AI Technology that Supports Optimal Operation and Maintenance: How Contribute to Renewable Energy Projects Toward Decarbonization

KOTARO SAKEMI[*1] YUKO TAKIGUCHI[*2]
RYOHEI OHASHI[*2] YUTARO TSUCHISAKA[*2]
KAORU IWASAKI[*3]

The importance of renewable energy projects for the purpose of decarbonization has been increasing, and the need for proper operation and maintenance (O&M) is growing among operators. This time, focusing on onshore and offshore wind farm, the capacities of which have been increasing, we applied ENERGY CLOUD®, which utilizes data analysis and Artificial Intelligence (AI) technology from Mitsubishi Heavy Industries, Ltd. (MHI). We also verified its effectiveness for O&M in the actual field with the aim of maximizing operating revenue of an entire wind farm. This report describes the visualization of equipment conditions, prediction of electricity market prices, optimization of periodic inspection plans, and support processes for O&M and electricity sales that have been effective in increasing operating revenue by several percent to ten percent.

1. Introduction

Today, there is worldwide demand for decarbonization and stable electric power supply, and the development of renewable energy power generation projects has been progressing all over the world. The Japanese government has set a target of 10 GW by 2030 and 30 GW to 45 GW by 2040 for offshore wind power generation, and in December 2021, for the first time in Japan, a competitive bidding process was held to select an offshore wind power generation operator. In the future, along with the construction of new wind power generation facilities, there will be a need for more advanced and efficient long-term O&M technologies. On the other hand, O&M of wind power generation facilities requires specialized technical knowledge, and the human resources involved in O&M in Japan is not as large as in Europe and the United States.

In this report, we applied ENERGY CLOUD, which utilizes MHI's data analysis and AI (Artificial Intelligence) technology, to wind power generation projects to verify the effectiveness of the AI technology using data from existing onshore wind farms in Japan and the United States, so that stable O&M can be carried out effectively.

2. ENERGY CLOUD

As shown in **Figure 1**, ENERGY CLOUD is a technology that provides our customers with solutions such as optimization in response to their needs by visualizing and future-predicting through data analysis tailored to them using AI and Internet of Things (IoT). The use of this technology enables the provision of comprehensive solutions based on MHI's know-how, which has been involved in our products from social infrastructure-related products to products for general consumers.

In providing ENERGY CLOUD, we analyze the accumulated and collected data to quickly find pointers for improvement and to support management efficiency and project optimization. This procedure from understanding the current situation with data analysis to optimization is standardized, so ENERGY CLOUD can be introduced in a short period of time to various facilities and fields.

*1 Chief Staff Manager, Business Development Department, Growth Strategy Office, Mitsubishi Heavy Industries, Ltd.
*2 EPI Department, Digital Innovation Headquarters, Mitsubishi Heavy Industries, Ltd.
*3 Manager, Wind Energy Department, Energy Systems, Mitsubishi Heavy Industries, Ltd.

ENERGY CLOUD has accumulated a variety of data based on electricity demand prediction[1] at factories and other consumers, and are now expanding the scope of application to optimize power generation and production processes in wind farm and factories to support operations such as labor saving and cost reduction.

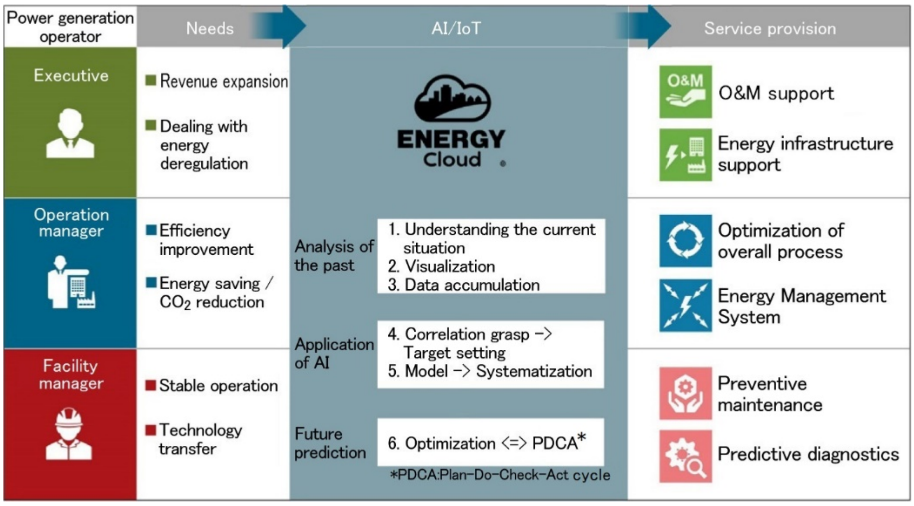

Figure 1 Proposal of ENERGY CLOUD solutions

3. Issue and measure with O&M of wind farms

To ensure stable operation of wind farms and maximize operating revenue, efficient and optimal O&M is required, taking into consideration for each turbine external factors such as wind and environmental conditions that change daily, and internal factors such as the performance of the power generation equipment itself and deterioration over time. In Japan, renewable energy has become widespread with feed-in tariff (FIT). However, as the number of wind farms for which the FIT period will expire increases and the feed-in premium (FIP) and free electricity market expand in the future, it is expected that the value of electricity will fluctuate significantly from the impact of electricity market prices. In the past, O&M was carried out in person based on intuition and experience cultivated over many years. However, as a future issue, it is necessary to comprehensively consider multiple factors such as equipment conditions, the electricity market that affect operating revenue and accumulated data.

Therefore, we visualized, predicted and optimized factors related to equipment and electricity markets using AI technology of ENERGY CLOUD to maximize operating revenue, while using MHI's wind turbine design and manufacturing know-how and the result of O&M at the same time. By inputting wind conditions and electricity market price data in addition to operation data related to wind power generation facilities into the ENERGY CLOUD to analyze each item in an integrated manner, guidance on O&M was output as shown in Figure 2. The guidance indicated which wind turbines should be inspected and when and how much power generation should be sold to which markets. The following chapters explain the analysis of each item and its effect on O&M.

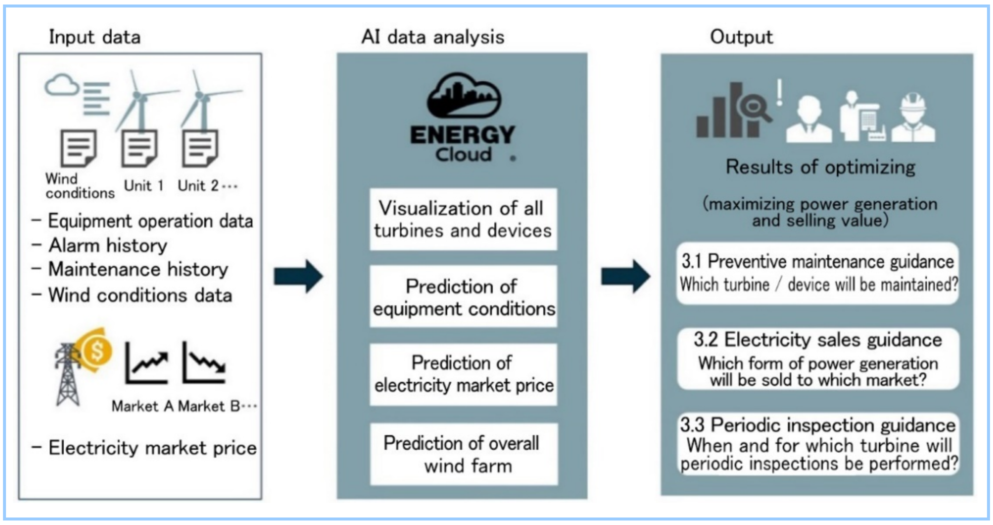

Figure 2 Maximization of operating revenue in wind farm

3.1 Preventive maintenance guidance

In Europe and the United States, nearly 100 wind turbines are installed at one wind farm in many cases, and offshore wind farms of the same scale are being planned in Japan. For this reason, the issues are to visualize the equipment conditions of multiple turbines efficiently so that they can be monitored at once, and to share information quickly among the entities that operate wind farm project at respective layers. Visualization is very important also for the prediction and optimization through data analysis as well as the reduction of O&M costs. Therefore, we developed an equipment condition visualization program taking the following into consideration and verified the possibility of using it for preventive maintenance.

- Visualization of evaluation index common to layers (executive, operation manager, and facility manager) obtained by integrating various data
- Visualization of availability (defined as internal availability) caused by power generation facility separately from external factors such as facility outage due to grid and wind conditions
- Proposal of maintenance focus points based on the information subdivide for each turbine and each device from the comprehensive overlooking information of the entire wind farm
- Visualization of the effect of maintenance in addition to equipment conditions such as deterioration

Figure 3 shows an example of visualized charts and the flow of their utilization for preventive maintenance. In the demonstration field at The United States, the effect of reducing the time required for facility managers to analyze data was achieved, and it was possible to understand the operating status at turbines that had been overlooked on-site, and improve the availability, and we were able to track the performance of the entire wind farm in each layer. In addition, the integration of data on the internal availability and maintenance history made it possible to simultaneously show the equipment conditions and on-site maintenance response in graphs, and visualize how maintenance work affects the availability. Furthermore, by identifying trends in each turbine and equipment, it was possible to select priorities for maintenance and propose effective preventive maintenance.

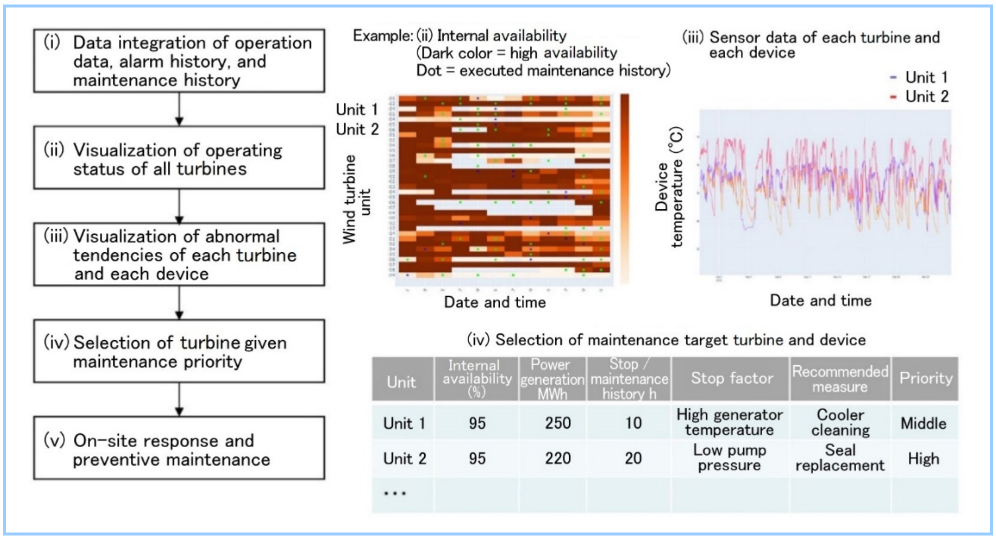

Figure 3 Visualization of equipment conditions for the purpose of preventive maintenance

3.2 Electricity sales guidance

In order to predict electricity market prices using AI and data analysis and provide guidance on the amount of electricity to be sold, it is necessary to consider the risk of market price volatility. However, the bidding method based on the general machine learning expected value prediction has an issue that the evaluation of risks in an uncertain environment is impossible. Therefore, we developed an optimal decision-making method for electricity market bidding under uncertainty by indicating which range and probability the target to be predicted falls into with a prediction interval (PI), and verified when and how much power generation should be sold to improve operating revenue. **Figure 4** shows the flow of the prediction interval estimation method and the optimization calculation.

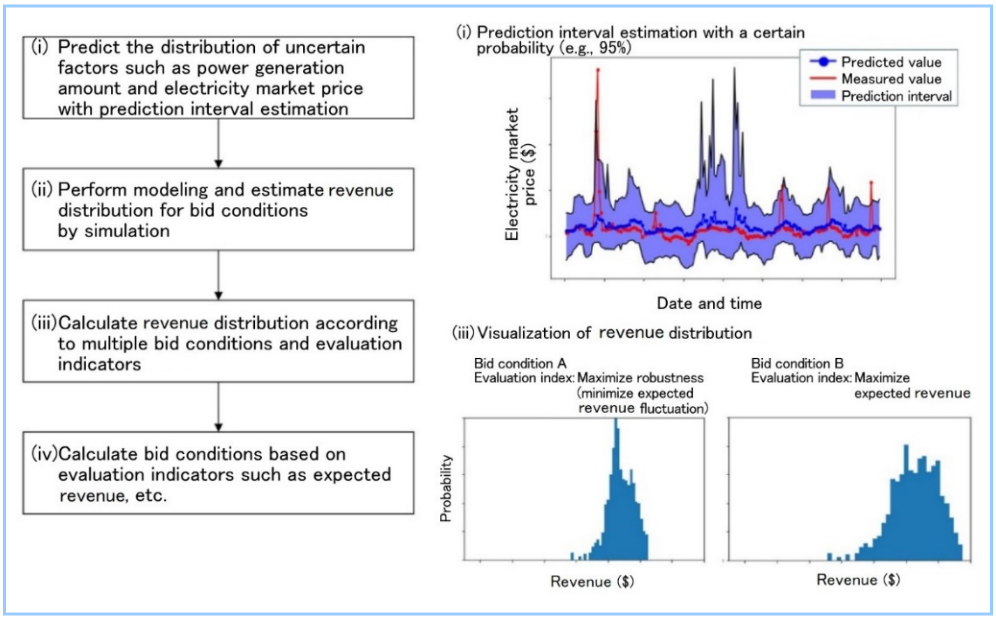

Figure 4 Prediction interval estimation method and optimization calculation according to preconditions

In this report, we verified this method at a wind farm that is actually bidding on the day ahead market (DA) and the real time market (RT) in the US electricity market, where electricity has been liberalized. The optimum bidding conditions whether it is to take the risk and make it the condition which can maximize the revenue or to limit the risk and minimize the loss differ depending on the power generation operator. Therefore, we have made it possible to calculate using multiple evaluation indexes such as maximizing earnings expectations of the revenue, minimizing losses, etc., in order to obtain bid results according to the operation policy of the power generation operator. In the demonstration field, we set user-desired bidding conditions that minimize the risk of fluctuations such as calculation of bid conditions, taking into account the risk of a sharp rise in market prices on the day, and as shown in **Figure 5**, we were able to show that it is possible to improve the revenue compared to the conventional method in bidding on the DA market and the RT market.

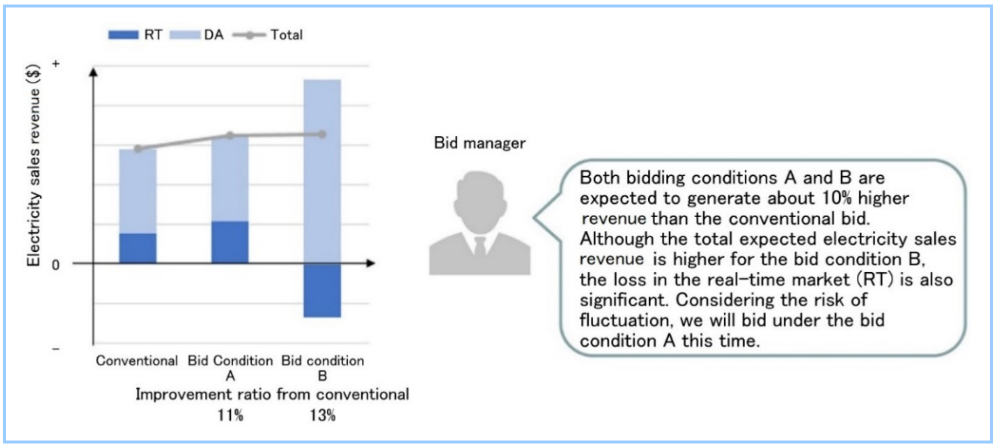

Figure 5 Example of calculation result of electricity sales revenue based on bidding conditions

3.3 Periodic inspection guidance

In its operational period of about 20 years, wind power generation equipment must be inspected in compliance with laws and regulations based on inspections specified by the manufacturer, and usually semi-annual and annual periodic inspections are conducted during periods of low wind speeds based on experience. However, since actual wind conditions change from year to year, the optimal timing of inspections must be reviewed on a case-by-case basis, and multiple factors other than wind conditions, such as expected power generation, must be considered at the same time in order to improve operating revenue. In this report, we developed a model that predicts expected power generation and calculates the optimal timing of periodic inspections to maximize operating revenue, as shown in the flow chart in **Figure 6**, after visualizing the above equipment conditions, and verified the model using field data in Japan.

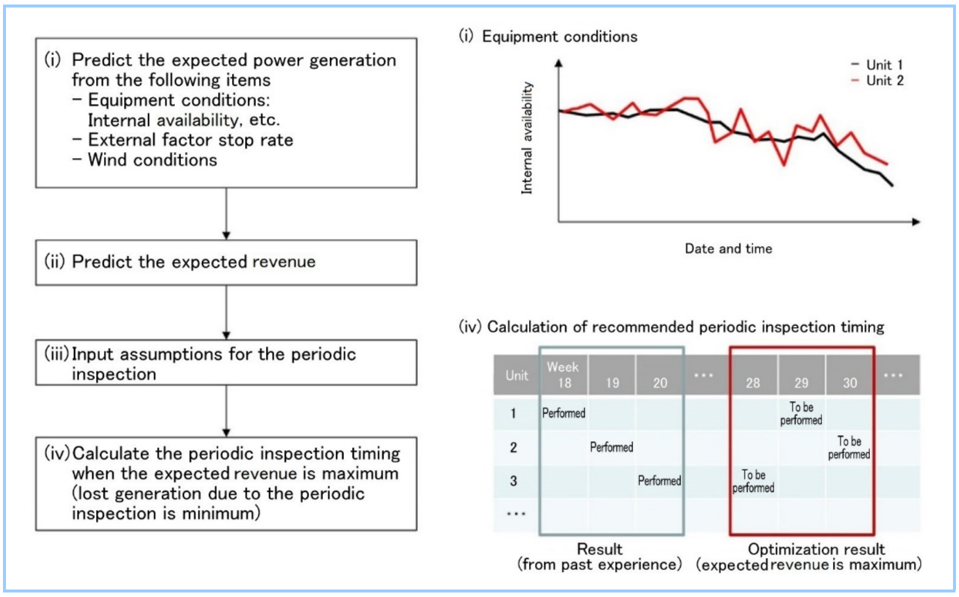

Figure 6 Optimization of periodic inspection timing based on power generation and expected revenue prediction

We first created models for a past annual inspection of wind power generation equipment and a future annual inspection plan six months ahead, and then compared the model with the actual results to check operating revenue before and after the optimization of the periodic inspection timing. The verification results indicated that operating revenue was improved as well as that the amount of power generation varied depending not only on the wind speed trends that were conventionally considered, but also on the equipment conditions, and confirmed the effectiveness of the optimization. On the other hand, in order to deploy reliable guidance results to the field, the improvement of the accuracy of wind speed prediction, which contributes significantly to operating revenue, and the explainability of the analysis results remain as future issues.

4. Conclusion

In this field demonstration, we used MHI's expertise in the design, manufacturing, and O&M of wind turbines as well as AI technology of the ENERGY CLOUD to effectively visualize, predict, and optimize equipment conditions, electricity market prices and periodic inspection timing, and obtained prospects for improving operating revenue by several percent to ten percent based on accumulated data. This report presented the results of the verification of operating revenue improvement using historical data of existing onshore wind farms in Japan and the United States. However, in addition to improving the profitability of existing businesses, this technology can be applied in the development phase of new projects to consider appropriate project investment and may effectively support wind farms for which the FIT period will expire to transfer to another electricity market or employ FIP.

Moving forward, we will improve the prediction accuracy of AI technology that supports optimal O&M and the explanatory technology of analysis results, and promote development for the service provision of Energy Management System (EMS), which utilizes wind power generation and renewable energy. We will thus contribute to the support of our customers' renewable energy projects toward decarbonization.

* ENERGY CLOUD® and related marks and logos are registered trademarks of Mitsubishi Heavy Industries, Ltd. in Japan and other countries.

References

(1) Teppei Teshima et al., Responding to the Various Needs for Energy Usage Electricity Optimization using Demand Prediction, Mitsubishi Heavy Industries Technical Review, Vol.55 No.4（2018）