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Numerical Analysis of Loss of Residual Heal Removal System (RHRS) during Mid-Loop Operation for Hanul NPP Units 1&2

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1. Introduction

As a part of supporting LPSD (Low Power and Shutdown) PSA (Probabilistic Safety Assessment) of Hanul NPP units 1&2, numerical analysis for a loss of RHRS (Residual Heat Removal system) during mid-loop operation was performed using RELAP5/MOD3.3 code[1]. The one of main purpose of thermal hydraulic analysis for PSA work is to estimate times allowable for operation actions in each accident[2]. For the purpose of ECT (Eddy Current Test), SG (Steam Generator) tube plugging, or replacement of RCP (Reactor Coolant Pump) seal, there is a need to drain coolant to half of cold and hot leg pipe and install nozzle dam at inlet and outlet SG plenum while the system is cooled down using the RHRS, which is called mid-loop operation. A loss of RHRS during mid-loop operation may cause more significant results than during RCS full condition due to reduced RCS inventory. In order to perform this kind of analysis, it is particularly important to establish a steady state of mid-loop operational initial condition. Mid-loop operation corresponds to POS(Plant Operational State) 5 and 11 in the category of LPSD PSA at Hanul NPP units 1&2[2].

2. Methods and Results

2.1 Analytical Model

The RELAP5/MOD3.3 was used for the analysis of loss of RHRS during mid-loop operation for Hanul NPP unit 1&2. The RELAP5/MOD3.3 is a one dimensional, two-fluid thermal hydraulic computer code. The code is generally applicable to transient, two-phase flow for light water (H_2O) or heavy water (D_2O) in piping networks and is not restricted in application to LWPR (Light Water Pressurized Reactor)[1]. Fig. 1 shows a nodalization of RELAP5/MOD3.3 model for Hanul NPP unit 1&2[3].

2.2 Analysis for steady state

The initial conditions of each POS (Plant Operating State) of Hanul NPP units 1&2 are shown in Table 1. It is of concern to establish a steady state for a transient analysis. To establish the steady state condition of each POS, a series of cooldown procedure steps from full power condition may be required. The Fig. 2 shows the steady state of POS 5 using RELAP5/MOD3.3 code.

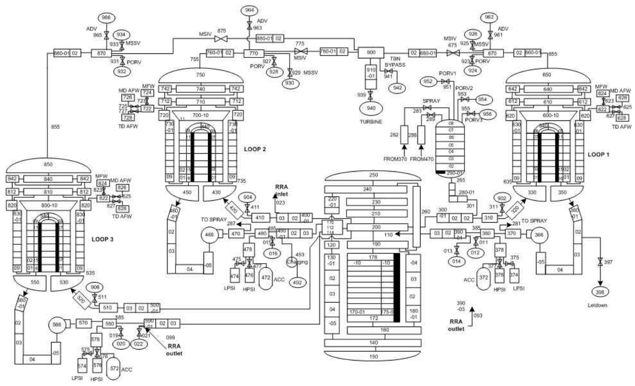

Fig. 1 Nodalization of Hanul NPP Units 1&2

Table 1. Initial conditions of POS 5 and POS 11

	POS 5	POS 11
Elapsed Time after Reactor Trip	76 hrs	705 hrs
Power Level	12.352 MWt	4.247 MWt
RCS Temp, Press	40 °C , 1 atm	40 °C , 1 atm
RCS Water Level	Mid-loop level	Mid-loop level
Big Openings	PZR & SG manway open	No

In the current analysis, final mid-loop state was achieved by proper control of letdown flow control. That is, RCS coolant was drained and controlled by using letdown line until average void in hot leg and cold leg becomes around 0.5.

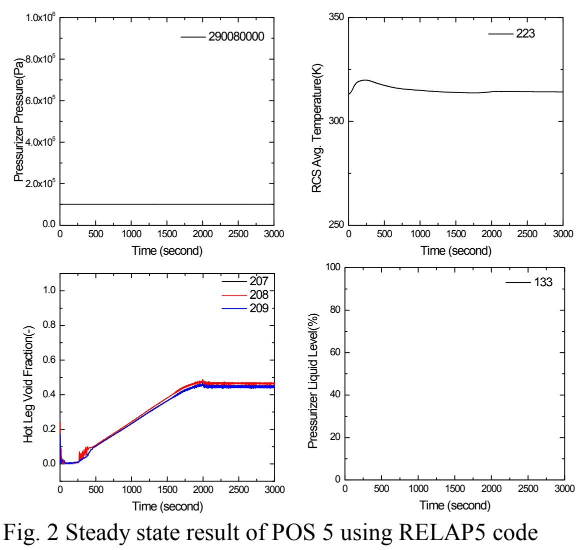

Fig. 2 Steady state result of POS 5 using RELAP5 code

2.3 Transient results for loss of RHRS

Fig. 3 shows transient results for loss of RHRS during POS 5. As the cooling capacity of RHRS is lost, coolant in top of core becomes heated up and finally saturated at 495 sec. The decrease of RCS inventory is accelerated due to existance of big opening (SG and Pressurizer manway open), which results in uncovery of top core at 1.72 hr. Finally fuel in the top core region experiences a damage at 3.13 hr.

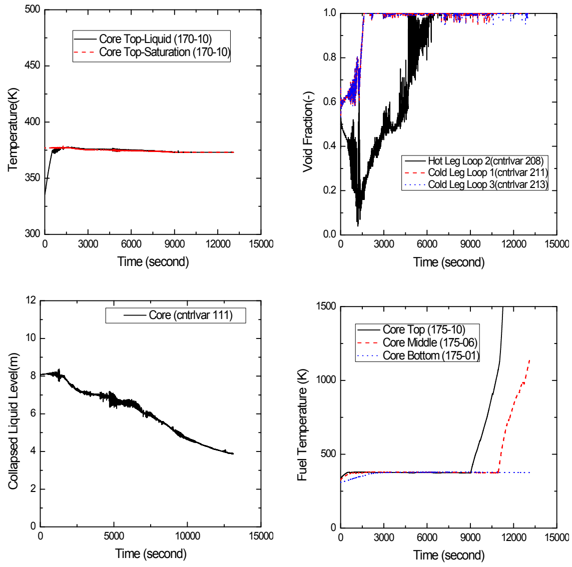

Fig. 3 Transient results in the case of loss of RHRS at POS 5

Fig. 4 shows transient results for loss of RHRS during POS 5 with gravity feed of water in RWST via emergency core cooling path 30 minutes after the accident. As shown in the Fig. 4, as operators take measures to feed emergency core cooling water from RWST through gravity feed line, core damage is delayed significantly.

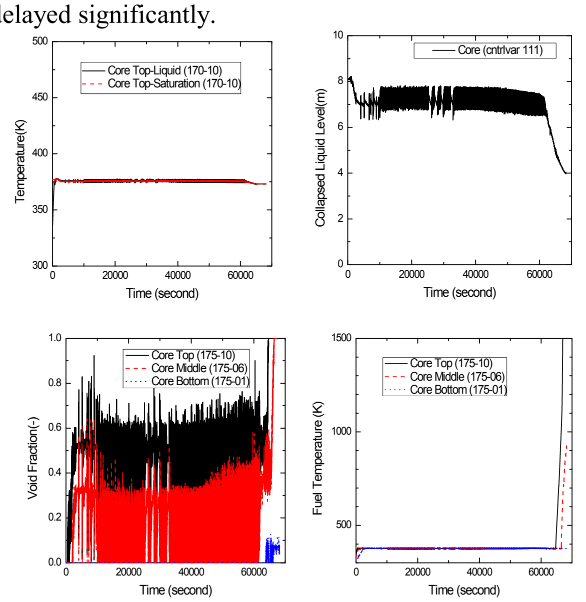

Fig. 4 Transient results in the case of loss of RHRS at POS 5 (with gravity feed 30 min. after loss of RHRS)

Fig. 5 shows transient results for loss of RHRS during POS 11. As the cooling capacity of RHRS is lost, coolant in top of core becomes heated up and finally saturated at 0.8 hr. The rate of decrease of RCS inventory is not severe compared with the accident during POS 5 due to reduced core power and non-existance of big opening(SG and Pressurizer manway closed), which results in uncovery of top core at 9.58 hr. Finally fuel in the top core region experiences a damage at 13.9 hr.

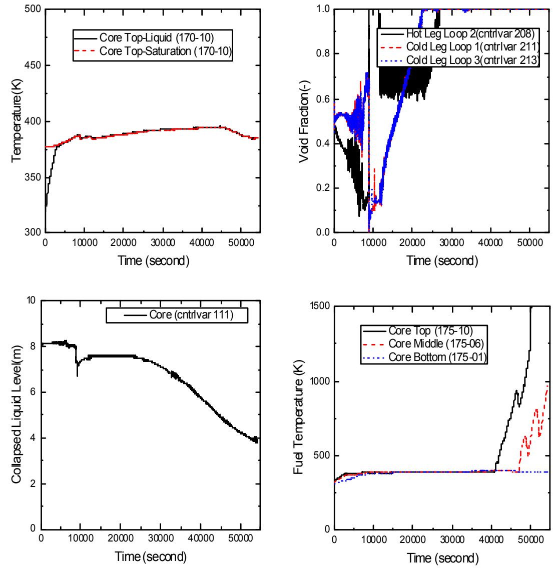

Fig. 5 Transient results in the case of loss of RHRS at POS 11

2.4 Comparison of results with similar analysis

In order to confirm and verify the results of analysis, comparison of the results with those of Shin Kori NPP units 1&2[4] was made for an accident during mid-loop operation. Even though Hanul NPP units 1&2 have rather different features (three loop, Westinghouse plant) from Shin Kori NPP units 1&2, they are similar in the respect with power and pressurized light water reactor (PLWR). Table 2 shows analysis summary for loss of RHRS (or loss of SDCS) at POS 5.

Table 2. Comparison of results between Hanul NPP units 1&2 and Shin Kori NPP units 1&2 at POS 5

	Hanul NPP 1&2	Shin Kori 1&2
Elapsed Time after Reactor Trip	76 hrs	84.4 hrs
Power Level	12.35 MWt	11.91 MWt
Core boiling time	495 sec	333 sec
Core uncovery time	1.72 hrs	1.37 hrs
Core damage time	3.13 hrs	3.06 hrs

Considering different aspects mentioned above and the comparative results between two plants, the analysis results of loss of RHRS during mid-loop operation for Hanul NPP units 1&2 seem to be reasonable.

3. Conclusions

RELAP5/MOD3.3 code was used to predict behaviors of RCS and fuels for the case of loss of RHRS during mid-loop operation at Hanul NPP units 1&2. The initial state of mid-loop operational condition was established by proper control of charging and letdown flow. Considering existing similar analysis results for this kind of accident, it can be concluded that RELAP5 code well predicts reasonably the behavior of RCS for loss of RHRS during mid-loop operation in Hanul NPP units 1&2. Thus the method developed in the analysis can be applied reasonably to support LPSD PSA.

REFERENCES

[1] RELAP5/MOD3.3 Code Manual, Volume II, Appendix A Input Requirements, USNRC, Jan. 2002.
[2] Probabilistic Safety Assessment for Hanul NPP Units 1&2, KHNP, 2015
[3] Hanul NPP Units 1&2 Final Safety Analysis Report, KHNP
[4] Probabilistic Safety Assessment for Shin Kori NPP Units 1&2, Part 4, KHNP