Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Verification of SAMG entry condition for APR1400

*Junghyun Yun, Taewan Kim, Jonghyun Kim,
KEPCO International Nuclear Graduate School, 1456-1 Shinam-Ri, Seosaeng-Mueon, Ulju-Gun,Ulsan
**Corresponding author: juhyun95@gmail.com*

1. Introduction

In the wake of the Fukushima accident, severe accident management has become important more than ever. While Emergency Operating Procedures (EOPs) focuses on cooling down the core during a design basis accident, the prime objective of severe accident management guideline (SAMG) is to prevent the release of radioactive material into the environment during a severe accident [1].

Only one fixed value of core exit temperature (CET) has been applied for several decades to different types of nuclear power plants (NPPs) in Korea. Although the different types of NPPs have different cladding materials and system designs, the identical CET, i.e., 650℃, is applied as the entry condition to the SAMG of all the NPPs (except CANDU plants), i.e., Westinghouse type, OPR1000, and APR1400.

In this paper, the transition point is re-evaluated for dominant severe accident sequences; station black-out (SBO), small break loss of coolant accident (SBLOCA), and medium break loss of coolant accident (MBLOCA). In cases of SBO and SBLOCA, the current SAMG entry condition seems proper, while it needs to be reconsidered for MBLOCA case.

2. MARS Modeling and Accident Scenarios

2.1 Modeling

MARS3.1 code was used to calculate plant behavior. The one-dimensional module of MARS code is based on RELAP5 code, to which multi-dimensional modeling and analysis capabilities were added to give MARS multi-dimensional analysis capability [2,3].

A steady state calculation was implemented to check input nodalization of MARS3.1. Table 1 shows the comparison of MARS results with APR1400 design values in full power condition. The deviation for each parameter is within 1.5%, which is reasonably small to be acceptable. Fig.1 shows the nodalization of APR1400. Input deck files from KHNP CRI were modified for this study.

Peak cladding temperature (PCT) and core exit temperature (CET) are the main focus of this paper. The PCT is the primary parameter to determine the transition point. Based on the previous studies [4,5,6], this paper assumes that the transition to the SAMG is required at the temperature over which the breakaway oxidation phenomena start to occur at the fuel. The PCT of oxidation breakaway was assumed to be 982℃ based on SKN3&4 PSA (Probabilistic Safety Assessment) report [7]. However, the PCT is not usually observable in the main control room. Then, the CET is used to determine the oxidation breakaway in the actual operation.

Therefore, this paper analyzes the CETs which are corresponding to the 982℃ PCT in the different accident scenarios. Then, the relevance of the current entry condition to the SAMG, i.e., 650℃, is investigated.

2.2 Accident Scenarios

To investigate the SAMG entry condition, three accidents are chosen which contribute to about 80% of core damage frequency in APR1400 [6]: 1) station blackout (60.8%), 2) small-break LOCA (16.8%), and 3) medium-break LOCA (3.3%). For each accident, the most severe scenario was selected from the PSA report. The most severe scenario was defined as one that leads to the core damage most quickly.

Table 1: Comparison of APR1400 design values with MARS results

	APR1400 design	MARS results	Deviation
Total reactor power(MWt)	3983	3983	0.00
Primary pressure(MPa)	15.514	15.59 15.59	0.49 0.49
Hot-leg temperature(K)	597.05	596.65	0.06
Cold-leg temperature(K)	563.75	563.66	0.01
Total mass flow(kg/s)	21000.0	21111.0	0.52
Steam pressure(MPa)	6.894	6.886	0.12
Total steam mass flow per SG(kg/s)	1138.9	1124.92	1.23
Feed water temperature(K)	505.35	505.62	0.05
SG Level(m)	12.439	12.436	0.02

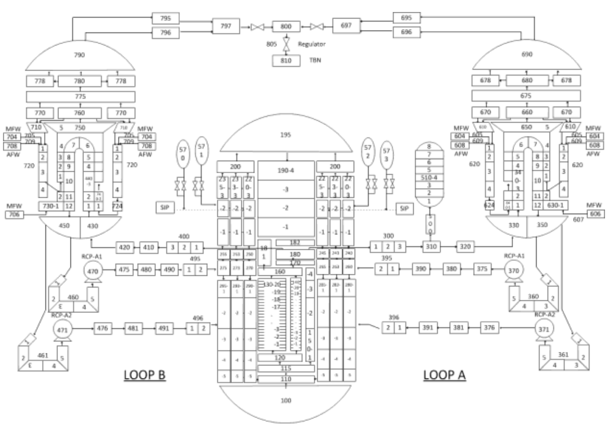

Fig. 1. Nodalization of APR1400

3. Verification of SAMG Entry Condition

3.1 Station blackout

The most severe scenario is that SBO occurs, AAC DG and turbine driven auxiliary feed pumps fail to start. Four RCP seal assemblies are assumed to have a leak in 3 minutes at 11.47 kg/sec, which is corresponding to the maximum flow rate of charging pump.

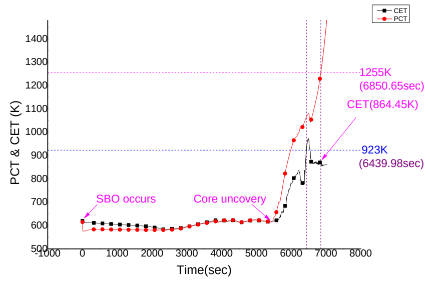

Fig. 2. CET and PCT calculation results for SBO

It seems that the current entry condition is appropriate for the most severe scenario of SBO. Fig.2 shows the calculation results of PCT and CET in the scenario. The current SAMG entry condition was reached at 6439.98 sec prior to 982℃ of the PCT, i.e., 6850.65 sec. The additional calculation showed that if the operators open the POSRVs at the 6439.98 sec, the cladding temperature can be reduced not to reach 1255K. Thus, this paper concludes that the entry condition is appropriate for the SBO scenario, because SAMG actions are effective with this entry condition.

3.2 Small Break LOCA (SBLOCA)

The most severe case in the SBLOCA is that the reactor trip happens successfully, but both safety injection and turbine driven auxiliary pumps fail to start. Through sensitivity analysis, the break size was decided as 0.02ft^2 which caused the earliest current transition point. Anticipated transient without scram (ATWS) is not considered in this study.

Fig. 3 shows the calculation result of PCT and CET in the scenario. The current transition temperature is reached 58.77 sec earlier than 982℃ of the PCT. The additional analysis showed that following SAMG actions are effective at the current transition temperature, but not for the transition at the higher temperature.

3.3 Medium Break LOCA (MBLOCA)

The most severe case in the MBLOCA is that the reactor is tripped at 10.01 sec, the safety injection pumps are unavailable, and the injection from the safety injection tank is actuated at 200.74 sec. The break size is chosen as 0.5ft^2 through the sensitivity analysis.

Fig. 3 shows the calculation result of PCT and CET for the scenario. The result shows that the PCT set-point, i.e., 982℃, is reached first and the CET at this temperature is only 538.76℃, which is lower than the current SAMG entry condition. The additional analysis showed that one of SAMG actions, i.e., the RCS injection, is not effective when the operators enter the SAMG at the current entry condition. However, it also shows that the 3 minute-earlier entry will be effective in reducing cladding temperature, as shown in Fig. 4.

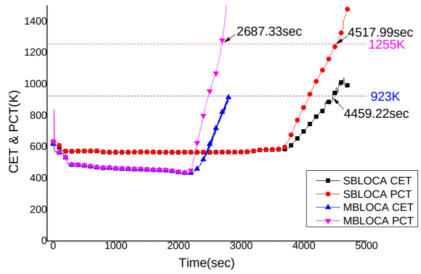

Fig. 3. CET and PCT for SBLOCA and MBLOCA

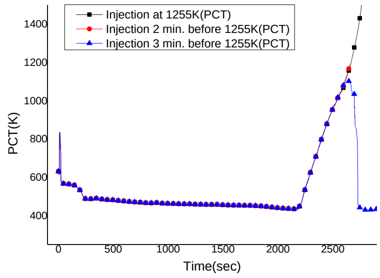

Fig. 4. PCT behaviors at the different injection time

5. Discussions

In this study, the current SAMG entry condition for APR1400 is reevaluated with three dominant events. The calculation results with the MARS showed that the current entry condition is appropriate for the scenarios in the SBO and SBLOCA. However, it seems that the current entry temperature is too high for the MBLOCA scenario. Therefore, more detailed analysis and the revision of the condition, if necessary, need to follow.

REFERENCES

[1] Rae Joon Park et al., Effect of SAMG entry condition on operator action time for severe accident mitigation, Nuclear Engineering and Design 241, p. 1807-1812, 2011

[2] Lee, W.J., et al., Validation of one-dimensional module of MARS2.1 computer code by comparing with the RELAP5/MOD3.3 developmental results, Korea Atomic Energy Research institute, KAERI/TR-2411, 2003

[3] KAERI, MARS CODE MANUAL VOLUME Ⅱ: Input Requirements, 2009

[4] S. Leistikow, G. Schanz, Nuclear Engineering and Design 103, p. 65-84, 1987

[5] M. Billone, Y. Yan, T. Burtseva, R. Daum, NUREG/CR-6967, 2008

[6] Nuclear Fuel Behavior in Loss-of-coolant Accident(LOCA) Conditions, EOCD report, ISBN 978-92-64-99091-3, 2009

[7] KHNP, SKN3&4 PSA (Probabilistic Safety Assessment) report, 2011