Analysis of the SMART's Increased Heat Removal Transients by the Secondary System

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1. Introduction

The SMART (system-integrated modular advanced reactor) is a 330 MWt advanced integral PWR designed by KAERI for seawater desalination and electricity generation. Unlike the loop type commercial reactors, the nuclear steam supply system (NSSS) of the SMART adopts the design concept of containing most of the reactor coolant system (RCS) components, such as a core, four reactor coolant pumps (RCPs), eight steam generators (SGs), and a pressurizer in a single leak-tight reactor pressure vessel as shown in Fig. 1. Due to these design characteristics, the SMART can fundamentally eliminate the possibility of large break loss of coolant accidents (LBLOCAs) [1].

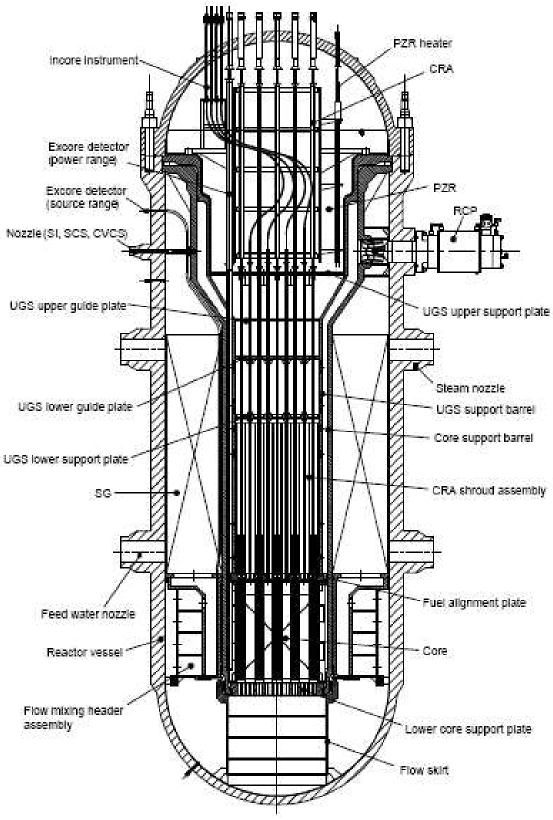

Fig. 1. Reactor coolant system (RCS) of the SMART.

The thermal hydraulic analysis of the increased heat removal transients by the secondary system which are expected to occur with moderate frequency is performed in the SMART. And the results of the transient analysis are reviewed to ensure that the values of relevant system parameters are satisfied with the acceptance criteria.

2. Methods and Results

2.1 Identification of Event and Causes

A number of transients can result in an unplanned increase in heat removal by the secondary system in the SMART. Those expected to occur with moderate frequency can be caused by the decrease in feedwater temperature, the increase in feedwater flow, the increase in main steam flow, the malfunction of passive residual heat removal system (PRHRS) and the inadvertent opening of a PRHRS safety relief valve (SRV) [2].

A heat removal rate by the secondary system in excess of the heat generation rate in the core causes a decrease in moderator temperature which inserts a positive reactivity and can lead to a core power increase and a decrease in shutdown margin. The core power increase will lead to a reactor trip.

2.2 Acceptance Criteria and Analysis Methods

In case of moderate frequency transients, the minimum departure from nucleate boiling ratio (MDNBR) should not exceed the specified acceptable fuel design limit (SAFDL) on MDNBR of 1.10 to maintain fuel cladding integrity. Pressure in the RCS and secondary system should be less than 110% of design pressure [3]. A thermal hydraulic analysis of the SMART has been performed using the TASS/SMR-S code [4]. Fig. 2 shows the TASS/SMR-S nodalization of the SMART.

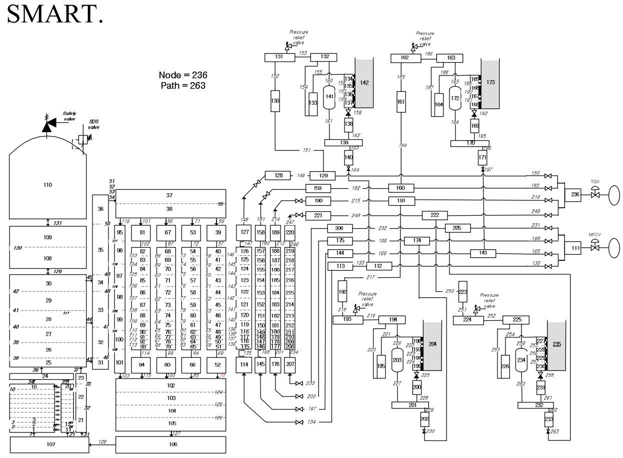

Fig. 2. TASS/SMR-S nodalization for the SMART.

Conservative initial/boundary conditions and assumptions are used to calculate the transient behavior. Limiting initial conditions are determined through the sensitivity study for the combination with thermal hydraulic parameters such as core power, temperature, pressure, flow rate and water level. Table I shows the major initial and boundary conditions for the calculation.

Table I: Initial conditions and assumptions for the increase in heat removal by the secondary system.

Parameter	value
Core power level, MWt	339.9(103%)
Core outlet coolant temperature, ℃	325.13
Pressurizer pressure, MPa	15.55
RCS mass flow rate, kg/s	2403.5
Shutdown rod worth, %△ρ	-8.5
Fuel temperature reactivity	Most negative
Moderator temperature reactivity	Most negative
Decay heat curve	ANS-73

The failure of one PRHRS train is considered as a single failure assumption. And it is also conservatively assumed that the most reactivity rod is stuck out and a loss of offsite power (LOOP) occurs immediately upon reactor trip.

2.3 Analysis Results

The inadvertent opening of a PRHRS SRV with the malfunction of feedwater control system (FWCS) was found to the most limiting transient in regard to core thermal margin and the pressure of the RCS and secondary system. So the transient behavior of this event is described mainly in this paper.

The inadvertent opening of a PRHRS SRV with the malfunction of FWCS causes an increase of the heat transfer from the RCS to the secondary system through the steam generator. Due to the negative moderator temperature coefficient, core power increases from the initial value of 103%. At 68.78s the high reactor power trip setpoint of 115% power is reached as shown in Fig. 3. The RCPs begin to coast down and the main steam and feedwater isolation valves are closed. The PRHRS is connected to the steam and feedwater line pipes and removes the residual heat generated in the core by the natural convection.

In Fig. 4, the DNBR decreases slowly with an increase in core power at the beginning of the transient, and reaches a minimum value of 1.14 at 74.35s when the core power rapidly decreases. This value is above the MDNBR limit of 1.10.

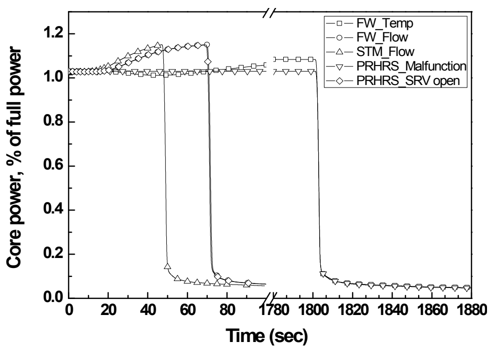

Fig. 3. Core power for the increased heat removal transients by the secondary system.

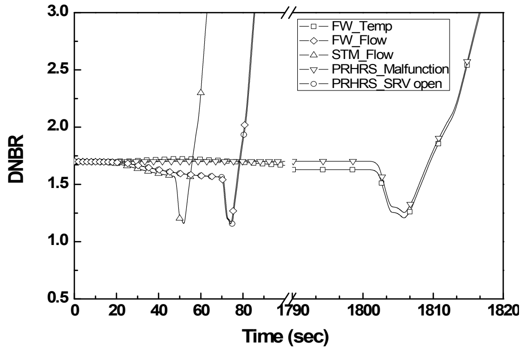

Fig. 4. DNBR for the increased heat removal transients by the secondary system.

After the PRHRS is connected to the feedwater and steam line pipes, the secondary system pressure increases for a period until the natural convection flow is well established as shown in Fig 5.

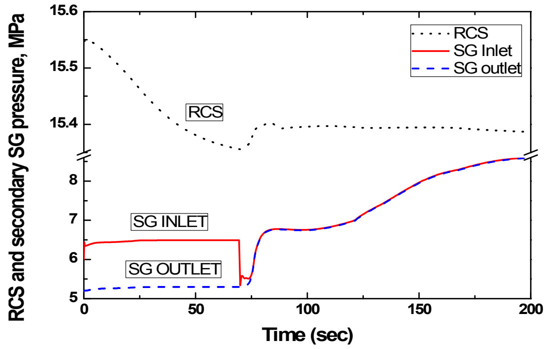

Fig. 5. RCS and Secondary SG pressure for the inadvertent opening of a PRHRS SRV with the malfunction of FWCS.

3. Conclusions

Thermal hydraulic analysis of the SMART for the increased heat removal transients by the secondary system expected to occur with moderate frequency is performed using the TASS/SMR-S code. As a result of calculation, all increased heat removal transients are bounded by the inadvertent opening event of a PRHRS SRV with the malfunction of FWCS. And all increased heat removal transients by the secondary system for the SMART result in the MDNBR greater than 1.10 throughout the transient. Also the system pressure remains well below 110% of the design pressure.

REFERENCES

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