Analysis of the Multiple SGTR of SMART

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1. Introduction

An advanced integral pressurized water reactor (PWR), SMART (System-integrated Modular Advanced ReacTor) with a rated thermal power of 330MW, is under development by KAERI [1].

SMART adopts helical once-through type steam generator producing the superheated steam in normal operation and passive residual heat removal system (PRHRS) for decay heat removal after the reactor shutdown as shown in the Fig. 1.

As a design basis event, the single steam generator tube rupture (SGTR) has been analyzed.

Recently, the licensing body requires the plant's capability for the multiple steam generator tube rupture (MSGTR) of the advanced reactor. Therefore, in this study, the analysis of the MSGTR in SMART has been accomplished to show the proper plant's response.

2. SMART Design against Multiple SGTR

The main concern in the MSGTR is the bypass possibility of the reactor coolant through the reactor building. In the conventional reactor, the opening time of the main steam safety valve (MSSV), which is the main bypass path through the reactor building, was calculated to estimate the margin of the operator action [2]. The MSSV opening time is estimated from thirty minutes to four hours depending on the number of the ruptured tubes. That is, it can be said that although the MSSV does not open within the operator response time, there is still small possibility that the primary coolant can bypass through the reactor building because of the human error.

In SMART however, there is little bypass possibility of the reactor coolant through the reactor building because the secondary system design pressure is the same as the primary system and the MSSV is not present. Moreover, if the MSGTR occurs, the main steam isolation valve (MSIV) and the feedwater isolation valve (FIV) is closed by the low feedwater flow signal and the PRHRS begins operation in the closed secondary loop to cool down the primary system by passive means. The passive mechanism prohibits the human errors from interfering the appropriate cooling and isolation sequence of the event.

3. Analysis of the Multiple SGTR

To show that there is no bypass possibility, the multiple SGTR is analyzed with TASS/SMR-S [3], the system analysis code used for the safety and performance analysis of SMART.

From two to five tube ruptures are considered. The nominal initial condition and best estimate analysis methodology are used. That is, the operating condition is in the normal operation state and the available control systems are all considered and set in automatic mode. The pressurizer level control system (PLCS) and pressurizer pressure control system (PPCS) are modeled. The control systems are assumed to be unavailable after the the reactor trip.

The analyses are focused to the maximum pressure of secondary system. The bypass path of the reactor building is the PRHRS safety relief valve with the opening set pressure of 17MPa.

The offsite power is assumed to be unavailable with the reactor trip, which causes the reactor coolant pump and feedwater pump to stop. The passive residual heat removal actuation signal caused by the low feedwater flow rate closes the main steam isolation valve (MSIV) and feedwater isolation valve (FIV) and the secondary system pressure increases rapidly.

The analysis results of the multiple SGTRs are shown form Fig. 2 to 4. When the SGTR occurs, the primary side pressure decreases due to the leak flow through the broken tube, while the secondary side

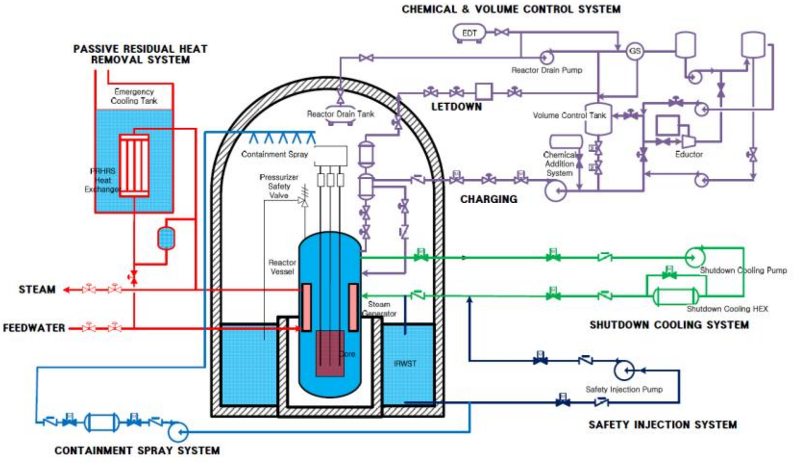

Fig. 1 The Layout of SMART

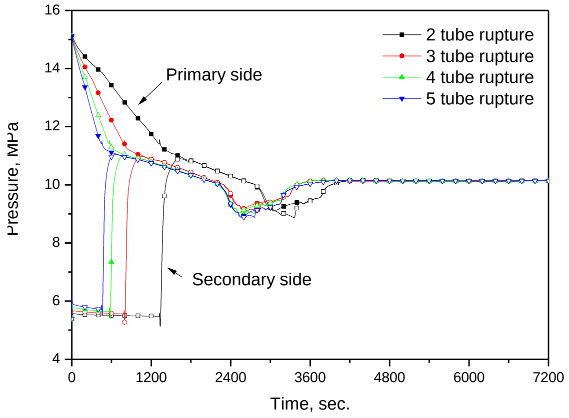

Fig. 2 Pressure of the broken side

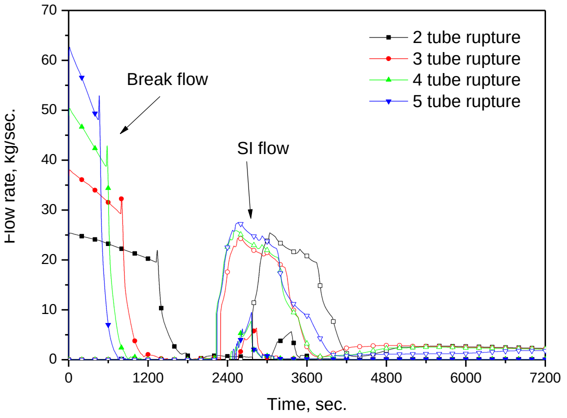

Fig. 3 Break flow and SI flow

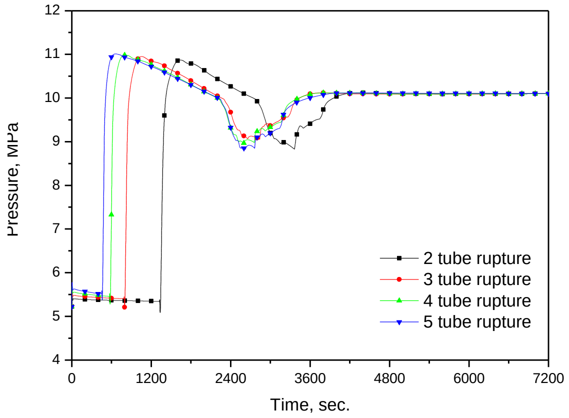

Fig. 4 Secondary system pressure

pressure increases as shown in Fig. 2. They move toward each other until balancing. After then, the pressure show decreasing trend. When the primary pressure reaches the safety injection actuation setpoint, the safety injection (SI) is delivered to the RCS to make up the coolant inventory loss as shown in Fig. 3. The maximum pressure of the secondary side is shown in Fig. 4. The maximum pressure increases according to the number of ruptured tubes. The maximum pressure always maintained much below the PRHRS safety relief valve set point.

4. Conclusions

The multiple steam generator tube rupture has been analyzed and the bypass possibility of the reactor coolant to the outside of the reactor building has been estimated. The main concerned parameter to determine the bypass possibility is the maximum pressure of the secondary system. The results show that the maximum pressure of the secondary system is well maintained below the PRHRS safety relief valve opening set point. Therefore, it can be said that there is no possibility of the reactor coolant bypass through the reactor building.

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