Real-time Model Development of Core Protection and Monitoring System for SMART Simulator Application

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1. Introduction

A multi-purpose best-estimate simulator for the SMART is being established which is purposed to be used as a tool to evaluate the impacts of design changes on the safety performance, and to improve and/or optimize the operating procedure of the SMART. In keeping with these purposes, a real-time model of the digital core protection and monitoring systems was developed on the basis of SCOPS and SCOMS algorithms of SMART[1,2]. Important features of the software models are described for the application to SMART simulator. A real-time performance of the models was examined for various simulation scenarios.

2. Methods and Results

2.1 Real-time Model Development

The SCOPS_SSIM and SCOMS_SSIM code are being developed as a protection and monitoring program for SMART simulator, respectively. These codes will be loaded as DLL or executable file in simulator platform. Each code receives system variables from the simulator, performs core protection or monitoring algorithms and then returns calculated variables to the simulator platform. The codes are developed based on SCOPS and SCOMS which were core simulation code for the analysis of SMART core protection and monitoring systems. SCOPS calculates the minimum DNBR and maximum LPD and keeps the core condition safe during anticipated occurrences or postulated accidents. SCOMS calculates the variables of limiting conditions for operation (LCO) and assists the operator in implementing the technical specification requirements for monitoring.

Software design bases and requirements are setup for simulator application as well as software performance requirements. Also, input/output variables, how to execute software and how to connect software with simulator platform are discussed and determined. Fig. 1 shows the SCOMS_SSIM software connection way with SMART simulator. The common memory of simulator is used as a data communication buffer. SCOMS_SSIM obtains system variables and then calculates pre-defined monitoring variables with real-time. System code, neutronics code, thermo-hydraulics code and all other related codes are linked with simulator platform, so does SCOMS_SSIM. These codes perform their unique algorithm and provide calculated information to common memory of simulator. As shown in Fig. 1, SCOMS_SSIM calculates LCO and monitoring variables with received system variable and library file. This inter-communication has to meet performance requirements. SCOPS_SSIM are connected with SMART simulator with similar way, too.

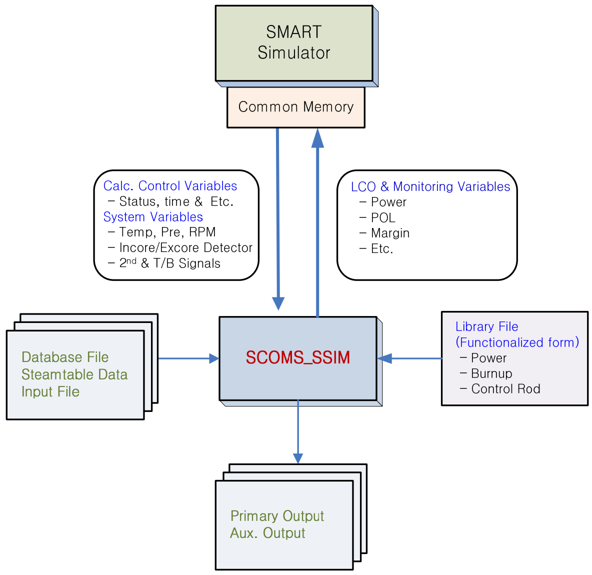

Fig. 1. SCOMS_SSIM code connection with Simulator

In model development, protection and monitoring algorithms are improved and input/output format is changed. The real-time capability of SCOMS_SSIM was enhanced in order to satisfy the performance requirement of simulator. SCOMS_SSIM synthesizes 3-dimensional core power distribution using incore detector signals with provided library as shown in Fig. 1. The library is functionalized with function of core power, burnup and control rod positions. The library is composed of several sets of coefficients used in synthesis of power calculation and provided by MASTER code calculation.

Fig. 2 shows the synthesized power distribution and its error. As seen, radial power distribution error (axially integrated 2-D power) shows the maximum 0.01% which is negligible value. These trivial errors are less than the truncation error of about 0.02% caused by the number of digits for the power distribution and detector signals[3].

SCOMS_SSIM			0.841	1.005	0.841			
MASTER			0.841	1.005	0.841			
% ERR.			0.004	0.009	0.004			
		0.839	1.118	1.174	1.118	0.839		
		0.839	1.118	1.174	1.118	0.839		
		0.003	0.009	0.006	0.009	0.004		
	0.839	1.100	1.001	1.067	1.001	1.100	0.839	
	0.839	1.100	1.001	1.067	1.001	1.100	0.839	
	0.003	0.007	0.001	-0.002	0.001	0.007	0.004	
0.841	1.118	1.001	1.048	1.002	1.048	1.001	1.118	0.841
0.841	1.118	1.001	1.048	1.001	1.048	1.001	1.118	0.841
0.007	0.009	0.001	-0.004	-0.002	-0.004	0.001	0.009	0.004
1.005	1.174	1.067	1.002	1.034	1.002	1.067	1.174	1.005
1.005	1.174	1.067	1.001	1.034	1.001	1.067	1.174	1.005
0.010	0.006	-0.002	-0.002	-0.006	-0.002	-0.002	0.006	0.010
0.841	1.118	1.001	1.048	1.002	1.048	1.001	1.118	0.841
0.841	1.118	1.001	1.048	1.001	1.048	1.001	1.118	0.841
0.004	0.009	0.001	-0.004	-0.002	-0.004	0.001	0.010	0.008
	0.839	1.100	1.001	1.067	1.001	1.100	0.839	
	0.839	1.100	1.001	1.067	1.001	1.100	0.839	
	0.004	0.007	0.001	-0.002	0.001	0.007	0.004	
		0.839	1.118	1.174	1.118	0.839		
		0.839	1.118	1.174	1.118	0.839		
		0.004	0.009	0.006	0.009	0.004		
			0.841	1.005	0.841			
			0.841	1.005	0.841			
			0.008	0.010	0.005			

MAX. ERROR = 0.010(56)

Fig. 2. Axially integrated power distribution error (MASTER vs. SCOMS_SSIM)

2.2 Performance Tests and Results

Real-time performance tests are done for SCOPS_SSIM and SCOMS_SSIM software. Several test cases were selected in order to verify the input/output processing performance and justness of real-time protection and monitoring algorithm. Input signals are arbitrary determined for the simulation of steady-state and transient conditions. Fig. 3 shows the one of test results of SCOPS_SSIM simulation. As a flow related accident, core flow sharply decreases and returns to initial value as time goes. Core flow is simulated with function of rotational speed of reactor pump. As seen in Fig, core flow rate changes proportional to pump speed and DNBR follows flow rate. Various simulation cases including noted flow accident are tested as follows:

- Trip(or Pretrip) variable generation
- LCO variable generation
- Power(1st, 2nd,T/B) calculation
- DNBR/LPD calculation
- Power distribution synthesis
- POL(Power Operation Limit) calculation.
- And real-time performance of most test cases

Though the results of all the cases are good agreements with expected or referenced results, more sophisticated simulations are needed for the various range of cases, especially, under the integrated platform situation, i.e., all the stand-alone software are coupled with platform.

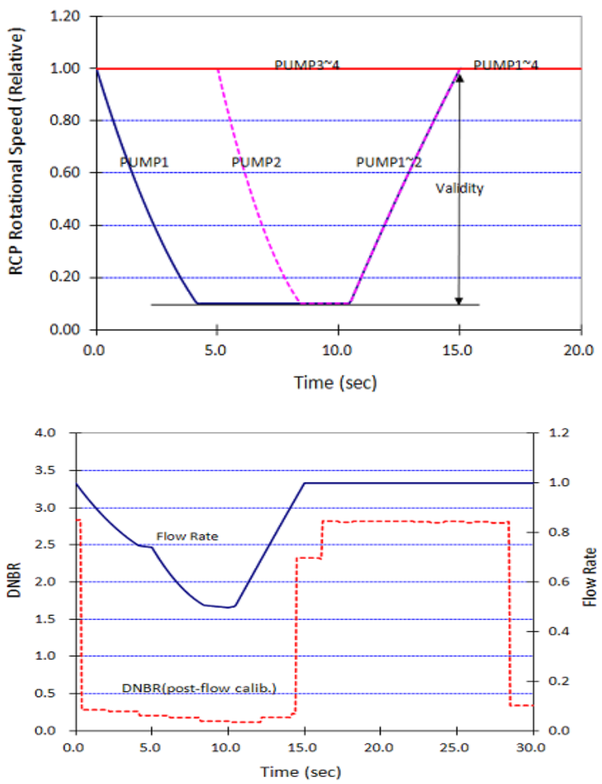

Fig. 3. Test results of SCOPS_SSIM software real-time performance

3. Conclusions

Areal-time model development of core protection and monitoring algorithms for SMART simulator is being studied. Software algorithms as well as design bases and requirements for core protection and monitoring are developed and various performance tests are done. From test results, it is judged that SCOPS_SSIM and SCOMS_SSIM algorithms and calculational capabilities are appropriate for core protection and monitoring program in SMART simulator.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea Government (MEST, No. 2012M2A8A4026261).

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