Analysis of Shin-Kori 2 High Pressurizer Pressure Trip Event for Assessment of SPACE Pressurizer

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1. Introduction

The Korean nuclear industry developed a thermal-hydraulic analysis code for the safety analysis of PWRs, named SPACE(Safety and Performance Analysis Code for Nuclear Power Plant). As a part of code validation effort, Shin-Kori Unit 2 high pressurizer pressure trip transient is analyzed and the pressure response from SPACE pressurizer component is compared with those from RETRAN. To isolate the effect of SPACE pressurizer model, the system transient is analyzed with RETRAN code and the thermal hydraulic conditions from RETRAN are used as boundary condition for SPACE pressurizer model.

2. Shin-Kori Unit 2 High Pressure Trip Event

2.1 Description of the Plant

The Shin-Kori Unit 2 is a OPR1000(Optimized Power Reactor 1000) type reactor. It has rated thermal output of 2,775MWt and electric output of 1,000 WMe. It has 2 steam generators, 2 hotlegs, 4 coldlegs, 4 RCP(Reactor Coolant Pump)s and 1 pressurizer.

2.2 Description of Transient

The high pressurizer pressure trip occurred during turbine trip and natural circulation test of Shin-Kori unit 2. The RPCS(Reactor Power Cutback System) was disabled for the test. The RPCS is designed to avoid reactor trip during load rejection by rapidly inserting control rods and reducing core power. The initial condition for the test was plant running at 100% power. The test was initiated by manual turbine trip. Sudden reduction in secondary energy removal resulted in increase of RCS temperature and pressure. Eventually the pressurizer pressure reached reactor trip setpoint and reactor trip occurred.

3. Computer Codes

3.1 General Description of the SPACE Code

The SPACE code is an advanced thermal hydraulic analysis code capable of two-fluid, three-field analysis[1]. The SPACE code has many component models required for modeling a PWR, such as reactor coolant pump, safety injection tank, etc. The programming language used in the new code is C++, for new generation of engineers who are more comfortable with C/C++ than old FORTRAN language. The SPACE code can be used in LBLOCA, SBLOCA and Non-LOCA analysis of PWRs. The version used is SPACE 2.16.

3.2 General Description of the RETRAN Code

The RETRAN code is a thermal hydraulic system analysis code for Non-LOCA safety analysis, developed by EPRI[2]. The version used is RETRAN-3D MOD 3.1k. The RETRAN code basically uses 3 or 4 equation model for thermal hydraulic analysis. The 3 or 4 equation model assumes homogenous volume properties. The RETRAN code provides pressurizer model which allows non-equilibrium thermodynamic conditions which allows vapor and liquid region to have different temperatures.

4. Calculation Results

4.1 RETRAN Input

The NSSS system response of Shin-Kori Unit 2 high pressure trip event is analyzed using RETRAN code. The OPR1000 RETRAN basedeck was used for the analysis. The RETRAN nodalization of the OPR1000 is shown in Fig. 1. Two hot legs, four cold legs, two steam generators are modeled. The sequence of event for the transient is shown in Table 1.

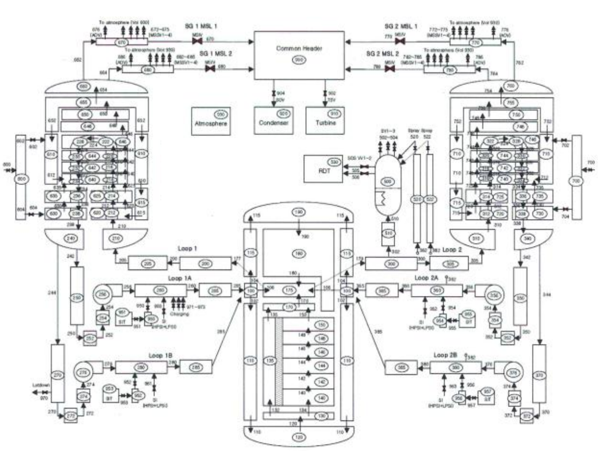

Fig. 1. RETRAN nodalization for OPR1000

Table 1. Major sequence of events

Event	Time [sec]
RPCS set to bypass mode	0
Turbine trip (manual)	27
Reactor trip (high pressurizer pressure)	36
End of calculation	1200

4.2 SPACE Input

For SPACE calculation, only the pressurizer and surge line are modelled. The surge line flow from hotleg is inputted as boundary condition. The surge flowrate from RETRAN calculation is used in flow boundary TFBC. The pressurizer spray flow rate is also from RETRAN. The pressurizer backup heater is modelled. To model heat capacity of pressurizer wall and surge line wall, heat structure input is used. However, heat loss to the atmosphere is not modelled.

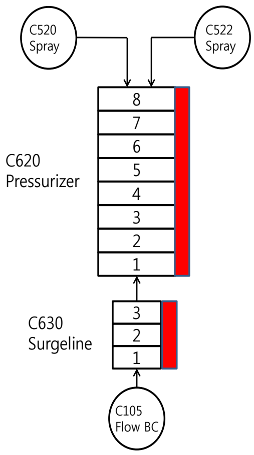

Fig. 1. SPACE Pressurizer Nodalization

4.3 Calculation Results

Fig. 2 shows pressurizer pressure response during the transient. After manual turbine trip, heat transfer to the secondary side is reduced and primary side temperature increases as the result of energy imbalance. Increase in RCS temperature results in expansion of primary coolant and increase of pressurizer pressure. Although pressurizer spray is activated to reduce pressure, the insurge flow rate is too high to stabilize pressurizer pressure. The pressurizer pressure reaches high pressure trip setpoint and reactor trip occurs. After reactor trip, the RCS pressure is reduced due to cooling through steam dump. As pressurizer pressure is reduced below certain point, the pressurizer heater is activated to increase pressure. The pressure response of RETRAN and plant data are somewhat different due to differences in control system and lack of operator action that is not modelled in RETRAN. The pressure response of RETRAN and SPACE show better agreement.

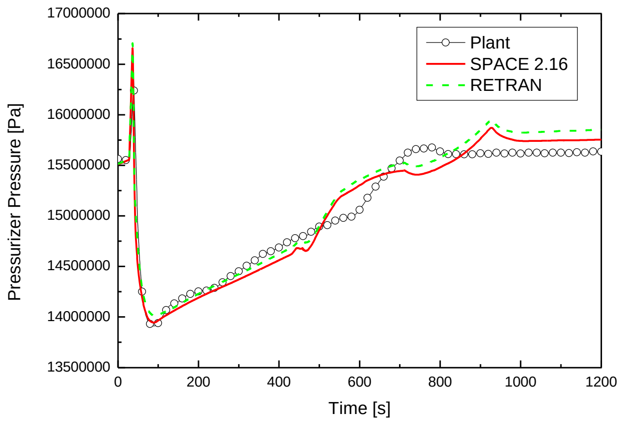

Fig. 2. Pressurizer pressure

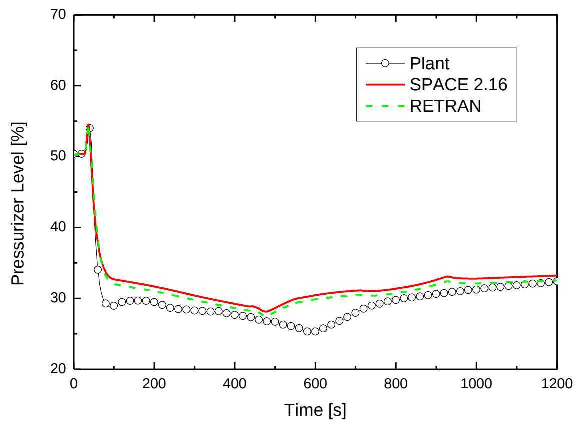

Fig. 3. Pressurizer level

5. Conclusions

Shin-Kori Unit 2 high pressurizer pressure trip transient is analyzed and the pressure response from SPACE pressurizer component is compared with those from RETRAN. The pressure response of RETRAN and SPACE show reasonable agreement.

Acknowledgement

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REFERENCES

[1] SPACE Users Manual, KHNP, 2015

[2] NP-7450(A), RETRAN-3D - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems Volume 3 : User's Manual, Electric Power Research Institute, 2004

[3] Dong-Hyuk Lee, Bum-Soo Youn, and Seyun Kim, Assessment of Pressurizer Transients using SPACE Code, Transactions of the Korean Nuclear Society Autumn Meeting 2011, KNS, 2011

[4] Nuclear Power Plant Accident Report 2012-03, Shin-Kori Unit 2 High Pressurizer Pressure Reactor Trip During Start-up Test, KINS, 2012