Digital Transformation for Power Plant with TOMONI™ Digital Solutions

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Mitsubishi Power, Ltd. (Mitsubishi Power) started a remote monitoring service for thermal power plants in 1999 and has been introducing TOMONI digital solutions for operation and maintenance (O&M) optimization, performance improvement and flexible operation support since 2017.

This report presents examples of TOMONI introduction to various power plants including gas turbine combined cycle (GTCC), geothermal power generation and steam power generation. Furthermore, as a way of utilizing digital solutions in the future, this report also introduces our efforts to expand the possibilities from operational improvement to operational reform with TOMONI, leading to a carbon-free society and energy transition by creating new users and use cases through a solution that combines OEM's physical technology with TOMONI's digital technology.

1. Introduction

"TOMONI" is the Japanese word for "together with" and reflects our will to solve problems together with our customers. Based on our abundant achievements as OEM, we started the development of TOMONI in 2015 as an integrated digital solution including an analysis platform for various types of power generation and have transformed internal business processes and have been providing services to Japan and overseas customers since 2017.

This paper shows TOMONI vision (**Figure 1**) and presents examples of introducing TOMONI into power generation facility.

In the design, construction, commissioning and service departments of our company, TOMONI's cloud environment made it possible to analyze and visualize data anywhere. As a result, not only has the number of users increased, but the way of working is also changing. Furthermore, in order to solve social issues such as changes in work styles due to the COVID-19 pandemics addition to the issues of technology transfer due to the declining and aging population, we are working on building a digital platform for online remote monitoring and support, and also presented examples in this paper.

Today, Mitsubishi Heavy Industries' ENERGY CLOUD® and Mitsubishi Power's TOMONI are promoting system cooperation with a view to decarbonizing and energy transition for the entire Mitsubishi Heavy Industries Group and these digital solutions are reaching the phase of practical application in various fields based on the expertise and experience cultivated in thermal power generation equipment.

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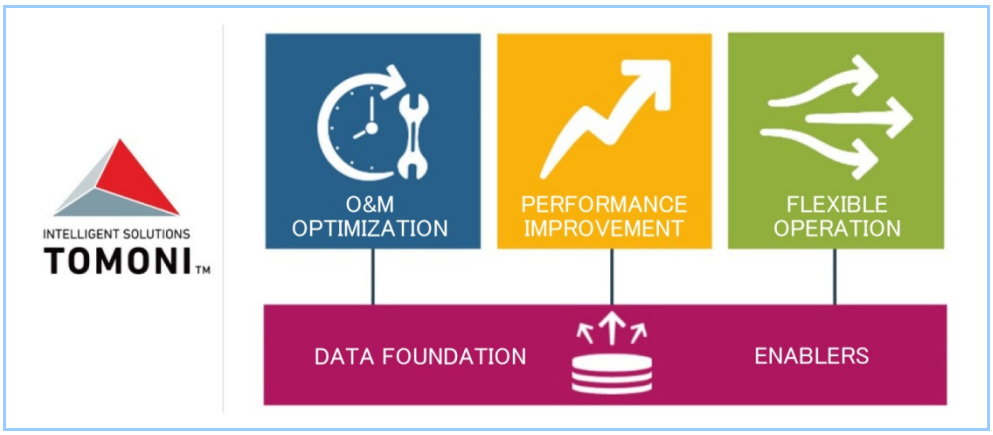

Figure 1 Configuration and advantages of TOMONI

2. Expanding provision of TOMONI digital solutions

Currently, we are providing TOMONI services to 81 thermal power plant units worldwide (as of the end of May 2021), centered on GTCC plants and steam power plants, with the connection to the cloud environment at a high cybersecurity level. TOMONI has contributed to customers as a foundation that supports comprehensive maintenance services for power generation facilities represented by long-term service agreements (LTSA) and supports availability guarantee of the power generation facilities In recent years, however, TOMONI has played a role as a communication hub centered on our remote monitoring center through which the customer and our company can easily share information on daily problems in power plant operation and take action to solve them, contributing to the establishment of good relationships with customers.

2.1 Introduction of TOMONI to GTCC plant

This section describes an example of the introduction of TOMONI into a GTCC plant in Japan. In this project, TOMONI has been introduced since the construction and commissioning stage and more than one year has been passed since the start of commercial operation of the plant. This project aims to attain the best mix of IT (Information Technology) and OT (Operational Technology) for the entire plant including the main equipment such as GT (Gas turbine), HRSG (Heat recovery steam generator), ST (Steam turbine), etc., the auxiliary equipment such as pumps, fans, heat exchangers, etc., as well as the management of water quality, alarm events, etc., from daily communication to regular inspection planning. Some of the delivered contents are shown below (**Table 1**).

Table 1 Summary of delivered TOMONI contents (example)

	Content name	Summary
1	GTCC Performance Diagnosis	Evaluates the combined cycle performance and visualizes the deterioration trends through automatic evaluation of the equipment and parameter level and shows the estimated factors when deterioration is observed to use them for maintenance planning.
2	Water Quality Assurance	Contributes to the early detection of water quality-related problems such as equipment corrosion by comprehensively evaluating water quality-related data and providing guidance.
3	Motor-Driven Equipment Diagnosis	Analyzes the motor current signal to diagnose abnormalities in rotating equipment (pumps, fans, motors, etc.) and contributes to optimization by replacing TBM (Time Based Maintenance) with CBM (Condition Based Maintenance).

These contents and related service operations can contribute to the decision making of each stakeholder. We will continue to have communication with customers to be aware of their needs and proceed with value creation (**Figure 2**).

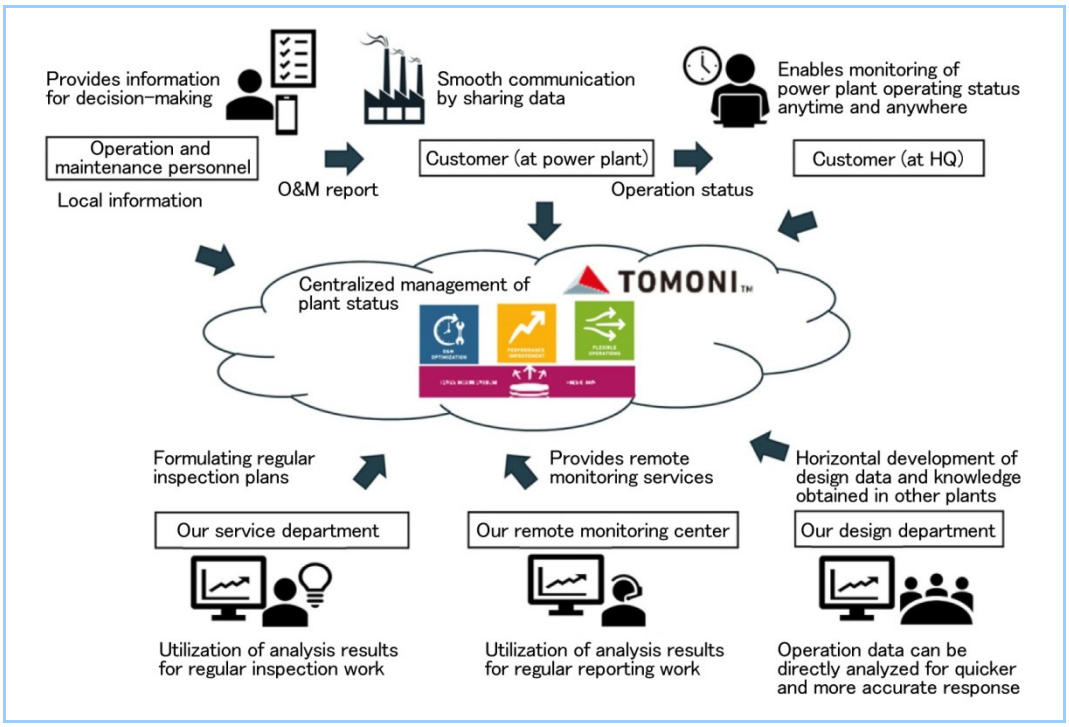

Figure 2 Image of utilization of TOMONI service

2.2 Introduction of digital solutions to geothermal power plant

The characteristics of geothermal power plant include the difficulty in maintaining optimum operating conditions due to the performance deterioration caused by geothermal gas and impurities contained in the geothermal fluid, as well as the aging of the production wells from which steam and hot water are obtained. In addition, since the performance deterioration and aging changes differ from plant to plant, it is difficult to take uniform measures.

Solutions for geothermal power generation can formulate optimal maintenance plans based on the result of the degradation prediction of the power generation efficiency with scaling condition such as silica and the result of remote monitoring (**Figure 3**).

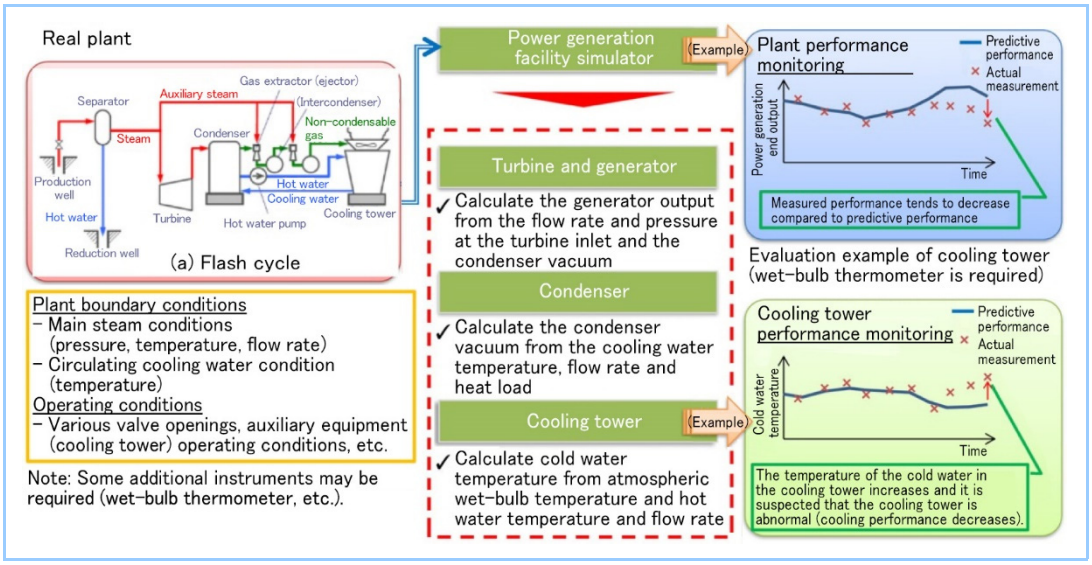

Figure 3 Conceptual diagram of performance monitoring of geothermal power plant

In addition, our remote monitoring and support service can reduce unplanned outage periods by detecting abnormalities, early planning of countermeasures and providing operational support.

By working more closely with our customers through the provision of digital solutions for geothermal power plant, we will pursue the optimization of geothermal power plant operation, support the economical operation and improved profitability of power plants and contribute to the stable supply of electric power and the reduction of the global environmental load.

2.3 Contribution to overseas steam power plants with remote monitoring

For overseas steam power plants, we support customer operations through remote monitoring using comprehensive anomaly detection service for the entire plant including boilers, steam turbines and generators and improve the plant efficiency and operation rate by suppressing unplanned outages and load restrictions and reducing aging deterioration of efficiency.

The anomaly detection captures state changes that differ from normal operating conditions, such as changes in process data. Then, through collaboration with JERA Co., Inc., which has a wealth of experience in plant operation, engineers (experts) evaluate the analytical results, identify the cause of abnormalities and provide a recommendation of further action for the power plant operators based on experience in Japan and overseas plants.

For a coal-fired power plant of JERA Co., Inc., In the first three years, the anomaly detection service identified 138 anomalies that needed remedial action:.

Prevented unplanned outages and load reduction (18 cases) Prevented the thermal performance deterioration (11 cases) and the reduction of countermeasure costs due to early detection (109 cases). In these three years, 35 days of unplanned outages were avoided, which led to significant loss avoidance. In addition, prevention of the thermal performance deterioration contributed to fuel cost saving.

The customer said, "Remote monitoring engineers from the Mitsubishi Power GSC and JERA DAC are a vital extension to our team at Pagbilao. We were already using our own data to determine action at our plant, but the additional support from Mitsubishi Power's expert knowledge and JERA's O&M experience is invaluable. We're able to prevent more unplanned outages, increase efficiency and reduce maintenance costs, which makes our plant more profitable and extends the life of our investment."

2.4 Support for building digitalization for existing thermal power plant

In addition to digital solutions for thermal power plant, we provide expertise to construct the system in order to help our customers build digitalization (**Figure 4**).

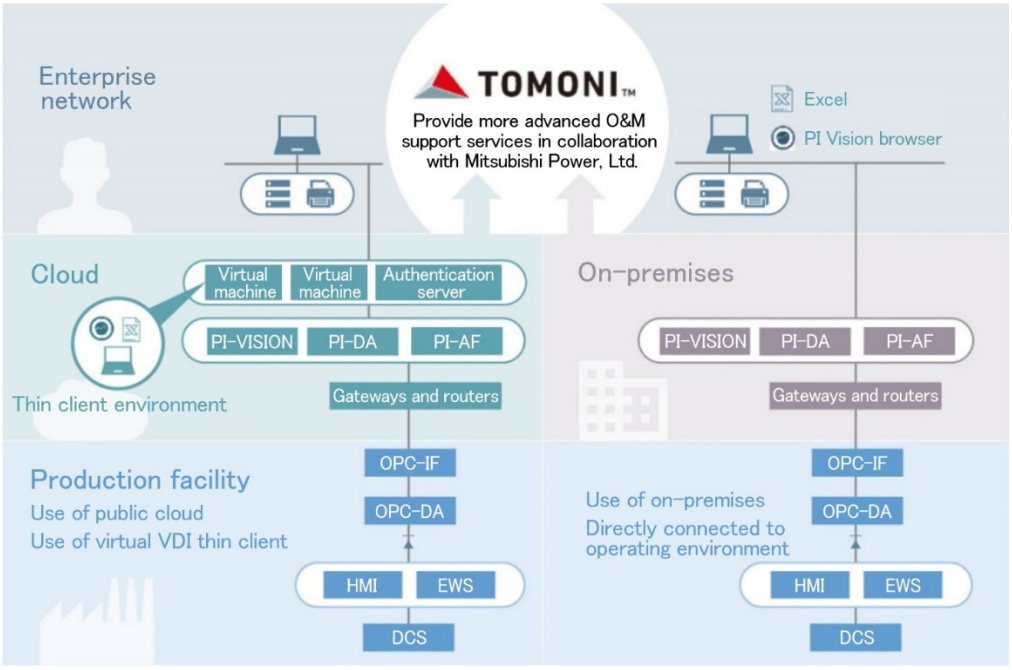

Figure 4 Configuration diagram of data analysis system utilizing PI System® (Example)

We provide services that support the feasibility study, implementation and data analysis work of a data analysis platform centered on OSIsoft® PI System®. Generally, in the support of data analysis, the establishment of an analysis environment is carried out, but it is also necessary to select the process signals to be collected and analyze what they mean by using the plant-specific design information and operation and control expertise.

We can provide support from the standpoint of both a OEM and a large user of PI System. For Daigas Gas and Power Solution Co., Ltd. and Nakayama Nagoya Kyodo Hatsuden Co., Ltd., we have built and delivered performance deterioration analysis and dedicated monitoring screens

that combine the expertise of the customers and Mitsubishi Power. The product and activities was well received. In addition, with TOMONI's expertise and PI System, we were able to reduce capital investment to large-scale data analysis system. .

3. New form of digital solutions provided by TOMONI

TOMONI not only provides the optimization of individual facility as introduced above, but also creates new users and use cases by combining OEM's physical technology with TOMONI's digital elemental technology and solutions. We expand the possibilities from operational improvement to operational reform with the digital solutions.

3.1 Autonomous operation of GTCC plant

For GTCC plants, aiming for autonomous operation of thermal power plant, we extracted the necessary gas turbine-centered mechanical technology and digital elemental technology and defined the customer value and autonomy level obtained from them to formulate a content development roadmap for each category and group. Currently, we have implemented the contents as a pilot plant in the demonstration facility at our Takasago Works for verification. Especially for autonomous plants, we are carrying out development aimed at power generation facility that can flexibly respond to increasingly complex and diverse customer needs. Some examples include groups of contents that improve availability by analyzing the unit startup process and trip factors during operation and avoiding abnormalities through preliminary inspections and tests, optimal plant hybrid operation in combination with renewable energy and storage batteries, load operation support according to the facility condition, etc., in addition to the traditional plant operation automation approach.

3.2 Utilization of digital solutions for soda recovery boiler

Soda recovery boilers are indispensable for the papermaking process and also for the power and steam supply in the factory. Furthermore, in the trend of energy transition and coal fade-out toward a carbon-free society, it is expected that the soda recovery boiler, which uses black liquor derived from biomass as fuel, will continue to be operated as a main unit of paper manufacturers. On the other hand, there is an urgent need to create a system and menu to support productivity improvement, life extension and the renewal of aged facility while keeping investment to the minimum amount necessary.

However, in recent years, the number of newly constructed recovery boiler units in Japan and overseas is small and dealing with the aging of experts with knowledge and experience in their construction and the fostering of successors are urgent issues. In order to solve this issue, we are providing and developing an operation optimization menu. In addition to the contents mentioned above, the menu includes boiler tube leak comprehensive diagnosis, the proposal of recommended inspection areas based on past cases as well as support for periodic inspections based on centralized management of inspection records, and a mechanism in which the history of response to occurred alarms is registered as knowledge that can be added by the customer or our company even during operation and used for technical transfer as guidance.

3.3 Development to support field service operation

Due to the liberalization of electric power, many business operators have been entering the power generation business and the power plant O&M market. We are working to support new business operators by improving the efficiency of field service operations using TOMONI.

As a tendency of O&M's field operation, during the regular inspection season of each power plant, the work schedules are congested and it is extremely difficult to adjust the dispatch schedule, resulting in a chronic shortage of engineers. In addition to the shortage of personnel, the problems with technology transfer and succession are becoming increasingly serious every year. Furthermore, due to the COVID-19 pandemics, Japan and overseas travel have been severely restricted or prohibited, making it even more difficult to secure logistics and resources for power plants commissioning and regular inspections. Until now, efforts to utilize digital technology have not progressed from the verification phase for a long time because its ability level does not reach the skills and experience of instructors and workers.

However, urgent issues have accelerated efforts for the remote support of field operations. Due to the communication infrastructure already established for remote monitoring, remote support for regular inspections and commissioning, with which 3D data such as piping layout and parts

information can be easily viewed through HoloLens or a tablet device even during field work, has been rapidly initiated in multiple projects in Japan and overseas toward its full-scale introduction.

We have developed the O&M solution as shown in **Figure 5** and have started to provide it to some customers.

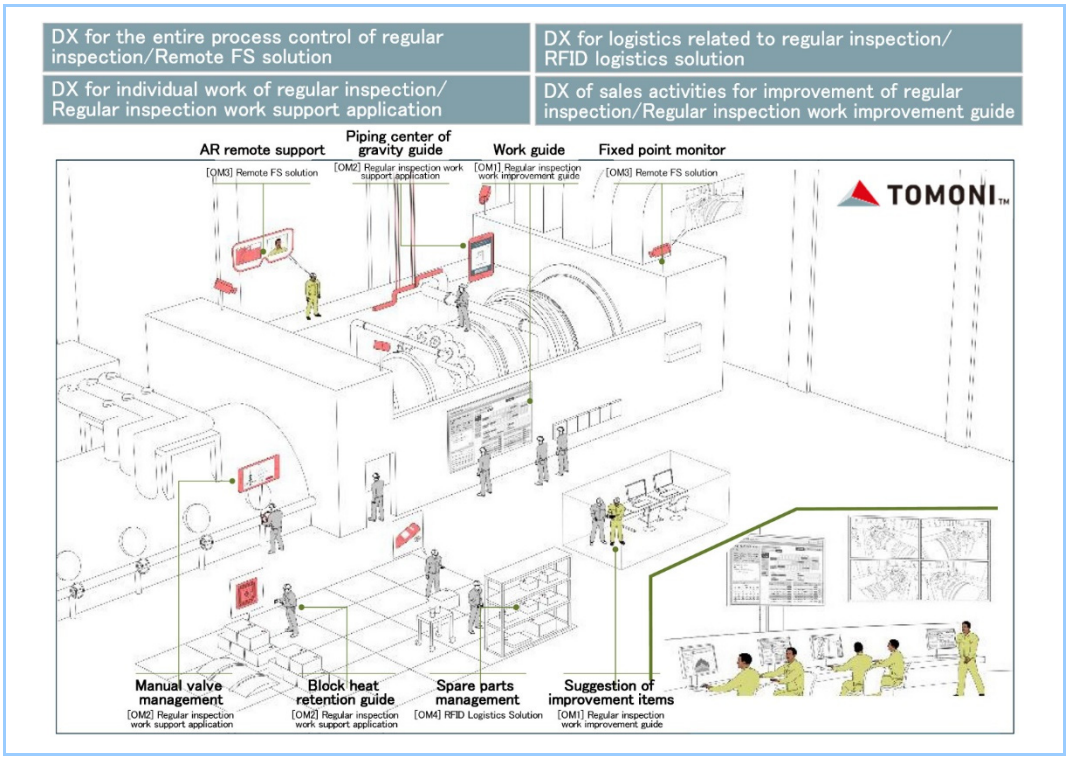

Figure 5 Introduction of ICT and O&M solutions for field operation

3.4 Status of efforts for future power plant O&M operation processes

We are working to build a digital platform suitable for new operation processes on the premise of online remote monitoring and support. In the future this will provide a customized menu tailored to individual tastes and occasions, both inside and outside the company and human interfaces that make analysis results easily accessible anytime and anywhere, enabling one-stop search, inventory status confirmation and ordering of parts and spares in conjunction with e-commerce.

It is expected that the relationship between customers and OEMs will change dramatically in the future with the use of seamless digital platforms. Through communication tools such as bulletin boards, chat, etc., linked to process data, unstructured data and TOMONI contents, we propose the optimal response to situations and events, support the customer's decision-making process and shorten the time to service provision. Due to heightened environmental awareness, purchasing behavior will change and it will be necessary to make the visualization of the entire supply chain easier.

In addition, as noted above, the situation where the shortage of human resources is becoming serious strongly promotes the remote operation and automation of field work with high safety risk. It is expected that personnel for routine work will be replaced by robots or AI as they becomes available and that data that was previously collected during patrols of the site and compiled in a report by personnel as a preliminary step to routine work will be automatically collected using wireless technology, stored on the TOMONI platform and combined with process information in the online environment, which will contribute to the maintenance of all facility and labor saving in management and operation work. We will demonstrate the effectiveness of this effort through field tests in the future.

4. Conclusion

MHI Group is working to improve the efficiency of power generation facility and promote the use of hydrogen and ammonia for the decarbonization of thermal power generation. To maximize and optimize the expertise cultivated by OEMs, we have steadily accumulated achievements such as the visualization of data including unstructured data, as well as process information, seamless data

linkage, user interface according to customer needs, etc. Furthermore, based on our delivery record, we have applied the aforementioned digital solutions that TOMONI is promoting for conventional thermal power generation facility covering the entire lifecycle from commissioning to O&M of geothermal and IGCC power generation facility.

In addition, by making the best use of the results of efficient work style reforms obtained through recent in-house measures, we have been providing one-through services from the building of a cloud to the operation phase through a new communication form that corresponds to the current remote work era and contributing to the more efficient operation of power plants.

Taking this remote monitoring service as a starting point, we will continue to contribute to the operation of power generation facility, as well as to the realization of a sustainable society through stable power supply and the reduction of global environmental load by increasing communication with customers and proposing solutions that meet and solve customer needs and problems.