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# Supporting Thermal Hydraulic Calculations for the SGTR Event Tree of SMART Level 1 PSA

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## 1. Introduction

SMART (**S**ystem integrated **M**odular **A**dvanced **R**eac**T**or) , is under development at the Korea Atomic Energy Research Institute (KAERI). SMART is an integral type pressurized water reactor which contains a pressurizer, 4 reactor coolant pumps (RCPs), and 8 steam generator cassettes(S/Gs) in a single reactor vessel [1]. This reactor has substantially enhanced its safety with an integral layout of its major components, 4 trains of safety injection system (SIS), and an adoption of 4 trains of passive residual heat removal system (PRHRS) instead of an active auxiliary feedwater system .

The thermal power is 330 MWth. During the conceptual design stage, a preliminary PSA was performed. PSA results identified that a steam generator tube rupture (SGTR) is one of the most important initiating events which results in a high core damage frequency [2]. Clear understanding of accident progression with various combinations of the safety systems helps to develop an event tree of SGTR accident in the Level 1 PSA. MIDAS/SMR computer code is used to simulate the severe accident progression initiated from a SGTR in SMART reactor. This code has the capability to model a helical steam generator which is the type adopted in the SMART reactor [3].

## 2. MIDAS/SMR Input Model

Figure 1 shows the nodalization for the SMART reactor in this analysis [4]. The primary side nodes consist of two lower plenums, a core and a core bypass, two upper plenums, a pressurizer, an RCP suction and discharge, S/Gs and bypasses, and a flow mixing head assembly. 8 S/Gs are modeled into four groups. Each group has 2 S/Gs. Every group is divided into 12 nodes including 10 active helical tube nodes. 4 RCPs are integrated into one RCP by increasing the flow rate. The secondary side nodes consist of secondary of S/Gs and 4 trains of PRHRS.

## 3. Simulation of a SGTR

A break is assumed to occur at just above tubesheet of S/G-1. The inner diameter of tube is 12 mm. So the break area is 1.131 x $10^{-4}$ $m^2$. Plant response depends on the status of the fault steam generator.

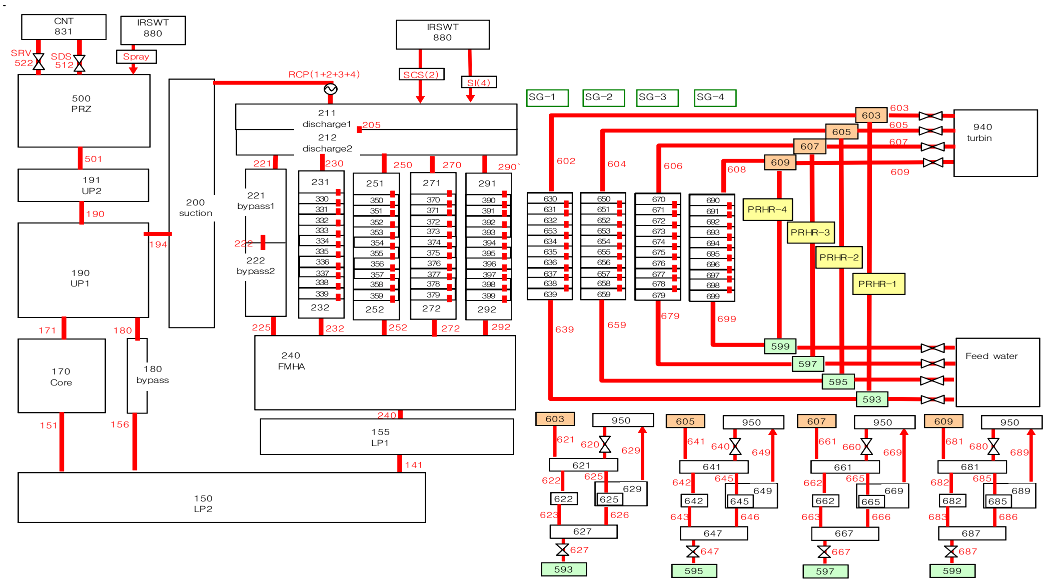


Figure 1 MIDAS/SMR nodalization for SMART reactor

### *3.1 Isolated Fault Steam Generator*

The design pressure of PRHRS is same as RCS pressure vessel which is 17 MPa. So the plant response to the SGTR accident is same as a general transient except small coolant leakage to the PRHRS. When the PRHRS is not available, the primary coolant flows out through the pressurizer safety valve (PSV). For this case an operator opens the SDS valve after the first opening of PSV in order to establish the feed and bleed operation. The RCS pressure behavior and the peak cladding temperature are presented in Fig. 1 both with and without the SDS valve open when the PRHRS is not available. The RCS pressure decreases rapidly below the SIS operation pressure after the SDS valve open. The RCS pressure becomes below the SCS pump shutoff head a long time before the core experiences damages. If the peak cladding temperature exceeds 1255 K (1800 $^{o}$F), it is assumed that the core is damaged. So the operator may inject the water into the RCS using the SCS pump from the in-containment refueling water storage (IRWST) when the SIS is not available. Table 1 summarized the important event and its timing when PRHRS is not available.

Table 1. The important event and its timing when PRHRS is not available.

| | No SDS | SDS-1[*1] | SDS-2[*1] | SDS-3[*1] | SDS-5[*1] |
|---|---|---|---|---|---|
| SGTR | 200 | 200 | 200 | 200 | 200 |
| Rx trip | 2897 | 2897 | 2897 | 2897 | 2897 |
| PRHRS | - | - | - | - | - |
| PSV open | 13,467 | 13,467 | 13,467 | 13,467 | 13,467 |
| SDS open | - | 17,067 | 20,667 | 24,267 | 31,365 |
| PZR P 10 MPa | - | 18,566 | 21,843 | 25,500 | 32,477 |
| PZR P 2.8MPa | - | 24,811 | 27,704 | 30,935 | 37,054 |
| Clad T 1255 K | 60,571 | 33,716 | 33,847 | 35,310 | 39,005 |
| End | 80,000 | 80,000 | 80,000 | 80,000 | 80,000 |

Note 1: number after dash mean the SDS valve open time after a SI signal generated.

### *3.2 Not Isolated Fault Steam Generator*

When the fault SG is not isolated, i.e., the MSIV in the faulted steam line is not closed, the coolant may flow out from RCS to the turbine or the condenser through the turbine bypass valve until the MSIV is closed. When the PRHRS is available, the SIS injects the water from IRWST to the core. If the MSIV is not closed, the core coolant inventory eventually becomes empty after the IRWST water is deleted. The operator may refill the IRWST to prevent the IRWST deletion.

## 4. Summary and Future Work

The SGTR accident for SMART was analyzed using MIDAS/SMR code. The plant responses are quite different from OPR-1000 because the design pressure of the PRHRS is same as the primary system. When the faulted SG is isolated, the system response for SGTR is same as the general transient event. If the faulted SG is not isolated, the primary coolant flows out to the turbine or the condenser and the core damage occurs after the IRWST is deleted. For this case the intentional depressurization of the RCS is not analyzed. The RCS depressurization may terminate the coolant flow out through the broken SG tube. The plant response with the intentional RCS depressurization by opening the SDS valve will be analyzed in the future.

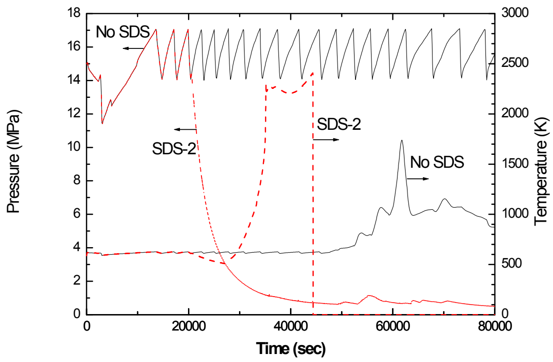


Fig. 1. The pressure and temperature behavior with and without SDS when the PRHRS is not available.

## REFERENCES

[1] SMART Reactor System Description, KAERI, 2010
[2] Preliminary PSA Report for Internal Events in SMART, KAERI, 2010
[3] Evaluation of MIDAS/SMR model for SMART, KAERI, 2009
[4] Calculation sheet of MIDAS/SMR code for the simulation of severe accident in SMART reactor, KAERI, 2010