Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

Zero Power Physics Test by using Core Simulator(CoSi) for OPR1000

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1. Introduction

Core Simulator(CoSi) has been developed to enhance the core management staff's proficiency for Zero Power Physics Test(ZPPT) of OPR1000. ZPPT mainly consists of three types of tests, which are to confirm the initial critical phenomena with boron dilution to determine boron end point(BEP), temperature reactivity coefficient to measure isothermal temperature coefficient(ITC) and bank worth measurement with boron dilution method for reference bank, swap method for regulating bank, and dynamic control rod worth measurement(DCRM) for equilibrium core. Core management staff performs ZPPT at least every one and half year. So periodic training for ZPPT should be required to minimize human error in that test and to be well acquainted with test procedures. CoSi could provide environments for readiness of all test procedure of initial OPR1000 core.

2. Core Simulator

2.1 CoSi Software Configurations

CoSi consists of three parts as illustrated in figure 1. RAST-K is a calculating engine for the neutronic physics in a core, Input Interface Modules treat control rod movement, boron concentration change and temperature feedback in coolant as an input data for RAST-K core calculation. Output Interface Modules handle the output data generated from RAST-K, which used to produce trend chart containing reactor power, coolant temperature, boron concentration and reactivity in a core. The 2D or 3D power distributions are displayed that are selected by user's decision. Output Interface Modules can also generate the major reactivity parameters into reactivity computer.

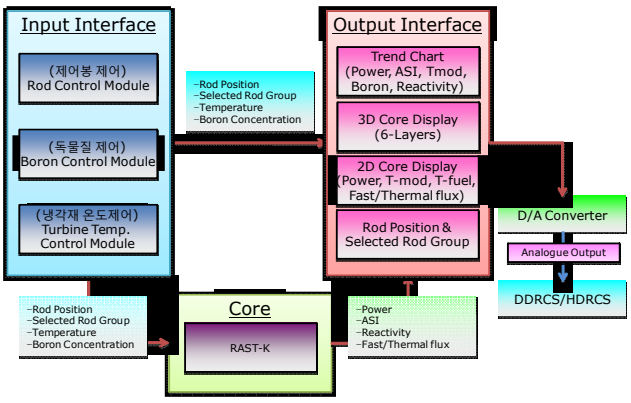

Fig. 1 Schematic Diagram of CoSi

2.2 CoSi Hardware Configurations

CoSi includes four monitoring panels of rod position and main core parameters in Main Control Room of OPR1000(Fig.2). CoSi's panels show fuel assembly and control rod bank position, reactor power(%), average moderator temperature(℃), boron concentration(ppm), boration and dilution information which handle moderator makeup water rate(liter/min) and boron makeup flow rate(liter/min), moderator heating/cooling rate(℃/min), vertical position of control bank and digital display of control bank position. CoSi is able to connect with reactivity computer and print on strip chart. CoSi provides real time chart for reactor core parameters.

Fig. 2 CoSi Hardware

3. ZPPT Simulation for OPR1000

3.1 Initial Critical Test

During critical approach test, Subcriticality is monitored with inverse count rate ratio in equation (1). Then, inverse count rate ratio is

$$\frac{C_0}{C_i} = \frac{1}{M} = 1 - K_{eff} \qquad (1)$$

Where C_0 is initial count rate (CPS), C_i is count rate at i-th loading step.

CoSi can clearly represent difference between subcritical and critical state of core. POAH(Point of Adding Heat) is founded by the related procedure. Final critical boron concentration at first critical point should be finalized by calibrating residual rod worth of lead bank.

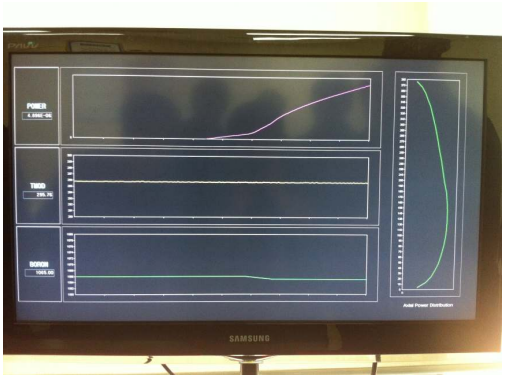

Fig. 3 Initial Critical Approach

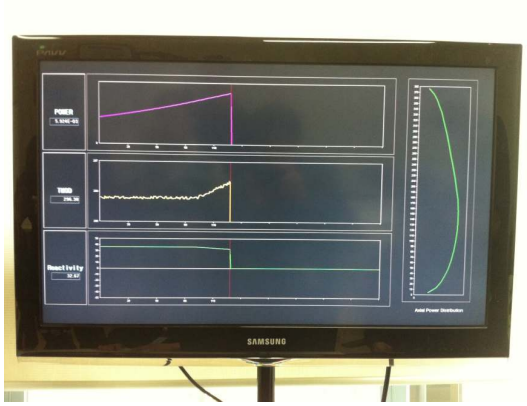

Fig. 4 POAH

3.2 Temperature Reactivity Measurement

Isothermal temperature coefficient can be measured as a same procedure used in commercial NPP(Nuclear Power Plant) . Both endpoint and slop methods are used in calculating ITC of OPR1000.

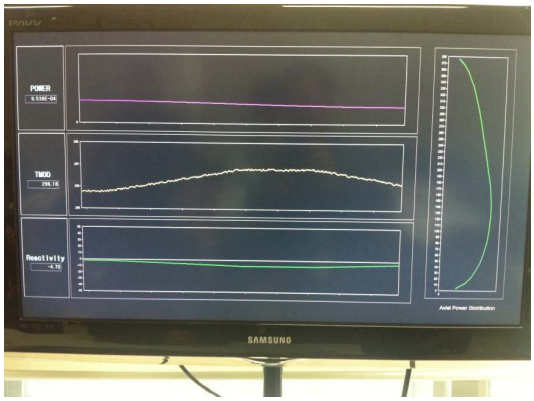

Fig. 5 ITC Measurement

3.3 Rod Worth Measurement

Rod worth can be measured by boron dilution method for reference bank, swapping method and dynamic control rod measurement. Reference rod bank must be measured by boron dilution method. These three methods are simulated in CoSi.

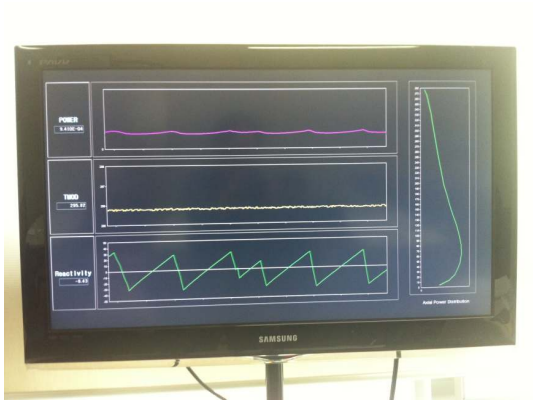

Fig. 6 Boron Dilution Method

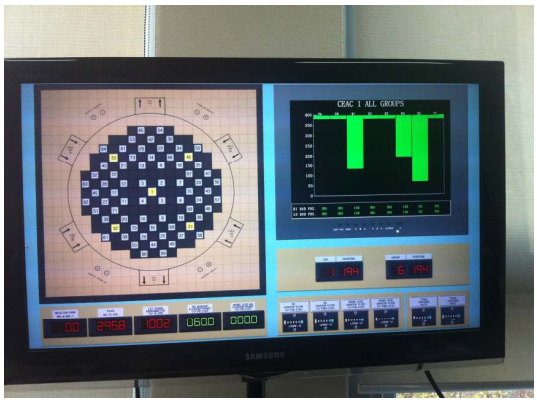

Fig. 7 Rod Swapping Method

4. Conclusion

CoSi has been developed for the training of core management staff in the area of zero power physics test in order to enhance the capacity of core management personnel in OPR1000. Through this training, reactor parameters in zero power physics test are determined as the same way as commercial nuclear power plant's test procedure before real reactor physics test.

Training test consists of confirming initial critical approach, point of adding heat, boron end point and measuring isothermal temperature coefficient and rod bank worth in a various way.

Reference

[1] "DOE Fundamentals Handbook Instrumentation and Control," DOE-HDBK-1013/2-92, Vol. 2, 1992.
[2] KHNP SWN, "Initial Fuel Loading," 9S-L-422-01, Test Procedure. 2012.
[3] KHNP SWN, "Low Power Physics Teest," 9S-L-422-02, Test Procedure. 2012.