Development of the Preliminary MELCOR1.8.6 Model for the SMART Severe Accident Analysis

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1. Introduction

SMART (SMAll and medium integral ReacTor) has a unique design concept adopting the integrated reactor system and the passive residual heat removal system. The severe accident analysis for SMART is needed to prepare the safety review and the licensing. For the safety review of the SMART design, identifying the safety issues in the early design stage is necessary to prevent the unexpected cost increase and the delay of the licensing schedule.

In this study, the MELCOR1.8.6 [1] model which is able to simulate the SMART design characteristics was developed to evaluate the severe accident for SMART. In addition, severe accident scenarios of SMART were selected based on preliminary PSA results of SMART-330.

2. Methods and Results

2.1 Design Characteristics of SMART

As shown in Fig. 1 [2], SMART is being designed as integral type, i.e. the reactor core, the steam generator (SG), the pressurizer, and the reactor coolant pump (RCP) are assembled in a reactor vessel. Therefore, the large break loss of coolant accident is intrinsically prevented because the pipe connecting reactor core and RCP does not exist. Also, SMART is expected to be featured with the passive safety system such as passive residual heat removal system to enhance the safety margin. The followings indicate the major design characteristics of SMART.

▪ Reactor Coolant System (RCS)

The RCS has a role to deliver the fission energy to the secondary system by the reactor coolant. To improve the heat transfer efficiency at the Steam Generator (SG), the SG tubes are being designed as a helical type. On the contrary to the general PWR, the reactor coolant passes outside of the SG helical tube wall.

▪ Passive Residual Heat Removal System (PRHRS)

The PRHRS removes residual heat of the reactor core passively using natural circulation flow phenomenon induced by density difference between the SG and the heat exchanger.

▪ Safety injection system (SIS)

By designing the refueling water storage tank in the containment, the recirculation mode which operates by the switch of the suction pipe for the coolant supply is not needed.

▪ Shutdown Cooling System (SCS) & Chemical and Volume Control System (CVCS)

The main design features for these systems are similar to that of the conventional PWR.

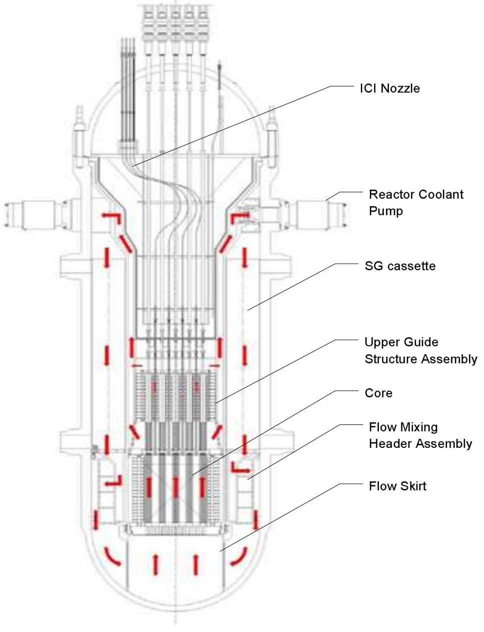

Fig. 1. Flow path of the SMART reactor vessel assembly.

2.2 Preliminary MELCOR1.8.6 Model for SMART

At present, the basic design of SMART had been completed, and the detailed design of SMART is ongoing. Based on the basic design [3], the MELCOR1.8.6 model for SMART severe accident analysis was developed as shown in Fig. 2 by subdividing the primary system as the reactor core, the guide structure, the pump suction and the discharge region, the SG cassette, the mixing header, the mixing header inlet, and the lower plenum.

According to the heat transfer from the reactor core to the reactor coolant, the control volume of the reactor core can be divided into the active core region and the core bypass region. The guide structure located above the reactor core is surrounded by the core support barrel assembly, and many holes are designed at the annular wall of the guide structure for the reactor coolant flow. According to the flow area of the holes, the guide structure control volume is divided into the upper and bottom regions. Also the annulus control volume contacting with the guide structure divided into upper and bottom regions. The reactor coolant from the reactor core passes through the guide structure, and moves to the RCP region. As the RCP provides the pressure head, the control volumes of the pump suction region and pump discharge region were modeled. While the reactor coolant passes in SG cassette, the coolant temperature drops by the heat transfer to the secondary coolant which flows into helical tubes. To simulate this temperature drop, the SG cassette was divided as 5 regions vertically. The reactor coolant moves from the SG cassette to the flow mixing header, and then flows into the lower plenum. The control volumes of the mixing header inlet, the mixing header, and the lower plenum were modeled.

The MELCOR1.8.6 is not able to simulate the heat transfer effect of helical tubes. However, it was found that the helical tube effect can be modeled by considering the characteristics of the helical tube heat transfer or heat transfer area geometry.

2.3 Severe Accident Scenarios of SMART

Generally, the severe accident scenario is determined by the level 2 Probabilistic Safety Assessment (PSA) results. To select the severe accident scenario for SMART, the preliminary Level 1 PSA results of SMART-330 [4] which was performed previously were used because there is no Level 2 PSA results for SMART currently. The severe accident scenarios were determined by cumulative contribution of the core damage frequency of level 1 PSA results. In results, total 7 severe accident scenarios, which are the SLOCA-16, CBW-2, GTRN-5, LOFW-4, REA-6, ATWS-3, and SGTR-4 shown in Table I, were selected. These accident scenarios cover 93.4% of the cumulative CDF contribution.

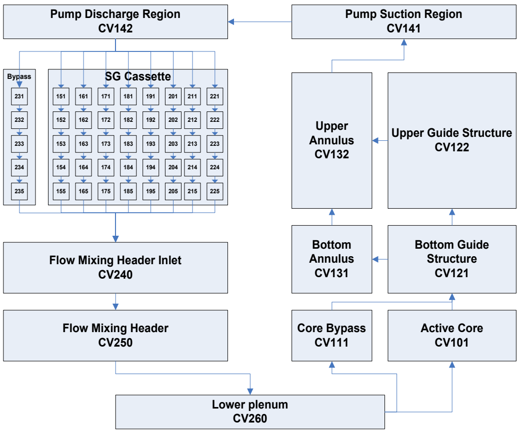

Fig. 2. Nodalization of the SMART reactor vessel assembly.

3. Conclusions

To evaluate the severe accident for SMART, a preliminary MELCOR analysis model was developed and severe accident scenarios were selected. Based on the developed preliminary MELCOR model, a detailed MELCOR model can be developed. And using this detailed model, severe accident analyses for SMART according to each accident scenario can be performed to assess the SMART design integrity and suitability.

REFERENCES

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Table I: Selected Severe Accident Scenarios for SMART

No.	Accident Scenario	Description	CDF (/yr)	Fraction (%)	Cumulative Contribution (%)
1	SLOCA-16	Failure of Makeup and Feed & Bleed after Small LOCA	4.50E-07	52.8	52.98
2	CBW-2	Reactor Shutdown Fails after withdrawal of CEA bank	1.17E-07	13.66	66.64
3	GTRN-5	Secondary Cooling using PRHRS and Feed water fails after General Transient	1.03E-07	12.01	78.65
4	LOFT-4	Secondary Cooling using PRHRS and Feed water system fails after Loss of Main Feed Water	4.59E-08	5.36	84.01
5	REA-6	Makeup and Primary Feed & Bleed fail after LOCA due to Rod Ejection	3.03E-08	3.53	87.54
6	ATWS-3	Emergency Boration fails after Reactor shutdown failure due to CEA malfunction	2.73E-08	3.19	90.73
7	SGTR-4	Secondary Cooling using CCW and Feed water fails after SGTR and PRHRS fail	2.28E-08	2.67	93.4