Severe Accident Analyses for SMART using MELCOR 1.8.6 code

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1. Introduction

The SMART (System-integrated Modular Advanced ReacTor) has a unique design concept such as the integrated reactor vessel assembly system and the passive residual heat removal system.[1] The severe accident evaluation in the regulatory side is needed to prepare the safety review and the licensing for the SMART in the nuclear regulatory agency. Moreover, the reliable evaluation of severe accident for the SMART is very important for ensuring public acceptance of the SMART. The public acceptance can be a critical factor for the SMART, because it can be used for various purposes such as a desalination system, district heating, and power source of a ship. In this paper, the MELCOR 1.8.6 model for SMART severe accident analysis was developed and the severe accident analyses were performed

2. Method and Results

2.1 Severe Accident Analysis Model for SMART

As shown in Figure 1, SMART is the small and medium power reactor that the core, reactor coolant pump (RCP), steam generator (SG), and pressurizer (PRZ) are designed in a reactor vessel assembly (RVA). Considering these systems and the characteristics, the MELCOR1.8.6 model for SMART was developed for the severe accident analysis. The SMART primary side consists of the reactor core, RCP, SG, PRZ, flow mixing header assembly, and lower plenum. The volumes of the reactor core and the lower plenum were modeled with the cells of 14 axial, 7 radial rings. The 4 RCPs were simulated as one with respect to the total capacity. The PRZ control volume is located in upper plenum of RVA. As a method of the pressure control of PRZ, the plus enthalpy is supplied to water in high water level and minus enthalpy in low water level. In the secondary side, 4 SG cassette channels which are connected with PRHRS were modeled to remove thermal energy from the reactor coolant.

2.2 Severe Accident Sequence and Calculation Results

Using the MELCOR 1.8.6 model, severe accident analyses were performed for 6 basic sequences such as the Small break Loss of Coolant Accident (SLOCA), Steam Generator Tube Rupture (SGTR), Loss of FeedWater (LOFW), GeNeral TRansient (GNTR),

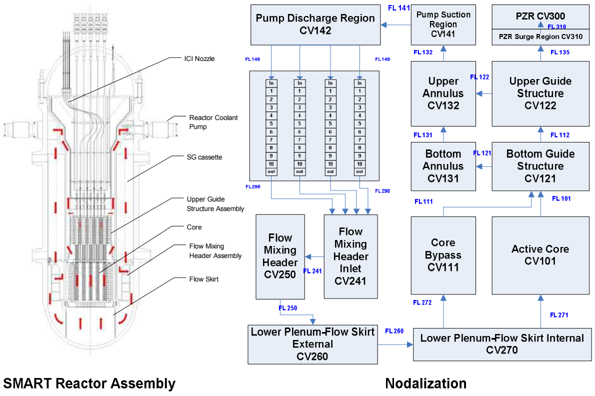

Fig. 1. SMART reactor assembly and nodalization of MELCOR1.8.6 model

Large Secondary Side Break MSIV Downstream (LSSB), Station BlackOut (SBO) which were determined by PSA results in SMART SSAR[1]. Table 1 shows the major event occurrence timing for accident sequences. These accident sequences in the table can be divided as the high and low pressure sequence. The SLOCA sequence is the low pressure sequence and the others are the high pressure sequence. Comparing the core uncover start time and RVA creep rupture time of each sequence, the accident progress of SLOCA sequence is faster than the sequences of the SGTR, LOFW, GNTR, LSSB and SBO. The sequences excepting SLOCA show the similar accident progress.

Figure 2 and 3 present the PRZ pressure and containment pressure with the sequence. From comparing the RVA creep rupture time in Table 1 with the Figure 2, 3, it can be found that the rapid decrease of PRZ pressure and considerable increases of the containment pressure are due to the RVA creep rupture. This indicates that the containment pressure is increased or decreased by the PRZ pressure because the hydrodynamic material with high temperature and pressure in RCS is released into the containment through the path of RVA creep rupture.

Figure 4 shows the containment pressures according to the working or not-working of CFS, FAR, and CSS. In the case of CFS working, the RVA creep rupture does not occur and CSS is not active. In the Figure 4, in case of CSS working, it was found that the containment pressure is considerably decreased although the RVA creep rupture occurs.

Figure 5 show the H_2 mole fraction with or without CFS, PAR, and CSS under SLOCA sequence. In this Figure, In the case of PAR working, H_2 mole fraction is

Table 1: Major Event Timing of Each Sequence

Event	SLOCA	SGTR	LOFW	GNTR	LSSB	SBO
Accident initiation	0	0	0	0	0	0
Reactor trip	35.5	2740	16.4	0	0.2	0
RCP trip	230	17313	7695	9018	9149	0
Core uncover start	7400	49100	41200	43600	44000	43200
Core dryout	24950	73900	60600	63000	63000	63800
RVA dryout	116900	116000	106300	108700	109100	109100
RVA creep rupture	117372	167062	156748	159187	159296	159996

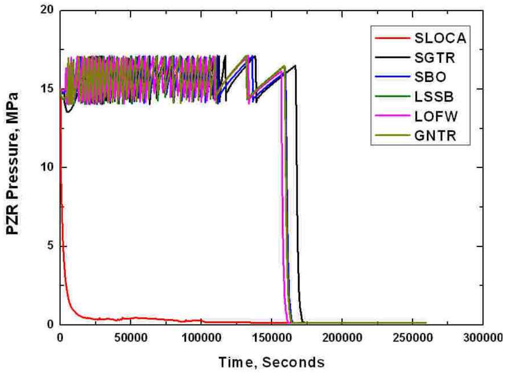

Fig 2. PRZ pressure of basic accident sequences

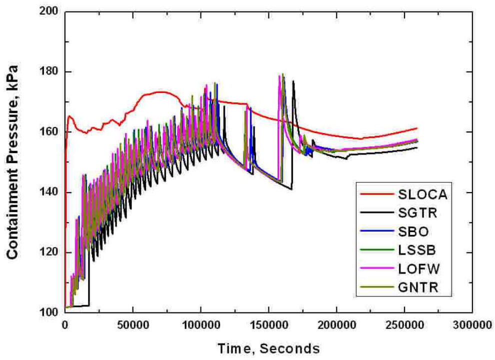

Fig 3. Containment pressure of basic accident sequences

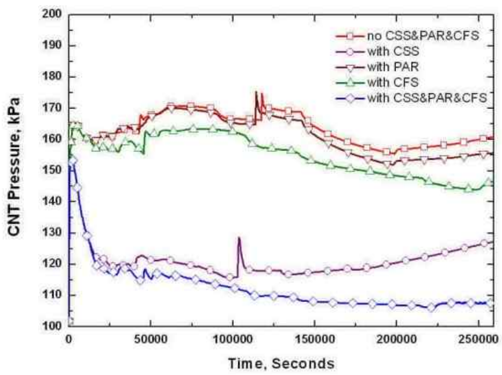

Fig 4. Containment pressure with or without CFS, PAR, and CSS under SLOCA sequence

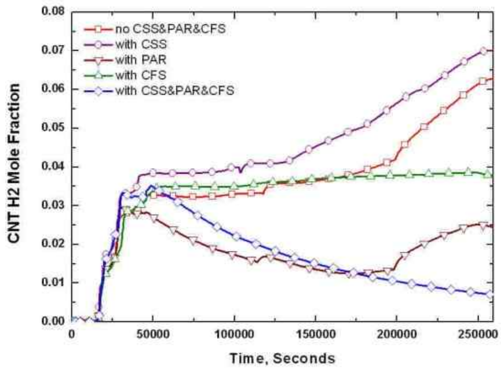

Fig 5. Containment H_2 mole fraction with or without CFS, PAR, and CSS under SLOCA sequence

maintained below 0.03. Also the H_2 mole fraction in case of CSS working is higher than the others. This phenomenon is due to the steam condensation in the containment.

3. Conclusion

In this study, the severe accident analysis model was developed for SMART and calculations were performed for several accident sequences to define the thermal hydraulic phenomena and functions of containment mitigation system such as CSS, PAR, and CFS. These analysis results using the severe accident analysis model can be used to offer regulatory insights for the safety review and licensing process in a timely manner.

REFERENCE

[1] SMART Standard Safety Analysis Report, Korea Atomic Energy Research Institute, 2011.

[2] Cho, D.K., 2005, Comparison of Source Term from ORIGEN2 and ORIGEN-ARP for Spent Nuclear Fuel Management, KAERI/TR-3078, Korea Atomic Energy Research Institute.