Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

System Model Initialization for Non-LOCA Analysis Using SPACE Code

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1. Introduction

Since 2010, non-LOCA safety analysis methodology has been developed using SPACE code, designed to predict the thermal-hydraulic response of Nuclear Steam Supply System (NSSS) to the anticipated transients and the postulated accidents [1~2]. Several nodalization schemes for the components such as steam generator and reactor vessel have been tested so far to find out optimized configuration leading to a preliminary system model for Non-LOCA analysis.

Intialization for any combination of major plant parameters such as core inlet temperature, pressurizer pressure and level, reactor coolant flow rate, and the steam generator inventory is very important to non-LOCA analysis unlike LOCA considering only nominal plant condition as an initial plant state.

In this paper, the initialization methods to obtain the necessary steady-state conditions are briefly presented for the major initial condition plant parameters such as core power and core inlet temperature.

2. Initialization

2.1 General description

An important consideration for non-LOCA transient analysis is the initial state from which a transient is initiated. Typical initialization approach adopted by many system codes such as RELAP5 and MARS is to solve the transient set of conservation equations until a steady state condition is obtained. This requires that long transients be run to obtain steady state conditions and special user-defined control system are required to drive the desired initial conditions. It imposes considerable burden on the users, especially the non-LOCA analysis users who have to perform a series of initial condition sensitivity study to identify the most limiting scenario in terms of figure-of-merit for each transient.

The RELAP5 provideS steady-state, nearly implicit scheme and self-initialization options, a generic set of controllers, to reduce the time, effort and cost to achieve desired steady state. Several similar initialization tools are designed in the SPACE code to provide the capability to model the NSSS control systems to quickly initialize the plant to the desired initial conditions.

2.2 Method

The major initial plant condition parameters are pressurizer pressure and level, reactor coolant flow rate, core inlet temperature, and steam generator level. Each initial parameter initialization is preformed as following: The initial steam generator level, pressurizer pressure and pressurizer level are initialized through control systems and the reactor coolant flow rate is initialized by controlling the geometric K-factor in reactor coolant system. The core inlet temperature is also initialized by controlling the secondary pressure.

Two simplified tests are performed to verify the SPACE code initialization capability and the results are presented in the following section.

3. Application Result

3.1 System Modeling for Non-LOCA

Preliminary system model for the Shin Kori Units 3 and 4 (SKN 3&4) was developed to simulate non-LOCA transients. The modeling consists of major components modeling and the supplementary modeling such as NSSS control systems, kinetics, and various valves. Figure 1 shows the schematic nodalization diagram for the non-LOCA analysis of the SKN 3&4. The system model consists of 182 hydrodynamic cells and 113 faces. This model includes the reactor vessel, two steam generators, pressurizer, four reactor coolant pumps, and the related piping. The core region was split into two separate channels to simulate asymmetric transients like steam line break.

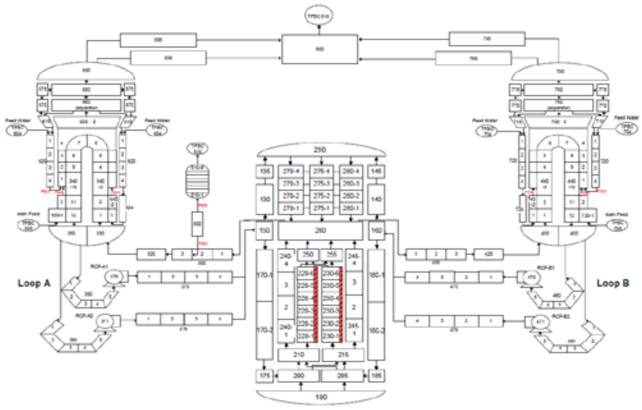

Fig.1. SPACE nodalization for Non-LOCA (SKN 3&4)

3.2 Steady-state initialization test

Based on the SKN 3&4 design data, the initial core power is assumed to be normal power (3,983MWt) and zero power (1MWt) with RCS cold leg temperature of

563.7K (555°F). The RCS cold leg temperature is initialized by adjusting the steam generator pressure. The pressruizer pressure and initial SG level are assumed to be 155.1bar (2,250 psia) and 76.87% WR These initial variables are initialized by control systems such as PPCS and FWCS. The total RCS flow rate is also assumed to be 20,991.2kg/s (166.6x10^6 lbm/hr).

Table I and Table II show the calculated values of the important parameters through full power and zero power steady state test. As shown in Table I and Table II, the SPACE results are close to the design data.

Table I: Design Data vs. Calculation Results (Full Power)

Items	SKN 3,4	SPACE
Pzr Pressure, psia	155.1	155.1
Hot leg temperature, K	597.04	596.93
Cold leg temperature, K	563.7	563.7
SG pressure, bar	68.95	68.85
Steam flow rate, kg/s	2,261.66	2,255.53

Table II: Design Data vs. Calculation Results (Zero Power)

Items	SKN 3,4	SPACE
Pzr Pressure, psia	155.1	155.1
Hot leg temperature, K	563.7	563.7
Cold leg temperature, K	563.7	563.7
SG pressure, bar	75.84	74.30
Steam flow rate, kg/s	0.57*	4.6

Note) * This value is calculated by 1/3,983 of steam flow rate at Full Power

Another simplified test is performed to evaluate the code initialization capability. For the test, the cold leg temperature is specified as initial conditions of 560.93K and 568.15K, respectively. The secondary pressure is controlled by controller for adjusting to the specified cold leg temperature. Figure 5 and 6 show the cold leg temperature and secondary pressure variation. The cold leg temperature reaches the desired temperature, 560.93K and 568.15K. In 560.93K, the steam generator pressure is initialized lower than that of 568.15K due to primary to secondary system heat balance. Other parameters, such as hot leg temperature, pressurizer pressure, reactor coolant flow, show a good agreement between the design data and the SPACE result.

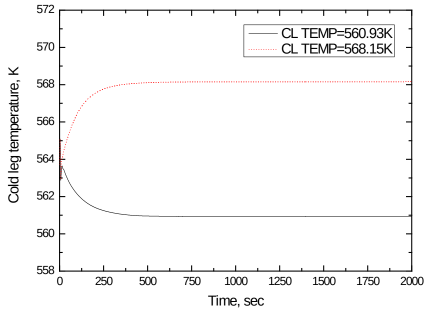

Fig.2. Cold leg temperature variation

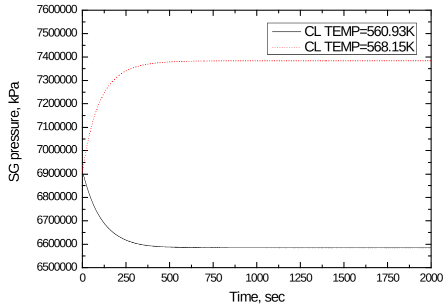

Fig.3. SG pressure variation

4. Conclusions

The SPACE system model for SKN 3&4 non-LOCA safety analysis is developed and several initialization options are implemented to the SPACE code in order to reduce the time, effort and cost to achieve a steady state. The steady state initialization and a test to evaluate the code initialization capability are also performed. The test results show that the SPACE code has sufficient capability to initialize the plant. This initialization and methodology still relys on the null transient which requires long computation time and impose considerable burden on the non-LOCA analyst. More study is needed in reducing the computational time to reach the steady state in future. Automatic initialization module implemented in the RETRAN-3D code [3] could be a good alternative to replace the initialization method based on null transient.

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