research reactors for isotope production or experimental purposes. The irradiation rig contains targets for neutron irradiation, and the irradiation period and method vary depending on the type and quantity of the irradiated material. Irradiation rigs are loaded or unloaded before the reactor starts operating or during power operation. When the irradiation rig is loaded or unloaded during power operation, the irradiation rig inserts reactivity into the core and perturbs the reactor power, which affects reactor safety[1]. The power control program adjusts the reactor power to within the normal range by moving the control rods. Therefore, it is necessary to evaluate that the power control program in the research reactor can controls the power properly during irradiation rig loading or unloading.

2. Simulation method

The simulation program incorporates various models to simulate the reactor response to irradiation rig loading and unloading. Developed based on MATLAB/SIMULINK[2], the program was modified to implement specific reactor characteristics and control logic. Figure 1 shows a schematic diagram of the models in the program[3]. The program model consists of a reactor dynamics model, a reactivity feedback model, and a control logic model.

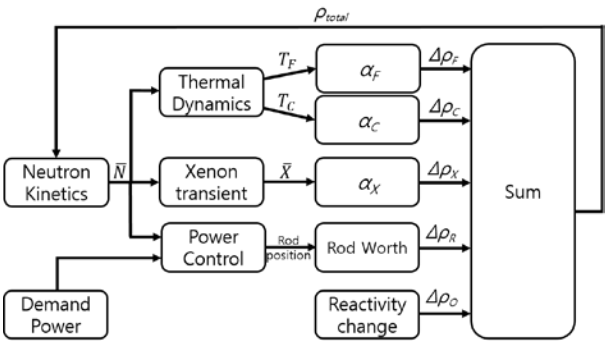

Fig.1 Schematic diagram of simulation program

3. Simulation results

The simulation of irradiation rig loading/unloading at power operation was performed based on the kinetic characteristics and power control logic of a typical research reactor. The irradiation rig was assumed to have a reactivity of 1mk when it is completely loaded. A loading/unloading time ranges from 1 to 100 seconds.

Fig. 2 shows the reactor power from simulation results of irradiation rig loading. The result shows that the faster the loading rate, the higher the reactor power overshoot. To control the rapid power change, the power control program inserts the control rods with a larger travel distance, resulting in a slight undershoot in the reactor power afterward. In case that the loading rate is slow, no undershoot is shown.

Fig.3 shows the simulation results of irradiation rig unloading. The result shows that the faster the unloading rate, the lower the reactor power undershoot. Rapid unloading cases results in power overshoot thereafter. The power during unloading shows the opposite behavior to that during loading.

Figure 4 shows the effect of the control rod reactivity worth on the reactor power during irradiation rig loading. Since the control rod reactivity worth represents the reactor power controllability, a higher control rod reactivity worth leads to a decrease in the peak of the reactor power. The control rod reactivity worth is determined by the neutron absorber design, but it also varies depending on the control rod position during reactor operation.

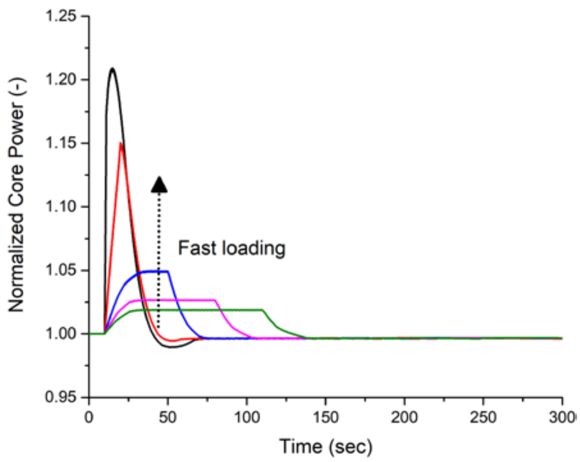

Fig.2 Normalized power during the loading of irradiation rig

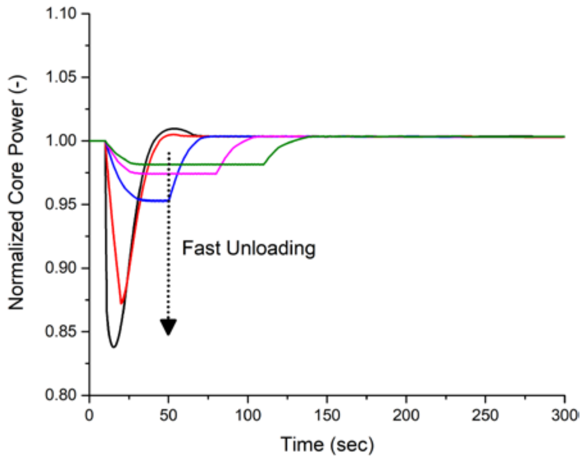

Fig.3 Normalized power during the unloading of irradiation rig

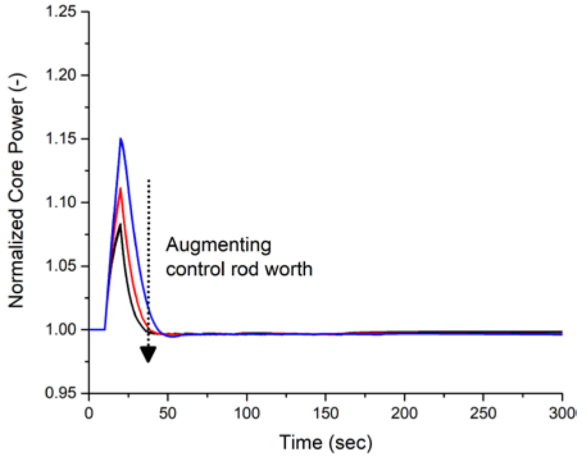

Fig.4 Normalized power during the loading of irradiation rig with different control rod worth

3. Conclusions

A simulation was performed on the loading and unloading of an irradiation rig during power operation in a research reactor. The simulation was conducted to investigate the effects of the loading/unloading speed of the irradiation rig and the control rod worth on the reactor power behavior.

The simulation aims to evaluate whether the reactor characteristics, such as the reactivity worth of the control rod and the power control program, can sufficiently control the reactivity change caused by the irradiation rig. To maintain the power within the operating range, it is necessary to limit the reactivity and reactivity insertion rate of the irradiation rig. The limit should be evaluated considering conservative reactor conditions and the effects of the power control program.

ACKNOWELGEMENTS

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[3] Donghyun Kim and Suki Park, Research reactor operation simulation for Control Rod Drive Mechanism endurance test plan, KNS, Oct, 2017.