Performance Evaluation of SMART Passive Safety System under Small Break Loss of Coolant Accident

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1. Introduction

SMART (System-integrated Modular Advanced ReacTor), which is developed by KAERI, is a small-scale integral-type reactor including core, reactor coolant pumps, steam generators and pressurizer within a single reactor vessel. Inherent and passive, simplified safety system is used in SMART for the safety enhancement.

When Small Break Loss of Coolant Accident (SBLOCA) occurs, the Passive Safety Injection System (PSIS) injects water into the reactor and removes heat from the core. PSIS is composed of 4 independent trains with a 33% capacity each, which contains of one Core Makeup Tank (CMT) and one Safety Injection Tank (SIT) with related valves, instrumentation equipment, one Safety Injection Line (SIL) and Pressure Balance Line (PBL). Any abnormal situation like low or high pressure signal in the pressurizer, SIL isolation valves opened by the CMT actuation signal, gradually borated water in the CMT will be injected into the RCS by gravity.

In this study, the performance of PSIS of SMART under SBLOCA has analyzed. The MARS-KS model was adopted to observe thermal-hydraulic behaviors depending on the number of CMTs, and SITs. As a result, the success criteria for PSIS were derived.

2. Steady-state Calculation

Nodalization of SMART is illustrated in Fig. 1. For conservatism, 103% core power was assumed. The results of steady-state calculation are summarized in Table 1.

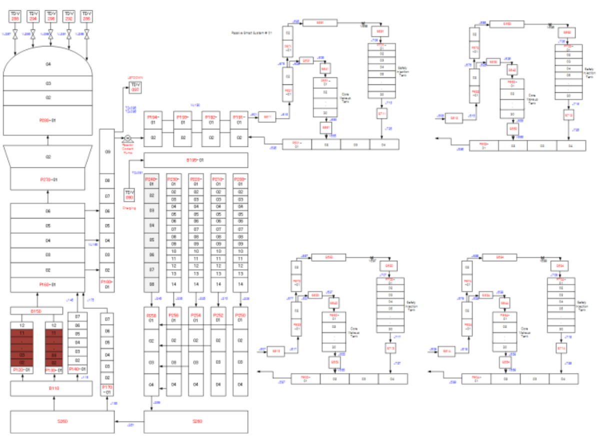

Fig. 1 Nodalization of SMART (CMT & SIT)

Table. 1 Thermal variables of steady-state calculation

Variables	Calculation(103%)
Core Power, MWt	339.9
RCS Flow, kg/s	1988.1
Average Core Flow, kg/s	1876.7
Hot Assembly Flow, kg/s	32.0
Core Bypass Flow, kg/s	79.4
Pressurizer Pressure, MPa	15.7
Pressurizer Temperature, ^{o}C	345.8
Core Pressure, MPa	15.8
S/G Inlet Temperature(1^{st}), ^{o}C	328.8
S/G Outlet Temperature(1^{st}), ^{o}C	300.0
Pressurizer Level, %	55.0
Feed Water Flow(2^{nd}), kg/s	165.6
Feed Water Pressure(2^{nd}), MPa	6.1
Feed Water Temperature(2^{nd}), ^{o}C	200.2
Outlet Pressure(2^{nd}), MPa	5.2

3. Loss of Coolant Accident – Safety Injection Nozzle

In this study, loss of coolant accident at safety injection nozzle was chosen for sensitivity analysis. Break occurs at safety injection nozzle in one passive safety system train. Break area was about 0.00196m^2. Table 2 represents major event occurrence time.

Table. 2 Major event occurrence time of SBLOCA

Event	Time [sec]
Emerging Break	0.001
Reaching Low Pressure Reactor Protection Standard of Pressurizer (12.13MPa)	389.0
Reaching CMT Isolation Valve Opening Standard	389.0
Turbine Shutdown	390.1
Insertion of Control Rod	390.6
Signal for Feedwater Low Flow Rate	391.3
Beginning of PRHRS Isolation Valve Opening Beginning of MFIV Closing	394.0
Beginning of MSIV Closing	419.0
Reaching Isolation Valve of SIT Opening Standard (1.78MPa)	3500.0

4. Analysis Results

There are 4 trains of passive safety system in SMART. Sensitivity evaluation was conducted for the number of CMTs and SITs with respect to accident mitigation.

4.1 Base case – No CMT, SIT

First of all, simulation was conduction in case of no CMT and SIT and no PRHRS. As demonstrated in Fig. 2, cladding temperature would increase due to the lack of the decay heat removal.

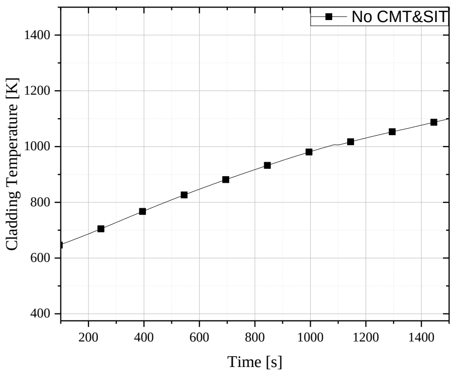

Fig. 2 The highest Cladding temperature in case of no CMT and SIT

4.2 Results for 1 CMT Case

In order to effect of CMT, the analysis has been conducted with varying the number of SIT when one CMT running. Results are demonstrated in Fig. 3. Cladding temperature increased till SIT injection started, and gradually decreased, which means the one CMT would not be sufficient to remove the decay heat. Only with additional SIT injection, the decay heat would be removed to prevent the core damage. Cooling performance would be improved as the number of SIT injection increased.

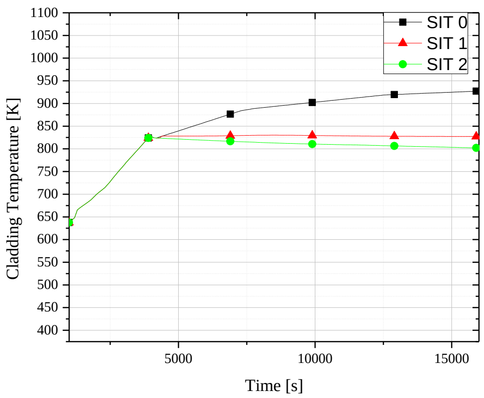

Fig. 3 The highest Cladding temperature in case of 1 CMT with varying number of SITs

4.3 Results for 2 CMT Case

Cooling performance in case with 2 CMTs has been analyzed. As can be seen in Fig. 4, the cladding temperature would be maintained until SIT injected because the flow through break point and the injected water from CMTs would remove the decay heat from the core. With SIT injection, the cladding temperature starts to decrease. Cooling performance would be improved as the number of SITs increased.

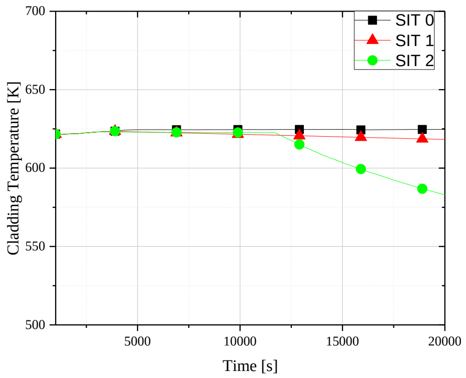

Fig. 4 The highest Cladding temperature in case of 2 CMT with varying number of SITs

5. Conclusion

In this study, PSIS performance analysis was conducted by using MARS code under loss of coolant accident at safety injection nozzle. The number of CMTs and SITs are varied to examine the effect of their injection. In conclusion, 1 CMT with 2 SITs or 2 CMTs 1 SIT are minimum requirements for SBLOCA. It is important to note that if the injection from CMT or SIT is sufficient, additional heat removal via secondary side (e.g., Passive Residual Heat Removal System) would not be necessary. This would be valuable insight for Event Tree construction and success criteria analysis for SMART PSA.

5. References

[1] MARS CODE MANUAL, KAERI, 2009.