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OPR1000 RCP Flow Coastdown Analysis using SPACE Code

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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). Current loss of flow transient analysis of OPR1000 uses COAST code to calculate transient RCS(Reactor Coolant System) flow. The COAST code calculates RCS loop flow using pump performance curves and RCP(Reactor Coolant Pump) inertia. In this paper, SPACE code is used to reproduce RCS flowrates calculated by COAST code.

2. CE Analysis Method for Loss of Flow

2.1 Description of loss of flow transient

The loss of flow transient is transient initiated by reduction of forced reactor coolant circulation. Typical loss of flow transients are complete loss of flow(CLOF) and locked rotor(LR). The complete loss of flow assumes trip of all RCPs. After RCP trip, pumps slowly loose speed and flow rates are reduced. The RCP does not stop immediately because of flywheel rotational inertia. The locked rotor accident assumes sudden stop of 1 RCP. For the locked rotor case, one RCP is assumed to lock and instantly stop rotating.

2.2 Description of CE analysis method

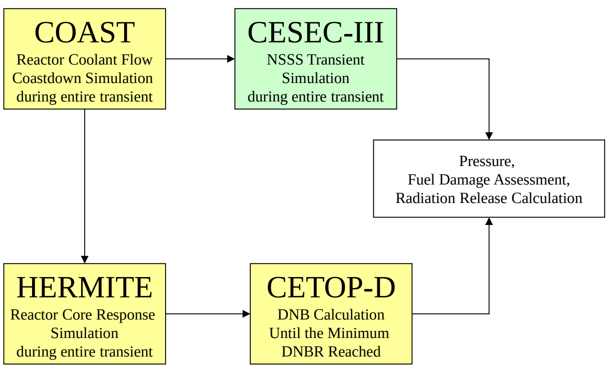

Fig. 1. CE Analysis Method for Loss of Flow Transient

In the original CE analysis method for loss of flow, the COAST code is used to calculate RCS flow during pump coastdown. The result from COAST is supplied to CESEC-III and HERMITE. CESEC-III calculates system parameters such as RCS pressure, temperature, MSSV steam flow rate. HERMITE calculates transient core power and generates an input file for CETOP-D. CETOP-D calculates the minimum DNBR during the transient. With the minimum DNBR from CETOP-D and MSSV steam release from CESEC-III, fuel damage and radiation release are calculated.

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 2.19.

3.2 Description of COAST Code

The COAST code calculates RCS flow rate for loss of flow transients. The COAST code uses 7 flow paths to represent the RCS system. Loss coefficients and fluid densities variations for each flow path are considered. It has detailed model for the RCP pump characteristics. Separate pump performance data for each RCP can be used. The pump input uses head, flow and torque data.

4. Calculation Results

4.1 SPACE Input

To reproduce COAST code results with SPACE code, the RCS system of OPR1000 was modeled using 8 hydraulic components. The reactor vessel was modeled with a pipe component with 2 cells. Each of hotleg was modeled with branch component. The coldleg and RCP were lumped together and modeled with a pump component (total of 4 pumps). A pressure boundary was added to reactor vessel to control pressure of RCS system. Heat structures were added to add heat to the reactor and remove heat from hotlegs. The RCP performance data were inputted using non-dimensional homologous curves. To match calculation conditions with reference COAST run, the initial RCS flowrates were set to 95% of design value. Loss coefficients along the flow paths were adjusted to get desired RCS flowrates. The rotational inertia of the RCP were adjusted to 90% of design value, same as in COAST run. The initiating event for complete loss of flow is RCP trip at t=0sec.

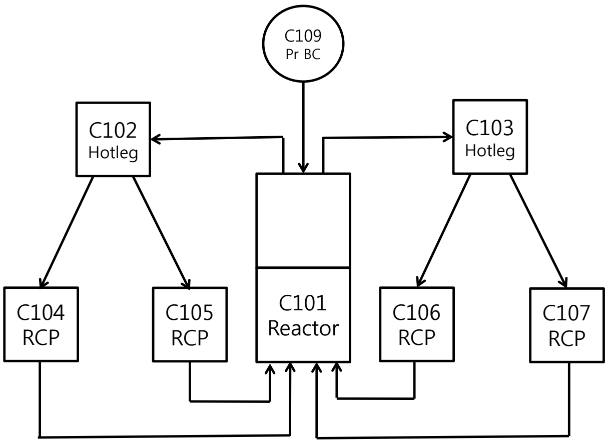

Fig. 2. SPACE Nodalization for OPR1000 Flow Coastdown

4.2 Calculation Results

RCP coastdown flowrate for complete loss flow transient was calculated with SPACE and COAST code and results were compared. The RCPs are tripped at t=0sec. After RCP trip, the RCS flow does not suddenly change to zero, since rotational inertia of RCP flywheel provides gradual reduction in RCS flow.

Fig. 3 shows normalized RCP speed as a function of time. At 10 seconds after RCP trip, the RCP is rotating at about 60% of normal operating speed. The results of SPACE code and COAST code show good agreement.

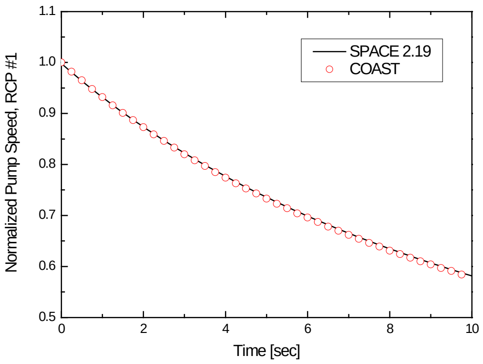

Fig. 3. Comparison of Normalized RCP Speed for SPACE and COAST

Fig. 4 shows normalized RCP flow as a function of time. At 10 seconds after reactor trip, the RCS flowrate is about 60% of normal flow. The results of SPACE code and COAST code show good agreement. From these results, we can conclude that using simplified SPACE nodalization, RCP flow coastdown from COAST can be reproduced using SPACE code.

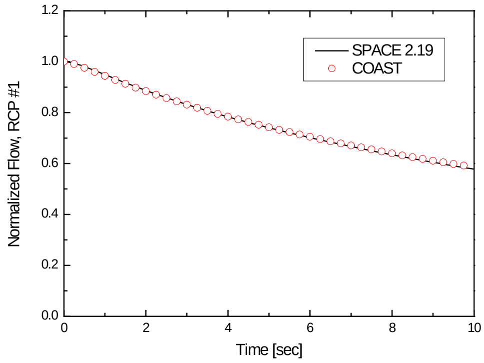

Fig. 4. Comparison of Normalized RCP Flow for SPACE and COAST

5. Conclusions

OPR1000 RCP flow coastdown analysis was performed using SPACE using simplified nodalization. Complete loss of flow(4 RCP trip) was analyzed. The results show good agreement with those from COAST code, which is CE code for calculating RCS flow during loss of flow transients. Through this study, we confirmed that SPACE code can be used instead of COAST code for RCP flow coastdown analysis.

Acknowledgement

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