The business environment of Yokogawa’s customers is drastically changing, and their expectations for Yokogawa and its control systems are also changing. In response, Yokogawa is evolving its control systems in accordance with the four key concepts of smart control, smart operation, smart engineering, and sustainable plant, to ensure the long-term, stable operation of customers’ plants. This paper introduces how Yokogawa’s control systems are evolving as a platform that meets customers’ expectations.

INTRODUCTION

More than 40 years have elapsed since Yokogawa released the first distributed control system (DCS) in 1975. Now, many customers are thinking about the role of control systems as producer goods, different from general consumer goods and luxury goods. Specifically, customers want to continue operating plants safely and to secure productivity while responding to changes in the market, and they are trying to identify how control systems and their vendors can help satisfy such requirements, and what they need to pay for. As a control system vendor, Yokogawa has a responsibility to answer such questions from customers. Under these circumstances, customers’ expectations for Yokogawa are changing. Yokogawa’s role will shift from being a vendor that simply offers hardware and software for a control system, to customers’ partner who solves their problems throughout the plant lifecycle. This paper introduces how Yokogawa is evolving control system products as a platform to meet customers’ expectations.

CHANGES IN BUSINESS ENVIRONMENT SURROUNDING CUSTOMERS

In the energy industry, sectors related to various new energy sources have been growing recently. However, the oil, gas, and petrochemical industries are expected to continue to play a major role in the next 20 to 30 years because demand remains high for products in these industries for constructing infrastructure, particularly in emerging countries. In these industries, product competition in the market is becoming severe due to the rise of emerging countries including BRICs, and for other reasons. Therefore, highly efficient, optimal production tailored to the situation is required. Under these circumstances, the business environment surrounding customers is changing greatly. Those changes, their impacts, and the required responses are described below.

Changes in Raw Materials and Products to be Produced

As a result of technological innovation and regulations regarding raw materials, as well as their globalized procurement, the qualities, compositions, prices, and supply forms differ in every case. In addition, depending on the diverse requirements of users, the production of various products in small quantities is required. Production equipment and instrumentation systems which can flexibly respond to changes in raw materials and products need to be introduced, and the renovation of existing plants and introduction of new equipment are also expected to increase.
Changes in Production Load

Depending on changes in demand for products, the production load of plants may change greatly, and so production efficiency must be improved. As a result, operators are forced to operate the plant more accurately than ever while monitoring a wide range of behaviors of the plant. In addition to production efficiency, it is also important to secure safety, identify problems in advance, and make appropriate improvements based on cause analysis immediately after problems have occurred.

Changes in Customers’ Attitude to Investment in Production Facilities

Return on investment in production facilities is strictly assessed in customers’ plants. For example, customers strongly desire to expand production opportunities by maximizing the use of production facilities and minimizing the downtime. Customers are keen to reduce downtime although it is impossible to eliminate it, and to continue production within safe limits.

Changes in Tasks of Persons in Charge of Production

By managing multiple distributed plants in an integrated manner, many customers are flexibly responding to changes in raw materials and production demand. However, in practice it is difficult to assign experts to all plants, as their number is limited. Meanwhile, plant operations are gradually being automated, although not fully.

Thus, the tasks required especially for general operators stationed in each plant are becoming narrowed down to more critical, complicated ones that are rarely executed. Among tasks that were conventionally carried out by general operators, simpler tasks and repetitive routine tasks are being automated while complicated tasks and non-routine tasks are left to operators. Furthermore, general operators are increasingly having to handle difficult tasks that were conventionally handled by experts.

For these reasons, it is necessary to minimize the load on operators, to give operators guidance on appropriate responses in real time, and to provide operators with practical training so that they can securely execute their tasks. It is also important to offer ongoing training at reasonable cost and suitable times. In addition, a system is needed that enables experts to assist general operators from remote sites.

Expectations for the Integration of Operation and Maintenance (O&M)

In recent years, customers are more strongly demanding plant operation that maximizes the profits generated by production facilities by optimizing their maintenance plan throughout all production activities. To maximize the capability of production facilities, operators need to identify disturbances to the plant, changes in production demand, and other factors. In addition, they need to understand the conditions of each equipment and device in the plant, and have the knowledge and skills required for effectively using them. Meanwhile, maintenance staff need to understand the operating conditions of each equipment and device in the plant, and to maintain them considering their influence on production activities. Therefore, the integration of operation and maintenance (O&M) information and its management are becoming increasingly important. During plant operation, it is important to make full use of such information, and to take into consideration the impact of operation and maintenance activities on production efficiency throughout the plant lifecycle.

Requirements for Future Control System

To respond to changes in the business environment of customers and to satisfy their expectations, control systems need to be enhanced from four fundamental viewpoints: schemes for automating plant operation; schemes that enable operators to monitor plant operation and take actions accordingly, engineering for configuring the entire system for a customer’s plant; and maintenance services to ensure long-term stable operation. The requirements for each of these are described below.

Smart Control
(Requirements for schemes for automating plant operation)

To improve the production efficiency of plants, it is necessary to operate each process while keeping its process values stable just within the limits while maximizing efficiency. Advanced process control (APC) is a well-known technology for this purpose. To increase the introduction of APC to customers’ plants, the period required for installation needs to be shortened and the costs lowered. In addition, it is important to precisely identify the conditions of customers’ processes.

Meanwhile, each process unit in a plant is often operated by multiple distributed autonomous controllers working in cooperation for the sake of reliability and maintainability. As the processes become more complex, the relations among these controllers tend to become stronger. In addition to changes in raw materials or production demand, a plant is always affected by changes in external conditions such as weather, temperature and operation procedures, as well as changing conditions due to aging facilities and so forth. Thus, the optimum balance among controllers and among process units fluctuates.

Therefore, a function that supervises and controls all process units in an integrated manner while managing multiple controllers in each process unit is needed. This function is called supervisory control, which performs task control, advanced control and optimal control across multiple controllers.

The left part of Figure 1 shows supervisory control in the production management and control hierarchy. Multiple controllers are used in each process unit for controlling it. The supervisory control in the layer above that of controllers optimally controls the process units using multiple controllers.

Advanced control functions including APC usually
operate for each process unit, and the balance of control among controllers does not need to be considered. Supervisory control functions such as APC can maintain the optimal control balances in response to various external fluctuations.

Furthermore, high-precision optimal control by using field digital technology and simulation technology is required. Yokogawa offers such optimal control functions, which operate effectively on a highly reliable platform that Yokogawa has cultivated for 40 years. The relation among supervisory control, advanced control, optimal control and simulation technology is shown in the right part of Figure 1.

Smart Operation
(Requirements for schemes with which operators monitor plant operation and take actions)

Due to changes in the market and O&M integration, the work of general operators is becoming more complex. Many customers clearly recognize that one of the important factors for preventing plant accidents, of which there are frequent reports these days, is the human-machine interface (HMI). The ISA101 (1) and ISA106 (2) international standards discuss how HMI should be.

The HMI is an important means that allows persons in charge to monitor plant operation and take actions in response, and so the role of the conventional console for HMI dedicated for the controllers of each vendor needs to be expanded. To achieve this, in addition to conventional data including production data and maintenance data, it is possible to use data obtained by smart control, field digital technology and simulation. Making use of this wealth of data, the HMI can be expanded into a tool which enables persons to understand the conditions of a plant at a glance, identify suitable measures, and securely take actions. Figure 2 shows the schemes and displayed contents which help persons make accurate decisions based on given information.

Yokogawa will offer schemes based on ISA101 that facilitate HMI design and that equalize the data from different data sources and convert them into easy-to-understand information. Furthermore, it will configure schemes that enable operators to securely share information about the current situation with experts at a remote site, and that automatically edit the optimum measures provided by experts as an electronic standard operating procedure (SOP) and make it available to general operators. In addition, by tightly combining field digital technology, simulation and its control systems, it will offer an operator training environment which precisely simulates plant operation.

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**Figure 1** Supervisory control

**Figure 2** Schemes for assisting persons in their work
Smart Engineering
(Requirements for engineering for configuring an entire system for a customer’s plant)

As plants are becoming more complicated, they are rarely controlled only with DCSs of a single vendor but usually use various systems from different vendors in combination. In recent years, safety instrumentation systems and DCSs are often combined as a system called an integrated control and safety system (ICSS). Implementation and settings in these systems are frequently changed during engineering work depending on the progress of the project and changes in customers’ requirements. In addition, engineering work is divided into work such as for each process unit and each control system. In the control system, it is further divided into field work, and work such as implementing applications of the control system and designing processes. As shown in Figure 3, the period of the engineering of a control system can be shortened by performing several tasks in parallel.

In view of this, Yokogawa provides an integrated engineering environment in which the engineering results from multiple systems and sites are consistently integrated, their modifications are managed, and not only is the modification history managed but also the consistency among modifications in the system is kept. In particular, Yokogawa provides a scheme that allows parallel execution of engineering and installation work in the field for I/O-related hardware which should be handled together with field devices, and engineering work in design and implementation of applications of a control system whose execution behavior requires the consent of the customer. To achieve this, the functions of engineering tools for designing and implementing applications must be improved dramatically so that information related to those works can be properly linked to at any time.

Sustainable Plant
(Requirements for maintenance services ensuring long-term stable operation)

After their plants start operation, customers place importance on continuing the stable, long-term production of their plants while maintaining and improving production efficiency. Yokogawa has therefore prepared a range of annual maintenance contracts, one of which provides maintenance service for a customer’s plant for as long as 25 years. Under this contract, Yokogawa works together with customers to draw up a maintenance plan and carry it out, which defines a replacement plan as needed for hardware components that deteriorate and software components that become difficult to maintain in the next 25 years, while minimizing the influence on plant operation. Meanwhile, as for components provided by Yokogawa such as control system products and field devices, Yokogawa offers long-term maintenance schemes.

For HMI devices, Yokogawa’s design policy is for HMI devices to be capable of operation and monitoring on controllers of a DCS at least one generation earlier, as it used to be. Thanks to this policy, HMI devices with a relatively short lifetime can be replaced with new ones without suspending the operation of controllers that directly control the process. As a result, this enables control systems to be updated according to the customer’s operation or maintenance schedule. Note that Yokogawa allows the partial exchange of hardware by making its components loosely-coupled, and increases the co-existence and connectivity of multiple pieces of software by using virtualization technology.

Meanwhile, as for computers and their operating systems, their lifetimes are relatively short compared with other components used in control systems. Yokogawa has forged alliances with computer vendors and secured longer supply and maintenance support than for existing PCs in the
market, enabling it to supply platforms that are not affected much by the support policy of Microsoft Corporation or the OS supplier. Because non-Yokogawa hardware and software used in the control system will increase in the future, some measures are necessary so that customers can safely use the system for a long time. Yokogawa will expand the schemes for the stable supply and maintenance support of non-Yokogawa components.

The current conditions of Yokogawa and non-Yokogawa hardware, software and applications, and their history of maintenance and modifications are important information for maintaining the whole system for a long time. However, many customers do not manage such information properly; it may be scattered, lost, or not kept up to date. Using the functions of the smart engineering environment described above, Yokogawa offers a framework shown in Figure 4, which can easily keep such information up to date and ensure maintenance of the components in customers’ plants while referring to the product maintenance information in Yokogawa.

**KEY TECHNOLOGIES TO SATISFY THE REQUIREMENTS**

The previous chapter described the requirements for the control system from four viewpoints. To satisfy those requirements, two key technologies, field digital and process simulation technologies, are necessary in addition to a highly reliable and high-performance platform for control systems.

**Field Digital Technology**

The field digital technology offers various added values to customers by enabling real-time data exchange between a control system and field devices with autonomous intelligence which are distributed throughout a plant.

Thanks to the evolution of microprocessors integrated in field devices, a control system can obtain multiple high-precision data from a single device. Furthermore, exchanging digitized data between a control system and field devices enables the communication to be unwired. This makes it possible to locate field devices at places that could not be located conventionally because of wiring problems, and to visualize process data that would otherwise be impossible. Because the volume of collectable data is increasing, it is possible to detect slight changes in a plant, identify causal relationships, and predict future plant behaviors precisely. In addition, devices transmitting data can increase their data reliability by a self-diagnosis function. In turn, this enables control, maintenance and other activities based only on reliable data, thus greatly contributing to reducing maintenance costs and improving the safety, efficiency and availability of the plant.

Field digital technology helps to reduce not only operating expenditure (OPEX) but also capital expenditure (CAPEX) in constructing a control system. With this technology, the information kept in remote field devices such as identifiers and settings can be obtained via communication and used for engineering and maintenance of the control system. Changes in a plant configuration, even such a change as replacement of a device without being reflected on the design documents, can be easily managed with the centralized device management functions, enabling maintenance to be performed quickly.

Furthermore, field digital technology facilitates the validation checks of multiple loops at the same time. These
include whether field devices at end points are connected to the control system properly, whether devices can return appropriate data in accordance with the instruction from the control system, and whether the settings in devices are set properly. This enables reliable loop checks to be conducted far more quickly compared with the conventional way, and the amount of work required for starting up a plant can be reduced. Conventionally, two engineers, one at a control system site and the other at a field site, conduct loop checks one by one while exchanging information using transceivers.

**Process Simulation Technology**

By combining simulation technology with field digital and the engineering of control systems, Yokogawa's control system offers many merits to customers. These include reducing the costs for creating process models, improving the accuracy of behavior prediction, and tracking of operating conditions to actual current situations.

For Yokogawa’s control systems, process models are developed as follows. First, in the early stage of design and implementation of control systems, fundamental simulation functions based on the standardized process models are applied to each process model. Then, as engineering progresses, tuning of the models is repeated and the models are improved. As a result, by the time of starting plant operation, the process models are ready to use with only short identification work needed, which drastically reduces the time and cost for building models. To achieve this, it is indispensable to closely unite the engineering functions of the control system and the simulation functions.

Before the start of plant operation, process simulation using process models can be used for other purposes than operator training. By simulating the behavior of a customer’s plant on the basis of their requirements at the time of basic design, Yokogawa and the customer can share the expected behaviors of the plant after the start of plant operation. In addition, even before the I/O hardware configuration is determined, process simulation can be used for debugging and inspecting applications to compensate their inspection on actual equipment, improve their quality and shorten the period required for inspection after starting up the plant.

Furthermore, after plant startup, process simulation can visualize the internal conditions in production equipment and processes that are difficult to measure using sensors, and can predict the future with an accelerated simulation. As a result, this can prompt the control logic or operators to take preemptive actions before processes become abnormal or before conditions become inefficient.

After the startup, it is necessary to change the process models in real time to flexibly respond to changes in raw materials or production demand. For example, process values in an actual plant can be incorporated into a model to adjust the operating conditions and parameters in the model in real time. In addition, the simulation results of step responses can be used for transfer function models for advanced control, or PID tuning for the simulated process.

In all cases, simulation accuracy and dependability of data used for simulation need to be secured. By actively using smart field devices with field digital technology, uncertain data provided by abnormal devices which adversely affect the simulation can be identified and eliminated. In addition, field devices are evolving in terms of the number of measurable points per device and in measurement speed, thus increasing the total number of measurable points. As a result, the number of available measured values excluding those with low dependability is sufficient for adjusting highly accurate models.

**CONCLUSION**

Yokogawa always puts priority on the customer and develops products in consideration of the values that customers are seeking. Yokogawa recognizes that customers purchase not Yokogawa’s control systems but its trusted brand. Customers pay money to Yokogawa not only for the hardware, software and applications of control systems but also for its maintenance services, update plans and actual work, and the skills of Yokogawa’s staff. Yokogawa will continue to develop and provide functions necessary for offering greater value than the price paid.

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