Development of Management Systems for Nuclear Power Plant of Hokuriku Electric Power Company

● Tatsuaki Nakamura ● Junichi Hasunuma ● Shintaro Suzuki

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Hokuriku Electric Power Company has been operating the Shika Nuclear Power Station that it constructed in Shika town, Ishikawa prefecture, for over 15 years since bringing Unit 1 of this plant online in July 1993. In addition to electricity generation, maintenance and inspection tasks constitute a big part of operating a large-scale nuclear power plant, and in recent years, problems at power stations in the nuclear power industry have led to several revisions of nationally regulated maintenance and inspection systems. This paper describes the background, objectives, development method, and features of the Maintenance Management System and Maintenance History Management System that make effective use of information technology to promote safer and more efficient maintenance work at large-scale nuclear power plants.

1. Introduction

The history of nuclear power in Japan began with the generation of 12.5 MW of electricity at the Japan Power Demonstration Reactor (JPDR) of the Japan Atomic Energy Research Institute (now Japan Atomic Energy Agency) on October 26, 1963 in Tokaimura, Ibaraki prefecture. This was followed by the launch of commercial nuclear power generation with the introduction of an advanced Calder Hall type reactor by the Japan Atomic Power Company in 1966. Power generation by today's mainstream light water reactors—boiling water reactor and pressurized water reactor—began in 1970. As of January 2008, 55 nuclear reactors are operating in Japan.[1),2)] A nuclear power station is a huge plant and inspection and maintenance tasks make up a big portion of its operation.

Conditions surrounding nuclear power generation have recently become increasingly severe following a criticality accident in 1999, the discovery in 2002 of falsified data at a nuclear power plant, and other events. Against this background, the Nuclear and Industrial Safety Agency (NISA), a regulatory organization of the Ministry of Economy, Trade and Industry (METI), has been holding a Study Group on Inspection Practices regularly since February 2002. This has resulted in evaluations of quality assurance regulations for nuclear power plants (JEAC4111-2003) and maintenance management regulations for nuclear power plants (JEAC4209-2003) in 2003, the subsequent revision of laws and ordinances governing the inspection system in the same year, and the implementation of security inspections, periodic inspections, and periodic safety judgements based on a quality assurance system in 2004.

Following the 2003 inspection-system revision, the occurrence of a secondary pipe rupture accident in 2004 led to heightened concern in society about aging plants, so it was decided to take another look at the system in 2005–2007. This review led to a study on

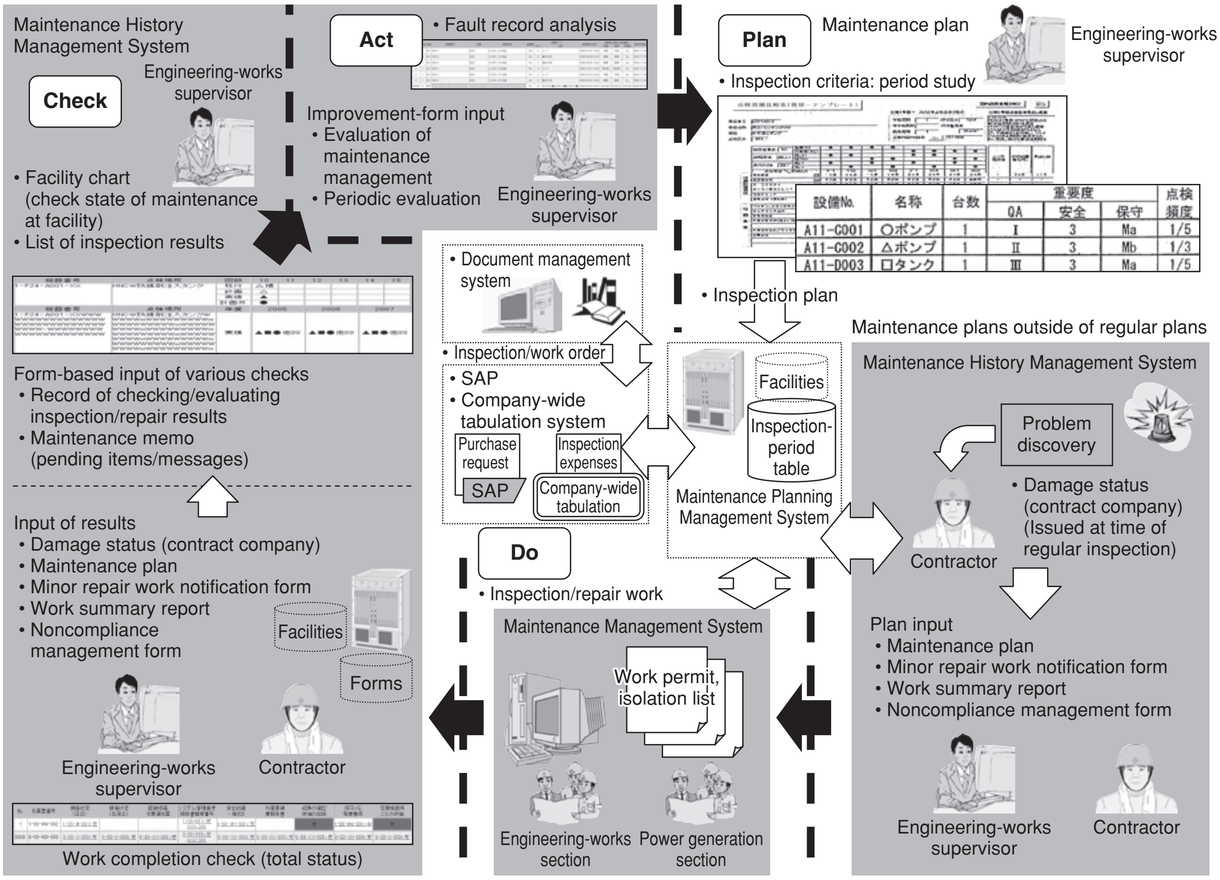


Figure 1
System flow of maintenance work.

the introduction of an Inspection System for Maintenance Activities Based on a Maintenance Program. Now, in 2008, specific measures are being promoted at the national level, and in the years ahead, the maintenance of nuclear power plants is expected to be carried out on the basis of this proposed inspection system.

As part of this effort to strengthen maintenance activities at nuclear power plants, Fujitsu has been working together with power companies to develop maintenance management systems. This includes system development at the Fugen Nuclear Power Station of the Power Reactor and Nuclear Fuel Development Corporation (now the Japan Atomic Energy Agency) since 1985 and system development at Tohoku Electric Power since 2002.

Using the experience and knowledge gained from these efforts, Fujitsu is collaborating with Hokuriku Electric Power Company to construct management systems for the Shika Nuclear Power Station, as described in this paper.

2. Overview of facility maintenance at Shika Nuclear Power Station

Hokuriku Electric Power Company began commercial operations with Unit 1 of the Shika Nuclear Power Station in July 1993 at a rated power output of 540 000 kW and brought Unit 2 online in March 2006 at a rated power output of 1 358 000 kW.[3] The system flow of plant maintenance at Hokuriku Electric Power Company is shown in **Figure 1**.

Plant maintenance is carried out on the basis of a Plan-Do-Check-Act cycle, as described below.

1) Plan

The process of drawing up an inspection plan for the various types of facilities in a nuclear power plant includes making plans such as periodic inspections and involves calculating expenses incurred for maintenance work. The systems used for these tasks are a maintenance planning management system and a company-wide estimation system developed by The Hokuden Information System Service Company, Inc. (HISS), a company in the Hokuriku Electric Power Company Group.

Furthermore, when maintenance work that falls outside established plans becomes necessary due to problems in facility equipment, inspection plans for that work have to be made and the work itself must be performed. The system used for these tasks consists of some of the functions of the Maintenance History Management System designed and developed jointly by Hokuriku Electric Power Company and Fujitsu.

2) Do

Before any maintenance work starts in a nuclear power plant, certain forms must be issued such as the "permit to work" (PTW) form and "isolation list" described below to ensure that the work is performed safely. Moreover, a check of the work done on the facility must be carried out in advance, and then on completion of the work, various report forms must be filled out and submitted to the relevant departments for approval. The system used for these purposes is the Maintenance Management System also designed and developed jointly by Hokuriku Electric Power Company and Fujitsu.

3) Check

Based on the content of the PTW, inspection and repair work will be evaluated and a maintenance memo will be prepared for facilities. This memo lists messages and pending items.

4) Act

Proposals for improvements are made based on various evaluations and analyses of fault records. The Maintenance History Management System is also used for the Check and Act tasks described above. This system can produce digital inspection results that enable inspection summaries to be prepared for later viewing and an inspection history of particular facilities to be referenced as needed.

3. Background to management system development

One reactor in a nuclear power plant includes about 20 000 major devices, 100 000 devices to be inspected, and up to 300 000 to 400 000 operation-related devices such as switches. Ensuring safety is top priority in maintenance work at a nuclear power plant. The management systems described in the previous section are essential for maintaining and managing these facilities in a safe and efficient manner.

The original Maintenance Management System developed in-house by Hokuriku Electric Power Company was put into use after Shika reactor Unit 1 was brought online. However, considering forecasts that the amount of maintenance work would increase once Unit 2 began to operate, it was decided to redevelop a system that would provide an even higher level of safety and achieve smooth maintenance operations. The Maintenance History Management System, meanwhile, came about due to the need to develop a new system to support inspections based on quality assurance regulations and maintenance management regulations introduced in 2003 to ensure safety in nuclear power plants.

Against this background, the need was felt at Shika Nuclear Power Station to make changes in maintenance management in accordance with the 2003 regulatory revisions. This, in conjunction with the upcoming launch of Unit 2 in 2006, prompted Hokuriku Electric Power Company to begin rough designs with HISS from 2003 toward the redevelopment and new development of the Maintenance Planning Management System, Maintenance Management System, and Maintenance History Management System. Full-scale development of the Maintenance Management System and Maintenance History Management System was assigned by Hokuriku Electric Power Company to Fujitsu.

4. System development method

Ideally, a system developer should coordinate not just with the information system department, but also with the departments in the nuclear power plant that will be using the system and with on-site personnel as well. However, it is extremely difficult to build consensus with users who are not knowledgeable about the design and development of an information system and with the information system department itself using only paper-based specifications. In particular, using diagrams that require prior training, such as those produced using the unified modeling language (UML) commonly used in information systems, has been found to be impractical.

In response to these problems, we chose to use a semi-prototype technique based on hypertext markup language (HTML) in our design work and proceeded to create and design interactive screens as close to the final image as possible. This design work followed the following procedure.

1) Configure screens and design basic items

In this step, we decide on screen formats and describe them in HTML (**Figure 2**).

2) Design common components

Here, we decide on common screen components and describe them in HTML (**Figure 3**).

3) Design detailed screens

In this step, we create detailed Web screens. Care must be taken here to make the size of input items on a screen, screen transitions, and the results of clicking on a button as close as possible to those of the final system. The basic idea behind screen design for the systems in question is to use the existing paper-based forms without modification as input screens and to design the screens so that the system can be deployed smoothly without the burden of training after the system operation has been begun. At the same time, we are revising the workflow. Some examples of detailed Web screens and workflow are shown in **Figure 4**.

Figure 2
Web screen of basic form.

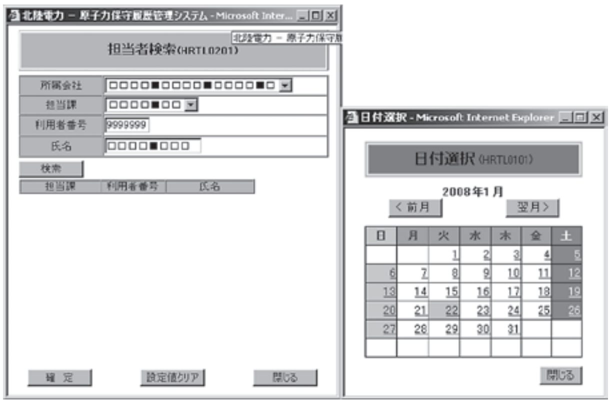
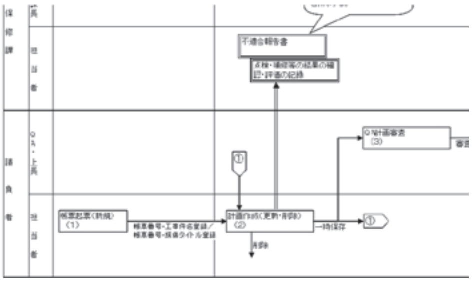


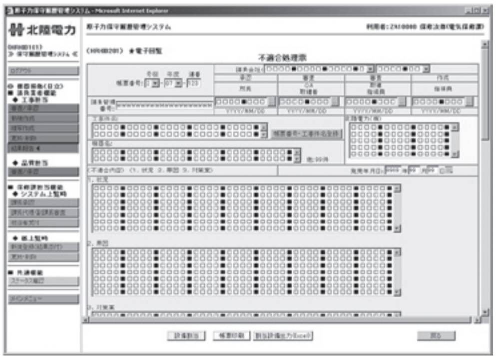
Figure 3
Web screens of common components.

Basically speaking, we first perform the design work shown in steps 1) and 2) and then create detailed Web screens and revise the workflow as many times as necessary in step 3) using the semi-prototype technique. Although this design technique requires much labor, it has many advantages such as reducing conflicts in specifications at the time of system testing and enabling the easiest-to-use system to be deter-



(a) Example of workflow

(b) Results of clicking the search button



(c) Form-input design (same look as paper form)

Figure 4
Detailed Web screens and workflow.

mined in the design stage.

5. Systems

5.1 Maintenance Management System

To ensure safety in maintenance work performed within the Shika Nuclear Power Station, various forms must be prepared. These are the PTW that summarizes the work to be performed, the list of devices targeted for inspection, and the isolation list that indicates necessary facility operations so that devices targeted for inspection can be maintained. Maintenance work may proceed once these forms have been approved by the engineering works department and other relevant departments. To support the maintenance work described in a PTW, the Maintenance Management System provides a function for handling PTW and isolation-list operations and their electronic flow and another function for ensuring safety. These two functions are described below.

5.1.1 PTW/isolation-list operations and electronic flow function

This function enables PTWs and isolation-lists to be filled out and submitted, reviewed and approved by senior personnel, and modified if necessary. Specific functions are summarized below.

1) Functions related to a PTW (create new PTW, create duplicates, update/delete, create/revise isolation list, list devices targeted for inspection)
2) Isolation devices master management and standard isolation master management
3) Approval processing (approval from engineering-works department, approval from reception department, approval from

person on duty in facilities department)

4) Printing of isolation tags

5) Request to modify PTW (request to cancel isolation work, request to modify isolation-work period, request to revise isolation list)

These five functions are described in more detail below.

1) PTW-related functions

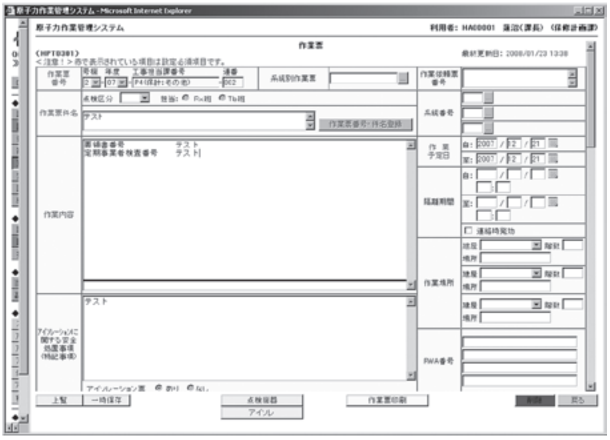
These PTW-related functions use an input interface with the same look as paper forms in order to facilitate maintenance work. Reference forms that inherit the content from previously submitted PTWs are also prepared to facilitate the preparation of new PTWs. These reference forms can be used to copy isolation lists that accompany PTWs. However, the list of devices targeted for inspection will not be copied because the number of times inspected differs from one time to the next.

2) Isolation devices master management and standard isolation master management

For isolation list creation, this function provides standard isolation master management, enabling template isolation lists to be registered. This helps to raise work efficiency at times of extensive inspection work such as in regular shutdown inspections. Furthermore, since maintenance work can overlap several departments when large-scale inspection work is carried out, as in regular shutdown inspections, a “system-by-system PTW” (parent work) that manages maintenance work in units of systems can be prepared to provide a common isolation list. Here, individual PTWs (subsidiary work) can be registered as related PTWs. Examples of PTW and isolation-list input screens are shown in **Figure 5**.

3) Approval processing

After the PTW has been filled out, a list of devices targeted for inspection, an isolation list, and associated documentation must be created and these must be reviewed and approved by senior personnel in the engineering-works department indicated on the forms using an electronic approval function. Then, after this approval has been received from the engineering-works department, work acceptance and approval must be obtained from the reception department and from the person on duty in the facilities department. Once these approvals have been obtained, the PTW becomes effective and maintenance work can proceed. To simplify the operations for obtaining acceptance and approval from the person on duty in the facilities department, two functions are provided to retrieve PTWs: one based on barcodes and the other on specify-



(a) PTW input screen

(b) Isolation-list input screen

Figure 5
Examples of PTW and isolation-list input screens.

Figure 6
Bar-code-based search screen for acceptance and approval.

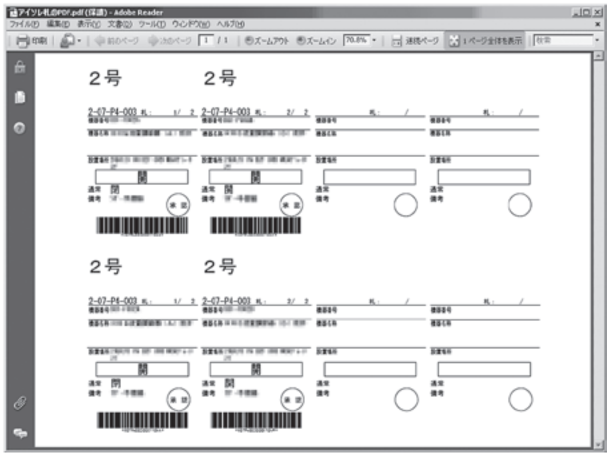


Figure 7
Isolation tags.

ing search conditions. These functions are also used for accepting and approving requests for PTW changes and work-completion reports. The barcode-based search screen for acceptance and approval is shown in **Figure 6**.

4) Printing of isolation tags

Isolation tags are usually printed before the PTW goes into effect. These tags are used to identify facilities that are objects of operations in an inspection, to describe their state, and to prohibit their operation, all as a safety precaution. In short, isolations tags help to prevent errors in on-site operations. The tags are printed on special preprinted paper using ordinary office-use laser printers as opposed to dedicated label printers. An example of an isolation tag is shown in **Figure 7**.

5) Request to modify PTW

Change request forms have been used in the past to make changes in work plans that arise during maintenance work and to request isolation implementation and restoration. This system also provides a function for creating change request forms. Requests for modifying PTWs include a classification as either major or minor. For isolation implementation and restoration requests, the minor classification makes for easy electronic flow so such requests can be made directly from the department in charge of maintenance[note 1)] to the department in charge of facilities.[note 2)] Editing work content and isolation lists, however, comes under the major classification, and approval for such changes must be obtained from senior personnel in the department in charge of maintenance. Examples of change request screens are shown in **Figure 8**.

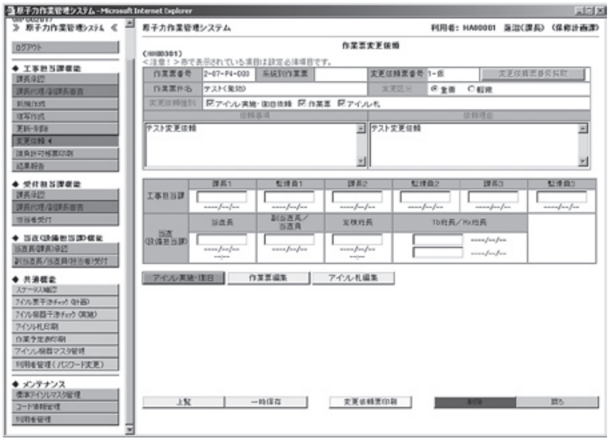
5.1.2 Function for ensuring safety

This function is provided to ensure safety in work performed within the plant. Considering that facility operations must deal with high temperatures, high pressures, and water or steam that may contain radioactive materials, it is essential to determine whether operations on certain facilities coincide with (i.e., could interfere with) other work involving operations on the same facilities. For example, if work A needs to open a valve on facility X while work B needs to close the same valve, some adjustments must be made such as suspending one of these work process. Four functions are provided to determine such interference conditions:

1) isolation-list interference check (Plan: perform

note 1) Department that inspects and repairs the facilities.

note 2) Department that operates the facilities.



(a) Change request screen

(b) Isolation implementation/restoration screen

Figure 8
Change request screens.

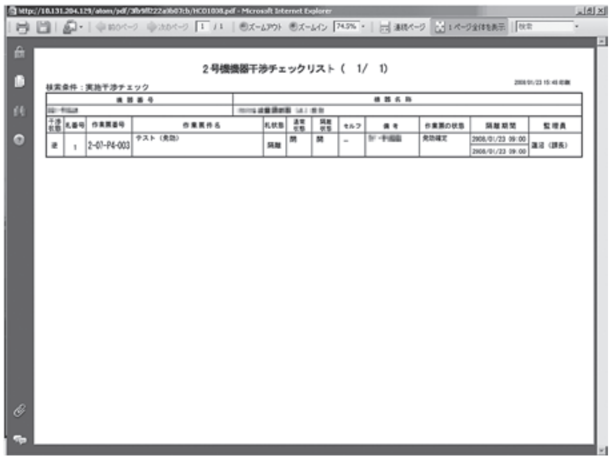


Figure 9
Screen for isolation interference check.

interference check against isolation list),

2) isolated-devices interference check (Do: perform interference check against isolated facilities),

3) isolation implementation/cancellation function (client server function, Web function),

4) output of various work forms (printing of contract permission form and printing of work schedule).

These functions are described below.

1) Isolation list interference check

The function determines the state of interference between PTWs by checking operation conditions of devices targeted in a particular PTW against other PTWs whose work days (days scheduled for isolation) fall after the start day of the PTW in question and against PTWs that have not yet finished.

2) Isolated-devices interference check

This function enables a user to specify a single facility and retrieve information about it to check whether it is currently being isolated. That is, it enables the user to check that other work is not interfering with a certain facility before any attempt is made to isolate its operations. Since it can take 15 minutes or more to reach a particular work site within a nuclear power plant, this function for prior checking can prevent wasted time and labor. The screen used to perform an isolation-interference check between PTWs is shown in **Figure 9**.

3) Isolation implementation/cancellation function

The current state of isolation—implemented or restored—must be accurately managed to enable the isolated-devices interference check described above to be performed. To make maintenance work more efficient, this system prints barcodes on isolation tags and specialized continuous barcode readers are installed

Figure 10
Screen for making isolation-related entries.

so that implementation/cancellation tags can be read in batches. The screen for making isolation implementation/restoration entries is shown in **Figure 10**. We chose to use a client/server system using dedicated personal computers for only this function to improve connectivity with the specialized barcode readers and enhance user operability.

4) Output of various work forms

To make it easy to check the status of PTWs, the system can print out all approved PTWs in a batch or only ones for a certain period.

5.2 Maintenance History Management System

Since the revisions to inspection systems went into effect in 2003, the government has required that maintenance work be performed on the basis of a quality management system (QMS). In other words, it is necessary to make plans (Plan) and carried them out (Do), keep a record of what has been done (history), get the results examined (Check), and make improvements (Act). The Maintenance History Management System was developed to support this work. It provides three functions: form management for unplanned maintenance function, work scheduling and results management function, and information retrieval and management function.

5.2.1 Form management for unplanned maintenance function

This function manages forms for maintenance that becomes necessary outside of regular plans. The forms that are managed cover device damage, noncompliance management, document management, minor repair work notification, and maintenance plan. Forms are managed either by electronic flow or paper-based routing and viewing depending on the type of form. In electronic-flow management, the flow in the Maintenance Management System and Maintenance History Management System is controlled on the basis of departments, senior personnel, and affiliated companies registered by common-user management. The flow in the Maintenance Management System is more complicated because there are more departments there that grant work permission. In this system, the approval of plans and the approval of results basically reside on the power-company and contract-company sides, respectively.

We can expect work to improve in plant maintenance by performing the Plan-Do-Check-Act cycle on the basis of a quality management system. Here, the types of forms that are used will also come under review, and in this regard, work improvements must be supported in a flexible manner. For this reason, we chose to use a system for noncompliance management (and also document management) in which only key pieces of information for configuring the form are input and the noncompliance management form itself is managed as a portable document format (PDF) attachment instead of filling out the entire form on a Web screen. Noncompliance management includes a prevention management form for managing possible noncompliance as a function for performing reliability centered maintenance in support of future inspections. It also enables a fault mode to be set for facilities that have experienced problems so that fault-mode analysis can

Figure 11
Noncompliance management screen.

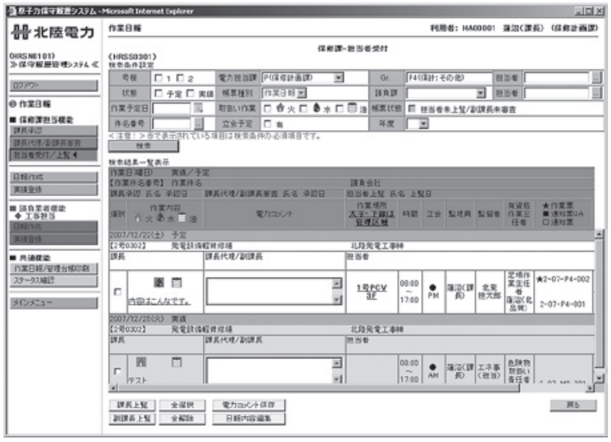


Figure 12
Daily report screen.

be performed at a later date. An example of a noncompliance management screen is shown in **Figure 11**.

5.2.2 Work scheduling and results management function

This function schedules actual work and manages the results. Eight specific functions and forms are targeted for management by this function.

1) Approval/examination functions
2) Daily reports
3) Record of checking and evaluating results of inspections and repairs
4) Maintenance memos
5) Evaluation of maintenance management at every periodic inspection
6) Periodic evaluation of maintenance management
7) Management of operating records
8) Work completion

Both electronic and paper-based forms exist for this function. Flow control is the same as that of the function required for unplanned maintenance described above.

The daily report function for checking the status of daily work provides a mechanism for receiving and processing reports from contract companies on a daily basis. Its interface allows the content to be checked from a list so that multiple daily reports can be processed efficiently. An example of a daily report screen is shown in **Figure 12**.

Once work has been completed, the PTW stored in the Maintenance Management System is given the status expired. A record of checking and evaluating the results of inspection, repair work, and other actions is implemented as a form for evaluating every single PTW that has been completed. If any of the operations associated with completing a PTW, recording the checking and evaluating of inspection and repair results, or completing evaluation at every periodic inspection are not carried out, the work completion verification operation in the Maintenance History Management System will remain incomplete. A function is therefore provided to prevent such evaluation mistakes and information gaps from occurring. A typical work completion screen is shown in **Figure 13**.

5.2.3 Information retrieval and management function

This function retrieves and manages stored information for the functions and forms for comprehending minor repair results, listing

Figure 13
Work completion screen.

inspection results, producing a chart of facilities, and analyzing fault records. These are described below.

1) Clear display of minor repair results

The number of man-hours required for contracted work can be tabulated as a result of consigning minor repair work to contract companies in the Hokuriku Electric Power Company Group.

2) List of inspection results

The results of inspections input from evaluation records are displayed in the form of a hoshitorihyo (score sheet used for sumo) to make it easy to view facilities for which inspections have not been performed regardless of whether inspection plans were made. It is also possible to refer to the history of unplanned inspections (the times at which they were performed).

3) Facilities chart

This enables the user to determine what forms have been filled out for a particular facility. This makes it possible to refer the inspection history from the facility side (not from the work side).

4) Fault record analysis

This function enables devices with faults to be searched for and records of those devices to be downloaded for later analysis on an Excel spreadsheet.

6. Conclusion

This paper explained the method for developing nuclear power plant maintenance-management systems and described functions in the Maintenance Management System and Maintenance History Management System. The Maintenance Management System was deployed in December 2006 and the Maintenance History Management System in December 2007. They have been running stably since then and have become essential to the safe and efficient operation of the nuclear power plant where they were deployed.

For the future, to promote safe maintenance and inspections in nuclear power plants, we will apply the Plan-Do-Check-Act cycle repeatedly to make ongoing improvements and extensions. We will also carry out design and development work to prevent the occurrence of major failures even after system improvements have been made.

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Tatsuaki Nakamura
Hokuriku Electric Power Co.
Mr. Nakamura joined Hokuriku Electric Power Co., Toyama, Japan in 1992 and has been engaged in the development of the Maintenance Management System for nuclear power plants.

Shintaro Suzuki
Fujitsu Ltd.
Mr. Suzuki joined Fujitsu Ltd., Tokyo, Japan in 1995 and has been engaged in the development of systems in the nuclear power field.

Junichi Hasunuma
Fujitsu Ltd.
Mr. Hasunuma joined Fujitsu Ltd., Tokyo, Japan in 1987 and has been engaged in the development of the Maintenance Management System for nuclear power plants.