The effect of core residual heat on success criteria during the shutdown and low power operation

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1. Introduction

Since it was known that the malfunction accident of the reactor residual heat removal system during shutdown in Diablo Canyon and Vogtle nuclear power plant could lead to the core damage of the malfunction accident, it has been important to research the safety during the shutdown and low power operation.

In this study, the thermal hydraulic analysis about the loss accident of shutdown cooling function based on the Plant Operating Status (POS) during shutdown and low power operation of Shin-Kori 1,2 was performed using RELAP5 MOD3.3.

2. Methods and Results

2.1 POS and in initial events

In this study, the planned preventative maintenance (overhaul) for the each POS and the classification of the plant shutdown type were refer to the report on shutdown and low power of YoungKwang 5,6 and the decay heat after an accident was assumed to be constant conservatively.

Based on these assumptions, the thermal hydraulic analysis of 5 POSs (POS 2, POS 3, POS 4A, POS 4B, POS 5) were performed. In case of POS2, SIT(Safety Injection Tank) model based on PSV Stuck Open was inserted and in case of POS 3 and POS 4A LOCA accident of the branch pipe of hot leg at the same time loss of coolant system was analyzed. In the case of the POS 4B, the analysis on the open event of pressurizer manway based on POS4A was performed and the ADV valve did not open.

Apart from this, the analysis on the core damage according to the recovery time of shutdown cooling system (SCS) per each POS was performed. Also, the proper the recovery time of SCS to prevent core damage was estimated. In POS 5, the possibility of residual heat removal using the gravity feedwater was tested and also the recovery time of the SCS was estimated.

2.2 Modeling

Shin-Kori 1, 2 with 2,815 MWt was composed two RCS loops, two SG, and 4 RCPs. Figure II-1 shows the RELAP5 Nodalization to simulate the loss of shutdown cooling function during the shutdown and low power operation of Shin-Kori 1,2. The core in the direction of axis was modeled with 12 control volumes, and each of the RCS Loop is consists of 1 hot leg, U Tube modeled with 12 control volumes, 2 suction legs, 2 different RCPs, and two cold legs.

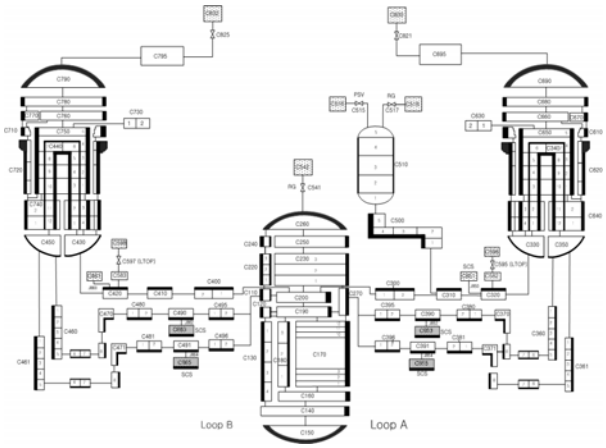

Fig.1. RELAP5/MOD3.3 Nodalization of Shin-Kori 1,2

2.3 Results

In case of POS 2, if shutdown cooling function was lost, the fuel rod temperature exceeded 1500K after approximately 2640 seconds. This could lead to the core damage after all.

In order to recover and run SCS, the operation conditions of SCS, pressure less than 410pisa and temperature less than 350 ˚F, must be satisfied. In POS 2, as shown in Fig. 2, those conditions were satisfied after 3,000 seconds. If the coolant from 4 SITs was injected at 1,800 seconds (30 minutes) after SCS was lost, SCS could be recovered. However, if the coolant from less than 4 SITs was injected, the operation conditions of SCS were not achieved.

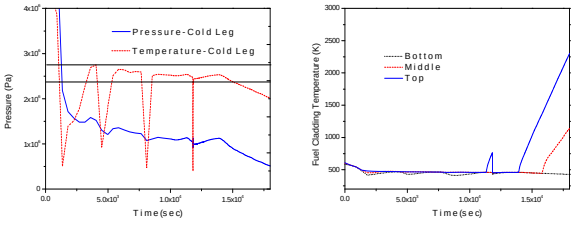

Fig.2. The profile of temperature and Pressure at cold leg and temperature of fuel cladding in POS 2

In POS 3, as shown in Fig. 3, the interval to meet the operation condition of SCS did not exist if shutdown

cooling function was lost. So the residual heat must be removed with only the secondary side of S/G. In this study, if ADV was opened, it was showed that the interval to meet the operation condition of SCS was between 7,350 and 14,210 seconds and the core damage occurred after 25,000 seconds. Therefore, if SCS is recovered before 14,210 seconds after accidents, the accident can be terminated.

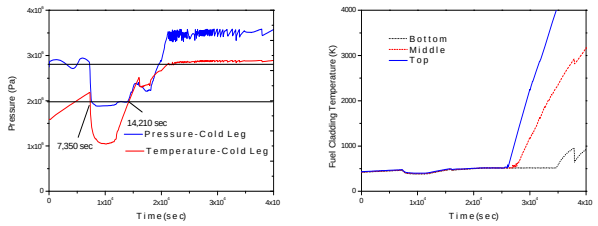

Fig. 3. The profile of temperature and Pressure at cold leg and temperature of fuel cladding in POS 3

In POS 4A, after the loss accident of shutdown cooling function, the function of the secondary side of the steam generator functions as heat removal source worked until the 40,000 seconds (11hours) and the core damage occurred after approximately 51,120 seconds. Therefore, as shown in Fig. 4, if the shutdown cooling system is recovered before 28,080 seconds which is the interval to meet the operation conditions of SCS, the accident can be terminated.

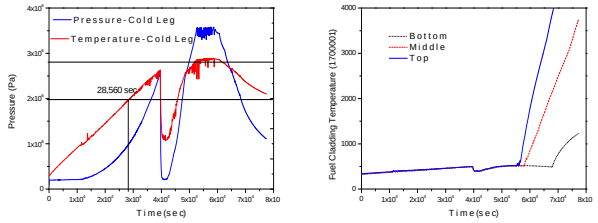

Fig. 4. The profile of temperature and Pressure at cold leg and temperature of fuel cladding in POS 4A

In POS 4B, the core damage occurred about 22,601 seconds after the loss accident of shutdown cooling function. As shown in Fig. 5, SCS could be operated at less than 15,360 seconds. So, if SCS is recovered before 15,360 seconds, the accident can be terminated.

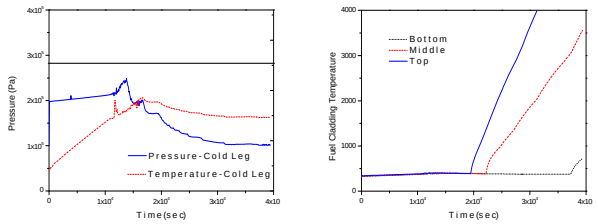

Fig. 5. The profile of temperature and Pressure at cold leg and temperature of fuel cladding in POS 4B

In POS 5, the possibility by gravity feedwater for the residual heat removal was evaluated. The gravity feedwater was supplied at 1,800 seconds after of SCS. Until 74,000 seconds the residual heat could be removed by the gravity feedwater. However, after gravity feedwater, to recover SCS, the removal of residual heat should be made between 4,000 and 13,000 seconds when the water level of the hot leg and cold leg is more than 50% level as shown in Fig. 6.

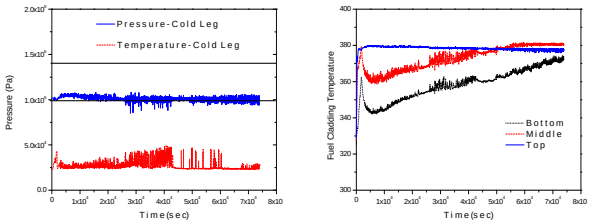

Fig. 6 The profile of temperature and Pressure at cold leg and temperature of fuel cladding in POS 5

3. Conclusion

The thermal hydraulic analysis were performed using RELAP5 MOD3.3 during shutdown and low power operation of Shin-Kori 1,2 according to POS 2, 3, 4, 4A, 5.

Based on these results, the operator action time without core damage due to the decay heat and the effect on the success criteria were evaluated during shutdown and low power operation.

Acknowledgement

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