Similarity Analysis of the VISTA Thermal-Hydraulic Integral Test Loop for a Small-Break LOCA of the SMART Design

Hyun-Sik Park [a*], Rae-Joon Park [a], Sang-Ki Moon [a], Hwang Bae [a],
Doo-Hyuk Kang [b], Yeon-Sik Cho [c], and 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
[c] Energy & Environment Systems Co., Ltd, 328 Guam-dong, Yuseong, Daejeon, 305-800, Korea
**Corresponding author: hspark@kaeri.re.kr*

1. Introduction

A thermal-hydraulic integral effect test facility, VISTA ITL [1], for SMART design is being constructed by the Korea Atomic Energy Research Institute (KAERI). The VISTA ITL is a modified version of an existing VISTA facility [2] to have the simulation capability of small-break loss of coolant accident (SBLOCA) by installing steam pressurizer, safety injection system, steam generator bypass, pump discharge line, dowcomer, PRHRS makeup tank, break simulator and 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 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.

The reference plant of the VISTA ITL is a 330-MW (thermal) class integral type reactor, SMART [3], which is being developed by the KAERI. The SMART reactor is characterized by the introduction of simplified and improved safety systems such as passive residual heat removal system (PRHRS) and its integral arrangement of the reactor vessel assembly.

In this study, a pre-test analysis of a SBLOCA is performed to understand the general behavior of the VISTA ITL and to assess the similarity between the VISTA ITL and the SMART design. The analysis is performed by using a best-estimate system analysis code, MARS-KS [4] which was developed by KAERI, with the same control logics, transient scenarios and nodalization scheme for both systems of VISTA ITL and SMART design. The analysis result can provide a good insight into unique design features of the VISTA ITL and the thermal-hydraulic characteristics of the SMART design.

2. Description of Analysis

A SBLOCA scenario for both the reference plant SMART and the VISTA ITL has been analyzed with the best-estimate system code MARS-KS [4].

Figures 1 and 2 show the MARS nodalization schemes used for the SMART design and the VISTA ITL, respectively. The nodalization schemes of both the SMART design and the VISTA ITL include all the reactor coolant systems, safety injection system and PRHRS, etc. For the SBLOCA assessment for the safety injection line break, the break line is assumed to be one of the available safety lines and only one of the 4 safety injection 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 to the SMART design. The break area is set to be reduced according to the flow rate scale ratio since the break flow would be choked during the simulation.

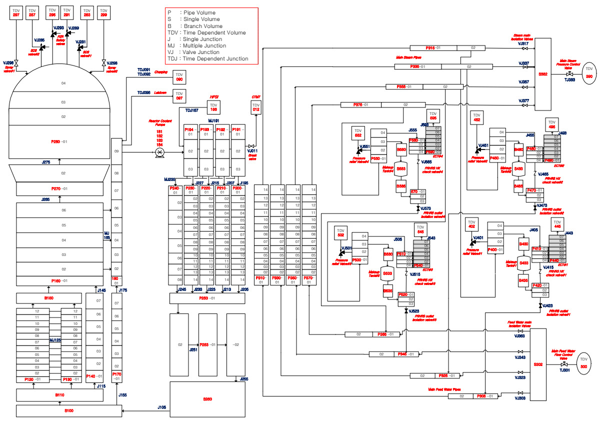


Figure 1. MARS nodalization for the SMART design

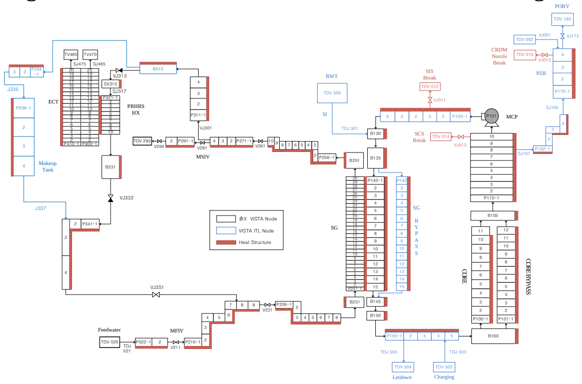


Figure 2. MARS nodalization for the VISTA ITL facility

3. Results of the Similarity Analysis

3.1 Steady-State Calculation

Table 1 shows the design parameters and calculated major design parameters of the SMART design, SMART simulation and VISTA ITL calculation at a steady state condition. The results show that most of the thermal-hydraulic parameters agree well between the calculated ones except for the lower primary temperature due to lower secondary pressure and temperature. The core power is a little higher in the VISTA ITL calculation.

Table 1 Comparison of the major parameters at a steady state condition

Parameter	SMART design value (VISTA)	MARS results for SMART	MARS results for VISTA ITL
Power [MWt]	330.0 (0.419)	330.0	0.548
PZR pressure [MPa]	15.0 (15.0)	14.97	15.0
1st Flow rate [kg/s]	2090.0 (2.656)	2107	2.668
SG 1st inlet temp. [K]	596.15 (-)	590.3	574.7
SG 1st outlet temp. [K]	568.85 (-)	562.2	536.1
Feedwater flowrate [kg/s]	160.8 (0.204)	160.8	0.204
Feedwater temp. [K]	473.15 (327.15)	473.2	327.7
SG 2nd inlet press. [MPa]	6.0 (4.5)	5.65	4.5
SG 2nd outlet press. [MPa]	5.2 (3.5)	5.37	3.8

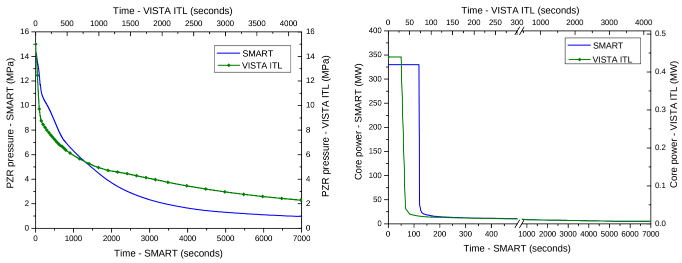
3.2 Transient Calculation

Table 2 shows the major sequence of events observed during the present analysis. 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 sequence of events for SBLOCA should be checked more in the near future. The primary pressure decreases slower in the SMART calculation than in the VISTA ITL, and both reactor trip and safety injection are delayed.

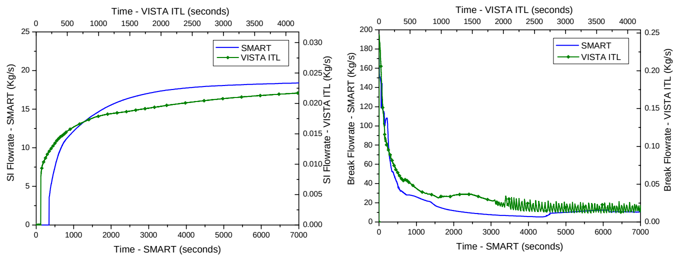
Table 2 Major sequence of events for SBLOCA

Event	Time (s) SMART (time for VISTA ITL)	Time (s) VISTA ITL
SIS break occur	0.0 (0.0)	0.0
Reach LPP set-point	117.63 (70.69)	36.005
LPP reactor trip signal	118.73 (71.35)	36.666
PRHR actuation signal	118.80 (71.39)	36.667
PRHRS IV full open	123.80 (71.4)	39.717
Safety injection signal	311.18 (187.0)	55.795
Safety injection start	344.18 (206.84)	75.595

Figure 3 shows the variations of the major parameters of pressurizer pressure, core power and flow rates of safety injection and break. The primary pressure maintains a higher value in the SMART design than in the VISTA ITL, as shown in Fig. 3(a). Therefore, both the reactor trip and safety injection are delayed, as shown in Fig. 3(b) and Fig. 3(c), respectively. The decay curve and safety injection flow rate are successfully given except for the delayed initiation. The similarity between the SMART design and the VISTA ITL was good for the break flow rate, as shown in Fig. 3(d). The difference of depressurization rate should be checked considering the other parameters of secondary system and PRHRS, etc.



(a) pressurizer pressure (b) core power



(c) safety injection flow (d) break flow rate

Figure 3 Comparison of calculation results

4. Conclusion

A SBLOCA for the safety injection line break has been analyzed with the MARS-KS code, to assess a thermal-hydraulic similarity between the SMART design and the VISTA ITL. The present similarity analysis provides a good insight into unique design features of the VISTA ITL and the thermal-hydraulics characteristic of the SMART design. However, more detailed further calculation is necessary in a near future.

REFERENCES

[1] H.S. Park, *et al.*, *An Integral Effect Test Program for SMART Design using the VISTA ITL Facility*, Transactions of the Korean Nuclear Society Spring Meeting, Pyeongchang, Korea, May 27-28, 2010.
[2] S.J. Yi, *et al.*, *Basic Design of the High Temperature/High Pressure Thermal-Hydraulic Test Facility*, KAERI internal report, KAERI, 2001.
[3] K.H. Ko, *et al.*, *SMART System Description*, KAERI internal report, KAERI, 2010.
[4] 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.