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Analysis of Main Steam Line Break and Induced Steam Generator Tube Rupture Accident Using SPACE code for OPR1000

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1. Introduction

Since the Fukushima nuclear accident, beyond design basis conditions has played an important role for developing the reactor coolant system (RCS) cooldown strategy and recovery action. Additional failures of the safety components are also considered in terms of sufficient safety margin with application of proper emergency operating procedures.

For the above reasons, KHNP (Korea Hydro & Nuclear Power Co.) submitted an Accident Management Plan (AMP) for nuclear power plants with enhanced standards in the event of an accident to the regulatory body in 2019. The AMP consists of design based accidents, multiple failure accidents that exceed design basis, severe accidents, and natural disasters that exceed design basis [1]. In 2020, the regulatory body began asking questions about KHNP's AMP submitted in 2019, and KHNP has been responding to the regulatory body's questions to date.

During the question and answer process, the regulatory body asked for an analysis of "Main Steam Line Break (MSLB) and induced Steam Generator Tube Ruptures (SGTR) accident" in addition to the nine accidents for which an AMP must be prepared under the law. In this paper, we analyzed the "MSLB and induced SGTR accident" for OPR1000 requested by the regulatory body to determine whether the accident had a similar level of risk to the nine multiple failure accidents prescribed by law.

2. Methods and Results

2.1 Major Code Modeling

MSLB and induced SGTR accident analysis used the SPACE 3.2 code. For this accident, the most important model is heat transfer model from primary system to secondary system. Basically, heat transfer coefficient included in the code is used. Fig 1 is SPACE nodalization for OPR1000.

2.2 Initial conditions and boundary conditions

For this accident analysis, important input parameters are initial core power, pressurizer pressure, pressurizer water level, core inlet temperature, RCS mass flow, Steam Generator (SG) pressure and SG inventory [2]. For the conservative assumption of this accident, it was assumed that there was basically no operator action.

The initial conditions are shown Table I [4].

Table I: Initial Conditions

Parameter	Design Value	SPACE Value
Core Power[MWt]	2,815	2,815
PZR Pressure[MPa]	15.51	15.51
PZR water level[%]	52.6	52.6
Core inlet Temp.[F]	568.98	568.95
Core flow[Kg/s]	15,309	15,309
SG Pressure[MPa]	7.54	7.51
SG water level[m]	79.0	79.0

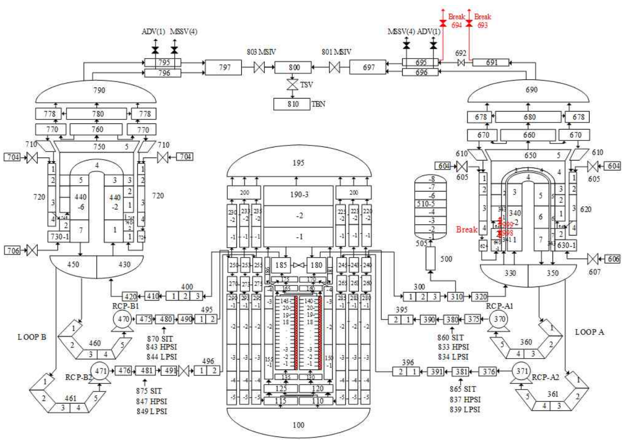

Fig. 1. Nodalization diagram of SPACE code for OPR1000.

2.3 Sequence of Event

For OPR1000, leak before break (LBB) concept is applied to main stream line from steam generator (SG) outlet to main steam solation valve (MSIV) [3]. Therefore the break location for MSLB was set at the downstream of MSIV. In addition, one steam generator tube was ruptured in LOOP A. Conservatively, we assumed that the MSLB and the SGTR were occurred at the same time.

When this accident occurs, SG low pressure signal is generated, followed by a reactor shutdown. The reactor trip signal is generated by a variable overpower trip (VOPT). Because the coolant flow out through the ruptured tube, the pressure of primary system decreases. The pressure of the primary system decrease to the set point of the safety injection. When the steam discharged from the broken steam line, main steam isolation system (MSIS) is operated by low SG pressure.

The MSIV was closed to prevent excessive cooling of the primary system by steam discharge and to avoid leakage of radioactive materials through the broken steam line. The sequence of the MSLB and induced SGTR is shown in Table I.

Table II: Sequence of event

Time(s)	Event
0.0	MSLB and induced SGTR occur
8.22	Reactor trip by VOPT
16.72	MSIV closed by SG low pressure
132.02	HPSI injection
469.02	MSSV open/close

2.4 Analysis

The SPACE code is used to analyze the thermal hydraulic behavior of the “MSLB and induced SGTR accident" in transient period.

Figures 2 to 8 present the result of main parameter of thermal hydraulic behavior. Figure 2 shows the core power. When this accident occurs, the core power decreases rapidly according to the reactor trip.

Figure 3 and 4 shows the pressures of the primary and secondary systems. The pressure of the SG decreased rapidly at the beginning of the accident due to the release of steam through the broken main steam line, but the pressure was increased again by the operation of MSIS. When MSIS signal was activated, the MSIV was closed. After that, the pressure of the SG increased due to heat transfer from primary side, and the increased pressure reaches the MSSV set point, and the MSSV is repeatedly opened and closed. Figure 5 shows the SG level. Affected SG side after the accident shows that the SG level increases as the coolant continuously leaks out due to SI injection. But the unaffected SG side shows a slow decrease in SG level as steam is released through MSSVs.

Figure 7 and 8 show the flow rate through the affected SG tube and steam line. At the start of accident, the discharge flow rate through the damaged part increased rapidly. As the reactor trip signal occurred, the coolant flow rate through the affected part decreased. However, due to the pressure difference between the primary and secondary system, the flow rate through the affected part increased again. When the MSIV was closed, the flow rate of affected SG tube gradually decreased. The flow of broken steam line was almost zero after than MSIV closed. When MSIV was closed, discharge flow of steam line was not released through the broken steam line. As a result, the SPACE code has been predicted the thermal hydraulic behavior of the MSLB and induced SGTR event reasonably well.

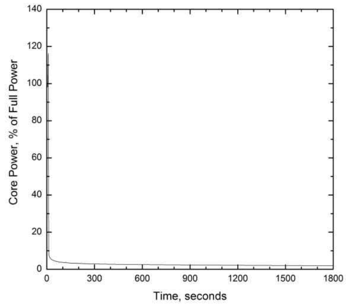

Fig. 2. Core Power

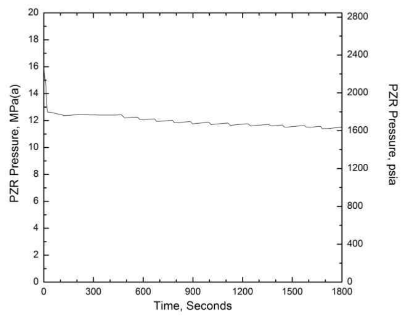

Fig. 3. PZR Pressure

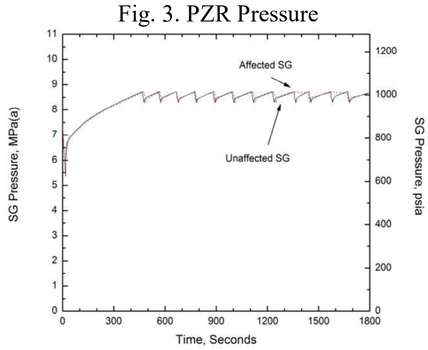

Fig. 4. SG Pressure

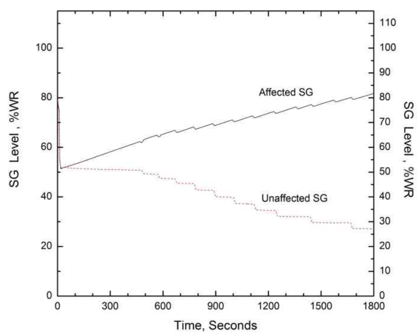

Fig. 5. SG Level

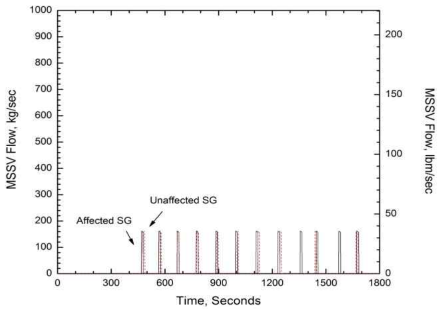

Fig. 6. MSSV Flow

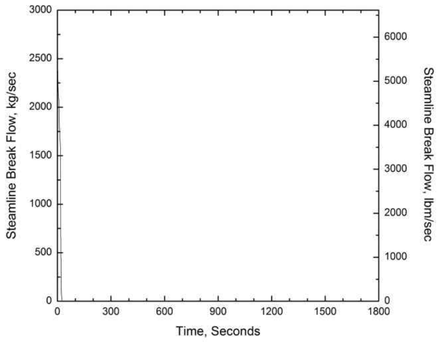

Fig. 7. Steam line Break Flow

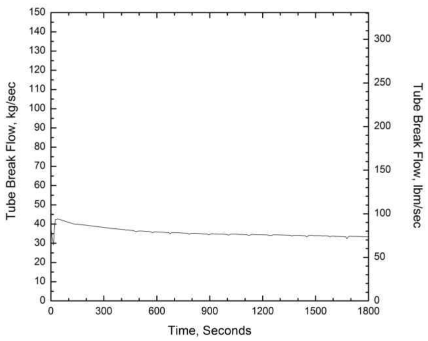

Fig. 8. Tube Break Flow

3. Conclusions

This study shows the result of thermal hydraulic behavior on the MSLB and induced SGTR accident using SPACE codes. The MSIV closing time and steam line break flow are the important factors because radioactive material can be released to outside of containment vessel through broken steam line. Because the OPR1000 nuclear power plant applied the LBB concept, the MSLB and induced SGTR event was considered at downstream break of MSIV. When MSIV was closed, radioactive material was not released through the broken steam line. Also, we verified the radiological effect of this event using a RADTRAD code used to calculate radiation dose in the AMP. We confirmed that dose result was well below the limit.

REFERENCES

[1] KHNP, Accident Management Plan for Hanul Units 3&4, 2020.
[2] KHNP, SPACE code manual, 2017.
[3] MinJeong Kim, Chang-Keun Yang, Seung-Chan LEE, Study on Main Steam Line Break Induced Steam Generator Tube Rupture Accident using SPACE code, Transactions of the Korean Nuclear Society Spring Meeting jeju, Korea, May 18-19, 2023
[4] KHNP, DEC Analysis Methodology Report, 2019.06