Sushi Sensor for Industrial IoT Solution Achieves “Sensemaking”

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In terms of Yokogawa’s digital transformation (“DX”), digitization that shows how to collect and integrate data, and digitalization that shows how to use data effectively, can help customers accelerate continuous value creation and transform their business operations.

This paper explains the importance of “sensing” (collecting data) and “sensemaking” (adding value to data) at each step of DX and introduces “Sushi Sensor” as a solution for solving customers’ equipment maintenance issues. The paper also outlines benefits to customers through specific examples of using Sushi Sensor. “Sensing” and “sensemaking” using Sushi Sensor can improve not only the efficiency of equipment maintenance but also product quality by integrating equipment data with operating data, thus achieving DX and ultimately transforming the entire plant, within and between plants and the entire company.

INTRODUCTION

Plant managers are responsible for improving production efficiency in a rapidly changing business environment while maintaining aging equipment. Maintaining the high availability and reliability of plant equipment while improving the operational performance is a key to continuing business.

Moreover, as innovative digital technologies such as artificial intelligence (AI), Industrial Internet of Things (IIoT), and big data have emerged in recent years, an increasing number of customers want to introduce these new digital technologies to improve productivity.

Production process data obtained by using operation technology (OT) have been used for improving the productivity of plants. Equipment data obtained from information technology (IT) are increasingly used for improving the efficiency of equipment maintenance. By uniting these data, innovative digital technologies have the potential to create new plant value.

Synaptic Business Automation is Yokogawa’s industrial automation (IA) business concept [(1)]. Based on this, we are working hard to improve customers’ productivity by achieving DX, which makes the most of digital technology and helps customers digitize their business.

Meanwhile, Yokogawa has accumulated business and domain knowledge through various OT projects in plants and acquired practical know-how. This enables us to satisfy customer requests by offering wireless solutions combined with IIoT sensors. Yokogawa’s Sushi Sensor is one such sensor that provides wireless solutions which are clearly differentiated in the plant field.

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Yokogawa released the first Sushi Sensor, a wireless vibration sensor, in March 2018. In July 2019, Yokogawa released wireless temperature and pressure sensors, expanding the sensor portfolio (Note 1: The wireless vibration sensor has been released in Japan and some other countries. Although the wireless pressure and temperature sensors are currently available only in Japan, these are due to be released overseas). This paper introduces Sushi Sensor, which is a solution for the IIoT that revolutionizes the two main DX steps of “sensing” and “sensemaking” and shows an approach to Yokogawa’s ideal DX.

YOKOGAWA’S IDEAL DX

Yokogawa’s ideal DX is achieved with three steps: digitization (digitization of information), digitalization (digitization of processes), and digital transformation of the whole corporate activity and culture.

Digitization

Digitization means digitizing information. Information visually recognized or recorded on paper is coded with 0 and 1 and electronically recorded as digital information so that computers can process it easily. Digitization facilitates data processing.

Digitization is the first step of DX in plant operation and equipment maintenance, and it is achieved by automating the data acquisition process that had been performed manually. Conventionally, data in a plant are collected from sensors via wired or wireless sensor networks. This is called “sensing.” Sensing is widely used for measuring the parameters of production processes and the important data of equipment. However, not all of the data required by customers are obtained; equipment for which real-time monitoring is not required and those at distant locations are not connected to sensor networks. These are usually monitored by an operator’s round checks.

The number of targets to be monitored is increasing as equipment is aging. Meanwhile, the number of workers available for operator rounds is decreasing due to the retirement of skilled workers and other reasons. Moreover, it costs much to collect measurement data from equipment that is difficult to access during operator rounds, for example, those located at height or in hazardous areas. However, collecting data in the field is increasingly important to improve production efficiency and product quality. To achieve digitization, it is necessary to deploy a huge number of sensors in a plant and operate them in a cost-effective manner.

Digitalization

Digitalization means digitizing the process of identifying any significant matter in digitized data and creating value. Collecting data is not customers’ goal; they want to obtain value or benefit from the data. For example, they want to detect any signs of abnormality of equipment early by monitoring the trend of data; they also want to predict failure or diagnose a malfunction by using AI and machine learning to analyze data. They expect new value to be created from data. Conventionally, the task of value creation was left to skilled workers who applied their intuition and experience to deliver accurate judgments. However, more and more skilled workers are retiring even as the number of points to be monitored is increasing. Some countermeasures are needed to overcome this situation. Moreover, there are still large amounts of equipment data that have not yet been digitized. These may bring value radically different from the existing value. Yokogawa calls this step of digitalization “sensemaking” [(2)].

Sensemaking facilitates the creation of significant value from data and has an important role in achieving DX. Currently, it is not easy for customers to understand and analyze the meaning of data and determine how to implement them in daily operation. In other words, many vendors provide customers with tools for digitization, but they have not successfully offered tools for digitalization to make full use of plant data. Vendors should offer a solution that facilitates the shift from sensing to sensemaking. Such a solution has a crucial role in achieving maintenance with digitized equipment data.

Figure 1 shows the shift in sensors’ role from sensing to sensemaking [(2)].

Key factors for the success of sensemaking are intelligent

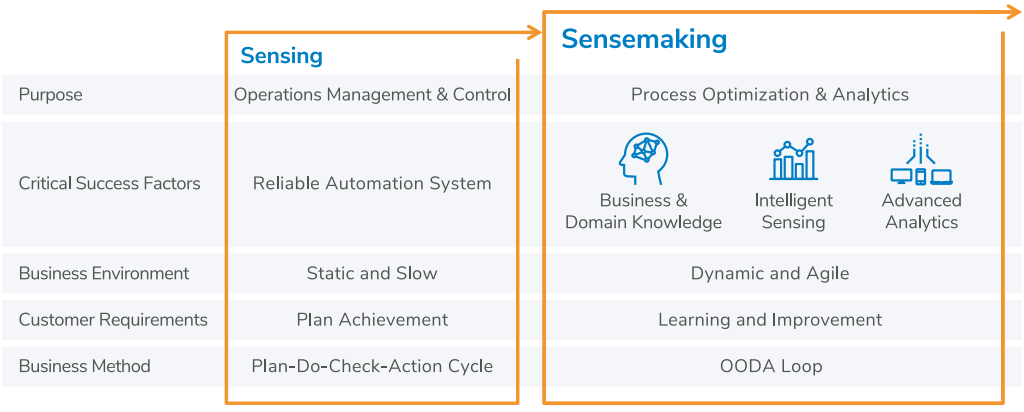

Figure 1 Role of sensor: The shift from sensing to sensemaking

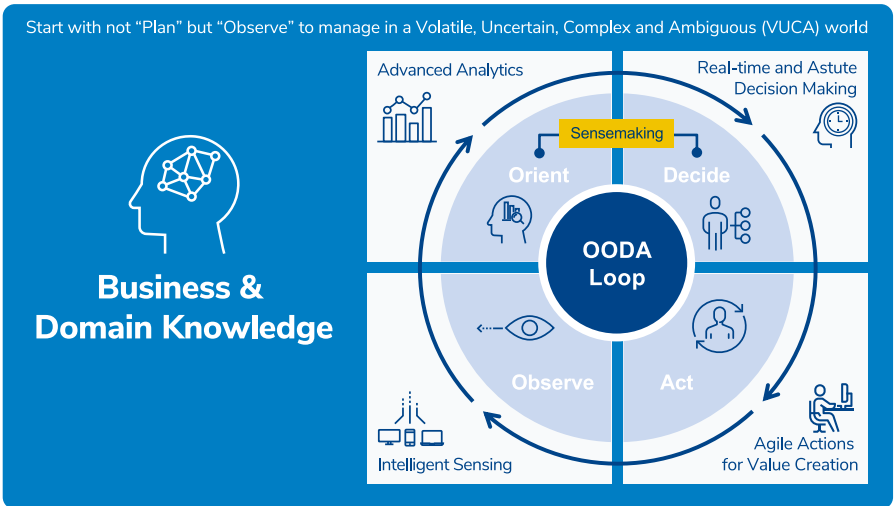

Figure 2 OODA loop that achieves sensemaking

sensing and advanced data analysis based on business and domain knowledge. Intelligent sensing means flexible, scalable sensing with excellent connectivity and environmental resistance such as explosionproof. Sensemaking is not achieved by the PDCA cycle, which is a conventional continual improvement method over a long period, but by the OODA loop, which is a continuous thinking method of repeating quick observation, judgment, decision-making and execution over a short period. Figure 2 shows the OODA loop that achieves sensemaking [(2)]. This loop effectively carries out the cycle of Observe (observation), Orient (judgement of conditions), Decide (decision-making), and Act (execution). In this loop, sensing assumes the role of observation through intelligent sensing while sensemaking is responsible for judgement of conditions through advanced data analysis and quick decisions in real time. Then, human workers take action for creating value and the loop then returns to observation. This loop works effectively in an environment that has much variability, uncertainty, complexity, and ambiguity.

Digital Transformation

The final step of DX aims to improve the operational performance of plants and promote the continuation of business. It transforms the whole corporate activity and culture digitally. In other words, it totally changes how a company, business, and people behave. Although value can be extracted by sensing and sensemaking, it is usually discussed in independent OT and IT fields. These include the operation of production processes by OT and equipment maintenance and energy management by IT. In this final step of DX, epoch-making value can be created by unifying the functions and data of OT and IT. For example, for optimizing the parameters of a production process, data on both the equipment state and performance information are digitized and fed back to the production process. This can increase the efficiency of production and the quality of products. Yokogawa has accumulated the domain knowledge of business and a production process in plant operation as well as OT and IT sensing technologies. By using AI/machine learning for advanced analysis, we can help customers proceed with digital transformation.

Through these three steps of DX, we can help customers improve profitability and sustainable growth.

CUSTOMERS’ CHALLENGES AND THEIR SOLUTIONS

A major concern of plant managers is unexpected shutdown due to any failure of plant equipment, which can easily cause losses worth hundreds of millions of yen in a single year. Moreover, the aging and shortage of the workforce greatly affect production and equipment maintenance work. Capital that can be spent on maintenance is limited, for example, to 1 to 2% of profits [(1)]. Plant managers have a responsibility to improve productivity and safety, offer education and training to workers, and secure workers while reducing operation cost.

The following sections describe customers’ challenges and Yokogawa’s solutions regarding plant equipment maintenance, along with the following three steps of DX.

Challenges for Digitization and Their Solutions

For digitization, sensing must overcome the following challenges.

- Can measure a broad range of physical quantities of equipment with high quality and reliability.
- Can digitize sensing data and place them online to drive the overall health and performance of equipment.
- Can be deployed and operated easily.
- Have enough environmental resistance to keep operating in a severe environment for a long time.

Yokogawa offers the following solutions to these challenges.

- Measurement of various physical quantities (vibration, temperature, pressure)

- Compact, lightweight with integral wireless and measurement functions
- Low power consumption and long-distance wireless communication
- Dustproof, waterproof, and explosionproof

Challenges for Digitalization and Their Solutions

For digitalization, sensemaking must overcome the following challenges.

- Can perform advanced data analysis.
- Can monitor the trend to effectively use measured data for equipment maintenance.
- Can detect signs of abnormality before equipment failure and can perform failure diagnosis.
- Have a system for equipment maintenance with excellent cost-effectiveness.

Yokogawa offers the following solutions to these challenges.

- Data-analysis type diagnosis and decision-making by using AI/machine learning
- Cloud environment that can store various data for analysis

Challenges for Digital Transformation and Its Solution

The customer challenge in the final step of DX is to secure a cloud environment that can save and unite production process data and equipment data. This environment is also required to have functions that can combine both types of data in a mutually complementary manner, analyze them, determine the action to take, and feed the results of the analysis back to the production site.

Business and domain knowledge has an important role to play in the solution. Yokogawa has accumulated technical knowledge in the production process industry over many years. In addition, through partnerships with customers, Yokogawa helps customers transform their business process and digitalize their management. With this solution, Yokogawa can offer promising and continuous business results.

ENABLING TECHNOLOGY [3]

Among the solutions offered by Yokogawa, this section focuses on Sushi Sensor, a wireless solution for the IIoT. Sushi Sensor follows the trend from digitization to digitalization and achieves the shift from sensing to sensemaking.

Sushi Sensor

Yokogawa can help customers digitize the sensing data in plants and place them online by introducing Sushi Sensor. Its features are as follows.

(1) Easy installation

Sushi Sensor uses the LoRaWAN communication standard. LoRaWAN is one of the low power wide area (LPWA) network protocols, which are now attracting attention as a wireless communication system for the IoT (for sensor devices). LoRaWAN is an open communication standard promoted by the LoRa Alliance of more than 500 IoT companies and users worldwide. Even in a plant packed with various equipment, this protocol ensures long-distance communication 1 km away from sensors to a gateway even in the “pipe jungle” of plants as long as the sensors and the gateway are located outdoors and are not surrounded by metal or concrete structures. LoRaWAN-compliance devices can be installed and operated easily without having to design wireless routes and install repeaters. Figure 3 shows a plant layout example with Sushi Sensor.

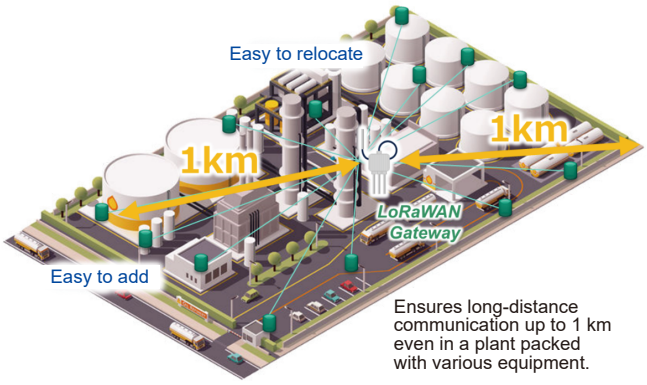

Figure 3 Example of plant layout with Sushi Sensor (easy installation)

Moreover, Sushi Sensor is battery-powered. The battery can be easily replaced and there is no need for wiring work. When the data update cycle is set to 1 hour, the wireless vibration sensor can operate for four years, and the wireless pressure sensor and the wireless temperature sensor for 10 years (depending on temperature conditions). The wireless vibration sensor can be easily fixed with screws or a magnet (optional).

(2) Environmental resistance

Sushi Sensor satisfies the basic challenges for a harsh plant environment: dustproof and waterproof (IP66/67), and explosionproof.

(3) Wide variety

Following the XS770A wireless vibration sensor, Yokogawa released the XS530 pressure measurement module, the XS550 temperature measurement module, and the XS110A wireless communication module with a built-in battery. The pressure and temperature sensors consist of a measuring module and the XS110A wireless communication module. The XS110A can be assembled to any measuring module. By replacing a measuring module, Sushi Sensor can measure various physical quantities. Taking advantage of this feature, Yokogawa is trying to grow the lineup of measuring modules and is expanding the portfolio of the Sushi Sensor.

(a) XS770A wireless vibration sensor

The XS770A wireless vibration sensor is fixed to the target equipment with M6 screws or a magnet (optional). In the case of magnet mounting, the measurement location can be easily changed. This feature is useful for temporary measurement.

(b) XS530 pressure measurement module
The XS530 pressure measurement module is screwed directly into piping. The XS530, connected with the XS110A, can substitute a pressure gauge that is widely used in many plants and can place data online.
(c) XS550 temperature measurement module
Although the XS770A wireless vibration sensor can measure the surface temperature of the target equipment, sometimes it is necessary to measure a wider temperature range and the temperature inside piping. To satisfy these needs, Yokogawa developed the XS550 temperature measurement module. This module, connected with the XS110A, operates as a temperature sensor when it is combined with a thermocouple. The range and accuracy of measurement depend on the type of thermocouple.

Previously, maintenance staff performed measurements with a portable device in operator rounds and wrote down the results on paper. Replacing these operator rounds or being added for these tasks, Sushi Sensor can digitize these data even at locations which are difficult for human workers to access due to danger or distance. Since Sushi Sensor does not depend on workers’ ability and availability, it ensures uniform quality of measurements and increases the frequency of inspections. As a result, it helps improve the efficiency of equipment maintenance, pass down skills that experts have accumulated over years, and alleviate the labor shortage.

APPLICATION CASE

This section shows how to use Sushi Sensor for achieving the shift “from sensing to sensemaking” in the OODA (observe, orient, decide, and act) loop.

Wireless Vibration Sensor

Case 1: Reducing the cost of operator rounds

A customer had outsourced the task of measuring the vibration at 200 rotary machines in a chemical plant, and the contract staff performed operator rounds and recorded the results manually. Since these non-digitized data only showed the equipment condition at the time of inspections, their usage was limited and the trend of the vibration condition could not be monitored. Therefore, equipment maintenance was performed as time-based maintenance (TBM), and as a result of this strategy, the plant was shut down, parts were replaced, and equipment was repaired at periodic maintenance intervals. The introduction of Sushi Sensor made it possible to monitor equipment conditions in real time and online. An alert issued in real time enables operators to take actions quickly for any abnormality. As a result, the maintenance strategy was changed to condition-based maintenance (CBM). TBM is a kind of PDCA cycle (long-term continual improvement method) while CBM is an OODA loop (continuous thinking method of short-term observation, judgment, decision-making and execution). Figure 4 shows how operator rounds were replaced with online monitoring with Sushi Sensor.

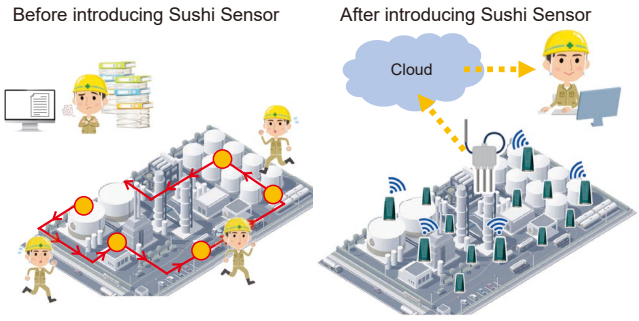

Figure 4 Operator rounds replaced with online monitoring with Sushi Sensor

Case 2: Detecting an abnormality of a ball bearing with the help of AI/machine learning

Five months after Sushi Sensor started to monitor rotary machines in a plant, it detected an unusual rise in acceleration peak values. This suggested that bearing wear had reached the final phase. When AI/machine learning was applied to the measurement data, it revealed that signs of abnormality had been detected three months before the failure as shown in Figure 5. This means that the combination of Sushi Sensor and AI/machine learning is useful for detecting signs of abnormality of ball bearings early, which is a cause of failure of rotary machines. This is a good example of sensemaking in which new value is created from digitized sensing data with the help of advanced analysis by AI/machine learning.

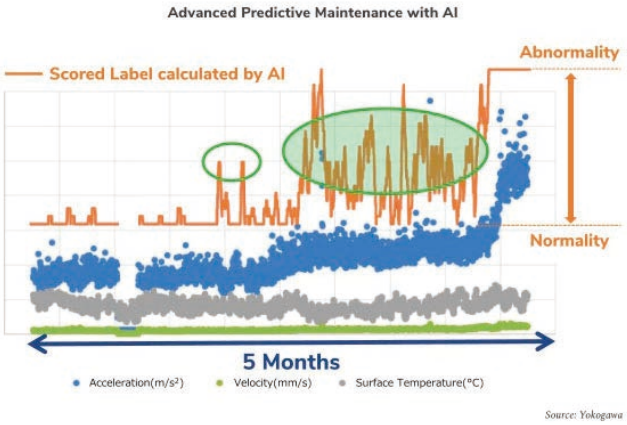

Figure 5 Advanced predictive maintenance with Sushi Sensor and AI

Wireless Pressure Sensor

Case 1: Detecting leaks and clogging of dust collectors and their piping

When leaks or clogging occur, dust collectors and their piping will break down, decreasing the operational efficiency of a plant. Pressure gauges are conventionally mounted to detect such abnormalities, and visual observation is performed during operator rounds. However, when measurement points are distributed across a wide area, it is difficult to perform

multipoint measurement due to the limited availability of workers and time. By replacing existing pressure gauges with Sushi Sensor or adding Sushi Sensor to these gauges, it is possible to increase the frequency and location of measurement. This also satisfies the demand of customers who want to acquire all equipment data required for maintenance and avoids the failure of equipment and the decline in operational efficiency.

Case 2: Pump output

Figure 6 shows an example of online pressure measurement. After driving pumps are switched, for example, from Pump A to Pump B, operators visually check pressure gauges mounted on the pump to make sure that operation continues as before. By replacing these pressure gauges with Sushi Sensor or adding Sushi Sensor to these gauges and placing the monitoring task online, it is possible to grasp the operational status of each pump in real time and improve maintenance efficiency. Since the correlation with the operational status of other pumps can be grasped in real time, operational efficiency will also improve.

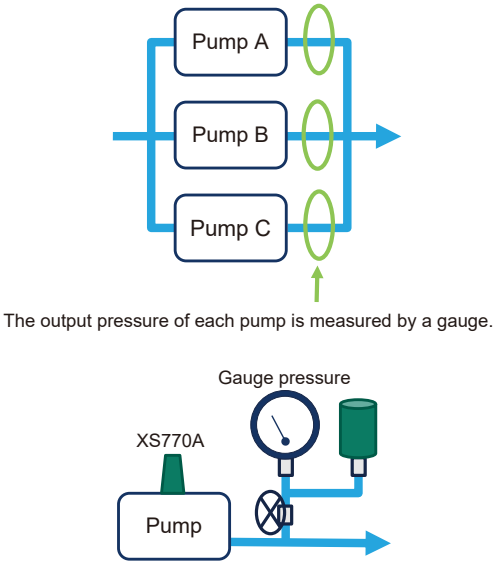

Figure 6 Example of online pressure measurement

Wireless Temperature Sensor

Case 1: Detecting leaks of safety valves

A safety valve is installed to vent the increased pressure of devices and piping. Under a certain condition, seat leakage occurs at this valve. In this case, operation must be stopped immediately to repair equipment, which greatly affects the production. It is also necessary to halt equipment to check for seat leakage visually because the trend cannot be monitored during operation. To solve this problem, we focused on the fact that the temperature of the output of the safety valve falls rapidly when seat leakage occurs. Sushi Sensor can measure the temperature difference between the input and output of a safety valve and detect the abnormal signs of seat leakage in real time. It is thus possible to avoid unexpected shutdown and ensure stable operation.

Case 2: Adding measurement points to multi-stage heat exchangers

In multi-stage heat exchangers, input and output temperatures are usually monitored online. However, this is usually done for the whole system, not each stage. Sushi Sensor can measure the input and output temperatures, monitor the trend, and grasp the state of each stage of multi-stage heat exchangers, making it possible to detect an abnormality of any single heat exchanger and improve maintenance efficiency. Figure 7 shows an example of monitoring a multi-stage heat exchanger.

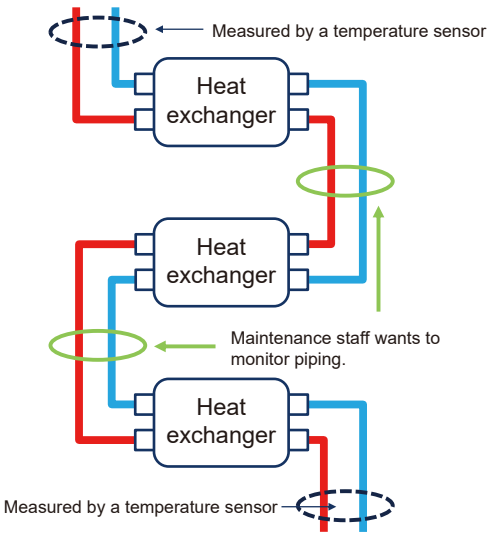

Figure 7 Example of monitoring a multi-stage heat exchanger

OT/IT Complementary Collaboration: Stabilizing Operation

Finally, a case of digital transformation is shown, in which production process data obtained by OT and equipment data obtained by IT were combined to complement each other and product quality was improved.

In production equipment, the XS770A wireless vibration sensor, which had been introduced to monitor the state of the rotary machine, revealed a correlation between the operation of this rotary machine and the quality of the product. Sushi Sensor for monitoring the state and maintaining a suitable operational condition also served to stabilize the quality of the product. This is a good example of digital transformation in which we were able to work together with the customer to transform their business process by using Yokogawa’s sensing technology and domain knowledge on the production process.

BENEFITS FOR CUSTOMERS

Compared with conventional operator rounds, the introduction of Sushi Sensor makes it possible to increase the number of measurement opportunities (locations and frequency) of data that show equipment conditions. When customers appropriately use the acquired data and perform suitable equipment management, they can avoid unexpected

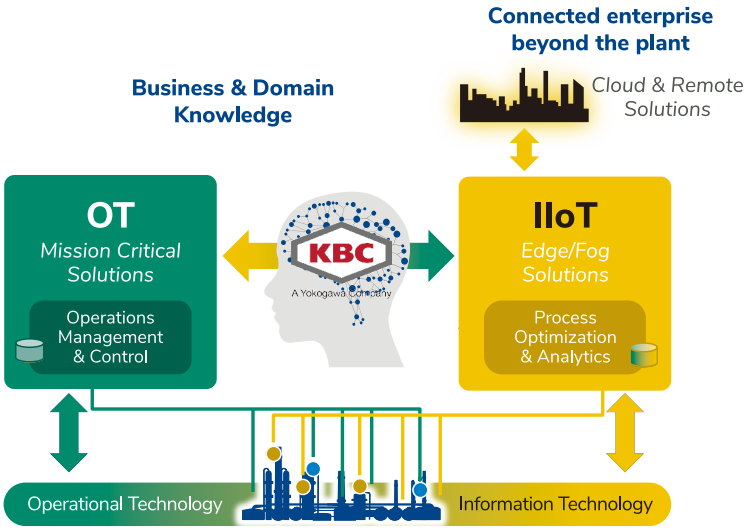

Figure 8 Yokogawa’s solution based on the integration of OT and IT

plant shutdown, improve the maintenance efficiency of equipment, and minimize plant downtime. As a result, the productivity of equipment is maximized, and products can be produced with stable quality as designed. Sushi Sensor can greatly contribute to not only equipment maintenance but also maintaining and improving operational efficiency, securing safe operation and stability, and maintaining and improving quality.

FUTURE DEVELOPMENT AND NEW VALUE CREATION

Achieving DX

In the cloud offered by Yokogawa, it is possible to analyze production process data and equipment data in an integrated manner, and these integrated data can be used for optimizing production. We will analyze the whole business of customers from identifying their potential problems to designing and implementing the optimum solution, executing safe and stable operation, and maintaining and improving production efficiency. Yokogawa has accumulated strength in the OT domain. By combining it with the latest IT, we will optimize the production process, automate and optimize the whole value chain including the supply chain, reduce risk, and improve efficiency.

The data saved and integrated in the cloud can be used not only for the target plant but also for any plants of the same kind all over the world. In the cloud, it is possible to combine real-time production process data that are collected via sensor networks and equipment data that are collected more frequently than in operator rounds, and it is also possible to analyze the integrated data precisely. Figure 8 shows Yokogawa’s solution based on the integration of OT and IT. Based on business and domain knowledge, production process data obtained from OT are combined in the cloud with equipment data that are obtained from IT (IIoT data). The data will bring about transformation beyond plants, i.e. transformation of corporate management, business, and people. This system will ensure high profitability and sustainable growth for customers.

Use of AI/machine Learning

With Yokogawa’s cloud environment, customers can integrate the data across the plant and seamlessly access the results of advanced analyses obtained by making full use of AI and machine-learning technologies. With the help of AI/machine learning, equipment abnormalities can be predicted and the details of failure can be diagnosed. The diagnostic results facilitate judgment, decision-making, and action for equipment maintenance. Moreover, integration with production process data will provide customers with guidelines on decision-making and actions that lead not only to maintenance activity but also product quality.

CONCLUSION

This paper discussed the three steps to achieve DX: digitization, digitalization, and digital transformation. We focused on the shift from sensing to sensemaking and explained how to achieve sensemaking through intelligent sensing based on business and domain knowledge, advanced data analysis, and a business method of the OODA loop (observing and judging conditions, making decisions, and taking action). Furthermore, we showed through several examples that Sushi Sensor can facilitate digitization and digitalization of plant equipment while minimizing maintenance cost and can secure the reliability and availability of equipment. The paper concluded that in the final digital transformation step we can help customers to create new value by taking advantage of our knowledge and experience about domains, and by using production process data that have not been fully used for equipment maintenance.

If AI, machine learning, and other advanced technologies can be fully used, it will be possible to create new value and maximize

the profits of the whole plant. In addition, sharing data via the cloud will make it possible to operate multiple similar plants efficiently, improve operational efficiency, and promote reforms in the whole plant, among multiple plants, and in the entire company.

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