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Improvement Plan for Reactivity Measurement System of HANARO

Beomwoo Park*, Byung-gun Park and Dong Hyuk Lee
Korea Atomic Energy Research Institute
**bwpark@kaeri.re.kr*

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1. Introduction

The reactivity worth of control absorber rods(CARs) and shut-off rods(SORs) is measured to ensure the safety during the refueling phase at HANARO, the research reactor in KAERI. After the full-power operation of the reactor is completed, the depleted fuels are discharged and replaced with the fresh fuels. At the startup phase of the refueled reactor, reload startup physics tests are performed to validate the designed neutronic characteristics of reload core[1]. At HANARO, the reload startup physics tests consist of the measurements of the critical CAR position and the shutdown margin. By comparing the measured critical CAR position with calculated one, the CAR's reactivity control capability is verified. The reactor's shutdown capability of shutdown system is also validated by ensuring the measured shutdown margin, defined as N-1 SORs reactivity worth, meets the acceptance criteria.

The Compensated Ion Chambers(CICs) and a multi-channel wide range digital reactivity computer have been used for HANARO's reload startup physics test. The reactivity computer is based on a personal computer equipped with an analog to digital converter, and the application program was developed in the MS-DOS environment. The reload startup physics tests are conducted following a procedure for measuring CAR and SOR reactivity worth at zero-power. The procedure includes steps for approaching criticality and measuring control rod worth and shutdown margin using CICs located outside the heavy water tank. Currently, one of the two CICs is in use due to operational issues.

When CAR or SOR reactivity measurements are performed using only one CIC, the measured value may not be accurate due to the relative position between the detector and rods. Additionally, the DOS-based reactivity computer currently in use is outdated, has difficulties in storing and transferring data to other PCs, and is specifically designed for use with the CIC. In this study, as a first step toward improving the long-term reactivity measurement system of HANARO, a procedure using three channels of Reactor Regulation System(RRS) signals is introduced into the reload physics tests to address inaccuracies caused by the using a single detector. Furthermore, the development of a Windows-based reactivity computer based on a real-time reactivity calculation program using the RRS is also introduced. This paper examines the expected improvements by replacing one CIC with the RRS and confirms that RRS signals are reliably acquired during the approach to critical at zero power.

2. Design requirement

The measurements of the critical CAR position and the shutdown margin are performed using one CIC during the reload physics tests as parts of periodic inspections of HANARO. The measured critical CAR position should match the calculated value within 10 %, and the measured shutdown margin, the minimum N-1 reactivity worth of the four SORs, should exceed 10 mk. The CAR worth measurement is not performed because it is supposed to be conducted using two CICs. Introducing the RRS instead of the CIC offers certain advantages.

During reactor startup after a long-term shutdown of HANARO, the neutron signal was not detected in the CIC due to the decay of fission products emitting delayed neutrons and high-energy photons for photo-neutrons. Instead of using the CIC, the logarithmic power signals of RRS were used with the inverse multiplication method to approach criticality[2]. In addition, there is an inconvenience in the process of reactivity calculation using CIC. Keithley-614 reads the current signal of CIC and generates 0.1~10 V every three decades of current signals, which the reactivity computer then reads as voltages. If the CIC current crosses the boundary of three decades, the reactivity computer has difficulty continuously determining the reactor power. Therefore, in case of large negative reactivity insertion, such as the shutdown margin measurement, the power level should be appropriately limited so that the current signal remains within three decades, or an algorithm should be implemented to determine the boundary of the current signal over three decades[3]. In contrast, the logarithmic power of RRS provides 0~10 V over a wide range of ten decades, eliminating the need to limit the power range of reload physics test. In addition, the shutdown margin measurement using one CIC always occurs under the condition where the SOR adjacent to the CIC is withdrawn, and the remaining SORs are inserted. If the shutdown margin is measured using three channels of RRS, the accuracy of the measured reactivity would be improved.

3. Data acquisition of RRS

To verify the feasibility of constructing a reactivity measurement system using three channels of RRS, time series data from RRS were obtained at 0.5 second intervals during the approach to criticality at HANARO.

The data acquisition was performed using an NI-9252, which has eight channels for -10~10 V inputs and reads 50k samples/s for each channel. The wires were connected to the logarithmic power terminals on the front of the panel of RRS as shown in Figure 1. The inverse multiplication method was applied to the obtained data while the CAR was gradually withdrawn, with the result shown in Figure 2. The critical CAR position was estimated as 224.9 mm. It was verified that the RRS signals are applicable for reload physics tests.

Figure 1. Data acquisition of RRS

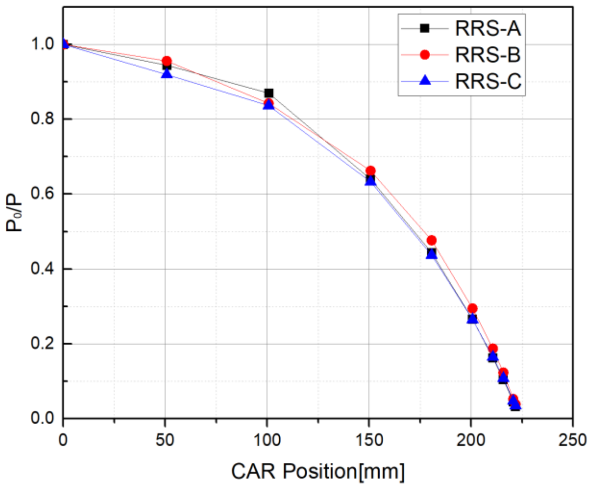

Figure 2. Inverse multiplication method using RRS

4. Conclusion

The reactivity measurement system using the CIC signal is planned to be replaced by the RRS signal for measuring the critical CAR position and the shutdown margin, which are the reload startup physics tests at HANARO. It is necessary to build a reactivity computer that calculates the reactivity from RRS signals in real-time. The results of this study is expected to enhance the accuracy of measurement, address the limitations of the CIC system, and modernize HANARO's reactor operations, ensuring safer, more reliable and efficient reactor performance while supporting future advancements in reactor control and measurement systems.

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