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APR1400 Locked Rotor Transient Analysis using KNAP

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1. Introduction

KEPRI (Korea Electric Power Research Institute) has developed 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 for most transients. For locked rotor transient DNBR analysis, UNICORN-TM code is used. UNICORN-TM is the unified code of RETRAN, MASTER and TORC. The UNICORN-TM has 1-D and 3-D neutron kinetics calculation capability. For locked rotor DNBR analysis, 1-D neutron kinetics is used. In this paper, we apply KNAP methodology to APR1400 (Advanced Power Reactor 1400) locked rotor analysis and compare the results with those in the APR1400 SSAR(Standard Safety Analysis Report).

The locked rotor transient is one of the "decrease in reactor coolant system flow rate" events and the results are typically described in the chapter 15.3.3 of SAR (Safety Analysis Report).

In this study, to confirm the applicability of the KNAP methodology and code system to APR1400, locked rotor transient is analyzed using UNICORN-TM code and the results are compared with those from APR1400 SSAR.

2. Analysis method

2.1 Description of the transient

The locked rotor transient is initiated when one of RCP(reactor coolant pump) rotor suddenly stops rotating or becomes locked. RCP rotor can be locked due to seizure of the upper or lower thrust bearing supporting the rotor. When locked rotor occurs, RCS flow rate for that RCP is suddenly reduced. This leads to reduced core flowrate and reduced DNBR. The reactor is tripped due to low RCS flow trip signal. Following reactor trip, loss of offsite power is assumed. The core power decreases as control rods drop to the core and insert negative reactivity. The transient is terminated when DNBR begins to increase due to reduction in core power.

2.2 Analysis method

The original CE analysis method is shown in Fig. 1. The COAST code is used to calculate reactor coolant flow rate during the transient. The result of 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 minimum DNBR from CETOP-D and MSSV steam release from CESEC-III, fuel damage and radiation release is calculated.

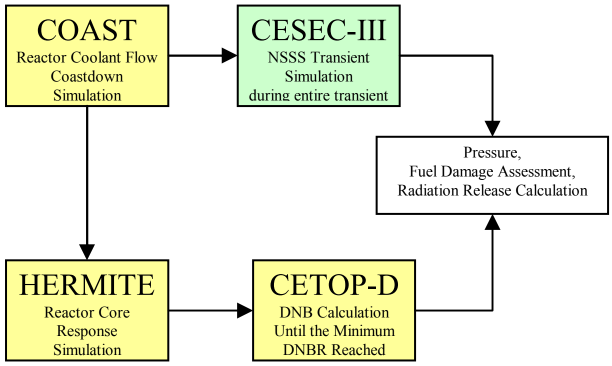

Figure 1. CE Loss of Flow Analysis Methodology

The KNAP methodology uses RETRAN-3D as the main analysis code. For 1-D or 3-D neutron kinetics calculation, UNICORN-TM is used in place of RETRAN-3D. For locked rotor DNBR analysis, UNICORN-TM replaces COAST and HERMITE in CE analysis method. For both HERMITE and UNICORN-TM, 1-D neutron kinetics calculation is used to calculate core power. The KNAP analysis methodology for loss of flow transient is shown in Fig. 2.

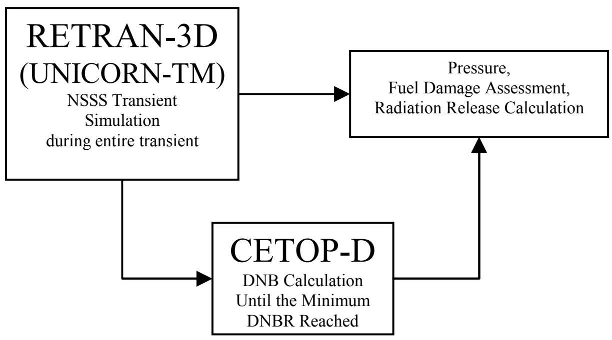

Figure 2. KNAP Loss of Flow Analysis Methodology

The UNICORN-TM code shares the same basic system nodalization with RETRAN-3D. The standard nodalization of APR1400 is as shown in Figure 3. The primary side nodalization includes 6-node reactor core section, 2 steam generators, 2 hotlegs, 4 coldlegs, 4 RCPs 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.

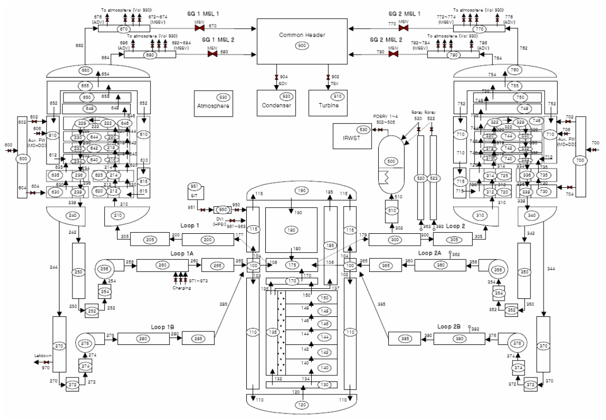

Figure 3. RETRAN Nodalization for APR1400

The locked rotor transient is modeled using pump stop card in RETRAN module of UNICORN-TM. The RETRAN-3D calculates system parameters, such as core flowrate, RCS pressure, temperature, and the time of reactor trip, etc. The core power is calculated by MASTER 1D module of UNICORN-TM. Core heat flux, core inlet temperature, RCS pressure, core flow rate are calculated by UNICORN-TM and transferred to CETOP-D for DNBR calculation.

3. Analysis results

3.1 Initial conditions and assumptions

Initial conditions for the locked rotor are chosen to minimize the minimum DNBR during the transient. The initial conditions and assumptions are as follows: maximum core power(102% of nominal value), maximum RCS pressure, and minimum core flowrate. The axial power shape for DNBR analysis is ASI=+0.3.

The transient is initiated by one RCP locks at t=0.0s. The reactor trip occurs by low hotleg RCS flowrate signal. The low RCS flowrate trip setpoint is assumed to be 80% of initial flow. A delay time of 1.2s for reactor trip signal is assumed after the setpoint is reached.

3.2 Analysis Results

The locked rotor transient is initiated by a sudden stop of one RCP. The flowrate of the loop with the locked RCP decreases rapidly. The core coolant flowrate also decreases. This results in reduced DNBR. The reactor trip signal is assumed to be generated by low hotleg RCS flowrate signal. The reactor trip occurs at t=1.36 sec. Until control rods drop to core and insert negative reactivity, the reactor power remains nearly constant. At the time of reactor trip, loss of offsite is assumed, and other 3 RCPs begin to coastdown. This leads to further reduction of DNBR until reactor power begins to decrease. The minimum DNBR occurs at t=2.6sec. The minimum DNBR from UNICORN-TM calculation is 1.10 and value obtained from SSAR is 1.11.

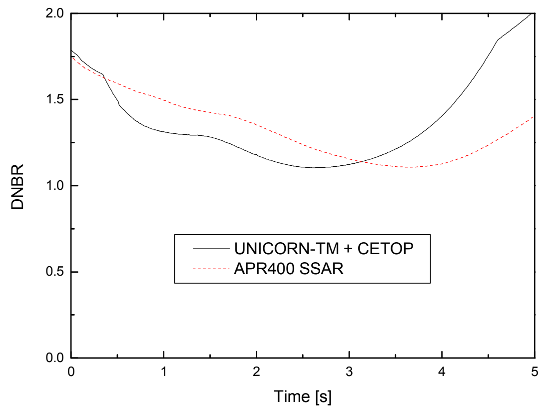

Figure 4. DNBR vs time

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 safety criteria for locked rotor requires dose evaluation, which is outside the scope of this paper.

4. Conclusion

The KNAP methodology is applied to APR1400 locked rotor transient and the results are compared with those mentioned in APR1400 SSAR. The mimimum DNBR value from UNICORN-TM calculation and those from APR1400 SSAR show similar results. This analysis supports the extension of applicability of KNAP methodology to APR1400.

Acknowledgements

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