APR1400 Complete Loss of Flow Accident Analysis using KNAP

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1. Introduction

KEPRI (Korea Electric Power Research Institute) has been developing safety analysis methodology for non-LOCA (Loss Of Coolant Accident) analysis of OPR1000 (Optimized Power Reactor 1000, formerly KSNP). The new methodology, named KNAP (Korea Non-LOCA Analysis Package), uses RETRAN as the main system analysis code. RETRAN code is a non-LOCA safety analysis code developed by EPRI. The new methodology will replace existing CE (Combustion Engineering) supplied codes and methodologies currently used in non-LOCA analysis of OPR1000. In this paper, we apply KNAP methodology to APR1400 (Advanced Power Reactor 1400).

The complete loss of flow transient is one of the "decrease in reactor coolant system flow rate" events and the results are typically described in the chapter 15.3.1 of SAR (Safety Analysis Report).

The APR1400 has been designed to generate 1,400MWe of electricity with advanced features for greatly enhanced safety and economic goals. The complete loss of flow transient in APR1400 SSAR (Standard Safety Analysis Report) is analyzed with COAST, HERMITE, CETOP and CESEC-III computer codes.

In this study, to confirm the applicability of the KNAP methodology and code system to APR1400, complete loss of flow transient is analyzed using RETRAN code and it is compared with results from APR1400 SSAR.

2. Analysis method

2.1 Description of the transient

The loss of flow transient is initiated by tripping of one or more RCPs. When RCP trip occurs, the power supply to the RCP pump is cut off. The RCP loses the motor torque and the speed of pump rotation begins to decrease. The rate of decrease of pump rotation, also called pump coastdown, is largely dependent on the moment of inertia of the pump. As pump speed decreases, the driving force for reactor coolant flow is reduced and reactor coolant flow rate decreases.

The loss of flow transient includes partial loss of flow and complete loss of flow. The event is initiated by RCP trip and reactor trip is initiated by low coolant flow signal. The main criteria for safety is the minimum DNBR(Departure from Nucleate Boiling Ratio). In terms of safety analysis, the complete loss of flow (in this plant, 4 pump trip) is usually more limiting than partial loss of flow. Therefore, the complete loss of flow transient is analyzed to cover both partial and complete loss of flow transient.

2.2 Analysis method

The KNAP methodology is used to analyze the complete loss of flow transient. The main analysis code is RETRAN-3D. For DNBR calculation, CETOP-D code is used.

The standard nodalization of APR1400 is as shown in Figure 1. The primary side nodalization includes 6-node reactor core section, 2 steam generators, 2 hotlegs, 4 coldlegs, 4 RCPs (Reactor Coolant Pump) and a pressurizer. The secondary side model includes multi-node steam generators, 4 main steam lines, MSSVs (Main Steam Safety Valve), and main/auxiliary feedwater.

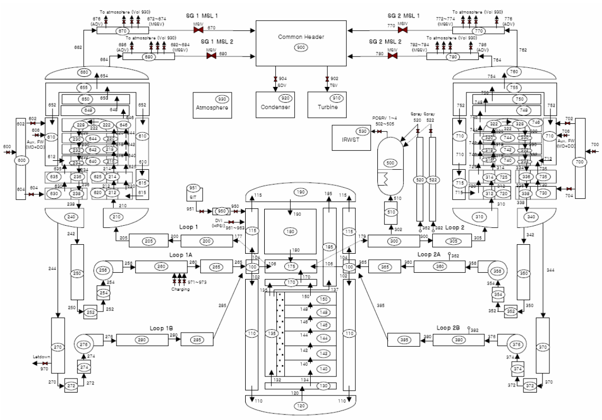

Figure 1. RETRAN Nodalization for APR1400

The complete loss of flow transient is modeled by tripping all reactor coolant pumps at the beginning of the transient. The RETRAN-3D calculates system parameters, such as core power, heat flux, RCS pressure, temperature, and the time of reactor trip, etc. Core heat flux, core inlet temperature, RCS pressure, core flow rate are calculated by RETRAN-3D and transferred to CETOP-D for DNBR calculation.

3. Analysis results

3.1 Initial conditions and assumptions

Initial conditions for the complete loss of flow are chosen to minimize minimum DNBR during the transient. The initial conditions and assumptions are as follows: maximum core power(102% of nominal value), maximum RCS pressure, and maximum core flowrate.

The axial power shape for DNBR analysis is ASI=+0.3. ROPM (Required Over Power Margin) of 118% is assumed.

The transient is initiated by RCP trip at t=0.0s. The low RCP speed trip setpoint is assumed to be 94.8% of initial speed. A delay time of 0.3s for reactor trip signal is assumed after the setpoint is reached.

3.2 Analysis Results

The complete loss of flow transient is initiated by RCP trip. The RCP loses the motor torque and the speed of pump rotation begins to decrease. The rate of decrease of pump rotation, also called pump coastdown, is largely dependent on the moment of inertia of the pump. As pump speed decreases, the driving force for reactor coolant flow is reduced and reactor coolant flow rate decreases. The decrease in core flowrate is shown in Figure 2. The results from RETRAN calculation show good agreement with those from SSAR.

The reactor trip is initiated by low RCP speed at about t=0.94s. The reactor is tripped early in the transient and the core power is reduced to decay heat level as shown in figure 3. The results from RETRAN calculation are similar to that from SSAR.

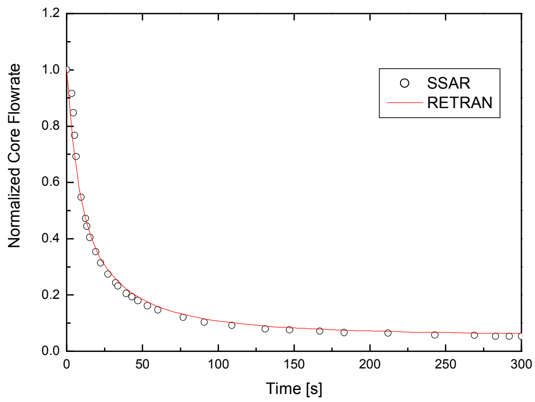

Figure 2. Core flowrate vs time

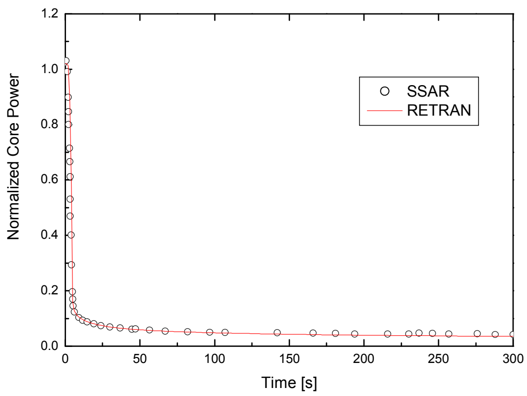

Figure 3. Core power vs time

The DNBR is calculated by CETOP-D. As core flowrate decreases, DNBR also begin to decrease. The DNBR continues to decrease until control rods are inserted and core heat flux begins to decrease. The minimum DNBR occurs around t=3s. The minimum DNBR remains above 1.35 and safety criterion is met.

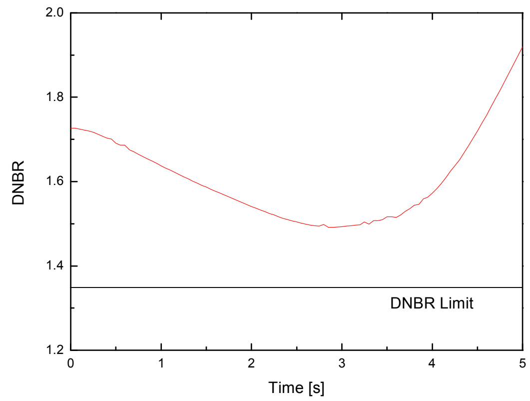

Figure 4. DNBR vs time

4. Conclusion

The KNAP methodology is applied to APR1400 complete loss of flow transient and the results are compared with those mentioned in APR1400 SSAR. The results from RETRAN calculation and SSAR show similar results.

The maximum RCS and secondary pressures do not exceed 110% of design pressure and the minimum DNBR remains above 1.35. So the safety criteria for complete loss of flow is met.

This analysis supports the extension of applicability of KNAP methodology to APR1400.

Acknowledgements

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