Comparison of SMART-SDA and SMART-PSS Behaviors Using an SBLOCA Scenario

Doo-Hyuk Kang [a*], Yung-Joo Ko[a], Jae-Seung Suh[a], Hyun-Sik Park[b], Sang-Ki Moon[b], Rae-Joon Park[b], Sung-Jae Yi[b]
[a]*System Engineering & Technology Co., Ltd., Room 303, InnoBizPark, HanNam University, 1646 Yuseong-daero, Yuseong-gu, Daejeon, 305-811, Korea*
[b]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea*
[*]*Corresponding author: dhkang@esentech.kr*

1. Introduction

SMART has been developed by KAERI [1], and SMART-Standard Design Approval (SDA) was recently granted in 2012. A SMART-Passive Safety System (PSS) is being developed by KAERI to improve the safety system. Active safety systems such as safety injection pumps will be replaced by a passive safety system [2], which is actuated only by the gravity force caused by the height difference. All tanks for the passive safety systems are higher than the injection nozzle, which is located around the reactor coolant pumps (RCPs).

In this study, an analysis of an SBLOCA scenario of safety injection line break accident was performed using the MARS-KS code to understand the general behavior between the SMART-SDA and the SMART-PSS design.

2. Methods and Results

2.1 SMART-SDA Design

Fig. 1 shows the MARS-KS nodalization scheme for the SMART-SDA, which includes all of the reactor coolant systems, a safety injection system, and PRHRS [3].

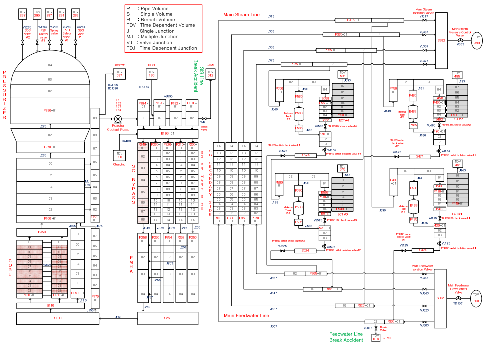


Fig. 1 MARS-KS nodalization for SMART-SDA

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 four safety injections is assumed to be active for the transient based on a single failure assumption.

2.2 SMART-PSS Design

Fig. 2 shows the MARS-KS nodalization scheme for the SMART-PSS, in which the passive safety systems are added to the SMART-SDA instead of active safety systems. The passive safety systems consist of four Core Makeup Tanks (CMT), CMT isolation valves and check valves, four Safety Injection Tanks (SIT), SIT isolation valves and check valves, connecting pipes, two Auto Depressurization System (ADS) valves, etc.

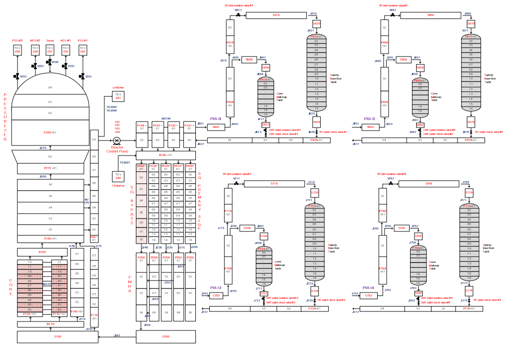


Fig. 2. MARS-KS Nodalization for SMART-PSS

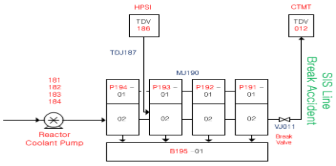
2.3 SBLOCA Scenario and Modeling

To simulate an SBLOCA, the safety injection line break system was initiated by opening the break valve at 0.0s after a steady-state condition as shown in Table 1.

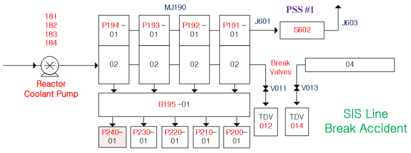
Table 1. Sequence of events for SIS Line Break SBLOCA

Events	Set-point (SDA)	Set-point (PSS)
SIS line break	0.0s	0.0s
LPP signal	12.13MPa	12.13MPa
CMT IV Open (PSS)	-	LPP signal + 0.0s
Reactor trip signal -LOOP -Feedwater Stop -RCP Coastdown Start	LPP signal + 1.1s	LPP signal + 1.1s
CRA Insertion	LPP signal + 1.6s	LPP signal + 1.6s
PRHR Operation Signal -FW/MS IV Close -PRHRS IV Open	LPP signal + 2.34s Stroking time : 20s Stroking time : 5s	LPP signal + 2.34s Stroking time : 20s Stroking time : 5s
Safety Injection signal	10.0 MPa	2.12 MPa
SI pump start (ADS) SIT IV Open (PSS)	SI signal + 30.0s	SI signal + 0.0s
ADS #1 valve Open (PSS)	-	CMT level < 35%
ADS #2 valve Open (PSS)	-	SIT level < 20%

A break system modeling of both SMART-SDA and SMART-PSS was used to assess the safety injection line break accident as shown in Fig. 3.



(a) SMART-SDA

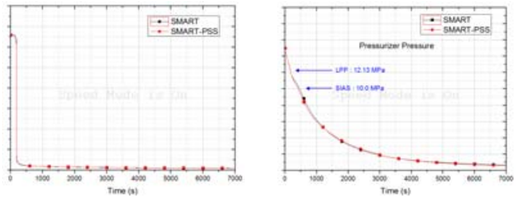


(b) SMART-PSS

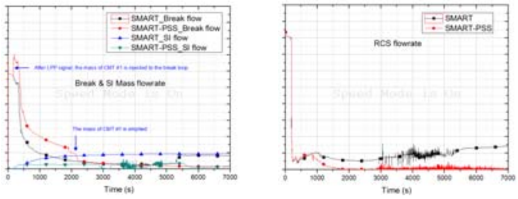
Fig. 3. Nodalization Schemes of Break System for both SMART-SDA and SMART-PSS

2.4 Results and Discussion

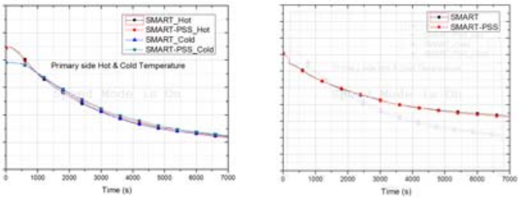
Fig. 4 shows the variations of the major parameters of core power, pressure, temperature, flow rate, and collapsed water level between the SMART-SDA and SMART-PSS.



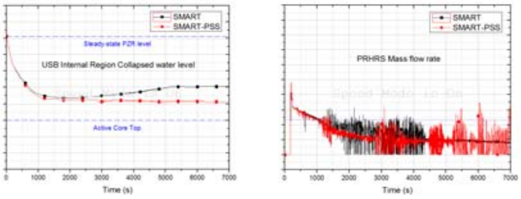
(a) Core power (b) PZR pressure



(c) Break & SI flow (d) RCS flow



(e) Hot & Cold Temp (f) PCT



(g) USB level (h) PRHRS flow

Fig. 4. Analysis results for SIS line break accident

The core power was tripped with a delay of 1.1 seconds after the LPP signal. The core power was reduced, as shown in Fig. 4(a), according to the reactivity table and decay power curve in the kinetics component. When the pressurizer pressure decreased and reached a low pressurizer set pressure of 12.13 MPa, a LPP signal was generated. The behaviors of core power and pressurizer pressure between SMART-SDA and SMART-PSS show similar trends.

The behaviors of the flow rates of the break and safety injection show different trends. The flow rate of the break in SMART-PSS sharply increased during the early period because the mass of CMT #1 is injected into the break line after the LPP signal, as shown in Fig. 4(c). The flow rate of the safety injection in SMART-PSS is smaller than that of SMART-SDA because the water capacity of CMTs and SITs is smaller than that of active safety systems. However, Owing to differences in height, passive safety systems have an advantage of being able to operate through the force of gravity.

Fig. 4(g) shows a variation of the collapsed water level of the internal upper support barrel (USB). The collapsed water level in SMART-PSS was maintained lower than that in SMART-SDA after the middle of the transient. It seems that the safety injection flow rate in SMART-PSS is smaller than that of SMART-SDA. However, the collapsed water level in SMART-PSS was maintained upper than that of the active core top level. It can be seen that the capability of an emergency core cooling system is sufficient during an accident situation.

3. Conclusions

An SBLOCA for the safety injection line break has been analyzed using the MARS-KS code to compare the thermal-hydraulic behaviors between the SMART-SDA and SMART-PSS. The present comparison analysis provides good insight into the passive safety system design features of the SMART-PSS and the thermal-hydraulics characteristic of the SMART design. It was found that the SMART-PSS has sufficient emergency core cooling capability during the transient period. Further study will be focused on the transient time. It should be able to compute the problem during 72 hours without AC power or operator action after an accident.

ACKNOWLEDGEMENT

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