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Assessment of the SPACE Code Using the ATLAS SLB-GB-01 Test

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1. Introduction

The Korea Nuclear Hydro & Nuclear Power Co. (KHNP) has developed a safety analysis code, called the Safety and Performance Analysis Code for Nuclear Power Plants (SPACE) by collaborative works with other Korean nuclear industries. The SPACE is a general-purpose best-estimated two-phase three-field thermal-hydraulic analysis code to analyze the safety and performance of pressurized water reactors (PWRs). The SPACE code has sufficient functions and capabilities to replace outdated vendor supplied codes and to be used for the safety analysis of operating PWRs and the design of advanced reactors.

As a result of the second phase of the SPACE code development project, the 2.14 version of the code was released through the successive various V&V works using integral loop test data or plant operating data.

In this study, the ATLAS main steam-line break (MSLB) test, SLB-GB-01, was simulated as a V&V work. The results were compared with the measured data.

2. ATLAS SLB Test Description

2.1 ATLAS

The ATLAS of Korea Atomic Energy Research Institute (KAERI) is an integral test loop designed to simulate the thermal-hydraulic phenomena in typical APR1400 or OPR1000 nuclear power plants during anticipated transients. The transients include large or small break LOCA, passive system concerned transients, and else other non-LOCA transients.

The core of ATLAS is composed of 396 electrical heaters or unheated rods of 1.905 m length to achieve target power level, 1.96 MW, which is equivalent to 8% rated power of the APR1400. The ATLAS volumes are scaled 1/288 and the height of each components is 1/2 scale to APR1400. The flows are scaled by 1/204 in the core and steam generators. The 175 U-tubes in each steam generator are provided with the average length and inner diameter of 9.46 m and 12 mm, respectively. The hot and cold legs are represented in two by two loops and scaled by 1/237 and 1/288, respectively, so as to conserve RCS flow characteristics of APR1400. The ATLAS has safety injection provisions to simulate direct vessel injection (DVI) facilities for the APR1400 and cold-leg injection facilities for the OPR1000.

2.2 MSLB Test

The ATLAS test SLB-GB-01 was performed to simulate the guillotine break of a main steam line of APR1400 in 2011. The break flow was limited by the flow restrictor installed at the steam exit nozzle of each steam generators. The restrictor size was 38.6 mm in diameter for choking condition. The break was started at the steady-state natural circulation condition. The safety injection was assumed as the minimum values according to the single failure criteria of one diesel generator fail. That is, the safety injection from safety injection pump was injected through only two paths, *i.e.*, DVI-1 and DVI-3, of four paths and the flow from safety injection tanks were not considered.

3. Modeling & Simulation

3.1 SPACE Code Modeling

For the simulation, the core was modeled as the averaged and hot cores which were divided in vertical 20 nodes, respectively. The flow paths in vessel, such as downcomer, bypass, *etc*., were set up to represent the flow directions in the core. The safety injection tanks were modeled with SIT model in the SPACE code and the safety injection pumps were implemented with the FACE model. Four DVI paths were separately modeled. The steam generator tubes were modeled with 12 control volumes and the secondary sides were divided into 19 volumes (Fig. 1).

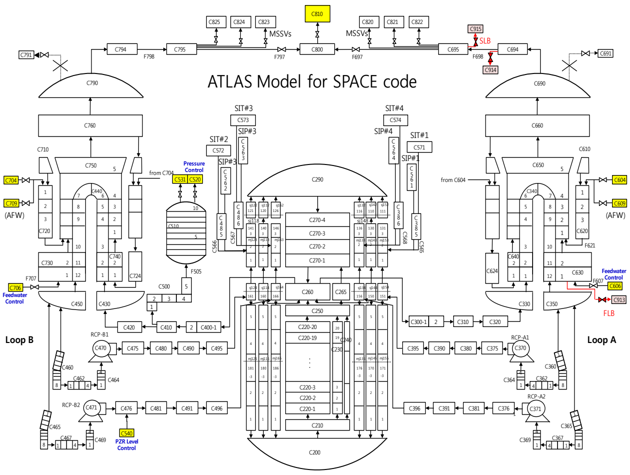

Fig. 1. SPACE Model for ATLAS SLB-GB-01

The main feedwaters were modeled through TFBC, which were connected to the economizer and the feeder ring like the APR1400. The auxiliary feedwater models were connected to the feeder rings only. The pressurizer was represented into vertical single PIPE composed of 10 nodes. The surge-line with 5 nodes was connected to intact loop hot-leg, and the spray line was from intact loop cold-leg. The hot and cold legs were modeled with 3 and 4 volumes, respectively. Both steam lines were modeled using 2 pipes, respectively, and joined into common head connected to the turbine represented with TFBC. The break was modeled between two steam line pipes connected to broken loop, *i.e.*, A-loop.

3.2 SLB Simulation

To simulate the test, ATLAS SLB-GB-01, the steady-state was pre-calculated to confirm the initial conditions and the transient was started using the restart function of the SPACE code. The results calculated by the SPACE code were compared with those measured in the test .

Table I: Initial & Boundary Conditions for SLB-GB-01

Parameters	Measured	Calculated
Core Power, MW	1.56	1.56
Pressurizer pressure, MPa	15.5	15.5
Core exit temperature, K	597.3	602.0
Core inlet temperature, K	563.8	566.4
$T_{HL} - T_{CL}$, K	34.2	35.2
Core flow, kg/sec	7.99	7.65
Pressurizer level, m	3.52	3.52
SG secondary pressure, MPa	7.83	7.88
Feedwater Flow, kg/s	0.44	0.44

The core power was regulated that the power summation of averaged and hot channel cores showed total power measured through the experiment (Fig. 2). The initiation or flow of safety injection was provided as inputs (Fig. 3). The auxiliary feedwater flow was also provided, which was actuated following the signal of steam generator low level (Fig. 4).

With the break start, the secondary system pressure is decreased rapidly (Fig. 5) due to the break, which led the low steam generator pressure signal (5.9 MPa) and the MSIVs closure to isolate the steam lines. Following the isolation and the auxiliary feedwater injection, the intact loop pressure was increased, but that of broken loop was continuously decreased (Fig. 6). In the case of break flow, the Ransom-Trapp model, which is the default critical flow model of the SPACE code, at *Cd* = 1.00, showed larger trends at the beginning of the break and less values after 390 sec. On the viewpoint of integrated break flow, they showed similar amounts each other (Fig. 7).

The pressurizer pressure and level were decreased by the excess heat removal through the steam generators (Fig. 8 & 9). The results of SPACE code, however, showed mitigated trends to those measured. Since the heat removal caused by the break was not sufficient in the case of the calculation, the drops were not reached to measured data. Through the sensitivity studies, the heat removal could be increased according to the initial primary loop flow increase. In the natural circulation condition, however, the loop flow was limited by the heat balance between the primary and secondary sides.

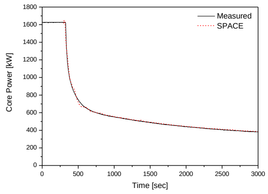

Fig. 2. Thermal Power

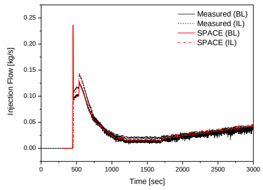

Fig. 3. Safety Injection Flow

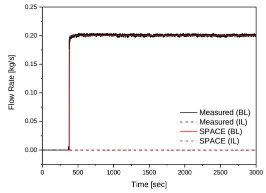

Fig. 4. Aux. Feedwater Flow

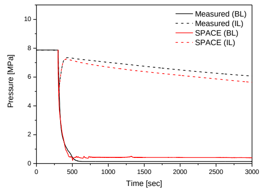

Fig. 5. SG Pressure

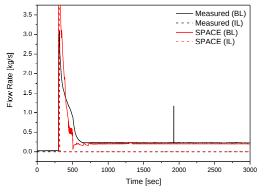

Fig. 6. Break Flow

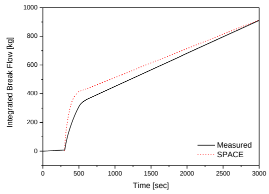

Fig. 7. Int. Break Flow

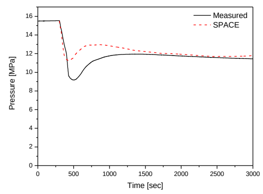

Fig. 8. PZR Pressure

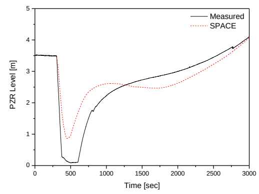

Fig. 9. PZR Level

4. Conclusions

The ATALS MSLB test, SLB-GB-01, was simulated using the SPACE code. The results were compared with experimental data. Through the simulation, it was concluded that the SPACE code can effectively simulate MSLB accidents.

REFERENCES

[1] S. J. Ha, *et al.*, Development of the SPACE Code for Nuclear Power Plants, Nuclear Engineering and Technology, Vol.43(1), p.45, 2011.
[2] W. P. BAEK, *et al.*, KAERI Integral Effect Test Program and the ATLAS Design, Nuclear Technology, Vol.152(2), p.183,(2005.
[3] K. D. KIM, *et al.*, “Quick Look Report on the Guillotine Break of the Main Steam Line Experiment with the ATLAS, SLB-GB-01,” S06NX08-A-1-TR-09, Korea Atomic Energy Research Institute, Daejeon, 2011.
[4] S. J. Ha, *et al.*, “SPACE 2.14 Manual Vol. 2: User’s Manual,” S06NX08-E-1-TR-29, Korea Hydro & Nuclear Power Co., 2013.
[5] Y. H. Kim, *et al.*, Assessment of SPACE Code Using the LSTF 10% MSLB Test, Trans. KNS Spring Meeting, Jeju, Korea, May 17-18, 2012.