# Case Study of Introducing TOMONI®, Digital Solution for Stable Plant Operation and Reduction of Power Generation Costs


EIJI HIRATA[*1] HIDETAKA HARAGUCHI[*2]
KENTARO MORIMOTO[*3] TAKAHIRO YAMAUCHI[*1]
MASATAKA NAKAJIMA[*1] AKIHIRO SHAMOTO[*1]

*This report presents a case study promoting digital transformation (DX) for the purpose of stable plant operation and reduction of power generation costs.*

*Mitsubishi Heavy Industries, Ltd. provides our customers with support for realizing stable operation of plant facilities and passing on skilled technologies to reduce the burden related to the operation, through offering applications we developed as the basis for remote monitoring, such as abnormality detection and plant performance diagnosis. In particular, introducing the fuel allocation optimization application and other applications for the first time to customers of ours using multiple units that we delivered was a DX promotion activity that reflected the operation and constraint information of the power plant obtained from the customers. We will continue to propose to our customers an eco-system in which machine systems cooperate by "Smart Connections" of a wide variety of machine products utilizing digital technology.*

## 1. Introduction

In recent years, while demand for state-of-the-art gas turbine combined cycle (hereinafter referred to as GTCC) plants has been increasing, there have been major issues of aging and decarbonization emerging in power generation facilities that have been in operation for a long time. In particular, problems such as the increasing number of equipment-related problems, increasing maintenance and management costs, and decreasing power generation efficiency have been pointed out. Mitsubishi Heavy Industries, Ltd. (hereinafter referred to as MHI) is the only manufacturer in Japan that provides all services, from design and manufacturing to installation and after-sales service with its own technologies, and solves and provides support for dealing with these problems by promoting digital transformation (hereinafter referred to as DX), that is, by utilizing TOMONI®, an intelligent solution we provide.

TOMONI has functions to collect running data on the TOMONI cloud platform, detect abnormalities, diagnose performance, and monitor short-term and medium-to-long-term running status and operation through dashboards, based on the experience of gas turbine remote monitoring that we started about 25 years ago. Meanwhile, customers expect more advanced operation and maintenance (hereinafter referred to as O&M) and the promotion of DX that bring stable operation, including plant startup and shutdown and lower power generation costs. By utilizing TOMONI to meet these expectations, a combination of our customers' own O&M know-how with our experience in the design and operation of gas turbines and steam power plants as well as elements of digital technology such as AI and machine learning will promote a DX that meets the expectations and lead it to a successful outcome. (1)-(12)

This report mainly presents the TOMONI application that we have started to provide to Setouchi Joint Thermal Power Co., Ltd., and describes how we are facing the customer's problems and solving them together, using the actual contents we have delivered. Although the case study presented herein was introduced to a specific plant, we believe that this technology can be widely deployed.

*1 Service Engineering Department, GTCC Business Division, Energy Systems
*2 Engineering Manager, Service Engineering Department, GTCC Business Division, Energy Systems
*3 Project Engineering Department, Steam Power Business Division, Energy Systems

# 2. Overview of plant to which TOMONI was introduced

## 2.1 Plant to which TOMONI was introduced

The plant presented in this report, to which TOMONI was introduced, aims to effectively utilize byproduct gases generated in the operation process of a steel mill to optimize energy efficiency and reduce environmental impact. The plant is equipped with a high-efficiency gas turbine power generation facility designed with the latest technology and a boiler power generation facility that is more than 50 years old. The effective utilization of these facilities is an important issue. First, the main features of the plant and its operation are described below (**Table1**).

**Table 1 Overview of facilities in Fukuyama Joint Power Plant**

| | Type of power generation | Fueled | Operation started |
|---|---|---|---|
| New Unit 1 | GTCC | blast furnace gas and mixed gas | July 1995 |
| New Unit 2 | | | December 2020 |
| Unit 4* | Boiler and turbine | blast furnace gas, mixed gas, coke oven gas, and heavy oil | February 1970 |
| Unit 5* | | | April 1971 |
| Unit 6 | | | September 1972 |

* Equipped with factory steam supply function

Extracted from Setouchi Joint Thermal Power Co., Ltd. website (13)

These facilities were installed at different time points, and there are differences in the fuels used and the operation methods. In particular, New Unit 2 incorporates the latest technology and is capable of highly efficient operation. Unit 5 and Unit 4, on the other hand, have deteriorated over many years of operation, but they are equipped with a factory steam supply function and contribute to the effective utilization of byproduct gas.

It is necessary for the operation of this plant to effectively utilize these facilities and optimize the energy efficiency. In addition, to reduce the environmental load, operation management of the plant in consideration of the characteristics of each facility is important. Next, the operation improvement policy and objectives are summarized below.

## 2.2 Issues and objectives of plant

Recently, as widely reported, there has been a wide range of problems such as work style reform, human resource shortage, and the transmission of technical know-how, not only in our technical reviews. In addition to these problems, maintenance and management costs and the risk of serious problems are increasing due to the lack of concrete plans for updating facilities despite the increasing age-related deterioration. To control these problems, it is necessary to realize more advanced operation management.

To efficiently solve this situation, we have set an objective of eliminating waste in conventional operations and utilized DX to address these issues. Our specific efforts are described below.

(1) Advancing the operation

With the reduction of power generation costs as a major promotion target, we introduced a fuel allocation optimization application to improve the operational efficiency of the entire plant by optimizing the fuel allocation of each facility.

(2) Keeping the operation at the optimum point

We introduced a GTCC maximum load optimizing application to reduce long-term power generation costs by improving operation in high-load regions without facility modification and with the plant reliability maintained.

(3) Early detecting and visualizing abnormalities

We introduced an abnormality sign detecting application (Pre-ACT) that performs real-time monitoring and data analysis simultaneously to achieve advanced diagnosis, which leads to early detection of abnormalities, stable plant operation, and quick response to the abnormalities.

(4) Visualizing facility conditions

For facility maintenance to maintain performance, it is important to establish an appropriate plan. We introduced an efficiency monitoring application for GTCC and boiler, turbine and generator (hereinafter referred to as BTG) plants that detects signs of efficiency decline, such as facility deterioration, and enables long-term planning of necessary maintenance for performance restoration, such as inspections and parts replacement. Here, "efficiency" refers to the power generation efficiency in converting energy into electricity, and "performance" refers to the capability of the equipment.

Through the above initiatives, we aim to improve the operational efficiency of the plant, solve the issue of advancing operational management against the background of increasing human resource shortages, and achieve sustainable operation of the plant. The next chapter details the specific implementation of these initiatives. We plan to verify the concrete effects of these initiatives by checking future operational data.

## 3. Case studies of introducing TOMONI applications

### 3.1 Fuel allocation optimization application

MHI provides an energy management system (hereinafter referred to as EMS) as a part of the energy transition aimed at sustainable energy use.

The EMS was developed by integrating the knowledge and know-how we have acquired as a comprehensive plant manufacturer, and is equipped with a control algorithm that can reflect the operating characteristics of the facilities. Specifically, the system builds plant models on the cloud that take into account the operating characteristics of multiple power generation facilities, defines requirements, and thereby derives optimal solutions that meet those requirements through repeated calculations.

This technology is indispensable for realizing highly accurate management of multiple fuels. Additionally, it has the potential to reduce energy costs and fossil fuel consumption in thermal power plants, thanks to its stability and flexibility. Below is a case study of introducing the TOMONI application, for which the fundamental technology of this EMS is used.

For the plant to which the TOMONI application was introduced, fuel allocation orders are an important task, which is directly linked to profitability, and even a small difference in the allocation can have a large impact on the overall efficiency. Therefore, in determining fuel allocation orders, it is necessary to understand the basic efficiency characteristics of each power generation facility and also to consider that fluctuations may occur due to the effects of periodic inspections and other external factors. In addition, since the operation is continuous 24 hours a day, it is essential to deploy personnel who can make decisions on fuel allocation orders at all times, and the decisions must be made in a short period of time.

Traditionally, the decisions on fuel allocation commands, which require a high level of skill, were made based on the expertise of skilled operators. However, a system has been established at Setouchi Joint Thermal Power Co., Ltd. to derive efficient fuel allocation commands that meet requirements by utilizing the EMS.

This application established a plant model in the cloud taking into account the operating characteristics of multiple power generation facilities. As shown in **Figure 1**, the model established this time targets a situation in which four out of five units are in operation (one BTG is a Stand-by unit). It has a complex configuration with various requirements added. For reference, the following are representative examples of the requirements defined.

1. Reduction of byproduct gas surplus (release)
2. Reduction of heavy oil consumption
3. Reduction of electricity supply from outside the premises
4. Supply of electricity and steam necessary for operation

If necessary, requirements other than those may be additionally defined.

As mentioned earlier, this model is built on the cloud, but it can accurately grasp electric power transmission demand and steam supply demand by linking to operational data on the plant side, and it is possible to detect demand changes and obtain the optimal solution by repeated calculations.

In the case of the introduction this time, the model establishment is limited to the state in which four out of five units are in operation, but we are planning further model establishment that assumes more diverse operating conditions by expanding the range of utilization.

In other words, we are aiming to improve the system, turning it into a comprehensive system that assumes short-term shutdown timings, including periodic inspections and blast furnace shutdowns. At the same time, we are also considering the use of technologies such as AI-based fuel allocation prediction based on past operation data and byproduct gas generation prediction.

The EMS presented in this section is a technology that can contribute to the improvement of operations by realizing operational optimization that goes beyond mere visualization, taking advantage of the knowledge of MHI, a comprehensive plant manufacturer.

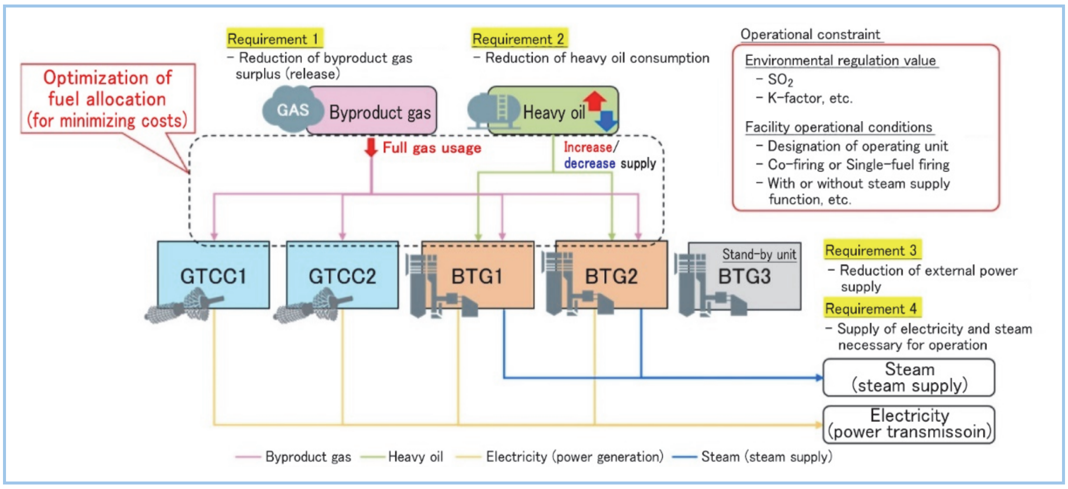


**Figure 1 Schematic of model introduced**

## 3.2 GTCC maximum load optimizing application

Gas turbines are designed with a specified combustion temperature. They are controlled so that the combustion temperature does not exceed the design-specified temperature when reaching the target load. The state of operation at this combustion temperature is called temperature-controlled operation (**Figure 2**). Generally, efficiency is maximized during temperature-controlled operation, so it is desirable to maintain this state while achieving the target load.

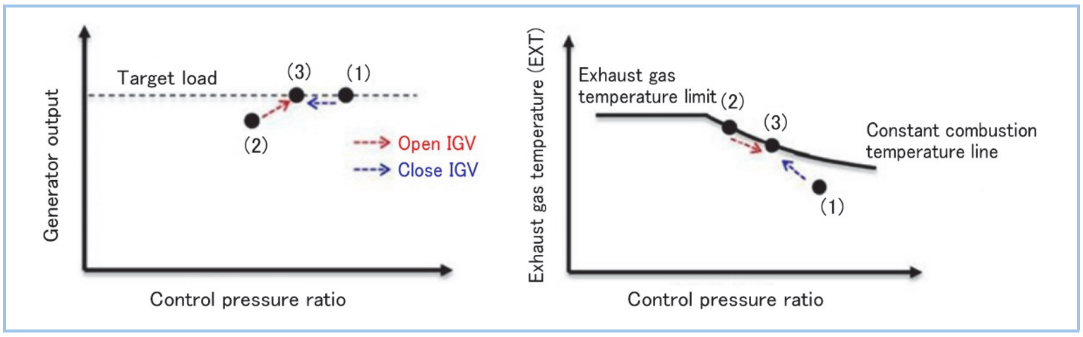


**Figure 2 Conceptual diagrams of our GTCC characteristics**

However, due to the deterioration of the GT and other factors, in some cases, the temperature-controlled operation may start before the target load is reached, and in other cases, the temperature-controlled operation may not start even after the target load is reached.

One of the control parameters to reach the target load is the set value of the opening of the inlet guide vane (hereinafter referred to as IGV) (**Figure 3**).

Normally, the IGV opening is determined by the compressor inlet temperature and target load, but by adjusting the IGV opening, the effects of GT degradation and other factors can be offset to achieve optimal operation that is temperature-controlled and satisfies the target load.

To realize this idea, we modified the control logic to be able to adjust the IGV opening. The control logic has the following functions.

1. Determine whether the temperature-controlled operation is ongoing and the target load is reached and whether the IGV opening should be closed or opened for optimum operation.
2. Define a condition for permitting IGV operation that the turbine operation is static and held close to the target load, rather than transient conditions such as at startup, based on monitoring of parameters other than the gas turbine.
3. Adjust the IGV opening to gradually reach the target load.

By using this control logic, achieving both temperature-controlled operation and target load was possible without exceeding the combustion temperature specified at the time of design. Furthermore, to visualize the effect of this, operation data connected to the TOMONI cloud is utilized.

The connection to the TOMONI cloud not only allows for an understanding of whether optimum operation is being maintained with the target load reached, but also makes it possible to indicate the amount of improvement in efficiency and output using operation data. A function to calculate and display the cumulative performance improvement (power output and fuel consumption) is also provided.

We believe that this effort has improved the efficiency of the GTCC plant and contributed to the improvement of the economic efficiency.

This section detailed the effort toward GTCC maximum load optimization.

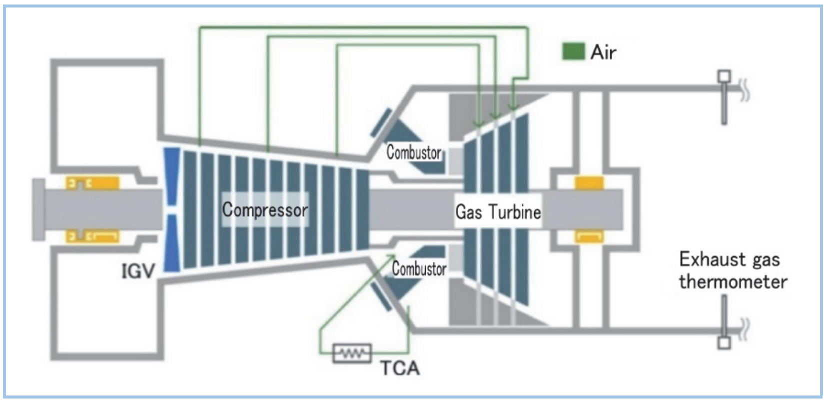


**Figure 3 Schematic diagram of our gas turbine mechanism**

### 3.3 Abnormality sign detecting application (Pre-ACT)

As of May 2025, MHI is providing remote monitoring services to 199 thermal power plants worldwide, mainly GTCC plants and steam power plants. This service plays an important role as a foundation to support comprehensive maintenance services and availability guarantees for power generation plants, as typified by the Long Term Service Agreement (LTSA) for gas turbines.

One of the most important objectives of remote monitoring is to prevent problems before they occur. MHI has enhanced real-time monitoring of gas turbines and steam turbines to quickly detect signs of abnormalities that could lead to problems.

To detect signs of abnormalities, it is effective to monitor not only trends but also parameter correlations. However, the number of monitoring points in a power plant is enormous, and it is difficult for a small number of people to keep monitoring all parameter correlations.

As such, we made it possible to monitor many plants connected to TOMONI for signs of abnormalities in real time by checking the correlation between parameters using a single indicator, the Mahalanobis distance. In other words, it is an MT (Mahalanobis-Taguchi) method-based anomaly prediction detection system (the application name "Pre-ACT").

MHI has accumulated a great deal of experience operating this independently developed Pre-ACT system and has modified its functions to suit actual power plant operations to continuously improve the effectiveness of the system.

One of the reasons why the customer selected our system this time is that MHI has a long track record in abnormality detection technology for GTCC plants, which was valued by the customer. On the other hand, recent years have seen requests from customers to operate this system on their own by utilizing cloud technology, which has been developed worldwide. In light of this situation, we have released "Pre-ACT Tuning", our Custom-developed application that we use to perform the initial setup of Pre-ACT and adjustments during operation, to our customers so that they can also operate Pre-ACT themselves. Pre-ACT Tuning allows for adjustment of detection sensitivity and other parameters, including detection thresholds.

Prior to the release of Pre-ACT Tuning to customers, we also reviewed the terminology used and user interface to make it an easy-to-use and general-purpose application even for those who do not have expert knowledge of the MT method. This made it possible for customers to apply our proven predictive detection application to any equipment, not limited to GTCC plant facilities, at their discretion. In fact, through our efforts this time, we could provide Pre-ACT not only to GTCC plants, but also to BTG plants (**Figure 4**).

Thus, the Pre-ACT, which realizes real-time monitoring and data analysis using cloud environments, can now be utilized to reflect the know-how of not only MHI but also our customers. We expect that Pre-ACT will contribute to our customers through its various utilizations in the future.

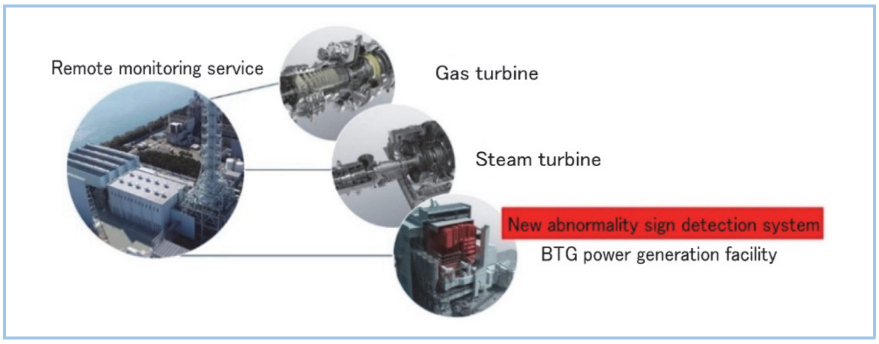


**Figure 4 Target equipment of abnormality sign detection system**

## 3.4 Efficiency monitoring application

3.4.1 Efficiency monitoring application (GTCC performance diagnosis)

Due to their high efficiency and low emission characteristics, GTCC plants play an important role not only in power generation but also in the utilization of byproduct gas from steel mills. To achieve efficient and stable operation of GTCC plants, it is essential to understand the operational condition of the main equipment, including the gas turbine, and properly maintain them. MHI has developed GTCC performance diagnosis application that evaluates the condition of GTCC plant equipment by combining the knowledge of the power generation equipment manufacturer with digital technology. This application calculates the amount of degradation by using the reference value of the GTCC plant and the efficiency calculation value based on the collected operation data, and enables monitoring of the transition over time. It embodies the concept of digital twin, in which physical structures and processes are reproduced in digital space for simulation and other purposes. Furthermore, this application is utilized for our internal analysis and improvement studies of GTCC plants. It is also introduced to thermal power plants that utilize natural gas or blast furnace gas as fuel, with the aim of supporting customers in the maintenance planning of their facilities.

**Figure 5** illustrates a screen shot of this application. The top panel on the left side of the screen shows the current lowest result of the equipment assessment that is automatically determined in five levels from A (high) to E (low) using the performance assessment. The application displays a trend graph of the gas turbine output or efficiency in the center of the left side of the screen, and the graph below it indicates the degradation of the gas turbine components. On the right side of the screen, the assessment results of the gas turbine components are listed, and when deterioration is recognized and the rating is lower than level B, the estimated factors are also displayed. This is intended to help properly capture the plant's operational status, formulate maintenance plans for equipment, and consider the next equipment inspection items.

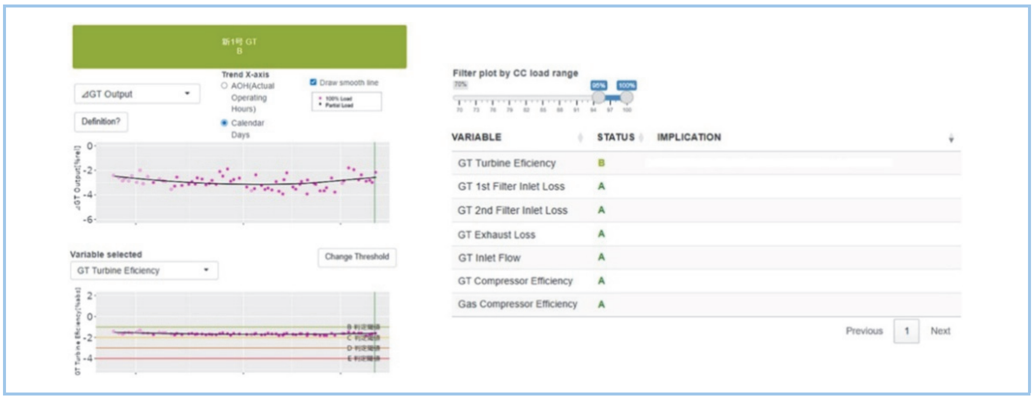


**Figure 5 Example of screenshot of gas turbine health assessment using GTCC performance diagnostic application**

3.4.2 Efficiency monitoring application (BTG performance diagnosis)

BTG plants utilize byproduct gas from steelmaking processes as fuel. In addition, the generated steam is used not only for power generation but also as process steam for steelmaking, making BTG plants essential facilities for steel mill operations.

In developing the efficiency monitoring application this time, we would like to highlight several key features:

(i) The newly developed application allows users to specify parameters such as power output and process steam supply flow, and then extract performance calculation data under equivalent operating conditions, which can be visualized as time-series graphs.

(ii) In addition to main plant equipment such as turbines and boilers, the application can calculate and monitor the performance of auxiliary equipment such as feedwater heaters and condensers. Although some equipment lacks instrumentation and therefore does not provide sufficient measurement data for performance calculations, the application uses estimated values based on correlations with other data to enable performance evaluation.

As a result, it has become easier to visualize the performance degradation trends of the BTG plant and to estimate the causes of the degradation. This enables better support for power plant operation planning, including the formulation of appropriate maintenance strategies, maintaining and improving plant performance, and considering equipment upgrades.

## 4. Conclusion

This report presented our initiatives for efficient and sustainable energy use through the utilization of DX and cloud environment, focusing on those for GTCC plants. In response to the arising issues of passing on skilled technologies and aging power generation facilities, we provide technologies such as the fuel allocation optimization application, the GTCC maximum load optimizing application, the abnormality sign detecting application (Pre-ACT), and the efficiency monitoring application (GTCC/BTG performance monitoring) through our intelligent solution TOMONI.

In the case study of introducing TOMONI to Setouchi Joint Thermal Power Co., Ltd. presented here, we expect that TOMONI can contribute to improving the operational efficiency of the entire plant through our initiatives to prevent problems before they occur by using the abnormality sign detecting system, diagnose the performance of GTCC and BTG plants, and optimize the maximum load of GTCC plants. We plan to verify the concrete effects of these initiatives by checking future operational data.

In addition, the optimization of energy efficiency and the reduction of environmental impact were realized through operation taking advantage of the characteristics of each facility. In particular, the introduction of fuel allocation optimization application is expected to effectively use byproduct gases and reduce fossil fuel consumption. We will further contribute to the realization of a sustainable energy society by combining our technological know-how and DX in the future.



## References

(1) Mitsubishi Heavy Industries, Ltd. Press Information, MHI to Establish New "Digital Innovation Headquarters" to Transform Customer Business Models through "Smart Connections" (2022.6)
(2) Ministry of Economy, Trade and Industry, Digital Transformation Stock (in Japanese)
(3) H. Ishigaki, et al., Digital Support for Plant and Equipment O&M Toward Carbon Neutrality, PETROTECH Vol.46 No.11 (2025) (in Japanese)
(4) H. Ishigaki, et al., Digitalization of Power Plants in a Rapidly Changing Era: Decarbonization, Rising Fuel Costs, Smart Maintenance, and AI, Thermal and Nuclear Power Vol.74 No.10 (2023) (in Japanese)
(5) D. Goto, et al., Smart Maintenance and Remote Monitoring by TOMONI® Utilizing Generative AI: Current Status and Future Prospects, Mitsubishi Heavy Industries Technical Review Vol.60 No.3 (2023)
(6) T. Tanaka, et al., The Latest Initiative of Intelligent Solution TOMONI® to Achieve Carbon Neutrality, Mitsubishi Heavy Industries Technical Review Vol.60 No.3 (2023)
(7) Y. Agata, et al., Intelligent Solution TOMONI® for Advanced Maintenance and Operation of Critical

Infrastructure, Mitsubishi Heavy Industries Technical Review Vol.59 No.3 (2022)
(8) M. Kajita, et al., ICT Utilization and Development of New Technologies in Thermal Power Plants for a Decarbonized Society, Piping Engineering Vol.64 No.3 (2022)
(9) H. Ishigaki, et al., Digital Transformation for Power Plant with TOMONI$_{TM}$ Digital Solutions, Mitsubishi Heavy Industries Technical Review Vol.58 No.3 (2021)
(10) T. Ai, et al., TOMONI® Digital Solutions: A Road to Decarbonized Society and Autonomous Power Plant, Journal of Gas Turbine Society of Japan Vol.49 No.5 (2021)
(11) H. Takagi, et al., Acquiring Explainability of Electricity Demand Forecasting Model Using Time-series XAI and Improving Its Performance, Mitsubishi Heavy Industries Technical Review Vol.61 No.3 (2023)
(12) Y. Isobe, et al., Technology Development of Energy Management System Beneficial for Carbon Neutral Era, Mitsubishi Heavy Industries Technical Review Vol.59 No.4 (2022)
(13) Setouchi Joint Thermal Power Co., Ltd. WebSite (in Japanese)