Assessment of OPR1000 Design Load-Following Operation Capability on Large Load Reduction

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1. Introduction

The national long-term energy plan is to build 10 more nuclear power plants (NPP) by 2030, to provide more than 50 percents of the total electric power demand [1]. When the NPPs are in a single grid system to charge such a large fraction of load, a load-follow operation is inevitable to manage the grid effectively. Such plant operation lays the plant systems and components in more unfavorable condition than the base load operation, requiring the reactor coolant system (RCS), fuel, instrumentations, mechanical integrity and other safety factors to be evaluated in overall. Lots of challengeable scenarios are often evaluated: 100-50-100%, 14-2-6-2 hour load change, ±5%/min ramp load change, ±10% step and large load change, etc.

In this study a reactor system response to large load reduction is assessed by using the MARS code. The assessment compares the preoperational test data and MARS calculated results.

2. Description of Load Reduction Test

2.1 OPR1000 Design Features

The NPPs of OPR1000 design, Ulchin 3 and 4, 5 and 6 and Younggwang 5 and 6 are currently operated at a base-load of around 1000MWe, respectively. Their inherent design aims at being capable of flexible and load-following operation, such as quick adjustment of the output power against an external load change without overly disturbing the neutron flux distribution and power instability. A specific aspect of the challenge for load-following operation is that NPPs can comply with specific grid requirements, in terms of frequency control, daily load-following, spinning reserve capabilities and large load reduction. To control such challenges, Reactivity Regulate System (RRS), Steam Bypass Control System (SBCS), Pressurizer Pressure (PPCS) and Level Control System (PLCS) and Feedwater Control System (FWCS) are installed in the OPR1000 design.

2.2 Full Load Reduction Tests

The full load reduction tests partially demonstrate the load following operation capability of a plant, that is, the RCS and the secondary system can be safely controlled against the abrupt load changes. In the NPPs of OPR design, they are normally performed at different three power levels, 50, 80 and 100 percents. The test criteria are that the plants should be safely controlled without a) initiating the Reactor Protection System (RPS) and Engineered Safety Features Actuation System (ESFAS), b) opening any safety valves, and c) causing reactor and turbine trips.

The full load reduction tests in Yonggwang 5 and 6 were performed in 2002, and the data showed that the OPR1000 design can meet the applicable criteria, as designed [2]. The Yonggwang 5 data at 80.7 percents of rated thermal power, 2272 MWt, was selected to assess the MARS code. To set up the initial conditions of the test, the reactor was operated over 30 minutes at 80.7% power, automatic modes of all plant control systems. When the operator manually initiated the loss of load, the reactor power was stepped down to 60% power by RPCS, then slowly reduced to 20% power by RRS to be in balance with turbine power. The rapid decrease of load and primary power actuated the SBCS, discharging the steam to the condenser. After reaching a peak of 8.2 MPa, the steam generator secondary pressure was favorably controlled and stabilized at 8.15MPa. Automatic operation of the PPCS and PLCS stabilized the pressure and level at the programmed setpoints. None of the pressurizer safety valves were opened. The RPS, ESFAS and turbine trip did not initiate.

3. MARS Modeling

To simulate the full load reduction test, the Yonggwang 5 RCS and secondary systems were modeled for MARS code input. From the information of its Safety Analysis Report [3], the MARS nodalization was made as seen in fig.1.

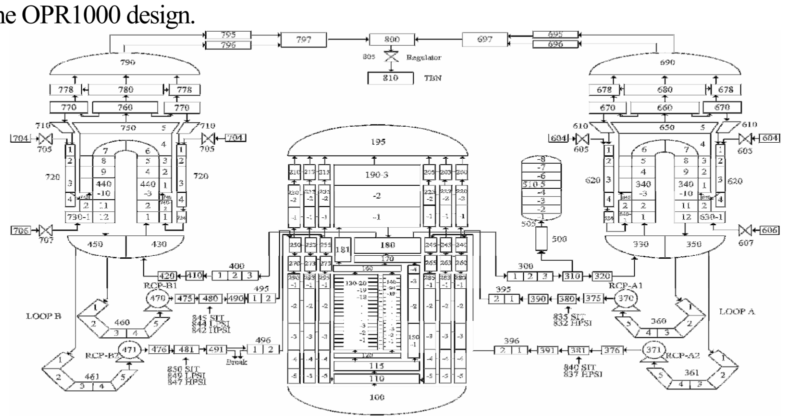

Figure 1 MARS Nodalization for Yonggwang 5 Load Reduction Test Simulation

The PPCS and PLCS logics were modeled by a combination of various MARS input options, control variables, general tables and time dependent flow/T-H boundary conditions, respectively. These models are important to get an accurate RCS response to full load reduction. In our calculation the reactor control system was not modeled, instead, the measured thermal power was directly applied as a table. The option of pressure and enthalpy boundaries was applied to the SBCS and FWCS.

Using the modeling of RCS, secondary system and control logics as above, a steady state run was performed to initialize the reactor conditions to correspond to the test initial conditions. As seen in Table 1, the calculated steady state conditions are in reasonable agreement with the test data.

Table 1 Steady State Initialization Results

Parameters	Load reduction test condition	MARS initialization
Reactor power (MWt)	2272	2272
PZR pressure (MPa)	15.38	15.43
PZR level (%)	48.60	48.98
Hot leg temp. (℃)	319.66	320.4
Cold leg temp. (℃)	296.79	296.4
S/G pressure (MPa)	7.36	7.42
S/G level (%)	73.75	73.4
FW temp. (℃)	222.0	222.0

4. Results and Discussions

The MARS transient run was initiated at time 0sec, and then time trends of some important parameters were compared with the measurement data. Calculated and measured pressurizer behaviors are shown in figs. 1 and 2, indicating the same trends that pressurizer pressure and water level decrease as the abrupt load reduction reduces the RCS specific volume.

Pressurizer level deviations, defined by difference between actual and programmed levels, were compared in fig.3. The MARS shows a reasonable prediction, except for the early transient period. The MARS results seem to be attributed to the uncertainty of measured data as well as a little higher prediction of the RCS average temperature.

The RCS average temperatures are shown in fig. 4. The calculated values stably varies from 308℃ to 300℃, in good agreement with the plant data, while being higher than the measured early in the transient. There seems to be differences design data and real plant data such as steam generator heat transfer area, coefficient, and recirculation ratio, certain margins or measure uncertainties, etc. The RCS average temperature is important to simulate the operational transients, because it is used as a parameter of control systems such as SBCS, PLCS and CVCS.

5. Conclusions

This study assessed the MARS code against the full load reduction test at 80% rated thermal power in Yonggwang 5. The calculated results compared with the measured plant data showed that MARS provide reasonable predictions of the RCS and secondary system behaviors during full load reduction in OPR1000 design.

REFERENCES

1. "10 More Nuclear Plants to Be Built", By Oh Young-jin, Staff Reporter, Koreatimes, 08-27-2008
2. Younggwang 5, 6 Preoperational Experience Record Serious, Younggwang Nuclear Headquarters, 2002.
3. Younggwang 5, 6 Final Safety Analysis Report, Chapter 1, 7, 10
4. KAERI/TR-2811/2004, MARS CODE MANUAL, VOLUME II, KAREI, 2007.2
5. Yong Jin Cho, Dong-Gu Kang, Seung Hoon Ahn, Jong Kap Kim, Assessment of MARS-KS code using Real Plant Transients of OPR-1000 Nuclear Power Plant, to be presented in the 7th JSME-KSME TFEC, Oct. 13-16, 2008, Sapporo, Japan.

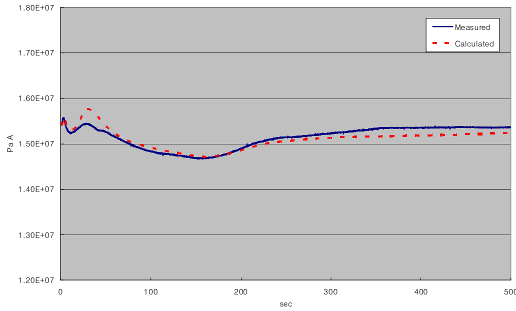

Figure 1 Comparison of Pressurizer Pressure Behaviors

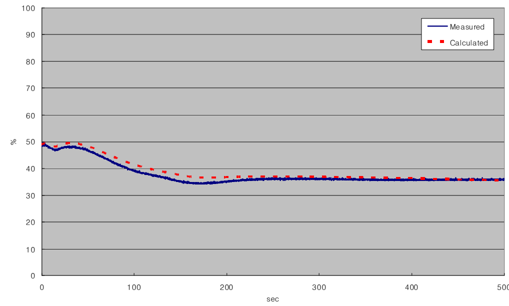

Figure 1 Comparison of Pressurizer Level Behaviors

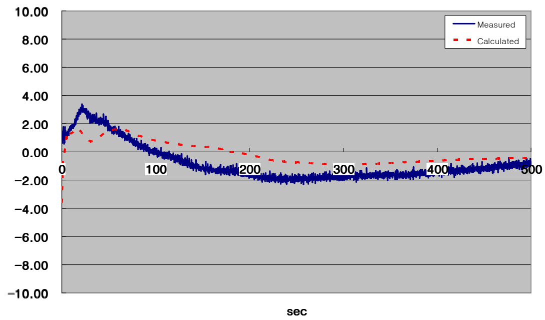

Figure 3 Level Error Transient

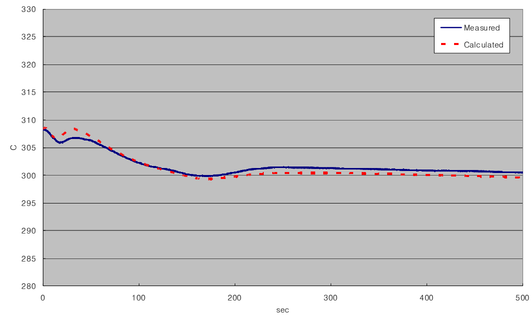

Figure 4 RCS Average Temperature Transient