Analysis of one PHTS Pump Trip Event of KALIMER-600

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1. Introduction

A Korea Advanced Liquid Metal Reactor (KALIMER) has been under development at KAERI [1]. The KALIMER has 600MW electricity and is composed of primary heat transfer system(PHTS), intermediate heat transfer system(IHTS) and a superheated steam cycle. Two pumps are installed in the PHTS and an event of one PHTS pump trip was evaluated by using a simulation code named MMS-LMR code.[2-5] The code consists of models for core dynamics, PTHS with two pumps, IHTS and SG (steam generator). In addition, a simplified feedwater system with a feedwater control valve that can simulate the feedwater flow and a constant steam pressure boundary were modeled.

2. Event Scenario

An event of abrupt one PHTS pump trip during normal operation was assumed and simulated. In other words, one out of two pumps was suddenly tripped during operation due to the shaft seizure or the loss of electric power to the pump. Since two causes could make different plant dynamics, the events from two causes were evaluated in turns. In the event of shaft seizure, the flow rate through the tripped pump suddenly dropped to zero without any coastdown flow. But the other case had the coastdown flow during some period (~300sec). Those were the difference of two causes. In addition, the other pump which is not tripped was assumed healthy and run with constant speed without any control actions during the event.

To avoid plant trip, high speed movement logic for control rods was introduced. During normal operation, the movement speed of control rods was set to be 0.02cm/s. However, the speed was adjusted for a short time (~10sec) to 4cm/s in this event. After the short period, the speed was returned to normal speed (0.02cm/s). Also, the reactor power control logic was transferred from the turbine-leading to the reactor-leading strategy for the quick response to the event.[6]

The trip parameters of KALIMER which could be affected by this event were a high flux (overpower), mismatch of power-to-flow ratio which meant the large discrepancy between the reactor power and the 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 check whether the variables would violate the setpoints or not.[7]

3. Analysis Results

3.1 Shat Seizure

The shaft seizure of one PHTS pump from unknown failure was assumed. When the shaft was seized, there was no coastdown flow through the pump because the impeller of the pump could not work. With this assumption and the event scenario, the plant behaviors were evaluated. The event occurred at 500 sec of the evaluation time.

Fig. 1 shows the evaluation results about the reactor power, temperatures, flow rates and power-to-flow ratio. The reactor power was stabilized after a short period and the temperatures were shown in a similar trend. Both variables were kept below the trip setpoints. The flow rate of the PHTS was promptly dropped to not 50% but 75% of full rate although one out of two pumps was tripped without coastdown. The reason was that the relation between the pressure and the flow rate of the pump was quadratic and so the flow rate with the same speed of the working pump was up to 75% of nominal flow rate of the plant. The plant was tripped as shown in the figure, because of the variable of the power-to-flow ratio which calculated the ratio of power over the rated flow rate.

Since the pump was tripped without coastdown flow, the reactor power was 100% and the rated flow rate was suddenly dropped to 75%. Accordingly, the value of the power-to-flow ratio was asymptotically 133% and it was larger than the trip setpoint of 119%. Then the reactor was tripped once the event occurred.

3.2 Loss of Electric Power to one Pump

The loss of electric power to of one PHTS pump from unknown failure was evaluated in a similar way. Comparing the first case, there was a big difference related to the coastdown flow. When the electric power was lost, the flow rate of the pump was exponentially downed to zero flow by the coastdown originated from the inertia momentum of the pump.

Fig. 2 shows evaluation results of this case. Unlikely to the first case, there was no reactor trip. This event could return to the normal operation of 75% rated power. Especially the variable of the power-to-flow ratio was kept below the trip setpoint because the coastdown flow existed through the core at the early stage of the event unlike the previous case. While the

coastdown went down, the reactor power could be decreased to a predetermined level of 75%. So, this event could overcome the sudden transient due to one pump trip without any reactor trip.

4. Conclusions

The event of one PHTS pump trip of KALIMER-600 was analyzed. In the case of the loss of the electric power of one pump of the PHTS, KALIMER-600 could be continuously operated without any violation of the trip conditions. However, in the case of the shaft seizure, KALIMER-600 was tripped by the parameter of the power-to-flow ratio.

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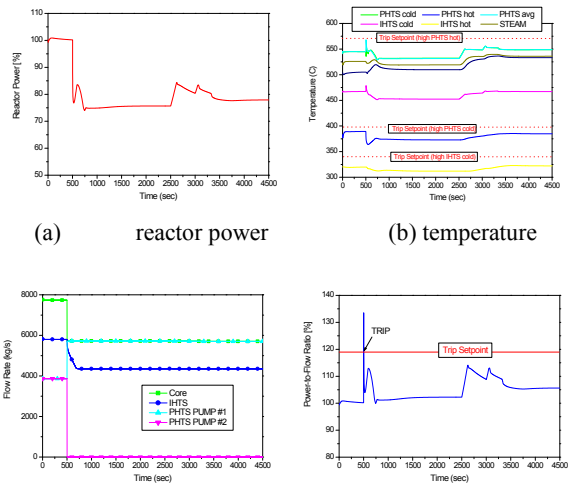

(a) reactor power (b) temperature

(c) flow rates (d) power-to-flow ratio

Fig. 1 Results of Shaft Seizure

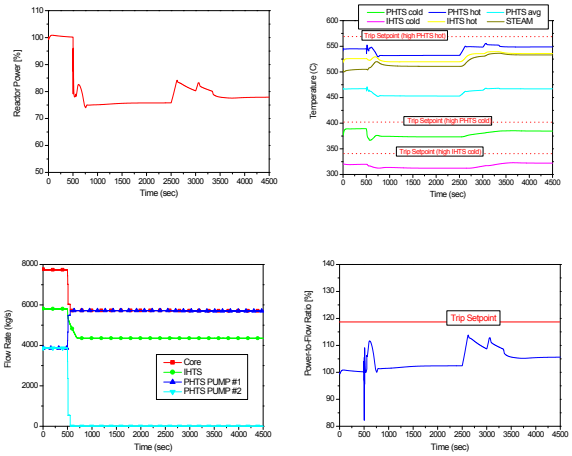

Fig. 2 Results of Electric Power Loss