Seismic Countermeasures for Environmental Radiation Monitoring System

Osamu Maekawa † **Takeshi Miyairi** † **Teruo Ebato** †

ABSTRACT

Environmental radiation monitoring system continually measures and monitors the air absorbed dose rates around nuclear facilities 24-hours a day, 365-days a year. These systems must continue to function even when a disaster occurs such as an earthquake. Fuji Electric takes countermeasures for earthquakes by duplicating transmissions lines with land radio equipment and installing backup power supplies, seismically isolated monitoring posts, and seismically evaluated equipment. Furthermore, we have developed new portable monitoring posts equipped with semiconductor detectors and monitoring cars equipped with the same functions as stationary monitoring posts, and we can supply equipment that makes measuring and monitoring possible without power supplies or transmission lines.

1. Introduction

An environmental radiation monitoring system (outdoor monitoring system) for a nuclear facility measures and monitors air absorbed dose rates around the nuclear facility 24-hours a day, 365-days a year.

The air absorbed dose rates to be measured is data that pertains to the "obligation to notify a nuclear emergency preparedness manager in the case that a radiation dose above the limit specified by a Cabinet Order has been detected near the border of an area where the nuclear site is located" as stipulated in the Act on Special Measures Concerning Nuclear Emergency Preparedness and outdoor monitoring equipment is essential for operation of a nuclear power plant.

Meanwhile, during normal operation, the healthy operating state of a nuclear facility is broadcast via the Internet to the neighboring community as well as to the public at large, and this also has the side of promoting Public Acceptance: social acceptance of nuclear energy policy (PA).

The promotion of nuclear power has gained momentum in the United States, Asia and elsewhere throughout the world because nuclear fuel can be recycled and the amount of CO_2 emissions is low. The situation concerning nuclear energy has been changing, however, as a result of the Great East Japan Earthquake, which occurred on March 11, 2011. Attention is particularly focused on safety measures for nuclear power plants, and outdoor monitoring systems are required to be capable of measuring air absorbed dose rates continuously even in the event of a disaster.

This paper introduces seismic countermeasures so that outdoor monitoring systems will be able to continue their measuring and monitoring activities in the event of an earthquake.

† Fuji Electric Co., Ltd.

2. Overview of Outdoor Monitoring Equipment

An outdoor monitoring system is configured from stationary monitoring posts for measuring the air absorbed dose rate and atmosphere in nuclear facilities (near the border of controlled areas) or outside of the facilities (neighboring communities), a monitoring system for issuing instructions or recording data in a central control room, and a telemeter system for transmitting data. A portable monitoring post which can be transported and installed outdoors and a monitoring car provided with measuring equipment that is able to take measurements while driving are available as ancillary equipment.

3. Seismic Countermeasures

In the event that an outdoor monitoring system is affected by an earthquake, the following types of damage are anticipated.

(a) Severed data transmission line due to landslide
(b) Severed power supply system due to damaged power distribution equipment
(c) Damage to buildings or devices due to shaking by the earthquake

Countermeasures to continue monitoring under these circumstances are described below.

3.1 Transmission channel redundancy

Optical cables are used for transmitting data from the monitoring posts (buildings) to a central control room. In the event that an optical cable is severed, the monitoring function would be lost, however, and therefore a backup system comprised primarily of satellite-based mobile phone lines had been used. However, the optimal form of the wireless unit was reconsidered on the basis of The Niigataken Chuetsu-oki Earthquake that occurred in July, 2007 and in consideration of the conditions at the time of the earthquake. Specifically, the wireless unit is required to:

(a) be unaffected by communication restrictions caused by an overconcentration of phone calls,
(b) have an antenna with low directionality (able to withstand tilting of the antenna due to earthquakes),
(c) be usable under poor conditions such as heavy snow or rain,
(d) be unaffected by obstructions (terrain or trees) as much as possible,
(e) be small in size because the installation site is cramped, and
(f) be rigid and durable.

Since there are no commercially available wireless units that satisfy all of the above requirements, Fuji Electric, in collaboration with a wireless equipment manufacturer, has developed a custom wireless unit for outdoor monitoring systems. This wireless unit is based on a small terrestrial radio device operating in the 400 MHz band, which has a proven track record in applications such as for river management, and has been customized to realize transmission specifications applicable for outdoor monitoring. In addition, to minimize downtime during inspections, we modified the unit so as to allow for the easy replacement of parts that are replaced periodically. The RS-232C standard was adopted for connection to the telemeter equipment, and this standard is also compatible with the previous model of outdoor monitoring system that is in operation.

As of the present date, radio propagation testing of the new wireless unit inside a nuclear power plant had been completed, and the unit is expected to be finished by March 31, 2012. Specifications of the wireless unit are listed in Table 1 and the implementation of the onsite propagation investigation is shown in Fig. 1.

Table 1 Specifications of the wireless unit

Item	Specification
Frequency band to be used	400 MHz band
Oscillation method	Synthesizer
Modulation method	Frequency modulation
Type of radio wave	F2D, F3E
Antenna type	Yagi antenna (400 MHz band, 50 Ω)
Communication method	Half-duplex communication
Coding method	NRZI Equal-length coding
Synchronization method	Asynchronous
Transmission rate	1,200 kbits/s
Code configuration	JIS X5203

3.2 Backup power supply

Power for a monitoring post is supplied via an overhead line from an onsite power distribution unit. In the event that the power distribution unit, electric pole or electric wire become damaged, the power supply will be cut off, and therefore a backup power source is also necessary and has been provided on the side of the building. Fuji Electric ensures the power source operation by using the combination of an uninterruptible power system and an engine generator according to the required backup time and capacity of the equipment. Fig. 2 shows the installed state of the backup power supply equipment.

3.3 Use of seismic isolated building structure

The stationary monitoring post has a building structure as shown in Fig. 3 and is installed on the site of a nuclear facility (near the boundary of a controlled area) or in a neighboring community. Inside the stationary monitoring post building, a radiation detector, measurement assembly, particulate monitor, meteorological monitoring equipment and telemeter equipment are provided. As to prevent damage to the equipment or a collapse of the building due to an earthquake, a seismic isolated building structure has been employed. The structure of the seismic isolation assembly at the base of the building is shown in Fig. 4.

Fig.1 Implementation of onsite propagation investigation

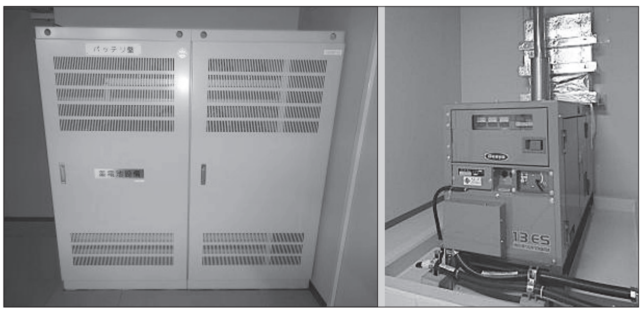

Fig.2 Installed state of backup power supply equipment

3.4 Seismic assessment of installed equipment

A seismic assessment evaluation of the equipment installed in a central control room was performed by means of an acceleration resistance test, and all the equipment was confirmed to be free of problems. Conditions and confirmation methods of the acceleration resistance test (for devices) are listed in Table 2, and Fig. 5 shows the circumstance in which the acceleration resistance test was implemented.

3.5 Portable monitoring post

Portable monitoring posts are measuring devices that can be transported to a measuring site in the event of a disaster or occurrence of a nuclear hazard for which emergency monitoring is required. Portable monitoring posts are required to be lightweight, so that they can be installed manually, and have the equivalent measuring performance as a stationary monitoring post. Fuji Electric has previously supported the elimination of devices, reduction of weight and ensured performance by providing a wide-range measurement model that uses a single NaI (Tl) scintillation detector capable of measuring from the low-dose region (by pulse measurement) to the high-dose region (by current measurement). To accommodate the needs of further weight reduction and long-term operation, Fuji Electric has newly developed a portable monitoring post that uses a lightweight and low-power semiconductor detector.

Specifications of the semiconductor type (latest type) and NaI (Tl) scintillation type (previous type) of portable monitoring posts are compared in Table 3, and Fig. 6 shows the appearance of semiconductor-type.

There are slight differences in the accuracy of dose rate measurment and the energy respones and directional characteristics, but like the previous type, the semiconductor type is capable of measurement of up to 10^5 μGy/h (10^8 nGy/h), which is the dosage rate expected in the event of an accident, and can be used as an alternative measuring system if a stationary monitor-

Fig.3 Appearance of stationary monitoring post (seismic isolated building)

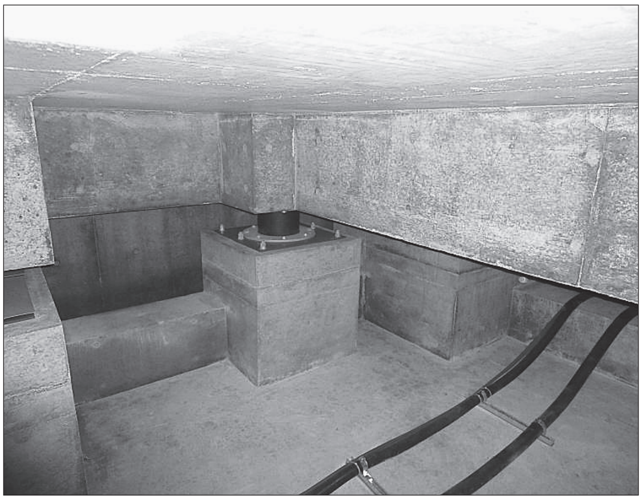

Fig.4 Structure of seismic isolation assembly (base of building)

Table 2 Conditions and confirmation methods of acceleration resistance test (for devices)

Vibration test conditions	Vibration frequency	33 Hz if the resonance frequency is 33 MHz or more The resonance frequency if the resonance frequency is less than 33 MHz	
	Acceleration	Vertical	29.4 m/s^2 (2,940 Gal)
		Horizontal	29.4 m/s^2 (2,940 Gal)
	Direction of vibration	Horizontal (back and forth, left and right), Vertical (along the 3-axis)	
	Vibration time	120 s (each axial direction)	
Items to confirm	○ No damage on devices before and after the test ○ No malfunction or failure before and after the test ○ Within allowable error range before and after the test		

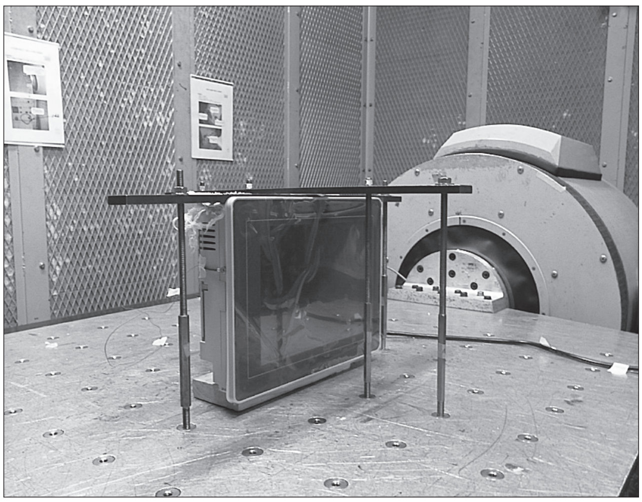

Fig.5 Acceleration resistance test circumstance

Table 3 Comparison of portable monitoring post specifications

Item	Semiconductor type (latest type)	NaI (Tl) scintillation type (previous type)
Detector	Silicon semiconductor detector	NaI (Tl) scintillation detector (wide-range)
Radiation to be measured	Gamma rays	Gamma rays
Measurement range	10^2 to 10^8 nGy/h	Low-dose region: 10 to 5×10^5 nGy/h High-dose region: 3×10^5 to 10^8 nGy/h
Accuracy of dose rate measurement	±20% (0.1 µGy/h or greater, ^{137}Cs reference)	±10% (^{137}Cs reference)
Energy range	60 keV to 3 Mev	Low-dose region: 50 keV to 3 MeV High-dose region: 50 keV or greater
Energy response	±30%, 60 keV to 3 Mev (^{137}Cs reference)	Low-dose region: ±20% (50 to less than 100 keV) ±10% (100 keV to 3 MeV) High-dose region: −50 to +25% (50 to 100 keV) −10 to +20% (100 to 400 keV) ±10% (400 keV to 3MeV)
Directional characteristics	+20%, (0 to ±90°)	+20%, (0 to ±90°)
Display	12.1 inch TFT color LCD	N/A
Data record	Stores per-minute dose rate values for one month	Stores per-minute dose rate values for one week
Data transmission	Ethernet* output (can be combined with satellite-based mobile phone)	RS-232C output

* : Ethernet is a trademark or registered trademark of Fuji Xerox Co., Ltd.

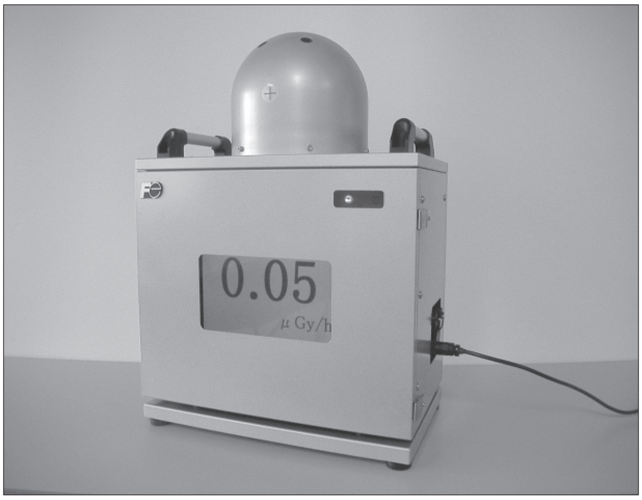

Fig.6 Semiconductor-type portable monitoring post

Fig.7 Appearance of monitoring car

ing post is not available. Moreover, lead-acid batteries and a wireless unit may be installed additionally so as to allow remote measurement and monitoring in locations where there is no power supply or transmission cables. Ethernet output is used for transmitting measurement data, and can be connected to various wireless devices according to the installation environment.

In the system for receiving the measured values, the use of a lightweight and compact notebook personal computer makes possible the flexible and real-time monitoring of measurement values from an off-site center or temporary emergency operation center in the event that the power plant has been affected by a disaster.

3.6 Monitoring car

A monitoring car is a modified cargo truck or minivan equipped with measuring devices. Fuji Electric has developed a monitoring car equipped with a function for measuring specific nuclides such as iodine and using a NaI (Tl) scintillation detector and a measurement unit (provided with a single channel analyzer function), an ionization chamber detector for measuring high-dose regions, and a radioactive particulate measurement device. Previous monitoring cars had limited onboard space and were only equipped with simplified equipment, but this time a larger vehicle was used to realize the same performance and the same functions as a stationary monitoring post with higher measurement precision. Additionally, a wireless unit is used to transmit data to an emergency operation center so that onsite conditions can be grasped in real-time even at a remote site. The monitoring car appearance is shown in Fig. 7 and the interior is shown

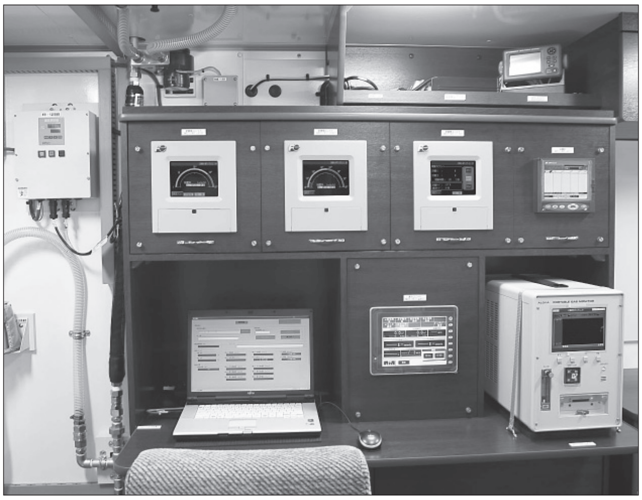

Fig.8 Interior of the monitoring car

Fig.9 Appearance of simplified monitoring posts

in Fig. 8.

3.7 Simplified monitoring post

In the event of an earthquake, air absorbed dose rate monitoring is required not only for the communities neighboring a nuclear facility but over a wide range area.

Fuji Electric has developed a simplified monitoring post consisting of a detector mounted on top of a compact enclosure. By providing a single NaI (Tl) scintillation detector capable of measurement from background levels to 10^5 nGy/h and the minimum functions required for monitoring, the price, dimensions and weight of the simplified monitoring post were held down. Also accurate measurement performance is ensured by utilizing components equivalent to those used in the stationary monitoring posts installed at nuclear power plants. Fig. 9 shows the appearance of simplified monitoring posts.

4. Future Efforts

The Great East Japan Earthquake caused unprecedented devastating damage by a tsunami. Stationary monitoring posts are the fundamental type of outdoor monitoring posts. However, in anticipation of various scenarios of damage, portable monitoring posts must also be provided, and performance improvements are the key for promoting their adoption. As an example of a specific initiative, Fuji Electric is in the process of developing a product that employs a semiconductor detector and by replacing heavy lead-acid batteries with lithium-ion batteries or by using solar cells, achieves both further weight reduction and longer term operation. Reducing the cost and furthering the popularization of simplified monitoring posts will promote more precise air absorbed dose rate monitoring around nuclear facilities.

5. Postscript

This paper has described the status to date of seismic countermeasures for outdoor monitoring systems to assure the safety and security of nuclear facilities and especially for nuclear power plants. In the future, by concentrating our efforts on improving the reliability of stationary monitoring posts and developing an emergency monitoring system, Fuji Electric intends to contribute for improving the reliability to utilize nuclear energy.

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