Sushi Sensor for Achieving Industrial IoT Solutions

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In plants, there is an increasing need for collecting more data to improve the efficiency of equipment maintenance and production. Since wireless sensors can be installed where wired ones would be cost-prohibitive, their demand is growing. In addition to ISA100 Wireless solutions, which are optimal for operations and safety, Yokogawa Electric Corporation has worked on applying wireless technologies to equipment maintenance. Backed by the rapidly increasing demand in recent years for introducing IoT to plant equipment, we conducted user interviews and proof-of-concept (PoC), identified specific requirements, and developed the Sushi Sensor. This paper introduces its concept and functions, and the technologies used to achieve the concept and functions.

INTRODUCTION

Plant equipment is usually maintained by operator rounds. Recently, there is an increasing need for advanced equipment maintenance such as condition-based maintenance (CBM) to cope with more complex processes and equipment, as well as aging plants. However, this cannot be achieved easily because field operators who inspect equipment in the field are aging, there is a lack of maintenance manpower due to the decreasing labor population, and the expertise and skills of veteran workers are not fully transferred to the next generation. To address this situation, Yokogawa proposes the "MIMAMORI" Plant Asset Health Monitoring solution to supplement conventional operator rounds. This solution monitors the health of plant equipment and detects signs of abnormality. To achieve this solution, Yokogawa developed the Sushi Sensor. With this compact wireless sensor that uses AI for data analysis, Yokogawa created new value and put the industrial IoT (IIoT) to practical use[(1)(2)]. This paper describes the product concept of the Sushi Sensor.

USER INTERVIEWS AND PROOF-OF-CONCEPT

Before starting development, Yokogawa conducted user interviews at more than 40 plants and proofs-of-concept (PoC) at four plants in Japan. As a result, we identified the following requirements for IIoT-enabled sensors:

(1) Easy deployment and operation
Easy deployment (installation and setup) and operation is essential for both temporary and permanent use. This is the top requirement because numerous sensors will need to be installed at various locations in plants.

(2) Environmental resistance
Sensors should be dustproof, waterproof, and explosionproof for use in harsh plant environments.

(3) Sensor portfolio
The sensor portfolio should be extensive to cover a broad range of physical quantities for equipment maintenance and environmental monitoring.

(4) Low power consumption and long life for battery-driven sensors
The battery life should be longer than the periodic maintenance interval, so that the batteries can be replaced during periodic maintenance.

(5) Long-distance communication
Wireless communication should cover a wide area to allow the sensors to be installed anywhere in a plant.

(6) Low cost
IoT sensors are not yet widely used in plants, and so the return on investment (ROI) cannot be determined precisely. As a result, a large budget cannot be allocated to equipment maintenance. Low initial cost and operating cost are mandatory for sensors and communication infrastructure.

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Although various IoT sensors are already on the market, virtually none satisfies the user requirements listed above, especially environmental resistance under harsh plant conditions, easy deployment, and long-distance communication capability.

TARGET EQUIPMENT

The user interviews revealed that for the "MIMAMORI" Plant Asset Health Monitoring solution, nearly half of plant monitoring sensors measure vibration and surface temperature. Therefore, Yokogawa's first Sushi Sensor was developed for vibration and surface temperature monitoring.

Figure 1 shows the major target equipment of the Sushi Sensor. These are pumps, motors, and other rotary machines, which are rarely or never checked during operator rounds or periodic inspections.

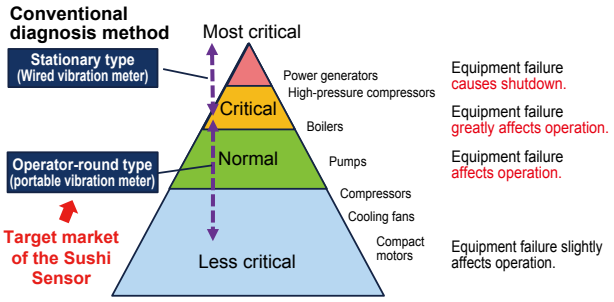

Figure 1 Major target equipment of the Sushi Sensor

Rotary machines of critical importance to plant operation, such as power generators and high-pressure compressors, are already continuously monitored by wired vibration sensors. The Sushi Sensor is not intended to monitor such equipment, but instead focuses on pumps, cooling fans, compact motors, and other rotary machines of relatively low importance, which are inspected during routine operator rounds or periodic inspections. The Sushi Sensor, which is an essential device for the "MIMAMORI" Plant Asset Health Monitoring solution, monitors trends in the vibration and surface temperature of such rotary machines. When trends show abnormal behavior or deviation from normal exceeds a threshold, the host system issues an alarm and urges the operator to take appropriate action.

Sensors for monitoring equipment, including the Sushi Sensor, do not require high real-time capability, which is essential for ISA100-compliant wireless field devices for instrumentation. A data collection cycle of a few minutes, a day, or even a week for some applications, is sufficient.

FEATURES OF SUSHI SENSOR

The Sushi Sensor was named after a traditional Japanese food-hand-shaped sushi combining rice with various ingredients. This food is easy to eat but in fact requires professional skill to prepare. These are also the features of the Sushi Sensor.

(a) Easy and simple
The Sushi Sensor is easy to install, set up, and use to monitor vibration and surface temperature.

(b) Professional
The Sushi Sensor has excellent environmental resistance: it is waterproof, dustproof, and explosionproof.

(c) Wide variety
The portfolio for equipment maintenance will be expanded.

These features are explained below.

Easy and Simple

The most important product concept is easy deployment.

(1) Easy installation
Figure 2 shows external views of the Sushi Sensor. Wireless functions, a battery, and sensors are integrated in a compact, lightweight body, enabling the Sushi Sensor to be easily mounted on equipment in the field. The Sushi Sensor can be mounted permanently with an M6 screw, or temporarily with an optional magnet. Temporary mounting is used for monitoring equipment that is showing signs of abnormality.

Figure 2 Sushi Sensor (Right: with magnet)

The Sushi Sensor uses the LoRaWAN [i] communication standard for wireless networks. LoRaWAN is a low-power, wide-area (LPWA) communication protocol, which has been attracting attention recently as a communication method for IoT sensor devices. The reasons for selecting LoRaWAN are: (1) LoRaWAN uses a sub-GHz frequency band for which a license is not required, so it is easy to construct both private and public communication infrastructure, (2) various services can be developed thanks to LoRaWAN's bidirectional communication, and (3) a broader range of infrastructure services and related devices are available for LoRaWAN than other standards.

The wide area coverage of LoRaWAN enables a gateway to receive data from sensors 1 km away even in the "pipe jungle" of plants as long as the sensors and the gateway are located outdoors and not surrounded by metal or concrete structures. This method eliminates the need for installing repeaters and substantially simplifies the design of wireless communication paths and gateway layout. Figure 3 shows an example of a Sushi Sensor layout in a plant.

i LoRaWAN is one of the LPWA networking protocols and is an open communication standard promoted by the LoRa Alliance of more than 500 IoT companies and users worldwide.

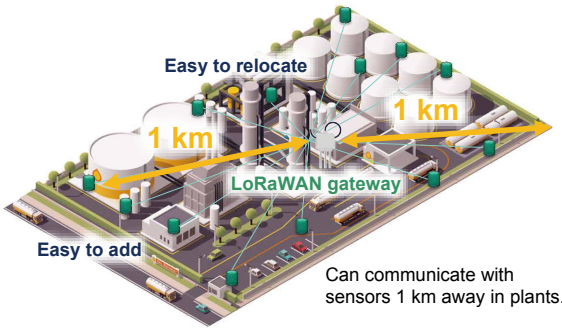

Figure 3 Example of plant layout using the Sushi Sensor

(2) Easy setting

The Sushi Sensor is set via the near field communication (NFC) function of smartphones. Sensor conditions (communication, battery level, and others) can also be checked.

(3) Easy data collection and monitoring

The use of GRANDSIGHT LoopOnEX Sushi Sensor Interface, which is explained below, enables plug-and-play operations; users can add a Sushi Sensor, set it up using a smartphone, and connect it to a gateway, and then the Sushi Sensor automatically starts to collect data and the host system monitors equipment data[3].

(4) Simple functions

There are two categories of wireless vibration sensor in the equipment maintenance market: those for measuring the magnitude of vibration for simple diagnosis, and those for analyzing the spectrum of vibration waveforms by FFT for detailed diagnosis. The Sushi Sensor targets the former. The simple functions also facilitate deployment and reduce costs.

Professional

The Sushi Sensor is an IIoT sensor with excellent environmental resistance and durability and thus can be used in harsh plant environments. It is dustproof and waterproof (IP 66/67), and explosionproof [ii]. These are basic requirements for sensors used in plants.

The sensor measures along three axes, for monitoring vibration in any direction. Users can easily replace the battery, and the battery life is long enough: 4 years when the data update cycle is 1 hour.

Wide Variation

A broad range of sensors are required for the "MIMAMORI" Plant Asset Health Monitoring solution. The first Sushi Sensor is for measuring vibration and surface temperature. Yokogawa plans to offer many other kinds of Sushi Sensor; just like the rice base of sushi, the wireless capability and battery technology are common to all types of Sushi Sensor while various sensor functions will be added to this core part like the toppings of sushi.

ii Application for intrinsic safety is pending in Japan.

SUSHI SENSOR SYSTEM

Sushi Sensor data are collected, stored, and monitored by a host system: a cloud server or an on-premise server. In either server, the LoopOnEX Sushi Sensor Interface of GRANDSIGHT, which is provided by Yokogawa Solution Service Corporation, must be installed. This application not only collects Sushi Sensor data but also provides an interface that transmits and visualizes the collected data to other systems for equipment maintenance or to machine learning and other applications. Figure 4 shows a configuration example of a Sushi Sensor system.

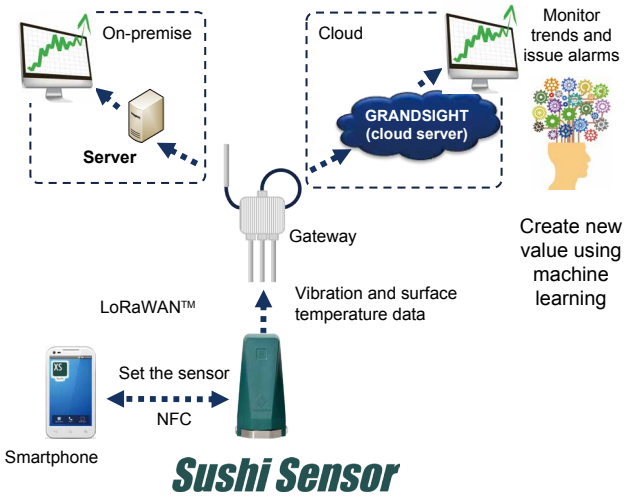

Figure 4 Configuration example of a Sushi Sensor system

The wireless network between the Sushi Sensor and the gateway uses LoRaWAN. A dedicated gateway is installed at each customer plant to connect the Sushi Sensor to the cloud or an on-premise server. In the future, public LoRaWAN networks provided by communication carriers may be used.

BENEFITS OF SUSHI SENSOR

The Sushi Sensor is expected to deliver the following four benefits.

(1) Preventing unexpected equipment failures and plant shutdowns

Signs of abnormality, which are not easily detected in operator rounds, can be detected early by monitoring the trend of equipment vibration and surface temperature. As explained in the introduction chapter, this achieves condition-based maintenance (CBM). This compact, lightweight sensor is easy to install and works stably even in harsh outdoor environments. These features enable customers to monitor equipment and machinery that have not been monitored in operator rounds because of difficulty of access.

(2) Improving the safety of field operators

Equipment at heights or hazardous locations can be monitored with the Sushi Sensor, helping to safeguard field operators by not having to visit such places frequently.

(3) Uniform judging criteria

Conventionally, equipment inspection relies heavily on the experience and intuition of individual field operators. By quantifying and visualizing their skills and experience, past inspection results can be effectively used as know-how. The variation in inspection quality caused by such difference in skills and experience can also be reduced.

(4) Advanced decision-making to supplement the dwindling number of experts

The cloud makes it possible to use machine learning and AI. Maintenance plans are efficiently carried out by combining equipment condition data with AI and machine learning. The accumulation of knowledge helps pass on expertise and experience to the next generation.

FUTURE DEVELOPMENTS

As described in the introduction, customers are finding it difficult to ensure the sound operation of their plants. To solve this problem, Yokogawa proposes the "MIMAMORI" Plant Asset Health Monitoring solution which uses the IIoT and AI. The Sushi Sensor and GRANDSIGHT serve as infrastructure for the IIoT.

Human operators will remain involved in monitoring data and making decisions based on the data. However, it is difficult for them to process vast amounts of data from numerous sensors installed at various locations in a plant. Therefore, the use of AI and machine learning will become imperative.

Yokogawa offers ISA100 Wireless-compliant field instruments for plant operation and safety, and is expanding the portfolio of the Sushi Sensor for monitoring equipment conditions. Both technologies will help digitize and quantify data that are necessary for plant operation and equipment maintenance, as well as for highly efficient plant management. Yokogawa will assist highly efficient plant management by providing consistent support covering plant operation and maintenance, and integrating the operation data from DCS and the equipment data collected by Sushi Sensors. Figure 5 shows Yokogawa's IIoT reference model, which features complementary collaboration of the two sets of data. Machine learning will create new value by maximizing the profit of the whole plant.

Multiple plants can share data via the cloud and efficiently operate similar facilities and equipment. This improves the efficiency of the whole business and enterprise.

Although this paper discussed application to plants, the Sushi Sensor is expected to improve the efficiency of maintaining social infrastructure such as electric power and utilities.

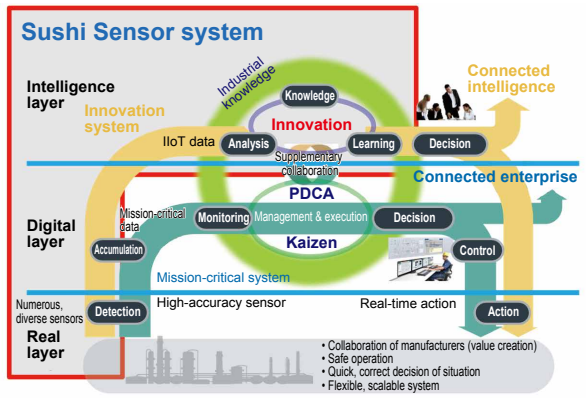

Figure 5 Yokogawa's IIoT reference model

CONCLUSION

Yokogawa has developed the Sushi Sensor, a field sensor for the IIoT and the "MIMAMORI" Plant Asset Health Monitoring solution. A system consisting of the Sushi Sensor and the cloud offers a new vision for plant equipment maintenance. Yokogawa will continue to offer value by innovating plant operation, improving operation efficiency, and revolutionizing maintenance.

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