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A Study on the Application of DRHRS in SMART Reactor

Y.S. Kim[1]*, D.H. Kang[2],Y.J.Youn[1], J.K.Park[1], K.H. Min[1], H.S. Park[1]

[1] *Korea Atomic Energy Research Institute*
1045 Daedeokdaero, Yuseong-gu, Daejeon, 305-353, Korea
[2] *System Engineering & Technology Co., Ltd.*
Inno Biz Park, Hanam Univ. 461-6 Jeonmin-dong, Yusung-gu, Daejon, 305-811, Korea
** Corresponding author: yskim3@kaeri.re.kr*

1. Introduction

A decay heat removal system using a passive concept is a key design feature for future nuclear power plants such as the APR1400 and SMART. Recently, small and medium reactors with passive design features have been under development worldwide. A direct residual heat removal system (DRHRS) was suggested by KAERI, which can be applied to any kind of reactors. For the preliminary stage, the application of DRHRS to the SMART reactor was investigated using the MARS-KS code.

A preliminary analysis showed that the application of DRHRS to the SMART reactor was found to be feasible based on the thermal hydraulic behaviours of the primary system.

2. Overview of DRHRS

DRHRS is a kind of decay heat removal system directly from the primary system. Like in a SMART reactor, DRHRS can be connected with the top of the pressurizer as inlet line and safety injection line as a return line. DRHRS consists of a cooling tank, a heat exchanger, and connected pipes. Fig. 1 shows as an example the application of DRHRS to a SMART reactor. The inlet line of the DRHRS is connected to the top of the pressurizer, and the return line of the condensed water is connected to one of the safety injection nozzles. Steam from the pressurizer flows to the exchanger in the cooling tank, where the steam is condensed into water. This condensed water is returned to the reactor vessel through one of the safety injection nozzles.

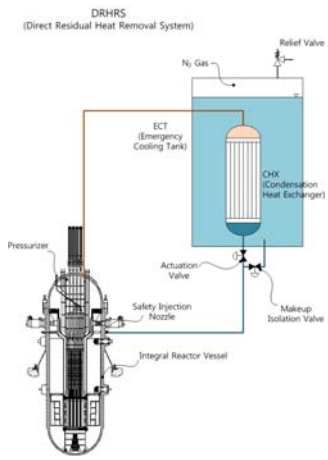

Fig. 1 Application of DRHRS to SMART reactor

3. Preliminary Analyses using MARS

For a preliminary analysis, an MARS nodalization was designed using one train of the existing passive residual heat removal system of the SMART reactor, as shown in Fig. 1. The inlet of DRHRS is connected to the top of the pressurizer, and the return line of the condensed water is connected to one of the safety injection nozzles.

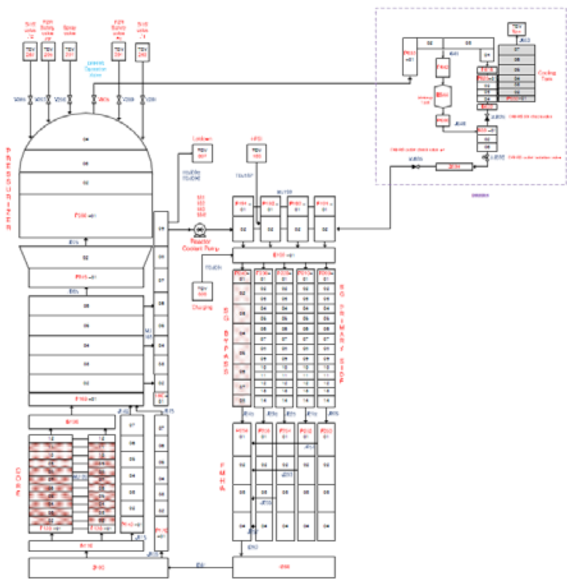

Fig. 2 Nodalization of MARS for DRHRS analyses

In the SMART design, the primary water inventory is quite large, and therefore there was no need for a makeup function. Although there was a makeup function in the original design of the passive residual heat removal system, as shown in Fig. 2, its function was eliminated later (actually, in the makeup function, it was found that there was no effect on the thermal hydraulic behaviors of the primary system). In addition, the authors found that the inlet and return lines were designed quite strictly in the original design, and the cooling capacity was only dependent on their thermal hydraulic conditions. To enhance the cooling capability, the sizes of the pipes and valves in the inlet and outlet lines were modified.

For the decay power, an ANS79 curve was used, and Fig. 3 shows the decay heat power with respect to the simulation time.

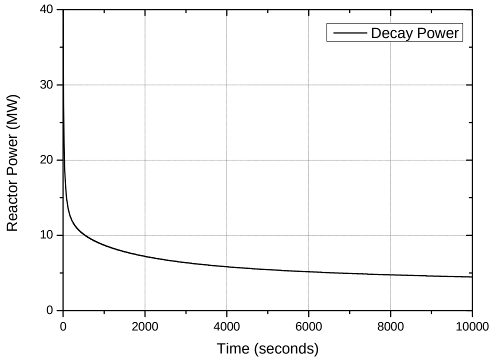

Fig. 3 Decay heat power

The pressurizer and steam generator pressures showed reasonable trends, as shown in Fig. 4.

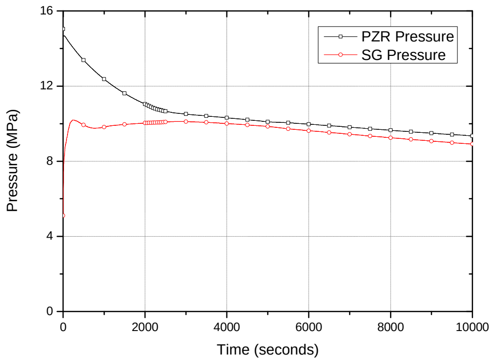

Fig. 4 PZR and SG pressures

The collapsed water fractions of the pressurizer, reactor vessel, and downcomer were compared in Fig. 5.

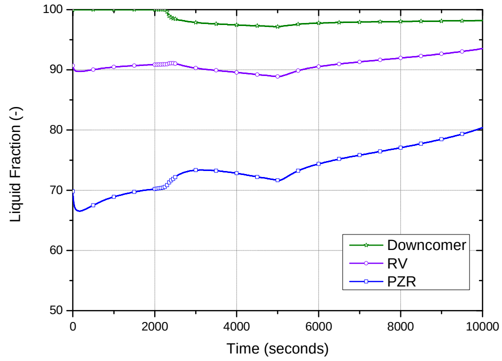

Fig. 5 PZR, RV, and downcomer levels

The cooling flowrates through the DRHRS were compared for the inlet and return lines, as shown in Fig. 6. As can be seen in the figure, the flow balances between the inlet and return lines were maintained for the simulation time.

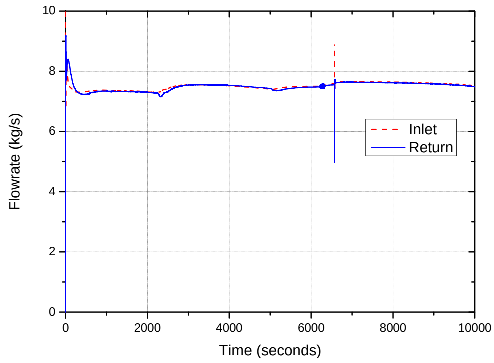

Fig. 6 PZR, RV, and downcomer levels

4. Conclusions

A feasibility study using the MARS code was performed. The application of DRHRS to the SMART reactor was investigated, and it was found that the existing PRHRS system can be used as DRHRS to remove the decay heat from the reactor vessel of a SMART reactor. From the preliminary analyses, most of the thermal hydraulic behaviors showed reasonable trends, which can give a kind of certainty for the adoption of DRHRS to a SMART reactor.

A further study will be conducted for the long term cooling aspect and optimization of the DRHRS system.