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FUJI ELECTRIC REVIEW

1

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Instrumentation and Control Systems

Fuji Electric Group

Fe *e-Front runners*

MICREX-NX

Pursuing possibilities.

Lifecycle total solution

Integrate latest leading hardware and software and application know-how, future-oriented system development with evolution. This is the lifecycle concept of MICREX-NX.

MICREX-NX realizes optimal plant operation in all phases of system design, commissioning, operation and maintenance. At renewal phase, MICREX-NX provides maximum effect with minimum capital investment.

The MICREX-NX lifecycle total solution offers cost reduction and long-term stable operation with constant evolution and variety of solution know-how.

The new process control system
MICREX-NX

CONTENTS

Cover photo:

Instrumentation and control systems are anticipated to become systems capable of considering carefully the comfort and safety of society and the global environment while contributing to the stable manufacture of high quality products with the desired productivity.

Fuji Electric strives to provide a total optimal system with vertically and horizontally integrated solutions that link seamlessly various components and solutions required on the shop floor.

The cover photograph represents an image of instrumentation and control system organized by the MICREX-NX new process control system, field devices, receivers, and the like.

Present Status and Fuji Electric's Involvement with Instrumentation and Control Systems

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1. Introduction

The investment environment surrounding the industrial system sector is continuing to grow due to increased public demand for capital investment. According to medium-range forecasts, the market for electric measurement equipment will continue to experience mild growth overall during the period from 2006 to 2009; government-based demand will continue to be limited and will level off; exports will be centered on China and other Asian countries and will continue to increase slightly, and public demand for investment to reduce the high cost of crude oil and to add value to products is expected.

Instrumentation and control systems are anticipated to become capable of considering carefully the comfort and safety of society and the global environment while contributing to the stable manufacture of high quality products with the desired productivity. Moreover, at plants where the manufacturing equipment is approaching the time for renewal, it is desired to utilize existing assets while migrating to a system capable of supporting future technological innovations.

Meanwhile, owing to the latest advances in IT (information technology) and personal computers, there are plans to combine instrumentation and control systems with MES (manufacturing execution system), ERP (enterprise resource planning), SCM (supply chain management) and other such core systems, or combine them with intelligent field devices, and there is demand for a comprehensive optimized system structure, from the field level to the level of production management and operation, based on a vertically and horizontally integrated solution that seamlessly integrates the various components and applications required at the production site.

On the other hand, the so-called "year 2007 problem" is one that Fuji Electric cannot avoid, and in establishing and executing a countermeasure policy, as a part of an effort to strengthen the rationale for an instrumentation and control system that provides vertical and horizontal integration solutions, and cognizant of the transmission of technology and of measures to prevent the hollowing out of this industry, Fuji Electric

again improved and enhanced the element technologies of the instrumentation and control system, i.e., the main constituent elements of control technology, engineering technology and device manufacturing technology, and constituent components such as measuring instruments.

This paper presents Fuji Electric's vertical and horizontal integration solution, and described the present status of and Fuji Electric's involvement with the abovementioned constituent elements.

2. Market Trends and Challenges for Instrumentation and Control Systems

2.1 Market trends and challenges for distributed control systems (DCSes)

In the 1990s, DCSes underwent a dramatic change from specialized systems for DCS manufacturers to open-standard systems used with UNIX[*1] and Windows[*2], which are the de facto standards for operating systems. SCADA (supervisory control and data acquisition), a monitoring and control package that uses Windows as its operating system, emerged first, and PC-based DCSes that use SCADA as middleware were introduced into monitoring and control systems. Then Internet technology and OPC[*3], the de facto standard interface of Windows, and field bus technology revolutionized the DCS market.

In the years since 2000, programmable logic controller (PLC) instrumentation systems have been introduced to the market, and the segregation of the instrumentation control domain among DCS manufacturers, PLC manufacturers and SCADA manufacturers has become even more complex.

On the other hand, the focus on DCSes has changed, from mere monitoring and control systems to systems that are being reconsidered by users as an effective means for reducing the TCO (total cost of

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*1: UNIX is a registered trademark in the U.S. and other countries, licensed through X/Open Company, Ltd.
*2: Windows is a registered trademark of U.S.-based Microsoft Corporation.
*3: OPC is a standard interface specification of Microsoft.

ownership) for the total lifecycle duration, from DCS adoption until renewal, and with the introduction of IT, as a way to optimize the operation of manufacturing systems.

In this context, a DCS does not exist by itself, but must be linked to an ERP, SCM or MES core business system to form a system that operates effectively. Seamless integration and the provision of MES products are huge challenges.

With longer service lives of equipment, DCSes are being required to provide long-term maintenance and protection. The extent to resolve the conflict between longer service life and higher versatility of general-purpose products based on open standards remains a huge challenge.

In the domestic Japanese DCS market, new plant demand is small, but the majority of demand arises from the need to renew equipment in order to maintain a plant. The challenge facing DCS manufacturers is achieve long-term operation while continuing to utilize a user's assets and providing a revolutionary system.

2.2 Market trends and challenges of measuring instruments

The market for measuring instruments has continued to diminish due to a reduction in capital investment over the long-term and lower prices, but in the past few years, the market has recovered as a result of increased in capital investment in Asian markets and especially China, and the enhancement of facilities in the basic materials industry, which is the main customer of measuring instruments.

Measuring instruments can be broadly categorized as field instruments such as transmitters and flow meters, receivers such as recorders and controllers, and analyzers. A noticeable recent trend among measuring instruments is the provision of functions that support networking. The first example of a field bus used in the field was announced in 1998, and the necessity of a field bus has become a frequent topic in recent business discussions. Communication functions such as Ethernet[*4] support are now required in receivers as well. Moreover, the trend toward globalization of measuring instruments is remarkable, and for transmitters, de facto standards are increasingly being used in the specifications, and the resulting low cost is often the key to receiving orders. On the other hand, however, there is a growing demand for specialized devices for particular customers.
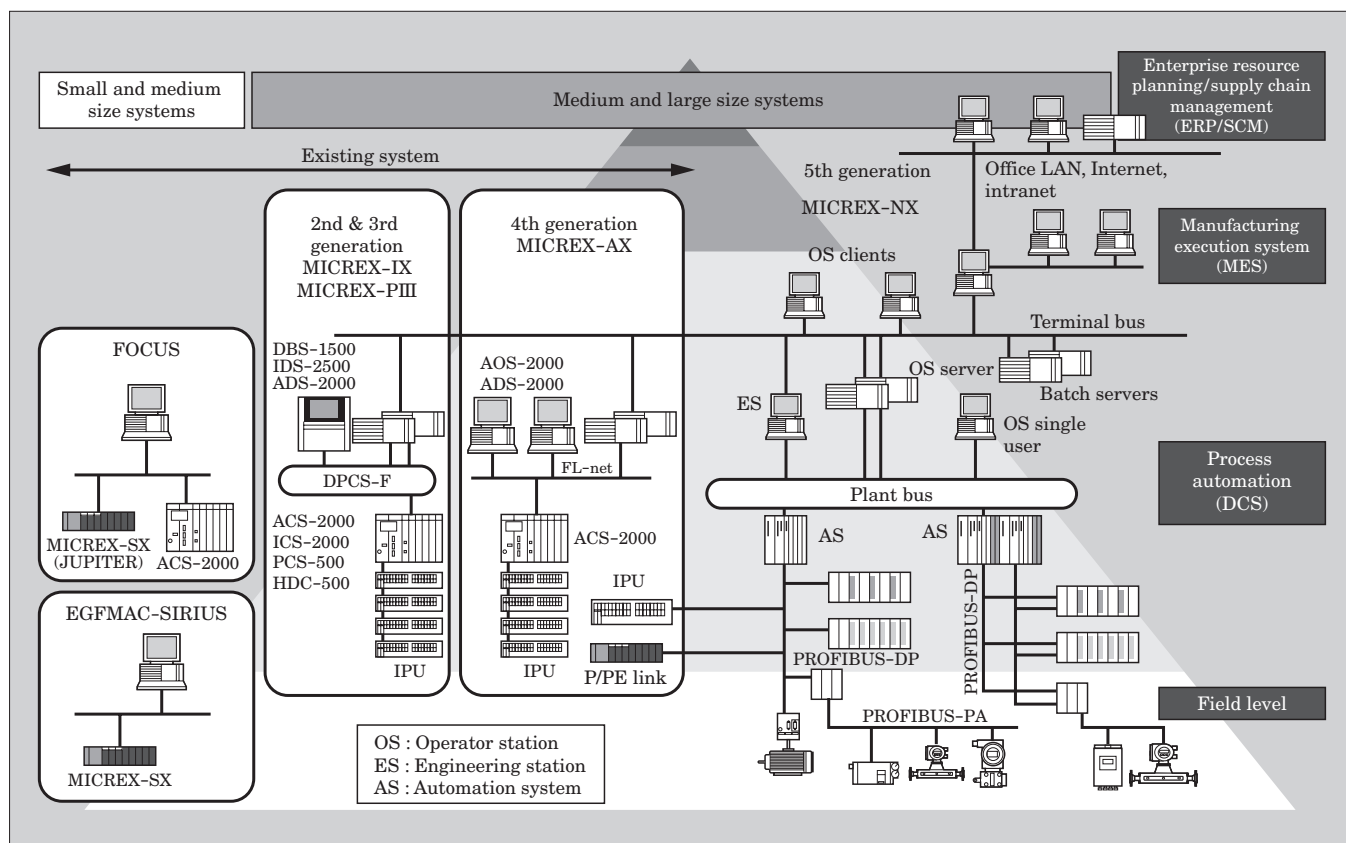
3. Fuji Electric's Involvement with Instrumentation and Control Systems

3.1 Involvement with DCS

Fuji Electric possesses excellent core technology

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*4: Ethernet is a registered trademark of U.S.-based Xerox Corporation.

Fig.1 MICREX system configuration

in the distinct fields of electric (E), instrumentation (I) and computer (C) control, and Fuji's DCS has been developed as a system capable of realizing an EIC integrated system.

In the latter half of the 1990s, Fuji Electric announced the MICREX-AX as a 4th generation DCS based on the concepts of open standards, evolution and inheritance.

Then in 2004, the MICREX-NX was introduced to the market as a 5th generation DCS. The MICREX-NX enables the realization of a vertically integrated system that seamlessly connects systems from the shop floor to the operating level, flexibly connects devices such as sensors, inverters and UPSes (uninterruptible power supplies) located on the shop floor, and also enables the realization of a horizontally integrated system capable of supporting all processes from the receipt of raw materials to shipping.

For medium and small size systems, there are also FOCUS and EGFMAC-SIRIUS systems, which can be constructed from a SCADA system and a general-purpose PLC, and which can support a wide variety of needs.

Figure 1 shows the system configuration of Fuji Electric's information control systems and their hierarchy.

(1) Vertical and horizontal integrated system

(a) Vertically integrated system

An MES is positioned between an instrumentation and control system and core business system, like an ERP or SCM, at manufacturing site. MES part is optimizing business resources (people and equipment). MES functions include schedule management, product inventory, progress management, production results management, production equipment management, quality management, and so on. Fuji Electric provides the MainGATE-Process plant production management system as an MES for the manufacturing industry. In response to user requests, optimal MES systems are being provided as solutions, and by seamlessly integrating the MES with a MICREX system, a system vertically integrated from the field level to the manufacturing control level can be realized.

(b) Horizontally integrated system

The MICREX-NX is a system that covers the range from process control to discrete control, and realizes consistent integration, from upstream raw materials equipment to downstream distribution and utility equipment. Furthermore, as shown in Fig. 2, these systems are used in various industries and enable the consolidation and integration of plants.

(2) Lifecycle solution

The MICREX-NX, as shown in Fig. 3, reduces the TCO in all phases of the lifecycle, from plant system construction to management (operation and maintenance), and renewal, and is capable of providing various solutions to run the plant optimally. This special edition introduces solutions in each sector.
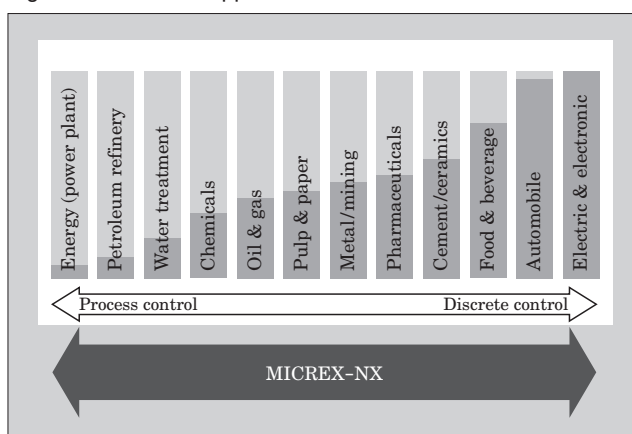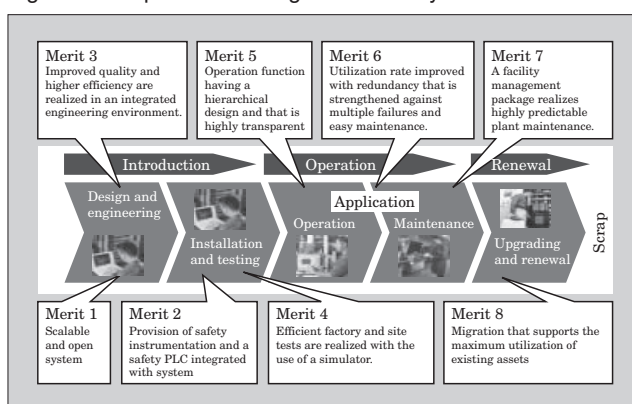
Fig.2 MICREX-NX application areas

Fig.3 Merits provided throughout the lifecycle

(a) Merits of use

① Supports scalability from small and medium-scale to large-scale plants

② Supports international standards at every level

③ Safety instrumentation and safety PLC system can be constructed with automation system (AS) standard components (CPU, I/O and modules)

(b) Engineering merits

An engineering station (ES) has an abundance of functions, as listed below, and these enable the engineering work time to be shortened and input errors to be reduced, thus improving quality and efficiency.

① Function blocks that are registered in a library are used to realize the AS control functions and to generate automatically the faceplate displayed at an operator station (OS). The AS and OS engineering work becomes integrated.

② An abundant library is provided for single control functions and for field control.

③ Software simulations of application software and of inputs and outputs can be performed. A dynamic plant simulator is also provided.

④ During the design phase for AS application software, the system can be designed without the need to be aware of redundancy.

⑤ With the automatic addressing function, the

system can be designed without the need to be aware of memory allocation.

(c) Management merits

① With a hierarchical design, constructed control functions are reflected in the operation, and operation is simplified.

② Sensors and control elements are easily connected to the PROFIBUS, thus enabling the provision of a highly transparent operation function.

③ Each DCS component can separately be made redundant, and linking these components will enable the system to be resistant to multiple failures.

④ DCS constituent elements can separately be made redundant according to the degree of importance of a process, thereby enabling the construction of a redundant system that has weighed the risk and return on investment.

⑤ A version cross checker function strengthens the management of the change history.

⑥ Automatic startup after the replacement of hardware improves the utilization rate.

(d) Renewal merits

When renewing an existing system, migration to the MICREX-NX can be implemented step-by-step.

① The multi-server function enables the MICREX-NX to be connected to an older generation network (DPCS-F or FL-net) and the older generation controller to be monitored from the OS.

② The MICREX-NX can be connected via link devices to P/PE-link or T-link devices, and may coexist with new and old PIOs.

③ A converter function enables the efficient utilization of application software assets.

(3) Solution packages

The MICREX-NX is capable of providing the following solution packages.

(a) Facility management package

The facility management package PDM (process device manager) comprehensively acquires device diagnostic information and device-specific information for field devices, facilities or the like, and provides diagnostic technology capable of detecting tendencies for failure in a plant or machinery, thus vastly improving the efficiency of such maintenance work as preventive maintenance, fixed cycle diagnostics, overhauls, etc.

(b) Batch system

The MICREX-NX's batch system is built on a software package base that complies with the IEC 61512 standard (ISA S88) and with FDA21 CFR Part 11 that concerns electronic recording and electronic signatures and was established by the U.S. Food and Drug Administration (FDA).

(c) Route control

This package performs the monitoring, control and diagnosis of systems that transfer fluids by pipe or pipeline. Product brands change daily, and chang-

es in the transfer route can easily be implemented without the need to create special programs.

(d) Operating support system

This package automatically captures operating information, and can automatically deploy that data in the operating flow, so that the operational know-how of a skilled operator may be inherited easily. This package is provided as a solution package for the year 2007 challenge.

(e) Field-specific packages

Field-specific package groups are prepared in a library for each manufacturing industry.

(4) Medium and small-size systems

In addition to the previous FOCUS system for small and medium-size control systems, in 2004, Fuji Electric began selling the EGFMAC-SIRIUS system capable of supporting small-scale control systems. Both systems are configured with a general-purpose SCADA and the MICREX-SX, which is a general-purpose PLC. By mounting Fuji Electric's instrumentation control-related know-how onto a general-purpose SCADA, the system is able to provide the same engineering environment and operating environment as with a conventional DCS.

(5) New involvement with engineering support systems

In addition to the engineering merits enumerated in section 3.1, paragraph (2), item (b), as in the HEART series, Fuji Electric has commercialized a specification and description language to increase the quality of specifications. Furthermore, by supporting all phases of engineering work with a common platform, continuity of the control system engineering can be established from price quotations and specification verification to onsite startup. This enhances the production technology capability, facilitates the inheritance of technology, and of course, improves productivity and quality.

(6) Advanced online optimization technology and control platform

Online optimization is the optimal online operation of a system, having been vertically integrated from the above-described field to production control and operation, for a certain objective, which is one of the vertical integration objectives. Fuji Electric is expanding the functionality of its FeTOP (Fuji Electric total optimization) system that was developed as an online optimization system for power plants. FeTOP has the basic functions of a load predicting function, non-linear optimization calculation function, non-interactive control function (multivariable model predicting function), and an interface for the user and DCSes of various companies, a database of actual data and the like, and aims to provide technology capable of realizing online optimization in various fields.

3.2 Present status of measuring devices and Fuji Electric's involvement

Measuring devices (sensors) are the original source

of process instrumentation, and play an important role in improving productivity, quality and preventative maintenance. Table 1 lists Fuji Electric's involvement in the improvement of measuring devices.

Fuji Electric's involvement in each type of measuring device is described below.

(1) Field devices

Representative examples of field devices include pressure and differential pressure transmitters, flow meters and temperature transmitters.

The specifications and performance of transmitters have been standardized, and competition in the global market is fierce. Even under these circumstances, there are demands for long-term stability, functions that support a field network, and a safety level (SIL: safety integrity level) that complies with IEC 61508. Also, for particular customers, Fuji Electric has developed transmitters that fully utilize Fuji's distinctive technologies, such as low power and network technologies.

Types of flow meters include the electromagnetic type, ultrasonic type and the like. The ultrasonic type is expected to generate increased demand due to its advantages of non-contact measurement and convenient installation. Fuji Electric is focusing on ultrasonic flow meters as a key device, and in 2005 brought to market a high-precision hybrid ultrasonic flow meter (composite method using transit time difference and Doppler effect; models: FSH and FSW) that is targeting use in identifying business transactions, and Fuji is moving ahead to develop a product line. Additionally, ultrasonic type meters are the main flow meters used with ultra pure water in semiconductor manufacturing, and in application to smaller aperture sizes, and the number of units sold is steadily increasing.

(2) Receivers

Receivers are broadly categorized as either recorders or controllers. Recorders are transitioning to paperless recording. There is backing for regulations and guidelines to prevent falsification of data from paper-based recorders (ink jet type), and that demand is being supported. Paperless recorders are required to support Web servers and provide data acquisition functions, and in 2005, Fuji Electric introduced a paperless recorder product (model number: PHR/L) fully equipped with a communication function.

Demand for single loop controllers used in the first process instruments was driven mainly by replacement demand, but that use is coming to an end. In medium and large-scale systems, controllers were replaced by DCSes and PLCs, and in small-scale systems, were replaced by upgraded temperature controllers and other general-purpose controllers. Temperature controllers feature improved communication functions, control operations, calculation functions and the like, and as a highly functional and high-precision general-purpose controller, their range of suitable applications is expanding. Fuji Electric introduced high functionality temperature controllers (models: PXH and PXG) to the market in 2005, and example applications of these temperature controllers are presented in this special issue. Also, it is strongly requested that temperature controllers for mechanical equipment be built-into the interior of that equipment, and the module type and board

Table 1 Fuji Electric's involvement to improve measuring devices

Model	Key technology	Fuji's involvement for improvement	Main fields of application					
			Materials production	Water treatment	Food, pharmaceuticals	Mechanical instrumentation	Semiconductors	Environmental measurements
Pressure, differential pressure transmitter	Micro silicon sensor, low power consumption, network	Compatibility with general-purpose (global standard) transmitter	○	○	○			
Ultrasonic flow meter	Pulse Doppler, composite method using transit time difference and doppler effect (world's first)	Increase accuracy, expand aperture range	○	○	○	○	○	
Temperature controller	High-speed control, advanced high resolution, network	Increase functionality, increase accuracy, modularization, integrate to a single board	○		○	○	○	
Recorder	High-speed sampling, network	Web server, improve data acquisition function (paperless recording)	○		○	○	○	
Gas analyzer	NDIR sensor, solid electrolyte sensor	Simultaneous measure of multiple components, direct insertion to measure flue gas	○			○		○

type, without a display control panel, are becoming the most common type of temperature controllers. There are needs for better control precision, for communication functions to be expanded and for PLC functions to be incorporated, and Fuji Electric will strive to support these needs.

(3) Analyzers

Gas analyzers are classified according to their use, whether for environmental monitoring, such as for monitoring air pollution, or for use in processes that measure the atmosphere in an industrial furnace or the like. The NDIR type, zirconium type, and magnetic type analyzers are based on traditional measurement principles, but are also equipped with multi-component measurement functions, and calculation functions such as auto calibration. Recently, a laser-based direct insertion type (type that directly attaches a sensor to a flue or chimney) was introduced. Fuji Electric has introduced an NDIR type analyzer equipped with various calculation functions (installation model: ZSU; compact model: ZSV) which can measure five different components (NO_x, SO_2, CO, CO_2, O_2) with a single analyzer, for air pollution monitoring and for process monitoring. Fuji is also working to bring this technology to the direct insertion type of analyzers.

Regulations are creating demand for analyzers for environmental monitoring-use. Timed to the start of VOC (volatile organic compound) emissions regulations that began in April 2006, NDIR VOC meters were introduced to the market in December 2005.

In response to demand for safe and delicious tasting water, Fuji Electric is introducing unique water quality meters (a trihalomethane meter, an acute toxicant monitor, an oil-on-water analyzer, etc.) to the market.

(4) Basic technology for manufacturing sensors

The sensor elements built-into the various measuring devices are based on so-called MEMS (micro electro mechanical systems) technology. Fuji Electric has cultivated this technology in the manufacture of sensors for pressure transmitters, inkjet elements for paper recorders, and the like, and in recent years, is actively working to expand its application range in various fields.

Fuji Electric is also involved in a so-called MEMS foundry service to combine wireless and sensor technology with MEMS, or to develop a sensor that incorporates biotechnology, and then to leverage the features of this technology and accept contracts from clients for micro-machining.

4. Conclusion

An overview of the trends and Fuji Electric's involvement with instrumentation and control systems has been presented.

By responding to demands for improved operating efficiency and higher quality of manufacturing systems, and by supporting future requirements for fewer human operators and for equipment replacement with succeeding generations, the role of instrumentation and control systems will become even more important.

Fuji Electric intends to continue to strive to provide customers with optimal solutions.

New Process Control System for a Steel Plant

Toru Ohshima
Mototaka Oomori

1. Introduction

The global demand for steel, especially in Eastern Asia, has been increasing rapidly in recent years. Japanese steel manufacturers, dependent on the healthy automobile industry, are transitioning from general steel material to high-class steel material, while preserving the crude steel production amount.

Large-scale capital investment for the renovation of blast furnaces at each plant has been completed, but the renovation and improvement of aging facilities is ongoing, and planned spending on capital investment projects has been revised upward for 2005. As a result, although demand for distributed control system (DCS), which forms the core part of the control system of a steel plant, is low in new plant construction, demand is expected to increase for the renovation of aging plants.

This paper describes an example application of Fuji Electric's MICREX-NX new process control system to a steel plant.

2. Characteristic Features of Steel Plants

2.1 General description of a steel plant

Typically located on a large compound and comprised of various facilities, steel-working plants consume large amounts of supplies and services (including water, energy, and the like). The plant processing is subdivided into the categories of iron making, steel making, and rolling. In the iron making process, iron ore is melted by hot air blown into a blast furnace, with coke as a reducing agent, to produce hot metal. Next in the steel making process, in a basic oxygen furnace (BOF), carbon is removed from the hot metal, and alloy elements are mixed in as necessary to form non-brittle molten steel, which is then cast. In the rolling process, the intermediate cast product is formed into various steel products such as heavy plates, thin plates, various shapes, steel pipes, and so on, and is surface-treated (plated, coated, polished) to form a finished product.

A steel plant is configured from tens of different types of equipment, each of which is controlled independently by a control system. Moreover, each control system is connected via a host computer to the main system (production management system) so that production plans can be managed comprehensively for the entire facility.

2.2 Challenges for steel plant DCS

The steel industry was one of the first manufacturing industries to adopt computer-based control and information control systems. Fuji Electric delivered its first DCS, the central part of a control system, in 1977 to a continuous casting facility at a steel plant. Subsequently, as steel plants developed, Fuji Electric's DCS also evolved, and Fuji Electric began selling the MICREX-NX in 2004 as a 5th generation DCS. A control system is configured from DCS, programmable controller (PLC) for electronic control, and computer for production control and for connecting to the main system.

Present challenges facing the DCS required by steel plants are described below.

(1) Steel plants are configured from many different types of equipment. Moreover, facilities are often expanded on a small-scale in order to improve product quality and productivity, and in doing so, many various control systems are installed additionally, thereby increasing the complexity of the configuration. Consequently, DCS is required to be easily connectable to control systems and devices made by different manufacturers, and to be capable of constructing a control system that can be connected to old DCS made by different manufacturers in an existing system.

(2) Steel plants operate continuously for 24 hours per day, and DCS downtime must be avoided in order to maintain stable and safe operation. However, in the case where the plant is down, the DCS must ensure fail safe facility and help to minimize the downtime.

(3) When updating an existing DCS, it is required that existing hardware and software assets can be utilized effectively, and that they can be replaced in minimal time.

(4) Equipment maintenance plays an important role in ensuring stable operation of a steel plant. Stable operation and efficient maintenance are required of DCS.

3. Example of MICREX-NX Application to a Steel Plant

Fuji Electric has delivered many DCS, mainly to steel plants, and claims Japan's top market share in control systems for BOF processes at steel plants. Below, an example of MICREX-NX application to a BOF process is presented and Fuji Electric's latest control system technology is described.

3.1 Construction of a MICREX-NX-based BOF control system

The BOF process is configured from many sub-systems, including top blowing and OG (oxygen converter gas recovery) equipment, a bottom blowing equipment, a lance hoist, a sub-lance equipment, a ferro alloy charging equipment, a flux charging equipment, etc. Table 1 shows the relationship between operation of the BOF process and the equipment used.

Control systems for different sub-systems are often configured of DCS and PLC from many different manufacturers, and a BOF DCS must seamlessly connect to the control system for these sub-systems and provide integrated monitoring and control.

The MICREX-NX enables the configuration of a control system that horizontally integrates these sub-systems. The functions necessary to construct the control system are described below (with reference to Fig. 1).
(1) A DCS (MICREX-PⅢ/ⅨX/AX) for an existing BOF can be connected via an operator station (OS) server to an existing control LAN (DPCS-F/FL-net compliant LAN). As a result, an existing DCS can also be monitored and operated from a new OS, thereby realizing the integration of both old and new DCS.
(2) By using P/PE-link and T-link link devices, existing devices such as a remote I/O device (FTU, FTK) and PLC (MICREX-F) can be connected directly to an automation system (AS).
(3) DCS made by other companies can be connected via the OS server to a JIS FL-net*1.
(4) PLC that has been delivered by other equipment manufacturers can be connected with an AS and a general-purpose LAN (Ethernet*2), or with a PRO FIBUS-DP.
(5) The process computer can be connected, via a process computer server on the terminal bus, to an Ethernet.
Connection can be made with a conventional socket communications interface protocol, or with OPC*3 transmission, which is a Windows*4 standard interface.

*1: FL-net is a network developed by JEMA.
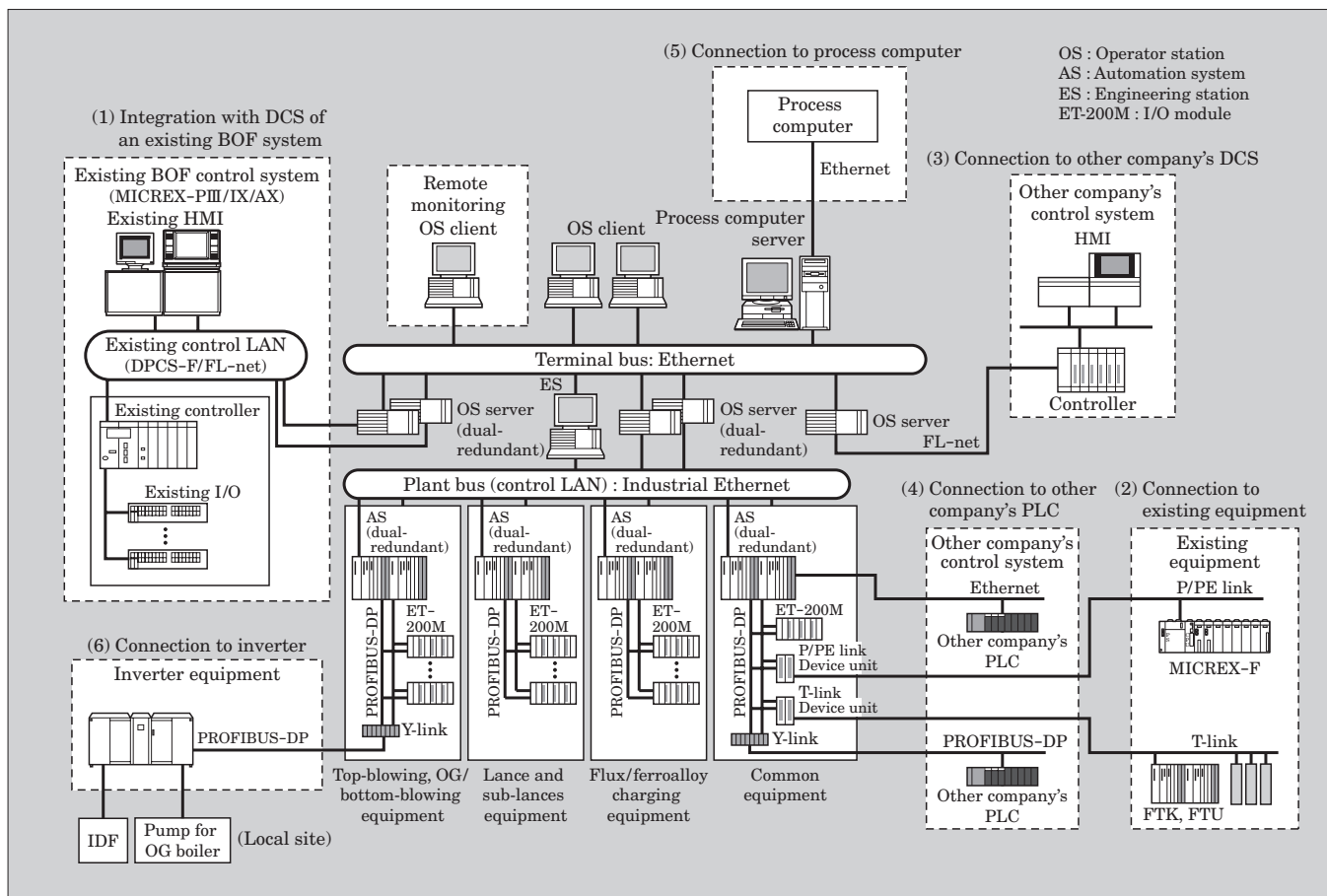*2: Ethernet is a registered trademark of US-based Xerox Corp.
*3: OPC is a registered trademark of US-based Microsoft.
*4: Windows is a registered trademark of US-based Microsoft.

Table 1   BOF operating processes and main equipment used

Operating process	Control / function	Equipment used	Overall equipment
Standby	Preparation for charging at an early stage	Flux charging equipment	
	Weighing of specified quantity of main raw material	Hot metal and scrap weighing equipment	
Charging of main raw material (hot metal, scrap)	Change flow rate of bottom gas blowing	Bottom blowing equipment	
	Static model calculation	Process computer	
Blowing	Control of lance height, oxygen flow rate and bottom gas blowing flow rate according to blowing pattern	Lance hoist equipment, top blowing equipment, bottom blowing equipment	
	Inactive zone constituting control, exhaust gas recovery control	OG equipment	
	Charging of slag-making material, charging of coolant, charging of sloping-preventative material	Flux charging equipment	
	Measurement of molten steel temperature, free oxygen concentration in molten steel, and carbon content	Sub-lance equipment	
	Dynamic control, blowing stop control	Process computer	
Tapping (final product adjustment and discharging)	Charging of ferroalloy	Ferroalloy charging equipment	

Fig.1 Example configuration of control system

(6) The inverter driving the IDF (induced draft fan) of a BOF and the pump associated with an OG boiler can be connected directly to a PROFIBUS-DP and controlled from an AS.

3.2 Ensuring high reliability and safety while maintaining stable operation

The BOF process encompasses multiple sub-systems, and the control system often becomes bulky in size. Stopping the operation of even one sub-system will lead to stoppage of the entire BOF process, and because the system is located upstream in steelworks, the impact on the entire steelworks will be large. Moreover, because large quantities of hot molten material and highly pressurized explosive gas are handled, a system malfunction can result in a major accident. For these reasons, high reliability and safety are required of the DCS of a BOF.

(1) Dual-redundancy of AS

Since the dual-redundant CPU switching time is short (30 ms) for an AS of the MICREX-NX, switching has no adverse effect on operation. Additionally, CPU modules can be replaced while online, without having to stop operation. After replacement, program and data information is automatically loaded from the driving system CPU to the replacement CPU in order to eliminate operational mistakes. The CPU, of course,

is able to support dual redundancy by selecting only required elements, including I/O devices and the I/O bus, and thus dual redundancy can be constructed in a highly cost effective manner.
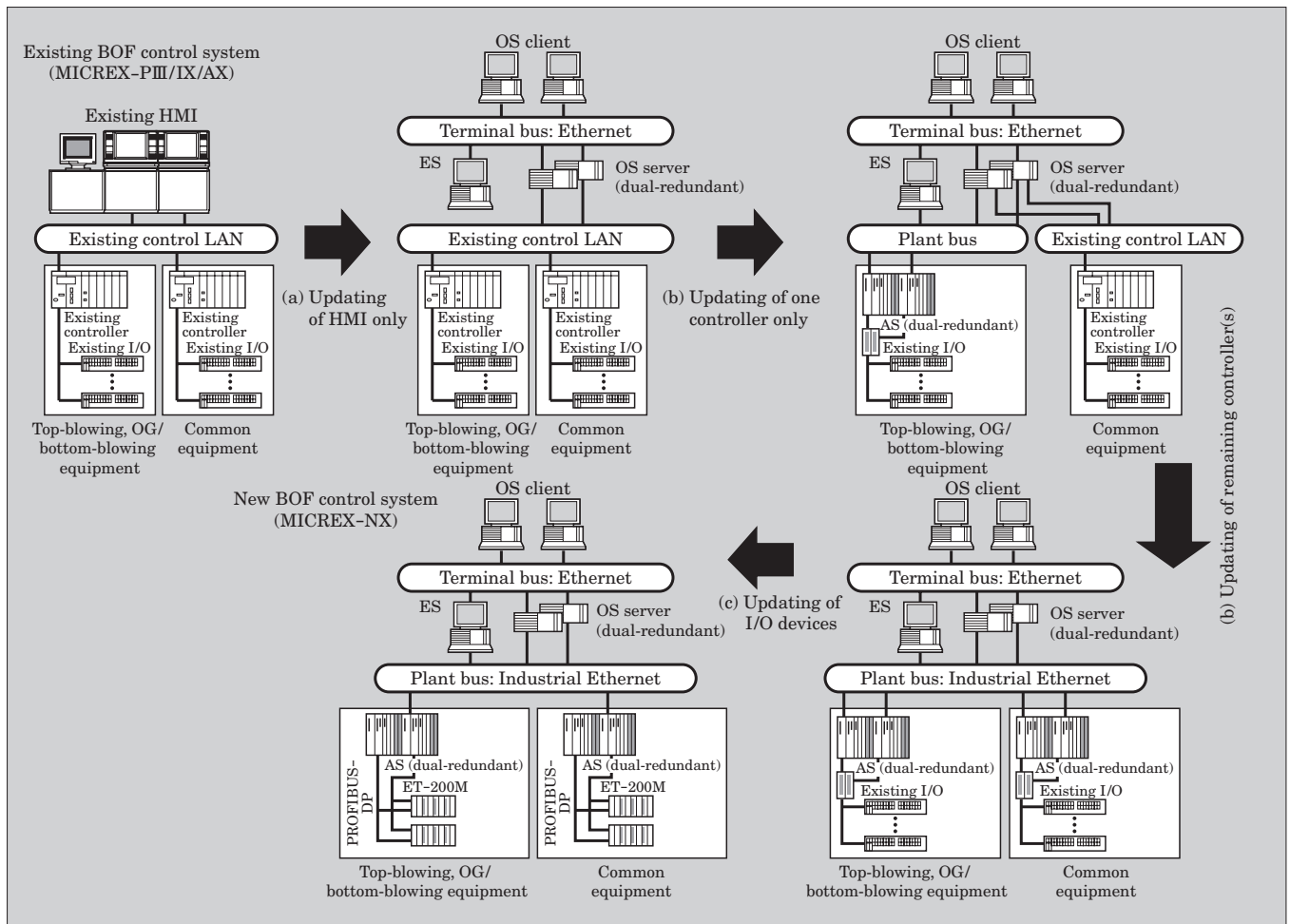
(2) Safety instrumentation system

The MICREX-NX conforms to the IEC 61508 international standard, and provides a safety instrumentation system that is compliant with SIL3 (safety integrity level 3), and should an error occur, is capable of running the processes in a safe state.

The top blower and OG equipment that operate under hazardous conditions because they handle explosive gas have previously been configured with an emergency shut-off outlet jig at the hardwired circuit for relay board backup, but with the MICREX-NX, a safety mechanism, should an error occur, can be configured with AS and I/O devices only.

With the MICREX-NX safety instrumentation system, a standard control program and a safety control program can co-exist within the same AS, and can be programmed with the same engineering language as used with a standard controller. Also, dedicated I/O modules for the safety instrumentation can run on the same PROFIBUS-DP as standard I/O modules, and both the AS and I/O can be constructed with a dual-redundant configuration.

By combining the safety instrumentation system

Fig.2 Example method for updating existing DCS

with a dual-redundant configuration, the BOF DCS is able to ensure safe operation of the plant and high reliability.

3.3 Method of updating DCS of an existing BOF

(1)　Partial updating of the DCS

The MICREX-NX provides a mechanism for maximizing effectiveness of a user's existing DCS, while also enabling partial updating of that DCS. Figure 2 shows an example of the updating method.

(a) Updating of HMI (human machine interface) only

(b) Updating of controller (continued use of existing I/O devices)

One controller can be updated, and a combination of new and old controllers can be used simultaneously. At such a time, the continued use of existing I/O devices is permitted.

(c) Updating of I/O devices

(2)　Method of updating controller within a short amount of time

The BOF process normally encompasses two or three BOFs, and the equipment shared among these furnaces. Each BOF stops for approximately 1 to 2 months for refractory maintenance, but the shared

equipment only stops for approximately 1 day, and therefore the controller updating must be implemented quickly, within a short amount of time.

The use of an existing external signal cable and connector terminal to perform onsite updating work quickly is described below with the example shown in Fig. 3.

(a) Advance preparation

During construction of a new AS locker, a connector converter plate is attached to connect the connector terminals of existing external signal cables to the new I/O devices, and a cable for trial run is prepared to connect the connector terminals of the existing external signal cable to the new connector converter plate.

Additionally, new temporary lockers are constructed for the AS and I/O devices. If there is no available space for the temporary structures, an easily moveable rack may be used.

(b) Trial run when operation is stopped

With the cable for trial run and the connector converter plate, the new I/O devices capture existing external signals, and trial runs that can be completed within the stoppage time are implemented.

(c) During operation (before completion of trial run)

Fig.3 Example method for updating existing equipment controller

(a) Advance preparations | (b) Trial run when operation is stopped

(d) After completion of trial run | (c) During operation (before completion of trial run)

After completion of a trial run, the trial run cable is removed from the existing locker, the original state is restored and operation implemented with the existing DCS.

The operations in (b) and (c) are repeated until all trial runs are completed.

(d) After completion of trial run

After all AS trial runs are completed, the locker is switched over and the connector terminal of the existing external signal cable is connected to the new locker connecter terminal.

By modifying and attaching existing lockers for the new AS and I/O devices, the work involved in constructing and installing new lockers can be eliminated. The decision of whether to replace a locker or to modify an existing locker is made by verifying the installation status of existing lockers and the status of attached existing controllers and I/O devices, and then choosing the method that saves the most time and cost.

(3) Updating of application software

In order to effectively utilize a user's existing as-

sets, application software is converted and a library of individual control functions is created for OS software and AS software so as to enable software to be created more efficiently and with higher quality.

3.4 Efficient maintenance that maintains stable operation

(1) In the control of a BOF comprised of multiple sub-systems, when a process malfunction occurs, it is necessary to have the ability to identify quickly the cause of the malfunction from among a large quantity of sub-system information.

The MICREX-NX is able to synchronize timings across the entire DCS, and applies a time stamp with 10 ms precision to various events and I/O signals, thus helping with the rapid analysis of a root cause when a malfunction occurs.

(2) Because the AS is capable of implementing electronic control, for which rapid response is required, simultaneously with process control, all equipment controllers can be standardized to the same model. Thus, fewer different types of parts are needed for maintenance and the maintenance work becomes more efficient.

(3) DCS printed circuit boards, depending on their installed location, are affected by dust and corrosive gas, and may age prematurely. With the MICREX-NX, the printed circuit boards are coated in accordance with the environment in which they used, thereby extending the useful service life of components.

(4) Maintenance procedures for the MICREX-NX can be provided as a combination of DCS-appropriate menus, selected from a wide range of service menus (such as present state diagnostics, preventative maintenance, corrective maintenance, etc.)

4. Conclusion

The MICREX-NX was developed as the foundation for a control system having a successful track record of more than 4,000 delivered systems. In Japan, DCS that conforms to various international and overseas standards is able to realize highly reliable operation.

Responding to user needs, Fuji Electric intends to continue to provide DCS that utilizes the improving operational safety and efficiency of steel plants.

New Process Control Systems in the Energy Sector

Yasuo Inamura

1. Introduction

The energy sector (thermal power plants, geothermal power plants, and the like) is transitioning at a rapid pace resulting from broader deregulation of the electric power industry, the rapidly increasing price of crude oil, and the reduction of global greenhouse gas as mandated by the Kyoto Protocol. Influenced by these trends, control systems in the energy sector are becoming more cost effective, and advancing towards greater reliability, globalization and the use of open standards.

Under these circumstances, Fuji Electric released the MICREX-NX new process control system in September 2004.

This paper describes the need for information control systems in the energy sector, and, as examples of actual applications that use the MICREX-NX, introduces a boiler control system for an independent power producer (IPP) by way of Mitsui Engineering and Shipbuilding (hereafter abbreviated as MES), and a geothermal power plant control system to be deployed in Iceland.

2. Trends of New Process Control Systems in the Energy Sector

2.1 Circumstances surrounding the energy sector

(1) Further deregulation of the electric power retailing market

As of 2005 in Japan, with the deregulation of the electric power retailing market, the range of PPS (power producer and suppliers) was expanded to 6,600 V and 50 kW or more, and transfer charges have been eliminated when supplying power across the service areas of power companies. As a result, market competition has been more severe.

(2) Greenhouse gas emission credits

With the reduction in global greenhouse gases as mandated by enactment of the Kyoto Protocol, the buying and selling of greenhouse emissions credits is accelerating. It is much more effective to acquire emission credits abroad, in countries working toward energy conservation, than in countries where energy conservation measures have already been advanced,

and this is expected to the construction of geothermal power plants, natural gas thermal power plants and the like overseas.

(3) Further reduction of fossil fuels

West Texas Intermediate (WTI) crude futures in April 2006 rose rapidly to more than $72 per barrel as the result of increased demand from China and India, the Iraq war, and so on. The trend toward a reduction in fossil fuels (and new energy development) is expected to continue in the future.

2.2 Need for new process control systems in the energy sector

(1) Highly reliable and cost effective systems

Under the present conditions of intensifying competition due to the deregulation of the electric power retailing market, new process control systems are required to provide even higher reliability and cost effectiveness than in the past.

(a) Instead of the controller in a conventional custom distributed control system (DCS), general-purpose, highly functional and highly reliable programmable controllers (PLC) are being used as components, to ensure the overall functionality, performance and reliability of the system product.

(b) Total cost is being reduced through the use of open standards technology, lower expenses through mass-production, and by accumulating technology and expertise that can be reused over the long-term.

(2) Lower total cost of ownership (TCO)

In addition to lowering the initial investment, reducing the costs of maintenance, equipment updating, and the like will help to decrease the TCO.

(3) Promotion of reusable software

Fuji Electric has a successful track record of delivering many boiler control systems, and has accumulated much technical expertise in automation, labor savings, optimal operation, operational and maintenance support, equipment diagnostics, and the like. New process control systems must facilitate the reuse of this expertise, so as to provide that expertise to the user.

(4) Globalization

In the summer of 2006, the Japanese government launched a plan whereby Japanese companies, in cooperation with other companies involved in reducing greenhouse gas emissions of developed countries, can purchase greenhouse gas emission credits, and as a result, Japanese companies are accelerating their overseas efforts for reducing greenhouse gas emissions. Also, capital investment is increasing in Southeast Asia and the so-called BRICs (Brazil, Russia, India and China) where high economic growth is continuing.

Therefore, process control systems for the energy sector are not only required to have English-language specifications, but also must be global systems for which parts can be procured and maintenance service performed overseas.

3. Example Applications of the MICREX-NX New Process Control System

3.1 The features of MICREX-NX

This section describes the advantages of using the MICREX-NX as a new process control system in the energy sector.

(1) Highly reliable system

The MICREX-NX enables the configuration of a control system having high reliability and availability by cross multiplying redundant transmission lines, operator stations (OS), servers, and controllers (AS: automation systems). Moreover, a dual-redundant AS uses an event synchronous method and is applicable to plants that do not permit even a short-term stoppage of the control operation.

(2) Software library

Fuji Electric's acquired energy sector expertise (programs) can be stored in libraries with a simple copy-and-paste procedure, and then reused.

Main examples of the software library are listed below.

- ○ Unit master controller, boiler master controller
- ○ ACC (boiler combustion control)
- ○ Feed water control, reactor pressure control, main steam temperature control
- ○ Boiler local control, turbine local control
- ○ Burner automatic control

(3) Support of globalization

The MICREX-NX or Siemens' PCS7 may be selected for overseas destinations. After delivery, Fuji Electric's overseas base or Siemens' after-sales service network, scattered throughout the world, may be used for maintenance servicing.

(4) Effective use of customers' assets

When updating existing control equipment made by Fuji Electric, a customer's hardware and software may continue to be used while changing over sequentially to a MICREX-NX-based system. Thus, customers' assets can be utilized effectively and changed over to the latest control system.

(5) Other

A time stamp function that reads digital input (DI) data at high-speed and is capable of time management can be used as a high-speed fault recorder for a power plant, and is useful in the first analysis of failure factors if an accident occur. Moreover, in the future, safety control systems will be used in protective circuits such as the main fuel trip (MFT) circuit of a power plant.

3.2 Example delivery to an IPP

(1) Facility overview

This plant is the largest biomass power plant in Japan that uses scrap chips of construction material as fuel. The plant was built by MES and is operated by an IPP.

Scrap chips of construction material are purchased from biomass raw fuel vendors and fuel suppliers established by waste disposal companies in the Tokyo metropolitan area, and electric power is generated by fluidized bed boilers and steam turbines using refuse paper and plastic fuel (RPF). The entire output of 50,000 kW is sold to the Tokyo Electric Power Co., Inc. The plant is scheduled to operate for 345 days per year.

Moreover, this plant is expected to become a large-scale business model for new energy, from input to output, in accordance with the Renewables Portfolio Standard (RPS). Figure 1 shows a portion of a new process control system prior to shipping.

(2) System configuration

This system uses the MICREX-NX new process control system. Figure 2 shows the system configuration. Operation is basically implemented with a desktop type human communication interface (HCI). The controller realizes high reliability through dual-redundancy of the control unit and power supply.

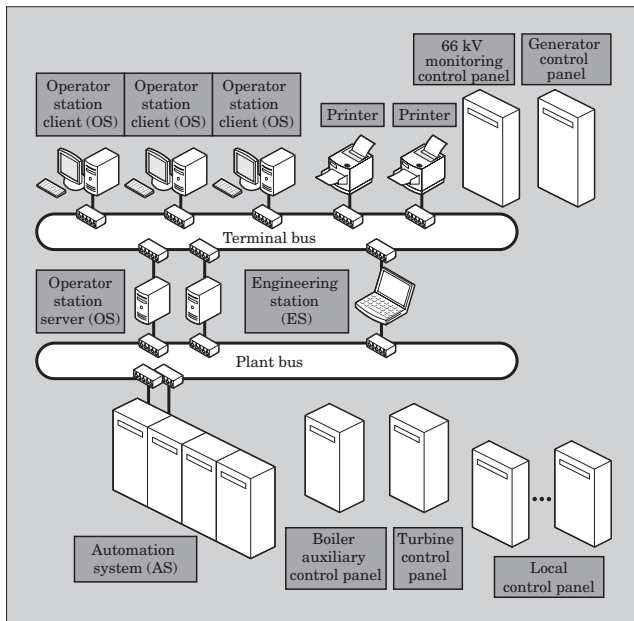A functional overview of main component devices is listed below.

(a) Automation system (AS) (dual redundancy): 1 set

Automated boiler control (ABC) and local control are realized on a single station.

Fig.1 MICREX-NX panels for an independent power producer

Fig.2 Configuration of control system for an independent power producer

Fig.3 Overview of basic control system for an independent power producer

(b) Operator station (OS): 3 units

An OS is an HCI from which the operator is able to monitor and operate the equipment. The following monitoring and operation is performed with an OS.

- ○ Loop monitoring and operation
- ○ Auxiliary mode selection and start/stop operation
- ○ Equipment monitoring via a graphic screen

(c) OS server (dual redundancy): 1 unit

The OS server enables central control of process data, alarms, operating history and other plant data.

(d) Engineering station (ES): 1 unit

The ES generates and modifies control programs for the controller, graphic screens and logging forms.

(e) Boiler auxiliary control panel: 1 set

This control panel has an MFT relay circuit to stop the equipment safely, even in cases where the DCS is functioning abnormally.

(f) Turbine control panel: 1 set

(g) Power generator control panel: 1 set

(h) 66 kV monitoring control panel: 1 set

(i) Local control panel: n sets

(3) System features

Figure 3 shows an overview of the basic control system. For fuel, this plant uses building scrap material, the properties of which can vary. The following control is implemented to improve the efficiency of the power generation.
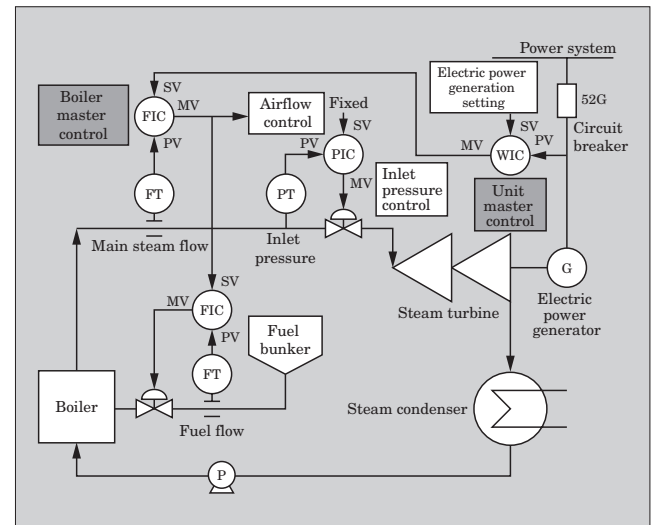
(a) Unit master control

The output of a provided power generation control adjusts the quantity of calories burned by the boiler.

(b) Boiler master control

In order to maintain the required quantity of calories for the boiler, even when the fuel properties vary, a main steam flow control is provided as the boiler master control.

Moreover, the boiler outlet main steam pressure is adjusted with the turbine inlet pressure control, and the output of the power generator is determined by the values set for the boiler unit master. With the exception of the power used by the power plant itself, the total amount of generated electric power is sold to the Tokyo Electric Power Co., Inc.

3.3 Example delivery to a geothermal power plant in Iceland

(1) Facility overview

Geothermal power creates electricity by using a turbine generator with steam that has been separated from hot water and steam emitted from a drilled underground steamwell. Geothermal power is an energy source that is friendly to the global environment and that emits almost no CO_2 gas, which is a cause of global warming. Iceland is the world's leading user of geothermal heat as a natural energy source, and geothermal power accounts for approximately 15 % of the Iceland's domestic electric power energy. Recently, a geothermal power plant was newly constructed in Reykjanes, which is located approximately 20 km from the Svartsengi Geothermal Power Plant. Fuji Electric received orders for a turbine, electric power generator and electric instrumentation to equip this new plant, and has successfully delivered that equipment. Figure 4 shows a view of the entire Svartsengi Geothermal Power Plant that will operate the Reykjanes plant.
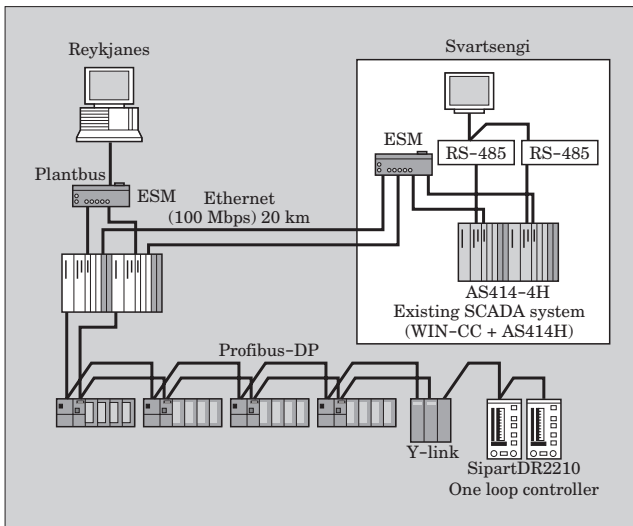
(2) System configuration

Two sets of new process control systems were delivered to Reykjanes. The main component devices for one set are listed below. Figure 5 shows the system configuration.

(a) PCS7 OS single server × 1 station

Fig.4 View of geothermal power plant in Iceland (Svartsengi Power Plant)

Fig.5 System configuration of geothermal power plant in Iceland

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*1: P-CIM is a registered trademark of AFCON Software & Electronics Ltd.

*2: Ethernet is a registered trademark of Xerox Corp.

(b) PCS7 AS control station × 1 station
  ○ CPU: dual redundant
  ○ I/O: single
  ○ I/O bus (PROFIBUS): dual redundant
(3) System features
  (a) Can be operated from an existing system made by Siemens
    The existing monitoring and control system of the Svartsengi Geothermal Power Plant is configured from a supervisory control and data acquisition (SCADA) system known as P-CIM*1 and an S7 controller made by Siemens. Operation and monitoring of the new process control system of the newly built Reykjanes Geothermal Power Plant are also implemented from the Svartsengi Geothermal Power Plant, located 20 km away. For this reason, the Reykjanes control system uses Siemens' PCS7. Moreover, connection to the Svartsengi Power Plant is implemented with an Ethernet*2 connection, via the Siemens' S7, to configure a system capable of easily operating and monitoring the Reykjanes control system from the Svartsengi Power Plant.
  (b) Use of high-speed fault recording
    For the fault analysis in the case of a turbine trip, a digital input module is used that is capable of time stamping the main signals with 10ms accuracy.
  (c) Time synchronization
    The system time of the Reykjanes Power Plant is synchronized to the time received from the time stamp of the existing Svartsengi Power Plant.

4. Conclusion

Recent trends of the latest process control systems in the energy sector have been discussed and an overview of examples of delivered systems that use the MICREX-NX have been presented. Fuji Electric will continue to adapt to meet the diverse needs of our customers, and to develop and supply high value-added new process control systems to the energy sector.

Network Wireless Sensor for Remote Monitoring of Gas Wells

Tetsuro Kurita
Takumi Gunji

1. Introduction

A rapid increase in the global demand for natural gas is being watched with keen interest due to the resource issue and international politics feud etc., and meanwhile, it advances the infrastructure equipment relating to the production and transportation and gives a considerable impact on the industrial world as well. It is prospective that such circumstances will be prolonged, and the huge investment to the downstream sectors such as LNG chains is intensifying the world's engineering companies and measurement manufacturers' activities. However, if the upstream sectors also pay attention to natural gas production sites, it has to say that the technical ability and total amount of investment input are relatively limited, and there are still many gas wells either ① no any measurement, or ② depending on mechanical type (disk) recorders and human-wave tactics, existing. Only a few gas wells ③ having a large production output are being monitored intensively with the traditional SCADA (supervisory control and data acquisition) system. It is said that the average downtime of gas wells around the world is 10%, and the improvement of production efficiency has become an important issue. With utilizing the sensor technology to monitor gas wells, Fuji Electric is aiming to improve production efficiency.

Canada, ranked 18th in terms of natural gas reserves, has become the most advanced country of remote monitoring, because it has been sensitive to the issue of resource saving and pursuing production efficiency from the earlier date. Fuji Electric has co-operated with a Canadian venture company to develop state-of-the-art devices for remote monitoring since it was aware of the tendency of the market 4 years ago. The partner, Zed.i Solutions Inc., regards ① the networking technology that enables to monitor gas and oil over an extremely wide area under N:N, ② providing unlimited expandability and high security to the transmitting and receiving sides, ③ a seamless

*1: LNG chain: The sequence, including production and transportation, from the gas field to the user. (LNG: liquefied natural gas)
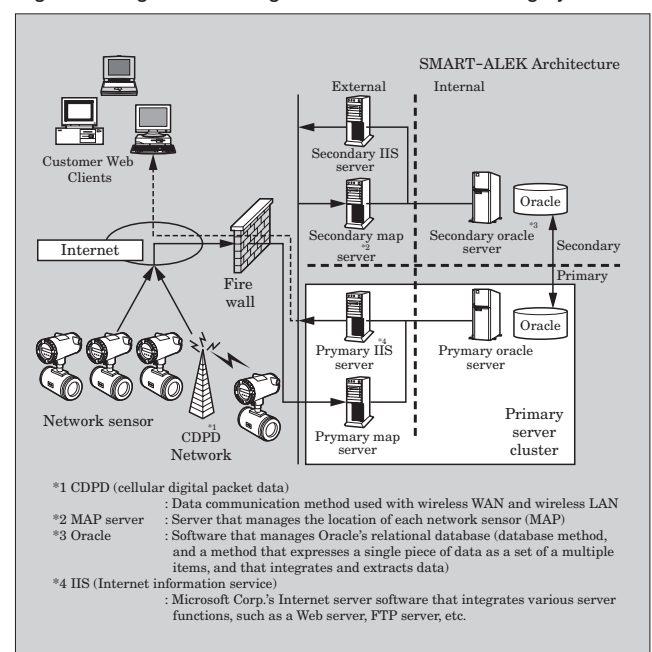
line without an intermediate system (such as SCADA host computer) become more briefly, and ④ the real explosion-proof wireless field device which is the only one of its kind in the world using the world's No. 1 low power-consumption sensor, as differentiating factors, and supplies business tools that are directly connected with operation, finance and management program for natural gas fields.

2. Outline of Network Wireless Sensor for Remote Monitoring of Gas Wells

2.1 Gas wells remote monitoring system

The network sensor for gas wells monitoring is a wireless field device equipped with an intelligent function for measuring the gas well flow rate. This wireless network sensor (WNS) was designed as an exclusive terminal for Zed.i Solutions' gas well monitoring systems. The sensor has its own networking terminal and IP (Internet protocol) address, and operates automatically to retain data even if communication being inter-

Fig.1 Configuration of a gas well remote monitoring system

*1 CDPD (cellular digital packet data)
: Data communication method used with wireless WAN and wireless LAN
*2 MAP server : Server that manages the location of each network sensor (MAP)
*3 Oracle : Software that manages Oracle's relational database (database method, and a method that expresses a single piece of data as a set of a multiple items, and that integrates and extracts data)
*4 IIS (Internet information service)
: Microsoft Corp.'s Internet server software that integrates various server functions, such as a Web server, FTP server, etc.

rupted. The network sensor forming the basis of the gas well monitoring system has a main function that is to convert the physical parameters of pressure and temperature of each well into digital information. Gas well information is stored in the network sensor, and then transmitted via public wireless or satellite-based communications to a network server. The gas well monitoring system enables end users to monitor, measure and analyze the performance of their gas wells and pipelines in real time via an end user interface. In addition, the monitoring system can be configured to send alarms remotely so that an operator can quickly ascertain and respond to problems when an alarm occurs. Because the gas well monitoring system is web-based, data can be accessed and utilized by the end user at any time.

Figure 1 shows the configuration of a gas well remote monitoring system.

In a gas well monitoring system, field devices communicate with a network server via a public wireless network or satellite-based communications and the Internet, and the end user is connected to the network. The gas well monitoring system implements the following basic functions.
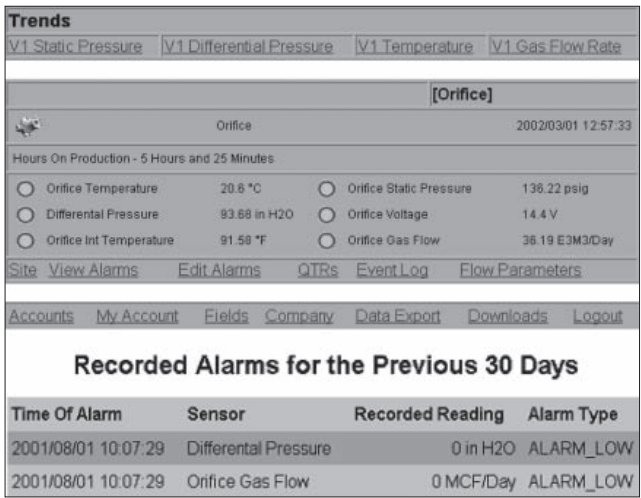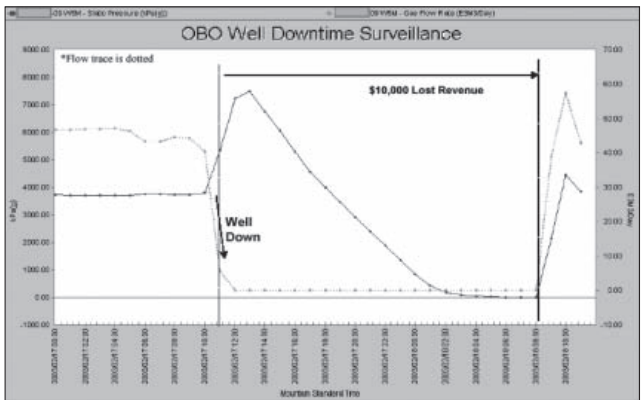
(1) Measurement of gas well pressure, flow rate and

temperature

(2) Transfer of data from the network sensor to the main network database

(3) Provision of raw data and computed information to the end user via the Internet

Figure 2 shows the user interface and Fig. 3 shows the historical trends of gas well monitoring systems.

Monitoring points that are equipped with a network sensor indicate not only the flow rate at the time of measurement, but can also show instantaneously the historical trends, alarms, recovery history, and the like, and can be used to ascertain the amount of remaining well reserves, lifespan, and so on.

For network sensors, Fuji Electric has been supplying the FCX-A II series of high-precision pressure sensor units and the associated interface unit to Zed.i Solutions.

2.2 V2X network sensor

The Version 2.0X (V2X) gas well monitoring system network sensor, newly developed in collaboration with Zed.i Solutions, inherits all the functionality of the previous Version 2.0 sensor, and an additional feature is the modification of the explosion-proof construction, that is, the previous pressure-resistant explosion-proof structure has been changed to an intrinsically-safe explosion-proof structure, and is made to be lighter in weight and low price, in support of the price likely-to-intensify competition among monitoring systems in the field of natural gas production. Just like Version 2.0 sensor measures the pressure, flow rate and temperature of a gas well or pipeline, stores the measured values, and then transmits those values reliably via a public wireless communications network to a network server. Since the V2X is used in hazardous locations where there is the risk of explosion, Canada's explosion-proof certification has been acquired. At present, the V2X is the world's only wireless field device rated at class 1 and division 1 explosion protection, which is

Fig.2 Web user interface

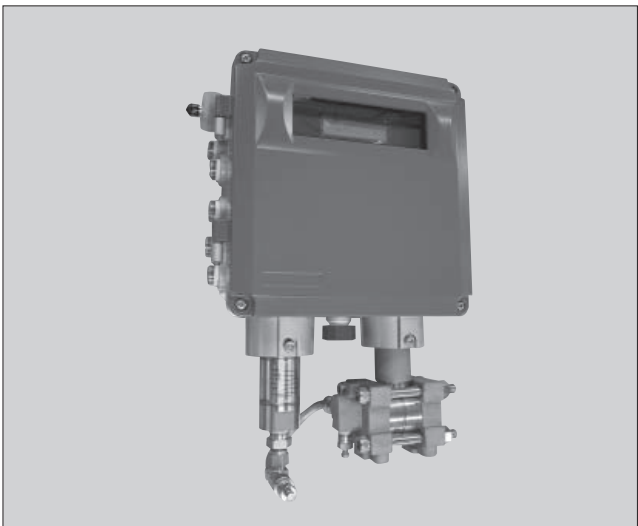Fig.3 Historical trends of gas well remote monitoring systems

Fig.4 External view of V2X network sensor

Table 1 V2X specifications

Service	Measurement of gas and oil flow rate		
Measurement range	Type	Pressure range	Differential pressure range
	FZA022	0 to 500 kPa	0 to 6 kPa
	FZA032	0 to 3 MPa	0 to 6 kPa
	FZA023	0 to 500 kPa	0 to 32 kPa
	FZA043	0 to 10 MPa	0 to 32 kPa
	FZA053	0 to 17.24 MPa	0 to 32 kPa
	FZA045	0 to 10 MPa	0 to 130 kPa
	FZA055	0 to 17.24 MPa	0 to 130 kPa
Materials	Diaphragm : 316L stainless steel Process cover : 316 stainless steel Bolts and nuts for process cover : Carbon steel Fill fluid : Silicone oil O-ring : Viton		
Mounting method	Pipe mounting (using bracket)		
Output signal	Public wireless (CDMA) or RS-232C for satellite-based transmission		
External I/O signals	Resistance temperature detector (4-line type) RS-485 (well head pressure gauge, turbine meter, etc.) Status input : Contact (2 contacts) Pulse input : Open collector (1 contact) Contact output : 1 contact		
Power source	Solar panel and rechargeable battery (capable of transmission up to 7 days without solar panel power input)		
Power consumption	3 W or less (during transmission)		
Intrinsic safety	CSA intrinsic safety Class 1 Div 1 Group C, D T3 (−40 to +60°C)		
Enclosure type	JIS C 0920 spray-proof type IEC IP56		
Mass	Approx. 12 kg		
Operating temperature	−40 to +60°C (main unit) LCD display : −20 to +60°C Modem : −20 to +60°C		
Humidity limit	95 % RH or less		

Table 2 V2X performance

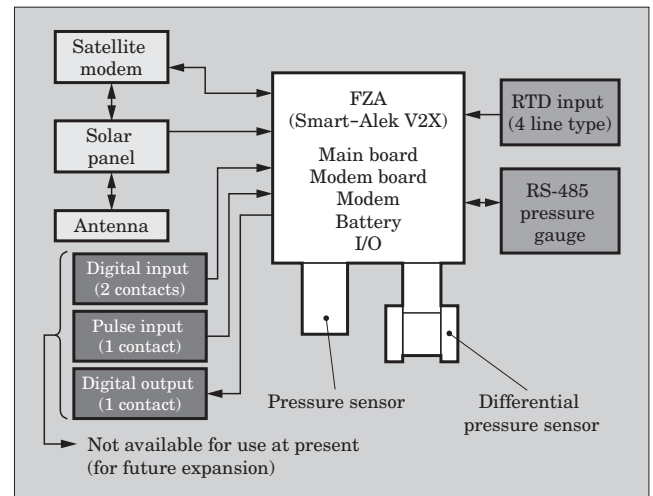| Accuracy	±0.1 % URL : Differential pressure sensor and gauge pressure sensor ±0.25°C/25°C (room temperature) : Resistance temperature detector (RTD) input (4-line type)
Supply voltage effect	±0.1 % URL : DP sensor, GP sensor ±0.25°C : RTD (battery voltage 6 to 8 V DC)
Current consumption	2 mA or lower (during standby) 500 mA or lower (when active)
Radiated EMI	FCC part15, ClassA

the highest level of explosion protection, and having intrinsically-safe explosion protection. Figure 4 shows the external appearance of the V2X network sensor for gas well monitoring systems.

The V2X network sensor operates with a rechargeable battery and a solar panel. Peripheral devices include the solar panel, an antenna and a resistance temperature detector (RTD). A characteristic of field devices is that they can be installed or replaced by one

Table 3 V2X functions

Wireless communication	CDMA : Data rate : 115.2 kbps RF power : 300 mW (typ.) Frequency : 824 to 893 MHz (cell phone) Operating temperature : −20 to +60°C Satellite : Data rate : 19,200 bps (RS-232, modem is installed separately)
Diagnostic function	Low battery voltage, internal temperature, sensor failure
Setting function	Re-range, LCD display (external switch), calibration
Data collection	Data collection for up to 35 days

Fig.5 V2X functional block diagram

person in a short time, and can be set up and adjusted (configured) with a laptop computer. For implementing a low power operation, the network sensor itself controls a scheduling function that activates the network sensor communications link. When a user initiates remote communication with a network sensor, the network sensor is accessed in synchronization with a predetermined data transfer interval. The data transfer interval is determined and set according to the sampling requirements and the type of communications (public wireless network or satellite-based communications).

The sampling interval for measurement can be set to various values if it is not less than one second. The main specifications, performance and functions of the V2X are listed in Tables 1, 2 and 3, respectively.

Figure 5 shows a functional block diagram of the V2X.

The V2X is configured from a main unit, a solar panel, an antenna and an RTD input. The main unit consists of a main board that implements the processing measurement, communications and control, a modem board for the modem interface, a modem for use with public wireless networks, a rechargeable battery, and differential pressure and pressure sensors. Also, in case of satellite-based communications, an external

modem unit is provided instead of the main unit's internal modem. Digital I/O and pulse input are also provided for future expansion. The network sensor is a unique as a field device, and may be a WNS that is capable of measuring the gas well flow rate or an RTU (remote terminal unit) that transmits the collective measured values from several types of sensors (such as a well head pressure and turbine meter) that are connected simultaneously.

3. Conclusion

An overview of the latest network sensor technol-ogy for using in remote monitoring of gas wells has been presented.

Fuji Electric's mission is to provide excellent technology (unlimited expandability to the transmitting and receiving sides, seamless performance that eliminates the need for an intermediate system), highly reliable sensor technology (the world's leading low power consumption sensor), and field devices (world's only intrinsically-safe wireless field device), to contribute to the efficient utilization of energy, and to improve production efficiency.

Fuji Electric's Latest High Functionality Temperature Controllers PXH, PXG and PXR, and Examples of their Application

Nobukazu Hagioka
Hiroaki Awane

1. Introduction

In the temperature controller sector, as with burner control for small scale boilers and air conditioning control, general-purpose temperature controllers have been somewhat limited in capacity, and demand has been increasing year-by-year for middle-class controllers that support high-speed control and valve operation. Targeting this sector, in 2005 Fuji Electric introduced the PXG temperature controller, equipped with the world's top class of temperature control functions.

With the addition of the PXG temperature controller for middle-class applications to Fuji Electric's PXH high-speed high functionality temperature controller for the high-end sector and the PXR general-purpose temperature controller for the low-end sector, Fuji Electric has arranged a lineup of temperature controllers suitable for all temperature control applications.

The first half of this paper describes the latest high functionality temperature controllers and in particular, Fuji Electric's most recent model, the PXG. The latter half of this paper presents application examples of the PXH and the PXG.

Fig.1 Fuji Electric's lineup of high functionality temperature controllers
(top row: PXH, middle row: PXG, bottom row: PXR)

2. Overview of High Functionality Temperature Controllers

Figure 1 shows Fuji Electric's most recent lineup of high functionality temperature controllers, and Fig. 2 shows the relative positioning of these temperature controller models.
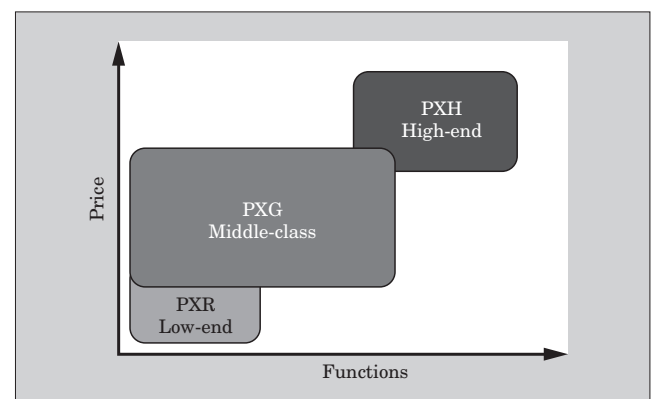
(1) PXH

The PXH is positioned as a high-end model that chiefly supports high-speed control of pressure, flow rate and the like. Responsive to the semiconductor production equipment sector where highly precise control is required, the PXH is a high-speed and high-precision temperature controller.

The cycle times for input sampling and control calculation are 50 ms, which is Fuji's fastest speed, and the temperature indicator has a resolution of 0.01°C.

(2) PXG

The PXG was brought to the market in August 2005, and is Fuji Electric's most recent high functionality temperature controller. This controller handles application in the wide area between the high-end PXH temperature controller and the low-end PXR temperature controller. Functionally, the PXG covers the range extending from a portion of the high-end area to the entire low-end area. The main feature of the PXG is its multi-functionality that supports nearly all tempera-

Fig.2 Map of Fuji Electric's latest high functionality temperature controllers

ture control applications.

(3) PXR

Since functions were added in August 2003, the PXR has enjoyed wide support as Fuji Electric's predominant temperature controller. Having a low price and equipped with the standard features of a self-tuning function and fuzzy control, the PXR supports a wide range of applications and permits the addition of such options as remote setpoint, heater break alarm, a communication function, and the like.

3. Features of the PXG High Functionality Temperature Controller

The PXG product line consists of three models, the PXG4 having front panel dimensions of 48 × 48 (mm), the PXG5 having dimensions of 48 × 96 (mm), and the PXG9 having dimensions of 96 × 96 (mm). These models have input sampling and control calculation cycle times of 200 ms (300 ms for the position feedback type) and their measurement input accuracy is ±0.3 % FS. The high performance of these models is comparable to that of prior temperature controllers. (See Fig. 3.)

The PXG inherits its hardware and internal construction from the PXR, which has a long track record of success. The control algorithm, which is the core software asset, is also inherited, but the PXG realizes enhanced peripheral functions and improved operability. (See Table 1.)

Representative functions of the PXG are introduced below. (See Table 2.)

(1) Control functions

In addition to functions for ON/OFF control, fuzzy control, self-tuning control, PID control and heating/cooling PID control that have equipped prior models, the PXG is also equipped with motor drive valve control, position feedback control, and 8 types control algorithm of PID2 control, and implements heating control with not only a heater, but also with steam, to support temperature control based on position feedback control. Moreover, after the completion of a batch

process, control stops, but temperature monitoring and temperature alarm functions often continue to operate in a temperature controller. For this type of application, the PXG is newly equipped with a control standby function that stops the control and PID2 control that helps to suppress overshoot upon return to the control loop (rise in temperature) from a standby state.

(2) 16-step ramp soak function

A ramp soak function with up to 4 patterns having 16 steps (32 segments) is provided as a standard function. This function is a simple programmed operating function. The PXG is also equipped with functions for continuous start mode upon return from a power failure, a guarantee soak function to compensate the control time of constant temperature sections, a PV start function, status event output, time signal event output, a delay start function that starts automatically when a certain amount of time has elapsed after power was turned on, a function for pattern switching based on digital input, and operational control, and the PXG specifications are comparable to those of a programmable controller.

(3) Soft start function

The PXG is equipped with a soft start function that suppresses the control output below a certain value for a predetermined amount of time. This function

Fig.3 Fuji Electric's PXG high functionality temperature controller

PXG9   PXG5   PXG4

Table 1 PXG control algorithm and features

Control algorithm	Features, application example, etc.
ON/OFF control (2-position control, 3-position control)	2-position control: simple ON/OFF control, 3-position control: Heating and cooling ON/OFF control (Used in equipment requiring not-high controllability and low cost.)
PID control	Used in control systems that include lead/lag factors. (Widely used for general temperature control.)
PID2 control	For a heating control system in which the control loop temporarily becomes an open loop, PID2 control can reduce the overshoot at the return to the control loop. (Used in batch furnace operations and the like.)
Fuzzy control	A fuzzy algorithm is used to improve overshoot and the disturbance response at the startup of a process. (Widely used for general temperature control.)
Self-tuning control	Self-tuning control automatically performs the PID tuning. Used when desired to reduce the labor involved in making adjustments. (Widely used for general temperature control.)
Heating and cooling PID control	Control is implemented using both heating and cooling. Used in control systems where heat is absorbed or generated due to the dissolution of resin and so on. (Used in plastics molding machines, etc.)
Motor drive valve control (servo control)	Implements motor drive valve control using a motor drive valve that is not equipped with a potentiometer. (Used in low-cost motor drive valve control systems.)
Position feedback control	Position feedback control receives positional information from a potentiometer and adjusts the valve position. (Used in flow rate control etc. in a plant.)

Table 2 List of new PXG functions

Function	Function summary
16-step ramp/ soak function	16-step (32-segment) large capacity program Usage may be split among up to 4 patterns. Continuous start possible upon return from a power failure. Guarantee soak, PV start Status may be output. Control may be based on a digital input.
Soft start function	Limits control output when power is turned ON for a certain amount of time. May start at an arbitrary time with a digital input trigger.
PID pallet (8 types)	8 groups of setting values (SV), PID setting Setting value (SV) and PID groups switchable as independent or linked. Switchable according to digital input or front panel user key.
Changeover of SV (8 types)	
Loop break alarm function	Capable of detecting control loop disconnection without an externally attached current transformer.
Load short-circuit alarm function	Using an externally attached current transformer, able to detect short-circuit of SSR and the like.
Event function (approx. 100 types)	Total of approximately 100 types of temperature alarms, timer operation and status events supported.
Digital input function (approx. 45 types)	Approximately 45 types of digital input functions supported.
Loader communication function	Provided with an RS-232C loader communication port. Custom loader software can be downloaded for free from the home page.
Digital input (5 points)	5 points can be provided for both digital input and output.
Digital output (5 points)	
Retransmission function	In addition to the 4 to 20 mA range, the voltage output is selectable. Voltage range can be switched from 0 to 10, 2 to 10, 0 to 5 and 1 to 5 V.
User key	User keys are provided on the front panel, and in addition to A/M switching, 27 types of functions may be assigned arbitrarily.
All displays off	Each parameter, including PV and SV, can be set arbitrarily for display or non-display. All displays off can also be specified.
Output designated function at fault	Control output during fault and during standby can be fixed to a designated value.
Output designated function during standby	
Startup mode select function	Control mode at startup is selectable from auto/manual/standby.
Universal input	Supports all types of input Supported with parameter switching only.

suppresses the current consumption of the equipment when power is turned on, and enables energy-saving operation. In control having multiple zones, this function corrects inter-zone fluctuation during startup. The soft start function can be activated when the power supply is turned on or at any arbitrary timing.

(4) 8-setting changeover and PID pallet changeover function

The PXG is capable of storing 8 groups of setup values (SV) and PID groups, and this function can be switched between synchronous and non-synchronous operation using the front panel key or digital input. As a result, highly accurate control can be realized with a PID value that is appropriate for the temperature setting.

The PID pallets are specified for normal/reverse operation, and when combined with motor drive valve control, are capable of supporting summer/winter switching in an air conditioning application.

(5) Loader communication port

The PXG is equipped with a loader communication (RS-232C) port as a standard feature at the bottom of the main unit. Additionally, loader software for a PC is provided free of charge, and the setting of many parameters for multiple functions can be implemented easily and reliably.

(6) User key

The front panel is equipped with a user key that enables a user to select functions freely. The user key can be defined according to various applications, including automatic/manual switching, control start/ stop, setting value changeover, ramp soak start/stop, and the like.

(7) Load short-circuit alarm function (option)

In addition to the previous heater break alarm function, measurement of the load current while the control output is OFF enables an alarm to be output, via a solid state relay (SSR) or the like, when trouble occurs at the operation side.

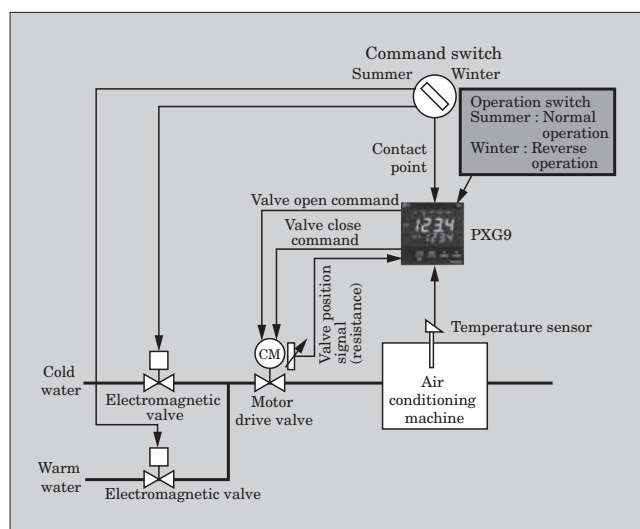## 4. Example Application of New-type of Temperature Controller

The PXG is equipped with functions that support various types of equipment. The PXH, in addition to a high level of basic performance, i.e., its input indicator accuracy and control calculation cycle, is also equipped with an abundance of inputs and outputs, a numerical value calculation function, and a T-link communication function for connection as an I/O device to Fuji Electric's programmable controller (PLC). The PXH is suitable for various applications ranging in size from a single apparatus to a plant facility. Example applications are described below.

4.1 Example application of PXG to the cold/warm water control for an air conditioning machine

An air conditioning machine is supplied with cold water in the summer and warm water in the winter. The PXG is equipped with a function for switching the control operation (normal or reverse operation) according to a contact input, and as shown in Fig. 4, by connecting the contact point of an command switch to the PXG, the control operation for the electric motor

valve can be switched to summer or winter settings in response to an increase or decrease in measured temperature values, thereby enabling air conditioning control to be implemented with a single control unit. Moreover, the PXG used here may be driven directly, and because the presence or absence of the valve posi-

tion signal input can be specified, a motor drive valve that does not output the valve position may also be used.

4.2 Example application of PXH to combustion control

In the combustion control of an industrial furnace or boiler, because of compliance with energy-savings measures and because of environmental problems and the like, there is a great need to control the ratio of air and fuel in order to achieve optimal combustion. Since it is necessary to control the mass flow rate of combustion gas and air after having been compensated for changes in density due to temperature and pressure fluctuations, multiple analog inputs and calculation functions are required, and therefore, a process controller (Fuji Electric's compact controller class) had previously been used for combustion control. However, as shown in Fig. 5, the PXH may also be used for combustion control. The PLC and PXH are connected by a T-link, and since the PLC treats the PXH's inputted measurement values, control calculated values and so on as I/O data, the flow rate setting of the combustion gas and air is calculated by the PLC, and can be provided to each PXH as a remote setup value. The temperature and pressure flow rate compensation calculation is embedded in the PXH as a control template, so that the user only has to set the various constants.

Fig.4 Example of PXG application to cold/warm water control for air conditioning machine

Fig.5 Example of PXH application to combustion control

Flow rate compensation calculation

$$Q = k01 \times \sqrt{PV1} \times \sqrt{\frac{Ai1 + k02}{k03} \times \frac{k04}{PV2 + k05}}$$

Q : Corrected flow rate
$PV1$: Flow rate (pressure difference), $PV2$: Temperature,
$Ai1$: Pressure, $k01$ to $k05$: Constants

*1 : In the gas flow rate controller, the MV of the temperature controller is transmitted from the PLC and set as R-SV.
*2 : In the air flow rate controller, the gas flow rate is multiplied by a percentage, and then transmitted from the PLC and set as R-SV.
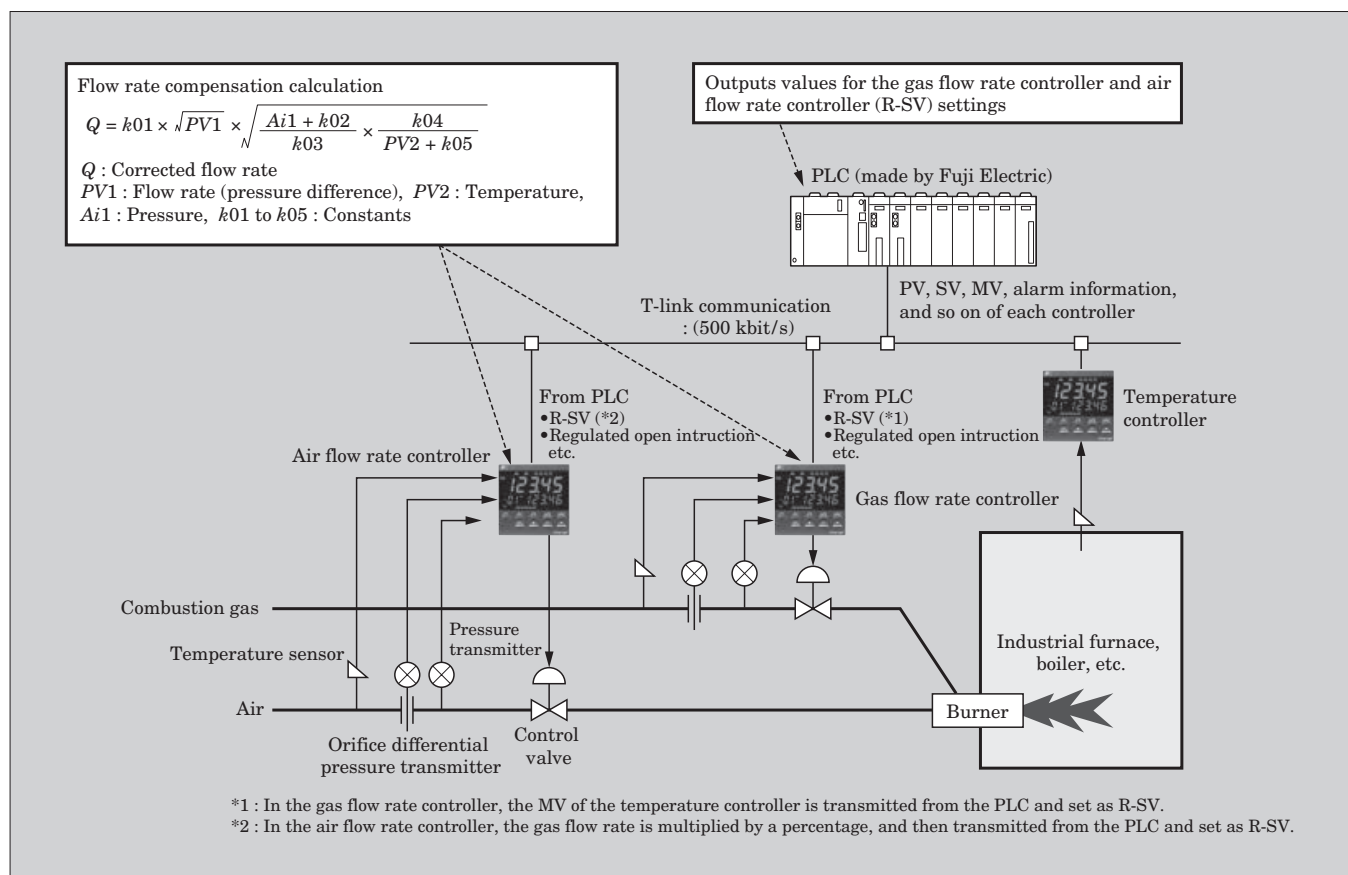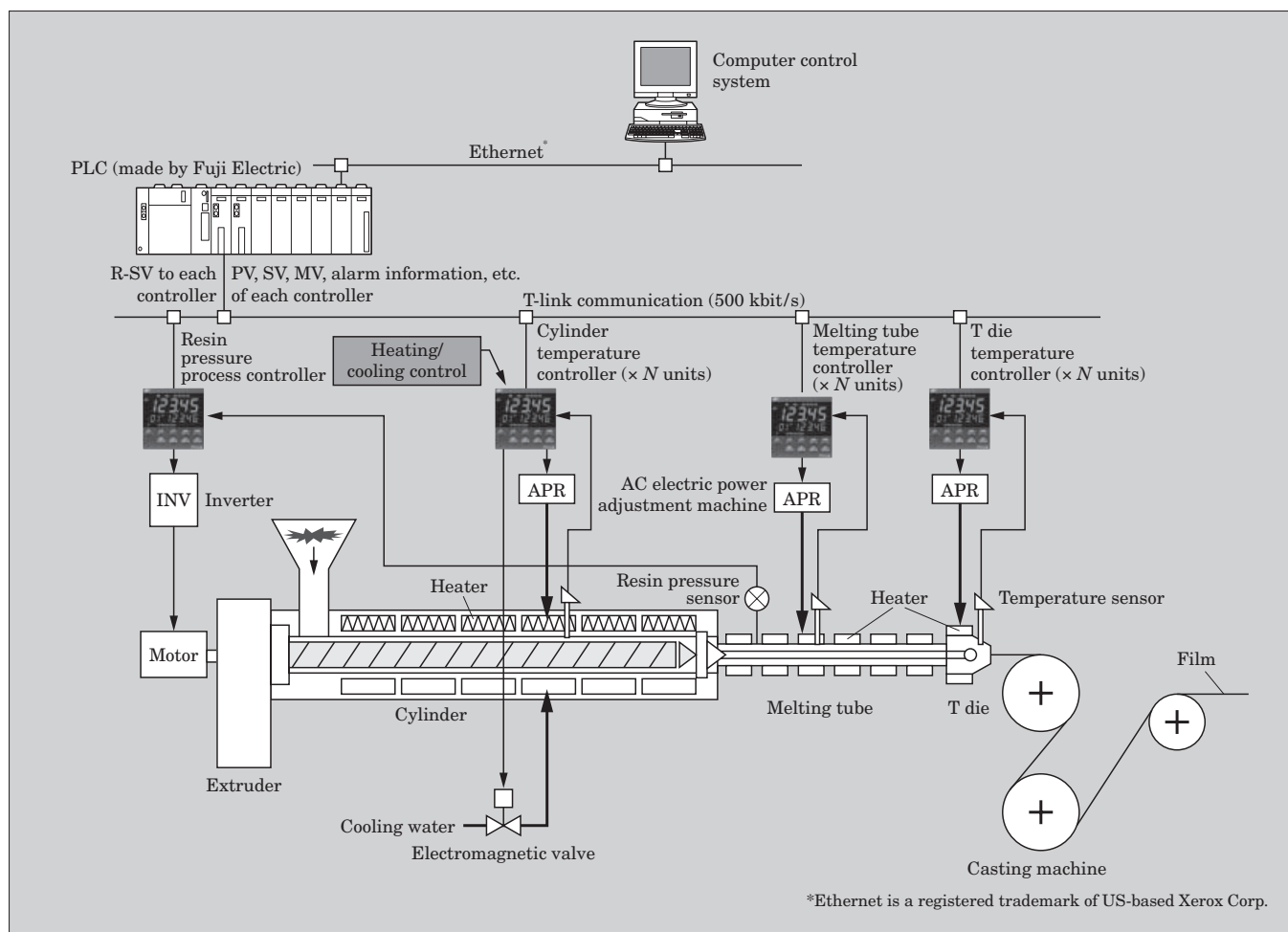
Fig.6 Example of PXH application to a film manufacturing line

Furthermore, because the calculation is performed with floating decimal point industrial values, special considerations for scaling are unnecessary and engineering work is simplified.

4.3 Example application of PXH to a film manufacturing line

A film manufacturing line consists of raw material equipment, an extruder, a melting tube, a T die, a casting machine, a vertical drawing machine, a horizontal drawing machine, a haul-off unit and a winder, and process control of temperature, pressure and so on is performed for each piece of equipment. Each process is easily influenced by external disturbances, which have a large impact on product quality, and therefore a high level of control performance is required. In addition to having high-speed and highly precise control functions, the PXH is also provided with a 2-degrees-of-freedom PID function, a PID pallet change function, and functions and parameters for overshoot suppression and for improving the disturbance response. The PXH is well suited for application as a process controller from this equipment.

Figure 6 shows a process control distribution dia-gram in the periphery of the extruder.

(1) Temperature control

The cylinders of an extruder use a heating and cooling type PXH developed for extruder-use to sup-press the effects of heat generated from the resin and to stabilize the resin temperature. Based on Fuji Electric's expertise accumulated through numerous de-liveries to this sector, auto-tuning control is employed and control constants can be obtained separately on the heating and cooling sides to realize a high degree of controllability.

(2) Resin pressure control

The rotational speed of the extruder's motor is controlled so that the resin pressure becomes constant, and with 50 ms high-speed control calculations, ap-propriate control is implemented in response to rapidly changing resin pressure.

(3) High-speed communications via T-link

The control loop for a film manufacturing line has many points, and a host computer accumulates and manages all control results as quality data. By con-necting Fuji Electric's PLC to the T-link (500 kbit/s), control data can be collected at high-speed.

5. Conclusion

Fuji Electric's multi-function temperature controllers, especially the PXG which is the latest model, and examples of their applications have been described.

Process control is diversifying toward DCSes (distributed control systems), PLCs and modularization, and there is deep-seated need for process controllers because of their convenience of use from a single unit, diffusion of risk, ease of maintenance, and the like.

The process controllers described in this paper are optimal for such types of applications.

The authors will be grateful if this paper is a useful reference when selecting a temperature controller or building a system in the future.

Reference

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