Feasibility Analysis on Simulation of PLCS Malfunction Event using SPACE Code

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1. Introduction

A computer code named 'Safety and Performance Analysis CodE (SPACE)' [1] has been being developed in order to replace several existing computer codes used in designing nuclear power plant (NPP) in Korea. This SPACE code is a system code and should be able to simulate various plant events, needed for safety analysis of pressurized water reactors (PWRs), such as loss of coolant accident (LOCA), steam line break (SLB), feedwater line break (FLB), steam generator tube rupture (SGTR), and several anticipated operational occurances (AOOs). Therefore, respective simulations of above events with the SPACE code should be verified and validated to utilize this code in the safety analysis.

In this work, a feasibility analysis is performed for the simulation of pressurizer level control system (PLCS) malfunction event for the Shin-Kori units 3 and 4 (SKN 3&4) [2].

2. PLCS Malfunction Event

The PLCS malfunction event is one of events in the increase of the reactor coolant system (RCS) inventory category described in section 15.5 of safety analysis report (SAR). Based on qualitative evaluations, the PLCS malfunction is selected to be the most limiting event in this category.

When in the automatic mode, the PLCS responds to changes in pressurizer level by changing charging and letdown flows to maintain the programmed level. The SKN 3&4 has two centrifugal charging pumps. Normally, one charging pump is running. The other charging pump is key-locked to prevent simultaneous operation of both charging pumps except pump switching operation. If the pressurizer level controller fails low or the level setpoint fails high, a low level signal can be transmitted to the controller. As response to this failed low level signal, the PLCS would control the charging flow to be maximized and close the letdown orifice isolation valves resulting in the minimum rate of mass discharge from the RCS as shown in Fig. 1 depicting the schematic nodalization.

The PLCS malfunction event is the event that pressurizes the RCS but does not threat the fuel integrity, hence the analysis of the PLCS malfunction event is performed with respect to the RCS pressurization.

3. Evaluation Methodology

In this work, the simulation of the PLCS malfunction event has been performed using the SPACE code.

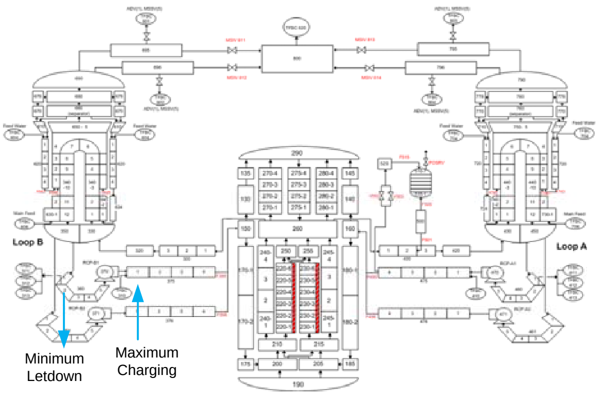

Fig. 1. SPCAE code nodalization for SKN 3&4.

3.1 Sequence of the events

The summarized sequence of events is as follows:

- PLCS malfunction
- Maximum charging and minimum letdown flow
- RCS pressurization
- Reactor and turbine trip
- Regulation of primary and secondary system pressure by POSRV and MSSV
- Operator action 1,800 seconds after event initiation

3.2 Iniial condition

The initial condition for the PLCS malfunction event is as follows:

Core power, MWt	*4,062.66*
PZR pressure, bar	*149.96*
PZR level, %	*60*
Core inlet temp., K	*569.26*
Charging flow, kg/s	*11.30*
Letdown flow, kg/s	*2.51*

3.3 Simulation Results

In order to adjust system parameters to the above initial condition, 3,000 second null-transient run was needed before the simulation of the PLCS malfunction event. The simulation of the main event was performed for 1,800 seconds and the results are as follows:

The most important viewpoint in this simulation is the trend of the RCS pressure change. When the PLCS malfunction occurs, the RCS pressure linearly increases because of net increase in the RCS inventory. This increase in the RCS pressure continues until a reactor trip occurs and the POSRV operates. Fig. 2 indicates the simulation result for the pressurizer pressure with the SPACE code. This figure shows that the pressurizer pressure linearly increases from initial value until it reaches the high pressurizer pressure trip setpoint about 270 seconds after the event initiation. Then the pressurizer pressure is regulated under a certain value by the POSRV operation. As shown in this figure, the simulation result expresses well the characteristics of the RCS pressure change.

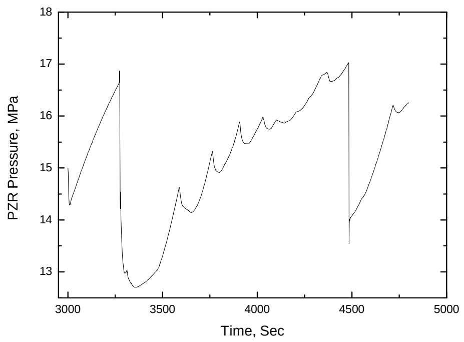

Fig. 2. Simulation result for pressurizer pressure.

For the PLCS malfunction event, the reactor is tripped by the high pressurizer pressure. In Fig. 3, the simulation result shows that the reactor power suddenly decreases due to reactor trip about 270 secs after the event initiation.

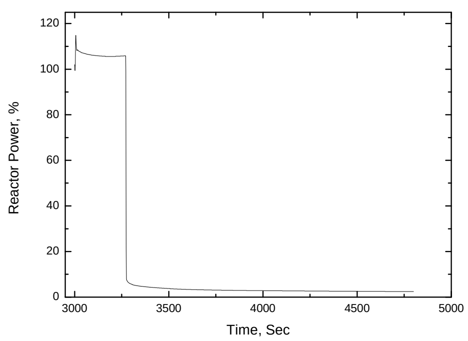

Fig. 3. Simulation result for reactor power.

During the PLCS malfunction event, the turbine is tripped following the reactor trip, resultng in the main steam isolation. This main steam isolation makes a sudden secondary pressure increase and the MSSVs open. By opening of the MSSVs, the secondary system pressurization is limited under a certain value. Fig. 4 and Fig. 5 indicate simulation results for these phenomena. As shown in Fig. 4, the steam generator (SG) pressure suddenly rises about 270 seconds after the event initiation, then is regulated by the operation of the MSSVs. Fig. 5 shows the simulation result for the total steam flow during the event. The steam flow suddenly decreases to near the zero value at the time the reactor is tripped. Then a little steam flow occurs according to the operation of MSSVs.

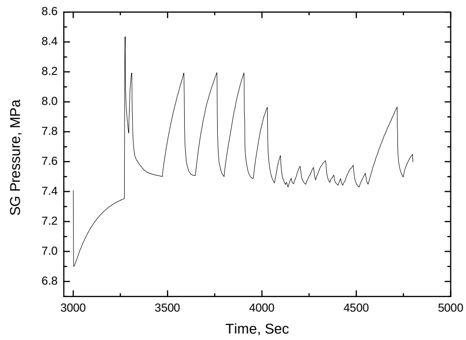

Fig. 4. Simulation result for steam generator pressure.

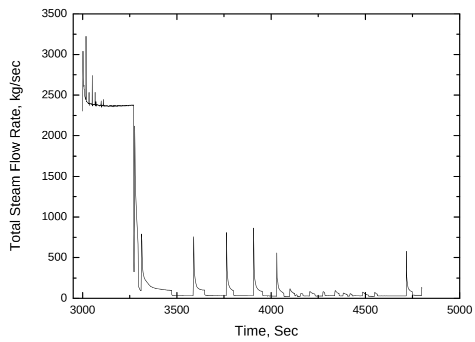

Fig. 5. Simulation result for total steam flow rate.

4. Conclusions

In this work, a feasibility analysis is performed for the simulation of the PLCS malfunction event using the SPACE code. From the results, the SPACE code is turned out to have sufficient simulation capability for the PLCS malfunction event even with deviations in compared with the SKN 3&4 FSAR result. Incompleteness of the modeling for the systems and components might be the reason for this discrepancy. In order to raise the accuracy of the simulation results, updating these modelings remains as future works.

Acknowledgment

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REFERENCES

[1] User’s Manual for SPACE code, KHNP, KEPCO-E&C and KAERI, 2011.
[2] SKN 3&4 Final Safety Analysis Report, Chapter 15.