Development Perspective of Regulatory Audit Code System for SFR Nuclear Safety Evaluation

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1. Introduction

A sodium-cooled fast reactor (SFR) in Korea is based on the KALIMER-600 concept developed by KAERI. Based on "Long-term R&D Plan for Future Reactor Systems" which was approved by the Korea Atomic Energy Commission in 2008, the KAERI designer is scheduled to apply the design certification of the prototype SFR in 2017. In order to establish regulatory infrastructure for the licensing of a prototype SFR, KINS has develop the regulatory requirements for the demonstration SFR since 2010, and are scheduled to develop the regulatory audit code systems in regard to core, fuel, and system, etc. since 2012.

In this study, the domestic code systems used for core design and safety evaluation of PWRs and the nuclear physics and code system for SFRs were briefly reviewed, and the development perspective of regulatory audit code system for SFR nuclear safety evaluation were derived.

2. Code Systems for Core Design and Safety Evaluation of PWRs

In order to establish the development perspective of regulatory audit code system for SFR nuclear safety analysis, the design and evaluation code systems for domestic PWR cores were investigated. For the independent verification calculation, KINS has distinct nuclear analysis tools from ones used by designer, which are shown in Table 1.

The regulatory nuclear code systems for PWRs consist of separate tools to verify lattice calculation, core analysis, criticality analysis and core inventory calculation, respectively. Also, in order to verify the spatial kinetics coupled system code used by designer, such as MARS/MASTER, the independent coupled code such as RELAP5/PARCS and MARS/COREDAX were developed. For the criticality analysis, the common code such as MCNP using the Monte Carlo method has been used.

3. Nuclear Physics and Code Systems for SFRs

3.1 Nuclear Physics

Fast reactors have fundamental differences in core characteristics compared to thermal reactors, which make assumptions and methods used in existing PWR analyses not applicable [1]. These features are as follows: (1) the scattering resonances of intermediate atomic mass nuclides such as Na-23 and Fe-56 and the lack of 1/E spectrum for the calculation of heavy isotope resonance absorption require very detailed modeling for slowing-down calculations, (2) the hard neutron spectrum in the keV and MeV range makes it important to model anisotropic scattering, inelastic scattering, (n,2n) reaction and unresolved resonance self-shielding, and (3) the long mean free path due to small absorption cross sections in fast energy region implies global coupling of the core and results in the dominant reactivity feedback by geometrical expansions.

3.2 Nuclear Analysis Code Systems

In order to understand the nuclear analysis systems of SFR cores, the current code ones applicable to SFRs were reviewed. The systems are as follows: ANL code system (USA) [1], ERANOS (CEA, France) [2], FAST (PSI, Switzerland) [3], and K-CORE (KAERI, Korea) [4], etc.

Table 1. Various Codes used for Design and Evaluation of PWR Cores

		Codes used by Designer	Codes used by KINS
Nuclear Design	Lattice Calculation	DIT, PARAGON, PHOENIX-P, KARMA, WIMS, CASMO	SCALE/TRITON, HELIOS
	Core Analysis	ROCS, ANC, ASTRA, RFSP, MASTER	COREDAX, PARCS
Criticality Analysis		MCNP, KENO	KENO, MCNP
Core Inventory Calculation		SAS2H, CASMO	SCALE/TRITON, ORIGEN

These code systems which employ the multi-step calculation process similar to existing PWR one consist of separate tools for cross-section generation, whole-core calculation, neutronics coupled system calculation, depletion calculation, perturbation analysis, criticality calculation as shown in Figure 1.

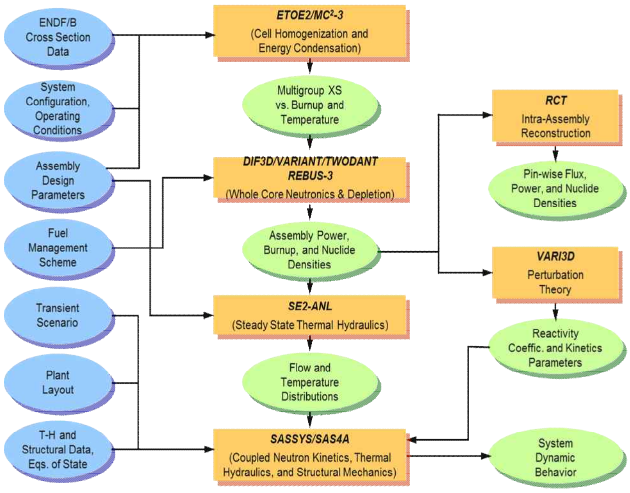

Figure 1. ANL Code System

In CONRAD system (CEA, EU) [5] and SHARP project (ANL, USA) [6] which are recently being developed, the reduced multi-step approximations is being tried to utilize directly cross-section library data without cell or assembly homogenization in core calculation.

4. Development Perspective of SFR Regulatory Nuclear Code System

Through the above review, the development strategy of SFR regulatory nuclear code system was derived.

In order to establish the regulatory code system, the system has to fundamentally include the tools which verify the lattice calculation for assembly-homogenized group constants and the whole-core calculation. These tools are required to employ the high fidelity methods to solve the district characteristics of SFR nuclear physics mentioned in Section 3.1. Namely, the lattice calculation code has to employ the method to implement detailed slowing-down calculation and treat anisotropic scattering, inelastic scattering, (n,2n) reaction and unresolved resonance self-shielding. The whole-core calculation code requires the transport theory capabilities for treatment of global coupling.

Also, the whole-core spatial kinetics capability is required to simulate physical phenomena accurately.

The development directions of these separate tools are to introduce and modify existing ones, or develop newly after evaluating the applicability of current tools for SFRs, advanced domestic tools excluding ones used in Korean SFR core design, and KINS nuclear evaluation codes for PWRs. The development plan of SFR regulatory code systems is shown in Table 2.

Table 2. Development Plan of SFR Regulatory Tools

	Years	Research Objective
1st	'12	Establishment of Development Strategy
	'13	Code Development for Evaluation of Static Reactor Characteristics - Cross-section generation - Whole-core calculation
	'14	
2nd	'15	Code Development for Evaluation of Reactor Dynamics - Neutron kinetics calculation - Neutronics coupled system calculation
	'16	Verification of Code Systems

5. Conclusions

In order to establish the development strategy of regulatory audit code system for SFR nuclear safety analysis, the domestic code systems used for core design and safety evaluation of PWRs and the nuclear physics and code system for SFRs were briefly reviewed. As a result, the development perspective of them was derived.

The regulatory audit code system for SFR nuclear safety evaluation will be developed employing the high fidelity methods to solve the specific characteristics for SFR cores compared to PWR ones.

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