Performance Analysis of the Passive Residual Heat Removal System in the SMART plant

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1. Introduction

Passive safety systems in nuclear power plant have been widely investigated [1, 2] due to its inherent characteristics of using natural forces such as natural convection and gravity to circulate the coolant, and less dependent on active components like pumps and diesel generators.

The Passive Residual Heat Removal System (PRHRS) is one of the innovative design features adopted in the SMART plant (660MWt) being developed at Korea Atomic Energy Research Institute (KAERI).

For a better understanding of the PRHRS operating characteristics, a performance analysis has been conducted by using TASS/SMR code [3]. The analysis results and also the features of the PRHRS in the SMART plant are presented.

2. Passive Residual Heat Removal System

In case the normal secondary system is not available to cool down the primary coolant system, the PRHRS removes the decay heat transferred through the steam generator. The PRHRS operates functionally equivalent to the auxiliary feedwater system.

Fig. 1 shows the schematic diagram of the PRHRS in the SMART plant. There are four PRHRS trains in SMART. Each train has a heat exchanger, an emergency cooldown tank, a makeup tank, and valves. The capacity of the heat exchanger in each PRHRS train is 1% of the plant nominal power (660MWt).

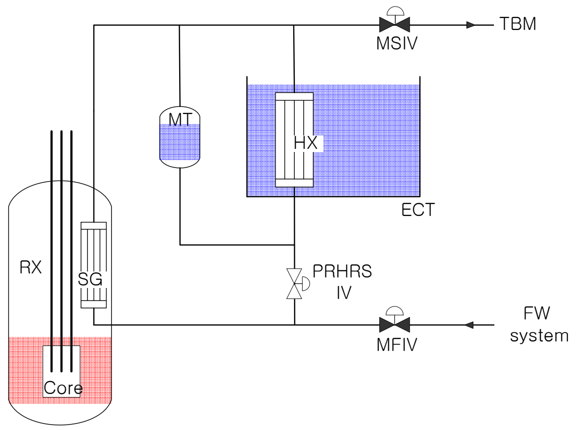

Fig. 1. Schematic diagram of the passive residual heat removal system in SMART plant (660MWt)

3. PRHRS performance

As an initial event, the main feedwater control valve was closed. The pressure of the primary side began to increase. After about 30 seconds from the initial event, the reactor trip condition was reached: the shutdown control rods start to fall down, the main steam isolation valve and the main feedwater isolation valve start to close, and the PRHRS isolation valves start to open. Assuming the single failure, only three PRHRS trains were operating.

The PRHRS performance was monitored for two hours after the initial event.

The pressure variation of the primary and secondary loop of the plant is shown in Fig. 1. The primary loop pressure was increasing sharply until the trip condition was reached. After the reactor trip signal was produced, the PRHRS started to operate and the primary loop pressure was continuously decreasing.

The pressure of the secondary side decreased slowly to about 4MPa from 5MPa and maintained its level during two hours.

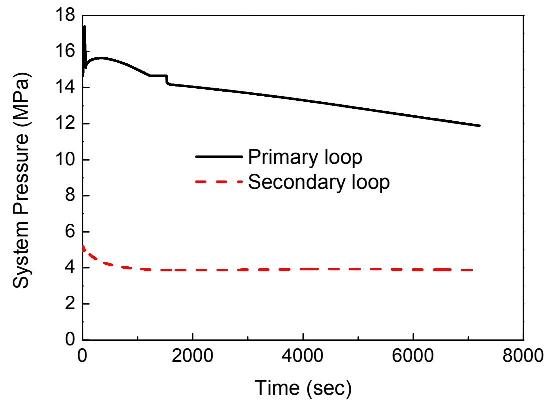

Fig. 2. Pressure variation in the primary and secondary loop of the plant

Fig. 3 shows the temperature variation in the steam generator. The temperature of the primary side and the secondary side was increasing sharply until the PRHRS started to work. The temperatures of the primary loop inlet, primary loop outlet and secondary loop outlet were almost same due to the large difference between the core decay power and the PRHRS heat removal rate. After the PRHRS started to operate, the temperature of the primary loop was continuously decreasing and its decrease rate was about 27℃/hour.

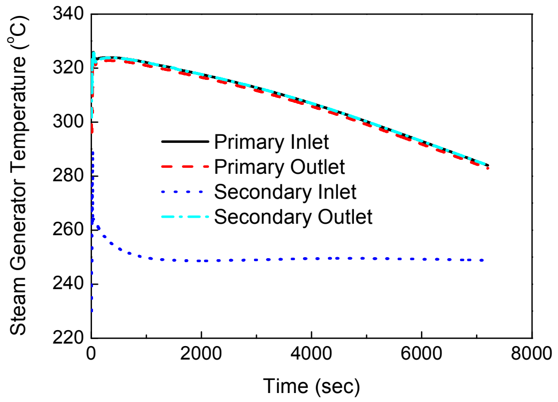

Fig. 3. Temperature variation in the primary and secondary loop of the plant

The core decay power and the heat transfer rate at the stream generator and PRHRS heat exchanger are shown in Fig. 4. The heat removal rate at the PRHRS heat exchanger was about 7MW per each train which is the design specification of the PRHRS. After about 100 seconds, the heat removal rate at the PRHRS heat exchanger became bigger than the core decay power. Until the PRHRS heat removal rate is bigger than the core decay power, the net amount of heat generated is stored in the reactor coolant, and it increases the coolant pressure and temperature.

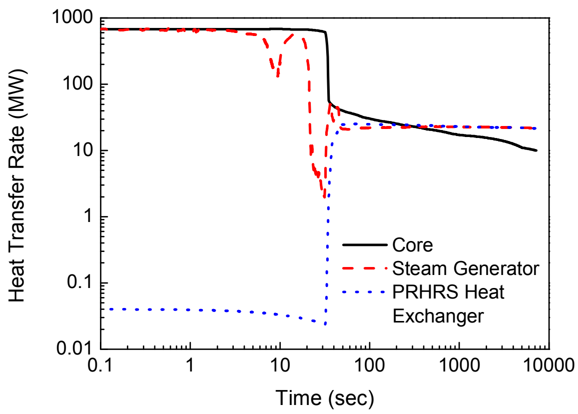

Fig. 4. Core decay power and heat transfer rate at the steam generator and PRHRS heat exchanger

4. Conclusions

The performance of the PRHRS in SMART plant was investigated and its results were presented. After the PRHRS started to work, the system pressure and temperature continuously decreased. This showed that the PRHRS effectively removed the reactor core decay heat.

REFERENCES

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