Analysis of one Feedwater Pump Stop Event of KALIMER-600

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1. Introduction

A sodium-cooled fast reactor (SFR) named KALIMER-600 has been developed at KAERI.[1] In this study, an event of one feedwater pump stop was evaluated by using a developed MMS-LMR code. The MMS-LMR code which can simulate the plant performance of KALIMER-600 was developed in previous studies.[2-4] The code was developed by adding some features of KALIMER-600 into the software component model of a commercial Modular Modeling System (MMS) code and by attaching sodium properties into the material library.[2-5]

Fig. 1 shows the schematic diagram of the MMS-LMR code. The code consists of models for core dynamics, PTHS (primary heat transfer system), IHTS (intermediate heat transfer model) and SG (steam generator). In addition, a feedwater system with a feedwater control valve which could manipulate the feedwater flow and a simplified steam pressure boundary which was assumed to keep constant during power operation were modeled. It looks very simple code but the tendency of the plant's behavior can be assumed to be very close to that of a real plant.

2. Scenario of One Feedwater Pump Stop Event

In this study, an event of abruptly stopping one feedwater pump during normal operation was assumed and simulated. The feedwater flow rate could be suggested to suddenly decrease to the half of full capacity in this event and the transient behavior of NSSS system of the KALIMER-600 was analyzed.

For continuous operation in case of this event, some control schemes related to the movement speed of the controls and the control logics of the flow rates of the NSSS system were changed.

During normal operation, the control rods speed is set to be 0.02cm/s although it seems to be very slow. Since a conceptual design of KALIMER-600 has been being performed in these days, it was suggested that 6 control rods of total 12 rods was moved to control the reactor power. So, the movement speed of control rods was very slow because lots of control rods took part in controlling the reactor power. This may be changed in further design and it will be discussed in further studies.

In this event, the rod speed should be adjusted to be 2cm/s during a short period after the event in order not to violate the reactor trip condition. The speed would return to 0.02cm/s after a short period. The trip parameters were high flux (overpower), mismatch of rector power versus PHTS flow rate, high hot pool temperature of PHTS, high cold pool temperature of PHTS, low sodium level of PHTS and high pressure of IHTS. In this event, mismatch of the reactor power versus PHTS flow rate, high hot pool temperature of PHTS and high cold pool temperature of PHTS might be violated but the other trip parameters must not be threaten.

When the rod speed was less than 2cm/sec, the reactor would be tripped because the hot pool temperature was over than the trip set point of KALIMER-600. The trip set point of the hot pool temperature in the primary pool was set 555℃ while its nominal value is 545℃ during normal operation. The margin for trip was so small and so the rod should move very quickly comparing to the normal speed.

This set point and the nominal value will be being changed to 574℃ and 510℃, respectively. However, the previous values were used in this study because all of the design data for a new sodium-cooled fast reactor have not been changed yet.

During normal operation, the flow rates of the PHTS and IHTS were changed according to the power level by some constraints of the control systems.[3,6] However, for this event, the flow rates were fixed to be the nominal values of full power operation because this event is a kind of abnormal event and the larger flow rates would be better to keep hot pool temperature under the trip set point.

3. Analysis Results

With control scheme mentioned in Chapter 2, a feedwater pump stop event was simulated by using the MMS-LMR code. The simulation scenario for the event is followings: Until 500 sec of simulation time, the steady state was analyzed and then the feedwater flow rate was suddenly decreased to 50% level of normal operation due to stop of one feedwater pump. Finally, the simulation continued to the end of simulation (2000sec) and some plant parameters such as reactor power, temperature and pressure etc.

Fig. 2 shows the analysis results and the plant could continuously operate without violating any trip conditions. Fig. 2-(a) shows the relative level of changes of the reactor power, feedwater flow rate, PHTS flow rate and IHTS flow rate. The reactor power was asymptotically decreased to level of 52% level. The relative level of flow rate of PHTS and IHTS first followed the reactor power and then the level was fixed to certain value (for example, a percentile external power demand) for a stable operation when the relative level was stabilized within a predefined band.

As shown in Fig. 2-(b), the temperature profiles of PHTS and IHTS were kept under the trip conditions. Also, the pressure of IHTS was maintained lower than them of normal operation as shown in Fig. 2-(c).

Fig. 2-(d) and (e) shows the reactivity change and the position of control rods during this event. Although there were some small fluctuations during 900 from 600 to 1500 sec of simulation time, the transient of this event could be stably managed. Fig. 2-(f) shows the temperature of steam and feedwater.

4. Conclusions

An event of one feedwater pump stop was analyzed in order to evaluate the performance of KALIMER-600 by using a simplified performance analyzer. With high speed of control rod movement of 2 cm/s in a short time, KALIMER-600 could continuously operate without any violation to the trip conditions. In this study, the temperature and the pressure of feedwater system was assumed to be constant and the steam pressure was constant. So, the results were a little limited. The effect of change of those conditions will be studied later by using a more detailed analyzer.

Also, in further studies, the assignment and the movement speed of control rods for maneuvering reactor power will be examined in details and other operational event such as one PHTS pump stop, one IHTS pump stop and one IHX isolation will be studied

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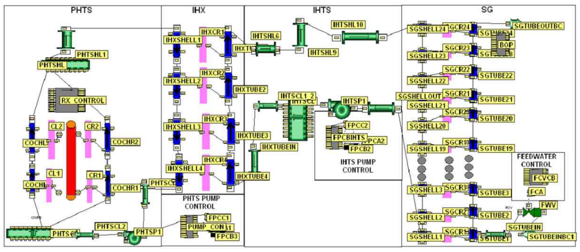
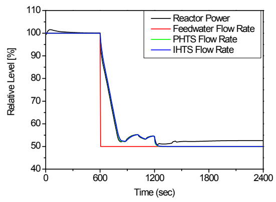
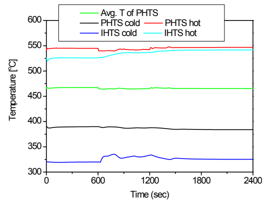


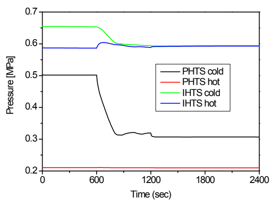
Fig. 1 Schematic diagram of MMS-LMR code



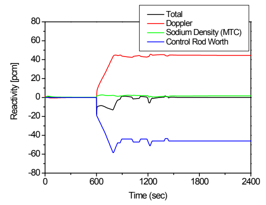
(a) Reactor power and flow rates



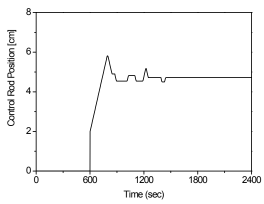
(b) Temperature



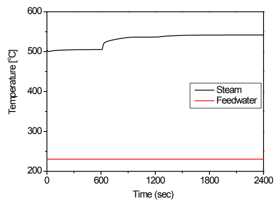
(c) Pressure



(d) Reactivity



(e) Control rods Position



(f) Temperature

Fig. 2 Simulation Results