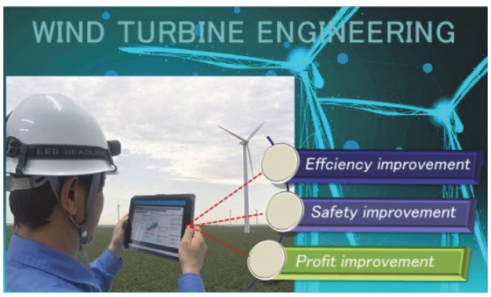
Solution Proposal Utilizing the Wind Turbine's Maintenance Support Tool - Aiming for Long-term Stable Operation of Wind Power Plant -



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https://www.mhi.com/products/energy/wind_turbine_plant_maintenance.html

With a growing renewable energy demand for the achievement of carbon neutrality, an increasing number of wind power generation facilities (hereafter referred to as wind turbines) are rapidly being installed in Japan. Wind turbines are required to supply stable power for the long-term. However, various challenges arise in the stage of post-construction operation, because the intricacy of the changing natural environment causes the components of wind turbines to deteriorate or malfunction, leading to the low availability of wind turbines.

To ensure customers to maintain stable operation of wind turbines, Mitsubishi Heavy Industries, Ltd. (MHI) has been working on the development of a comprehensive support tool for maintenance. This was brought to fruition as our newly released product "Maintenance Support Tool for Wind Turbines". With the introduction of this tool into the wind farms of customers, we have started providing technical services.

1. Features of our Maintenance Support Tool

When operating wind turbines for a long time, the importance lies in managing maintenance and profitability. The former is for public safety and stable operation, and the latter is for keeping the wind farm business successful.

However, the customers are responsible for a wide range of tasks including daily data monitoring, the conduct of inspection/repair work considering the weather, and recovery from failure/shutdown. There are many issues to run a wind farm safely, effectively, and economically.

Therefore, MHI has started providing technical support services that will be a solution to various issues. This was enabled by building an advanced system using big data consisting of wind turbine operation/maintenance records and others, as well as by means of digital transformation (DX) of a vast amount of analog information such as our extensive experience and expertise acquired after years of engagement in the wind power generation business.

Our Maintenance Support Tool visualizes the operation conditions by aggregating/analyzing daily wind turbine data via an edge device (i.e., Gateway PC) that is installed at the wind farm after an annual contract is signed between the customer and MHI. The maintenance support information such as facility diagnosis and technical information is shared on a cloud server dedicated to the customer.

The employment of this tool can help enhance the facility's availability and asset value, because of its wide applicability to, for example, facility maintenance, reduction of the risk of low availability, improvement of efficiency in operational maintenance, and wind turbine control upgrading.

Figure 1 illustrates an overall view of the Maintenance Support Tool and an image of the application scene.

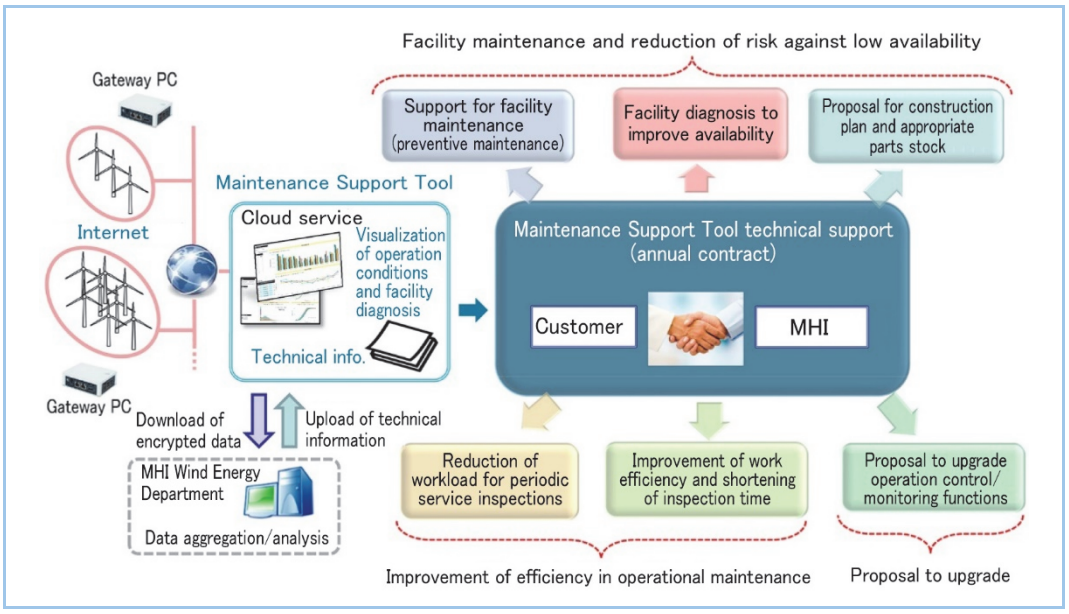

Figure 1 Technical support by Maintenance Support Tool

2. Availability improvement by Maintenance Support Tool

The key metric for the management of wind turbine operation is the availability. The requisite for maintaining high availability are the effective execution of facility maintenance, the prevention of wind turbine failure/shutdown, and the minimized downtime.

As shown in **Figure 2**, the approach to facility maintenance is twofold: “Breakdown Maintenance (BM)” conducted after some failure or accident occurred, and “Preventive Maintenance” conducted to prevent failures and accidents.

In addition, preventive maintenance generally refers to “Time Based Maintenance (TBM)”, which is conducted to replace parts or repair on occasions such as patrol/regular inspections according to schedule after the lifespan of components is estimated based on the specifications and other documents.

However, since each of the wind turbines is subject to different wind strength and operating hours depending on their installed environment, the progression of degradation or fatigue of components also differs. TBM thus fails to prevent failures, resulting in low availability of wind turbines for some cases.

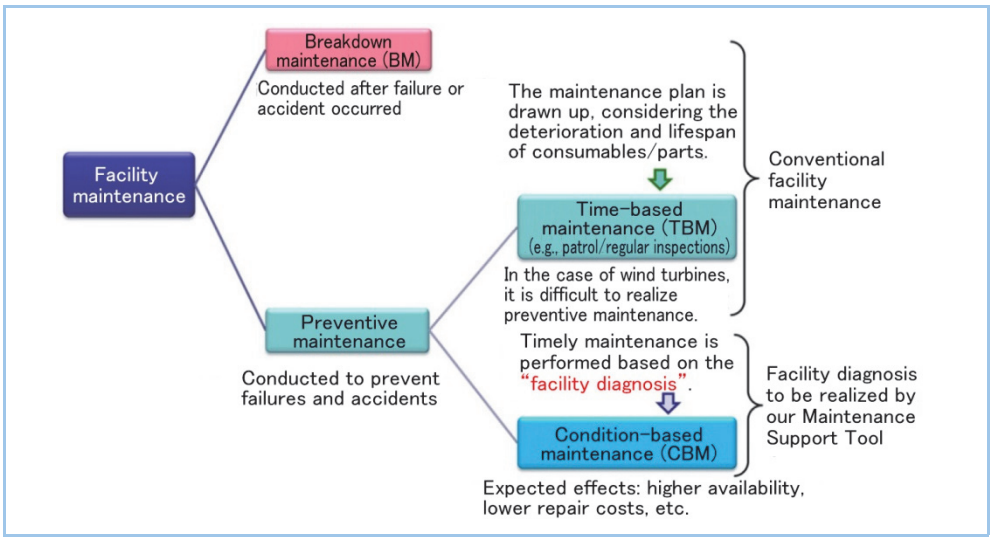

Figure 2 Systems of facility maintenance

We, therefore, recommend adopting another method of preventive maintenance: “Condition Based Maintenance (CBM)”. In CBM, facility diagnosis is performed by collecting and analyzing the operational data to detect signs of parts deterioration at an early stage. Thus, timely action can be

taken. This prevents a serious failure or accident from happening, while the effects such as higher availability and lower repair costs can be expected.

For developing the function of "facility diagnosis", which is essential to the realization of CBM, MHI uses the operational data and failure history for the past 10 years or more. The algorithm, which the data of both abnormal and normal operation conditions are statistically analyzed to automatically identify abnormal signs, is being verified.

Figure 3 illustrates the mechanism of facility diagnosis more specifically. The characteristic data required to identify abnormal conditions are extracted from the daily operational data, and the measured values are compared with the planned values to automatically determine if there are any abnormal signs. The results will be automatically sent to the customers.

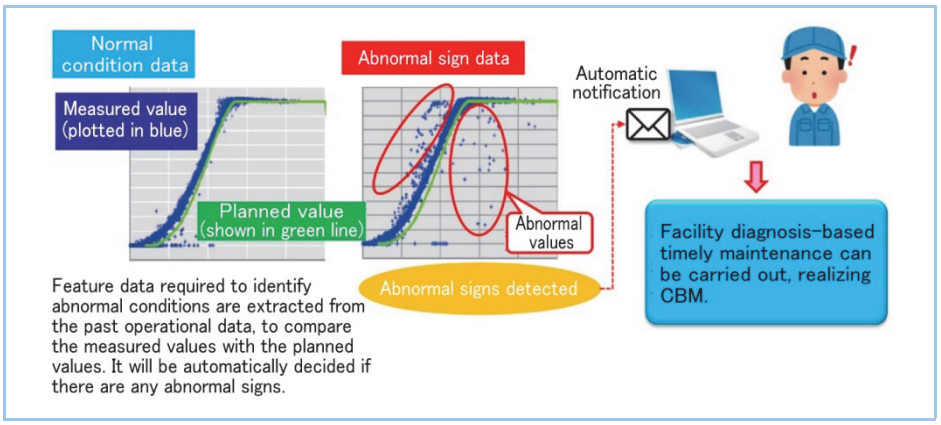

Figure 3 Conceptual diagram of facility diagnosis by Maintenance Support Tool

The Maintenance Support Tool is equipped as standard with this function of facility diagnosis. Therefore, CBM can be realized without burdening customers with an extra workload.

Furthermore, facility diagnosis can provide indications of equipment/facility abnormal conditions and their degree of degradation. This enables to determine which repair work should be prioritized and which parts replacement or repair work is unnecessary, thus helping to optimize maintenance costs.

3. Line-up of Maintenance Support Tool functions

Based on the voices of the customers who have maintained wind turbines for many years, our Maintenance Support Tool has repeatedly expanded its functions in the form of a solution proposal for various issues that are not limited to facility diagnosis. **Figure 4** shows the major line-up of the functions. These groups of functions for maintenance support can be divided into two groups: one in which the standard functions are put together as the basic package, and one in which the optional functions are lined up for customers to choose one by one depending on their needs and budget.

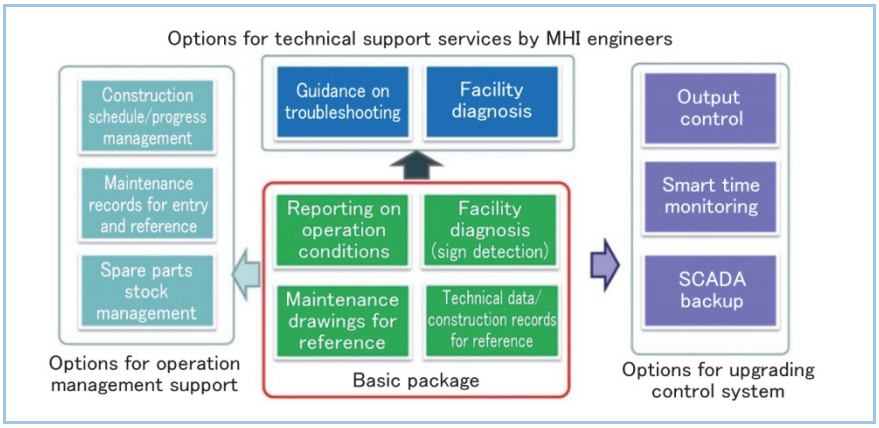

Figure 4 Group of functions for maintenance support

The following is a summary of the functions.

(1) Basic package

This is a start-up package consisting of the basic functions that are expected to be used frequently in the process of operational maintenance, including facility diagnosis.

In operational information reporting and facility diagnosis (sign detection), operational data are automatically collected on a daily basis, which are then outputted in a format useful for operation management. Other functions include the presentation using a graph (visualization) to make it easy to compare units or analyze them, and the automatic notification in the case of abnormal signs being observed in certain types of equipment.

Reference to maintenance drawings and reference to technical data/construction records are the functions by which drawings or technical data required for on-site maintenance work can be accessed from tablets and smartphones.

(2) Options for technical support services by MHI engineers

This subgroup of options is related to the technical advice services for customers who consider it necessary to receive technical support such as dealing with problems in direct dialog with MHI engineers, and/or for customers who require the facility diagnosis report to be submitted on a regular basis.

(3) Options for operation management support

This subgroup pertains to the function that can be used to manage the history of each wind turbine and spare parts stock. Specifically, customers can easily enter their daily maintenance operation records (such as maintenance records, construction records, and troubleshooting records) via tablets or smartphones to store related information as a database.

(4) Options for upgrading control system

There is also a group of other optional functions to meet a variety of customer needs, including changing the function of the wind turbine operation control system.

The past examples of the expanded functions include the output control system enabling the target output of the entire wind farm or each wind turbine to be set at an arbitrary value, the smart time function to monitor the diagnosis results and the real-time trend data via smartphones and tablets, and the SCADA (Supervisory Control And Data Acquisition) backup system that can be used as an alternative monitoring system when the remote monitoring system fails to function.

4. Expected advantages from using tool

The use of our Maintenance Support Tool is expected to give the following advantages to the customers who operate wind turbines.

(1) Improvement of work efficiency
- Labor savings in reporting on operation/maintenance records
- Improved efficiency of the tasks for regular inspections and periodic service inspections
- Improved efficiency in organizing and visualizing data required to make a decision on construction plan or business management

(2) Better maintainability
- Understanding of facility conditions to realize appropriate planning of regular inspections and repair work
- Detection of abnormal signs to avoid the long-term shutdown due to the failure of parts, and prevent a serious failure from happening

(3) Higher profitability
- Reduction of management costs owing to the improved work efficiency
- Reduction of repair costs because of preventive maintenance
- Increase in revenues by dealing with abnormal signs at an early stage and reducing the downtime (i.e., higher availability)

5. Future prospect

Making use of its experience and expertise accumulated through the years of engagement in the wind power generation business, MHI's Wind Energy Department has been taking up the challenge to support customers who are faced with various difficulties in operating wind turbines.

Specifically, we offer engineering support services for the various wind turbines of other manufactures including offshore wind turbines.

Likewise, we are currently working to make our Maintenance Support Tool applicable to the other manufacture's wind turbines. A large-scale introduction of wind power will take place to achieve carbon neutrality. We will further proceed with DX and contribute to realizing a sustainable society by meeting the needs of customers who want to realize long-term stable operation of wind farms.