An Integral Effect Test of Complete Loss of RCS Flowrate for SMART with the VISTA-ITL

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1. Introduction

A thermal-hydraulic integral effect test facility, VISTA-ITL [1], for the SMART design [2] 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) [3], passive residual heat removal system (PRHRS) performance tests [4], and complete loss of RCS (Reactor Coolant System) flowrate (CLOF), *etc*. 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.

A CLOF test was successfully performed by using the VISTA-ITL facility recently and its major results have been discussed.

2. Sequence of CLOF (CLOF-02)

Table 1 shows the major sequence of event for the CLOF test. The thermal-hydraulic behavior happens 1.664 times faster in the VISTA-ITL than in the SMART design according to the time scale ratio. The CLOF accident is an anticipated operating transient, which causes the complete loss of primary flow rate by the initiation of the reactor coolant pump (RCP) coastdown due to the failure of the electricity supply to RCP. In this case it could increase the core outlet temperature rapidly due to the RCP coastdown and then the pressurizer pressure increases with the volume expansion of the RCS inventory. When the pressurizer pressure reaches the high pressurizer pressure (HPP) trip set-point (16.53 MPa), the reactor trips by the reactor trip signal which was generated with a 1.1 seconds (in VISTA-ITL: 0.66 seconds) delay. With an additional 0.5 seconds (in VISTA-ITL: 0.3 seconds) delay the control rod is inserted. As the PRHRS actuation signal is generated by the low feed-water flow-rate 1.1 seconds (in VISTA-ITL: 0.66 seconds) after the HPP, the SG is isolated from the turbine by the isolation of the main steam and feed-water isolation valves and it is connected to the PRHRS. With the operation of PRHRS, two-phase natural circulation occurred inside the PRHRS. The decay heat generated from the reactor core was transferred through the SG and eventually it was removed by the PRHRS heat exchanger which is located in a water-filled ECT.

Table 1 Major sequence of a CLOF test

Event	Trip signal and Set-point	
	SMART	VISTA-ITL
Transient occurs	RCP coastdown	RCP coastdown
Reach HPP set-point	HPP = 16.53 MPa	
HPP reactor trip signal	HPP+1.1 s	HPP+0.66s
- FW Stop		
PRHR actuation signal	HPP+1.1 s	HPP+0.66 s
Control rod insert	HPP+1.6 s	HPP+0.96 s
PRHRS IV open	PRHRAS+5.0 s	PRHRAS+3.0 s
MSIV/FIV close	PRHRAS+15.0 s	PRHRAS+9.01 s

3. Discussion and Results

3.1 Steady state

Table 2 shows the comparison of the major parameters between SMART design and VISTA-ITL at a steady state condition. The primary and secondary system flow rates with the 103% rated core power are 2.63 kg/s and 0.15 kg/s, respectively. The primary system pressure of 103% rated core power is 15.0 MPa, the pressurizer level is about 70%, and inlet/outlet temperatures of steam generator primary side are maintained at 323℃ and 296℃ respectively.

Table 2. Comparison of the major parameters at a steady state condition

Parameter	SMART (Design value)	VISTA-ITL (Target value)	VISTA-ITL (Test data)
Power (MW)	330 * 1.03	0.451	0.451
PZR pres. (MPa)	15.0	15.0	15.0
1st Flowrate (kg/s)	2090.0	2.63	2.62
SG 1st inlet Temp. (℃)	323.0	323.0	324.0
SG 1st outlet Temp. (℃)	296.0	296.0	296.0
F.W. flow-rate (kg/s)	160.8	0.15	0.15
SG 2nd inlet pres. (MPa)	6.0	6.0	5.98
SG 2nd outlet pres. (MPa)	5.2	5.2	5.2
SG 2nd inlet Temp. (℃)	200.0	50.0	55.9
SG 2nd outlet Temp. (℃)	> 298.0	> 298.0	317.0

3.2 Transient

Table 3 show the test results of the major sequence for a CLOF (CLOF-02) test. When the RCP starts to coasdown, the RCS began to be pressurized rapidly. As the pressurizer pressure reached the HPP trip set-point (16.53 MPa) 11 s after the pump coastdown (Das time: 339 s). The reactor trip was generated about 1.0 s after the HPP signal. Consequently with the reactor trip signal, the feed water was stopped at 12 s. It was shown that the PRHRS actuation signal occurred at 13 s. The PRHRS IV valves open at 17 s and the MSIV/FIV close at 26 s.

Table 3 Test results of major sequence for CLOF

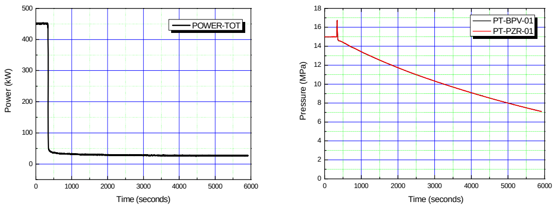
Event	Das time (seconds)	After RCP coastdown time (seconds)
RCP coastdown	328	0
Reach HPP set-point	339	11
Reach reactor trip signal	340	12
- FW Stop		
PRHR actuation signal	341	13
Reactor trip	341	13
PRHRS IV open	345	17
MSIV/FIV close	354	26
Test end	5,914	5,586

Fig. 1 shows the variations of the major parameters. The decay power curve and safety injection flow rate are successfully given for the test. The core power was well simulated during the test, as shown in Fig. 1(a).

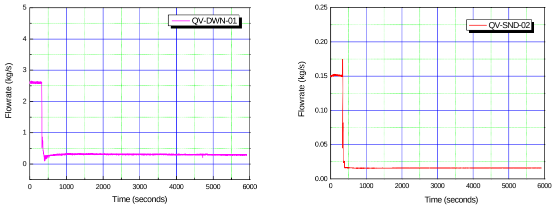
Fig. 1(b) shows the pressure behavior of the primary system. The primary pressure increased rapidly during the pump coastdown. The pressure increased up to 16.53 MPa during a short period 11 s after the pump coastdown. After then, the feedwater stopped, the reactor tripped, and the PRHRS was actuated to cause the pressure to decrease gradually.

Fig. 1(c) shows the primary system flow rate. The flow rate was 2.62 kg/s in the steady-state. After the pump coastdown, the primary flow rate decreased dramatically and it recovered a little to maintain a steady flow rate of about 12.0% of the rated RCS flow rate (0.315 kg/s) during the whole test period.

Fig. 1(d) shows the secondary system flow rate. The initial flow rate was about 0.15 kg/s. As the PRHRS system was operated, feed-water flow rate showed a dramatic change at the beginning and natural circulation was achieved within a few seconds. After that, the natural circulation flow rate showed a gradual decrease at a constant rate. The natural circulation flow rate depends on a heat balance between the PRHRS heat exchanger and the SG, and the hydraulic resistance in the loop. The initial maximum value of natural circulation flow rate was about 0.016 kg/s and was 10.6% of the rate feed-water flow rate (0.15 kg/s) in maximum.



(a) Core power (b) Primary system pressures



(c) Primary system flow rate (d) PRHRS flow rate

Fig. 1 Test results of major parameters

4. Conclusions

An integral effect test has been performed successfully to provide the data to assess the simulation capability of the TASS/SMR code [5] for the complete loss of RCS flow rate (CLOF) scenario for the SMART design. The steady-state conditions were achieved to satisfy the initial test conditions presented in the test requirement and its boundary conditions were properly simulated. The CLOF scenario in the SMART design was reproduced well by using the VISTA-ITL facility. A natural circulation flow rate in the PRHRS loop was about 10.6% of its rated value in the early state of the PRHRS operation and the RCS flow rate was 12.0% of the rated RCS flow rate.

REFERENCES

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