SBLOCA-LOSI Analysis with Passive Auxiliary Feedwater System

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1. Introduction

Small Break Loss of Coolant Accident (SBLOCA) together with the complete Loss of one Safety Injection system (LOSI) (either the High-Pressure Safety Injection (HPSI) or the Low-Pressure Safety Injection (LPSI)) is a Design Extension Condition (DEC) accident. When the SBLOCA-LOSI occurs, the Reactor Coolant System (RCS) pressure decreases due to the break flow, and the RCS inventory is not recovered due to the failure of the safety injection. Without proper operator actions, fuel can be exposed and damaged due to a decrease in the RCS inventory (Fig. 1). For the LOSI, loss of either HPSI or LPSI should be assumed. But if HPSI operates normally, it is possible to cope with SBLOCA without LPSI. Therefore, only loss of HPSI is considered in this study.

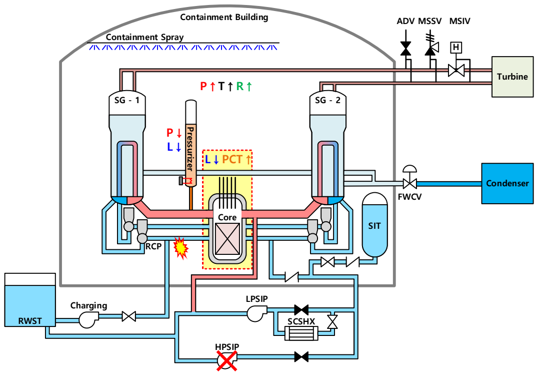


Fig. 1. Schematic diagrams of SBLOCA-LOSI

According to the Emergency Operation Guidelines (EOGs), main operator actions include followings: (1) manual trip of Reactor Coolant Pumps (RCPs) and (2) RCS cooldown by Atmospheric Dump Valves (ADVs) opening operation of both Steam Generators (SGs). To confirm that operator actions are proper for SBLOCA-LOSI accident mitigation, several analyses [1,2] have been performed using system analysis codes, and they published that the RCS was successfully cooled to the entry condition of the Shutdown Cooling System (SCS) without the fuel damage by operator actions.

The existing EOG based on the active safety system may change as the passive safety system is adopted. In Republic of Korea, the Passive Auxiliary Feedwater System (PAFS) was developed as an advanced design feature to completely replace the active Auxiliary Feedwater System (AFWS) [3] (Fig. 2). Operator actions to mitigate SBLOCA-LOSI may differ if PAFS is installed instead of AFWS. Therefore, in this study, a system code analysis was conducted on how accident mitigation proceeds during SBLOCA-LOSI due to the installation of PAFS instead of AFWS. The reference plant is a 2-loop 1000 MWe PWR and the analysis was conducted using RELAP5/MOD3.3 [4].

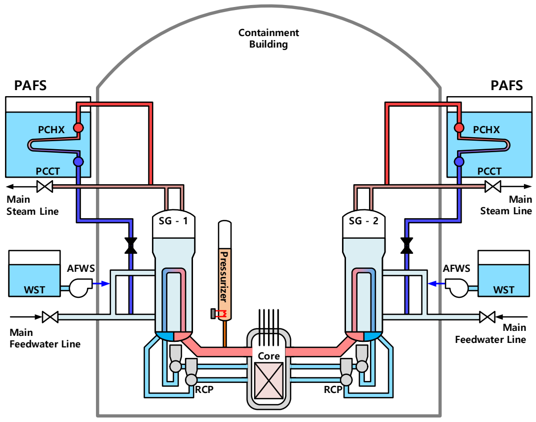


Fig. 2. Schematic diagrams of the PAFS/AFWS

2. SBLOCA-LOSI Analysis Model

SBLOCA-LOSI analyses were performed based on the OPR1000 nodalization as shown in Fig. 3. It consists of RCS, secondary side, and safety systems such as AFWS or PAFS. Also, it includes Pressurizer Pressure Control System (PPCS), Pressurizer Level Control System (PLCS), Feedwater Control System (FWCS), Steam and Bypass Control System (SBCS), etc. The PAFS model is connected to main steam line instead of AFWS (Fig. 3).

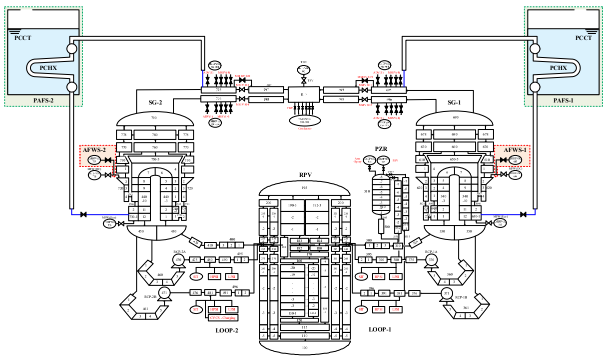
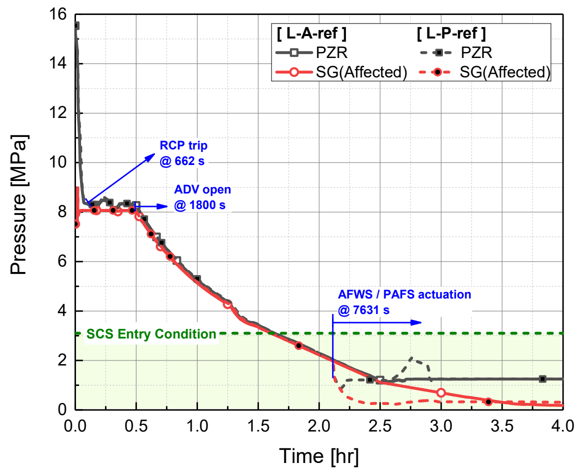


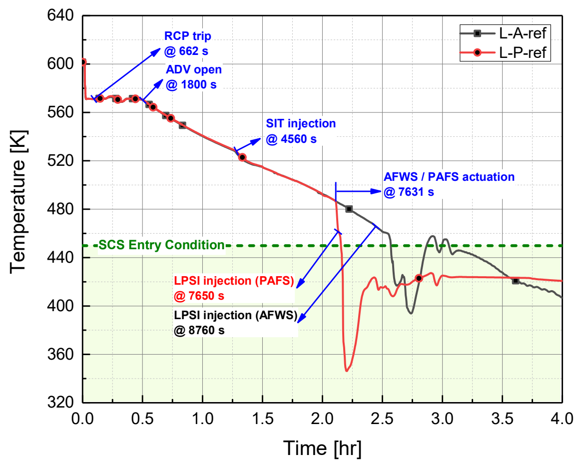
Fig. 3. RELAP5 nodalization for DEC accident analysis

3. SBLOCA-LOSI Simulation Results

Figure 4 shows the simulation results of the L-A-ref as a reference case of SBLOCA-LOSI with AFWS. After SBLOCA occurs, the PZR pressure decreases rapidly and remains at approximately 8 MPa following the SG pressure. SG pressure is maintained at approximately 8 MPa by SBCS without MSSVs opening. The RCS pressure continuously reduces to the safety injection system actuation set-point, but the HPSI does not operate. Until the ADVs open operation, RCS heat removal is achieved through steam release operation to the condenser by SBCS and the mass-energy release through the break.



(a) PZR and SG pressure



(b) RCS temperature (hot-leg)

Fig. 4. Simulation results of SBLOCA-LOSI

The operator opens the ADVs of both SGs at 30 minutes to perform a RCS cooldown rate control. It decreases the RCS temperature. The RCS pressure decreases rapidly to the SIT injection set-point. The core level is restored by SIT injection. The RCS pressure and temperature reach the SCS entry condition within 3 hours, and the SBLOCA-LOSI is successfully mitigated.

Figure 4 shows the simulation results of the L-P-ref as the reference case of SBLOCA-LOSI with PAFS. The analysis was performed assuming that PAFS was activated at the same time as AFWS, and ADVs were closed at the time of PAFS operation. Thermal-hydraulic behaviors are the same before the AFWS or PAFS actuation. When using AFWS, the RCS cooldown rate is continuously controlled through ADV, while when using PAFS, the RCS cools rapidly to the SCS entry condition. This results in earlier LPSI injection time than AFWS simulation, and the accident is quickly mitigated.

4. Conclusions

In this study, we analyzed how operator actions may change during SBLOCA-LOSI if PAFS is installed instead of active AFWS for 1,000 MWe PWR using RELAP5/MOD3.3. Main findings from the accident analyses are as follows. 1) Compared to the AFWS operation, the only change in operator action due to the introduction of PAFS is the ADV operation. ADVs should be closed during PAFS operation time to maintain the SG inventory. 2) As with using AFWS, during SBLOCA-LOSI, the SCS entry conditions can be reached by the PAFS within about 3 hours with operator actions without the fuel damage. 3) Regarding the RCS cooldown with ADV, the introduction of PAFS can simplify operator action because ADV control operation is not required after the PAFS actuation. The results of this study can be used to develop the accident mitigation strategies.

ACKNOWLEDGEMENT

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