Assessment of Thermal-hydraulic Behavior following the Spray Event at Shinkori Unit 1 Using MARS Code

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1. Introduction

An inadvertent event involving the containment spray initiation occurred at Shinkori (SKN) Unit 1 [1] during its shutdown operation. The event was initiated by the unexpected opening of the isolation valve between the containment spray line and the shutdown cooling system (SDCS). After initiation of the transient, operator started the safety injection system (SIS) and finally terminated the spray flow by closing the isolation valve. It was reported that more than 400 tons of borated water was sprayed into the containment by this event, while reactor vessel core remained uncovered throughout the transient [2].

The present study is to calculate the thermal-hydraulic response of the plant using the MARS code [3]. Overall plant behavior was already reported and evaluated through the recorded plant data. However, a reasonable representation of the event is needed to investigate the specific plant behavior such as the change in SDC flow rate or the margin of the core water which was not included in the measured data. The present study will contribute to further studies on effectiveness of operator actions on this kind of events.

2. Sequence of Events

2.1 Initial Conditions

Before the event, SKN Unit 1 was being operated at initial stage at the cold shutdown mode as listed in Table 1. Three reactor coolant pumps (RCP) except RCP 2B were running and the SDCS train 1 was in operation to adjust heat up rate of the plant.

Table I. Initial condition

Parameters	Value
Pressurizer pressure/ level (wr)	27.04 kg/cm^2/33.8 %
SG 1/2 pressure	5.64/5.445 kg/cm^2
SG 1/2 level (wr)	75/42 %
SG 1/2 temperature	145/146 °C
Hot leg 1/2 temperature	147.8/147.8°C
Cold leg 1A/1B temperature	147.5/147.5°C
Cold leg 2A/2B temperature	147.8/147.4°C
RCP flow rate (1A, 1B, 2A)*	9270.506 lb/sec
Reactor Power*	3.65 MWth

* Estimated from the FSAR

2.2 Sequence of Events

The event occurred at 14:17:28 of September 17, 2010. The following table shows a sequence of major event regarding that 14:00 as 0 second.

Table II. Sequence of major events

Event	Time, sec
Break open (CS-V0035)	1037
RCP trip (1A, 1B, 2A)	1106
SI actuation (HPSI1,2 LPSI 2)	2180
LPSI pump 2 trip and break isolation	3240
SI termination	3624

3. Code and Modeling

3.1 MARS Code

MARS-KS1.2 code was used in the present study. The code, as a best estimate two-phase thermal-hydraulic code, has been applied to calculate system thermal-hydraulic response during the loss-of-coolant accident (LOCA) and transient of the various types of nuclear power plants.

3.2 Modeling of Plant

Fig. 1 shows a modeling diagram of the SKN Unit 1. Modeling of reactor coolant system including reactor vessel and steam generator was typical to the OPR 1000. As shown in Fig.1, the SDCS, high and low pressure safety injection system (HP/LPSIS), a part of the containment spray system were additionally modeled. The total number of volumes, junctions, and heat structures were, 254, 305, and 230 respectively.

In this study, the core decay heat was assumed as constant (3.65 MWth) throughout the transient and the heat removal by the SDC heat exchanger was ignored. The break was located at the containment spray line. The LPSI/HPSI pump performance curves were implemented. The detailed piping networks for (1) from hot leg through LPSI pump 1 to cold legs 1A and 1B, (2) from LPSI pump 1 through SDCS heat exchanger to break valve, (3) from refueling water tank through LPSI pump 2, HPSI pumps 1 and 2 to the cold leg injection nozzle were modeled.

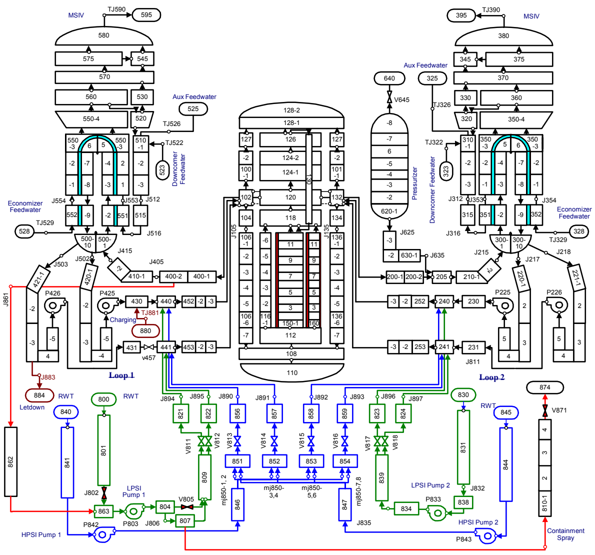

Fig. 1 Modeling of SKN Unit 1

4. Result and Discussion

Fig.2 shows a comparison of the calculated pressure at the pressurizer and the plant data. After 2100 sec, a deviation from the data was found, which is reasoned for the absence of the detailed modeling including the containment spray pipe lines, spray rings, nozzles, etc. Since the break area was being changed during the actual transient, such a dynamic modeling should be implemented. However, a fixed break area which can be regarded as a representative over the whole transient was used in this study.

Fig. 3 shows a comparison of flow rate from the LPSI train 1. Overall behavior was well predicted, however, an overprediction was found, which can be a reason for the pressure jump after 3000 seconds in Fig. 2.

Fig. 4 shows the predicted water level at reactor vessel. One can find the core level was kept higher than the active core region and the margin was greater than 1 m.

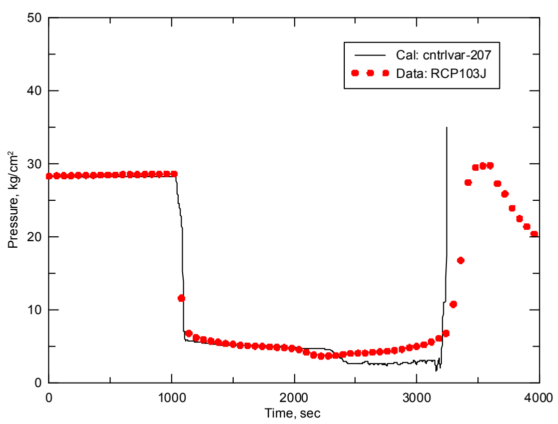

Fig. 2 Comparison of pressurizer pressure

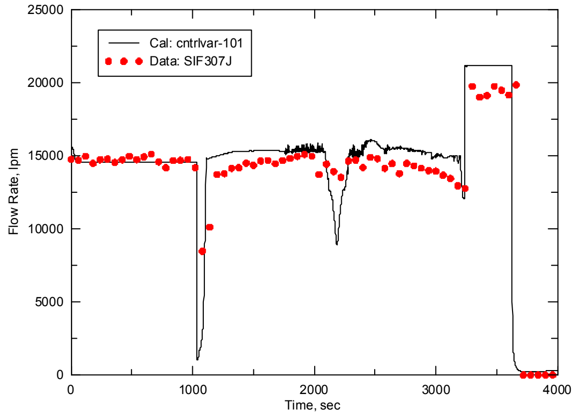

Fig. 3 Comparison of SDC/LPSI 1 flow rate

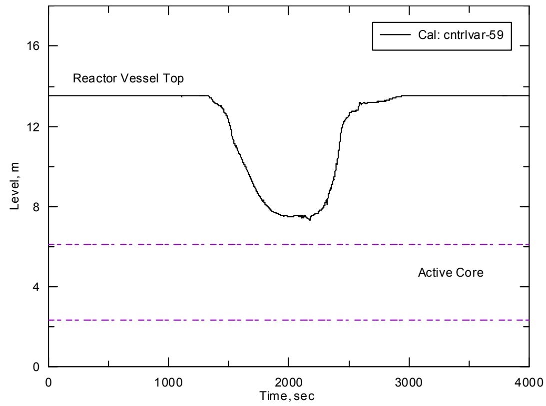

Fig. 4 Collapsed water level at reactor vessel

5. Conclusions

Thermal-hydraulic response following the actual event involving the containment spray at Shinkori Unit 1 was calculated using MARS code. Through the calculation, it was confirmed that the margin to the core uncovery was greater than 1 m throughout the transient Some deviations in the calculation results from the plant data was regarded due to the modeling of break at the spray line, which needs a further study on the modeling scheme.

REFERENCES

[1] KHNP, Final Safety Analysis Report, Shinkori Units 1, 2, Sept. 2008 (*in Korean*)

[2] KINS, Event Inspection Report on Containment Spray Event at SKN Unit 1 2010, Nov. 2010 (*in Korean*)

[3] KAERI, MARS Code Manual, Volume I: Code Structure, System Models, and Solution Methods, KAERI/TR-2812/2004, December 2009.