

High-performance Dust-radiation Monitoring System by Simultaneous Discrimination of Alpha and Beta Rays

Akihisa Kaihara
Makoto Namai
Hiroshi Arima
Hitoshi Kuwabara

OVERVIEW: A dust-radiation monitoring system is installed in every nuclear power plant to collect dust suspended in the air and to monitor radiation levels in all areas inside the plant for radiation exposure control and work management purposes. The existing types of radiation monitoring systems are as sensitive to natural radioactivity as to artificial radioactivity, so it is necessary to develop a monitoring system that can discriminate between the two types of radioactivity whenever a change is detected in the measured radiation level. Since the natural radioactivity depends primarily on radon that radiates alpha and beta rays, and its decay-product nuclides, we have developed a system to significantly improve the monitoring performance of artificial radioactivity. We achieved this by concurrently measuring the alpha and beta rays with a single detector in order to discriminate natural radiation according to the ratio of radioactivity between the two types of rays. The dust sampler is built as an autonomous distributed system capable of operating independently. For information monitoring, we have adopted a cutting-edge data-control system consisting of a high-performance information control server and a general-purpose LAN. This system is open and highly scalable and can provide trend data monitoring and central-control of field equipment and devices.

INTRODUCTION

NUCLEAR power plants use various types of dust-radiation monitoring systems to collect and measure the radioactivity (beta rays) of dust in the air inside the plant. These monitoring systems are also sensitive to natural radioactivity that fluctuates depending on the state of air ventilation (air-conditioning) inside the building and on weather conditions (rain, day/night, etc.). It has been the common demand, therefore, that the existing dust-radiation monitors should determine, upon detecting a change in the measured radioactivity of beta rays, whether the change is attributable to natural or artificial radiation.

Against this background, we have developed a dust-radiation monitoring system to monitor artificial radioactivity (beta rays) at high precision and to determine natural radioactivity (primarily attributable to radon and its decay-product nuclide) in real time. And this system has been installed in Fukushima Daini Nuclear Power Station of Tokyo Electric Power Co., Inc.

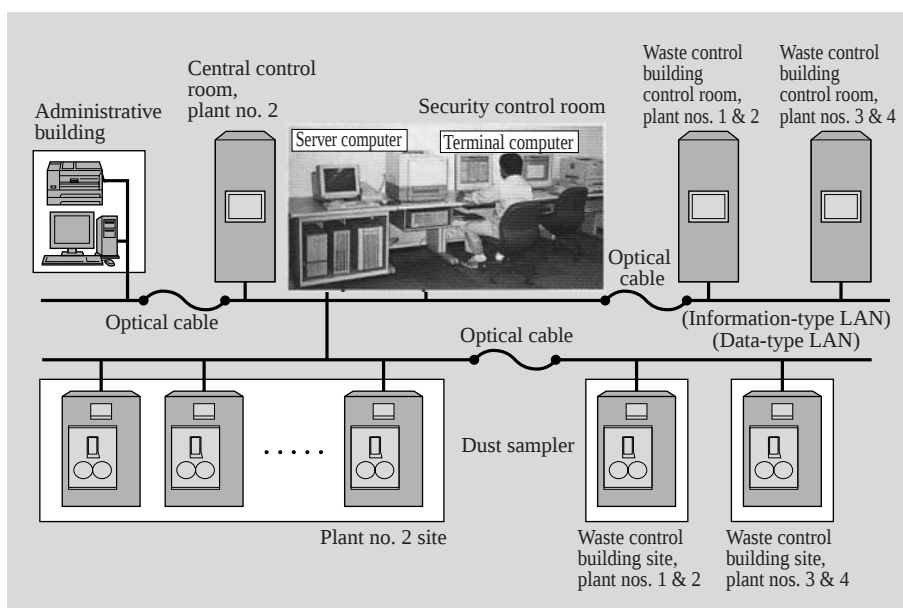
CENTRALLY CONTROLLED DUST-RADIATION MONITORING SYSTEM

The centrally controlled dust-radiation monitoring system for Fukushima Daini Nuclear Power Station, the common waste-treatment facilities for Nos. 1 and 2 plants, and the same for Nos. 3 and 4 plants of the Tokyo Electric Power Company consists of six sets of dust samplers. These samplers automatically collect data at 15 measuring points by switching with valves, and the data are monitored in a security control room and an administrative building. The primary functions of the system, including those related to the discrimination between natural and artificial radioactivity, improved maintainability and performance, are described below.

Discrimination Between Natural and Artificial Radioactivity

Recent dust-radiation monitoring systems measure the total level of beta rays consisting of both natural and artificial radioactivity and must efficiently discriminate artificial radioactivity from the total radiation level. Moreover, the large percentage of

Fig. 1— Central Monitoring System of Fukushima Daini Nuclear Power Station, Tokyo Electric Power Co. The nuclear power plant employs a system developed by Hitachi, for the first time in Japan. This system can monitor artificial radioactivity at a high degree of accuracy through the determination of natural radioactivity (e.g., radon), which fluctuates according to meteorological and other conditions, in real time by concurrently monitoring radiation from alpha and beta rays measured from dust suspended in the air. It is the newest type of a data control system using a general purpose LAN for central control through terminal computers, including trend monitoring (over a three-year period) and remote control of field equipment.



natural radioactivity is attributable to radon and its decay-product nuclides, and the ratio between alpha and beta rays radiated from natural radioactivity is nearly constant so long as the environmental conditions do not change significantly.

Taking this fact into account, we have developed a dust-radiation monitoring system as a means to improve the monitor of the artificial radioactivity. We did this first by evaluating the influence of natural radioactivity by measuring and monitoring the portion of alpha rays in natural radioactivity and, then, by discriminating the portion of artificial radioactivity from beta rays measured at the same time.

Improvement of System Maintainability

The dust sampler is designed to be detachable from the rest of the system under the local mode and operated on its own. The overall maintainability of the system has been greatly improved by such measures as the front-panel operation that enables the dust sampler installed in the front and facilitates the regular replacement of the paper filters. In previous models, it was necessary to pull out the movable unit and open the sealed box in order to replace the filters.

Integrated Central Control

The server computer collects the measurement data from the multiple dust-samplers installed in each building through a general-purpose LAN for central control purposes and provides the security control room, central operation room, and administrative building with necessary information. At each terminal,

operators can monitor current radioactivity density measured by the respective dust samplers. On the terminal in the security control room, in particular, it is possible by remote control to switch the dust collection points of each dust sampler and/or set the collection timing so as to raise the level of monitoring and operation.

DUST SAMPLER

Alpha and Beta Rays Discrimination

The detector for simultaneously detecting alpha and beta rays is a proven composite detector made of ZnS (Ag) (for detecting alpha rays) and a plastic scintillator (for detecting beta rays) overlapping one another. Two types of signal discriminator circuits are available: "crest discrimination" and "waveform discrimination." We selected the waveform discrimination because it is superior in the discrimination characteristics to the other type for our purpose.

The structure of the radiation measurement section of the dust sampler is shown in Fig. 2. It concurrently detects both alpha- and beta-ray signals and transmits the measured signals to the subsequent stage, rise-time-to-height converter (RHC). The RHC efficiently segregates alpha rays and beta rays into two groups of different crests according to the difference in the rising time of the respective pulse waveforms. It also outputs signals from each of the two groups to the following stage of each counter circuit as an alpha-ray signal or a beta-ray signal. Alpha-ray-to-beta-ray signal-mixing ratio is less than 1.0% and beta-ray-to-alpha-ray signal-mixing ratio is less than 0.1% so as to substantially

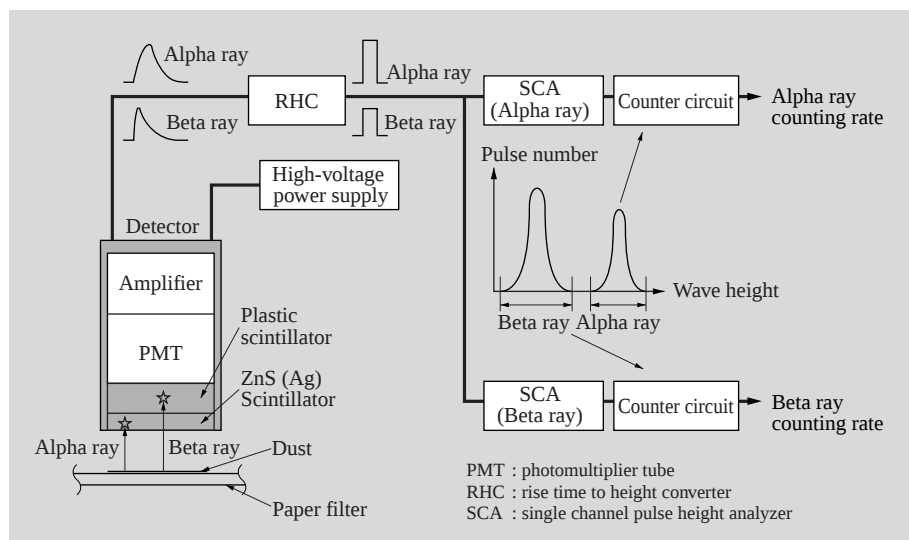


Fig. 2—Configuration of the Radiation Counter of the Dust Sampler.

It efficiently separates and measures alpha and beta rays according to the waveform discrimination method to discriminate between the two types of rays from the difference of rising times of the radiation waveforms at the respective scintillators upon concurrently detecting alpha and beta rays by using detectors.

improve the accuracy of monitoring the ratio of alpha rays to beta rays. Thus, the influence of natural radioactivity on the measurement of total radioactivity could be determined.

Real-time Measurement

Dust radiation is so small that dust must be collected by sucking dust-containing air into a pump through a paper filter. It is, therefore, structured to measure radiation as the dust is being collected so that alpha and beta rays may be concurrently and continuously measured in real time.

The time to collect dust is set by the user depending on the conditions, and the measured values will be provided as the radiation control data. Key data include dust radioactivity density and alpha-ray-to-beta-ray counting ratio, which enable the influence of natural radioactivity to be evaluated in real time whenever the radioactivity fluctuates.

In addition, the dust sampler is configured as an autonomous distributed system that can independently continue to accumulate data even while the server computer is at rest.

Improved Performance of Monitoring Function, Operability, and Maintainability

The most frequently performed on-site maintenance on the dust sampler is the replacement of paper filters. In the past, the pump had to be stopped in order to open the closed box to inspect or replace the paper filter, which was in a roll form in a closed compartment.

To improve the maintainability of the system, it has been redesigned so that the paper filter, previously

installed in a lateral position, is stored vertically in the front panel with only the detector and the dust collecting section of the filter left in the closed container. This setup makes it easier to monitor or replace the paper filter. Flow control by the mass-flow meter is now performed with the dust-collector pump operating under the optimum load condition so as to extend the operating life of deteriorative parts and to

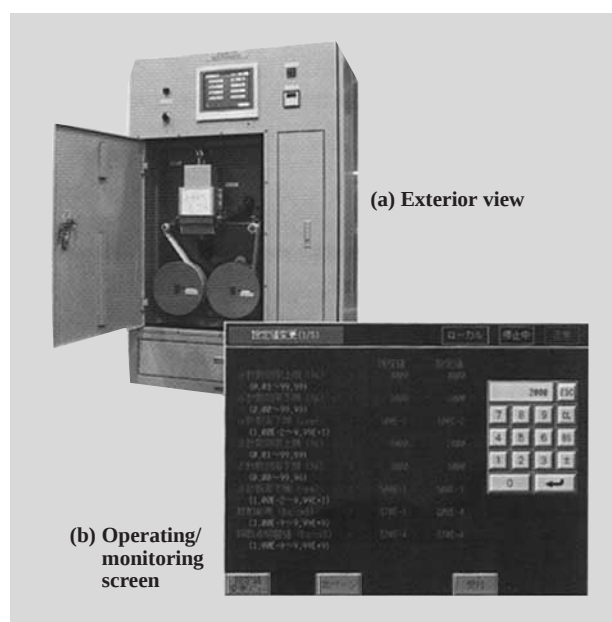


Fig. 3—Exterior View (a) and the Operating/Monitoring Screen (b) of the Dust Sampler.

Maintainability is improved by using a roll of paper filter (90-m roll) installed in the front panel for ease of replacement, and the dust collector component is reduced in size. The touch-screen color display helps improve the monitoring/operating performance.

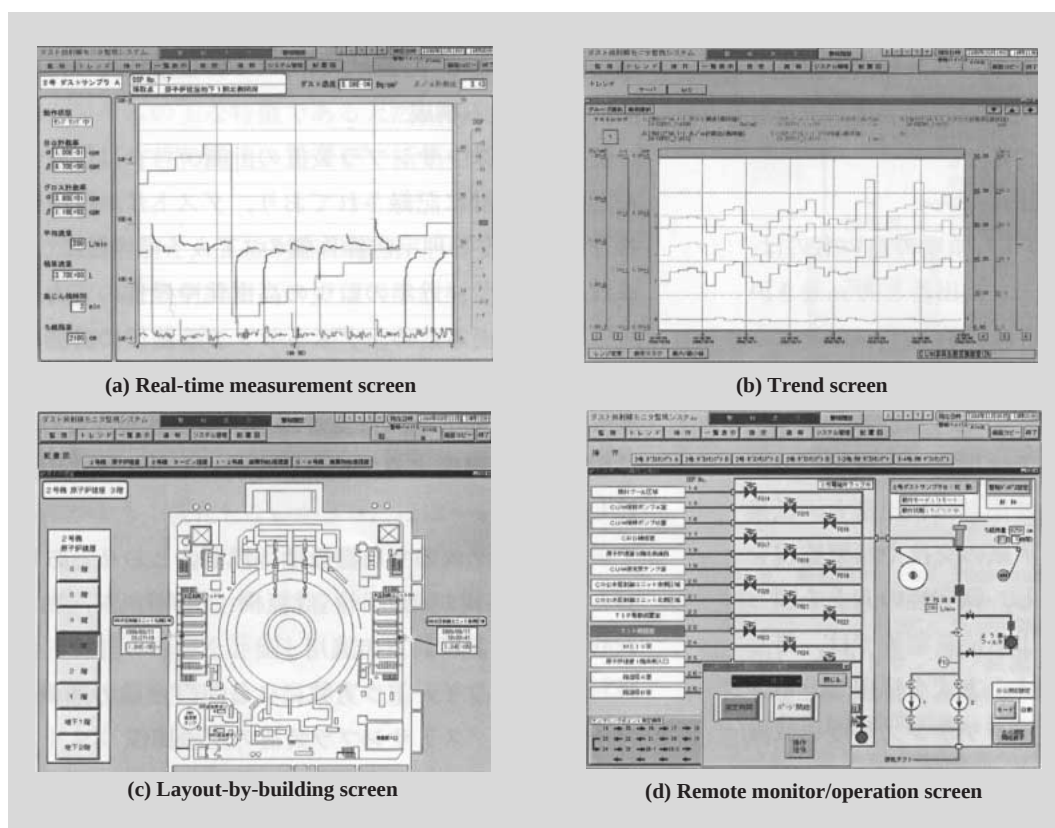


Fig. 4 — Terminal Monitor Screens.

While the monitoring screens display values measured in real time at every dust collection point on the real time measurement screen, they can also depict the trend of radioactivity over the period of three years at every collection point. This facilitates grasping and analyzing the trend of radiation density. Furthermore, the position of dust collection points is indicated on the layout screen by building together with the current radiation density to help increase the monitoring performance. The monitor/operation screen enables to monitor the state of dust samplers as well as the remote operation of the integrated central control from the security room.

minimize the required frequency of the maintenance service.

Meanwhile, the monitor functions, operation, and maintenance have been significantly improved, compared to the previous system, by locating all the switches and indicators (e.g., including those notifying the time to replace the paper filter) on a color touch screen. (See Fig. 3)

DUST-RADIATION MONITORING SYSTEM System Configuration

Up to now, data measured by the dust sampler was typically recorded by a recording device installed in the security control room, while the dust sampler itself was operated by switches mounted on the control panel in the same control room.

On the contrary, in order to satisfy the requirements for a more sophisticated monitoring system and labor-saving operational systems in recent years, the newly

developed system has been designed as an open and scalable system. Accordingly, the data measured by the dust samplers is collected by the server computer through the general-purpose LAN in real time and transmitted to terminals installed in the central control room, the security control room, and the administrative building.

The main features of the system are listed below.

- (1) Operation by compact monitoring control server computer, general-purpose LAN, and redundant large-capacity storage memory.
- (2) Reduced number of CRTs by the adoption of the multi-window system and remote control of the dust samplers by using a PC mouse.
- (3) 50% reduced floor space

Human Interface

Dust-radiation data sent to each terminal may be output as an alarm (warning), a trend display, a screen

display of all data measured at about 80 dust-collection points, or printouts.

The hardware is operated by pressing buttons displayed on the screen by using a mouse. This operation is set up in such a way so that operators feel as if they were operating hardware switches. And the continuously operating dust samplers can be remotely controlled from the security control room. The remote operation screen is arranged to enable operators to grasp the state of operation at a glance by displaying the conditions of dust-sampler filters, change-over valves, and measurement schedules. (See Fig. 4) Taking advantage of the multi-windows environment and high-resolution ($1,280 \times 1,024$ dots) full-color (65,000 colors) screen, these displays are arranged to facilitate central monitoring and equipment operation.

Measurement Data Management

The server computer can collect data accumulated by the dust samplers during the previous week upon resuming operation after the discontinuance of operation so that any data missed during the interrupted period can be replenished. The data management will be further improved by storing measured data, equipment operation records, and alarm conditions for period of three years in the redundant large-capacity memory. And this data will serve as the database of the server computer. Data stored in this database are arranged so that they can be displayed — to make a trend report by specifying the desired dust collection point, date and time — or freely processed by a commercial spreadsheet or other software for trend and/or comparative analysis.

CONCLUSIONS

We have developed a new dust-radiation monitoring system with advanced monitoring, operation, and maintenance functions. It employs integrated central control to improve the monitoring performance of artificial radioactivity. This system has been developed with the aim of applying its flexibility and scalability in nuclear power plants requiring advanced radiation monitoring.

The authors would like to express their sincere gratitude to Tokyo Electric Power Co., Inc. for their valuable support and guidance.

REFERENCES

- (1) Abe et al., "Environment radiation monitoring," Nuclear Safety Research Association (July 1987).
- (2) Hayakawa et al., "Radon group in the atmosphere and Environment radioactivity," The Atomic Energy Society of Japan (1990).

ABOUT THE AUTHORS



Akihisa Kaihara

Joined Hitachi, Ltd. in 1971, and now works at the Information Control Systems Div. of the Power & Industrial Systems. He is currently engaged in the development of control and instrumentation systems for nuclear power station. Mr. Kaihara can be reached by e-mail at akihisa_kaihara@pis.hitachi.co.jp.



Makoto Namai

Joined Hitachi, Ltd. in 1977, and now works at the Information Control Systems Div. of the Power & Industrial Systems. He is currently engaged in the design of computing control systems. Mr. Namai can be reached by e-mail at makoto_namai@pis.hitachi.co.jp.



Hiroshi Arima

Joined Hitachi, Ltd. in 1981, and now works at the Nuclear Systems Div. of the Power & Industrial Systems. He is currently engaged in the planning of preventive maintenance for nuclear power station. Mr. Arima can be reached by e-mail at hiroshi_arima@pis.hitachi.co.jp.



Hitoshi Kuwabara

Joined Hitachi Engineering Co., Ltd. in 1981, and now works at the Information Control Systems Div. of the Power & Industrial Systems. He is currently engaged in the development of control and instrumentation systems for nuclear power station. Mr. Kuwabara can be reached by e-mail at hitoshi_kuwabara@pis.hitachi.co.jp.