Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Main Steam Line Break Analysis for the Fully Passive Safety System of SMART

Seong Wook Lee*, Ji-Han Chun, Kyoo Hwan Bae, Keung Koo Kim
Korea Atomic Energy Research Institute, 1045 Deadeok-dearo, Yuseong-go, Daejeon, Korea
**Corresponding author: leesw@kaeri.re.kr*

1. Introduction

The standard design approval of SMART (System-integrated Modular Advanced ReacTor) developed by KAERI and KEPCO consortium was issued on July 4, 2012 [1].

Although SMART has enhanced safety compared to the conventional reactor, there is a demand to meet the “passive safety performance requirements” [2] after the Fukushima accident. The passive safety performance requirements are the capabilities to maintain the plant at a safe shutdown condition for a minimum of 72 hours without AC power supply or operator action in case of design basis accident (DBA).

To satisfy the requirements, KAERI is developing a safety enhanced SMART by adopting a passive safety injection system.

The passive safety injection system developed for SMART is a gravity-driven injection system, which consists of four trains, each of which includes a pressure balance line, core makeup tank (CMT), safety injection tank (SIT) and injection line. The similar concept was introduced in the AP600 [4] or AP1000 designs [5]. The layout of the fully passive safety system of SMART is shown in Fig. 1. The CMT plays an important role to inject borated water into the RCS to prevent or dissolve the return to power (re-criticality) condition during the event of increase in heat removal by the secondary system. The main steam line break accident (MSLB) is the most limiting accident for an increase in heat removal by the secondary system.

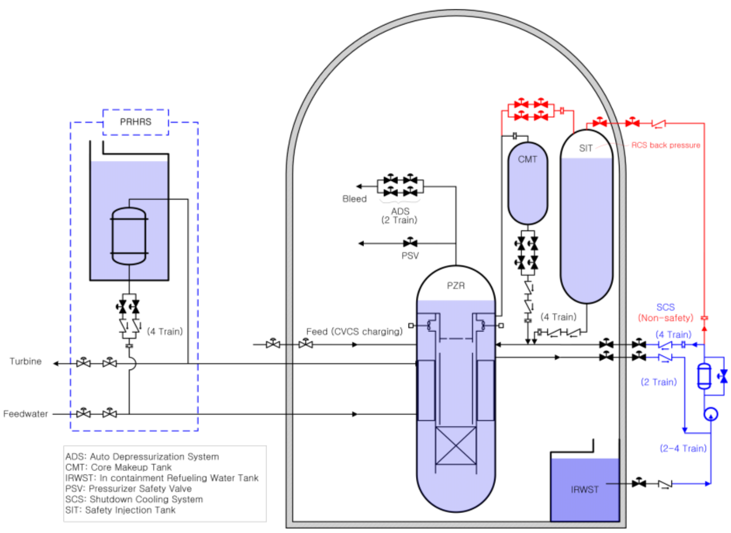

Fig. 1. Fully Passive Safety System of SMART

In this study, the safety analysis results of MSLBs at hot full power condition and at hot zero power condition in view of re-criticality are given.

2. Analysis Methodology

In the SMART standard design state, the most conservative initial condition for the MSLB was identified as high core power, low RCS flow, high core inlet temperature, high pressurizer pressure, and low pressurizer level. For the current calculation, it is considered reasonable to assume the same initial condition as SMART standard design because there is no change in RCS and other main systems.

The Loss Of Offsite Power (LOOP) affects the sequence of events and the consequence of MSLB accident because the cause of shutdown and the cooling rate are different. Therefore, the assumed LOOP occurrence time should be considered in the analysis.

For the thermal hydraulic analysis, MARS/KS code [6] is used. The modeling of the fully passive safety system is developed and appended to the existing SMART modeling. The node modeling of the passive safety injection system is shown in Fig. 2.

The guillotine break of the section steam pipe is analyzed. Reactor trip signal can be generated by core variable overpower, pressurizer low pressure or main steam line low pressure. If LOOP condition is considered, the RCP low speed signal can be included. The run out flow rate of feed water pump, one of the important parameters affecting the RCS cooling rate, is assumed to be 140% of the rated flow. The reactivity feedback, FTC (Fuel Temperature Coefficient) and MTC (Moderator Temperature Coefficient) are assumed to have most negative values. And the PRHRS (Passive Residual Heat Removal System) isolation valves are opened by the main steam line low pressure signal. Four trains of PRHRS are assumed to be applicable for cooling the primary system. The borated water in the CMT is injected to the RCS by either the main steam line low pressure or the pressurizer low pressure signal.

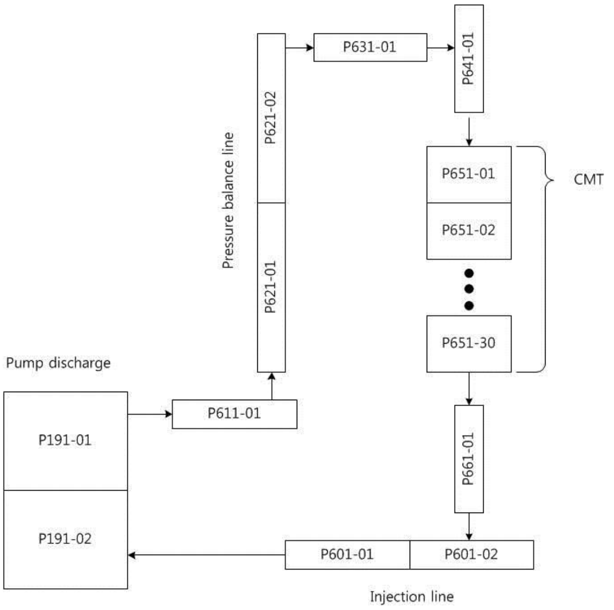

Fig. 2. Nodalization of the passive safety injection system including CMT and associated piping systems

3. Analysis Results and Discussion

The MSLB analysis results for full power condition and zero power condition are shown in Fig. 3 and Fig. 4. When LOOP is assumed, the reactor trip signal is generated by the RCP low speed in spite of the power level. On the other hand, when LOOP is not considered, the reactor is tripped by the variable overpower signal

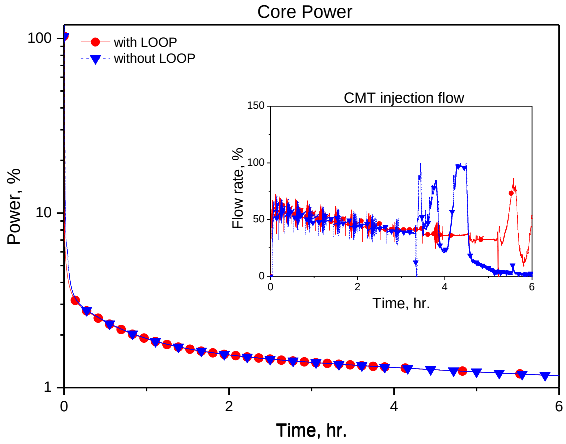

Fig. 3. MSLB analysis results for full power conditions: core power and CMT injection flow

for the full power case and by the main steam line low pressure signal for zero power case, respectively.

After reactor trip, the CMT injection is initiated by the main steam line low pressure signal in a few ten seconds. Due to the injection of the borated water, the core is maintained subcritical state and the power shows decreasing trend throughout the transient. As time goes on, the CMT flow shows fluctuating behavior. This is caused by the void formation in the pressure balance line and CMT that unable to supply consistent driving force for injection.

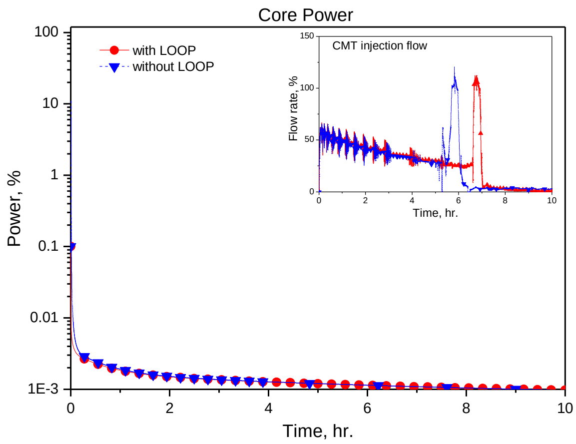

Fig. 4. MSLB analysis results for zero power conditions: core power and CMT injection flow

4. Conclusions

The MSLB accident has been analyzed for the SMART adopting fully passive safety system in the aspect of re-criticality.

The results show that the core remains subcritical condition throughout the transient due to the borated water injected by the CMT.

As further works, many kinds of analyses and sensitivity studies should be performed for the design establishment and improvement of the fully passive system of SMART.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (Safety Enhancement Research for SMART Construction, 2013M2B9A1000877).

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