Feasibility Study on the Steady State Initialization of SPACE code

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1. Introduction

Recently, Korean nuclear industry is developing the new computer code SPACE [1] with the detailed thermal hydraulic model for Non-LOCA and LOCA transient analysis. As a part of this project, KNF takes part in developing the safety analysis methodology using SPACE code. However, SPACE code often has been stopped by unknown reasons that users cannot trace, because the developing computer code has many logical bugs and errors inevitably. Despite such poor surroundings, KNF is trying to develop the SPACE model for OPR1000 nuclear power plant to study the steady state initialization of SPACE code. In this paper, the SPACE model and the results for the steady state initialization study will be described. The results are incomplete in some respects but sufficient to show the current status of SPACE code.

2. Analysis Methods

The SPACE code is a variable nodal code; therefore, the users should build the desired plant model by defining the control volumes and flow paths with heat conductors to account for heat transfer in both the primary and secondary systems. In this section, the important models built in this study are described.

2.1 Nodal Model

The basic nodal model is designed to simulate the appropriate NSSS responses for Non-LOCA transients. The nodal model used in this paper composes the primary and secondary system. The primary system includes the reactor core, reactor coolant pipes, steam generators (volumes inside U-tubes) and reactor coolant pumps. The secondary system includes the steam generator secondary side, main steam pipes and turbine. The nodal structure for Non-LOCA transient analysis does not need to be complex because the Non-LOCA transient analysis does not focus on the local geometry effects.

2.2 Vessel Model

The vessel model is composed of the nuclear fuel and adjacent coolant channels. The choice of the vessel nodal structure is largely based upon prior KNF's experience of the KNF from analysis methods and tools used in performing Non-LOCA safety analyses. The core heat generation and conduction is modeled using the solid cylindrical active heat structures with three material regions representing the fuel pellet, the gap and the cladding. The pellet region is subdivided into three radial sections. The one node axial representation of the core is sufficiently detailed for point-kinetics reactivity feedback calculation driven by changes in core average properties. The whole core is divided into two volumes: left and right side core. The left and right side cores communicate through the mixing flow faces. The design ratios of mixing in the lower and upper plenum are assumed to study the steady state initialization.

The built-in fuel-to-coolant heat transfer model and the material properties are used in this study.

2.3 Reactor Coolant System Model

The reactor coolant system is consisted of the pipes and reactor coolant pumps. The pipes employ three regions: one for hot leg, one for suction leg and one for discharge leg. The reactor coolant pump is modeled using the pump component of SPACE code. The pump performance data to calculate the pump head and torque are obtained from the design data. These are the homologous curves and the corresponding reference operating condition. The reference operating condition is defined by the rated conditions of pump speed, head, density and motor torque. SPACE calculates the pump behavior through the use of these curves such that the head and torque are uniquely defined as functions of volumetric flow and speed.

2.4 Steam Generator Model

The steam generator is modeled with primary and secondary side volumes of U-tubes. The U-tubes have a function to transfer the heat from the primary side to the secondary side. It is important that the heat transfer between two volumes should be simulated properly. The heat structure component and heat transfer correlations of SPACE code are used to calculate the heat transfer across the U-tubes. The secondary volumes are modeled using the vertically oriented pipe component with two cells for the phase separation.

2.5 Pressurizer Model

The pressurizer model is made up of the pressurizer volume, surge line volume, the safety valves and pressurizer relief tank. The pressurizer volume is modeled using the pipe component with two cells for the phase separation. The pressurizer model must include the pressurizer heaters, the pressurizer sprays, and pressurizer relief and safety valves. For the purpose of steady state initialization, the heaters and sprays are not considered. The safety valves are modeled as the pressure-type valve using the valve component of SPACE code and the critical flow model is taken into consideration at the valve face. The pressurizer surge line and pressurizer relief tank are modeled as separate cells.

2.6 Reactor Kinetics Model

SPACE code allows the point kinetics model to be used for the neutronic calculation. In this study, the core conductor power generation is determined using the point kinetics calculations with one prompt neutron group, six delayed neutron groups, and eleven delayed gamma emitters. The total reactivity is based on contributions from moderator feedback, the Doppler effect, boron concentration changes, control rod movement and reactor trips. For the steady state initialization study, the kinetics parameters are selected to simulate the reactor core kinetics appropriately but the reactivity feedbacks is paid no regard to avoid the complexity in the steady state initialization.

2.7 Balance of Plant Model

The balance of plant model includes the steam system, feedwater system, main piping from steam generator outlet up to the turbine stop valves and a portion of main feedwater piping. The steam system is divided into a separate cell for each of the steam lines. The common header is not connected to prevent the pressure oscillations between two steam generators. The main feedwater is modeled as the flow boundary using the TFBC (Temporal Face Boundary Condition) component.

3. Results of Steady State Initialization

In order to study the steady state initialization using newly developed computer code, the SPACE model prepared as above is initialized as close as possible to the nominal plant conditions. The problem time is chosen as 1800 seconds to confirm the steady state. Figure 1 and Figure 2 show the time vs. pressurizer pressure, the time vs. feedwater and steam flow rates respectively. Per Figures 1 and 2, the plant parameters are stabilized with small oscillation after about 400 seconds. This oscillation comes from the repetitive changes of the heat transfer mode on steam generator (SG) shell side. Figure 3 shows the heat transfer coefficients of U-tube wall of SG shell side. The heat transfer coefficients are changed from 1600 to 5500 Btu/hr-ft^2 dramatically and this discontinuity makes the primary-to-secondary heat transfer unstable.

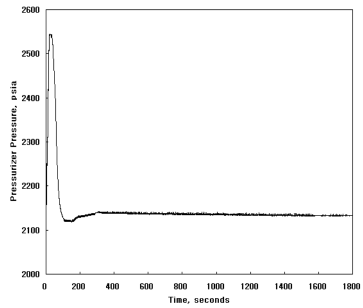

Fig. 1. Pressurizer pressure

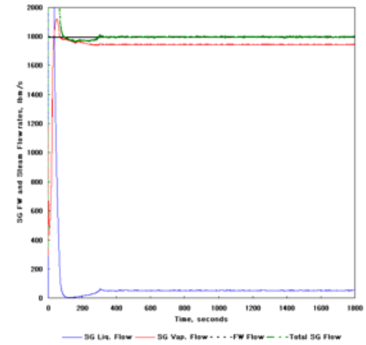

Fig. 2. Feedwater and steam flow rates

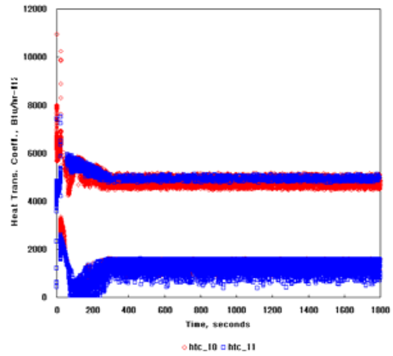

Fig. 3. Heat transfer coefficients on SG shell side

4. Conclusion

The steady state initialization is studied using SPACE code, which is newly developed by Korea nuclear industry for the nuclear power plant safety analysis. The general results show the steady state convergence except some parameters such as the heat transfer modes and coefficients.

ACKNOWLEDGMENT

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REFERENCES

[1] "User's manual for SPACE code," Korea Electric Power Research Institute, March 2010.