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Development of IT Facility Advanced Management & Maintenance System Solution for Power and Energy System Service Businesses

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OVERVIEW: With terms such as Industrie 4.0 and the Industrial Internet (1) trending in the market, there has been a rise in demand for advanced facility management and maintenance systems that use IT to maintain corporate production facilities and energy facilities, predict failures from online monitoring or data acquisition, and undertake preventive measures. Hitachi has responded to this demand by using the IoT to develop an advanced maintenance system platform, and by providing actual advanced maintenance services including failure prediction. This platform is called CMMS. This article provides an overview of CMMS and discusses examples of its application to maintenance services in the form of gas engine generation equipment, high-voltage motors, and photovoltaic equipment.

INTRODUCTION

THE power and energy sectors are attempting to connect the information technology (IT) known as the Internet of things (IoT) to maintenance services. While the equipment in these sectors use large numbers of sensors to monitor conditions remotely, it also needs failure prediction capability. A shortage of experienced maintenance technicians is creating growing demand for maintenance assistance systems that can enable maintenance work by less-experienced maintenance technicians.

With attitudes toward maintenance changing, one trend that has arisen is the division of maintenance approaches into after-the-fact maintenance, time-based maintenance (TBM), and condition-based maintenance (CBM) approaches in accordance with equipment performance and maintenance cost. After-the-fact maintenance is maintenance that is done to repair failed parts or broken equipment after problems arise. TBM is maintenance that is done to repair/replace old or malfunctioning parts discovered during periodic inspections. CBM is maintenance that is done by detecting failures, errors or other condition changes before emergency stops are generated.

Power Systems Company, Hitachi, Ltd. and Hitachi Power Solutions Co., Ltd. (Hitachi Power) have provided maintenance services to the power and energy sectors for many years. In response to the maintenance environment described above, both companies together have spent about three years developing an advanced IoT-driven maintenance system platform, and have been using it to provide advanced equipment maintenance services. This article provides an overview of these activities, and presents some example applications of the platform developed.

OVERALL CONCEPT OF CMMS

Hitachi's computerized maintenance management system (CMMS) is an IT platform that enables advanced facility maintenance. Fig. 1 illustrates its overall concept. CMMS assists CBM by providing early detection of changes in facility conditions. When condition changes are difficult to assess, experienced maintenance technicians from multiple maintenance sites provide logistical support that ensures high-quality maintenance work.

CMMS Software Configuration and Features

This software is an IT platform that provides eight functions to assist in all areas of maintenance work. The eight functions are used for (1) equipment management for managing equipment installation locations, configurations, and failure histories, (2) document management for managing documents

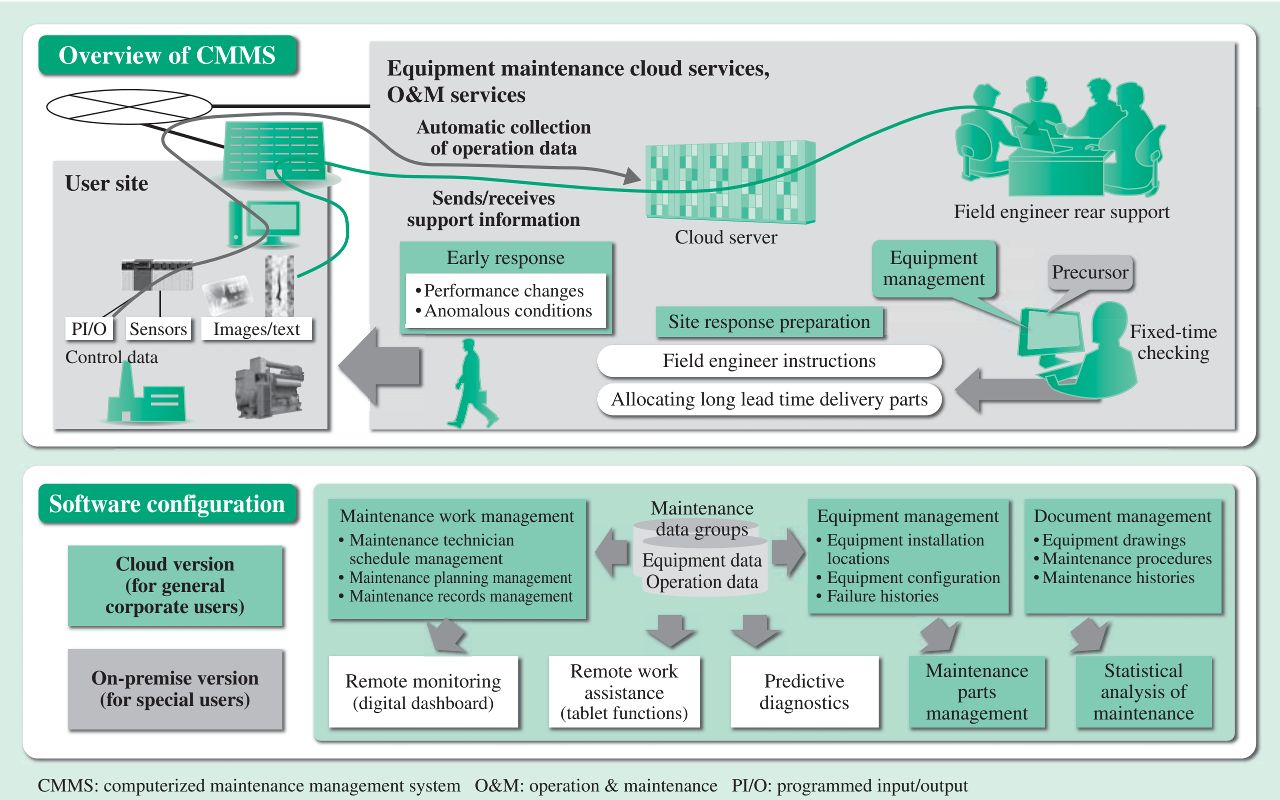

Fig. 1—Overall Concept of CMMS.
The illustration shows the concept of the CMMS platform, which provides services such as remote monitoring, remote work assistance, predictive diagnostics, equipment management and document management and assists with advanced maintenance work.

such as equipment drawings and maintenance procedures, (3) maintenance work management that assists with work such as maintenance planning and maintenance technician scheduling, (4) maintenance part management for managing the inventory of replacement parts and storage locations, (5) remote monitoring using digital dashboard technology, (6) remote work assistance using tablets or mobile terminals, (7) predictive diagnostics to notify of changes in equipment conditions, and (8) statistical maintenance analysis to statistically analyze gathered data.

This system is available in two formats tailored to different user characteristics (such as whether the user permits data removal) and equipment characteristics (geographical distribution). For general users, the cloud-based version provides it as a service. For special users, the on-premise version provides as a system.

The sections below provide a detailed look at three characteristic functions among the eight functions provided by CMMS—the functions for predictive diagnostics, remote monitoring, and remote work assistance.

Predictive Diagnostics System

The Hitachi Power Anomaly Measure Pickup System provides early detection of unusual conditions in equipment by combining the maintenance service expertise that has accumulated over many years with information and communications technology (ICT) and data mining technology (see Fig. 2).

This system detects a variety of abnormal conditions such as failure precursors that can superficially resemble normal operation, parameters set incorrectly due to human error, and differences in input materials or material quality. Early detection and remediation of these abnormal conditions can prevent sudden equipment shutdowns or drops in quality.

Anomaly detection is done by using data mining technology for vector quantization clustering (VQC) or local subspace classifiers (LSCs). Since both of these methods are nonparametric algorithms, their statistical effects are low, and they enable rapid system configuration since no model construction is required (see Fig. 3). In addition to these benefits, the processing needed to output results can be done rapidly, making these methods good at detecting anomalies in transient conditions.

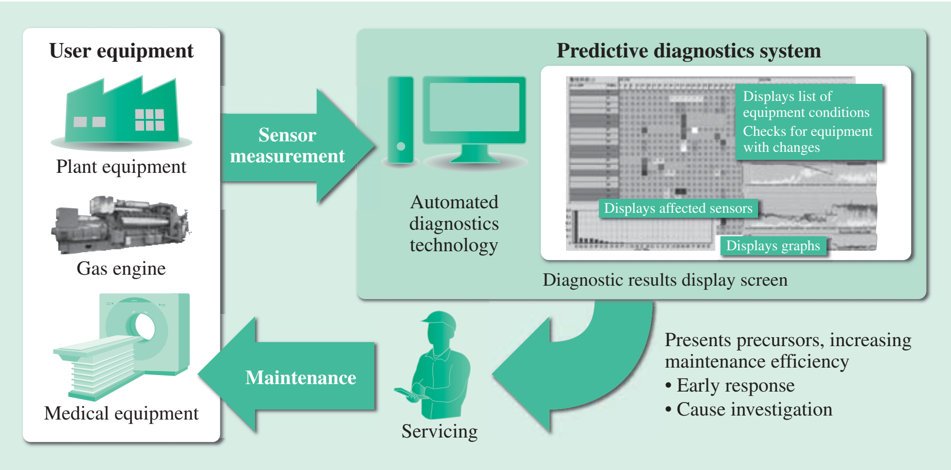

Fig. 2—Predictive Diagnostics System.
The predictive diagnostics system provides data-gathering/storage, diagnostic processing and display of results, as well as early detection of changes in conditions to help infer causes.

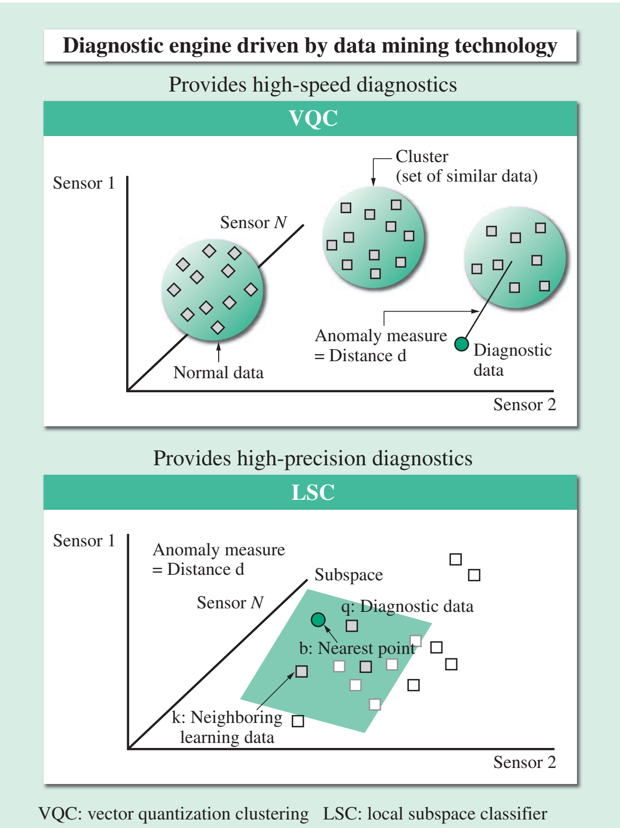

Fig. 3—Diagnostic Engine.
The diagnostic engine uses equipment operating conditions and sensor signal movements to select optimal diagnostic algorithm and implements it in the system.

This system applies machine learning to data gathered from equipment sensors to learn the normal (usual) data patterns, and to evaluate whether anomalies are present by analyzing the degree of deviation between the routinely gathered data and learned data. If an anomaly is detected, the cause can be surmised from the types of sensors that have the greatest impact on the deviation, and the degree of deviation detected. The criticality level can then be assessed.

By giving maintenance technicians early notice of unusual condition information, this system can prevent failures and ensure replacement part lead times.

Hitachi is planning to enhance this system by adding to its predictive detection ability with a function that will surmise failure causes by comparing the results of past failure analysis with predictive analysis results.

Remote Monitoring (Digital Dashboard)

The remote monitoring function uses digital dashboard technology to provide centralized round-the-clock monitoring of equipment warnings, sending equipment operation statuses to the user. The function provides timely response instructions to maintenance technicians, and maintenance information in cooperation with design department technical support.

This digital dashboard assists with remote monitoring of equipment and machinery, enabling the optimal display for unified management of the operation statuses of multiple pieces of equipment.

One feature of the remote monitoring function is the method for gathering and sending data. Output values from equipment or machinery sensors are sent to a server with unique IDs identifying each sensor value. Each user terminal can specify these sensor value IDs to display the desired values, then the server can use them as keys so that only the sensor values that need to be displayed are sent to the user terminals. This method ensures that information is sent in realtime with no lags caused by drift between the database information storage cycle and the cycle in which the database is referenced by the user terminals (see Fig. 4).

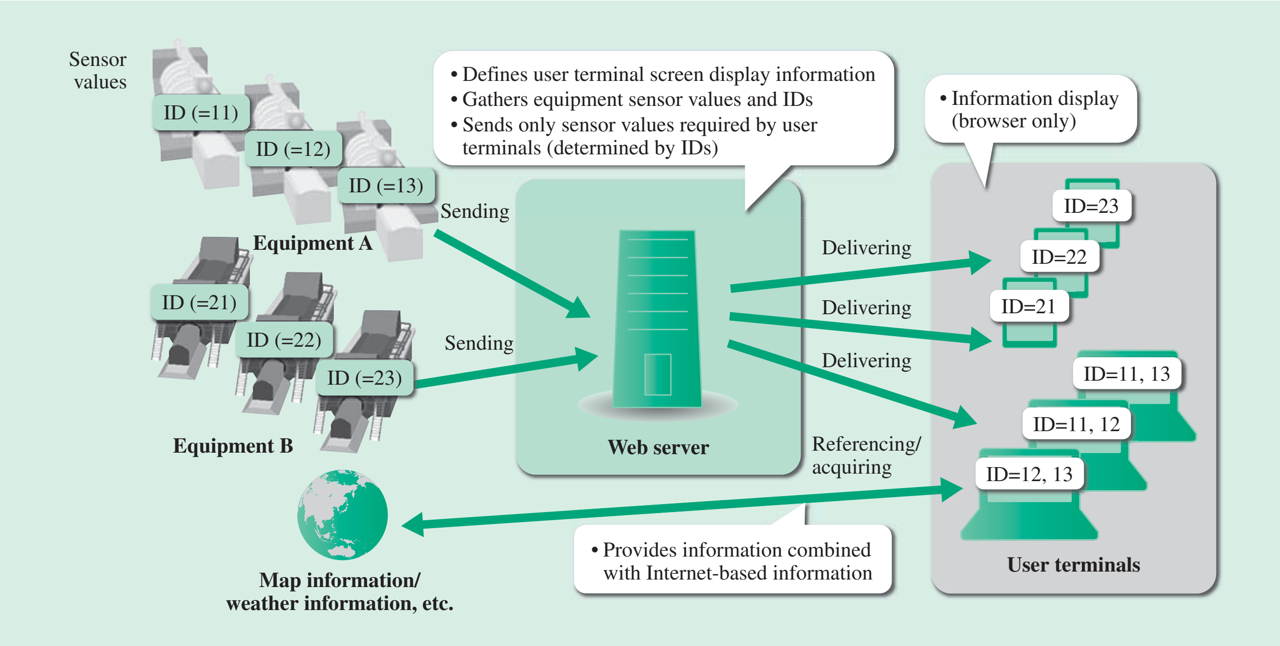

Fig. 4—Digital Dashboard Configuration Example.
The digital dashboard provides unified management of multiple facility operation conditions, enabling optimal display.

When sensors are added or changed as equipment is upgraded or expanded, the function can be flexibly adapted just by reworking the user terminal screen design, with no need to revise the data-gathering and distribution processes or the database structure.

Trend graphs, bar graphs, lists, image information, and other information elements on the user terminal display screens are implemented as modules, which makes it easy to change screen layouts and enable or disable the display of particular elements. The user terminals also provide map information(2), weather information(3), and other information combined with information from the Internet. These features enable the screen design and the information provided to be tailored to the user's needs (see Fig. 5).

(1) Administrator screen (2) Maintenance manager screen

Fig. 5—Output Screen Example.
Screens can display sensor information in forms such as images, trend graphs, and bar graphs.

Remote Work Assistance

The remote work assistance function seamlessly links the tablet terminals of maintenance technicians on sites to the logistical support environment at the center. It enables the proper work instructions to be provided in the form of videos, images, recordings, and written documents to assist with the safety and precision of site work (see Fig. 6).

In the future, Hitachi intends to draw on its many years of accumulated maintenance service expertise to make further refinements to the IT platform, helping create more advanced maintenance technologies. This will create and expand advanced maintenance business opportunities, providing maintenance services and remote monitoring systems for power generation equipment and other key infrastructure equipment.

APPLICATIONS

Applications for Gas Engine Power Generators

The Ohnuma Works, Hitachi Power (located in Hitachi, Ibaraki Prefecture) provides maintenance services for small gas engine power generators throughout Japan. To enable predictive diagnostics for these small gas engine power generators, the factory started developing a predictive diagnostics system in 2008. Actual equipment use and operation testing/

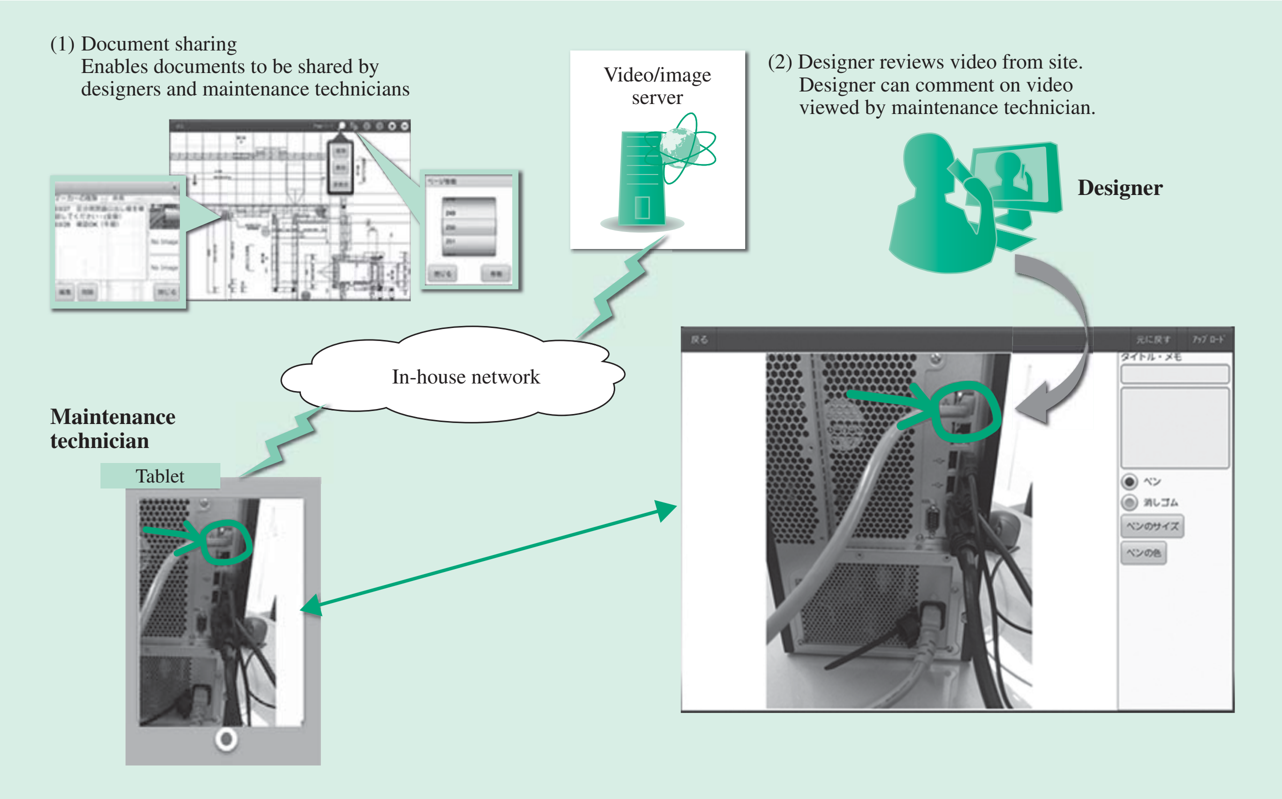

Fig. 6—Remote Work Assistance Function.
The remote work assistance function seamlessly connects the site terminals to the logistical support environment, providing the proper instructions to assist with the safety and precision of site work.

evaluation started in FY2011, and this system is now being used in 160 generators.

Specifically, about 30 sensor signals measured in 30-second cycles are diagnosed daily. The system has shown positive results, detecting up to about 70% of failure causes (see Fig. 7).

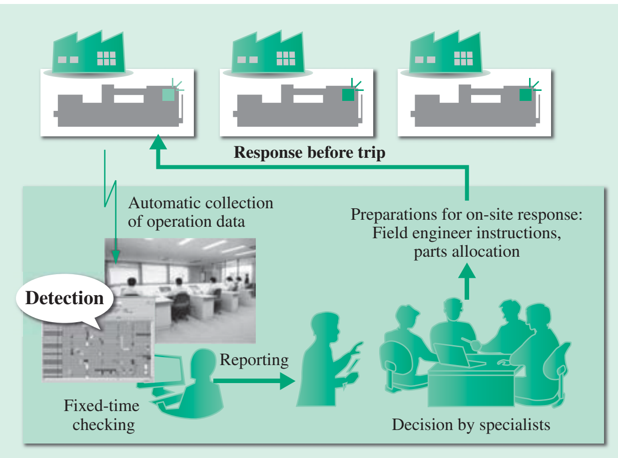

Fig. 7—Operation of Predictive Diagnostics System.
Predictive diagnostics system results are checked daily, enabling response before problems arise.

Anomalies have traditionally been evaluated using threshold values, but the effects of individual unit characteristics and seasonal changes in installation environments result in inadequate detection precision. The use of Hitachi's predictive diagnostics system is now providing benefits and enabling the detection rate stated above.

Motor Maintenance Service

The mainstream approach to motor maintenance has always consisted of routine inspections combined with after-the-fact maintenance in the form of response measures taken when signs of problems arise. When these signs arise, technicians have traditionally made assessments based on sensory evidence—measuring parameters such as vibrations to manage absolute values, listening for abnormal sounds, and taking similar steps. Routine inspection management has also largely consisted of recording daily inspection items and speaking to users, which is a method that is not well adapted to trend management with a time-series axis. Hitachi has improved this approach using trend management that incorporates predictive diagnostic technology.

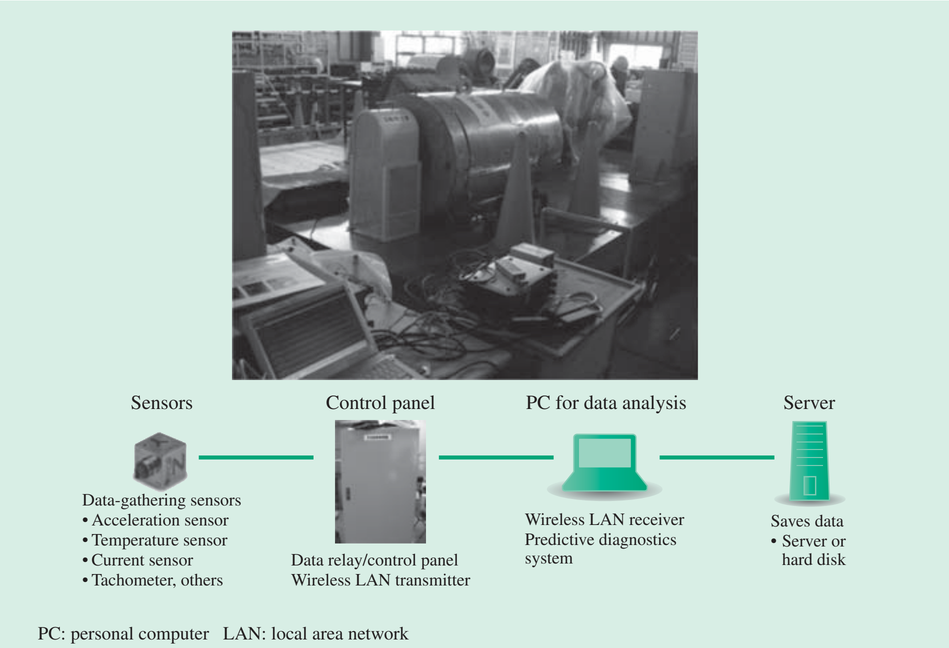

Fig. 8—In-house Verification Testing and Test Configuration.
To verify the accuracy of the analysis/precursors, continuous operational testing is performed on aging motors up to the point of motor bearing burnout.

As shown in Fig. 8, Hitachi's predictive diagnostics service for motors is provided by repeatedly performing in-house verification testing while using this system as a uniform integrated tool to handle processes ranging from data-gathering to analysis and diagnoses of degradation trends and failure precursors.

The features of Hitachi's predictive diagnostics system for motors include:

(1) 24-hour automated data-gathering and analysis
(2) Hitachi's 24-hour monitoring service
(3) Threshold value management (conventional)
(4) Trend management
(5) Expandability to all equipment that include motors

In addition to conventional threshold value management, signs of problems are also detected by comparing process trends using Hitachi's predictive diagnostics technology. This approach is highly effective for equipment that makes it difficult to analyze data under uniform conditions due to a changing ambient environment or changing loads. Moreover, the system's automated gathering and storage of maintenance and management information is beneficial since it lets equipment maintenance staff devote themselves to the work needed for other equipment or production. Hitachi also has a remote monitoring center, and can provide 24-hour monitoring of equipment statuses at the user's request.

O&M Service for Photovoltaic Equipment

Japan's photovoltaic market has expanded greatly since the start of a feed-in tariff (FIT) system in July 2012. It is important to minimize drops in the utilization factors of constructed photovoltaic power generation equipment through early detection of failures and rapid repairs, and there is a growing demand for high-quality operation and maintenance (O&M) services.

This section looks at the solar panel failure diagnostics service Hitachi has developed independently.

Solar panel failure diagnostics is generally conducted using string monitors (a string is a unit consisting of multiple photovoltaic modules connected in a series). This method requires sensitivity to be set low to prevent false-positives since anomalies are assessed by relative comparisons to adjacent strings or average values. To solve this problem, Hitachi has developed a failure diagnostic model that uses the physics of semiconductor devices to enable high-precision diagnoses by comparison with theoretical values(4).

Fig. 9 illustrates an example application of this diagnostic model for a typical string monitor. In this example, a crack has occurred in the glass of a single solar panel—a problem difficult for a string monitor to detect but clearly detected using Hitachi's failure diagnostic model.

In addition to strings, this diagnostic model can also be applied to sensing targets such as connection boxes or power conditioning systems (PCSs) according to the customer's needs.

Diagnostic ability varies according to the sensing target and failure mode, but power generation capacity

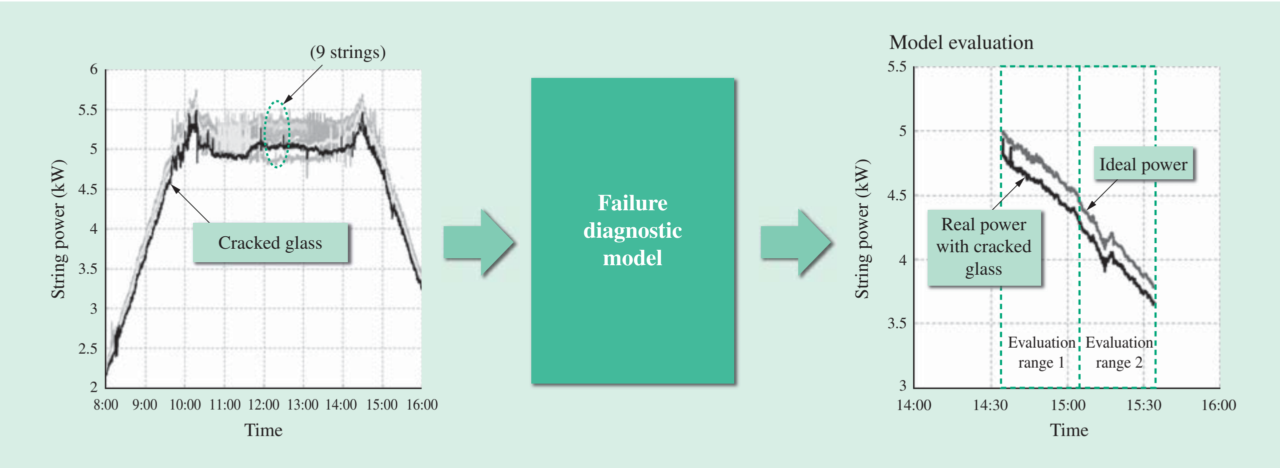

Fig. 9—Failure Detection Example.
A single cracked solar panel undetectable with a string monitor can be detected using Hitachi's failure diagnostic model.

drops of 2.5% or more are generally detectable. Providing online monitoring over a cloud environment enables early failure detection and a reduction in equipment investment.

CONCLUSIONS

Hitachi's advanced IT facility maintenance system has been used for maintenance of gas engine power generation equipment, large motors, photovoltaic power generation equipment, and other power and energy products to improve the added value of equipment maintenance/remote monitoring services.

In the future, Hitachi plans to refine the functions of this system as an equipment maintenance platform to expand its application to products in other fields, and to help provide services tailored to the needs of customers.

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