Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

A SBLOCA Test of Safety Injection System for SMART with the VISTA-ITL and Its Simulation with the MARS-KS Code

Hyun-Sik Park [a*], Byoung-Yeon Min [a], Rae-Joon Park [a], Sang-Ki Moon [a], Hwang Bae [a], Doo-Hyuk Kang [b], Jae-Seung Suh [b] and Sung-Jae Yi [a]
[a] Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong, Daejeon, 305-600, Korea
[b] System Engineering and Technology, 575 Yongsan-dong, Yuseong, Daejeon, 305-500, Korea
**Corresponding author: hspark@kaeri.re.kr*

1. Introduction

A thermal-hydraulic integral effect test facility, VISTA-ITL [1], for the SMART design has been constructed by the Korea Atomic Energy Research Institute (KAERI). The VISTA-ITL is a revised version of an existing VISTA facility to have the simulation capability of small-break loss of coolant accident (SBLOCA). It is newly equipped with the steam pressurizer, the safety injection system, the steam generator bypass, the pump discharge line, the dowcomer, the PRHRS makeup tank, the break simulator and the break measuring system, etc.

The VISTA-ITL is a 1/2.77-height, 1/1310-volume scaled test facility based on the design features of SMART. The reference scale ratios of length (1/2.77) and area (1/472.9) are based on the elevation difference between the core and steam generator centers and the core flow area, respectively. According to the scaling law, the reduced height scaling results in time-reducing results in the model as the time scale ratio is 1/1.664.

Three SBLOCA tests were successfully performed by using the VISTA-ITL facility recently. The breaks are guillotine breaks and their locations are on the SIS line (nozzle part of the RCP discharge), on the suction line of SCS (nozzle part of the RCP suction), and the PSV (safety valve line connected to the pressurizer top) line.

In this study, the SIS line-break SBLOCA test of SB-SIS-06 has been discussed and the test results have been analyzed with the best-estimate system code, MARS-KS [2] which was developed by KAERI, to assess its simulation capability on the SBLOCA scenario for the SMART design [3].

2. A Typical SBLOCA Test (SB-SIS-06)

As a safety injection system (SIS) nozzle is broken in the SMART design, the primary system pressure decreases with the discharge of the coolant through the break. When the primary pressure reaches the low pressurizer pressure (LPP) set-point, the reactor trip signal is generated with a 1.1 s (in VISTA-ITL: 0.66 s) delay. As the turbine trip and the loss of off-site power (LOOP) are assumed to occur consequently after the reactor trip, the LOOP occurs, the feedwater is not supplied and the RCP begins to coastdown. With an additional 0.5 s (in VISTA-ITL: 0.3 s) delay, the control rod is inserted. When the PRHRS actuation signal is generated by the low feedwater flowrate 2.2 s (in VISTA-ITL: 1.32 s) after the LPP, the SG is isolated from the turbine by the isolation of the main steam and feedwater isolation valves and it is connected to the PRHRS. The safety injection actuation signal was generated when the RCS pressure reaches below the safety injection actuation signal and the SI water is injected with the time delay of 30 s (in VISTA-ITL: 18.03 s).

The break nozzle diameter is 50 mm in the SMART design and the scaled-down value is 1.77 mm in the VISTA-ITL. The set-points of LPP and SIAS were 12.3 and 10.0 MPa, respectively. The detailed experimental results are discussed in Section 3 together with the simulation results.

3. Simulation Results on the SB-SIS-06 Test

3.1 Nodalization

Figure 1 shows the MARS nodalization diagram used for the VISTA-ITL. The nodalization diagram includes all the reactor coolant systems, safety injection system and PRHRS, etc. For the SBLOCA scenario of the safety injection line break (SB-SIS-06), the break line is assumed to be one of the available safety lines and only one of the 4 safety injections is assumed to be active for the transient based on a single failure assumption. The safety injection flow rate of the VISTA-ITL is scaled down by applying the appropriate scaling ratios of 1/787 to the SMART design. The break area is set to be reduced according to the flow rate scale ratio.

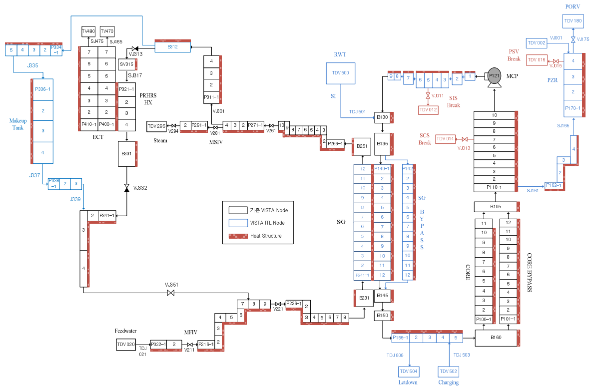


Figure 1. MARS nodalization diagram for the VISTA-ITL

3.2 Steady-State Calculation

Table 1 Comparison of the major parameters at 103% power

Parameter	SMART (design value)	VISTA-ITL (ideal value)	VISTA-ITL (test data)	VISTA -ITL (MARS)
Power [MWt]	330.0	0.432	0.451	0.432
PZR pres. [MPa]	15.0	15.0	15.0	15.0
1^{st} flow rate [kg/s]	2090.0	2.65	2.57	2.63
SG 1^{st} inlet T. [K]	596.15	596.15	595.4	595.8
SG 1^{st} outlet T. [K]	568.85	568.85	567.4	567.2
FW flowrate [kg/s]	160.8	0.204	0.155	0.156
FW temp. [K]	473.15	327.15	329.8	329.6
SG 2^{nd} inlet P [MPa]	6.0	6.0	6.0	5.8
SG 2^{nd} outlet P [MPa]	5.2	5.2	5.2	5.2

Table 1 shows comparison of the major parameters of the SMART design, the ideal value, test data and MARS-KS calculation results of VISTA-ITL at 103% rated power condition. The simulation results show that most of the thermal-hydraulic parameters agree well one another. The heat loss of about 19 kW was estimated and added during the test. The feed water flow rate is lower during the test than the ideal value due to the low injected feed water temperature to match the heat balance.

3.3 Transient Calculation

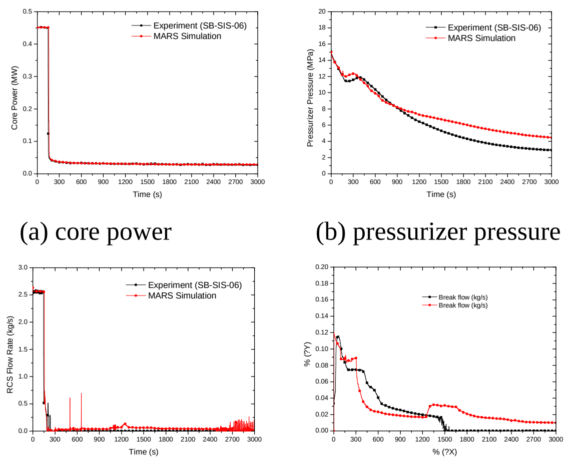
Table 2 shows the major sequence of events for the SB-SIS-06 test and Figure 3 shows the variations of the major parameters of core power, pressurizer pressure, and flow rates of reactor coolant system (RCS) and break. The decay power curve and safety injection flow rate are successfully given both for the test and the simulation.

Table 2 Major sequence of events for SB-SIS-06

Event	Time SMART design	Time VISTA-ITL	Time (s) Measured VISTA-ITL	Time (s) Calculated VISTA-ITL
Break occur	0.0	0.0	0.0	0.0
LPP set-point	LPP	LPP	143.5	154.41
LPP reactor trip signal	LPP+1.1 s	LPP+ 0.66 s	144.16	155.07
PRHRS actuation signal	LPP+2.2 s	LPP+ 0.96 s	145.7	155.74
PRHRS IV full open	PRHRSAS + 5.0 s	PRHRSAS + 3 s	146.5	158.74
SI signal	SIAS	SIAS	646.5	586.71
SI start	SIAS+30 s	SIAS+18 s	664.53	604.75

The core power was well simulated during the simulation, as shown in Fig. 3(a). The primary pressure decreased rapidly during the single-phase blowdown period, as shown in Fig. 3(b). As the depressurization is slower in the MARS-KS simulation, the LPP-related events occur about 11 s later than in the test. The overall trend of primary pressure behavior is well simulated during the initial period but it is higher at the later period after 880 s. As the pressure decreased rapidly during the initial period before safety injection signal, the safety injection signal was generated about 60 s earlier in the simulation than that in the experiment. The simulated RCS flow rate was in good agreement with the test data during the initial period of about 1,200 s, as shown in Fig. 3(c). In the present simulation the discharge coefficient of 0.6 was used to match the initial break flow rate of the SB-SIS-06 test. The plateau region was kept higher during a shorter period in the simulation than that in the test. The discrepancy after 1,200 s should be checked in detail as a further work, which is also related to the RCS flow rate.

The similarity between the VISTA-ITL data and its simulation results was good for the major thermal-hydraulic parameters as described in Fig. 3.



(a) core power (b) pressurizer pressure

(c) RCS flow rate (d) break flow rate

Figure 3 Comparison of calculation results

4. Conclusion

A SBLOCA test for the safety injection line break (SB-SIS-06) has been performed and the test was simulated with the MARS-KS code, to assess its simulation capability for the SBLOCA scenario of the SMART design. The SBLOCA scenario in the SMART design was well reproduced by using the VISTA-ITL facility and the measured thermal-hydraulic data was properly simulated with the MARS-KS code. The present SBLOCA test and analysis results could provide a comprehensive understanding on the thermal-hydraulic characteristics of the SBLOCA behavior of the SMART design.

REFERENCES

[1] H.S. Park, *et al.*, *Construction Report of the VISTA-ITL*, KAERI internal report, KAERI, March 2011.

[2] B.D. Chung, *et al.*, *Development and Assessment of Multi-Dimensional Flow Models in the Thermal-Hydraulic System Analysis Code MARS*, KAERI/TR-3011/2005, 2005.

[3] K.H. Lee, *et al.*, *SMART SBLOCA Safety Analysis Methodology*, KAERI internal report, KAERI, 2010.