Service Solutions to Support the Stable Operation of Equipment

KITATANI, Yasuharu* FUJITA, Fumihiko‡ DAITO, Takeshi‡

ABSTRACT

In order to achieve production plans, it is necessary to carry out maintenance activities that reduce equipment failure and ensure stable operation. The maintenance activities are basically involved in implementing the maintenance PDCA cycle that consists of activities to formulate maintenance plans with consideration of time and cost, continually monitor equipment conditions and solve problems as they arise, throughout the life cycle of equipment. Fuji Electric is providing cloud-based equipment maintenance services that utilize IoT. These services support stable operation through equipment maintenance. The information required for the maintenance PDCA cycle is managed in an integrated manner by linking equipment maintenance records, operation monitoring functions and equipment diagnostic functions.

1. Introduction

Quality and cost as well as production per hour may greatly vary depending on the equipment introduced. Accordingly, production plans depend on the equipment capacity and adequately utilizing the equipment capacity is important.

Fuji Electric is providing cloud-based comprehensive equipment management services that integrate the energy management system (EMS), maintenance and operation monitoring services in a cloud. Of those services, this paper presents the cloud-based equipment maintenance services, which are service solutions that support stable operation of equipment.

2. Stable Operation of Equipment Achieved with Equipment Maintenance

In maintenance activities to extend the operation period by reducing instances of equipment failure and ensure efficient and stable production, the key is to first formulate maintenance plans when equipment is introduced. However, carrying out as scheduled the maintenance plans made in advance is difficult as the operation period becomes longer. To deal with this situation, it is necessary to formulate maintenance plans with consideration of time and cost and carry out activities including soundness checks and deterioration diagnosis of the equipment according to the plans as well as prevention of and recovery from equipment degradation throughout the life cycle from introduction to replacement (disposal) of the equipment.

These activities are called a maintenance PDCA cycle as shown in Fig. 1.

(1) Formulation of maintenance plans

The intervals of general and detailed inspection, timing of replacement of limited-life parts, timing of preventive maintenance including overhauls and timing of replacement of the entire equipment are organized into maintenance plans based on the equipment-specific management criteria. To calculate the maintenance costs for each fiscal year, maintenance plans in consideration of equalization between fiscal years are formulated.

(2) Maintenance work

Maintenance work includes breakdown maintenance to deal with unexpected failure as well as preventive maintenance. To identify the cause of any failure in a short time, advance arrangements such as education of maintenance workers, preparation

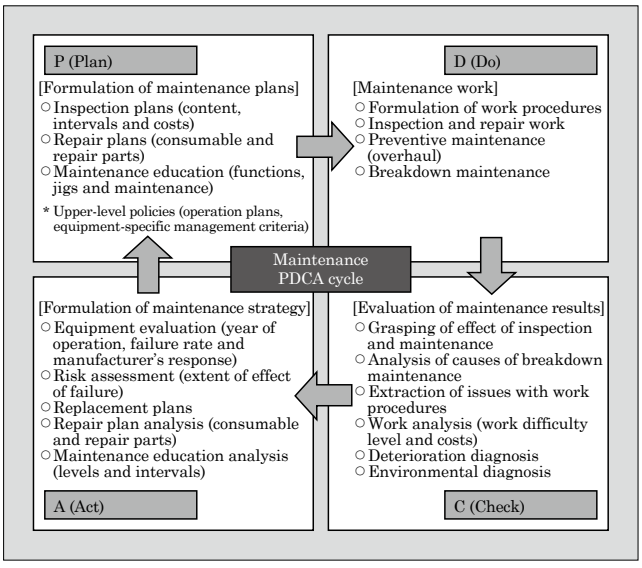

Fig.1 Outline of maintenance PDCA cycle

* Industrial Infrastructure Business Group, Fuji Electric Co., Ltd.

‡ Corporate R&D Headquarters, Fuji Electric Co., Ltd.

of tools and cooperation with the manufacturer are required. With machinery and equipment, failures caused by degradation due to cumulative operating time or repeated stress are common and management of failure history (description and cause of the failure and response history) and sharing of information are required.

(3) Evaluation of maintenance results

To evaluate maintenance results, the effect of work based on the maintenance plans must be grasped. In addition, the results of environmental diagnosis and deterioration diagnosis are also required because the progress of degradation depends on the installation environment and operating (load) conditions.

(4) Formulation of maintenance strategy

To formulate the maintenance strategy, the workers must assess the risk related to stable operation of the equipment. For pieces of equipment that may greatly affect production activities if they break down, equipment replacement must be considered based on the maintenance evaluation (year of operation, failure rate and manufacturer's response) in addition to reviewing the content of maintenance.

3. Cloud-Based Equipment Maintenance Services Utilizing IoT

Fuji Electric provides cloud-based equipment maintenance services for supporting maintenance activities. The information required for the maintenance PDCA cycle is managed in an integrated manner by linking equipment maintenance records, operation monitoring functions and equipment diagnostic functions to support stable operation of the equipment with equipment maintenance. This chapter describes equipment maintenance services that make use of the Internet of Things (IoT), edge devices, work support and security measures.

3.1 Easy-to-understand equipment maintenance records achieved with hierarchization

Equipment maintenance records provide a system of managing the installation location, operation history, inspection plans, failure reports, replacement parts inventory information, deterioration diagnosis results, etc. based on equipment ledgers (year of delivery, manufacturer information, maintenance contact, consumable parts list, etc.). The maintenance PDCA cycle is run by accumulating and using these types of information.

The basic functions required of equipment maintenance records include ease of information updating. The information in the equipment maintenance records must be updated every time the equipment is partially replaced due to aging. In addition, to deal with generation changes of persons in charge of management, a data structure that allows intuitive operation and a management system that can be easily understood are required. Accordingly, the equipment ledgers of equipment maintenance records provided by Fuji Electric have a hierarchical (tree) management structure corresponding with the actual locations such as "site → building → line → equipment → device." Figure 2 presents an overview of an equipment ledger in a map format. After selecting equipment from the location information, information relating to maintenance such as the basic information, inspection information and failure information of the equipment can be viewed and updated.

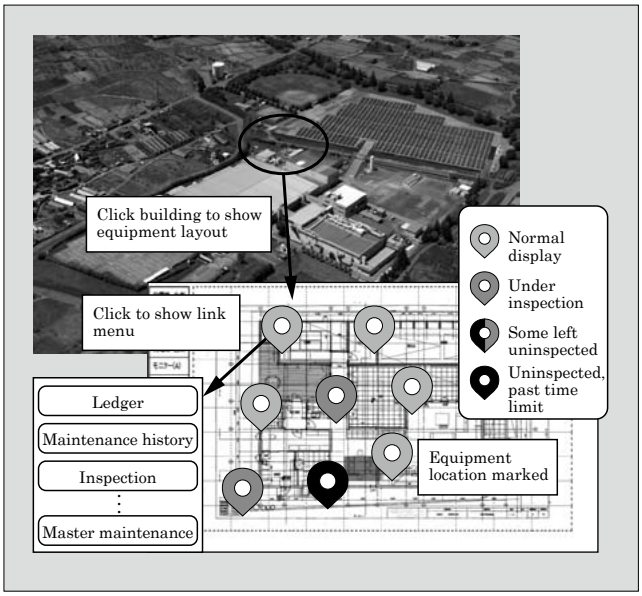

Fig.2 Overview of equipment ledger in map format

3.2 Operation monitoring and equipment diagnostic functions

Fuji Electric's cloud-based equipment maintenance services have the operation monitoring functions linked with the equipment diagnostic functions as described earlier and allow workers to accurately grasp the details of any equipment that shows signs of hindering plant operation. In addition, the operation monitoring screen and equipment diagnosis screen for an arbitrary piece of equipment can be viewed on one display, which makes it easy for workers to simultaneously monitor more than one piece of priority equipment.

(1) Operation monitoring functions with multi-overview

The items to be focused on in plant monitoring may change depending on the season, content of production, failure history, etc. For that reason, it is essential to have a multi-overview function that allows overall monitoring and partial detailed monitoring to be combined freely when monitoring a plant. Figure 3 shows a sample screen with a multi-view display of energy monitoring, plant monitoring, equipment diagnosis and equipment parts management. The main features are as follows:

Fig.3 Example of multi-overview monitoring screen

(a) Screens can be managed in a hierarchical manner according to the purpose of monitoring.
(b) To compare between screens with different management systems, arbitrary screens can be selected for multi-view display without the need for developing software.

(2) Control system monitoring function

To stably operate equipment in an industrial plant, it is necessary not only to monitor the state of the equipment but also to compare the configuration information, performance information, operation information, etc. of the control system in a combined manner. For example, in order to predict intermittent failure, the cause of which is difficult to identify, various types of information such as the server CPU load variation, resource conditions including the memory resources and disk space and operating conditions of the controller are monitored on a daily basis. Fuji Electric makes various proposals for preventing intermittent failure by appropriately strengthening the resources based on a prediction. Table 1 shows examples of monitoring items.

Table 1 Examples of monitoring items

Target		Monitoring item
System information	Server	Cumulative operating time and outage time of system
		System and server logs
		Usage rate (CPU, memory, disk) and process statuses
		Numbers of executed jobs, error jobs, etc.
	Controller	Configuration information (configuration, quantity, versions, serial numbers)
		Cumulative operating time and outage time of system
		Major and minor failure information
	Network	System and network counters
		Registered memory area data
	Peripheral equipment	Uptime and numbers of relay activations and deactivations
		Operating delay time and number of communication errors
Environmental data		Temperature and humidity

(3) Rotating machine equipment diagnostic function

Vibration diagnosis, which is a type of equipment diagnosis offered by Fuji Electric, provides constant diagnosis for the soundness of equipment based on information from the vibration sensor installed on important rotating machine equipment. When any error is detected, an alarm is displayed on the monitoring screen and an e-mail message is sent to the specified contacts. One effect of introduction is that it saves the labor of measuring the vibration of rotating machine equipment which is usually performed by maintenance workers who go around the site. In addition, abnormal vibrations can be detected promptly and this helps to reduce operation loss and ensure manufacturing quality.

The vibration sensor uses a specified low-power radio to send measurement data, which minimizes the length of the signal cable and makes it easy to install the sensor on existing equipment.

Figure 4 shows an example of vibration diagnosis linked with plant monitoring.

(4) Diagnostic function for valve-regulated lead-acid batteries

Fuji Electric's lead-acid battery diagnosis provides diagnosis to check for signs of any rapid characteristic deterioration of valve-regulated lead-acid batteries of uninterruptible power systems (UPSs) that cannot be detected by inspections that are carried out once or twice a year. Using sensors mounted on a valve-regulated lead-acid battery, the voltage, internal resistance and temperature are continuously measured for each cell and the characteristic variations are visualized. The main features are as follows:

(a) For communication between a sensor and edge device BRM (battery remote checker), 2.4 GHz wireless communication is used. This allows sensors to be easily installed on a valve-regulated lead-acid battery of up to 192 cells.
(b) The cloud-based operation makes it easier to

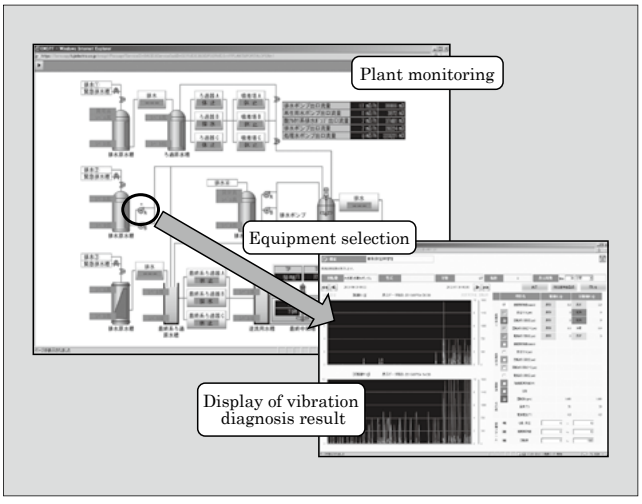

Fig.4 Vibration diagnosis linked with plant monitoring

share information.

(c) A maintenance contract can be made available in which a replacement is immediately prepared and installed when deterioration of the valve-regulated lead-acid battery is detected.

3.3 Edge devices for industrial plants

There are a variety of edge devices used on production sites for different purposes such as devices for collecting data from PIO signals and connecting with transmission lines. This section describes an edge device connected to the control LAN of the control system to collect operation data of devices that constitute the control system. The edge device automatically collects operation data from controllers that constitute the control system such as a distributed control system (DCS) and programmable logic controller (PLC) and PCs connected with the control LAN and stores them in network-attached storage (NAS) and cloud. Figure 5 shows a connection configuration of the edge device for industrial plants.

(1) Communication and data collection to support various networks

The edge device for industrial plants is capable of selecting multiple communication modules such as FL-net-compliant LAN, Ethernet*1, DPCS-F and PE-link*2. It also has communication protocols compatible with the networks to be connected with, which allows collection of data from target devices including legacy devices. Furthermore, environmental data such as temperature and humidity, which are essential to prediction of failure due to aging, can be collected.

(2) Data accumulation and analysis

The collected data are accumulated in the NAS to prevent data loss. Data that cover a long time period are accumulated in a cloud to be used for analysis of resource insufficiency, etc.

(3) PC support tool

Definition of types of data to be collected and collection intervals can be easily configured by connecting a PC support tool. Maintenance workers can use this PC support tool to refer to the data before and after occurrence of failure for identifying the cause of the failure.

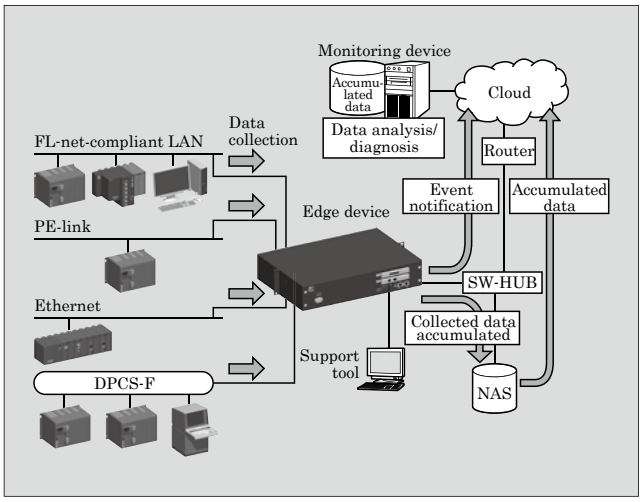

Fig.5 Connection configuration of edge device for industrial plants

*1: Ethernet: Trademark or registered trademark of Fuji Xerox Co., Ltd.

*2: DPCS-F, PE-link: Fuji Electric's control networks

3.4 Work support

The IoT covers maintenance workers as well as devices. The wearable device provided by Fuji Electric is in the form of glasses equipped with a camera and small monitor as shown in Fig. 6, which enables maintenance workers to send what they are seeing to the headquarters as a video without being aware of it. It also allows them to view the drawings required and receive remote work support from the headquarters while using bi-directional audio communication in a hands-free manner. The following are examples of use.

(1) Storage of work history

Work reports mainly include the results of work. For that reason, the submitted work check lists alone do not allow the manager to easily and completely grasp whether the work is carried out according to the procedure and the reports are correct. If the maintenance workers wear the wearable devices and keep the recording function activated, the work history can be stored without the need for them to be aware of it.

(2) Inspection support

In preventive maintenance work, an inspection procedure manual, etc. must be prepared in advance to check the soundness of the equipment based on the inspection check sheet. Introduction of the wearable device allows the inspection items on the check sheet to be shown on the small monitor according to the procedure. By using this, the results of inspection are input by voice and the inspection items can be confirmed and the results of inspection input in a complete hands-free manner. Furthermore, if the inspection procedure is unclear, the help function can be used to play a video of work procedure, etc., which allows smooth execution of inspection work.

(3) Learning support

The inspection support function described above

Fig.6 Example of how glasses-type wearable device is worn

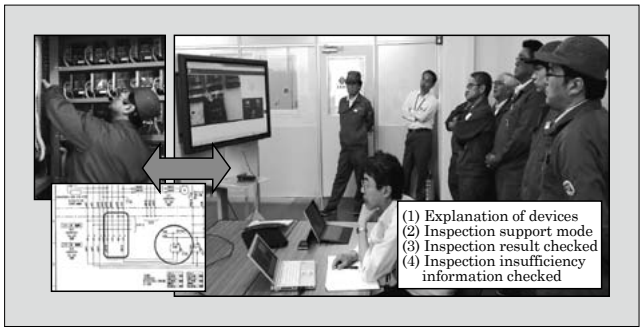

Fig.7 Practical training with inspection practice behavior remotely monitored

can also be used for self-learning of equipment inspection methods in maintenance worker education and training. The actual inspection can be practiced by playing the video as many times as necessary to check the inspection procedure and the techniques can be reliably acquired. How the inspection is carried out can be checked by the instructor using the monitor installed in the headquarters to give detailed advice. Figure 7 shows how the remote monitoring practical training for inspection behavior is given.

3.5 Security measures

The cloud-based equipment maintenance services provided by Fuji Electric ensure security of Web applications so that customers can use the services without anxiety.

(1) Ensured safety of installation environment

Possible risks relating to cloud services include deliberate attacks and suspension of services due to loss of power. As measures against deliberate attacks, server installation location zoning and authentication systems have been introduced. To deal with loss of power in disaster situations, UPSs have been employed to ensure safety of the installation environment.

(2) Ensured safety of cloud system

Safety measures in the network and service infrastructure are as shown below.

(a) Network

Communications are encrypted for protection against data leakage caused by wiretapping.

(b) ID management

An ID system that does not allow identification of personal information is used. Passwords required for accessing the cloud services are encrypted for storage to build a system that prevents viewing by other users.

(c) SQL statements (database language) and OS commands

Many cloud systems linked with databases create SQL statements based on the information input by the users to operate the databases. Any inadequacy in how the SQL statements are built may lead to an abuse of databases. To address this vulnerability, the actual values are not directly input into SQL statements but replaced by temporary symbols to indirectly assign the actual values. To deal with the vulnerability to illegitimate execution of OS commands of the Web server due to attacks from outside, measures have been taken such as avoidance of using a language function that allows similar direct operation.

4. Postscript

This paper has described service solutions that support stable operation of equipment. Utilization of the IoT realizes further stable operation and reduction of operation costs of plants and equipment and has a great potential. We intend to make use of the IoT to further enhance the functions of the cloud-based equipment maintenance services, thereby contributing to stable operation of customer equipment.

Fuji Electric

Innovating Energy Technology