An Assessment of MARS-KS code using Real Plant Transients of OPR-1000 Nuclear Power Plant

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1. Introduction

KINS launched the first 3-years stage project of the national mid- and long-term R&D plan, which aims at structuring a best-estimate (BE) reactor thermal-hydraulic analysis system (hereinafter, RETAS), composed of the computer codes as self-maintainable and technology-independent as practicable.

In this paper, an assessment is provided for one of verification and validation works of MARS-KS of RETAS (REactor Thermal-hydraulic Analysis System).[1]

2. Description of OPR-1000 Transient

2.1 Reactor Trip of Ulchin Unit 3

At April 3, 2000, during UCN Unit 3 operated at 100% full power, 2815MWth, A/D converter used in de-aerator level controller of Turbine Condenser System was out of order. This malfunction of A/D converter generated the low-low level signal of de-aerator storage tank and this signal made the main feedwater pump trip. Loss of main feedwater resulted to steam generator low-low level, reactor was tripped and turbine stop valve was closed. After reactor and turbine tripped, emergency diesel generator had been started and auxiliary feedwater pump also started normally.

2.2 Reactor Trip of Ulchin Unit 4

At September 20, 2000, during UCN Unit 4 operated at 100% full power, 2815MWth, the 13.8 keV bus breaker which supply electrical power to reactor coolant pump was opened. This made the RCPs stopped, reactor trip signal was generated and reactor was tripped.

3. Computer Code Model

3.1 Description of MARS-KS[3]

The backbones of MARS are RELAP5/MOD3.2 and COBRA-TF. MARS development was initially intended to make the most of the merits of the two codes: the former is a versatile and robust system analysis code based on 1-D two-fluid model for two-phase flow, whereas the latter is based on a 3-D two-fluid, three-field model. In this assessment, one dimensional model was used because there were no significant multi-dimensional phenomena.

3.2 Nodalization of nuclear power plant

In order to simulate the Ulchin 5 pre-operational test, the nodalization was used as shown in figure 1. Nodalization was performed according to MARS user's guidelines and all calculation sheet follows quality assurance format.

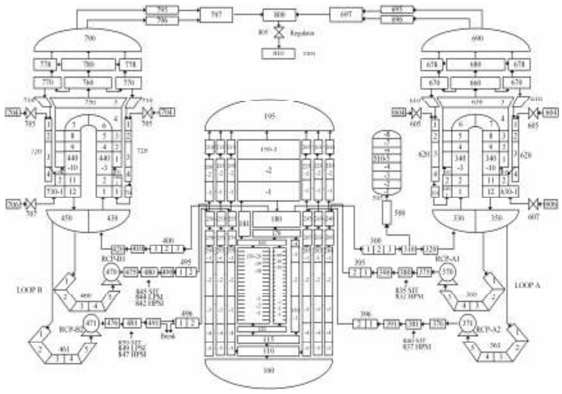

Figure 1. Ulchin 5&6 MARS-KS Nodalization

3.3 Plant Control Modeling[4]

To simulate the Ulchin 5 pre-operational test correctly, pressurizer level control system (PLCS) and pressurizer pressure control system (PPCS) should be modeled. PLCS was modeled as charging and letdown and PPCS was simulated by pressurizer heaters (backup heater and proportional heater) and spray. Of course, the MARS input models of PLCS and PPCS were consisted of time dependent junctions/volumes, control variables and general tables.

4. Results and Discussions

4.1 Reactor Trip of Ulchin Unit 3

As described in the previous section, at April 3, 2000, during UCN Unit 3 operated at 100% full power, 2815MWth, A/D converter used in de-aerator level controller of Turbine Condenser System was out of order and generation of the low-low level signal of de-aerator storage tank made the main feedwater pump trip. Detailed sequences are listed in table 1.

In this case, the time when main feed pumps were tripped was set as the accident start during 100% full power normal operation. From 0 to 400 seconds, steady state was simulated and main feed pumps were tripped at 400 seconds. Reactor thermal power decreased rapidly until reactor control system was operated and at 440 seconds reactor was tripped as shown in figure 11. In this paper, reactor thermal power control system was not modeled and the power was simulated by general table as boundary condition.

Table 1. Sequences of Event for Ulchin Unit 3 Reactor Trip

TIME (SEC)	PLANT	TIME (SEC)	MARS
0	Sequence Start	0	Simulation Start
400	MPWP 1&2 STOP	400	MFWP 1&2 STOP
440	SG1/2 WR : 44.7/43.4%	437	SG1 WR < 42.9%
		438	SG2 WR < 42.9%
445	RX TRIP (SGWR < 42.9%)	437	RX TRIP (SG WR < 42.9%)
540	AFAS-2 (SG2 WR < 23.5%)		
545	AFWP-02B start	570.6	AFAS-1 (SG2 WR < 23.5%)
550	AFWP-02A start	571.6	AFWP start
590	AFAS-1 (SG1 WR < 23.5%)	593.2	AFAS-2 (SG1 WR < 23.5%)
595	AFWP-01A start	594.2	AFWP start
605	AFWP-01B start	1000.0	Simulation End

In figure 2, pressurizer behavior was shown. After the reactor trip, pressurizer pressure and water level decreased as the specific volume, as function of temperature and pressure, was reduced. The shape of these pressurizer T-H parameters is reasonably predicted. Considering the uncertainties, calculated results well predict the plant data.

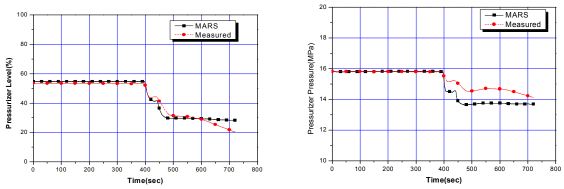

Figure 2. Ulchin 3 Normalized Pressurizer Level and Pressure

Because turbine was modeled as pressure boundary condition, steam generator water level shows almost same trend of plant data. In figure 3, calculated results show good agreement with plant data.

In some sense, the most important comparison can be RCS hot leg temperature because this incident scenario can be categorized by DNBR limiting case in view of regulatory safety analysis. Considering under-prediction of the calculated pressurizer pressure, calculated DNBR should be lower than that of real plant data.

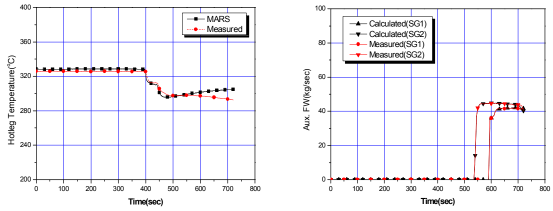

Figure 15. Ulchin 3 Hot Leg Fluid Temperature and Aux.Feed flow

4.2. Reactor Trip of Ulchin Unit 4

At September 20, 2000, during UCN Unit 4 operated at 100% full power, 2815MWth, the 13.8 keV bus breaker which supply electrical power to reactor coolant pump was opened. This made the RCPs stopped, reactor trip signal was generated and reactor was tripped. This event is typical sequence of "LOFA (Loss of Flow Accident)" in FSAR chapter 15.3 and is limited by departure from nucleate boiling ratio (DNBR). Detailed sequences are listed in table 1.

Table 2. Sequences of Event for Ulchin Unit 4 Reactor Trip

TIME (SEC)	PLANT	TIME (SEC)	MARS
0	Sequence Start	0	Simulation Start
575	Reactor Coolant Pump Trip	575	Reactor Coolant Pump Trip
576	Turbine Trip	576	Turbine Trip
577	Reactor Trip	577	Reactor Trip
588	MFIV Closed	588	MFIV Closed
598	AFWP-01A start	598	AFWP-01A start
598	AFWP-01B start	598	AFWP-01B start
		1000	Simulation End

This event was simulated from 0 second and during 575 seconds, reactor coolant system was maintained as steady state. Reactor coolant pump was tripped at 575 seconds due to loss of offsite electrical power and 1 second later, turbine stop valve closed with same reason. As described earlier, DPS made reactor trip at 577 seconds and main feedwater isolation valves (MFIVs) were closed at 588 seconds. At 10 seconds later after MFIV closed, auxiliary feedwater pumps started and thermal-hydraulic conditions of reactor coolant system were stabilized.

Figure 17 shows reactor power behavior and reactor trip occurred at 576 seconds and the differences after reactor trip are resulted from nuclear modeling. In the figure, plant data represent neutron flux and calculation result shows reactor power including decay power.

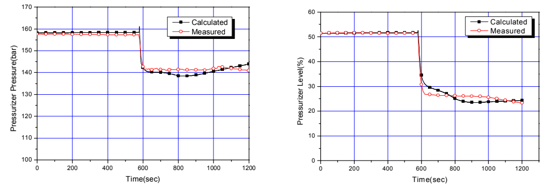

Figure 18. Ulchin 4 Pressurizer Pressure and Level

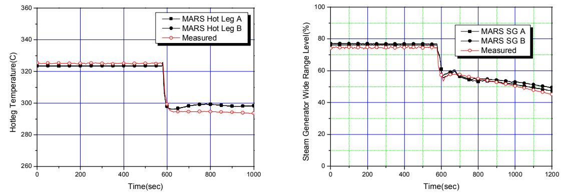

Figure 20. Ulchin 4 Hot Leg Temperature and SG Level

5. CONCLUSIONS AND FUTURE WORKS

MARS-KS version assessment was performed and the code calculation results showed that RCS temperature and secondary thermal-hydraulic parameters were well predicted and pressurizer T-H parameters such as liquid level also predicted reasonably well.

As future works, the followings will be performed.

- Assessment for IET Experiments to validate MARS-KS for non-LOCA analysis
- MARS-KS assessment for various nuclear power plant incident data

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