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Safety Analysis for Hanul #5 Reactor Trip due to RCP Trip

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1. Introduction

The purpose of this study is to investigate the reactor shutdown events caused by the trip of two reactor coolant pumps at Hanul #5 on July 5, 2017 and to confirm whether the reactor system is maintained in a safe state during the transient period.

During the transient period, the following items are analyzed to evaluate the reactor system and nuclear fuel integrity.

- Analysis of power plant operation data and satisfaction of safety limits of operating variables
- Review and validate design related to reactor coolant pump trip event
- Assessment of reactor system and nuclear fuel integrity using system safety code

2. Methods and Results

2.1 Event Overview

Hanul #5 started commercial operation on July 29, 2004. The reactor shutdown events caused by the trip of two reactor coolant pumps at Hanul #5 on July 5, 2017. Major sequence of events is as table I.

Table I: Sequence of events

Time	Event
18:09	"BUS SW01N INOPERABLE" alarm occurrence
18:10	RCP 01B/02B trip
18:11	Reactor trip (DNBR LO, LPD HI)
18:11	Action after reactor trip
18:16	Accident diagnosis
18:26	Emergency-01 (reactor trip) entry

2.2 Analysis Method

We used RETRAN-3D, a best estimate system safety analysis code developed by EPRI, USA, to analyze the thermal hydrodynamic behavior of the main system of Hanul #5 in transient period. In order to simulate the nuclear steam supply system of Hanul #5, the main system in the power plant is modeled as 123 control volumes and 173 junctions used to connect control volumes and to express the boundary conditions as shown in figure 1.

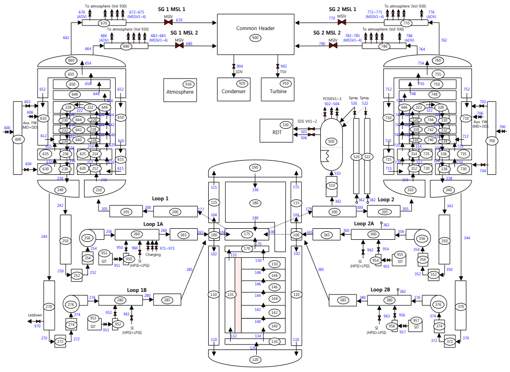

Fig. 1. OPR1000 RETRAN-3D model.

2.3 Analysis results

Figure 2 compares the temperature changes of the reactor coolant. The temperature difference between the hot and cold legs decreased due to the decrease of core power due to the reactor trip. The average temperature of the coolant decreases at the beginning as the steam generator secondary pressure(temperature) decreases, then gradually increases, and slowly decreases after about 800 seconds.

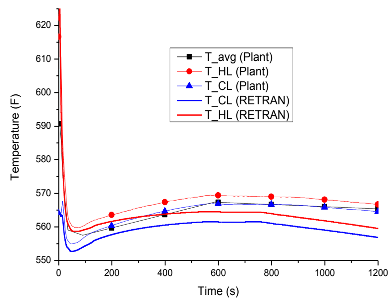

Fig. 2. RCS temperature change comparison.

Figure 3 and 4 show the pressurizer pressure and water level changes, respectively. Transient behavior of the pressure and water level of the pressurizer also show changes due to reactor trip. The core power and coolant average temperature decreases with reactor trip, the coolant shrinks and the pressurizer water level and pressure decreases. After that, the pressure recovers gradually similar to the coolant average temperature. The water level also tends to be similar to the pressure.

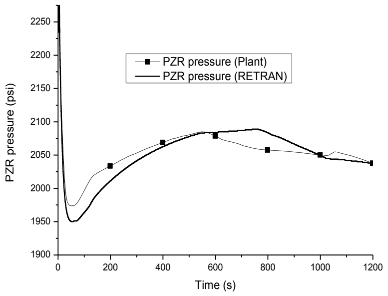

Fig. 3. Pressurizer pressure change comparison.

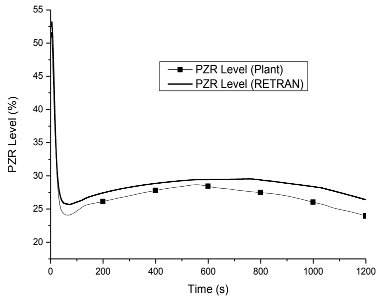

Fig. 4. Pressurizer water level change comparison.

Figure 5 compares the pressure of the secondary side of the steam generator, the code calculation result and the power plant data are similar in overall trend, but the code calculation result is slightly lower.

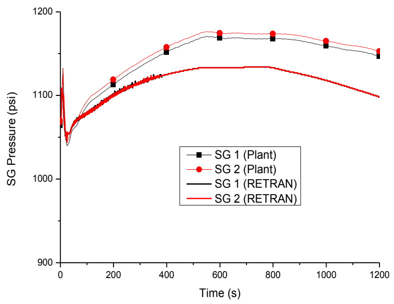

Fig. 5. SG secondary side pressure change comparison.

Figure 6 compares the steam generator level. As the reactor trip due to the trip of the reactor coolant pump causes the reactor power to decrease rapidly, the secondary side of the steam generator shrinks and the water level of the steam generator sharply decreases in the early stage. After that, the water level decreases due to the decreases of the feed water flow rate, and the tendency that gradually recovered by the change of the feed water flow rate is similar to that of the measured plant data.

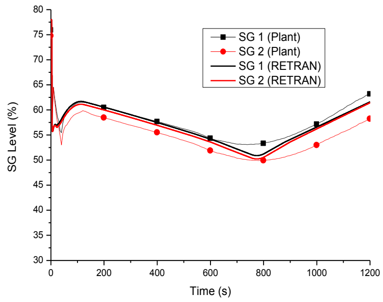

Fig. 6. SG water level change comparison.

Figure 7 shows the DNBR over time. Two RCP trips occur at 0 second, and at 0.87 second the RCP speed reaches the low speed set point (94.8%). The reactor trip signal is generated in 1.17 seconds and insertion of the control rod starts after 0.5 second. During the first 3 seconds of the event, the DNBR value decreases due to the reduction of the reactor coolant flow rate by 2 RCPs trip. The minimum DNBR value is about 1.57 and is maintained above the DNBR limit. After the reactor trip, the reactor power and the heat flux decrease, the DNBR increase again. If the reactor is tripped and power decrease to decay heat level, it will remain safe in terms of DNBR.

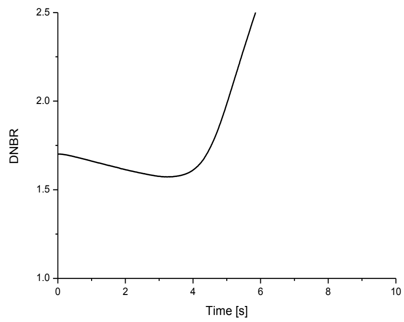

Fig. 7. Change of DNBR over time (0~10 seconds).

2.4 Conclusion of code evaluation

The safety criteria for this accident may comply with the safety standards for ANS Condition II. ANS Condition II events can occur once a year, the safety standard is the maximum pressure(less than 110% of the design pressure) of the primary and secondary system and the minimum DNBR(DNBR limit value). During the transient period, the pressurizer and the steam generator were remained below 110% of the design pressures of 175.8 ㎏/㎠(2,500 psi) and 89.3 ㎏/㎠(1,270 psi). In terms of DNBR, it was confirmed that the minimum DNBR occurred in about 3 seconds and the DNBR limit value(1.21) was satisfied.

3. Conclusions

The reactor trip due to the trip of the reactor coolant pump at Hanul #5 on July 5, 2017 was assessed to confirm whether the reactor system remained safe during the transient period and the integrity of the nuclear fuel was maintained. The range of evaluation was analyzed by analyzing the main operating variables of the power plant during the transient period, and it was confirmed whether each operating variable was kept within the limit. We also analyzed the transient events using system safety analysis codes to confirm the safety of the system and fuel during the transient period. As a result of the evaluation, the main operating variables of the power plant during the transient period were kept within the appropriate range and did not exceed the safety limit. With the appropriate action of the operator, the power plant remained safe after the transient event. As a result of analysis using the systematic safety analysis code, it was confirmed that the maximum pressure and minimum DNBR satisfied the limit of safety analysis and the integrity of the nuclear fuel and reactor system was maintained.

REFERENCES

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[3] 2014-50003339-단-0482TM, Safety Evaluation Report for Reactor Trip due to the Malfunction of Electrical System of ShinKori 1 Unit, KHNP, 2014.