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

Modeling of Station Blackout Accident for APR1400 with Recent MELCOR Versions

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1. Introduction

The consequence of the long-term station blackout (SBO) accompanying loss of ultimate heat sink have been vividly shown in the Fukushima accident. Such a high temperature and high pressure scenario may cause creep rupture of the reactor coolant system (RCS) boundary, or high pressure melt ejection. Therefore, a strategy to depressurize RCS is the first priority for severe accident management.

The draft of Severe Accident Management Guidelines (SAMGs) for APR1400 [1] describes that if RCS pressure is higher than or equal to 17.5 kg/cm^2(a), the relevant mitigation strategy, depressurization of RCS, should be carried out. The atmospheric dump valve (ADV) is one of the means to achieve it. It is desirable that the opening of one of the four valves can depressurize the RCS pressure till the safety injection tanks inject water at around 43.9 kg/cm^2(a). This requires opening of at least one ADV as well as the ADV, which could be done for an intact steam generator with manual operation even under the condition of loss of alternating current power supply.

Korea Institute of Nuclear Safety (KINS) has been developing a detailed MELCOR model for SBO analysis of APR1400, considering natural circulation [2]. This model is based on the MELCOR 1.8.6yv version [3], which is the latest one among the 1.8.6 versions. The code developer, however, recommends to use more recent version v2.1 [4] with SNAP (Symbolic Nuclear Analysis Package). Therefore, the first aim of this study is to model a SBO sequence followed by depressurization of RCS through opening of an ADV. Secondly, effects of the different code versions and execution environment are examined using the most up-to-date v1.8.6 and v2.1 versions under the SNAP environment and the command modes.

2. Analysis Methods

The SBO model is being developed by reconstructing the existing MELCOR model in detail, referring to the ShinKori Units 3&4 Final Safety Analysis Report [5]. The SOARCA approach [6] is also referred to modeling RCS of the Surry plant. A preliminary ADV model was included in the input deck, so that RCS depressurization may be simulated in accordance with the SAMG strategy. Thus, an accident scenario is selected to study the effect of ADV operation. In this scenario, the auxilliary feedwater (AFW) pump runs from the initiation of the event to 8 hours. After the pump trips, there may be core disintegration, and then RCS is depressurized through opening of an ADV when the start of the SAMG implementation is declared, i.e., at the time when the core exit temperature becomes higher than 649℃.

2.1 System Modeling

The detailed models of the reactor vessel, hot leg, cold leg and steam generator are focused on natural circulation in the RCS during the core melt. Reactor core consists of 35 control volumes (C.Vs), divided into 5 rings and 12 axial nodes as shown in Fig. 1. The RCS and the secondary side are shown in Fig. 2.

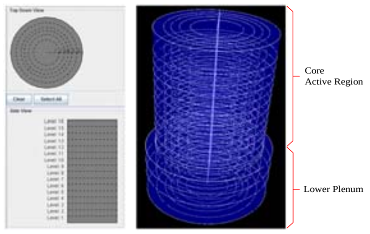


Fig. 1. View of the reactor core model.

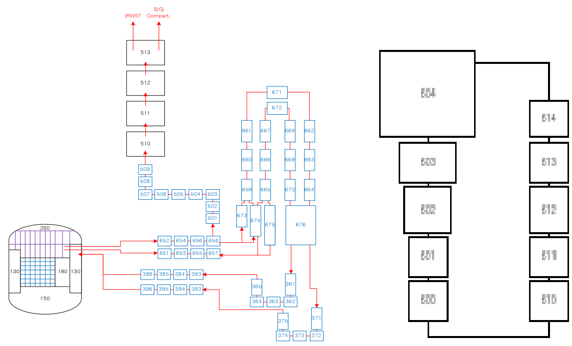


Fig. 2. Nodalization for the RCS and the steam generator secondary side.

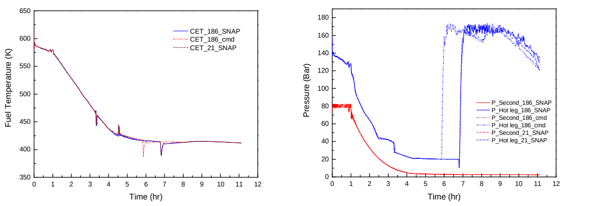
2.2 MELCOR running environment

The MELCOR 2.1 v4803 is the most up-to-date one that was released in September 2012. Regardless of the MELCOR versions, they can be run from command-line or with SNAP v2.2.4 which has the Model Editor Graphical User Interface. Three cases are to be compared: v1.8.6 execution from command-line and with SNAP, and v2.1 with SNAP. Since the SBO input model has been developed to work with MELCOR 1.8.6, it is necessary to convert the 1.8.6 version input data to 2.x input for running with the version 2.1. This has been done successfully with the converter provided by the developer. The selected SBO sequence for the comparison includes the AFW pump operation from 0 to 8 hours, and the opening of the ADV at 1 hour after the initiation of the accident.

3. Analysis Results

3.1 Effect of MELCOR running environment

Different environments for MELCOR running are compared for the special scenario described in Sec. 2.2. As shown in Figs. 2(a) and 2(b), there is a noticeable difference in the estimation of the primary pressure between the SNAP and cmd environment, while minor deviation is given between v1.8.6 and v2.1 under the same SNAP environment. The reason of the difference is not so clear at this point, leaving needs for further examination.



(a) core exit temp. (b) primary & secondary pres.

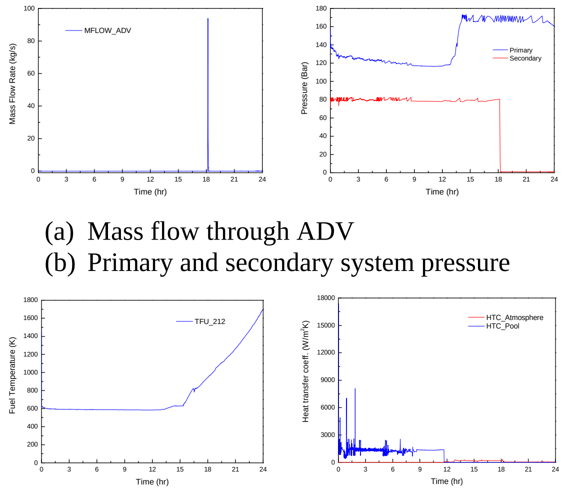
Fig. 3. Comparisons of core exit temperature, primary and secondary pressure in different computer working environments.

3.2 RCS depressurization through ADV opening

The scenario for the RCS depressurization by opening the ADV, described in Sec. 2.1, is analyzed with MELCOR v1.8.6yv under the SNAP environment. The sequence of event is described in Table I, while Figs. 4(a) through 4(d) show the effect of ADV opening on the RCS pressure and fuel temperature. The results show that the secondary system depressurization using ADV does not affect the primary system pressure after the steam generator dryout, as expected. It means that the valve opening should be accompanied by emergency water makeup. When the design details of this measure are known, they will be included in this input model.

Table I: Sequence of the event

Events	Timing	
	sec	hr
Trip of main FW pump & reactor	0.0	0.0
Aux. FW pump on	0.04	0.01
Aux. FW pump trip	28,800	8.0
Steam generator dryout	45,749	12.7
Start of core uncovering	54,037	15.0
Core exit temperature ≥649℃	65,382	18.2
ADV opened	65,382	18.2
Creep rupture at lower head	83,658	23.2



(a) Mass flow through ADV
(b) Primary and secondary system pressure

(c) Representative fuel (UO_2) temperature
(d) Atmosphere and pool heat transfer coefficients at the steam generator tube

Fig. 4. Mass flow, primary and secondary system pressure, fuel temperature and heat transfer coefficients. As a function of time.

4. Conclusions

It has been found that difference in the MELCOR execution environment can affect analysis results. Based on the result, the SBO sequence accompanied by opening of an ADV at 1 hour after the initiation of the SAMG stage has been tentatively analyzed with MELCOR 1.8.6yv with SNAP. The result shows that the ADV opening only is not effective for RCS depressurization. Therefore, the emergency water makeup to the secondary system will be considered in the further development of this input model.

REFERENCES

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