

MHPS-TOMONI: Thermal Power Generation Digitalization Platform Cloud/Edge Service and System Architecture



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To increase the efficiency and reliability of a power plant by utilizing ICT, collaboration between the power plant operator and the plant manufacturer is indispensable. Mitsubishi Hitachi Power Systems, Ltd. (MHPS, our company) places an emphasis on providing a solution in which "we work together with the customer." This report introduces the cloud/edge service, system architecture, cyber security, data analysis technology and examples of service application of MHPS-TOMONI (thermal power generation digitalization service) that our company provides.

1. Introduction

To increase the efficiency and reliability of a power plant by utilizing ICT (Information and Communication Technology), the combination of collaboration with the customer, which is the power plant operator, and the insight of our experienced technicians, is indispensable. Our company places an emphasis on providing a solution in which "we work together with the customer."

MHPS-TOMONI, a thermal power generation digitalization service, is a comprehensive digital solution developed by our company to solve the problems of every customer involved in the operation of a power plant, and consists of a variety of hardware, software and services. For MHPS-TOMONI, information communication technology (ICT) such as big data analysis based on partnership with customers and artificial intelligence (AI) technology, in addition to innovative technologies and expertise on thermal power generation and the operation and maintenance (O&M) know-how that our company has cultivated for decades, is utilized to the utmost. In this approach, we target the improvement of the product value of MHPS-TOMONI through not only our own efforts, but also in cooperation with various industry-leading partner companies.

This report focuses on how MHPS-TOMONI is constructed in terms of the system and introduces the platform, system architecture and case examples of main applications to products.

2. System configuration of MHPS-TOMONI

The MHPS-TOMONI system consists of two components: a cloud service and an edge service. The cloud service realizes advanced technology efficiently and stably by collaborating with industry-leading technological partners, including global cloud platform Microsoft Azure and OSIsoft's data management platform PI System. In addition, as a service for users, customer applications and in-house applications are built in the cloud. Customers and internal users can access these applications via the internet, and various services such as the analysis and visualization of data are available therein. Furthermore, internal users at domestic and overseas bases can use the virtual desktop environment built on MHPS-TOMONI. With this globally-common working environment, various collaborations such as data analysis and service development are possible.

As the edge service, an in-house developed edge device "Secure Gateway (data diode)" is

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installed in the power plant. This enables data transmission to the cloud with the security of the power plant ensured. In addition, the edge equipment provides applications requiring high-frequency sampling data and high-speed response, applications based on machine learning and the performance improvement functions of the power plant, whereby a mechanism to monitor the operational status thereof in the cloud is constructed (**Figure 1**).

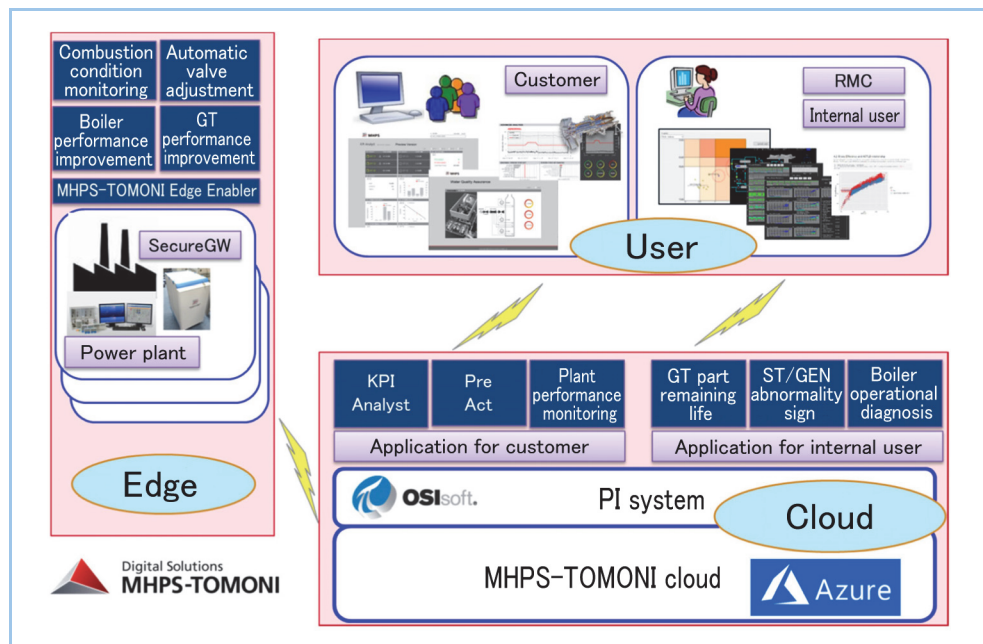


Figure 1 System configuration of MHPS-TOMONI

3. Main technologies of MHPS-TOMONI

3.1 Cyber security

When ICT is applied to a thermal power plant, which is critical infrastructure, ensuring cyber security must be considered first. MHPS-TOMONI ensures security from the two aspects of cloud and edge.

(1) Cloud side security

The MHPS-TOMONI cloud adopts Microsoft Azure as its foundation. Azure conforms to various guidelines such as ISO 27001, 27017, etc., and provides a variety of security tools. Making the most of these tools, MHPS-TOMONI operates ensuring cloud security compliant with ISO/IEC 27017, NIST 800-53.

This series of security measures (firewall, encryption, vulnerability management, security patch updates and log monitoring) compliant with NIST (National Institute of Standards and Technology) characteristically requires two-factor authentication to access the cloud. The security is strengthened by not permitting access with simple ID/password for all customer users, internal users and cloud operators.

(2) Edge side security

To ensure the safe operation of the power plant against recently frequent cyber-attacks, The cyber security measure in ICT utilization is the most important task. MHPS-TOMONI encrypts communication between the power plant and the cloud, uses digital certificates for authentication and restricts access to both. In particular, all communication connections to the power plant are disallowed. In addition, Secure Gateway is installed to ensure security measures on the plant side control network. Secure Gateway has a data diode function and physically blocks access from the outside of the plant by one-way communication, only permitting data transmission from the plant side to the outside. In addition to this data diode function, the Secure Gateway permits limited communication from the outside to the inside using a serial cable, realizing flexible operation while maintaining the security strength (**Figure 2**).

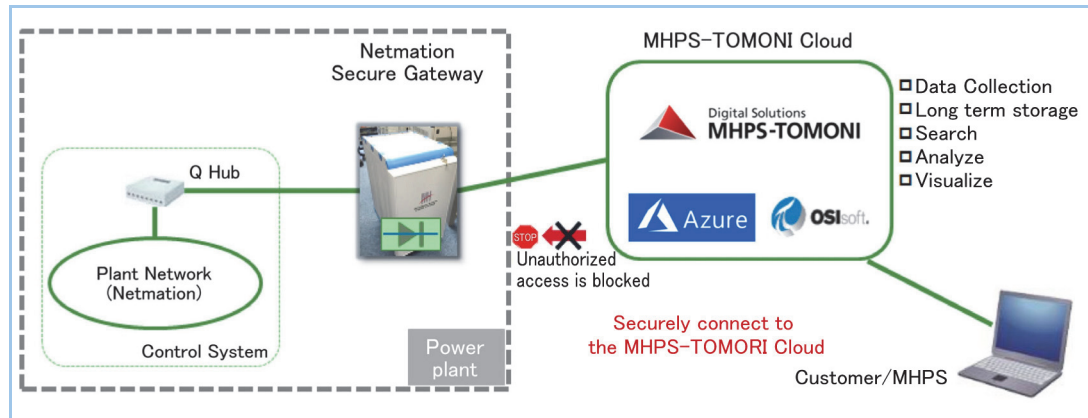


Figure 2 MHPs-TOMONI security measures

3.2 Data analysis system

By accumulating the past long-term data of the power plant in the PI System (database) in the cloud, it is possible to easily retrieve digital data and visualize trend graphs, etc. (Figure 3). Moreover, performance calculation, life-time calculation, etc., are carried out by using the calculation engine of PI System, Excel and a dedicated application.

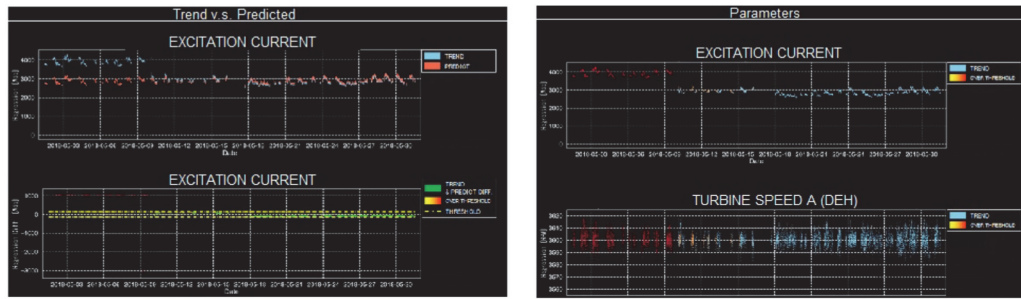


Figure 3 Trend graph



Figure 4 Performance comparison screen before and after remodeling of equipment

By utilizing R, Python, etc., accumulated past data are analyzed (statistical processing and machine learning) to provide a more valuable solution to the customer. The data analysis environment is seamlessly and securely connected to databases and web applications. Data analysts can perform data mining, data processing, web application development using data analysis/GUI framework based on R and Python, so the time required to visualize the data analysis results is

greatly shortened. **Figure 4** shows an example of a web screen that displays visualized results of statistical analysis using R. This screen is an interactive screen created so that the user can easily compare the performance before and after the remodeling of the equipment. Such functions can be combined with a strong authentication system on Azure and securely provided to the customer.

4. Application examples of services using MHPS-TOMONI

4.1 Remote monitoring service

MHPS established remote monitoring centers in the Takasago Works in 1999 and in Orlando, U.S.A. in 2001, and operates a remote monitoring service of gas turbine combined cycle power plant on a round-the-clock basis with specialized staff members. In 2016, we established a remote monitoring center in the Philippines as a new monitoring base and started a remote monitoring service utilizing MHPS-TOMONI mainly for conventional power plants. Currently, these remote monitoring centers monitor approximately 150 power plants in countries all around the world, centering on large-scale gas turbines, to support customers' operations (**Figure 5**). The infrastructure of the remote monitoring center in the Philippines is based on the MHPS-TOMONI cloud, and the other centers are shifting as planned or interconnecting thereto.

In a thermal power plant, it is important to monitor a wide range of sensor signals, to detect predictor abnormalities at an early stage, and to take appropriate measures so that the equipment will not trip due to problems. MHPS developed its own abnormality detection system to which a pattern recognition technology called MT system (Mahalanobis-Taguchi system) is applied and have utilized it in the remote monitoring service of large gas turbines so far. We also offer an abnormality sign detecting application service, called "Pre-ACT," as a menu item of MHPS-TOMONI in addition to 24-hour monitoring service with professional staff members.

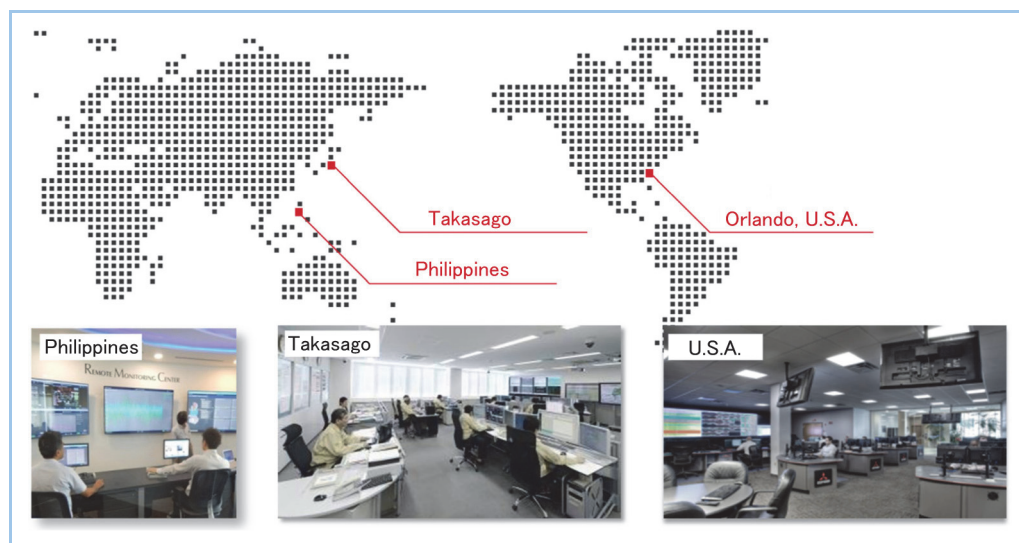


Figure 5 Remote monitoring centers for thermal power plants

4.2 Pre-ACT (abnormality sign detection system)

Pre-ACT is an application that consists of two functions: abnormality sign detection and failure area estimation, and informs the user of the estimated nonconforming part and inspection items using e-mail or a web screen when the system detects an abnormality that is a predictor of equipment problems.

The aforementioned MT system that has been proven in the remote monitoring of large gas turbines is applied to the abnormality sign detection program. One of the features of the MT system is that the correlation between multiple sensor signals can be managed with one index called Mahalanobis distance (MD). The system can detect a slight misalignment of correlation, which is an abnormality sign, as an increase in the MD value even when each sensor signal does not exceed the threshold of alarm or protection operation set in the control device. For this reason, the system has achieved significant results in the early detection of abnormality signs and the efficiency improvement of the monitoring of large-scale gas turbines requiring the monitoring of a large number of sensor signals (**Figure 6**).

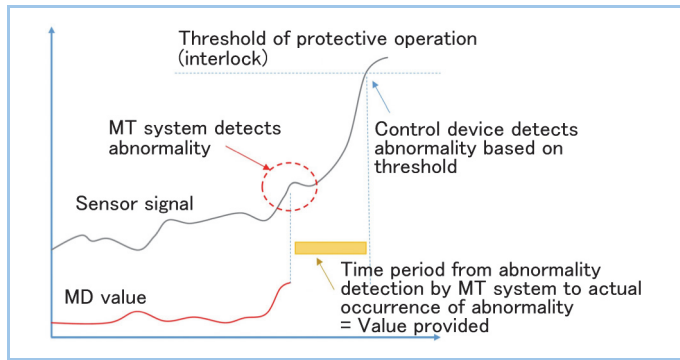


Figure 6 Abnormality sign detection by MT system

The failure area estimation program automatically estimates nonconforming points based on pattern matching between sensor signal behavior and a nonconformance database (learning database). When the MT system detects an abnormality, a nonconformity of a pattern close to the behavior of the actual sensor signal is automatically extracted from the learning database, and notification of the nonconformity and the inspection item for the nonconformity is made by email. Using this information, the customer performs inspection and check (Figure 7).

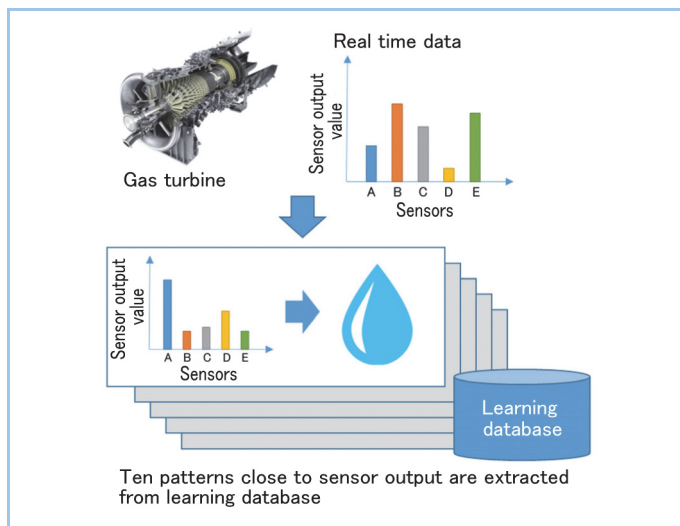


Figure 7 Failure area estimation by pattern matching

A Pre-ACT web screen for the customer is also available. Figure 8 shows the web screen for a large gas turbine. This screen displays the power generation output and the trend of the MD value during normal operation, and displays the sensor signal considered to be the cause of the increase of the MD value and the top 10 ranking of the estimated nonconformity point when the system detects an abnormality.

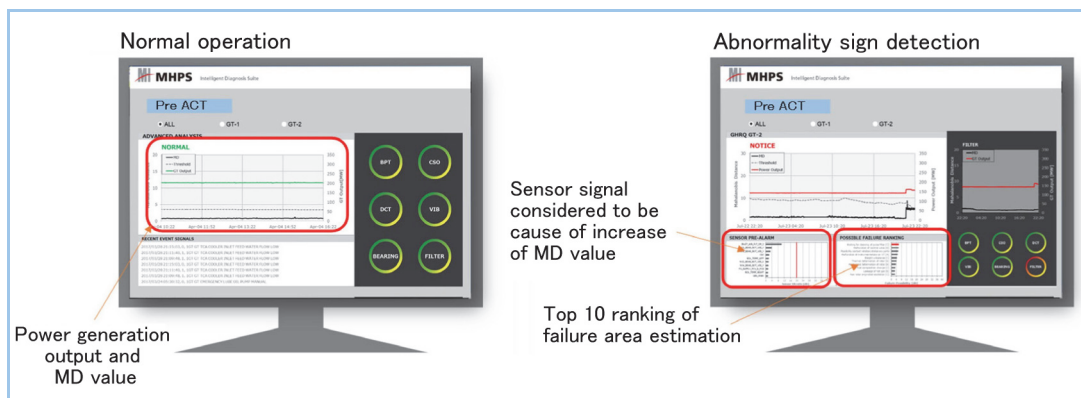


Figure 8 Web screen of Pre-ACT for large gas turbine

4.3 MHPS-TOMONI Edge Enabler

We provide a device called MHPS-TOMONI Edge Enabler as a mechanism to efficiently and effectively apply control expansion solutions such as performance enhancement and operational improvement (**Figure 9**).

By installing the system at the edge and interfacing with the control device on the plant network, it is possible to provide the results calculated and processed by the Edge Enabler to the control device. By linking with DIASYS NetmationTM, which is our in-house developed control device, more advanced plant control is realized.

The Edge Enabler also includes the functions of Secure Gateway, and can be connected securely to the MHPS-TOMONI cloud. Periodic monitoring of the control improvement status by MHPS makes it possible to provide the best condition. In addition, since the customer can select whether to enable or disable the function, it is possible to use the system while confirming the return on investment. The Edge Enabler is applied to the adjustment of the opening of a gas turbine inlet guide vane (IGV), optimization of the gas turbine cooling air flow rate, automation of control valve adjustment and digital twinning of a boiler⁽¹⁾.

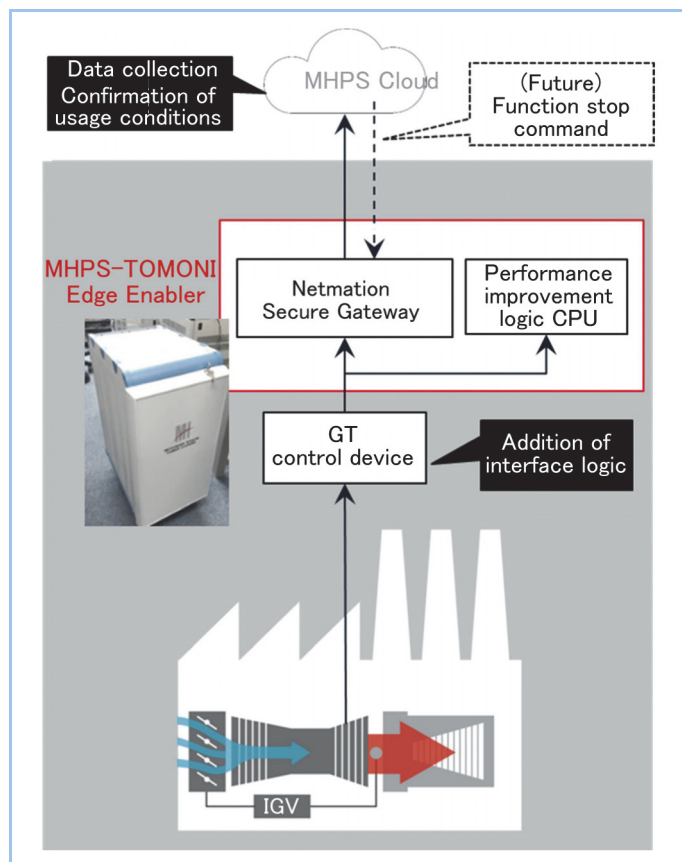


Figure 9 Conceptual diagram of MHPS-TOMONI Edge Enabler

4.4 Support of customer's digitalization

In recent years, there have been an increasing number of cases where power generation companies themselves build monitoring systems that store, visualize and analyze operational data to inherit the knowledge of experts, nurture and secure young employees, operate a power plant as a stable social infrastructure and enhance their competitiveness through the use of ICT technology. For these customers, as one of the MHPS-TOMONI services, our company utilizes our knowledge of the power plant business and MHPS-TOMONI construction experience to support customers in establishing their remote monitoring systems. Specifically, we propose an architecture that considers the operational form and initial/running cost, provide security education and examine connecting methods between the power plant and PI System.

In particular, in terms of security measures, since the number of connections between power plants and external networks resulting from constructing remote monitoring systems is on the rise as mentioned above, we understand the overview of the security risks of power plants based on the global standard (IEC 62443-2-1) and support the formulation of action plans to deal with risks.

5. Conclusion

This report introduced the platform, cloud/edge service and system architecture of MHPS-TOMONI (thermal power generation digitalization). At present, many solutions are under trial operation, but we will promote research and development in the future and create solutions that further match customer needs. In addition, we will continue to provide highly-competitive solutions by incorporating the latest technologies.

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References

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