Ship IoT System for Efficient Operation Management of Exhaust Gas Cleaning Systems

YASUNOBU, Tomohiro*

ABSTRACT

Recent stricter international environmental regulations in the maritime industry have been encouraging the installation of exhaust gas cleaning systems (EGCS) to purify the exhaust gas emitted from ships. As part of this effort, Fuji Electric has developed a ship IoT system that utilizes increasingly popular ship-to-shore broadband communications. This IoT system is able to monitor EGCS measurement log data and alarms by utilizing a cloud server. It also provides a diagnostic function to predict abnormalities and facilitates timely maintenance before equipment malfunctions in order to shorten equipment downtime and reduce the work costs required for troubleshooting.

1. Introduction

In recent years, stricter international environmental regulations in the ship industry have increased the need to switch from conventionally used fuels to fuels that conform to environmental regulations and install exhaust gas cleaning systems (EGCS). However, systems that comply with environmental regulations are more sophisticated than conventional ship equipment and are difficult to handle, making it difficult for crew members alone to deal with equipment failures. In addition, ships often sail at sea throughout the year, which results in the unique problem that manufacturers are not able to attend ships immediately. On the other hand, the spread of land-to-ship broadband communications using satellite communications is rapidly advancing, and ships sailing at sea can enjoy fixed-price, high-speed communication services.

To resolve the ship-specific problems described above, Fuji Electric has developed an Internet of Things (IoT) system for ships to be applied to EGCSs[(1)]. This equipment is used to monitor measurement log data and alarms using a cloud server. When a fault occurs in the equipment, remote support can be provided, such as by determining the point of failure from the measurement log data and providing repair instructions without anyone having to attend the ship. The ship IoT system provides a diagnostic function to predict abnormalities utilizing Fuji Electric's artificial intelligence (AI) technology[(2)], enabling condition-based maintenance (CBM), in which faults in equipment are predicted, and maintenance is performed at optimal times. The function helps reduce downtime caused by equipment failure and suggests the optimal timing for replacement and the purchase of spares.

2. Ship IoT Systems and Current New Needs

Figure 1 shows a configuration diagram of the ship IoT system. In this system, the edge device "FiTSA Σ" embedded in the IoT relay panel installed on the ship transmits measurement log data stored in the EGCS monitoring control panel and the alarm history of each device to the Fuji Electric cloud server at fixed periods using satellite communications. The ship management company can monitor ship data by accessing the cloud server. Taking into consideration the characteristics of satellite communications, the communication protocol adopted for cloud servers is Message Queue Telemetry Transport* (MQTT), which uses retransmission and other means to ensure the reachability of information even when the network environment is unstable. The connection between the IoT relay panel and the line used by the ship management company can be completed by setting a fixed IP address and a default gateway, just like a typical Internet connection. In addition, regarding the security of cloud servers, risk reduction and protection of important information are implemented in accordance with ISO/IEC 27017:2015 (cloud security standard) and Fuji Electric's security policy.

Fuji Electric began offering the ship IoT system in April 2021[(1)]. Figure 2 shows the workflow of response to failures before and after the introduction of the ship IoT system. Prior to the introduction of the system, if a fault occurred in a ship's system or equipment, the situation would be reported by email from the ship to

* Power Electronics Industry Business Group, Fuji Electric Co., Ltd.

* MQTT is short for Message Queue Telemetry Transport, which is a lightweight messaging protocol that communicates using the TCP/IP protocol.

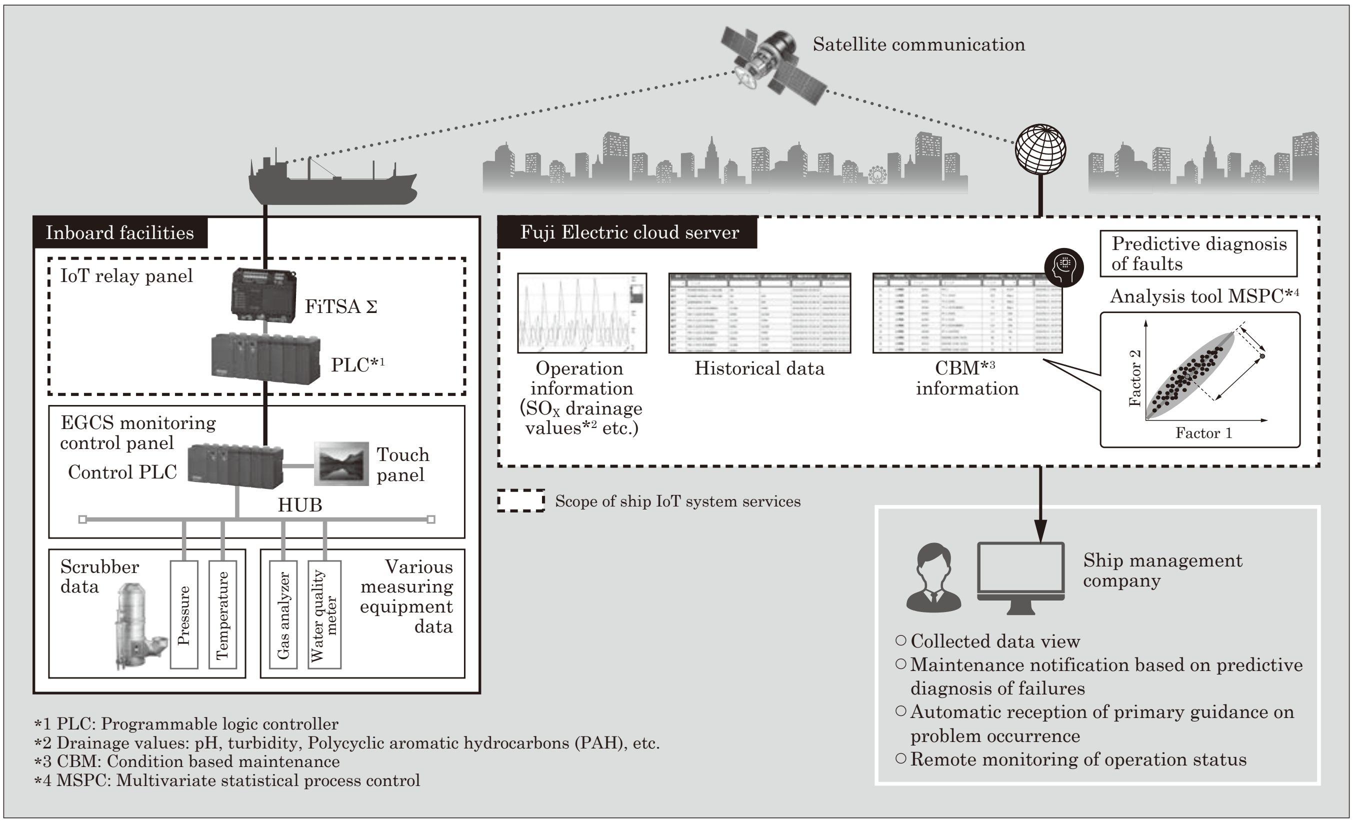


Fig.1 Ship IoT system configuration diagram

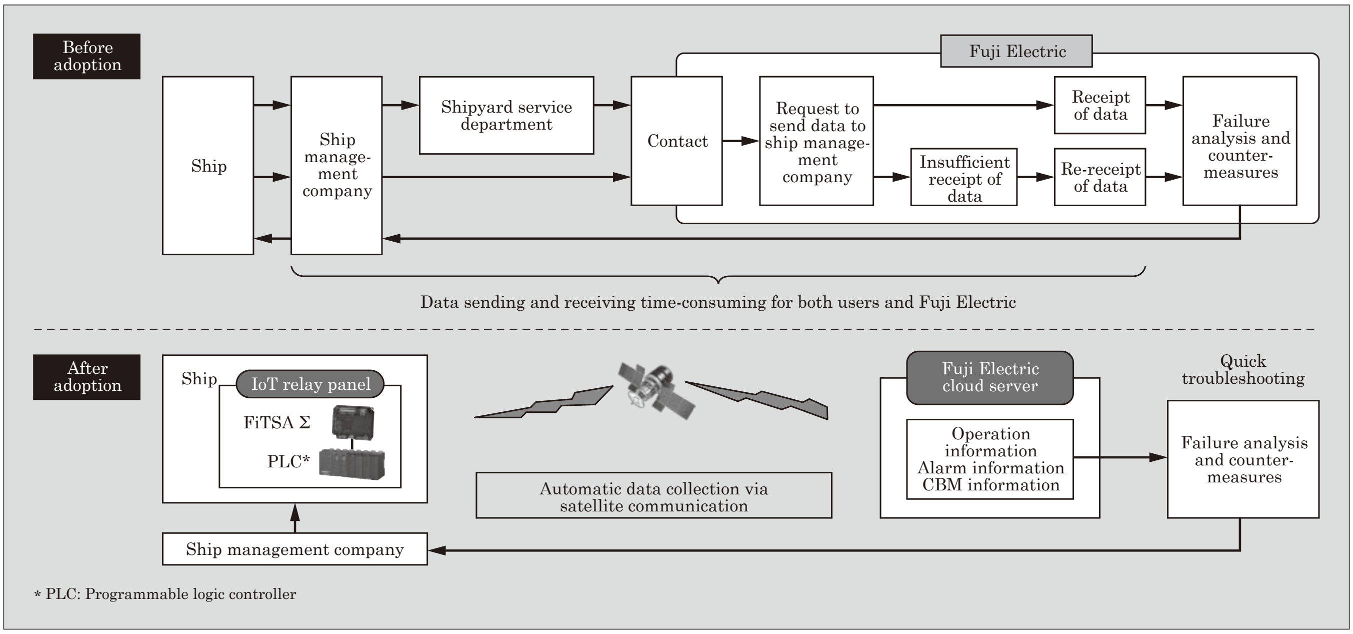


Fig.2 Workflow of responses to failures before and after the introduction of the ship IoT system

the ship management company, who would request a fix from Fuji Electric, the supplier of the system or equipment that seems to be the cause of the problem. Upon receiving the request, Fuji Electric would contact the ship management company about the cause of the fault and solutions, and the ship management company would relay information to the ship. If the problem could not be resolved by the provided solutions, the situation would be reported to Fuji Electric again. The same interaction would be repeated until the fault is resolved, and therefore, resolving problems generally took a lot of time.

The introduction of the ship IoT system allows Fuji Electric to understand the condition of the facilities and the issued alarms by checking the measurement log data and historical data stored in the cloud server without waiting for a call from the ship management company, enabling quick responses to failures. In addition, the ship IoT system automatically delivers an email containing the details of the alarm and what action to take when an alarm is issued, enabling the ship's crew to respond quickly without waiting for the manufacturer to contact them.

In recent years, however, ship management companies and crew members who use EGCSs have increasingly been calling for the ability to find how to respond to problems via the cloud server and the ability to use collected data to prevent problems.

3. New Services to Streamline Operations Management

To meet the needs described in Chapter 2, we have developed a diagnostic function to predict abnormalities utilizing Fuji Electric's analytics and AI technology[(2)].

For the ship IoT system, we built our diagnostic services to predict faults by adopting multivariate statistical process control (MSPC), which falls under the diagnostic technology category of analytics and AI technologies. Figure 3 is an overview of our MSPC. MSPC uses multivariate analysis to quantify out of the ordinary values from the correlation of multiple data. Ships operate around the world, and their equipment runs under various seasons, temperatures, weather, and other conditions. Therefore, even given the same equipment, the data characteristics differ from ship to ship. In addition, satellite communications are used to send and receive data, but data may be lost due to weather or sea conditions. To deal with usage environments that are specific to each ship, this service preprocesses data using data cleansing and characteristic acquisition technology to automatically generate a sound model. The condition of the facility can be understood from the deviation (Q value) between the sound model and the present value. Furthermore, the contribution of the Q value is shown for each diagnosis, which makes it possible to know which measurement values deviate significantly, allowing the cause of the deviation to also be identified. Conventional services

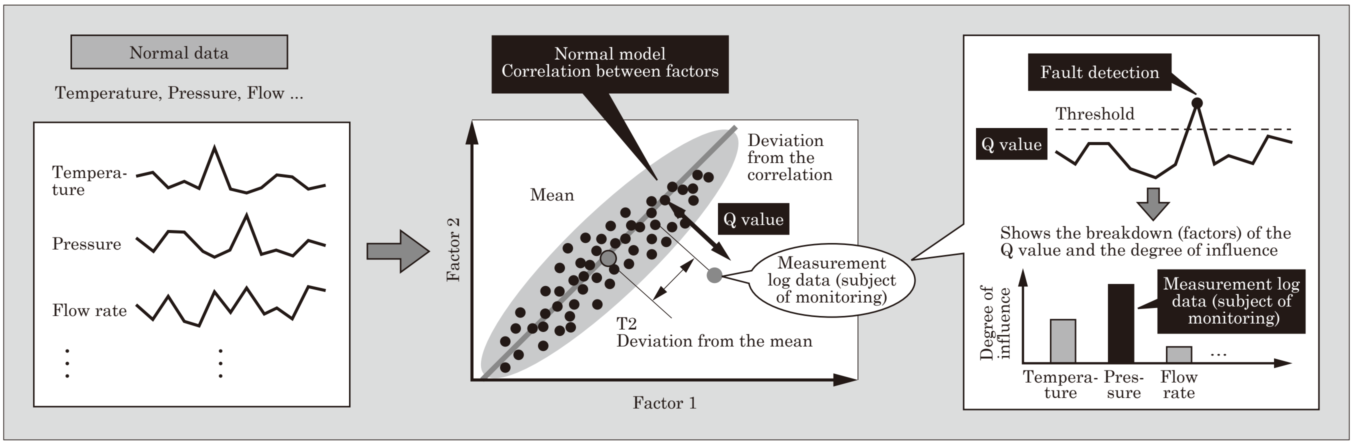
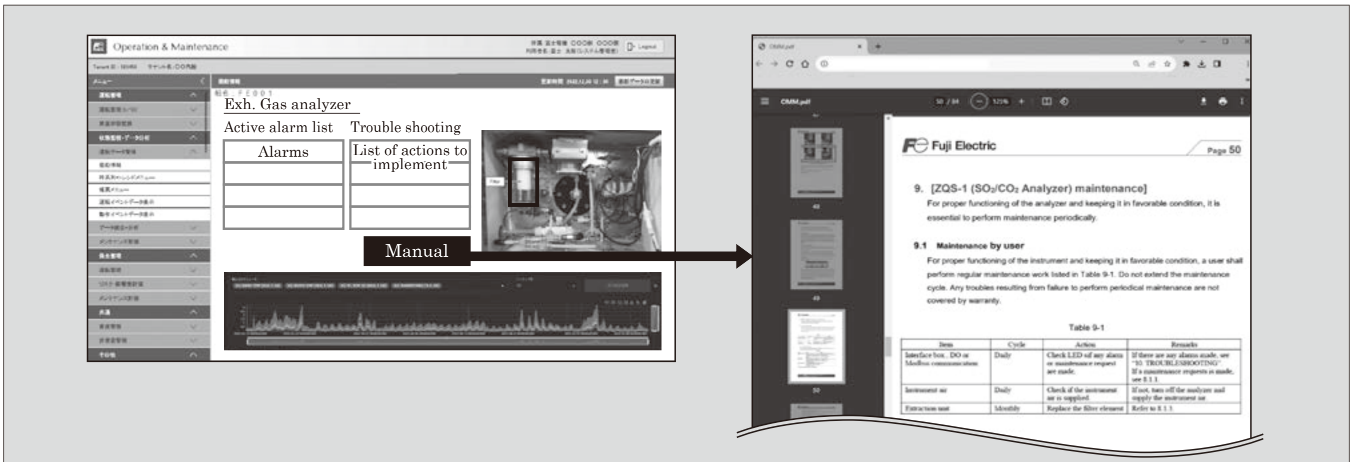


Fig.3 Overview of MSPC



(a) Screen for the predictive diagnosis of faults (b) Maintenance manual (excerpt)

Fig.4 Predictive diagnosis of faults screen (as of March 2023) often perform upper and lower limit monitoring for each measurement value, but MSPC can detect signs of faults that would be missed by the this method.

Figure 4 shows the screen for predictive diagnosis of faults for the Fuji Electric gas analyzer used in our EGCS. The alarm shown here does not indicate an equipment failure, but rather the detection of a tendency of the equipment to deviate from the normal state, and this tendency is determined based on the results of the predictive diagnosis of faults. The generated alarm and troubleshooting for the alarm are linked together, and the maintenance manual can be displayed by clicking the View Manual button. This allows the crew of the ship to take appropriate and prompt action. In the past, when equipment failed, troubleshooting was time-consuming because it was necessary to find the maintenance items in the instruction manual according to the problem. However, by utilizing this diagnostic function to predict faults, the equipment downtime and labor required to respond to problems can be reduced.

4. Postscript

This paper has described a ship IoT system that achieves the efficient operation management of exhaust gas purification systems. Going forward, we will expand the scope of predictive diagnosis of faults and propose the optimal maintenance and replacement timing for spare parts to reduce the burden of ship maintenance. We will also respond to needs for solutions for ship equipment other than EGCSs.

Although the adoption of fuels that comply with environmental regulations and the development of equipment compatible with these fuels have progressed remarkably, the safe and efficient use of new fuel oil is also essential, and the need for remote monitoring by combining sensors and IoT devices is increasing. In addition, development in the automatic operation of ships is progressing, and with the aim of keeping marine operations safe, the need for remote monitoring and other diagnostic methods for the prediction of faults is expected to increase further. In light of this social environment, Fuji Electric will continue to provide services that utilize its strengths in analytics and AI technology.

References

(1) Kawamura, S. EGCS IoT / Remote Monitoring System. FUJI ELECTRIC REVIEW. 2021, vol.67, no.4, p.276-278.

(2) Seya, A. Diagnostic Solution for Machinery and Equipment That Uses AI for Real-Time Detection of Defective Products. FUJI ELECTRIC REVIEW. 2021, vol.67, no.3, p.139-143.

Fuji Electric

Innovating Energy Technology