Nuclear Facility Radiation Monitoring System

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1. Introduction

Radiation control at nuclear power facilities is implemented in accordance with various laws and regulations for the safety of workers in the facility and local residents. Radiation monitoring systems are critical systems that operate 24 hours a day, monitoring the radiation conditions in work environments inside the facility and the radiation concentrations in air and fluids discharged outside the facility.

In a radiation monitoring system, the data signals from radiation detectors installed at each worksite are transmitted to a central control room where radiation levels and alarm activation are monitored on a radiation monitoring panel and where a radiation control computer processes the data and outputs the data on a display or as a printout.

In conventional systems, extremely weak radiation signals had to be converted into electrical signals, amplified and then transmitted. Furthermore, the detection mechanisms differed according to the type of radiation to be measured, and as a result, the latter stage signal transmission methods also differed, and the radiation detectors installed at each worksite and the radiation monitoring panel which installed in the central control room were connected by cables in a 1-to-1 correspondence.

Applying the conventional system configuration to a monitoring system having a large number of radiation monitors distributed throughout multiple facilities would require the construction of an enormous hardware structure, and this was a limiting factor for system construction.

Recently, as radiation control at nuclear power facilities becomes more advanced, radiation monitoring systems are being required to provide improved reliability, labor saving maintenance and inspections, and enhanced monitoring functions.

Meanwhile, there has been remarkable progress in the development of IC and other semiconductor technology, transmission processing technology and data processing technology.

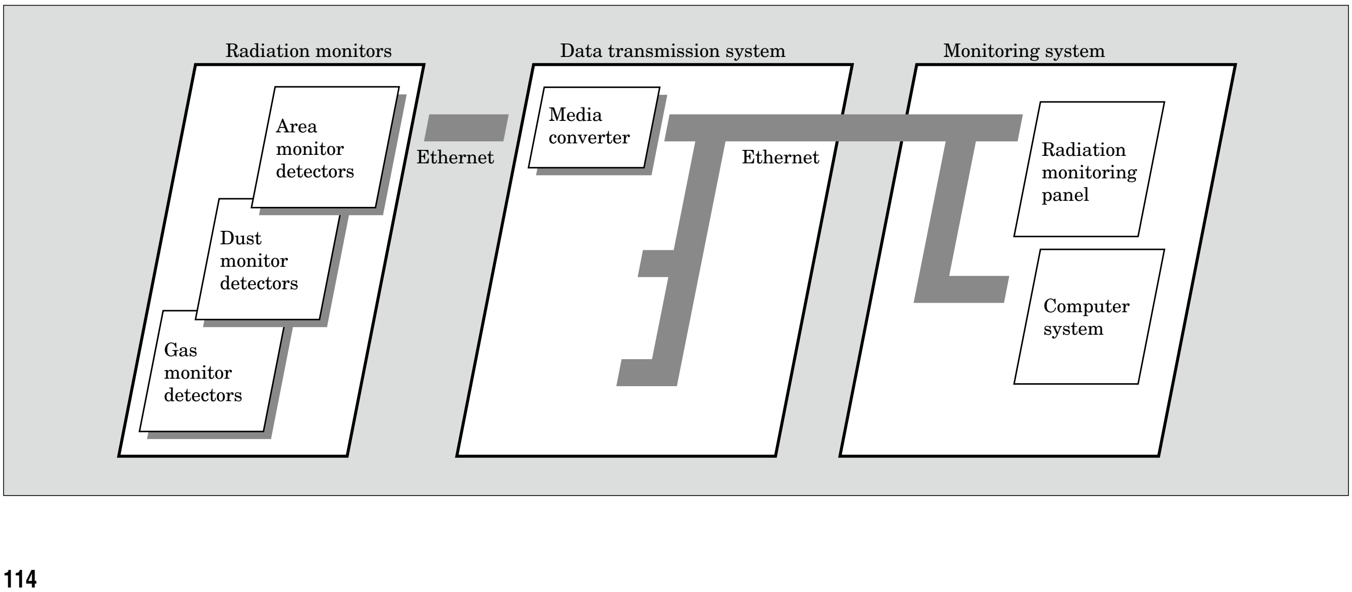
Under these conditions, Fuji Electric is providing large-scale radiation monitoring systems that incorporate the latest technology, and this paper introduces these systems.

2. Overview

Fuji Electric has developed radiation monitoring systems in accordance with the following objectives.

(1) To develop new semiconductor radiation sensors in

Fig.1 Concept of nuclear power facility radiation monitoring system



order to increase the detection sensitivity (efficiency).

(2) To make radiation detectors more intelligent and to improve their reliability and maintainability, to integrate into a radiation detector the characteristic functions for radiation measurement (configured with custom circuits for each type of radiation to be measured, α-ray, β-ray, γ-ray and so on, since signal levels vary according the type of measurement) having been distributed previously between a central control room and onsite locations, and to use a general-purpose transmission interface.

(3) To incorporate the latest data transmission technology in the transmission of signals from the radiation detectors to a central control room or to a radiation control computer, and to achieve higher reliability and faster transmission speeds for large amounts of data.

The configuration of a developed system based on these objectives is shown in Fig. 1.

All the functions required to measure radiation were successfully installed in a radiation monitor, and the signal processing results are output as digital data. The transmission interface is the IEEE-802.3 standard (Ethernet*1), regardless of the type of monitor, and an always-on self-diagnostic function and a remote automated inspection function were added to realize labor savings for maintenance and inspections. Additionally, the radiation sensor uses a newly developed large-size semiconductor sensor.

A data transmission system can be constructed flexibly according to the number of detectors to be connected and the size of the facility. Figure 1 shows a schematic diagram of a large-scale system in the case where Ethernet is used as the transmission interface. Each radiation detector's output is in Ethernet 100 BASE-TX format, transmitted through a media converter to transfer large quantities of data optically to a central radiation monitoring and control system.

3. Radiation Monitors

The functional configuration of a radiation detector is shown in Fig. 2. Previously, radiation monitors were provided with onsite sensors and pre-amps only, and the remaining functions were all housed in a radiation monitoring panel. In the past, a monitor loop was formed by assembling multiple hardware modules according to the type of each sensor, but now using a

*1: Ethernet is a registered trademark of Xerox Corp., USA.

Fig.2 Radiation detector functions and configuration

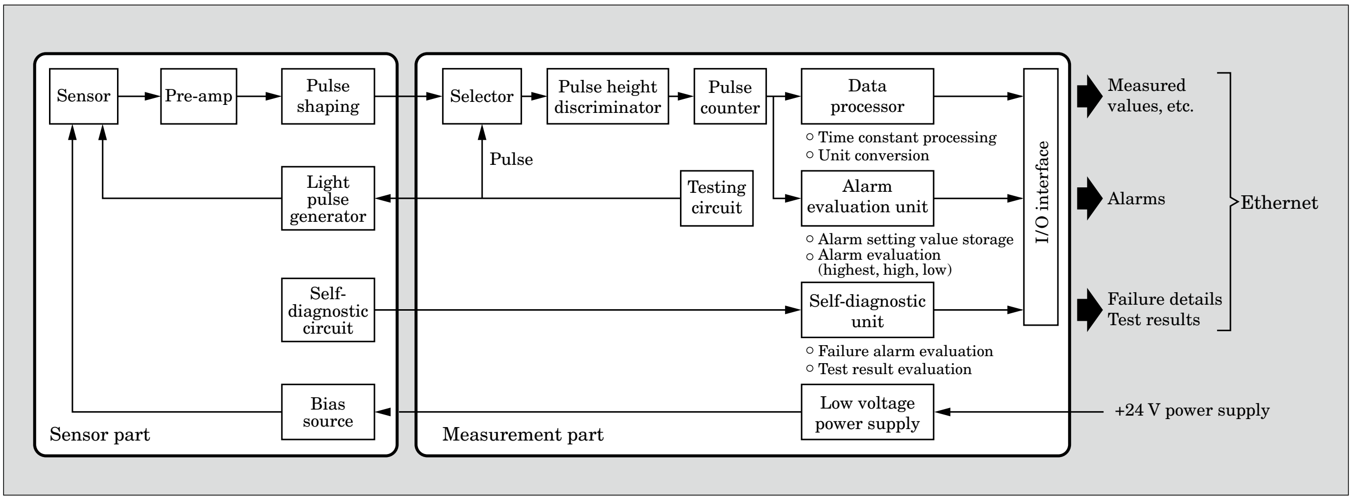


Table 1 Types and main functions of radiation detectors

Monitor types	Main specifications	
	Detectors	Measurement range
γ-ray area monitor	Ionization chamber detector	10^{-2} to 10^{4} μSv/h
	Semiconductor detector	10^{-1} to 10^{4} μSv/h
Neutron area monitor	^{3}He proportional counter tube	10^{-2} to 10^{4} μSv/h
α-ray dust monitor	Semiconductor detector	10^{-2} to 10^{4} s^{-1} (cps)
β-ray dust monitor	Semiconductor detector	10^{-1} to 10^{5} s^{-1} (cps)
β-ray gas monitor	Plastic scintillation detector	10^{-1} to 10^{5} s^{-1} (cps)
Iodine monitor	NaI (T*l*) scintillation detector	10^{-1} to 10^{5} s^{-1} (cps)

single-chip micro computer, and all these functions are incorporated into a single CPU board and housed in the detector.

A radiation detector consists of a sensor part and a measuring part. Common functions that do not depend on the type of monitor are provided in the measuring part and functions that differ according to the type of radiation to be measured are provided in the sensor part.

The radiation detector has the following always-on self-diagnostic functions, and sends an automatic transmission to the data monitoring and control system when an abnormality occurs.

(1) Continuous monitoring of discrimination level
(2) Continuous bias voltage monitoring
(3) CPU checking (RAM, ROM)
(4) Continuous DO/AO monitoring
(5) Continuous monitoring for temperature abnormalities

Additionally, the radiation detector also has a function for receiving remote commands from the central control room, implementing the following tests automatically, and notifying the central control room of the results.

(1) Light pulse test

An internal light pulse generator produces light pulses to verify the integrity of the entire monitor loop, including the sensors. The frequency of the light pulses can be set arbitrarily by the radiation monitoring system.

(2) Alarm test

This test verifies the integrity of an internal alarm circuit by incrementing and decrementing inputted data and verifying the alarm output.

(3) Maximum and minimum calibration

An internal test circuit produces electrical pulses which are counted to verify the maximum and minimum limits of the measurement range.

Table 1 lists the main specifications of radiation detectors.

Figure 3 shows a neutron area monitor detector. The energy range to be measured is 0.025 eV to 15 MeV, which sufficiently covers the range of energy of neutrons emitted from a nuclear power facility. (External dimensions: approx. 257 mm (dia.) × 388 mm (H) × 250 mm (dia.) (bottom); Mass: approx. 15 kg.)

Figure 4 shows a semiconductor γ-ray area monitor detector that is capable of measuring energy in the range from 55 to 1,500 keV. (External dimensions: 120 mm (W) × 100 mm (D) × 190 mm (H); Mass: approx 1.3 kg.)

Figure 5 shows the measurement part combined with the detector (sensor). The front panel has an LCD display, and can display measured radiation values. Various settings and operations are controlled by a dedicated infrared ray remote controller. Changes to the alarm setting value and the like can be accomplished by remote operation via a LAN. An alarm display is installed on the upper side, and alarms can be displayed or sounded at an onsite location. (External dimensions: 190 mm (W) × 70 mm (D) × 242 mm (H), not including projections; Mass: approx. 2.7 kg.)

The interface specifications for transmitting data to the center from the measuring part are as follows.

(1) Transmission method: IEEE-802.3 standard (Ethernet)
(2) Transmission data: Radiation measurement values, alarm contents, failure contents, test results, etc.

Fig.3 Neutron area monitor detector

Fig.4 Semiconductor γ-ray area monitor detector

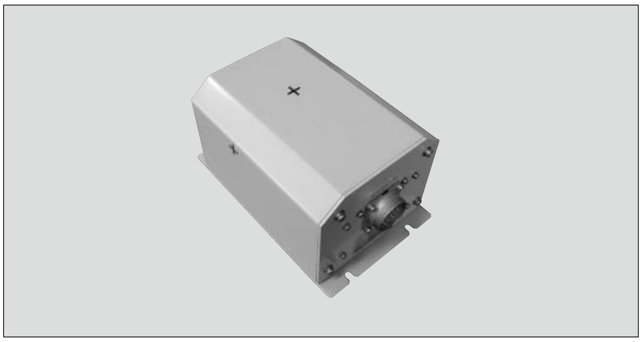


Fig.5 Measurement part

Fig.6 Configuration of nuclear power facility radiation monitoring system

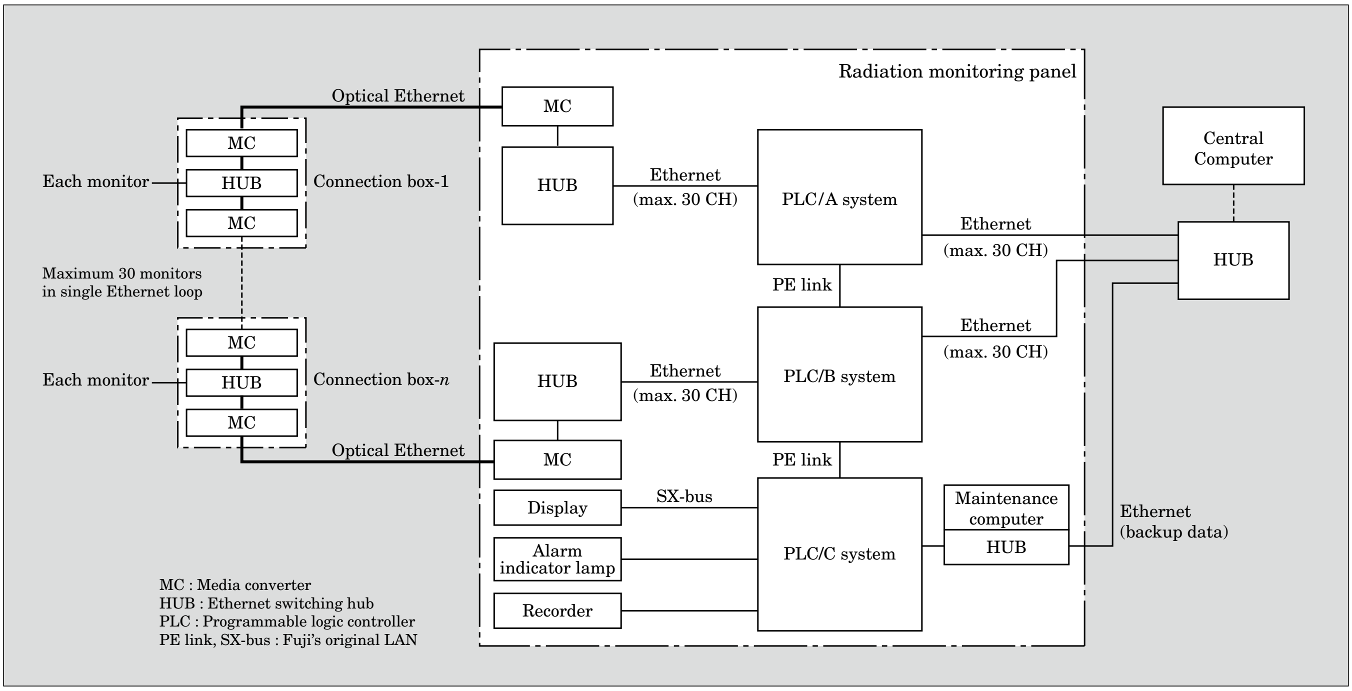
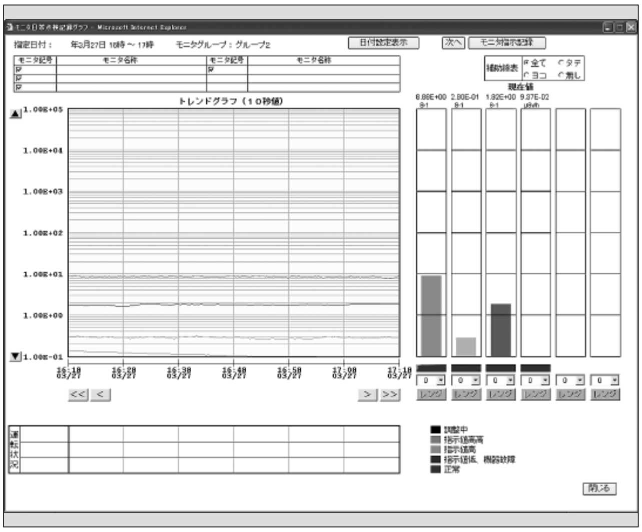


Fig.7 Example of central computer display



4. System Configuration

The development of radiation monitors having an Ethernet interface enables a radiation monitoring system to be constructed according to the size of the facility. Figure 6 shows an example configuration of a radiation monitoring system.

This system is capable of connecting a maximum of 30 radiation monitor channels in a single Ethernet loop. Multiple Ethernet loops can be combined to construct a large-scale system. The signal from each radiation monitor is input to an Ethernet switching hub (HUB), fed through a media converter (MC), and transmitted via an optical Ethernet to the radiation monitoring panel. A maximum of 3 radiation monitor channels are connected to a HUB and are installed at a suitable location according to the layout of the facility.

A pair of programmable controllers (PLC/A and PLC/B) are installed in the radiation monitoring panel, and are connected to each side of the optical Ethernet via a MC. Radiation monitoring data is transmitted every second to both of these controllers, enabling data to be acquired even when there is mechanical failure of a LAN device onsite or in the monitoring panel. Additionally, each radiation monitor is also provided with an Ethernet interface and can transmit data directly to a central computer. Figure 7 shows an example of a central computer display.

The HUB is shared by the system, and may be replaced in the case of failure. The PLC/C implements essential command, data recording and alarm functions at the radiation monitoring panel.

5. Postscript

This paper has introduced Fuji Electric's nuclear facility radiation monitoring systems. The systems and components introduced here have been designed such that all characteristic functions for radiation measurement are installed in the radiation detector, and the signal processing results are output as digital data. As a result, there are almost no restrictions on the system configuration, and future advances in data processing technology will be easy to incorporate.

Fuji Electric intends to continue its developmental efforts, aiming for higher reliability, maintainability and productivity.