Development of Turbine-leading Power Maneuvering Strategy for a Sodium-cooled Fast Reactor

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1. Introduction

A sodium-cooled fast reactor (SFR) has been developed at KAERI.[1] In this study, a turbine-leading power maneuvering strategy for the SFR was developed by using the modified MMS-LMR-SG code.

The MMS-LMR-SG code is a simple SFR plant analyzer and has been developed by modifying a commercial Modular Modeling System (MMS) code with specific features of KALIMER-600. [2,3,4] The MMS-LMR-SG was modified in order to simulate the thermodynamic behaviors of the turbine and the feedwater system of the plant. A turbine with turbine control valve and feedwater system including a feedwater control valve and a feedwater pump were newly developed. To simplify the analysis, the feedwater condition at inlet of feedwater pump and the outlet condition of the turbine were considered as the fixed pressure boundary conditions. Then, some controllers for steam flow rate, steam pressure and the control rod movement were implemented in the MMS-LMR-SG code.

The turbine-leading strategy is as follows: the turbine control valve is opened to meet the turbine power with the power demand. As steam flow rate increases, the steam pressure is reduced. Thereafter the feedwater control valve opening is increased based on the reduced steam pressure signal. [5,6] Fig. 1 shows the control logics for turbine-leading power maneuvering strategy.

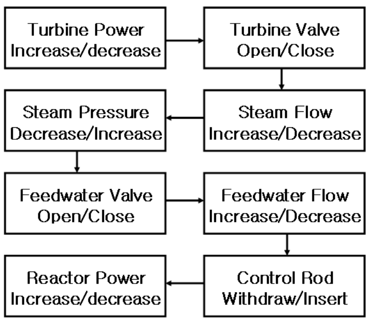

Fig. 1 Control Logic for turbine-leading strategy

2. Constraints for Power Maneuvering Strategy

Some constraints for the power maneuvering strategy in order to ensure the safety and the performance of the SFR were set up. The temperature in the cold pool of the primary pool should be kept at less than 420 ℃ in order not to violate the creep condition of the reactor vessel. In addition, the operation of the constant averaged temperature in the primary pool was suggested in order to minimize the change of the volume of the primary pool and the reactivity of the core resulting from change of the coolant temperature. To meet the constraints, the control logic of variable flow rates in the primary pool and the intermediate loop was adopted. And, the steam pressure should be kept constant in order to minimize the impact to the turbine system during power maneuvering. A turbine-leading strategy was developed with these constraints.

In the strategy, the controlled variables are the temperature, the pressure and the core power level and the controllable variables are the flow rates of the primary pool (PHTS) and the intermediate loop (IHTS), the movement speed and the position of the control rod and the control valve positions of feedwater and the turbine system. Also, the maneuvering strategy was developed to have a capability for 10% step power change and 5%/min ramp power change.

3. Simulation of Power Maneuvering

To ensure the developed strategy, a simulation was performed. The scenario of the simulation was follows: the power demand to the turbine system was kept as a full-rated power for 1500 sec in order to analysis a steady state, and then the power demand was suddenly dropped to 90% and maintained to 3500 sec. After that, the power demand was decreased to 50% with ramp rate of 5%/min and kept to 7000 sec. Finally, the power demand was recovered up to 100% and kept to the end of analysis (9000 sec).

Fig. 2 shows the simulation results. As shown Fig. 2-(a), the turbine power and core power followed the power demand with small fluctuations and deviations. In Fig. 2-(b) shows the temperature distribution during the power maneuvering. The averaged temperature, the hot temperature and the cold temperature of the PHTS was kept constant. Also, the cold pool temperature did not violate the constraint. These characteristics could be achieved by variable flow rate control logic for the PHTS and the IHTS. Fig. 2-(c) shows the percentile flow rates of the PHTS, the IHTS and feedwater system.

Fig. 2-(d) shows the position of control rod during the power maneuvering. Fig. 2–(e) represents the pressures of the outlet of feedwater pump (FWP) and feedwater control valve (FCV) and the inlet of turbine control valve (TCV). As shown Fig. 2-(e), the steam could be kept constant during simulation although there were

some fluctuations. Fig. 2-(f) shows the position of turbine control valve and the feedwater control valve and the speed of the feedwater pump. The position of turbine control valve seems to be a little low at 50% power. It will be overcome by optimization of the turbine system later. Also, some fluctuations of the core power, pressures and the valve positions will be able to be minimized by optimal tuning of control gains of the controllers used in the control system for the valves and the pumps.

5. Conclusions

In this study, a simple turbine system and a feedwater system were inserted into the MMS-LMR-SG code and the turbine-leading power maneuvering strategy for a SFR was developed. From the simulation of a power maneuvering event, the developed strategy was proved to be a good alternative to control the steam pressure, turbine power and the core power. Some fluctuations and better response characteristics will be improved by optimization of plant and the optimal tuning of the control parameters of the control systems.

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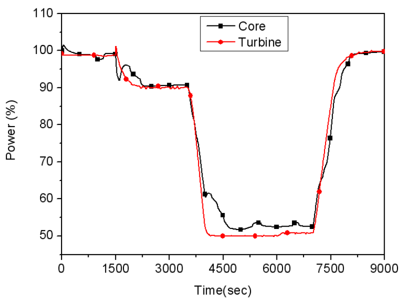
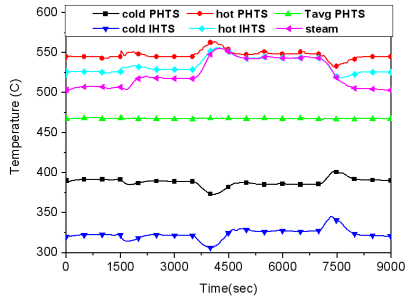
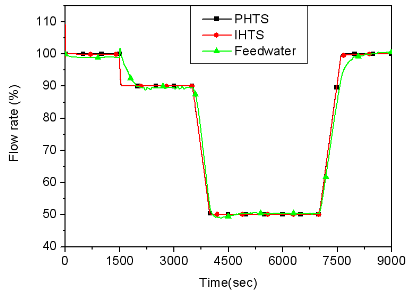


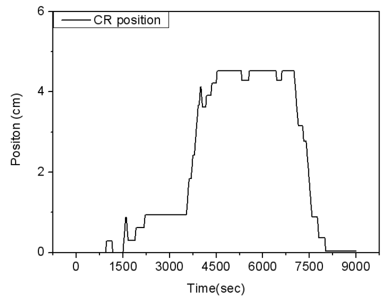
(a) Power



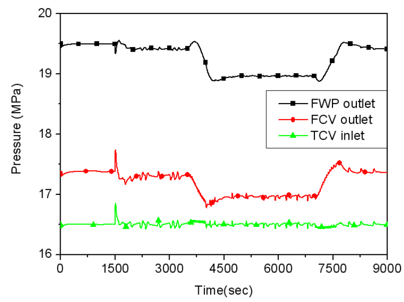
(b) temperature



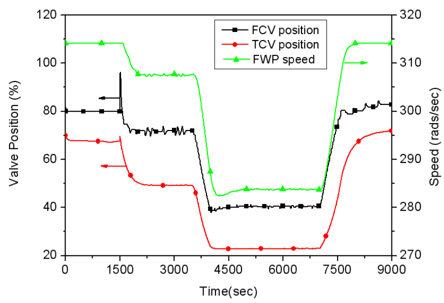
(c) flow rate



(d) control rod position



(e) pressure



(f) valve position and feedwater pump speed

Fig. 2 Simulation Result