Service Solutions to Support the Stable Operation of Equipment

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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 of operation plans, maintenance education and so on were taken. The education planning activities are called a maintenance PDCA cycle.
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.

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:
(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

Table 1 Examples of monitoring items

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

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

*1: Ethernet: Trademark or registered trademark of Fuji Xerox Co., Ltd.
*2: DPCS-F, PE-link: Fuji Electric’s control networks
Service Solutions to Support the Stable Operation of Equipment

Safetymeasuresinthenetworkandserviceinfra-
structureareasshownbelow.

(a) Network
Communications are encrypted for protection
againstdataleakagecausedbywiretapping.

(b) ID management
An ID system that does not allow identification
ofpersonalinformationisused.Passwordsrequired
foraccessingthecloudservicesareencryptedfor
storagetobuildasystemthatpreventsviewingby
otherusers.

(c) SQL statements (database language) and OS
commands
Manycloudsystemslinkedwithdatabasescre-
estSQLstatementsbasedontheinformationinput
bytheuserstooperatethe databases. Anyinade-
quacyinhowtheSQLstatementsarebuiltmaylead
toanabus eofdatabases. To addressthisvulner-
ability, the actual values are not directly input into
SQLstatementsbutreplacedbytemporarysymbolsto
indirectlyassigntheactualvalues. 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 avoid-
ance of using a language function that allows simi-
lardirectoperation.

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 equip-
ment maintenance services, thereby contributing to
stable operation of customer equipment.

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Fig.7 Practical training with inspection practice behavior re-
motely monitored

3.5 Security measures
The cloud-based equipment maintenance services
provided by Fuji Electric ensure security of Web applica-
tions 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 infra-
structure 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 inade-
quacy in how the SQL statements are built may lead
to an abuse of databases. To address this vulner-
ability, 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 avoid-
ance of using a language function that allows similar
direct operation.

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
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