Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

Demonstration Test of Vanadium Fixed In-Core Detector Assembly

Kyung-Gun Kim*, Do-yeon Kim, Yu Sun Choi
Korea Hydro & Nuclear Power Co., Ltd Central Research Institute (KHNP-CRI), 70, 1312-gil
Yuseong-daero, Yusong-gu, Daejeon, Korea
**Corresponding author: kgun.kim@khnp.co.kr*

1. Introduction

Rhodium emitter based In-Core Instruments (ICIs) have been used in KSNP (Korea Standard Nuclear Plant) for core neutron flux measurement. Rhodium based ICIs have been used in OPR1000 for about 30 years, and the same type of Rhodium based ICIs are applied in APR1400. Although the entire ICIs used for KSNP had been imported by 2002, starting with the demonstration test of the localized ICIs in an OPR1000 for 3 cycles, an experience in developing ICI has been identically accumulated in Korea. As the reactor fuel cycle lengthened from 12 months to 18 months, ICIs have to be frequently replaced due to the high depletion rate of rhodium for neutron irradiation even though their mechanical life time enough left. This is the reason why the ICIs installed in the center area of the core should be replaced after the end of the second cycle, because the service life could be ended in the middle of the third cycle as shown in Fig. 1. Frequent ICIs replacement gives rise to increasing purchase costs, discarded ICIs storage spaces, and worker radiation exposure dose. In order to resolve these problems, Long-lived ICI with vanadium emitter have been developed. Two vanadium ICIs installed in July, 2021 at an OPR1000 and the signals, sensitivity and accumulated charges is being measured so far stably. [1]

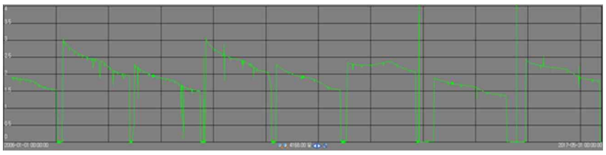

Fig. 1 Rhodium ICI output current trend

2. Vanadium ICI design

Vanadium material have a relatively small neutron reaction cross-section compared to the rhodium, so that the irradiation life of vanadium detector is comparatively longer than that of rhodium detector, but the magnitude of output current signal is smaller than that of rhodium detector.[2][3] For this reason, when vanadium emitter having the same size as the rhodium emitter is used, it is difficult to process a signal in Plant Monitoring System (PMS) of OPR1000, so the diameter of the vanadium emitter is increased. Fig. 2 shows a cross-sectional view of the rhodium ICI and the developed vanadium ICI. The outer diameter of the vanadium ICI assembly is the same as that of the rhodium ICI assembly so that it can be inserted into the ICI guide tube of nuclear fuel, and the diameter of the detector and thermocouple has also increased as the emitter size has increased.

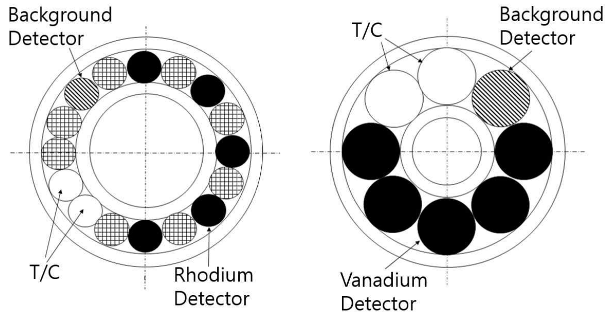

Fig. 2 Cross-sectional view of Rhodium and Vanadium ICI

3. Vanadium ICI installation in OPR1000

Two vanadium ICIs were installed at the No. 20 ICI position and No. 41 ICI position, respectively. ICI installation positions were selected as a position that meets the requirements of the licensing document, such as ICI operability requirements, radial tilt power distribution measurement requirements, and core exit temperature monitoring requirements. In addition to consider the ICI output signal characteristics according to the power level, ICI No. 20 was installed at the center area of the core, and ICI No. 41 was installed outside area of the core.

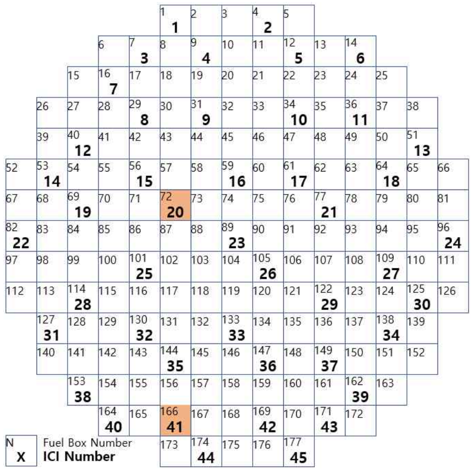

Fig. 3 ICI installation position core map

4. ICI signal acquisition

Vanadium ICI output signals have been acquired through the signal acquisition system named PDAS-V that functions the same as the OPR1000 Plant Data Acquisition System (PDAS). PDAS-V performs functions of amplifying, analog-to-digital conversion, and storing 10 neutron detector signals, 2 background detector signals, and 2 thermocouple signals in every 100 milliseconds. Fig. 4 shows schematic vanadium signal acquisition flow.

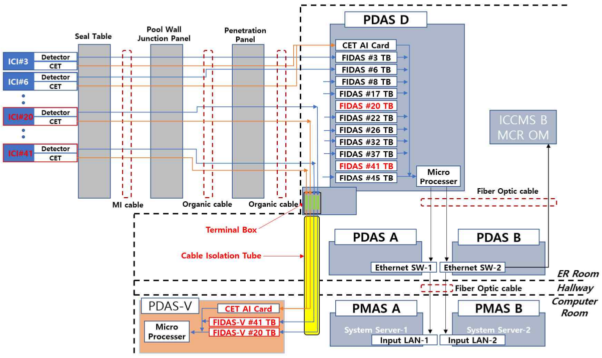

Fig. 4 Schematic diagram of FIDAS-V signal wiring

5. Analysis of vanadium detector signal

The five detector emitters of the vanadium ICIs are located at a height of 10%, 30%, 50%, 70%, and 90% in the axial direction of the core, and the bottom is No. 1 and the top is No. 5 to measure the neutron flux at the corresponding position. All emitter output current signals began to be generated below 1% reactor thermal power (COLSS BDLT). Neutron flux value and sensitivity reduction trend calculated from the measured vanadium detector output current signals are as follow Fig. 5 and Fig. 6.

5.1. Neutron flux trend of vanadium detector

The position of the No. 41 vanadium ICI is quadrant symmetric position with No. 5, 14, and 30 ICIs. The calculated neutron flux of the vanadium ICI was compared with the diagonal No.5 rhodium ICI neutron flux. The neutron flux calculated from the vanadium ICI output current signal measured during the power ascension showed an error within 2%.

5.2. Relative sensitivity depletion trend

The depletion of relative sensitivity was shown about 0.12% in three months. Assuming full-power operation for 10 years, the relative sensitivity depletion could be estimated by about 5%.

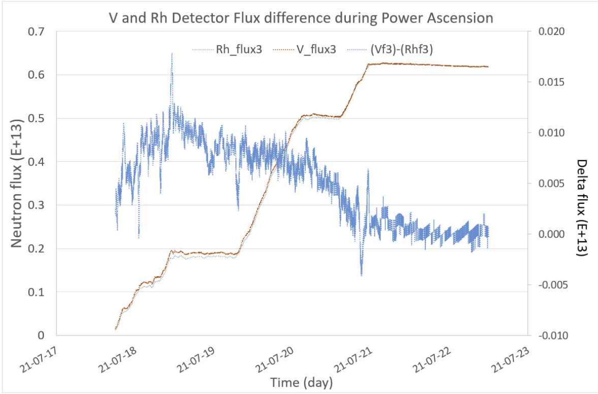

Fig. 5 Flux difference of V and Rh detector during reactor power ascension

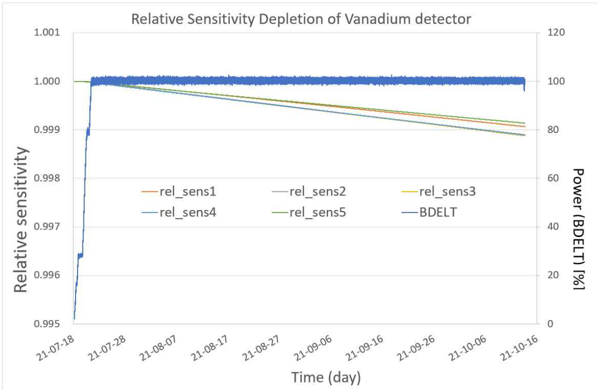

Fig. 6 Relative sensitivity depletion of V detectors

6. Conclusion

Two vanadium ICI assemblies have been installed to perform the demonstration test in OPR1000. In this demonstration test, the flux difference between the flux calculated from the output current of vanadium detectors and that of No. 5 rhodium detectors calculated by PMS is less than 2%, which is evaluated to meet the neutron flux measurement performance requirement of the rhodium ICI. And the sensitivity depletion is expected to be sufficient over 10 years of vanadium ICI design life time.

REFERENCES

[1] Yu Sun Choi, "Status of Long-lived Self Powered Neutron Detector Development in KHNP", Trans. Of KNS Autumn Meeting, Yeosu, Oct 25-26, 2018.
[2] Willian H. Todt, "Characteristics of Self-Powered Neutron Detectors used in Power Reactors", Imaging and Sensing Technology Corporation, Horseheads, New York.
[3] Cha, Kyoon Ho, "Depletion Sensitivity Evaluation of Rhodium and Vanadium Self-Powered Neutron Detector (SPND) using Monte Carlo Method", Journal of Sensor Science and Technology, Vol 25, No. 4 (2016) pp.264-270