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Evaluation of Load-Following Strategies for a KALIMER-600

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1. Introduction

A sodium-cooled fast reactor (SFR) has been developed at KAERI.[1] In this study, three power maneuvering strategies for the SFR was evaluated by using the developed MMS-LMR-BOP code.

The MMS-LMR-BOP code is a simple SFR plant analyzer and has been developed by modifying a commercial Modular Modeling System (MMS) code with the specific features of KALIMER-600. [2,3,4] The MMS-LMR-BOP code has a NSSS model and a BOP model. The NSSS model is divided into two parts of the primary pool and the intermediate loop according to the SFR plant's design. The BOP model consists of some turbines, a steam cycle and a feedwater cycle including three preheaters. Fig. 1 shows the schematic diagram of MMS-LMR-BOP code.

In this study, three control strategies of turbine-leading, reactor-leading and feedwater-leading were evaluated. The turbine-leading strategy is as follows: the turbine control valve is opened to meet the turbine power with the power demand. As the 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] In the turbine-leading strategy, the average temperature of primary pool is kept constant by adjusting the position of the control rod in the core. Secondly, the reactor-leading is to start controlling the reactor power according to the power demand. Then, the feedwater flow rate are controlled to keep the cold temperature of the intermediate loop constant and the steam pressure is maintained as a nominal value by the turbine control valve. Finally, in the Feedwater-leading strategy, the flow rate of feedwater is adjusted to a certain value to control the turbine power to meet the power demand by movement of the feedwater valve. And, the steam pressure is controlled as constant by the turbine control valve. The reactor power was controlled to keep the average temperature of the primary pool constant by movement of the control rod.

2. Constraints for Load-Following Strategies

Some constraints were set up for the load-following strategies in order to ensure the safety and the performance of the SFR. [7] 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 average temperature in the primary pool was suggested, except for the reactor-leading strategy, in order to minimize the change of the volume of the primary pool and the reactivity of the core resulting from a 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 load-following.

3. Evaluation Results

To evaluate the three strategies, some simulation was performed. The scenario of the simulation was as follows: the power demand to the turbine system was kept at a full-rated power for 4800 sec in order to analyze a steady state, and then the power demand was suddenly dropped to 90% and maintained to 7200 sec. After that, the power demand was decreased to 50% with ramp rate of 5%/min and kept to 12000 sec. Finally, the power demand was recovered up to 100% and kept to the end of analysis (15000 sec).

Fig. 2 shows the evaluation results of under turbine-, reactor- and feedwater-leading strategies according to the power demand, respectively. As shown in Fig.2-(a), the turbine power well follows the power demand in the turbine-leading mode and the reactor power well follows the demand in the reactor-leading mode. Under feedwater-leading mode, the power of the reactor and the turbine asymptotically follow the power demand. Fig. 2-(b) shows the temperature behaviors of each strategy. The average temperature is well maintained in the turbine- and feedwater-leading strategy while the average temperature varied according to the power demand in the reactor-leading strategy. Fig. 2-(c) shows the pressures of the main steam. The steam pressures are well kept as a constant under all strategies. That means the steam pressure can be easily controlled under all strategies.

4. Conclusions

In this study, a simple steam-turbine system and a feedwater system were modeled in the MMS-LMR-BOP code and the turbine-, reactor- and feedwater-leading load-following strategies for a SFR were evaluated. From the results of a load-following event, all of the strategies were proved to be a good alternative in order to control the steam pressure, turbine power and the reactor power. According to the plant operational mode, a strategy will be selected in order to minimize the fluctuation of core or turbine power. In further studies with an exact model, all the control parameters of the SFR plant will optimally tuned.

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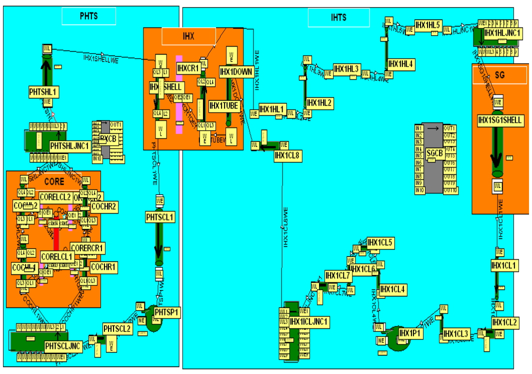
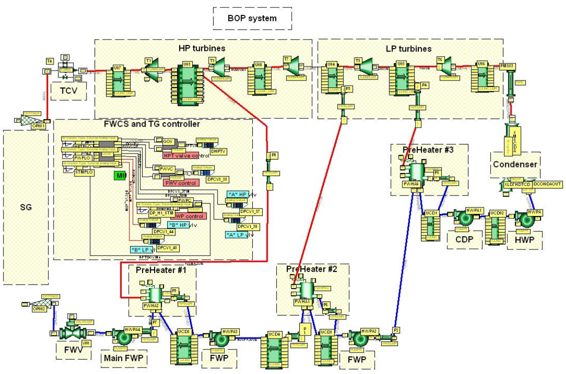
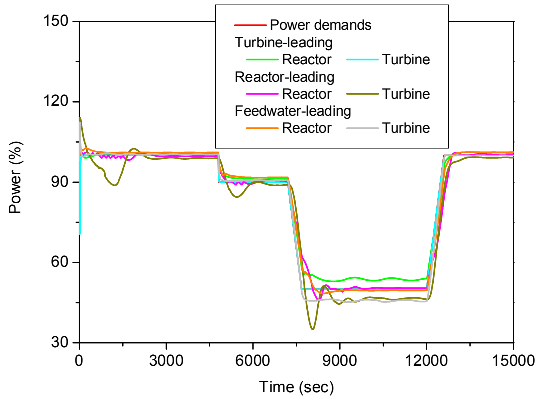


(a) NSSS model

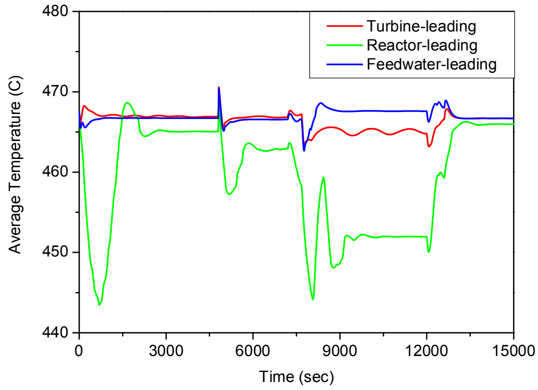


(b) BOP model

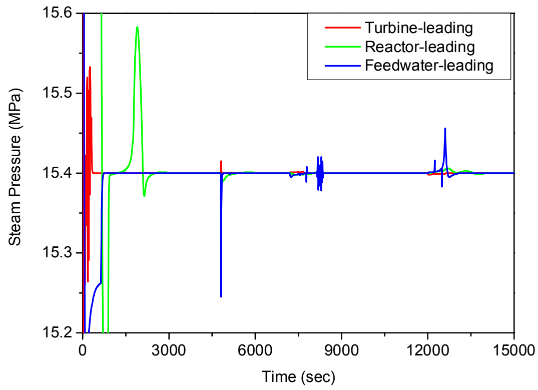
Fig, 1 Schematic diagram of MMS-LMR-BOP code



(a) Power



(b) Temperature



(c) Steam Pressure

Fig. 2 Evaluation Results