Challenge to Smarter Data Intelligence by Co-innovation with Users

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Conventionally, the manufacturing industry of Japan has been continuously striving for efficiency and quality improvements through Kaizen activities, achieving successful results. To overcome the recent labor shortage, rising cost of raw materials, and severe competition in the global marketplace, there is a greater need for improvement and new value creation by leveraging the intelligence of operating data. With the spread of the Internet of Things (IoT) enabling huge amounts of diversified data to be acquired on-site, and advanced, commoditized analysis technology that enables new value to be easily derived from data, it is crucial for the data scientists of vendors to collaborate with users to create new value by co-innovating to maximize the effects of this approach.

This paper describes two cases of co-innovation between Yokogawa and users as a reference for future co-innovating activities. Moreover, with a view to the era of widespread IoT, this paper introduces a co-innovating platform, Industry IoT Data Logging & Dashboard, which integrates IT data with operational technology (OT) data.

INTRODUCTION

In the process industry, the spread of DCS is making it easier to monitor, extract, and analyze data. Data of this type are called operational technology (OT) data, and some users are actively using such data to solve their problems. In addition, the Internet of Things (IoT) has made it possible to acquire another type of data (IT data). However, some users cannot imagine what value will be created by combining OT and IT data, and are simply overwhelmed by large amounts of information and how to use valuable data.

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When we encourage customers to introduce Yokogawa's Sushi Sensor and other IT sensors, sometimes we cannot persuade them. Some hesitate, saying that although they understand data can be obtained easily, they don't understand how it could benefit their equipment and business. Others, who have been analyzing OT data and working on improvements, are also confused, considering that they already have large quantities of OT data and cannot handle any more. They do not see the new information era as an opportunity, but as a nuisance.

In the IoT age, new values will be mined from data. The experience and know-how with which users have solved various problems will be used to perform analyses and make processes more intelligent. But as some users realize, the quantity of data available is growing too fast to be handled by them alone. So, it is important to find appropriate partners to co-create value.

This paper introduces two cases of Yokogawa's co-

creation with users to make their plants more intelligent.

- In the wastewater treatment process of an oil refinery, we analyzed data to identify the cause of a fall in the throughput.
- Focusing on the data stored in the production site, we took measures to improve operation by using time series correlation analysis, frequency analysis, and the FRIT theory for calculating control parameters [(1)].

We then outline the functions of the Industrial IoT Data Logging & Dashboard. Yokogawa is developing this platform for the related co-creation environment so that when various data become available in the future, the IT and OT data can be united to create new value.

VALUE CO-CREATION PROJECTS WITH CUSTOMERS

This chapter introduces co-creation projects with users.

In the first project, we analyzed process data in wastewater treatment facilities in an oil refinery and solved the problem of a fall in the throughput.

Yokogawa has been offering a process data analysis solution to help identify the causes of customer problems regarding quality and operation. In more than 150 cases we have analyzed over the past ten years, we formed an analysis team with customers, combined the data-driven approach with analysis leveraging our knowledge of processes and operations, and co-created a solution to the customers' problems. Customers highly evaluate this approach, not only for solving problems but also for improving the skills of engineers.

In the second case, we used Yokogawa's controllability improvement consulting service to alleviate the heavy workload on operators and reduce energy losses in the continuous process of a chemical plant. As a process automation supplier, Yokogawa has been involved in the startup and commissioning of systems for various processes for more than 40 years and has acquired extensive technologies and know-how. Based on this experience, we provide customers with a controllability improvement consulting service and help them solve difficult problems.

Co-creation Project in Wastewater Treatment Facilities in an Oil Refinery

Customer's commitment

The customer had tried to solve various problems by using process data. Through some projects, however, the customer recognized the value of Yokogawa's analysis technology and we have since been working together on problems. Among several co-creation cases, this paper introduces a project for the wastewater treatment process.

The problem of the wastewater treatment process of the oil refinery

Wastewater containing oil is discharged from production equipment in an oil refinery, and the wastewater treatment process purifies it physically, chemically, and biologically. If wastewater is not treated as planned, the volume in the production process must be reduced accordingly. As such, this process is crucial for the whole oil refinery. However, the high priority on improving this process is not because it is indispensable for maintaining production, but because the wastewater causes serious environmental impact.

There were two problems concerning the wastewater treatment process in this oil refinery.

- Fall in the throughput of wastewater treatment
- Increase in workforce required for operation, adjustment, and manipulation

Yokogawa's action

This section explains four steps to solving the problem of the wastewater treatment process.

(a) Text mining

The wastewater treatment process involves many facilities including separators, floatation tubs, aerators, and precipitators. We analyzed the daily operation log and identified the locations of bottlenecks and frequent abnormalities. Figure 1 shows the results of the analysis. Analyzing text data helps identify the most frequent abnormalities, and by focusing on these, we can stabilize the process more efficiently and quickly.

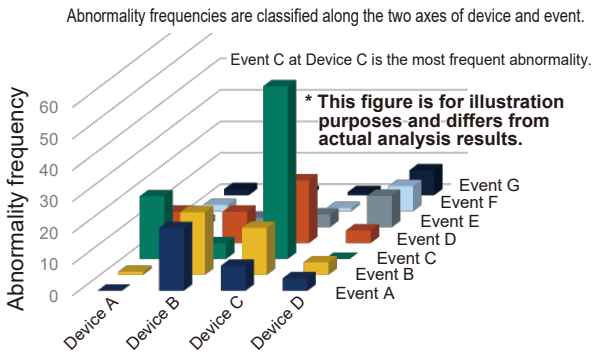

Figure 1 Quantification of the cause and frequency of abnormalities

(b) Cluster analysis

The conditions (quantity and quality) of the wastewater discharged from production facilities change constantly. We classified the conditions by using the inflow rate data of the wastewater process. Cluster analysis revealed that the throughput declined most when the inflow of wastewater from a specific production equipment increased. By categorizing wastewater conditions in real time, it is possible to reveal the cause of the fall in the throughput and to operate the process in accordance with wastewater conditions.

(c) Regression analysis

Chemical oxygen demand (COD), mixed liquor suspended solids (MLSS), and mixed liquor volatile suspended solids (MLVSS) are indicators of the quality of the wastewater treatment process, and these are often managed by offline

sampling analysis. Even if other process values are obtained every minute, sampling these indicators just once a day is insufficient for analysis. Therefore, regression analysis is used to create a model that estimates analytical values from continuous data. This approach increases the number of data for an analysis target, which helps identify previously hidden behaviors. As shown in Figure 2, we used regression analysis to visualize the quality value and convert MLSS and MLVSS from sampled (discontinuous) values to linear (continuous) estimates for analysis.

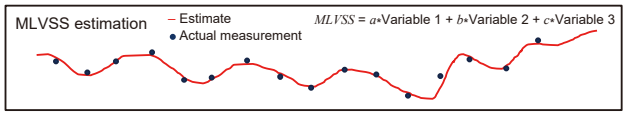

Figure 2 Visualizing the quality value

(d) Sensitivity analysis

To increase the output of production equipment, it is necessary to identify the cause of the fall in the throughput of wastewater treatment. Considering co-linearity, we performed stepwise regression and sensitivity analysis and obtained several findings. One is that it is necessary to monitor the upper limit of MLSS (MLVSS) in an aerator more closely to keep wastewater treatment running stably, rather than the lower limit of MLSS (MLVSS) that was previously monitored.

Proposal of the following step

To stabilize the throughput, plans are being made for installing new sensors and refurbishing facilities based on the analysis results.

By visualizing MLSS and MLVSS online, we aim to control the quality of these parameters and stabilize operations. In addition, we aim to convert from time-based maintenance (TBM) to condition-based maintenance (CBM). This is expected to reduce the workforce necessary for operation, adjustment, and manipulation.

Project for a Continuous Process in a Chemical Plant

Customer's problem

The next project is about a continuous process in a plant without brand changes (Figure 3). In many continuous chemical processes, unreacted raw materials are returned to the previous process, and thus process fluctuations tend to spread. Similar events occurred in this plant, increasing the workload of operators and energy losses.

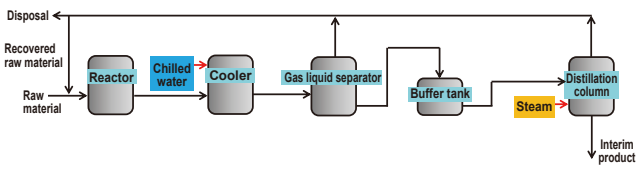

Figure 3 Customer's process flow

Yokogawa's solution

This problem can be solved in two steps.

First, process data analysis is performed to specify the target (the location that spreads process fluctuations to other processes and greatly affects them). In a continuous process, it is necessary to consider its characteristic time lag. The relationship between the temperature at one point and flow rate changes at another point cannot be revealed by simply comparing data at the two separate points in a trend graph (see the upper panel in Figure 4). In contrast, the cross-correlation coefficient graph works well. In this graph, the correlation coefficient of Point X is calculated every second that the trend graph of Point Y is shifted to the left. As shown in the lower panel in Figure 4, a peak appears when it is shifted to the left for 40 minutes. This means that changes at Point X reach Point Y in 40 minutes. By repeating this analysis on candidate points, it is possible to identify the point where changes affect other points most greatly, and the control loop to be improved in order to suppress changes at that point.

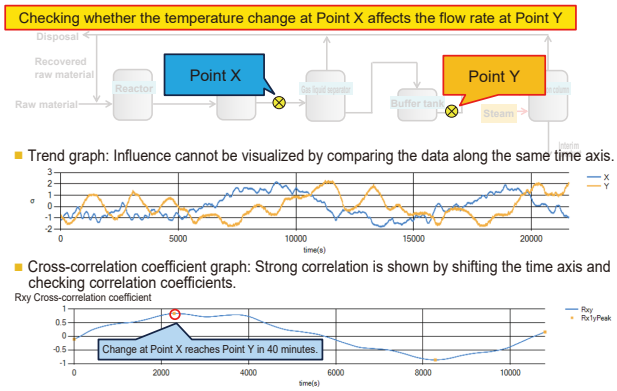

Figure 4 Data analysis method effective for continuous process

Next, we improve the controllability of the identified control loop. For this purpose, we use the fictitious reference iterative tuning (FRIT) control theory. By using only process data during normal operation, this control theory can determine the optimal control parameter to stabilize the process. Following this theory, we used big data accumulated during normal operation, determined the optimal control parameter, and established an improvement method. There was no need to conduct tests in actual plants (patent applied [(2)]).

Analysis Results and Benefits to the Customer

Figure 5 shows the result of improving controllability by using the analytic method described above. It successfully reduced process fluctuations at crucial plant components by about 80% and stabilized the process. This stabilization reduced the need for manual intervention by about 80% and improved operation. Figure 6 shows some of these optimization effects.

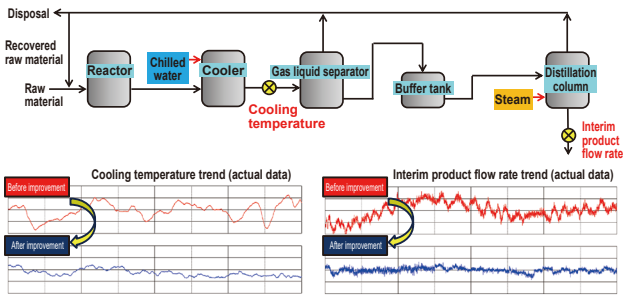

Figure 5 Stabilization by controllability improvement

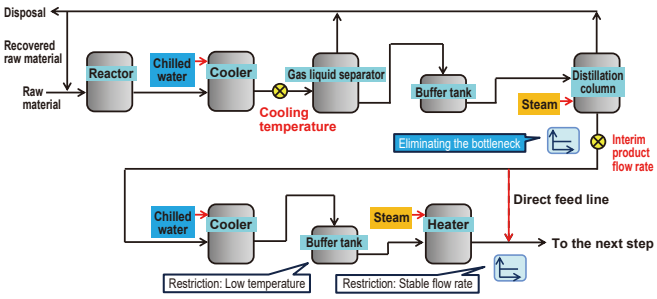

Figure 6 Optimization by controllability improvement

There were several problems before the improvement, such as unstable cooling temperature. Operation had to be performed at a much lower temperature than the ideal (cost-effective) set point. The improvement in controllability allowed the temperature to be shifted toward the ideal point, which reduced the amount of steam of a distillation column in the following process and thus also reduced the power consumption. Another problem was the greatly fluctuating flow rate of the interim product. To stabilize it before feeding to the next step, a buffer tank was needed. In addition, the interim product had to be cooled before sending it to the tank. Therefore, extra energy was needed to cool the interim product and then heat it again.

Clearly, the fluctuating flow rate of the interim product was a bottleneck at the plant, so we performed a controllability improvement to stabilize this flow rate. As a result, the interim product could be fed directly to the next step. This improvement has reduced the energy cost alone by more than 10 million yen per year. If the reduction in operator workload and material loss is included, the total effect is tens of millions of yen per year.

Proposal for the Next Step

The customer and Yokogawa are now rolling out these improvements in other plants with brand changes. As high-mix low-volume production is the norm in the industry, the increasing volume of irregular products generated during brand changes is becoming a problem. In this plant, we performed a series of improvements from process data analysis to controllability improvement, and successfully stabilized the process during normal operation as well as brand changes. Currently, we are identifying manufacturing conditions that will minimize the amount of irregular products and are determining their parameters.

COOPERATION OF THE INDUSTRIAL IOT DATA LOGGING & DASHBOARD AND VARIOUS IT/OT SENSORS

So far, this paper has introduced a value co-creation project with customers. As shown above, it is becoming increasingly important to analyze data that used to be processed separately or that had been difficult to collect, and then to add new value (intelligence) to these data. A platform for this task is described below.

Yokogawa has developed the Industrial IoT Data Logging & Dashboard, which is a solution platform that integrates IT data and OT data and achieves advanced maintenance. Running on GRANDSIGHT™ (Yokogawa's value co-creation environment) [3], this solution helps develop strategic decision-making solutions and other value-added solutions (Figure 7).

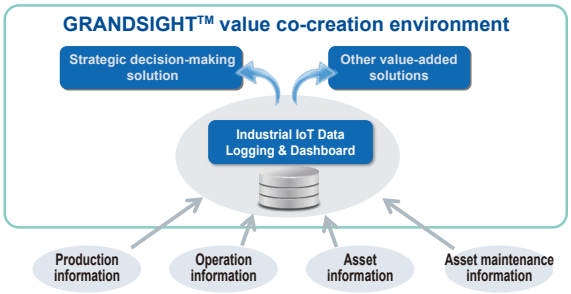

Figure 7 Value co-creation by GRANDSIGHT and the Industrial IoT Data Logging & Dashboard

To achieve advanced maintenance in plants, it is necessary to continuously obtain information about the state of equipment and devices. Yokogawa has developed Sushi Sensor to do this. This sensor is mounted on equipment or devices and monitors their state continuously. The XS770A integral vibration sensor can continuously monitor the acceleration and speed of the vibration of target pumps and their surface temperature over many years. The XS550 temperature sensor can keep monitoring the temperature of target devices, for example each stage of a multi-stage heat exchanger, over many years. How to use these data is key to creating new value in the future.

Meanwhile, Yokogawa also uses OT data for control. These data are obtained from OT sensors (such as transmitters and flowmeters), actuators, and PLC instrumentation systems, all of which satisfy mission-critical requirements. OT data will also become crucial for sophisticated maintenance in plants.

Main Functions of the Industrial IoT Data Logging & Dashboard

The main functions of the Industrial IoT Data Logging & Dashboard (IIoTDLDB) are listed below.

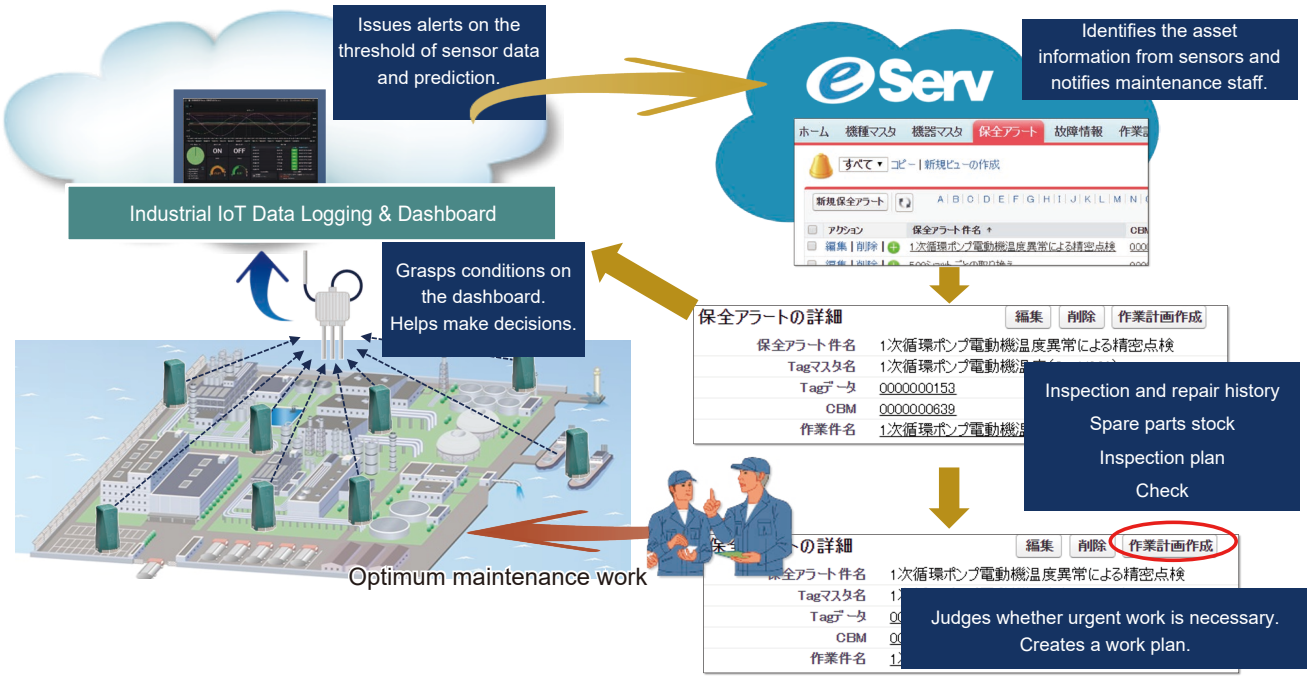

Figure 8 Cooperation of IT/OT sensors and maintenance action

- Data acquisition and accumulation
  The IIoTDLDB can collect and accumulate IT data from Sushi Sensor and Modbus-compliant devices as well as OT data from OPC-compliant devices and PLC devices.
- Threshold judgment and prediction
  When the normal range and the prediction range of data are specified, the IIoTDLDB can perform threshold judgment. By calculating predicted values, it can predict and judge the time of exceeding the threshold. This function gives operators enough time to plan maintenance work in advance.
- Issuing alerts
  In addition to the results of threshold judgment and prediction, the IIoTDLDB can issue alerts. It can write an alert in the OPC contact tag, send an e-mail, or issue a maintenance alert to eServ™, Yokogawa's cloud-based computerized maintenance management system.

By combining sensor data and the computerized maintenance management system, the alert is not processed as sensor data but for target equipment, enabling maintenance action to be taken for the target equipment more quickly.

IT data and OT data are collected by various sensors and stored in the IIoTDLDB. The results of the judgment are transmitted to the computerized maintenance management system. Since information on each sensor and target equipment is registered in this system, operators can check their inspection and repair history, spare parts stock, and existing inspection plans. They can also refer to the details and trend of data via the link to the IIoTDLDB. Based on these data, operators can judge the necessity and urgency of maintenance work and register the plan (Figure 8).

Cooperating with IT/OT sensors and helping operators make decisions

By not evaluating IT data alone but combining them with OT data, operators can make decisions on maintenance more quickly. For example, by comparing IT data on vibrations and OT data on operation indexes, operators can determine whether the vibration of equipment is caused by load or deterioration and then decide whether maintenance work is needed.

In addition to the functions described above, the IIoTDLDB comes with the following functions that help grasp conditions and make decisions.

- Displaying trends and saving events
  The IIoTDLDB can create a trend graph of IT data and OT data. When any balance or trend of the data looks useful, operators can save the graph as an event and refer to it at any time.
- Dashboard function
  The IIoTDLDB can create a dashboard with multiple data panes. With various IT data and OT data displayed on a single screen, operators can comprehensively understand the state of certain equipment and make quick, correct decisions (Figure 9).

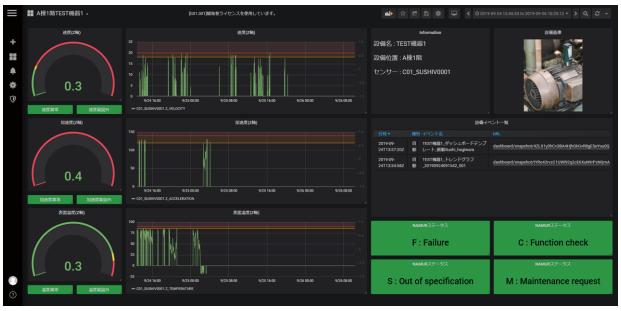

Figure 9 Dashboard that helps operators grasp conditions and make decisions

CONCLUSION

To illustrate Yokogawa's value co-creation activities with customers, this paper introduced solutions that use two technologies: data analysis and controllability improvement. Although the methods are different, they have a common point: they use currently available data, analyze them from a new viewpoint, solve problems, and create value, without needing to install additional sensors.

As the IoT age progresses, various new sensors are being developed and released, making it possible to collect data that could not be collected in the past. The focus is now shifting to how to use such data. However, people should recognize that it is possible to create new value even with existing data alone by applying new technology and looking at the data from a new viewpoint. If customers and Yokogawa work together to create value toward the common goal, we can gain greater value and intelligence from data.

IT sensors are expected to be installed more widely, allowing IT data to be obtained more easily. Therefore, a platform that unites the data from existing OT system sensors and the data from new IT sensors and creates new value is an important part of value co-creation.

By looking at existing OT data from various viewpoints, we will be able to develop a wider range of solutions and create new value. In other words, we should look at existing OT data from a new viewpoint as well as evaluate them in combination with new IT data. To do this, we should assume that even seemingly unimportant data could be used to create new value. Yokogawa will continue to help customers achieve this in various ways.

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