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MELCOR Simulation of Postulated Severe Accidents in OPR1000

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1. Introduction

Since the Fukushima accident in 2011, severe accidents of a nuclear power plant have been a target of big debate whether the defense-in-depth philosophy applied to current nuclear system is still vigorous enough to ensure the protection of the operators and the public. Thus an accurate prediction of severe accident has become a critical task for the nuclear engineers with reliable employment of Probabilistic Risk Analysis (PRA). According to a recent PRA result, Small Break Loss Of Coolant Accident (SBLOCA) without safety injection and Station Black Out (SBO) show high probability of proceeding to severe accidents [1]. Thus, these accident scenarios need to be evaluated properly with reliable prediction tools. Song and Ahn analyzed SBO sequences in KSNP using MELCOR 1.8.5 [2]. Park and Song examined SBLOCA scenarios based on the PSA of KNSP using MAAP 4.06 [3]. Their studies utilized severe accident database. In continuation of the further analysis, several scenarios of postulated SBO and SBLOCA in OPR1000 are investigated using the severe accident database and MELCOR 1.8.6.

2. MELCOR Modeling and Accident Scenarios

2.1 MELCOR Modeling

MELCOR nodalization for OPR1000 is shown in Fig. 1. The primary system consists of core, 4 cold legs, 2 hot legs, pressurizer, and safety injection systems such as High Pressure Safety Injection (HPSI), Low Pressure Safety Injection (LPSI), and Safety Injection Tank (SIT).

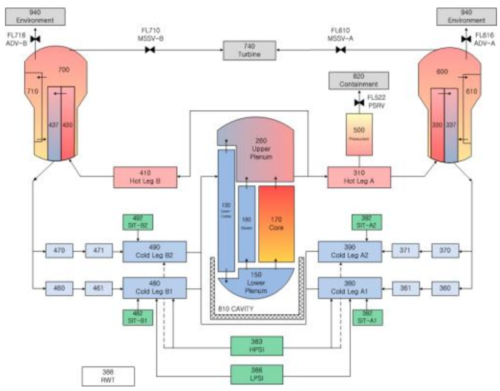

Fig. 1. MELCOR Nodalization of OPR1000

The secondary system was somewhat simplified. However, key components of safety systems such as AFW (Auxiliary Feed Water), ADV (Atmospheric Dumping Valve), and MSSV (Main Steam Safety Valve) were modeled. SIT and MSSV are operated under constant pressure due to passive device while other components were controlled with fixed actuation time. The accident was initiated at 0 sec and calculation times of SBO and SBLOCA were about 100,000 sec and 250,000 sec, respectively.

2.2 SBO Scenarios

Three cases of SBO scenarios were selected in this study and respective description is shown in Table 1. The case 1 considers heat removal through ADV and AFW of loop A. Ten minutes were setup for time opening ADV open and injecting AFW. These components continued for 4 hours. AC power was recovered before RPV failure and since then HPSI was activated. Case 2 was similar to Case 1 except that the ADV was not activated. Case 3 is the most severe scenario hypothesizing that any safety system was not operable.

Table 1. Description of SBO simulation cases

Case	2nd. Heat Removal	AC Recovery	HPSI
1	ADV, AFW	before RPV failure	On / REC
2	MSSV, AFW	before RPV failure	On / REC
3	MSSV	N/A	N/A

2.3 SBLOCA Scenarios

Table 2 summarizes the SBLOCA simulation cases. A small 1 inch break was assumed to occur in cold leg of loop A. In Case 4, times opening ADV and AFW of Loop B were setup at 10 sec and 15 sec, respectively. HPSI was actuated without recirculation. On the other hand, in Case 5, ADV opening was not modeled and recirculation with HPSI injection was modeled. Case 6 simulates no safety injection but only MSSV opening was simulated.

Table 2. Description of SBLOCA simulation cases

Case	Break Size	2nd. Heat Removal	HPSI	LPSI
4		ADV, MSSV, AFW	On	N/A
5	1"	MSSV, AFW	On / Rec	N/A
6		MSSV	N/A	N/A

3. Results

SBO and SBLOCA simulation results are summarized in Table 3 in terms of time of core uncover, core dryout, clad melting, fuel melting, fuel relocation, and RPV failure. Observing SBO simulation results, Case 1 shows behavior delaying the accidents sequences by far the most. However, RPV failure occurred after 64,800 sec since accident initiation regardless of the actuation of safety injection systems. By contrast, Case 3 simulation result shows the earliest core damage, in which core dryout occurs around 6,562s and time of RPV failure is 15,440s. Figs. 2 and 3 show water level in core and UO_2 mass in vessel of three cases simulated, respectively.

In case of SBLOCA simulation, change of core water level and UO_2 mass in vessel are shown in Figs. 4 and 5, respectively. In Case 5, the management of severe accidents management seems successful. However, Cases 4 and 6 undergo fuel melting and vessel failure. In Case 4, although HPSI, ADV and AFW were actuated, a failure of HPSI recirculation leads to core meltdown. SBLOCA scenario without safety injection was calculated as early core meltdown around 16,150 s in case 6.

Table 3. Summary of SBO and SBLOCA simulation results

	Case1	Case2	Case3	Case4	Case5	Case6
Core uncovery	47,500s	32,900s	6,562s	117,178s	N/A	5,185s
Core dryout	50,570s	36,454s	8,516s	157,959s	N/A	8,596s
Clad melt	52,446s	37,259s	9,266s	153,123s	N/A	8,875s
Fuel melt	52,504s	37,320s	9,321s	153,563s	N/A	8,927s
Fuel relocation	52,518s	37,332s	9,352s	158,780s	N/A	8,944s
RPV failure	64,800s	46,240s	15,440s	175,300s	N/A	16,150s

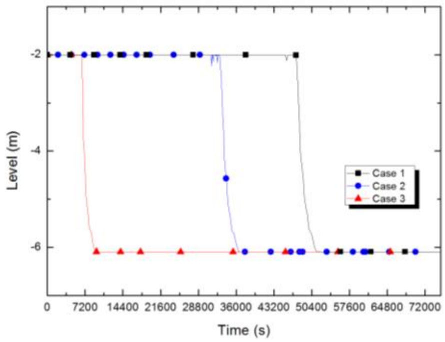

Fig. 2 Core Water Level of SBO

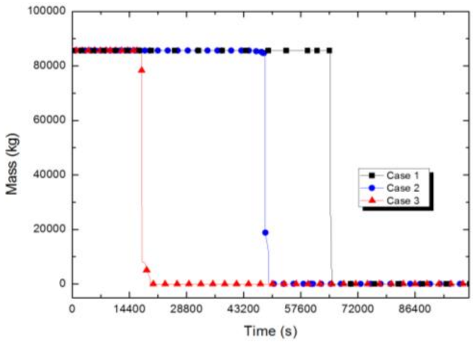

Fig. 3 UO_2 Mass in Vessel of SBO

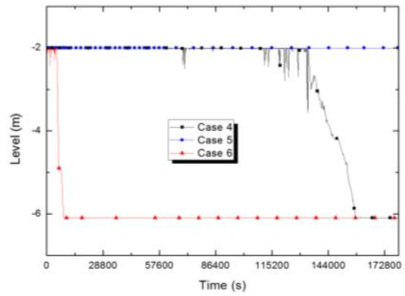

Fig. 4 Core Water Level of SBLOCA

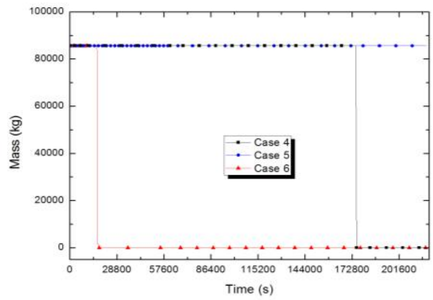

Fig. 5 UO_2 Mass in Vessel of SBLOCA

4. Conclusions

MELCOR simulations were performed for several postulated severe accidents scenarios. It is observed that safety systems utilizing ADV and HPSI with recirculation are key factors for severe accidents management. However, sensitivity on the actuation timing of the safety systems, break size and positions needs to be investigated.

Acknowledgement

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