Application of Multi-Dimensional Core Transient Analysis for RCP Locked Rotor Accident

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Introduction

KNF/KHNP currently uses the LR methodology using SPACE (safety and performance analysis code for nuclear power plants). The method consists of core power calculation with point kinetics model and hot pin behavior calculation with the detailed fuel model. The point kinetics model with conservative assumptions makes more severe results compared to realistic core power behavior. Therefore, it is required to use 3D kinetics model at the core power calculation. Recently, the topical methodology of CEA ejection accident analysis for APR1400 plant has been submitted, which uses CHASER (a coupling code for 3-dimensional core analysis) developed by KNF, and approved by KOREA institute of nuclear safety (KINS).

This poster presents the application of the LR analysis methodology based on CHASER 3D kinetics model for core power calculation instead of using SPACE point kinetics model. In the present study, the current hot pin behavior calculation logic using SPACE code is not changed to maintain the conservatism of the current hot pin calculation. All the evaluations are simulated for an APR1400 plant with PLUS7[TM] fuel.

Methodology

☐ Coupling Scheme and Calculation Flow Chart

Figure 1 shows main flow chart of the LR analysis including code coupling scheme for pin-by-pin level power behavior transient.

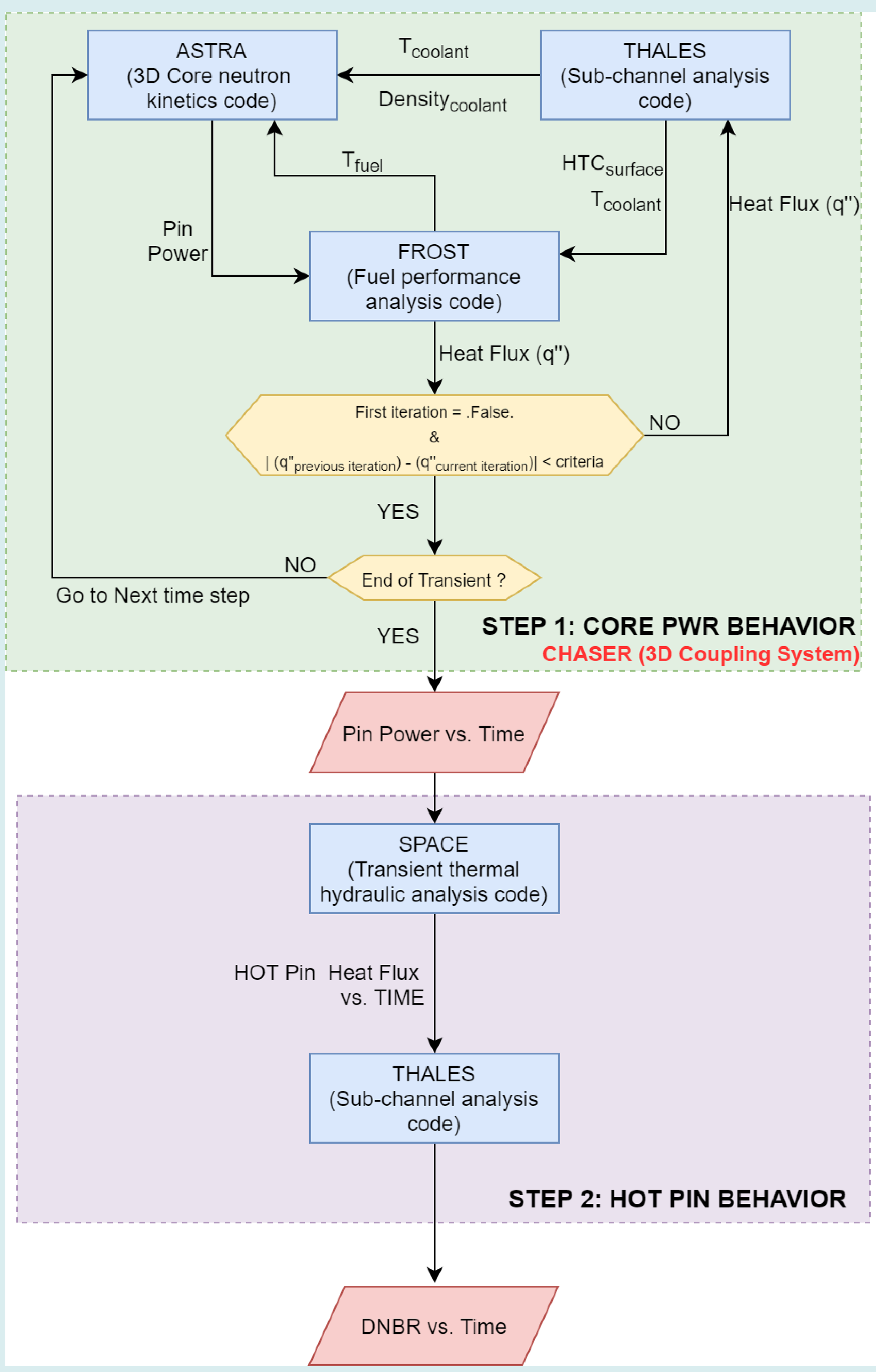

Fig 1. Main flow chart of the LR analysis

For the pin-by-pin power behavior (step 1), CHASER controls the results of core analysis code using message passing interface (MPI). ASTRA (3D core neutron kinetics code) calculates nuclear power and FROST (fuel performance analysis) calculates fuel temperature and THALES (subchannel analysis code) calculates coolant temperature/ density. The hot pin behavior (step 2) is conducted after the end of step 1. The hot pin power behavior with time is transferred from CHASER to SPACE code and it calculates fuel surface heat flux during the transient. THALES calculates DNBR using KCE-1 CHF correlation with the transferred heat flux.

☐ Axial Power Distribution Grouping

Since most APDs are similar to others, the number of analysis cases is reduced. Figure 2 shows the extremely various APDs. Figure 3 shows the representative APDs.

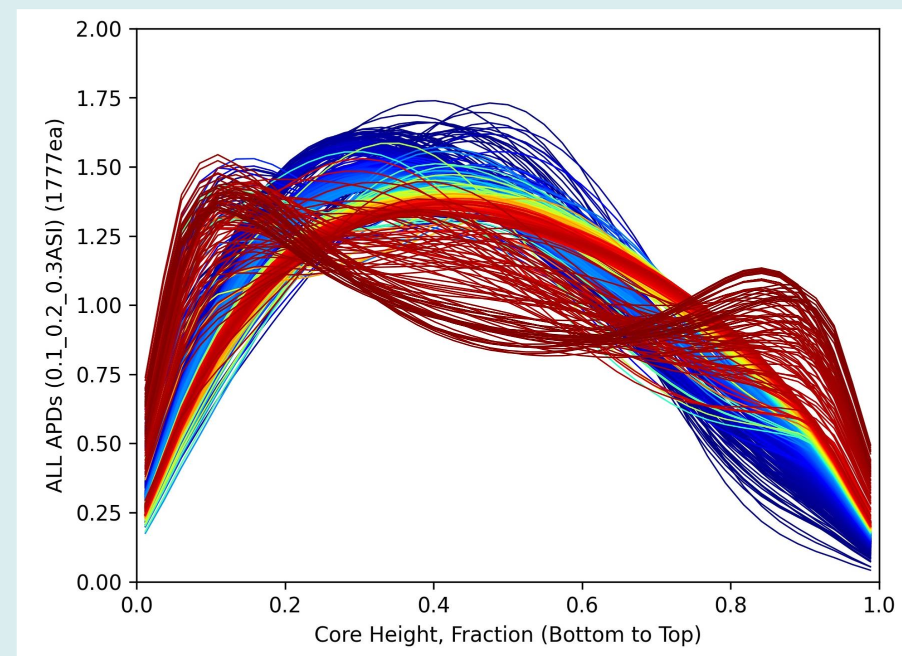

Fig 2. Total APDs for 0.1, 0.2, 0.3 ASI

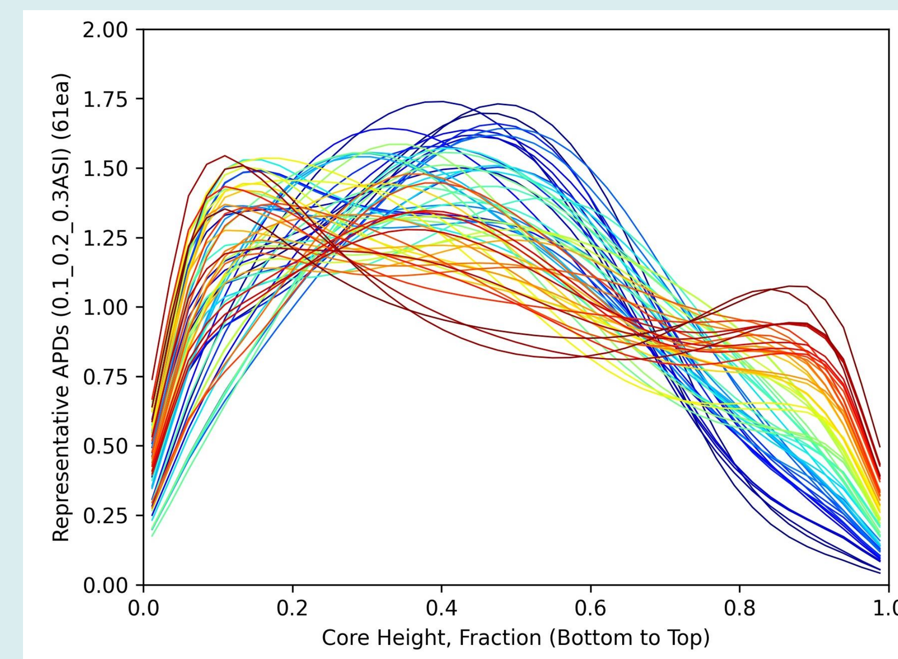

Fig 3. Representative APDs

☐ Analysis Results

Table 1 and Figure 4 shows minimum DNBR results between the 3D kinetics (CHASER, 3D) and the point kinetics (SPACE, 0D) methodology. Initial conditions and analysis assumptions between 3D and 0D are the same except analysis model. DNBR results are significantly improved by using CHASER(3D). This trend is caused by faster core power reduction and power distribution change due to the 3D effect.

Table 1. DNBR Results for CHASER(3D) and SPACE(0D)

	0.1ASI		0.2ASI		0.3ASI	
	C(3D)	S(0D)	C(3D)	S(0D)	C(3D)	S(0D)
AVG	1.318	1.069	1.382	1.155	1.404	1.277
S. Dev.[2]	0.022	0.078	0.026	0.107	0.006	0.087
MIN	1.281	0.958	1.344	1.006	1.392	1.133

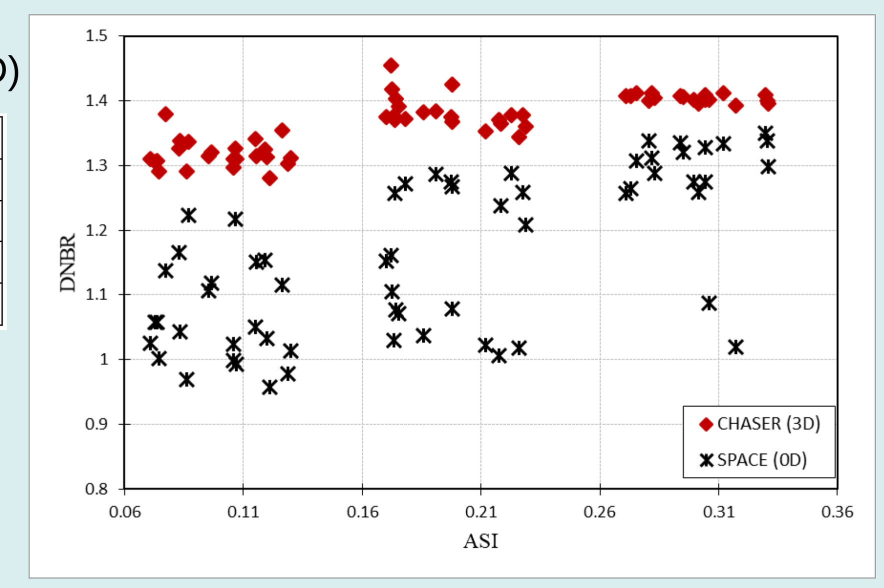

Fig 4. DNBR vs. ASI

The faster core power reduction is due to the explicit modeling of neutron absorption by CEA insertion in CHASER(3D). SPACE(0D) for core power calculation assumes the same negative reactivity insertion data after reactor trip for all APD cases. The radial and axial core power distribution are changed in CHASER(3D) due to core flow reduction and CEA insertion. Core flow reduction results in the radial power peak decrease before CEA insertion. CEA insertion leads to APD movements to the bottom. (see Fig. 5)

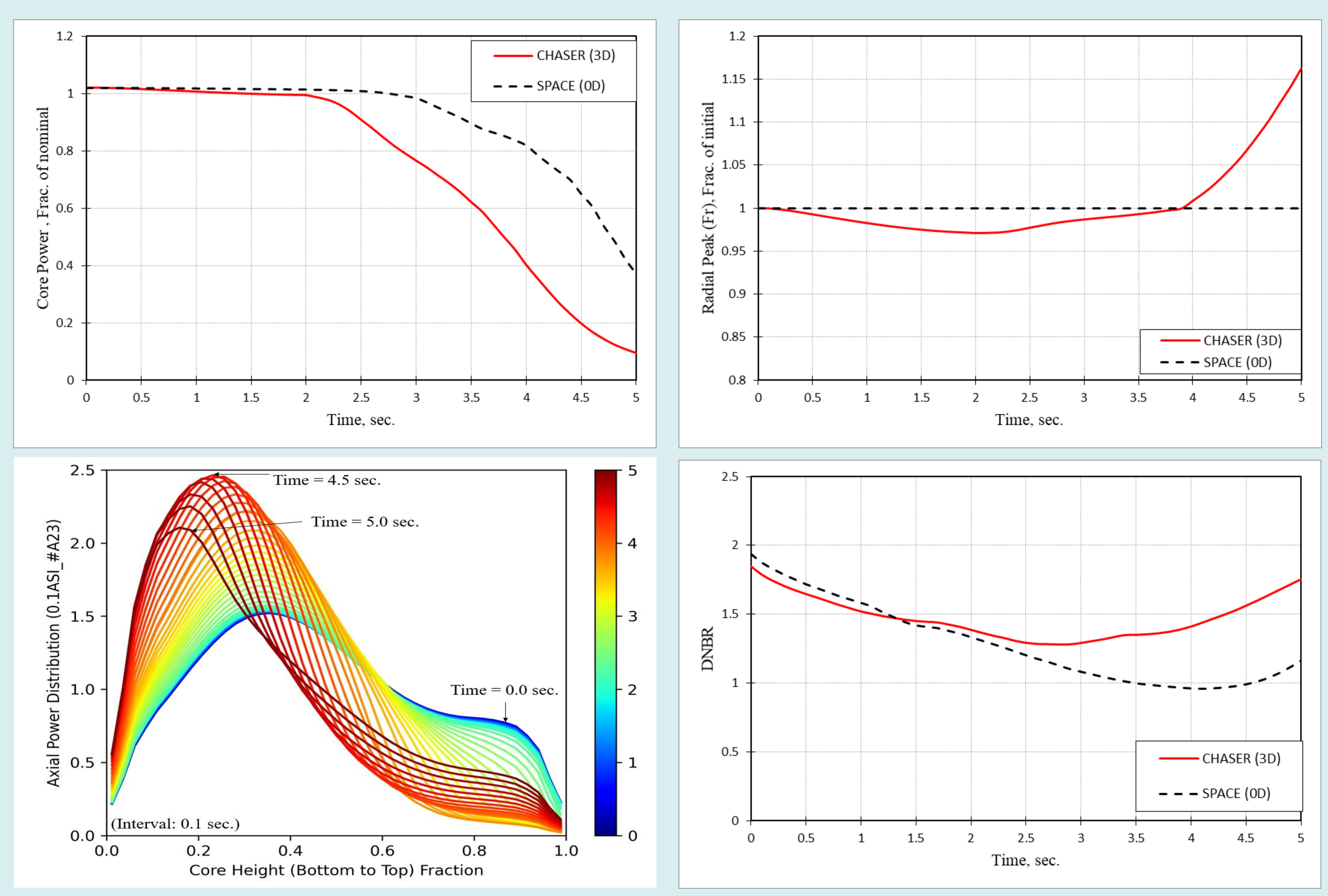

Fig 5. Main parameter behaviors with time

Conclusion

The LR analysis was conducted using the 3D neutron kinetics system (CHASER) for the pin-by-pin power behavior calculation and the transient thermal hydraulic analysis code (SPACE) for the hot pin behavior calculation. CHASER calculates faster core power reduction and power distribution changes due to the explicit modeling of neutron absorption by CEA insertion and thermal hydraulic condition changes. In conclusion, this 3D kinetics model results in more safety margin for DNBR than the current point kinetics model.