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Development of Core Simulator for Education & Training of Low Power Physics Test

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1. Introduction

After every outage of nuclear power plant, low power physics test (LPPT) is essential for verifying the nuclear design and robustness of reactor safety. Because outage is performed by every 18 months for each station, understanding of core management staff performing the LPPT is very lack. First of all, they are cannot be trained using reactivity computer due to no real analogue signal from reactor core or simulator.

LPPT is largely consisting of five measurement steps as below;

- Approach to first criticality
- Search Point of Adding Heat(POAH)
- Measurement of Boron End Point
- Measurement of Isothermal Temperature Coefficient
- Measurement of Control Rod Worth

Core simulator (CoSi) is developed so intuitive that core management staff or students for studying nuclear engineering could understand the reactor physics phenomena. CoSi software is made up of three main modules which are data input module, core calculation module, output display module. Hardware is realized panel of main control room easy for trainee to operate.

In the next Section, detailed software and hardware of CoSi are introduced to simulate the five measurement steps of LPPT.

2. Core Simulator

2.1 Software Module

As shown Figure 1, CoSi software module is made up of three main modules which are data input module, core calculation module, output display module.

2.1.1 Input Module

Input module has useful sub-modules which can control rod device, boron concentration, and moderator temperature. These parameters are used for input data for three dimensional core calculation and are displayed on output panel in real time.

2.1.2 RAST-K : Three Dimensional Real Time Core Kinetic Calculation Prgram

In order to calculate exact core power and feedback effect as time varying, 3-D real time core kinetic calculation should be performed. For these use RAST-K[1] program is applied in CoSi. RAST-K was already verified at over 50 dynamic control rod measurements (DCRM) of domestic PWR. 2 and 3 Dimensional neutron diffusion equation can be solved by non-linear NEM/ANM CMFD (Nodal Expansion Method/Analytic Nodal Method) using RAST-K program. Eigen value and adjoint flux is obtained for steady state, and transient state can also be analyzed. For verification of CoSi, some benchmark problems were performed. Figure 2 shows the result of comparison for NEACRP 3D fast transient case C1 at steady state [2]. The maximum error is 0.007. As shown in Figure 3, RAST-K is also compared with PACKS code results for MSLB the second-phase benchmark problem [3]. The results of RAST-K are similar with those of PACKS and mean value.

2.1.3 Output Module

In output module, it extracts from calculation result of RAST-K as like reactor power, axial shape index, reactivity, and fast/thermal flux for providing current core state to user. Also it converts digital detector flux readings to real analogue signal for providing reactivity computer.

2.2 Hardware

As shown Figure 4, CoSi hardware is 4 display panel and high performance PC server. Those display panels can operate the core condition.

2.2.1 Display Panel

In output module, it has 2 LCD monitor and 2 LCD touch monitor for user friendly interface as shown in figure 4. Display I provides core map and control or shutdown bank position. Display II shows trend chart which can display power level (%FP), axial shape index (ASI), moderator temperature (℃), boron concentration (ppm), and reactivity (pcm). In display III, control bank and shutdown bank can be chosen by touch mode. Display IV is used to change test modes, set the administrator mode. Moreover, rod moving lever and bank selection switch are installed on the panel.

2.2.2 Analogue Signal Output Module

One of special function of CoSi is to generate analogue signals of ex-core detector and moderator temperature which are converted using the digital to analogue. Digital ex-core detector signal come from results of RAST-K. Figure 5 shows

3. Results

Software and hardware was developed for core management staff of nuclear power plant and student studying nuclear engineering. The accuracy of core simulator was proven by benchmarking problem and nuclear design data. Training and education was performed several times on core management staffs at nuclear education center in Kori. Preliminary LPPT was also performed on Shin Kori staff for initial core condition. These training and education was of much help for testing staff and achieving the LPPT.

Acknowledgement

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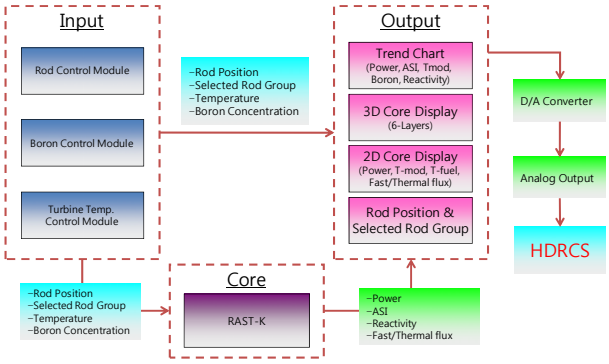

Figure 1 Modules of CoSi Software

0.1721	0.2868	0.2755	0.6803	0.9993	0.9648	0.4389	0.5217
0.1705	0.2845	0.2739	0.6778	0.9978	0.9638	0.4387	0.5219
0.002	0.002	0.002	0.003	0.002	0.001	0.000	0.000
0.2868	0.3682	0.4498	0.7585	0.9794	1.0000	0.7968	0.4619
0.2845	0.3653	0.4473	0.7560	0.9775	1.0000	0.7976	0.4623
0.002	0.003	0.003	0.002	0.002	0.000	0.001	0.000
0.2755	0.4498	0.3458	0.7391	0.9472	0.9428	0.8860	
0.2739	0.4473	0.3441	0.7371	0.9466	0.9434	0.8886	
0.002	0.003	0.002	0.002	0.001	0.001	0.003	
0.6803	0.7585	0.7391	0.7862	0.7366	0.8220	0.5970	
0.6778	0.7560	0.7371	0.7848	0.7362	0.8235	0.5985	
0.003	0.002	0.002	0.001	0.000	0.001	0.002	
0.9993	0.9794	0.9472	0.7366	0.3425	0.4456		
0.9978	0.9775	0.9466	0.7362	0.3423	0.4471		
0.002	0.002	0.001	0.000	0.000	0.001		
0.9648	1.0000	0.9428	0.8220	0.4456		RAST-K	
0.9638	1.0000	0.9434	0.8235	0.4471		PANTHER	
0.001	0.000	0.001	0.001	0.001		ERR	
0.4389	0.7968	0.8860	0.5970				
0.4387	0.7976	0.8886	0.5985		MAX.	0.003	
0.000	0.001	0.003	0.002		AVG.	0.001	
0.5217	0.4619						
0.5219	0.4623						
0.000	0.000						

Figure 2 NEACRP 3D Fast Transient: Case C1 steady state

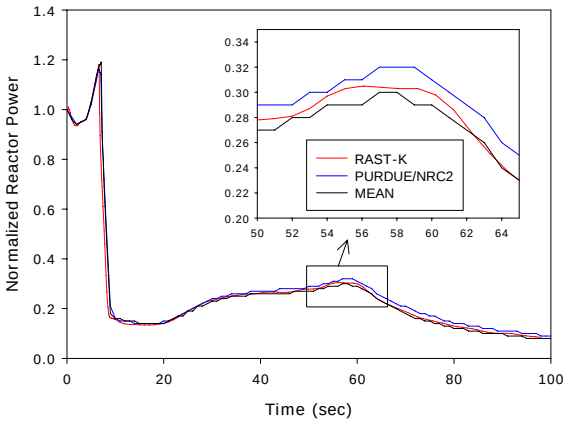

Figure 3 MSLB Benchmark: Core Power Variation

Figure 4 CoSi Hardware

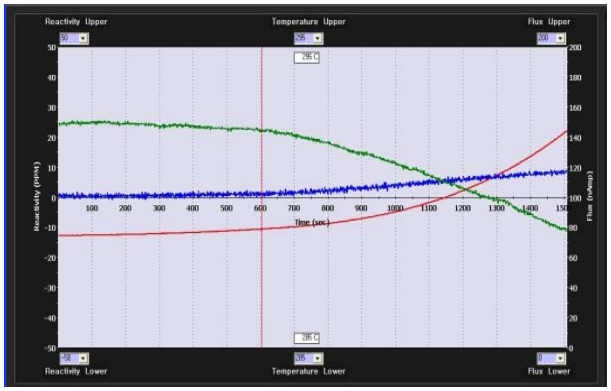

Figure 5 Test Result Using Reactivity Computer