Replacement of Neutron Detectors for RPS and RRS of HANARO

Hyung Kyoo Kim, Yeong San Choe, Young Ki Kim, Hoan Sung Jung, Joong Hee Lee, In Cheol Lim
KAERI, 1045 Daedeok-daero, Yuseong, Daejeon, 305-353, Korea
Corresponding author: kimhk@kaeri.re.kr

1. Introduction

The HANARO neutron measurement system is used as a part of the Reactor Regulating System (RRS) and Reactor Protection System (RPS). The HANARO neutron measurement system, which was supplied by Thermo Gamma Metrics (TGM) in 1994, consists of a neutron detector assembly with a cable, wide-range neutron amplifier, and signal processor. It is designed to measure the neutron flux with the detector in a high gamma radiation and electrical noise environment.

As shown in Fig. 1, the neutron detector is housed in a vertical well installed symmetrically at three locations on the outer wall of the reflector tank. The vertical well is designed to accommodate two neutron detectors, one for the RPS and the other for the RRS. The first instability of the logarithmic power was observed at RRS Ch. A in 2004, and since then, a similar phenomenon has been found several times in the same channel. Despite the amplifier and signal processor performance the neutron detector cable assembly showed a symptom of aging due to radiation damage.

It was necessary that the existing neutron detector and cable assembly be replaced with a newly-developed detector model. Two fission chambers had been replaced with newly-developed detectors in 2006, and three others had been replaced in 2010 as preventive maintenance. The remaining detector will be replaced in 2011.

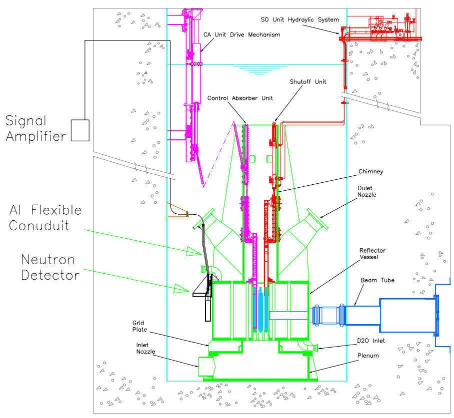

Fig. 1. Location of the Neutron Measurement System for HANARO

2. Description of Neutron Detector Assembly

A fission chamber based flux-monitoring system, a proven neutron instrumentation system that can also be used for Log Rate trips, is commercially available. The fission chambers are used to detect a neutron flux due to their proven high reliability in harsh environments and because of their ability to operate under a high gamma flux without damage or loss of sensitivity. The fission chamber flux monitoring system is relatively more sensitive to a wide-range of neutrons to cover the start-up region as well. For this reason, fission chambers are widely used for reactor tripping and monitoring reactor power. The fission chambers of HANARO are also used in both the RPS and RRS. The RRS uses the analog signals for reactor power control, and the RPS uses contact outputs for tripping the reactor. The neutron detector assembly of the HANARO neutron measurement system consists of a guarded fission chamber inserted into a housing, HN-type connectors, mineral insulated cables, and solid copper sheathed coaxial cables. The signal from the detector is composed of a series of charge pulses that result from alpha decay, gamma photon interaction, and the fission of uranium atoms when a neutron is absorbed. The pulse signal from alpha decay and gamma radiation is eliminated by amplitude discrimination because the neutron pulse signal is much larger. The signals from a wide range of amplifiers are transmitted to the signal processors. The signal processors convert the signals from the amplifiers into surveillance values that represent the percent of reactor power level on a linear scale, percent of reactor power level on a log scale, and the rate of change of the log power level in percent per second.

3. Evaluation of neutron measurement system

We conducted a close examination of all neutron detectors in 2006. The life of a neutron detector is generally considered to be 8-10 years. We examined the detector and cable to find the cause of log power instability in two methods: an electrical insulation check and cable short check using a Time Domain Reflectrometer (TDR). We checked the power supply, discriminator, and band pass filter (BPF) voltages, as well as the insulation detectors and cables, and the signal processor indications, in the control room.

3.1 Insulation Test

Electrical insulation starts to age as soon as it is made, and this ageing deteriorates its performance. High insulation resistance indicates that the leakage current under DC voltage is low. In general, neutron detectors are supposed to have a higher performance when the insulation resistance is higher. In 2006, all neutron detector assemblies of HANARO, including the cable assemblies, were examined for the insulation resistance of their detectors and cables. If the insulation resistance was poor, the detector assemblies were evacuated and backfilled with nitrogen to improve the insulation resistance. The evacuation and backfill with nitrogen gas were conducted on bad insulation cable assemblies so as to prevent the dielectric breakdown of cable assemblies by removing moisture.

$$R = \frac{V_2 - V_1}{I_2 - I_1}, \qquad (1)$$

where V_1 and V_2 are the applied voltage, and I_1 and I_2 are the leakage current. Fig. 3 shows the insulation test for the neutron detector assemblies.

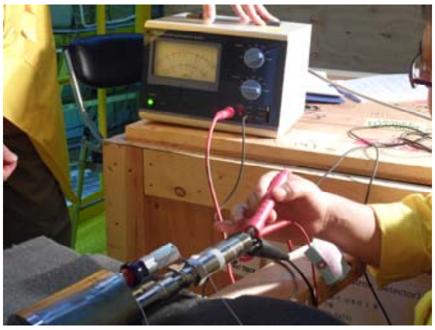

Fig. 2. Insulation Test for Neutron Detector with Cable

3.2 Cable Check Using TDR

TDR works on the same principle as radar. The TDR measures the time it takes for a transmitted signal to travel down the cable, locate the problem, and reflect back. The TDR then converts this time to distance and displays the information as a waveform and/or distance reading on the front LCD panel.

We carried out a TDR test for all channels, but no defects were found. The plot patterns of cables for RRS Ch. B are shown in Fig. 3.

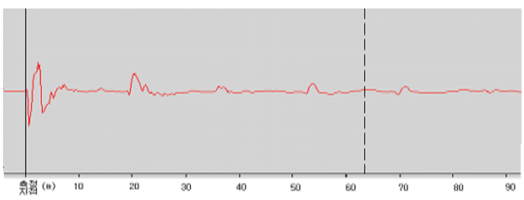

Fig. 3.a. High Voltage Cable

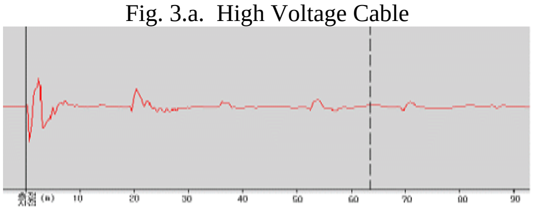

Fig. 3.b. Signal Voltage Cable

Fig. 3. TDR Plot of RRS Ch. B

4. Replacement of Neutron Detectors

In 2008, the neutron detector for RRS Ch. A and RPS Ch. B were replaced with newly developed neutron detectors. Three other detectors were replaced in 2010. The structure of the newly developed neutron detector assembly is shown in Fig. 3. The signal cable assembly of the new detector uses a bellows conduit for easy installation. It is also separated by a splitter to improve the maintainability [4]. Before installation, a pressure test was performed on all new detectors using ultra pure dry nitrogen (99.999%) up to 15 psi. There was no noticeable pressure drop after 10 minutes. An insulation resistance test for the new detector assemblies was conducted. We carried out an evacuation and backfilling with nitrogen to improve the insulation resistance several times before installation.

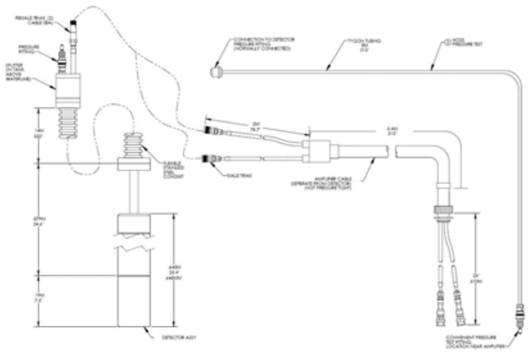

Fig. 4. Structure of New Detector Cable Assembly

3. Conclusions

In 2004, the instability of logarithmic power was observed at RRS Ch. A for the first time. We anticipated that this was a sign of deterioration, and we therefore checked all neutron detectors at HANARO in 2006. Upon further checking and review, it was determined that the deterioration was progressing in all detectors as expected. In 2008, we successfully completed the replacement of two of the worst neutron detectors, including the one in which the instability had been originally observed. Three others were replaced in 2010. The remaining detector is going to be replaced with a new one in 2011. When the replacement of all neutron detectors is completed, it will improve the reactor safety and stability.

REFERENCES

[1] "Instruction Manual for Neutron Flux Monitor for HANARO, KAERI", Thermo Gamma Metrics, 2000.
[2] B.J. Jun et al., "Year-2005 HANARO Operation," KAERI/MR-443/2005, KAERI, Daejeon, Korea, 2005.
[3] I.C. Lim et al., "Year-2006 HANARO Operation," KAERI/MR-465/2006, KAERI, Daejeon, Korea, 2005.
[4] Y.K.Kim, "Technical Specification for Neutron Detector Assembly for HANARO," KAERI, Daejeon, Korea, 2007.