Analysis of SAMG entry condition considering operator action time in NPPs

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1. Introduction

The current severe accident prevention and mitigation strategies for Korean NPPs have emergency operating procedures (EOPs) and severe accident management guidelines (SAMGs), respectively. EOPs are critical for ensuring reactor safety and preventing severe accidents during design basis accidents (DBAs) in NPPs. If the accident conditions become more severe than the DBA, EOPs may end. Such an event is called beyond DBA or severe accident. Therefore, SAMGs have been developed to mitigate severe accident phenomena, and prevent radioactive material releases [1]. When the SAMGs are entered, the EOPs are finished. The criteria of changing from the EOPs to the SAMGs is an entry condition of the SAMGs. Therefore, the entry condition is very important for the operator action to have sufficient time to mitigate the severe accident. However, a core exit temperature (CET) of 650℃, constitutes automatic SAMG entry condition [2]. In other words, other variables are not considered for determining SAMG entry conditions. Also, the fixed SAMG entry condition for every kind of accident scenarios is not reasonable, since current entry condition is determined without considering operator action time. Therefore, SAMG entry condition need to be verified to consider operator action time.

To analyze the SAMG entry condition, this study analyzed the level 1 and 2 PSA reports for OPR 1000 [3]. For the result analysis, four dominant accident events were selected: SBLOCA, MBLOCA, LBLOCA, and SBO.

2. Analysis of SAMG entry condition

2.1 Description

To analyze the SAMG entry condition, an analysis methodology for entry condition was developed. The required steps to develop the analysis methodology are as follows: selectin of reference plant, selection of initiating event, development of severe accident data base (DB) using a simulation tool, analysis of developed severe accident DB and suggest proper SAMG entry condition considering operator action time, and verification and validation. In this paper, OPR 1000 is selected as the reference plant. This plant is a South Korean two-loop 1000MWe PWR, developed as the first Korean Standard NPP. A total of 12 units are in operation in South Korea. To select the initiating events, level 1 and 2 PSA reports for OPR 1000 are analyzed. Based on level 1 and 2 PSA reports, four dominant initiating events: SBLOCAs, MBLOCAs, LBLOCAs, and SBO are selected. Since there is little data for nuclear accident, the data were obtained by simulating selected scenarios from the simulation code. Through the review result for reliable severe accident code, since current SAMG and PSA reports have been developed based on MAAP code for OPR 1000, MAAP code was selected. This code is a computer code developed by EPRI that simulates the response of a PWR during severe accidents in NPPs. Also, MAAP5 treats the full spectrum of important phenomena that could occur during an accident, simultaneously modeling those that relate to thermal-hydraulic and fission products.

2.2 Analysis results of severe accident DB

The developed severe accident DB are analyzed to compare the required action time which is from SAMG entrance to SI operation and available time for operator action from SAMG entrance to RV failure. Table I shows time of significant events and comparison of required action time and available operator action time for SBLOCA #1. In sequence SBLOCA #1, the available is enough by comparison with minimum required action time. However, the available operator action time is not enough by comparison with maximum required action time except for break size of within 0.001 ft^2 as given in Table I. The all selected scenarios showed similar trends and were omitted from this paper to save space.

Table I: Available operator action time to RV failure during SI operation mode (SBLOCA #1)

Significant events (sec)	Break size (ft^2)			
	0.001	0.01	0.015	0.02
Reaching time to CET 650	225,197	60,843	42,281	32,998
Time of H2 generation in core	220,152	59,752	41,637	32,446
Molten fuel relocation time	239,444	68,593	48,557	38,948
RV failure time	253,905	76,094	55,241	45,567
Required action time to SI	Max: 16,840 sec, Min: 8,810 sec			

Available time for operator action from SAMG entrance to RV failure	28,708	15,251	12,960	12,569

3. Results

In order to suggest a new SAMG entry condition, the measured variables which are closely related to core damage were acquired. The major measured variables are as follows: H2 generation amount in core, mass of water and temperature in core, pressure, temperature, and water level in PRZ, temperature and pressure in RCS, temperature and pressure in containment, and SG water level and pressure. Based on the comparison between measured variables and core damage, mass of water in core was selected as variables which indicate core damage precisely. With the simulation results, the proper SAMG entry condition for SBLOCA #1 are as follows: failure of all system which are to mitigate core damage, CET over 430℃, and decrement of water level in core below the initial value. Fig. 1 shows the mass of water in core and CET calculation for SBLOCA #1. When the SAMG entry condition is changed from 650℃ to suggested condition the available action time is increased about 800 sec as given in Fig. 1.

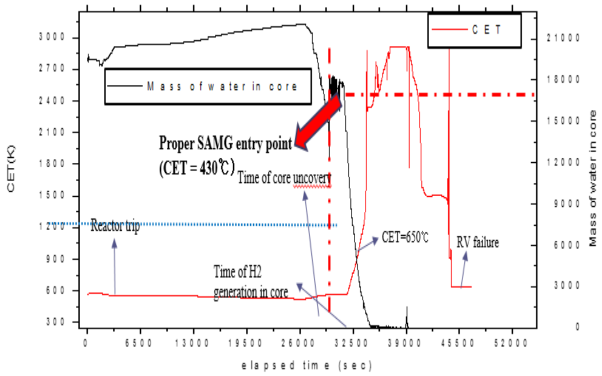

Fig. 1. Mass of water in core and CET calculation for SBLOCA #1

To verity the suggested SAMG entry condition, considered severe accident sequences were simulated considering operator action time and reflecting the suggested SAMG entry condition. Fig. 2 shows the simulation result for SBLOCA # 1. As a result, if the SI recirculation operation succeed, RV failure can be prevented. Table Ⅱ shows time of significant events related to failure in SI recirculation operation for SBLOCA # 1. Although failure of the recirculation operation may cause RV failure, it can be confirmed that the operator action time is increased.

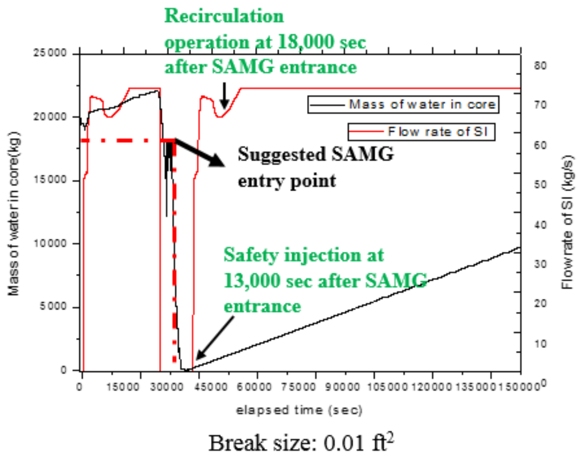

Fig. 2. In case of success of SI recirculation operation for SBLOCA #1

Table Ⅱ: Failure of recirculation operation for SBLOCA #1

Significant events (sec)	Break size (ft^2)			
	0.001	0.01	0.015	0.02
Core uncover time (sec)	213,879	57,740	40,758	31,670
Time of H2 generation in core (sec)	217,417	60,145	41,784	35,451
Molten fuel relocation time (sec)	245,517	100,412	98,738	96,568
RV failure time (sec)	259,200	110,741	100,415	99,671

4. Conclusions

Severe accident mitigation strategies are widely divided into EOP and SAMG. The objectives of these mitigation strategies are different. The main objective of the SAMG is to prevent a release of radioactive material into the environment during severe accident. However, current SAMG entry conditions have some problems. Since SAMG entry condition is only depending on CET 650, SAMGs are not reliable. Additionally, available operator action time from the time of entrance to the time of RV failure is insufficient, and operator's performance is not considered. Therefore, current SAMG entry condition should be improve.

In this paper, the SAMG entry condition analysis methodology is developed considering operator action time. Based on simulation results, the available action time from the time of SAMG entrance to the time of RV failure is not enough. Therefore, a new entry condition are suggested to consider the operator action time. When the SAMG entry condition is changed from CET 650℃ to the suggested variables, the available action time is increased from about 350 to 4300 seconds. Also, the developed methodology was verified through the simulation which is considering operation action time and reflecting the suggested entry condition. Through the simulation result, the suggested variables are a suitably effective transition point for revision of the current SAMG entry conditions.

REFERENCES

[1] R.J. Park and S.W Hong, "Effect of SAMG entry condition on operator action time for severe accident mitigation," Nuclear Engineering and Design (NED), 241, pp.1807-1812 2011.

[2] Ha JJ, Jin YH., "Development of accident management guidance for Korean standard nuclear power plant," (Report no. KAERI/RR-1939), Korea Atomic Energy Research Institute, Daejeon &South Korea 1998.

[3] KEPCO, "Ulchin Units 3, 4 Final Probabilistic Safety Assessment Report," Korea Electric Power Corporation, Daejeon &South Korea 1999.