

Development and Operation of IoT Platform to Support Smart Maintenance of Factory Infrastructure



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In addition to the problems of aging equipment and a shortage of maintenance personnel, addressing new demands such as carbon neutrality has become a challenge in the field of industrial maintenance. In response, Mitsubishi Heavy Industries, Ltd. has built an IoT platform integrating sensing, data aggregation, visualization, and analytics for factory infrastructure. This platform was applied to high-pressure gas supply facilities and electrical facilities, resulting in a reduction in inspection labor hours of 50% or more, indicating the potential for early detection of abnormalities, improved maintenance levels, and less energy loss. Through this initiative, MHI will contribute to the stable supply of products through the advancement of factory infrastructure and the creation of customer value.

1. Introduction

In recent years, the field of industrial maintenance has been shifting toward "smart maintenance" that achieves both safety and efficiency through the use of digital technologies such as IoT and AI, while facing structural challenges such as aging equipment, a shortage of maintenance personnel, and the increased burden of inspections.^{(1), (2)} Furthermore, to achieve carbon neutrality by 2050, the importance of leveraging data to contribute to energy savings, the transition to non-fossil energy, and reduction of greenhouse gas emissions by plants, factories, and establishments has been increasing.⁽³⁾

Based on these social requirements and internal challenges, Mitsubishi Heavy Industries, Ltd. (hereinafter referred to as MHI) has positioned automation of patrol inspection and meter reading, condition-based maintenance, and early detection of abnormal signs through remote monitoring as priority themes that will contribute toward smart maintenance and carbon neutrality. On the other hand, to apply smart maintenance to actual facilities, the physical parameters to be measured, installation environment, required accuracy, and conditions of compliance with legislation and technical standards differ depending on each targeted equipment. Therefore, integrally designing the sensor selection, communication methods, IoT gateways, server applications, and operation rules in accordance with these conditions is important. Given this situation, MHI has built a customizable IoT sensing platform to ensure flexible deployment and operations, establishing a framework that scales from small-scale proof of concept to company-wide rollouts.

In this report, the current status and challenges of infrastructure facility management at MHI, as well as an overview of the IoT sensing and data visualization/analysis platform that supports smart maintenance, are described. Furthermore, through examples of streamlining patrol inspection work for high-pressure gas supply facilities and advancing electrical facility maintenance, the roles of the in-house IoT platform to advance maintenance work and create new value are described.

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2. Current status and challenges of infrastructure facility management at MHI plants

The Infrastructure Facility Management Department of the Value Chain Headquarters at MHI is responsible for infrastructure maintenance management at the company's 13 domestic factories. Since its establishment in 2016, the department has focused on the standardization and improvement of processes across divisions. However, efforts to adopt digital technologies and leverage data remained limited. In light of this, when planning the 10-year vision for facilities management in 2023, a backcasting approach was utilized to evaluate necessary technologies and develop a technology roadmap. In this process, the importance of initiatives such as "automation of inspection and meter reading" and "condition-based maintenance" from the standpoint of value to the recipient of the infrastructure service and feasibility became clear. MHI manages approximately 60,000 facilities, expending significant resources on visual inspections and periodic maintenance during non-operating days. Managing a vast number of inspection items poses a significant challenge, particularly in preventing human errors such as missed checks and data entry mistakes. It is anticipated that automating data collection and facility condition monitoring will resolve the aforementioned challenges. Moreover, by leveraging accumulated data, technical know-how, and human resources reallocated through improved efficiency, new value can be created in areas such as energy savings, carbon neutrality, and enhanced plant availability.

3. IoT platform that realizes smart maintenance

MHI developed this IoT platform as part of its smart factory and maintenance initiatives to enable the agile, cost-effective construction and operation of data analysis systems. The platform's scope and features are detailed in **Figure 1**. Standardizing system deployment via "templates" is designed to cut implementation costs and accelerate design and setup phases. Capabilities span from on-site sensing (IoT sensors, cameras, PLCs) and gateway-based data routing/storage, to advanced data visualization and analytics in the back office.

Automating inspection work requires selecting IoT sensors and devices that comply with various regulatory and technical standards. However, achieving this is difficult when relying on a single vendor's lineup. To address this, MHI evaluated various commercially available sensors to ensure multi-vendor and multi-protocol compatibility and integrated the necessary communication software into the IoT gateways. This approach yielded a highly flexible system with a minimal number of components. On the server side, adopting environment-agnostic software—capable of running both on-premises and in the cloud—established a flexible configuration that facilitates rapid Proof of Concept (PoC) deployments in local environments.

Alongside the deployment of these data processing systems, MHI prioritized personnel training tailored to department-specific needs. This included fostering a problem-solving mindset through prototyping and upskilling site engineers in IoT sensor operation. Through these holistic initiatives, the concept of "start small, scale up" in remote monitoring has been successfully realized, paving the way for the smart maintenance activities detailed in the following chapters.

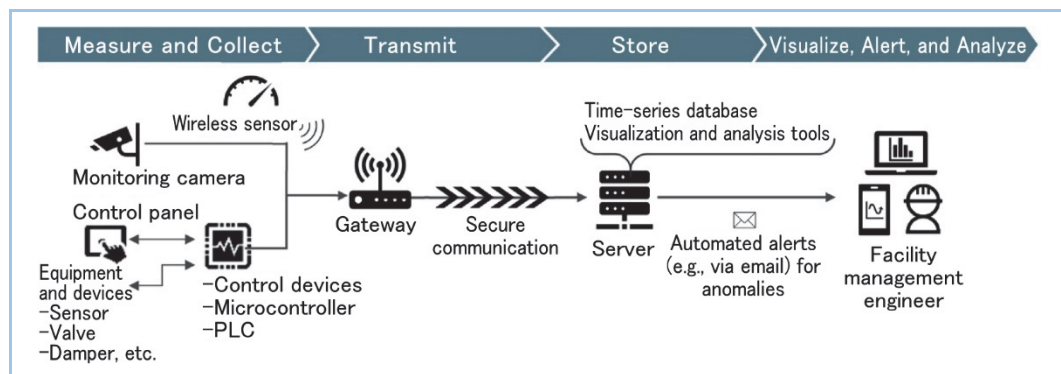


Figure 1 Architecture of the IoT platform for smart maintenance

4. Case examples of smart maintenance using the IoT platform

4.1 Optimizing and upgrading inspection processes for high-pressure gas supply facilities

Facilities which supply industrial gases used in the manufacturing processes at MHI factories, such as carbon dioxide, argon, nitrogen, and oxygen, are located in various areas. In compliance with regulations related to high-pressure gas maintenance, patrol inspections are carried out three times a day. These tasks involve reading on-site meters such as pressure gauges, conducting visual inspections of piping, and recording and reporting the results. Because personnel must traverse the expansive site regardless of weather conditions, the significant physical burden was a major challenge. Therefore, MHI aimed to automate data collection using IoT sensors for items previously subject to manual visual inspection. While camera-based image analysis was initially proposed to digitize meter readings⁽⁴⁾, this method posed several challenges. Certain facilities utilize float-type level gauges or meters with shapes that are difficult to read even with the human eye. Furthermore, ensuring image analysis accuracy is difficult for outdoor targets due to unstable imaging conditions. Another issue was the inflated running costs driven by the heavy communication and computational resources required for image transmission and processing. To overcome these limitations, MHI utilized the platform described in the previous chapter to construct a system integrating sensors that directly measure physical quantities—such as retrofittable needle-angle sensors, current sensors, and temperature sensors. This approach significantly improved measurement stability while reducing operational costs.

Following close coordination with regulatory authorities such as prefectural governments, operations transitioned to a hybrid inspection model. Of the three daily inspections, one is now conducted via conventional patrol, while the remaining two are performed remotely using this system (**Figure 2**). Successfully deployed at two domestic factories, this approach saves approximately 2,500 labor hours annually and eliminates human errors such as manual reading and data entry mistakes. Furthermore, high-frequency data collection at one-minute intervals, coupled with automated alerts for threshold deviations, enables rapid responses to anomalies, thereby contributing to a higher level of maintenance.

Furthermore, integrating data collection and visualization functions into daily operations enables facility engineers to pursue data-driven improvements in supply quality and gas loss reduction. Moving forward, sharing these insights across relevant departments is anticipated to enhance overall productivity and quality throughout MHI's manufacturing processes.

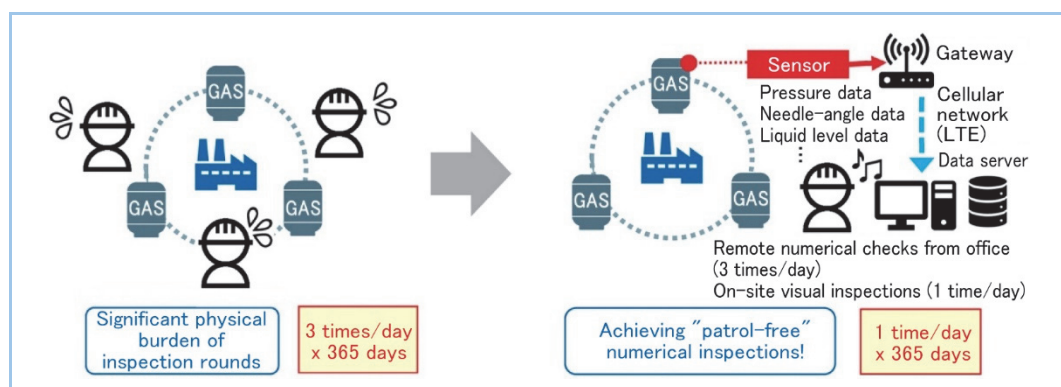


Figure 2 Conceptual image of remote monitoring in high-pressure gas supply facilities

4.2 Optimizing and upgrading maintenance processes for electrical facilities

Electrical fires and electrocution accidents caused by electrical leakage in power cables and equipment at any manufacturing facility pose severe risks for operators, including MHI. These incidents can result in employee injuries, prolonged production halts, and a loss of public trust. To prevent such accidents, MHI conducts insulation resistance measurements across all electrical circuits and equipment to identify leakage risks and implement countermeasures. However, the sheer number of systems to manage is vast. For instance, the MHI Hiroshima Machinery Works houses approximately 21,000 circuits, demanding significant labor for measurement tasks. Consequently,

inspection frequency is limited to about once a year, potentially delaying the detection of electrical leaks. Furthermore, when a leakage risk is detected, isolating the root cause requires cutting the power, leading to unplanned downtime—another major operational challenge.

To address these challenges, MHI constructed a system to monitor the operational and leakage conditions of the entire facility at the Hiroshima Machinery Works by installing IoT sensors in upstream electrical substations. Specifically, retrofitable IoT sensors were deployed to collect data such as power consumption and leakage current (I_0 current, including both resistive and capacitive components) flowing through transformer ground wires. By applying multivariate analysis based on the expertise of MHI's electrical maintenance engineers, a logic was developed to classify each circuit into three statuses: "abnormal," "normal," and "inconclusive." This enabled a new operational policy: triggering immediate targeted inspections for "abnormal" cases, extending the inspection interval for "normal" circuits, and conducting conventional device-level insulation resistance measurements for "inconclusive" cases (**Figure 3**). While standalone devices for measuring leakage current already existed, performing the multi-variable correlation analysis essential for determining appropriate responses was difficult with conventional, single-function systems. The high flexibility of the aforementioned IoT platform enabled the efficient collection, visualization, and analysis of multiple operational parameters, facilitating rapid and cost-effective development from PoC to full-scale operation. Through this initiative, the risk of electrical fires and electrocution across approximately 21,000 circuits can now be automatically evaluated using just 350 sensors installed in upstream substations. This efficiency is projected to reduce inspection labor hours by approximately 60% (**Table 1** compares the conventional and new methods). Continuous monitoring allows for the early detection and swift resolution of anomalies. Furthermore, analyzing trend correlations between equipment operating states and leakage currents allows root causes to be inferred while the equipment remains online. This drastically narrows the scope of inspections requiring power isolation, thereby minimizing the risk of unplanned downtime.

Furthermore, leveraging this data provides insights into energy usage alongside enhancing the maintenance quality of electrical facilities. Typically, justifying the return on investment (ROI) based solely on energy visualization is difficult, which frequently poses a barrier to implementation. However, by deploying smart technologies with the primary goal of enhancing facility maintenance—as demonstrated in this case study—energy data can be utilized secondarily. This enables advanced energy management while still achieving the primary benefits of improved safety and reduced inspection labor hours. This strategy is highly rational from an ROI perspective and serves as an effective approach for advancing both smart maintenance and carbon neutrality initiatives.

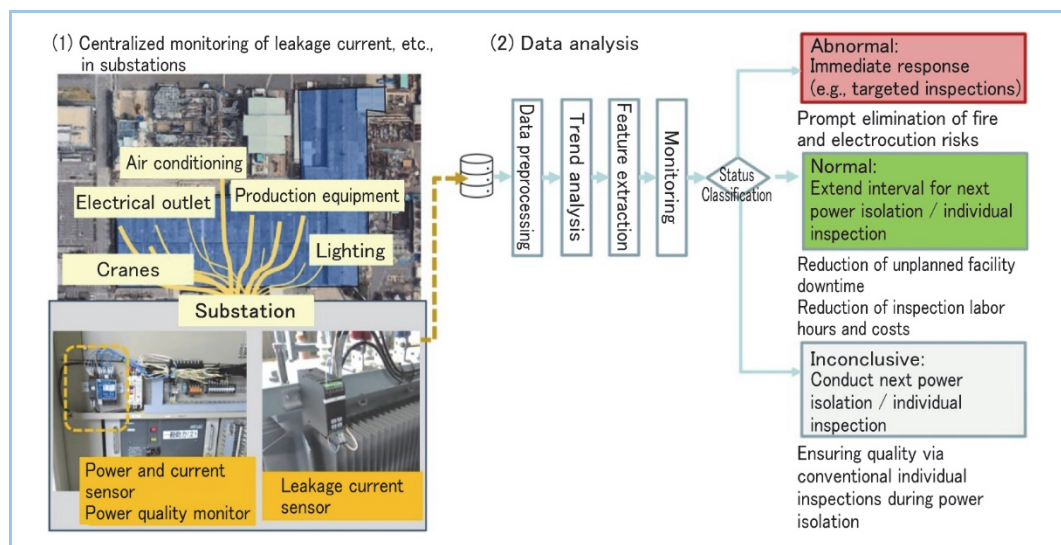


Figure 3 Data and decision flow for enhancing maintenance operations for electrical facilities

Table 1 Comparison of conventional and new methods for enhancing electrical facility maintenance

	Conventional method Individual diagnosis via power isolation and manual patrols	New method Centralized monitoring via sensors in upstream substations
Measurement Location	Individual equipment across the manufacturing facility	Upstream substations
Labor Burden & Scope	[High Burden] Manual measurement of approx. 21,000 individual circuits via patrols	[Low Burden] Automated monitoring of just 350 locations via sensors
Impact on Production	[Unavoidable] Power isolation is strictly required for diagnosis	[None] Continuous diagnostics while equipment remains online
Diagnostic Certainty	[High] Clear status classification via individual component evaluation	[Trade-off] Pinpointing can be difficult due to aggregated upstream monitoring
Data Frequency	[Low] Once a year	[High] Continuous monitoring
Anomaly Detection in Production Equipment	[Difficult] Operating conditions cannot be reproduced during power isolation. Requires teardown inspections.	[Possible] Anomalies can be inferred during operation (requires targeted follow-up inspections to pinpoint defective parts).

5. Conclusion

In this report, an approach to realizing smart maintenance utilizing an IoT platform was presented to address structural challenges in infrastructure facility management. Through case studies applying this smart maintenance model to high-pressure gas and electrical facilities, it was confirmed that reducing labor hours and enhancing safety levels can be achieved simultaneously by combining remote inspections with sensor-based condition evaluations. In particular, the system's highly scalable architecture effectively adapts to diverse environmental conditions across different manufacturing facilities, facilitating rapid and cost-effective deployment from proof of concept to full-scale operation. Furthermore, utilizing collected maintenance data for secondary applications, such as energy management, demonstrates the potential to significantly improve the return on investment (ROI).

Moving forward, MHI will continue to accelerate the company-wide rollout of these systems. Enhancing the maintenance quality of factory infrastructure contributes to the stable operation of manufacturing processes and, by extension, ensures on-time product delivery. Additionally, by integrating the expertise gained from data utilization and IoT platform technologies into MHI's products and services, the company aims to help customers achieve their own smart maintenance and carbon neutrality goals, thereby creating new value.

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