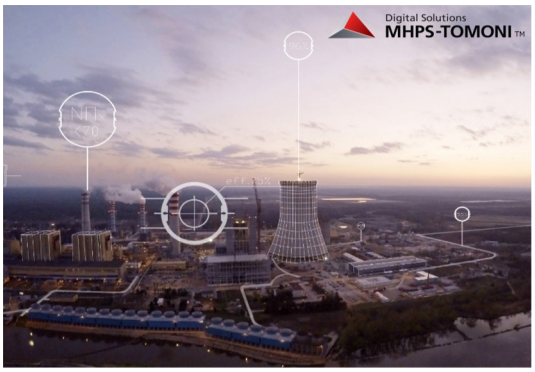
MHPS-TOMONI®: Sophisticated Power Plant Operation through Digital Solutions



DAIJIRO HIRASAKI*1 AKIHISA ENDO*2

ITARU ENDO*3

Mitsubishi Hitachi Power Systems, Ltd. (MHPS) has offered remote monitoring services for thermal power plants as digital solutions since 1999. As the efficient operation of power plants is becoming ever more important, in 2007 MHPS achieved advanced plant operation by improving availability using an anomaly detection system.

As another milestone in the digital solutions journey, in March 2017 "MHPS-TOMONI®" was launched, and the operational data of operating power plants around the world is being analyzed to promote the development of applications that can address customer business challenges. This paper gives an insightful introduction of MHPS-TOMONI®, a digital solution developed by MHPS that is being applied to actual power plants in the field.

1. Introduction

MHPS-TOMONI® is a comprehensive digital solution including an analytical platform developed for the optimization of power plant operation. "TOMONI" is the Japanese word for "together with" and reflects our "customer first principle" to solve problems together with customers. This paper presents MHPS-TOMONI®, which we have been researching, designing, implementing, and enhancing to meet the diversifying needs of customers in changing business environments, such as the increasing use of renewable energy, saving manpower, and expanding the need for technology transmission.

We operate customer portal sites that provide service information to customers with service contracts, and provide a wide range of information such as technical bulletins, monthly operational reports, mounted parts information, etc. In addition to such information, customers who have introduced MHPS-TOMONI® are able to obtain information on analysis and diagnosis results, etc., in a more timely manner. Through MHPS-TOMONI®, MHPS offers the three values of O&M optimization, performance improvement and flexible operation to customers (**Figure 1**).

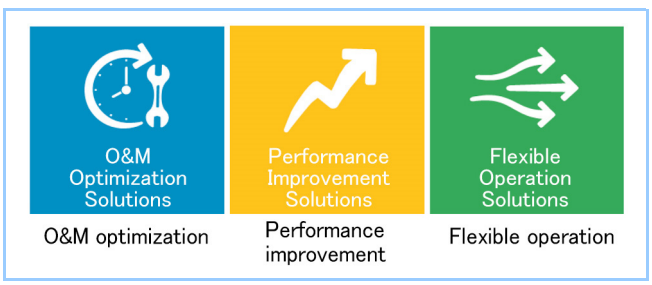


Figure 1 Three advantages of MHPS-TOMONI®

*1 Group Manager, Project Engineering Department, Power & Energy Solution Business Headquarters, Mitsubishi Hitachi Power Systems,Ltd.

*2 Engineering Manager, Power & Energy Solution Business Headquarters, Mitsubishi Hitachi Power Systems,Ltd.

*3 Power & Energy Solution Business Headquarters, Mitsubishi Hitachi Power Systems,Ltd.

We are promoting application development for gas turbines, boilers, steam turbines, generators, air quality control systems (AQCS) and other plant auxiliary equipment to enable information analysis and to provide solutions throughout the plant.

As a comprehensive manufacturer that has been involved in the field of thermal power generation for many years, MHPS used its expertise to provide solutions that meet the business challenges of customers based not only on the latest AI technology and statistical processing, but also on our accumulated EPC expertise.

2. Digital platform

MHPS-TOMONI® is a cloud- and edge-based system. The cloud offers the built-in applications, which can be accessed via the Internet, and that provide services such as data analysis and visualization. On the other hand, the edge-based part of the system carries out data transmission from the power plant to our company cloud with high data security through the installation of the "Netmation Secure Gateway (NSGW)" edge device developed by our company. In addition, we are developing equipment that is to be installed on the edge side and has function to transmit sampling data more frequently and to link information with the cloud with high affinity.

The above analysis platform consists of three layers: ICT foundation, high-precision AI application and service application. (**Figure 2**)

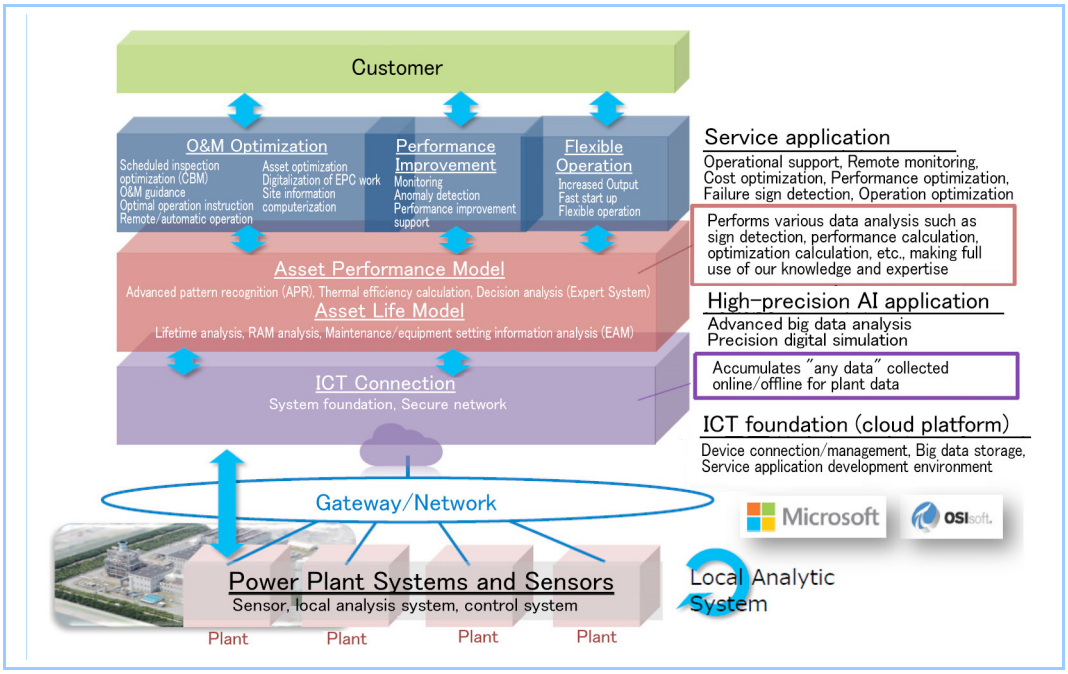


Figure 2 MHPS-TOMONI® platform

2.1 ICT foundation

MHPS concluded a partnership agreement with Microsoft and OSIsoft to establish an ICT platform for storing power plant operational data safely and developing value-added applications thereon. Microsoft Azure Cloud is used by a wide range of users irrespective of industry, and features highly-reliable security. OSIsoft PI System has been the de facto standard in the plant industry including power generation as a data historian (software for data accumulation and visualization), and is used by many power producers. By using software that is highly compatible with our customers, we built an environment in which information can be linked more quickly.

2.2 High-precision AI application

Anomaly detection using statistical methods works at this layer. In addition, asset models used for thermal efficiency calculation and product life analysis of power plants are also implemented in this layer.

Furthermore, a mechanism that links structured data and unstructured data and automatically determines how a power plant nonconforming event is caused using sensor data and the fault tree analysis (FTA) database is also implemented in this layer.

2.3 Service application

We defined three values for power producers, O&M optimization, performance improvement and flexible operation, and planned applications based on these categories. For example, for a service application for thermal power generation, monitor not only gas turbine hot gas path parts that require life management, but also about 60 items including consumables and replacements parts of the major equipment. It also calculates the stress developed in the parts based on the operation mode to calculate the optimal timing for part replacement. In addition, for the development of the GUI (Graphic User Interface), we collaborated with the Advanced Design Center of Mitsubishi Heavy Industries, Ltd. and external design companies to study user friendliness based on ergonomics and analyzed when, by whom and in what situation is the application used.

3. Cyber security

Thermal power plants are important pieces of infrastructure that provide electricity, an essential utility and lifeline, so ensuring the cyber security needs to be considered as a top priority. MHPS-TOMONI® ensures security as follows.

The cloud foundation of MHPS-TOMONI® complies with ISO/IEC27017 and NIST800-53. The security measures (i.e., firewall, encryption, vulnerability management, security patch update, and log monitoring) of the National Institute of Standards and Technology (NIST)) characteristically require two-factor authentication for access.

On the other hand, the communication between the thermal power plant and the cloud is encrypted. By restricting access to both sides by using authentication with digital certificates, all communication connections – especially to the power plant – are blocked. Furthermore, to ensure the security measures of the plant side control network, NSGW is installed. Its data diode (one-way communication) function permits data transmission only from the power plant side to the outside, and access from outside the power plant is physically blocked. In addition to the one-way communication function, NSGW permits limited communication from the outside to the inside with a serial cable, realizing flexible operation while maintaining high-level security (**Figure 3**).

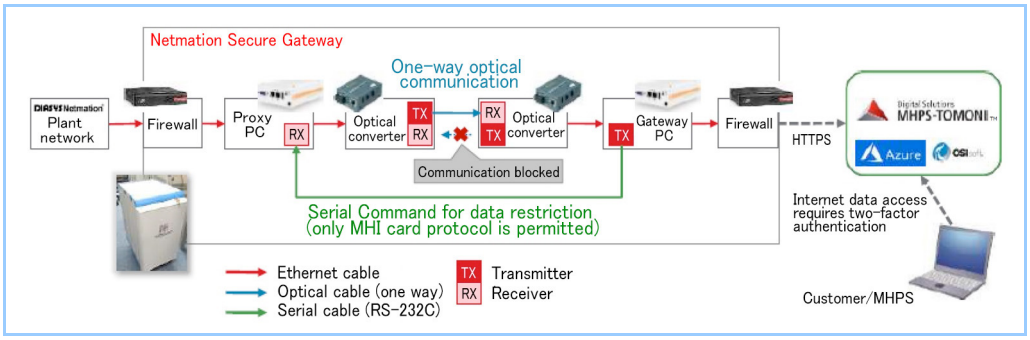


Figure 3 Cyber security of MHPS-TOMONI®

4. ICT services and applications for thermal power plants

4.1 Remote monitoring service

MHPS established remote monitoring centers at Takasago Works in 1999 and in Orlando, USA in 2001, and our specialized staff provide remote monitoring services for GTCC (gas turbine combined cycle) power plants on a 24-hour basis. We established remote monitoring centers in the Philippines in 2016 and at Nagasaki Works in 2019 as new monitoring bases, and also launched remote monitoring services using MHPS-TOMONI® mainly for steam power plants (**Figure 4**). Currently, these remote monitoring centers monitor about 150 power generation facilities around the world, mainly including large gas turbines, to provide customer operational support. The infrastructure of the remote monitoring centers in the Philippines and Nagasaki Works is based on the MHPS-TOMONI® cloud, and other centers are also gradually transitioning to its use or interconnecting one after another aiming at global deployment.

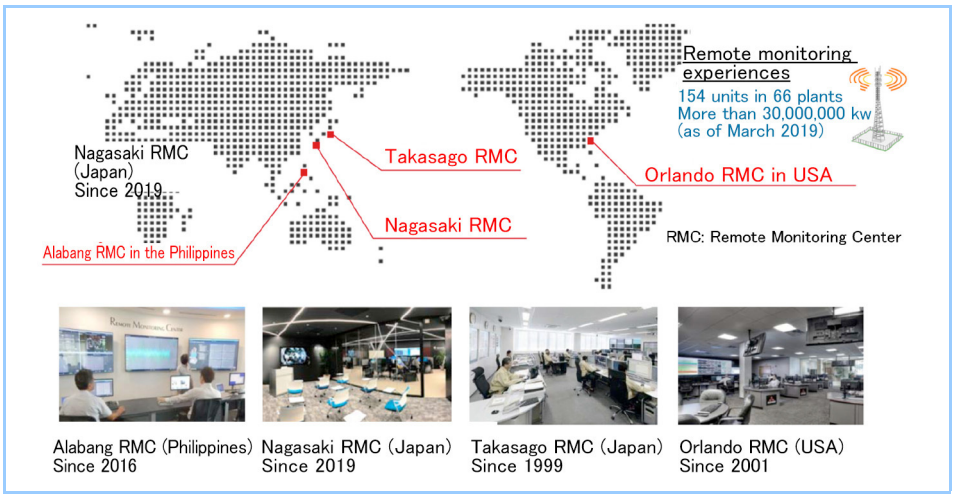


Figure 4 Remote monitoring centers of MHPS-TOMONI®

4.2 ICT applications

MHPS-TOMONI® provides the solutions using ICT and covers the entire thermal power generation field. **Figure 5** gives examples of these solutions. These solutions were developed based on operational data, information on nonconformities and countermeasures obtained from all over the world, and were prepared to realize the optimum operational pattern for the fleet compatible with each product model.

Each solution will not only provide value through ICT software, but also provide optimal solutions based on the customer's business goals, such as the proposal of the modification of the major equipment through optimization.

MHPS has prepared customer portal sites that provide service information to customers with a service contract, and MHPS-TOMONI® provides functions via these customer portal sites.

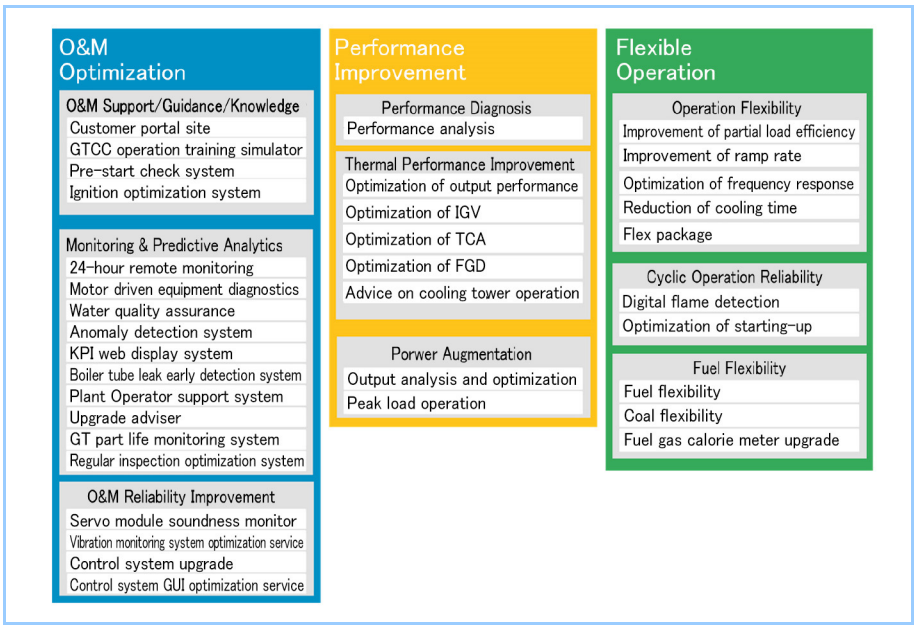


Figure 5 Solution examples of MHPS-TOMONI®

Figure 6 shows the ICT solution examples for GTCC. We make the best mix of solutions based on customer value.

(1) Anomaly detection

Early detection of abnormalities using various APR (Advanced Pattern Recognition) technologies. Detects signs of abnormalities before protective operation of the controller and provides preventive measures.

(2) Operational support for abnormalities

Supports and guides operators in the central control room by providing countermeasure instructions when alarms are initiated. The latest countermeasures from the

cloud database are provided, making it unnecessary to look them up in a paper manual.

(3) Performance degradation analysis

Analysis of the cause of deterioration of major equipment (GT/ST/HRSG/generator) and performance of the entire GTCC. Performance analysis of the GTCC is possible through the use of the latest heat balance calculation technology.

(4) KPI (Key Performance Indicators) Monitoring

Through the use of web technology, the key performance indicators of the power plant are monitored and displayed on mobile terminal devices, etc. In addition to real-time information on a specific power plant, the availability rate and deterioration status compared with other fleets are monitored.

(5) Enhancement of inspection work

Monitoring the abnormalities of plant auxiliary equipment and motors using electrical current analysis technology. Abnormal trends can be determined by measuring the electrical current of on-site motors (motors for pumps, motors for small compressors, etc.).

(6) Optimization of periodic inspection timing

The timing of periodic inspections is optimized based on the operational pattern and deterioration state of the main equipment, as well as the load applied to individual parts.

(7) Optimization of water quality management

The system automatically presents current issues and improvement plans by monitoring and analyzing the water quality of the raw water, waste water, circulating water and boiler feedwater, which results in optimized water and chemical consumption.

(8) Enhancement of control equipment (MHPS-TOMONI® Edge Enabler)

A solution package that utilizes MHPS-TOMONI® Edge Enabler, which was developed as an enhancement for OT (Operational Technology). The customer can select the use of the optimization program arbitrarily.

(9) AI-CPFM (Combustion Pressure Fluctuation Monitoring system)

A new combustion vibration avoidance system equipped with AI (machine learning). Further advanced combustion optimization technology is provided.

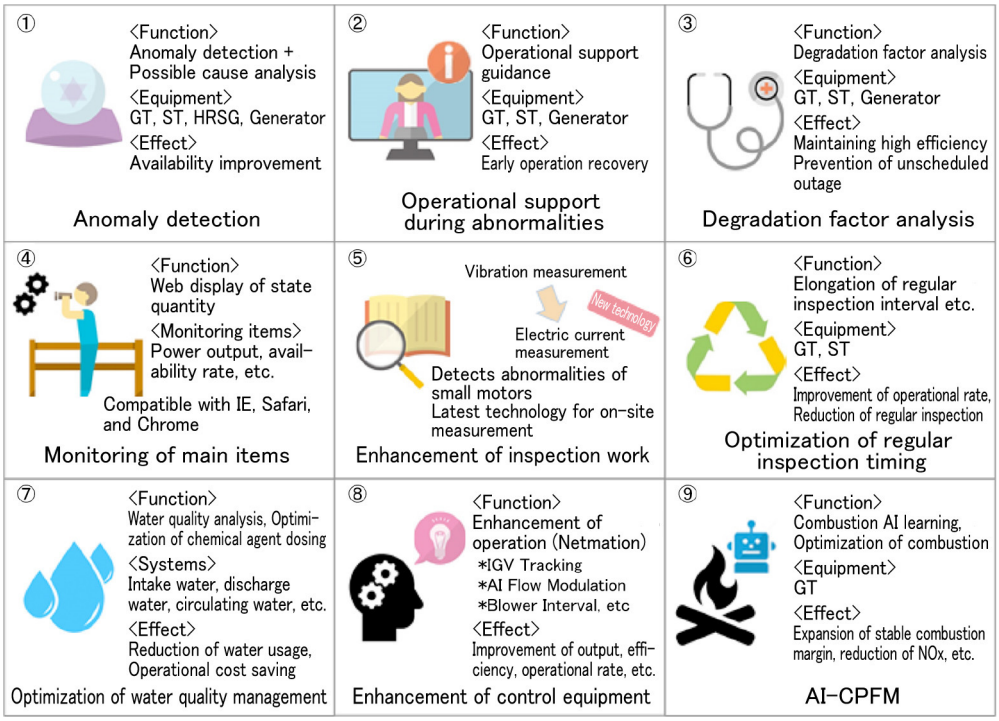


Figure 6 MHPS-TOMONI® service package examples

An example of an application using the aforementioned anomaly detection function is presented hereinafter. The anomaly detection system (Pre-ACT) provided by MHPS was originally developed independently and applied based on the proprietary MT method (Mahalanobis Taguchi method) used for remote monitoring services. It consists of two functions: anomaly detection and

failure point prediction. The MT method manages the correlation of multiple signals with one index (MD: Mahalanobis Distance). The system predicts anomalies before the threshold value of the alarm or protective function provided in the device for each sensor signal is exceeded, and contributes to preventive measures based on early detection and the improvement of the monitoring efficiency. The failure point prediction program has a mechanism for automatically predicting nonconforming points based on pattern matching between the behavior of sensor signals (SN ratio) and nonconformity events in the nonconformity database (learning database), as well as one for making notification of inspection items for the predicted nonconformity via email and the web.

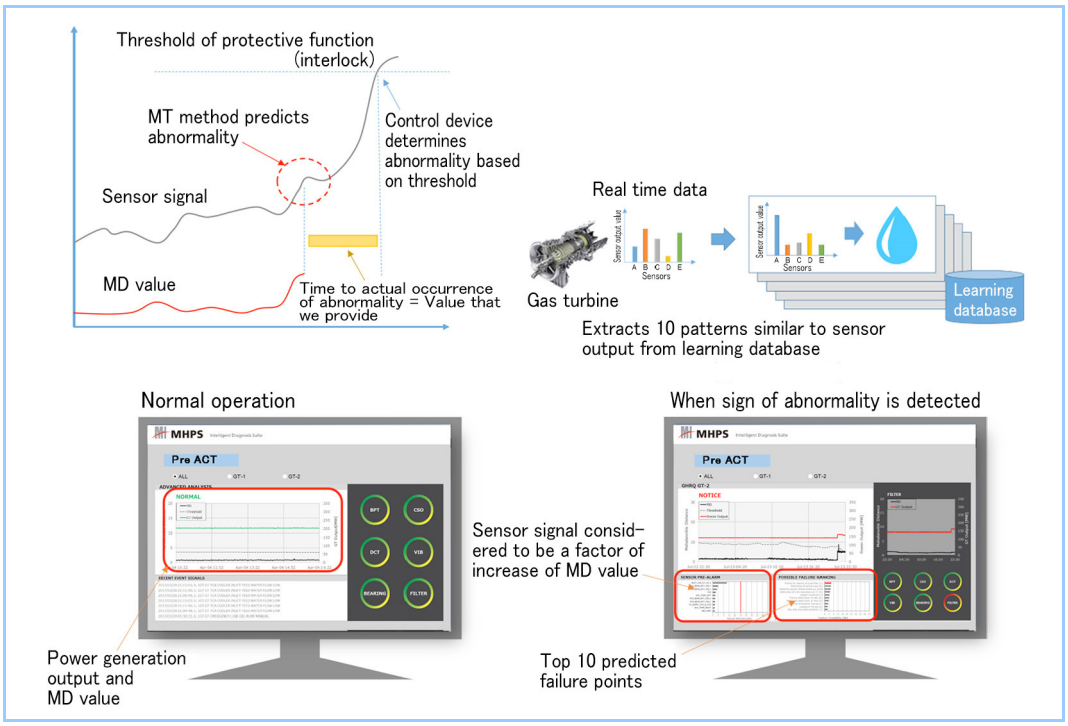


Figure 7 Functional overview of Pre-ACT

5. Conclusion

MHPS-TOMONI® was launched in March 2017 as a digital solution for power plants. Value-added applications implemented in the cloud, such as technology to derive optimal operational control based on an analysis of operating conditions, anomaly detection technology using artificial intelligence (AI) and statistical methods, and technology to derive deterioration trends and countermeasures based on advanced heat balance calculation, have grown rapidly in recent years. Simultaneously, a device (NSGW) that transmits information issued by the main equipment of a power plant while ensuring high-level security was developed, and we have started providing digital solutions that stand out from our competitors to our customers around the world.

Aiming at autonomous operation of thermal power generation facilities, we will further expand digital solutions, and develop and provide solutions that respond to the fast-changing electric power business in the aspects of hardware and software to contribute to the sustainable growth of society.

References

(1) H Aiki, et.al., Boiler Digital Twin Applying Machine Learning, Mitsubishi Heavy Industries Technical Review Vol. 55 No. 4 (2018)

(2) H Ishigaki, et.al., MHPS-TOMONI: Thermal Power Generation Digitalization Platform Cloud/Edge Service and System Architecture, Mitsubishi Heavy Industries Technical Review Vol. 55 No. 4 (2018)