Assessment of MEDUSA code with Turbine trip & Natural Circulation Test of YGN Unit 6

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1. Introduction

MEDUSA is a system thermal hydraulics code developed by Korea Power Engineering Company (KOPEC) for Non-LOCA and LOCA analyses, using two-fluid and three-field governing equations. A lot of effort has been made to verify the applicability of the MEDUSA code especially to Non-LOCA analysis by comparing the analysis results with those from the current licensing code CESEC-III[1-3]. In this paper, the turbine trip & natural circulation(NC) test, which is one of the power ascension tests(PATs) for OPR1000[4], is analyzed using the MEDUSA code, and the results are compared with the test data, as an effort for code validation.

2. Test description

2.1 Initinal conditions.

The required plant initial conditions for turbine trip & NC test are as follows: (1) Power is stabilized at a level greater than 95%. (2) RCS average temperature remains stabilized during 30 minutes monitoring. (3) pressurizer pressure is stabilized within the range of $158.2 \pm 1.7 kg/cm^2a$. (4) Pressurizer level is stabilized at the programmed level. (5) Steam generator 1 and 2 levels are stabilized at normal range.

The plant equipment and systems are operational in the following modes: (1) The CEDMCS is in automatic sequential mode. (2) Both FWCSs are in automatic control mode. (3) The SBCS is in automatic control mode with all turbine bypass valves in automatic mode. (4) The PPCS and PLCS are in automatic control mode. (5) The DPS is in the “enable” position for reactor trip. (6) RPCS is out of service.

2.2 Description of test procedure

In this test, the turbine trip without RPCS is carried out to demonstrate that the plant control systems such as the SBCS, FWCS, PLCS and PPCS respond automatically as designed to achieve stabilized hot standby conditions after the normal reactor trip. A turbine trip is manually initiated by pressing the turbine trip button in the control room. This method demonstrates that DPS will provide the automatic reactor trip on a turbine trip since RPCS is out of service during testing. If no trip on DPS, the operator will initiate a manual reactor trip and perform the Standard Post Trip Action(SPTA).

After the plant has achieved a stable hot standby condition, all four RCPs will be tripped by manual as simultaneously as possible to perform the natural circulation cooldown. Natural circulation conditions are verified by observing the cold leg and hot leg temperature difference within the acceptance criteria, 57 ^oF.

3. Analysis Results

Fig. 1 shows the comparison of pressurizer pressure variation between Turbine trip & NC test and the MEDUSA analysis. Turbine trip is initiated at 553 seconds, and then the reactor is tripped by the DPS upon sensing the turbine trip since the RPCS is out of service.

The overall behavior of pressurizer pressure shows a good agreement between tests and the analysis results, except at around 600 seconds. At around this time, pressurizer pressure in the analysis is increasing more rapidly than the test data due to the late re-opening of TBVs. The integral control logic of SBCS depends on operation history, that is, the level error accumulated until this time. In the simulation, the accumulated level error is assumed to be zero at the beginning of the test, since there is no information about the operation history. This seems the reason why the opening time of TBVs is somewhat late compared to the real plant data.

For the natural circulation test, pressurizer pressure is gradually decreased from about 1700 seconds and dropped rapidly at 2400 seconds. It seems that operator operates the auxiliary spray manually to prevent over-pressure at the time of rapid de-pressurizing of RCS. Then the SBCS adjusts the modulation setpoint to an increased value, to compensate the decrease of pressurizer pressure, resulting in closure of TBVs. Consequently pressurizer pressure is increased again until TBVs are re-opened. But, in the MEDUSA analysis there is no operator action causing the sudden decrease of pressurizer pressure and pressurizer pressure is always automatically controlled by PPCS. Therefore, pressurizer pressure shows somewhat different trend from the plant data at the end phase of the test.

Fig. 2 shows the comparison of RCS temperature variations. When the reactor is tripped, the hot leg temperature is rapidly dropped, whereas the cold leg temperature is a little increased due to the reduction of

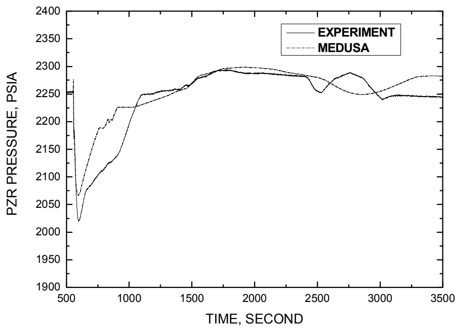

Figure 1. Pressurizer pressure

primary-to-secondary heat transfer. After several minutes, the RCS loop temperature difference is stabilized at about 0.9°F in the test and 1.2°F in the analysis, respectively. After all RCPs are tripped at around 1450 seconds, the reduction of RCS flow rate results in an increase in the hot leg temperature causing the loop temperature difference to increase. The RCS loop temperature difference is finally stabilized at about 24 °F in the test and 22 °F in the analysis.

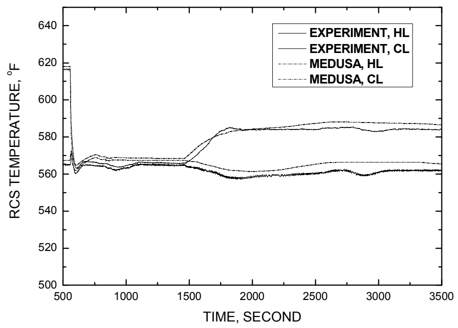

Figure 2. RCS temperature

Fig. 3 shows the comparison of steam generator pressure variation. The turbine trip causes a rapid decrease in secondary steam flow rate, resulting in an increase of the steam generator pressure. Then the rapid decrease of steam flow causes the SBCS to open TBVs in a quick open mode to reduce the SG pressure. About 30 seconds after the turbine trip in both the test and the MEDUSA analysis, the SBCS starts to close and then modulates TBVs in accordance with the main steam pressure setpoint, 1183psia.

Both in the analysis and test, the SG pressure starts to decrease at around 1500 seconds, as SBCS pressurizer bias program adjusts SG pressure setpoint to a lower value to compensate the increased pressurizer pressure. The difference between the analysis and the plant data shown at around 2700 seconds is mainly due to the effect of the manual operation of auxiliary spray. The operator action is to reduce primary system pressure, but it affects the secondary system pressure via the SBCS pressurizer bias program. Except the effect of the operator action, which is not modeled in the analysis, the overall behavior of secondary pressure shows a good agreement between test and the analysis results.

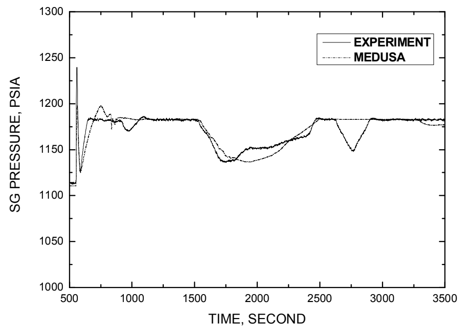

Figure 3. Steam generator pressure

4. Conclusion

As an effort of the code validation, a real plant test, turbine trip & natural circulation, is simulated using MEDUSA code. The analysis results agree well with the test data, except the effect of the manual operation of auxiliary spray at the end phase of the test, which is not modeled in the analysis. Based on this, it is concluded that MEDUSA is applicable to the analysis of a real plant thermal hydraulic response to system transients such as turbine trip & natural circulation test.

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