Development of IoT-based radiation detector for real-time measurement of decontamination effects

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1. Introduction

After the permanent shutdown of the nuclear power plant is decided and the nuclear spent fuel is withdrawn, system decontamination work is performed so that the radiation dose inside various devices and pipes is reduced to a level that the dismantling worker can work.

In order to confirm the decontamination effect, the radiation dose before and after decontamination of the decontamination target should be measured.

Recently, IoT based portable wireless radiation detector has been developed to replace the current method of direct meaurement by decontamination workers. By transmitting the measured dose rate by wireless communication technology, this detector can provide basic data to check whether the worker is working in accordance with ALARA(as low as reasonably achievable) conditions.

Since the decontamination target has a difference in radiation dose depending on the stage of decontamination, it will be required to develop a device capable of high-precision measurement in a wide range. In this study, two detectors, scintillation (scintillator + SIPM) and Geiger Muller, will be installed to solve this problem and designed to be automatically selected depending on the level of radiation dose being measured. In the decontamination process, a detector for measuring radiation dose must be able to be used while moving vertically and horizontally, so a movable support that can be loaded and moved vetically and horizontally is also designed. Also, in order to check the decontamination effect in real time, it is designed to transmit data to the radiation integated management system using Zigbee-based wireless communication.

2. Methods and Results

2.1 Dual detector for gamma-ray measurement

The configuration of the detector developed in this study was designed to measure a wide range of dose using two detectors: a scintillation detector and a Geiger-Müller counter. [1] Figure 1 shows the radiation detector configuration including sensor part and data processing part. The scintillation detector of the sensor part was manufactured using CsI(Tl) and SIPM, and the Geiger-Müller counter was manufactured by composing the GM tube and high voltage circuit. [2] The dosimetry range was designed to measure a dose of 0.1μSv to 1Sv, and the analog signal measured by the detector was converted to digital and processed with the MCU.

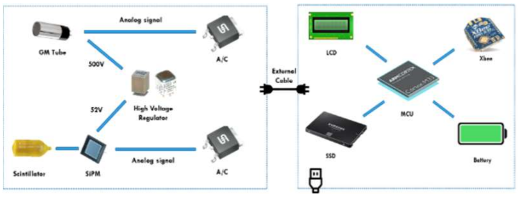

Fig. 1. IoT-based Radiation Detector Configuration

The MCU of the data processing unit uses an ARM M7 chip for high-speed processing, and processes the data from both instruments and displays them on the LCD. The algorithm is configured in the MCU so that the scintillation detector operates in the low-dose section and the GM detector operates in the high-dose section to measure automatically. It is sent wirelessly to the server using Zigbee communication.

2.2 IoT-based wireless communication network

The dose information data measured through the detector is encrypted and transmitted to the server in real time through Zigbee communication In order to transmit data smoothly by using wireless communication in a nuclear power plant, as shown in Figure 2, several routers and coordinators are included between radiation detectors and the server. Through this, it is possible to check the dose value of the radiation measurement point in real time outside the reactor building such as the main control room. [3]

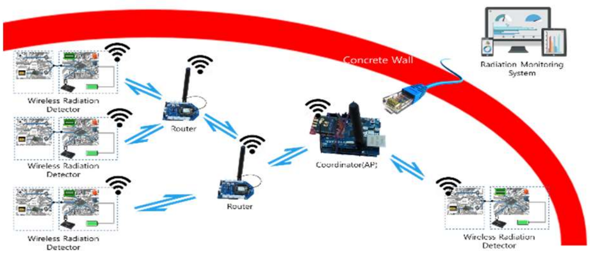

Fig. 2 Wireless network configuration using IoT-based Zigbee communication

2.3 prototype development

The information stored in the server includes the detector ID, measurement time, count, dose value, battery status, etc., and the decontamination coefficient is automatically calculated so that the decontamination status can be checked in real time in the control room. The decontamination factor (DF) is calculated as follows, and in general, the target value of the decontamination factor for decontamination operation is 30.

$$\mathrm{DF} = \frac{DR_{(before)}}{DR_{(after)}}$$

DF: Decontamination Factor
$\mathbf{DR_{(before)}}$: Dose Rate Measurements before Decontamination
$\mathbf{DR_{(after)}}$: Dose Rate Measurements after Decontamination

The wireless radiation detector uses a built-in rechargeable battery and is equipped with a power saving function that can be switched to standby mode remotely from the control room outside of the system decontamination operation period for long-term use. Figure 3 is a prototype of the developed detector. It is designed for stable installation in a nuclear power plant, and can basically measure up to 2m in height by adjusting a tripod. However, there are places higher than 2m in the structure of actual nuclear power plants and surface radiation dose measurement at such a high position is possible by using an additional support. And a multi-joint support is developed to enable measurement even in complex structures that cannot be installed vertically.

Fig. 3 Prototype of IoT-based wireless radiation detector

In order to confirm the measurement precision of the developed detector, simultaneous measurements were performed with a commercial detector and compared with each other. Figure 4 shows the measurement results while moving the developed detector and the commercial detector at a certain distance (1 cm, 5 cm, 10 cm, 20 cm) from the radiation source (Cs-137, 5 µCi). The measurement result of the developed detector showed a pattern similar to that of a commercial detector, and it was confirmed that the dose decreased according to the inverse square of the distance. Similar results were confirmed for other sources such as Co-60 and Na-22.

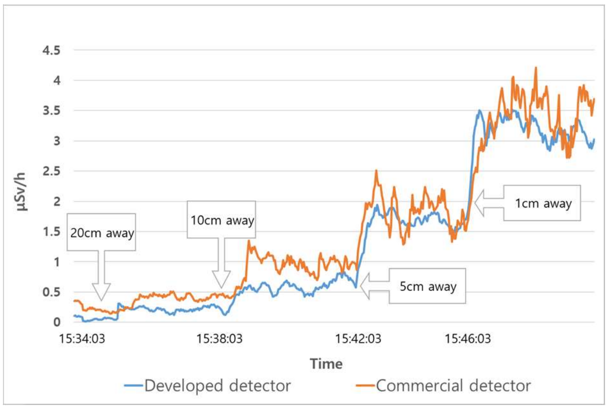

Fig. 4 Comparison of measured radiation values

3. Conclusions

The radiation detector developed in this study can simultaneously measure a wide range of high-precision measurements by applying a scintillation detector and a Geiger-Müller counter .

Also, It is designed to be easily moved vertically or horizontally and to transmit the measured data wirelessly through Zigbee-based wireless communication.

In the future, it plans to improve the degree of precision, including high dose, by conducting a calibration test by a certification institute.

Due to its portability and convenience, this developed radiation detecor is expected to be used not only in measuring radiation dose in the decontamination process of nuclear power plants, but also in operating nuclear power plants.

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