Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22-23, 2025

Reliability Improvement of the Failed Fuel Detection System in HANARO

Youngsan Choi, Jiye Jeong, Soonkyu Hong, Seunggyu Doo, Minwoo Lee, Kyungchul Kim, Minsu Kim*

HANARO Management Division, Korea Atomic Energy Research Institute
898-111 Daeduk-Daero., Yuseong-Gu, Daejeon
**Corresponding author:yschoe@kaeri.re.kr*

***Keywords :** HANARO, FFDS, Electrical Noise, Multiple channels

1. Introduction

In a multi-channel measurement system for radiation monitoring, reducing the differences in measurements between channels is crucial to ensure the accuracy, reliability, and safety of the data. The use of multiple channels enhances reliability and allows for cross-validation of measurements. However, significant discrepancies among channels complicate integrated analysis and undermine consistency in results.
In the case of the Hanaro reactor, the radiation measurements using the Failed Fuel Detection System (FFDS) are directly linked to safety and require precise radiation dose measurements. If there are significant discrepancies between channels, the reliability of the measurements can be compromised, potentially failing to accurately reflect the actual radiation levels. This could negatively impact reactor operational efficiency. Delays in responding to an emergency situation due to inaccurate data could lead to severe safety incidents. Therefore, an in-depth examination of the channel deviations in the Hanaro FFDS system is imperative.

2. Methods and Results

2.1 Primary cooling system radiation detector

The FFDS is designed to detect early signs of fuel rod failure and prevent the escalation of accidents. It consists of various components, including detectors, signal amplifiers, and signal processors. The system's configuration is depicted in the diagram below.

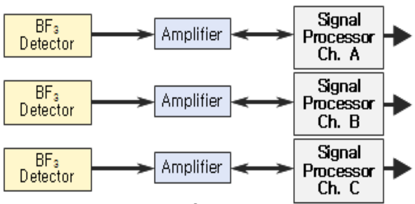

Fig. 1 FFDS Device configuration

The BF3 detector, installed beneath the piping of the primary cooling system, measures the delayed neutrons from the primary coolant to detect potential fuel rod failure. The pulse signal, proportional to the delayed neutrons from the BF3 detector, passes through the amplification circuitry of the signal amplifier and is then input into the Single Channel Pulse Analyzer. Finally, the selected current pulse signal is sent to the signal processor. The signal processor monitors the delayed neutron count rate, and if it exceeds the set point in the reactor protection system, it generates an emergency shutdown signal for the reactor. [1]

2.2 Theoretical analysis

From a maintenance perspective, an increase in the deviation between channels can be interpreted as a deterioration in system performance. If the deviations caused by detector performance degradation due to aging and damage, as well as issues in the electronic circuits such as noise and desynchronization, are not continuously minimized, it could lead to problems in evaluating the equipment's lifespan and performance.
Radiation measurement equipment must meet relevant regulations and international standards (e.g., IEC, ISO), which generally require high levels of measurement accuracy and reproducibility. In a multi-channel system, errors can be detected by comparing the measurements from each channel. However, if the deviation between channels is large, it becomes difficult to determine which channel provides reliable values, reducing the overall system's reliability.

Differences in electrical characteristics of components (e.g., detectors, amplifiers, and signal processors) or environmental factors can cause measurement discrepancies between channels of the same equipment configuration. This is a critical issue related to nuclear safety. According to the IEC 60761 international standard, it is advisable to maintain the deviation between channels within a measurement ratio of ±5~10%, ensuring accurate data collection and reliable analysis.

2.3 Practical cause mitigation.

2.3.1 High Voltage Adjustment

High voltage adjustment and electrical noise shielding play a crucial role in reducing deviations between

channels.
High voltage adjustment is performed to accurately measure the charge generated by radiation in each sensor or measurement device, optimizing electrical characteristics during this process to ensure consistent sensitivity across all channels. This ensures that each channel can detect radiation at a uniform level.

To enhance the accuracy and reliability of the measurement signals, the high voltage supplied to each detector was adjusted three times by considering the installation location of the instruments and the flow rate differences between the primary cooling pumps. The voltage supply values were directly entered on the control room signal indication panel for adjustment. This procedure was carried out in accordance with the manufacturer's manual recommendations, and the results are as follows.

Table I: High voltage adjustment results

Unit : VDC

Parameter	Ch. A	Ch. B	Ch. C
Delayed neutron	1558 → 1560	1552	1560

2.3.2 Electrical noise shielding

Noise shielding plays a vital role in preventing external electromagnetic interference (EMI) or high-frequency signals from contaminating the signal lines, ensuring that the data between channels remains consistent and allowing for more accurate radiation measurements. Mobile phone signals, which contain high-frequency signals, can interfere with the low-current measurement signals of the FFDS, causing noise or distortion. This interference can lead to unnecessary abnormal signals, such as "No count fail," particularly during low-dose measurements, transmitting inaccurate information. Shielding tape is employed to mitigate such interference, and by wrapping it around the outer sheath of the low-current signal lines, the impact of noise is significantly reduced.

Fig. 2 Electric noise shielding tape attachment

By applying these techniques, deviations between channels can be minimized, ensuring that each measurement device consistently provides accurate values, thereby guaranteeing reliable radiation measurements and further enhancing the trustworthiness and safety of Hanaro's operations.

The reason why each channel of the same equipment configuration fails to measure identical values can arise from differences in the electrical characteristics of components such as detectors, amplifiers, and signal processors, or from environmental factors. This is a critical issue related to nuclear safety. According to the IEC 60761 international standard, it is recommended to maintain the deviation between channels within a measurement ratio of ±5~10%, which ensures accurate data collection and reliable analysis. Through the above two measures, the deviation between channels has been reduced to within the recommended range, and the results are as follows.

Number of channels: 3

Measured values: A, B, C channel count rate

Reference value calculation: $Rcf = \dfrac{A+B+C}{3}$

Channel deviation rate: $\left(\dfrac{A(\text{or } B, C) - Rcf}{Rcf}\right) * 100$

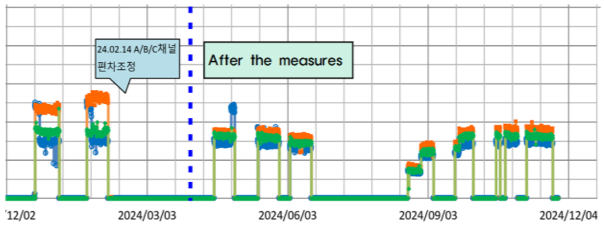

Fig. 3. Results of reducing deviation between signals by two measures

3. Conclusions

Reducing the measurement deviations between channels in the FFDS is essential for accurate radiation dose measurement, ensuring safety, and guaranteeing system reliability. Therefore, this issue has been carefully examined. Adjusting the high voltage optimizes the sensitivity of each channel, ensuring consistent output for the same radiation intensity. Additionally, noise shielding minimizes the electrical noise generated in each channel, ensuring reliable data acquisition. Through these methods, the performance of the FFDS system can be enhanced, which will significantly contribute to the stable operation of Hanaro.

REFERENCES

[1] Y.T.Lim, Channel Calibration of Primary Cooling Water Radiation, HANARO Operating Procedure, 2018