Analysis of one IHX Isolation Event of a Sodium-cooled Fast Reactor

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1. Introduction

A conceptual sodium-cooled fast rector with 600MW of electricity developed at KAERI [1]. It is a pool-type reactor and is composed of primary heat transfer system (PHTS), intermediate heat transfer system (IHTS) and a superheated steam cycle. Four intermediate heat exchangers (IHX's) between PHTS and IHTS were installed in the plant, and an event of one IHX isolation was evaluated using a simulation code named MMS-LMR code. [2-5] The code can simulate core dynamics based on the point-kinetics equation with the reactivity feedback mechanism and control rod model as well as thermodynamic behavior of the plant including PTHS IHX, IHTS and steam generator (SG). In addition, it has a model for a simplified feedwater system with a feedwater control valve that can simulate the feedwater flow, and a constant steam pressure boundary condition.

2. Event Scenario

An event of a single IHX isolation during normal operation was assumed and simulated. In other words, one out of four IHX's was suddenly isolated during operation due to some failures such as a tube break of the IHX or tube blockage due to a loose part of some components in the IHTS loop. With this event, the operational condition which doesn't cause the plant to trip.

When one IHX among four IHX's was isolated, the reactor power must go down to 75% of nominal value because the capacity of the overall heat transfer between PHTS and IHTS decreases to 75% of full load. Then, the plant could continue to operate without tripping the plant.

Also, the control rod must move fast in order to accommodate the sudden change of the heat transfer rate without violating trip conditions of the plant. So, high-speed movement logic for the control rods was introduced. During normal operation, the movement speed of the control rods was set to be 0.02cm/s. However, the speed was adjusted for one second to 4cm/s in this event. After one second, the speed returned to normal speed of 0.02cm/s. Also, reactor power control logic was transferred from a turbine-leading to reactor-leading strategy for a quick response to the event. [6-9]

For considering realistic practice, the delay of the control actions coping with this event was suggested and the control movement started after two seconds from isolating the IHX. It was a conservative assumption for the time constant of the control rod drive mechanism which generated the signals for movement of control rod.

Finally, the control logic for the reactor power change is set to step mode which can manipulate the reactor power of with 10% decrease at once. Normally, the rate of the reactor power change was set to 5%/min but it's too slow to accommodate this event. So, the change rate of the reactor power was set to step mode of 10%.

The trip parameters of the plant that could be affected by this event were a high flux (overpower); mismatch of power-to-flow ratio which meant a large discrepancy between the reactor power and flow rate of the PHTS; high core outlet temperature; high core inlet temperature; and high SG shell outlet temperature. Those setpoints were provisionally 112%, 119%, 571℃, 400℃ and 340℃ in turns. All variables related to the trip were estimated in order to identify whether the variables would violate the setpoints. [7, 8]

3. Analysis Results

Fig. 1 shows the simulation results of the reactor power, temperatures, flow rates, and power-to-flow ratio. The event of one IHX isolation started at 500sec of the simulation time. Before that time, a steady state of the plant was simulated and then the simulation continued to 4000 sec in order to assure the stable operation of the plant.

Firstly, the reactor power was examined during this event as shown in the Fig. 1-(a). It was stabilized at 73% of the nominal value from 100% with small fluctuations and it didn't make trip condition of the plant.

Secondly, the parameter of power-to-flow ratio was shown in the Fig. 1-(b) and it didn't also violate the trip condition.

Thirdly, the temperature profiles were studied and there were two trip setpoints with regard to the temperature such as the hot pool temperature which should be less than 571℃ and the cold pool temperature of PHTS which should be less than 400℃. No trip occurred with these temperature setpoints in this simulation as shown in the Fig. 1-(c).

Then, other parameters such as reactivity change in the core and the position of control rod during the simulation were shown in the Fig. 1-(d) and (e).

As shown in the figure, all the parameters which were important to safety and operation of the plant were stable during the event.

4. Conclusions

The event of a single IHX isolation of a sodium-cooled fast reactor was analyzed. As the result of the simulation, the plant could continue to operate with low power level without tripping the plant by the control logics implemented in the plant although a conservative assumption of delay of control scheme was introduced.

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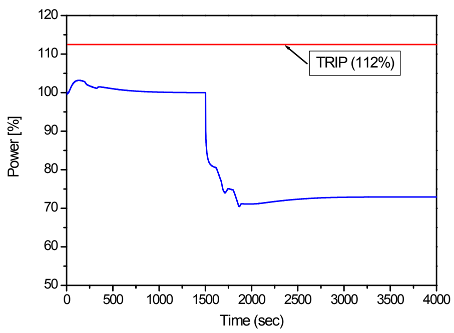
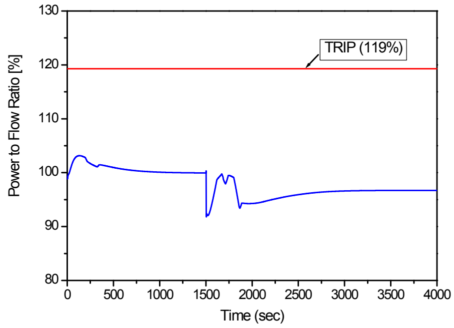
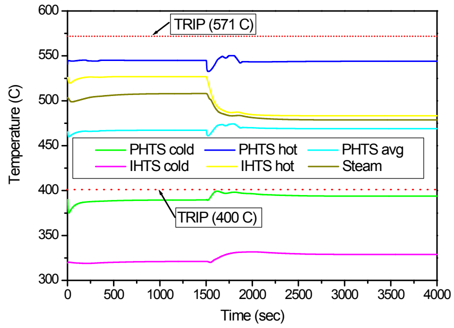


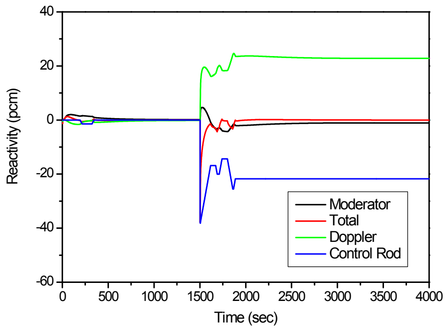
(a) reactor power



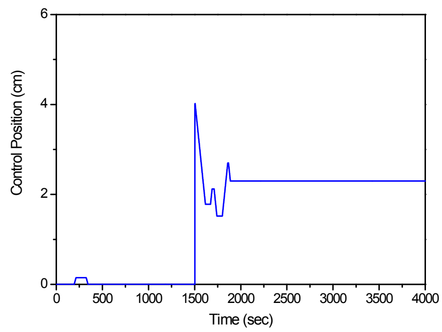
(b) power-to-flow ratio



(c) temperature



(d) reactivity



(e) control rod position

Fig. 1 Results of Simulation