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Instrumentation and Control Solution Contributing to Industry and Society

Fuji Electric

Innovating Energy Technology

FUJI ELECTRIC
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Instrumentation and Control Solution Contributing to Industry and Society

In order to create a sustainable society where we can live a safe and secure life, we require prompt solutions to issues such as environmental pollution and global warming. The role of industrial and social infrastructure, which forms the basis of people's lives, is becoming increasingly significant.

Fuji Electric aims to offer solutions for overall life cycles of equipment and facilities encompassing the entire production activities of customers based on the three pillars of "stable supply of energy," "realization of energy conservation" and "provision of safety and security" in the field of industrial and social infrastructure. Instrumentation and control technology is a fundamental technology for that purpose. It includes components such as sensor technology, control technology, systematization technology and optimization algorithms, which are organically linked together via a network to offer optimum solutions to customers.

In this special issue, we present our approaches to Instrumentation and control solutions that contribute to industry and society and the latest technologies and components that support them.

Cover Photo:

Cross Stack Laser Gas Analyzer "ZSS," vibration sensor, controller "XCS-3000" of small- and medium-scale monitoring and control system "MICREX-VieW XX," and high function Integrating dosemeter "DOSE e"

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Preface

Expectations of New Technologies for Instrumentation and Control Engineering

MASUDA Shiro*

In the fields of instrumentation and control, the trends toward more advanced and diverse technology have progressed dramatically with the development of peripheral technologies for communications, information processing, semiconductors, and so on. In the instrumentation field, applications of sophisticated electronic instrumentation technology have advanced, and the objects to be measured are also becoming more diverse with measurements in the life science field, measurements of the environment, measurements of human sensations and behavior, etc. Moreover, in the control field, there is increasing demand for control technology for high-speed and high-precision temperature control and positioning control, and the like, at manufacturing sites, and in consideration of safety and energy savings, the requested control technology is also becoming more diverse. Additionally, regarding the underlying control theory that supports control technology, control systems are evolving from conventional techniques, such as optimal control, robust control and adaptive control, to such techniques as hybrid control, quantization control, formation control, and so on, that expand the range of applications. In recent years, environmental and energy related applications such as smart grids have also been pursued actively.

In this paper, from among the instrumentation and control engineering topics exhibiting such various developments, I want to describe the topics that I myself am watching. In recent years, there has been interest in big data science that effectively uses large amounts of data sent over the Internet, and in the control and instrumentation fields as well, research into data driven control that directly utilizes data that has been accumulated in manufacturing processes has attracted attention as a recent new trend. In contrast to the research for convention control system design, which is separated into a phase for identifying a system model using data obtained from a real system and a phase for designing the control system using the system model, the data-driven controller design approach aims to utilize directly the data obtained from the real system for control system design. From the perspective of a user of control technology, the performance of the controlled system is diagnosed using observed data, and the effect of the developed control technology is evaluated according to data obtained as the result of the application of the control. In other words, from the diagnosis of the control performance until the evaluation of the control results, the data obtained from the control system provides the information for making a determination, and therefore an approach focused on data is appropriate for the onsite needs. Moreover, data processing technology is common to engineering in general, and the intensive utilization of and fusion with information and communication technology (ICT), which has exhibited remarkable development in recent years, is also anticipated. Analysis and design based on mathematical models and physical models is, without a doubt, important and necessary, but technology focused on data to be handled directly by the user ought to be watched as a technology that will expand in the future.

The development of virtual instrumentation technology, such as software sensors and virtual metrology, is also worthy of attention as a technology related to both the instrumentation and control fields. The objective of this technology is to estimate variables that cannot be measured in real-time from variables that can be measured online, and practical applications are being advanced in various fields such as petrochemicals, steel, semiconductor manufacturing, pharmaceuticals, and so forth. To accomplish this objective, a model that provides a quantitative relationship between variables that are measurable online and estimated variables is needed. This model may be based on physical and chemical laws, or may be a statistical model derived from measured data. The latter is positioned as a data-based measuring technique since, as with the data-driven control introduced above, data accumulated during the manufacturing process can be used directly. Additionally, virtual instrumentation technology is also considered to be a technology related to estimation and prediction based on dynamic simulation, and it is thought that virtual instrumentation technology will play an important role in relation to state estimation theory, typified by Kalman filters, and to computer simulations of large-scale systems.

Lastly, I want to discuss technology that improves the stability of processes. At chemical plants and the

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like, the plant is maintained in an appropriate state and the operating safety is ensured based on instrumentation and control technology, but in cases where the plant state can no longer be maintained at an appropriate level, an alarm is issued and the operator is requested to take action. If the alarm setting is not suitable, however, the alarm will be generated frequently, and the operator can no longer be expected to appropriate action. For this reason, an approach to alarm management that aims to operate the alarm appropriately and to maximally leverage the excellent response capability of the human operator is important. In this approach, in addition to instrumentation and control engineering, the excellent human properties of resourcefulness and flexibility are utilized with an aim to realize a resilient system. While instrumentation and control engineering are expected to continue to evolve in the future without slowing down, how human elements can be incorporated therein has become even more an important theme. We look forward to new ideas and concepts for the theme as future technology.

Instrumentation and Control Technologies Supporting Solutions: Current Status and Future Outlook

KONDO Shiro*　FUKUZUMI Mitsunori*

1. Introduction

The industrial infrastructure business of Fuji Electric targets factories, facilities and industrial parks to provide our customers with a "smarter operation" through three pillars: "a stable energy supply," "the realization of energy savings" and "the provision of safety and security." By focusing on the entire production activities of customers, we are able to provide solutions for all of the life cycles of equipment and facilities. Fuji Electric has positioned its instrumentation and control technologies as fundamental technologies of industrial infrastructure businesses, and by organically connecting equipment and facilities through control technology, sensor technology and network technology, we achieve visualization and supply solutions.

In this special issue, we will introduce some applicable solutions of instrumentation and control technologies, as well as the latest technologies and components that support them. In this paper, we will describe the current status and future outlook of solution supporting instrumentation and control technologies.

2. Market and Technology Trends

2.1 Customer challenges and needs

(1) Meeting the needs of globalization

Manufacturers are being desired to meet overseas need to supply their products to the market in a timely manner. In addition to placing manufacturing bases near promising markets, they are being integrated in countries and regions that provide low cost manufacturing through reduced labor costs, etc. To meet these needs, integrated management of distributed sites, global supply chain management, security and intellectual property protection are all very important.

By mixing in human resources of different cultures, it is required that there be work standardization, work history management and a safety design for conventional on-site equipment. As a result, various efforts are made at establishing international standards to meet these needs.

(2) Meeting the needs of an environmental society

It is strongly desired that measures be taken to suppress global warming and achieve zero-emission operations. Besides, Japan has been aiming at a sustainable environmental society, giving consideration to recovery from the Great East Japan Earthquake in March 2011. In order to achieve this, we have been making efforts to achieve a sustainable social framework that provides efficient in-house power generation including natural energy sources such as solar power, as well as realizing the miniaturization of facilities and equipment, and steady monitoring and enhancement of operation efficiency. One effective measure is in the proliferation of electric vehicles and plug-in hybrid vehicles (PHVs) and the development of infrastructure such as quick charging stations has also been making progress. From the environmental aspect, in order to respond to toxic substances control measures including the "Air Pollution Control Act" and "Water Pollution Control Act," we need to measure in real time the release of discharged gases and drainage from plants under adverse conditions (low concentration, very small quantities and with high dust) and to optimize drainage control using the measurement result.

(3) Ensuring high reliability and safety

Regardless of the age of facilities, higher operating rates are demanded in those of production sites, and there needs to be minimization of shutdowns and opportunity losses that accompany accidents and damage to equipment. On one hand, developed nations such as Japan have to deal with the increasing number of retirements of skilled personnel engaged in on-site work, which also leads to concern over response to emergency situations. In addition to a high level of reliability and safety being required of facilities, operation support technologies are being anticipated that can predict the lifespan of facilities and equipment, as well as detect early abnormal signs so as to induce maintenance measures before accidents occur.

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In order to achieve these goals, facilities need to be equipped with intelligence functions for self-diagnosis and functional safety so that even if an accident were to occur, operations could continue through redundancy of equipment and other measures. Furthermore, systems themselves are being required to provide appropriate operating guidance and assistance to workers to respond to non-steady states such as abnormalities, start-ups and shutdowns.

2.2 Technological trends[1]

We will now introduce some of the trends related to the major technologies for meeting the challenges and needs of customers.

(1) International standardization

Standardization in the instrumentation control field of industrial processes is making active progress through alliances to create standards such as TC65 (industrial process instrumentation control) of IEC (International Electrotechnical Commission), TC8 (system aspects related to the electrical power supply), TC59 (performance of household electrical appliances) and TC95 (measuring relays and protective devices). Among these efforts, action is being taken toward the establishment of interoperability standards such as field networks and wireless for industrial uses, as well as environmental and safety standards including control system security (IEC 62443) and functional safety (IEC 61508), while also taking action to standardize activities related to management planning, etc. Machine and equipment safety is also making progress in various fields and equipment standards, especially with respect to the higher level standards of ISO 12100 (machine safety). This, in turn, has led to the introduction of safety instrumented systems in Japan.

(2) Field networks

With regard to field networks*1, various networks are standardized and utilized according to the characteristics of the field in which the networks are intended to be used.

In the field of factory automation (FA), PROFIBUS/PROFINET, EtherNet/IP and CC-Link have been becoming mainstream as network protocols. Among these, EtherCAT, MECHATROLINK and PROFINET IRT have become the mainstream for drive systems that require high precision and high speed.

In the process automation field (PA), 4 to 20 mA analog communication is still the standard, but digital communication via protocols such as HART and FOUNDATION Fieldbus are gradually gaining acceptance.

For wireless applications for industrial uses, utilization has begun for instrumentation applications via wireless protocols such as the WirelessHART and ISA100.11a standards, even as the protocols continue to be developed to overcome reliability issues. Furthermore, with regard to wireless technologies for industrial uses, standards among TC65 of IEC are being discussed in order to establish a framework that supports the coexistence of various wireless systems (wireless coexistence).

(3) Field equipment technologies

In order to facilitate sensor installation and maintenance, there has been a greater need for wireless sensors, as well as long-term drive and maintenance-free sensors supported by batteries and self-powered technology. To achieve this, MEMS*2 technology has been utilized, aiming at miniaturization and power savings.

From the aspect of plant asset management, demand has been increasing for field equipment that have intelligent functions for storing and transmitting various information such as their model type, life expectancy based on operation time and usage frequency, etc.

In general, instrumentation sensors expand the range of conventional temperature, pressure, flow rate and level sensors. From the viewpoint of safety and security and environmental measures based on past earthquakes and accidents, radiation dosimeters, vibration sensors and exhaust gas analyzers have been attracting attention.

3. Fuji Electric's Efforts in the Field of Instrumentation and Control Technologies

3.1 "Connection" concept

Fuji Electric's industrial infrastructure business has developed the following menu of five solu-

***1: Field Networks**

These are industrial use networks which mainly aim at control communication between controllers and field equipment. They make notification to controllers with regard to values such as temperatures, pressures, speeds and positions that were measured in the field equipment related to process automation (PA) for petrochemical plants and factory automation (FA) for automobile manufacturers, etc. Optimized control is carried out by notifying I/O and actuators of the results calculated by the controller based on the various measurements.

***2: MEMS**

This is an acronym for "Micro Electro Mechanical Systems." It can also refer to micro machines. This is the generic name for devices that integrate components such as sensors, actuators and electronic circuits in silicon substrates featured in semiconductor process technologies. As application examples, this technology is seen in the small nozzles at the heads of inkjet printers and in pressure, acceleration, flow and vibration sensors.

tions for helping our customers achieve a stable and enhanced production capacity and lower production costs.

(1) Stable supply of energy solution

This is a solution for supplying the stable amount of energy required by factories and plants.

(2) Energy savings solution

This solution achieves total energy savings ranging from the energy savings of individual equipment and facilities at manufacturing sites to advanced energy management of an entire factory.

(3) Safety, security and environmental solution

This solution realizes an environment devoted to secure "manufacturing."

(4) Automation and efficiency solution

The solution achieves automation and efficiency results from the viewpoint of entire optimization.

(5) Stable operation of equipment solution

This solution supports the stable operation of various facilities and equipment.

As shown in Fig. 1, the instrumentation and control technologies conceived by Fuji Electric "connect" the elemental technologies of control systems, measuring equipment and sensors, radiation equipment, power electronics and advanced control technologies, as well as become a core fundamental technology bearing the control scene of the solutions. (Refer to "Instrumentation and Control System Solutions to Support Stable Operation, Energy Efficiency and Environmental Conservation" on page 10 and "Drive Control System Solutions Utilizing High-Speed Controller and Large-Capacity Network" on page 16.)

Fuji Electric has constructed control systems suited to the scale of operations through a control system platform, and in addition to this, is working to solve the diverse challenges of its customers through various technologies represented by its advanced control technologies, environmental measurement technologies, and service technologies.

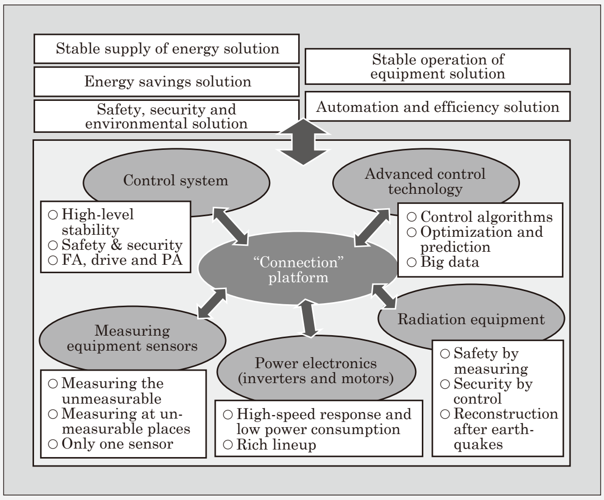

Fig.1 Fuji Electric's instrumentation and control technologies

3.2 Control system platform

In order to achieve our "connection" concept, we developed a control system platform (see Fig. 2). This platform consists of a control system layer, software library layer and engineering environment.

The control system layer is composed of a controller, network, HMI, database, etc. We have a rich lineup of various components to obtain an optimal cost performance that corresponds to the system scale and facility importance ranging from simple constructions consisting of only a controller and I/O to highly-reliable redundant systems.

The software library layer is an extremely important component of the control system platform. There was a time when the evaluation of the control system was determined mainly by the performance and functionality of hardware, which was represented by the controller and network. However, in today's world, with the remarkable evolution of hardware technology, engineering (quality, lead time, cost reduction, etc.) has become much more significant. The software library layer is the component that corresponds to this change, and it consists of a group of software that has made common the advanced control technology developed by Fuji Electric over many years, which is used in each industry, organization and product. Fuji Electric is dedicated to accumulating its control technologies and is making efforts to ensure that the latest technologies have commonality in the future. This software library layer can be used freely

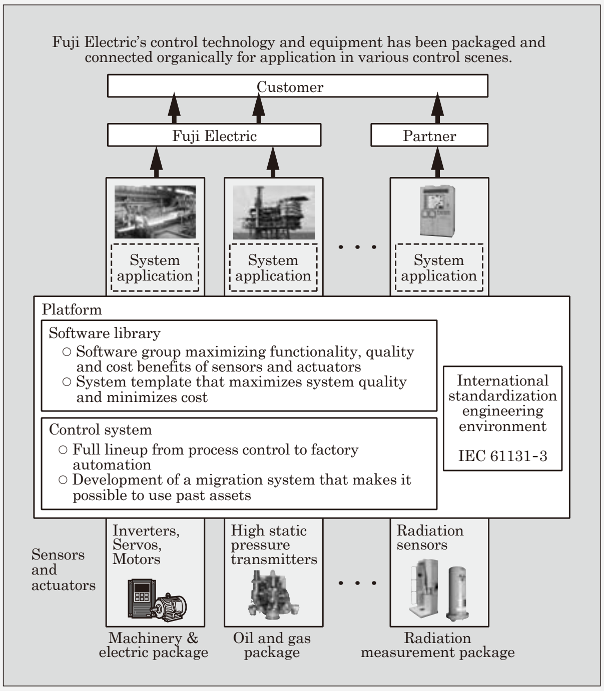

Fig.2 Control system platform

from the application constructed on the control system platform.

The engineering environment has been integrated to comply with the international standards IEC 61131-3, and the control software that functions on the platform can be handled in a manner that is globally integrated regardless of the software library or application, thus maintaining compatibility not dependent on the application system.

Separate industry packages (industry dedicated functions) such as a continuous process control system, batch process control system, drive control system and power generation system have been built on the control system platform, allowing for solutions that meet the needs of each industry.

3.3 Control system

Figure 3 shows Fuji Electric's monitoring control system position map. The "MICREX-NX" is a control system for large and medium scale operations, and it conforms to several international standards such as IEC 61508 (functional safety), IEC 61511 (safety), ISA S88 (batch control), FDA 21 CFR Part11 (electronic records and signatures of food and drug products). It has been mostly used in iron and steel energy centers, as well as in the chemical, pharmaceutical, and water treatment fields. Since commencing sales in 2004, over 250 systems have been sold and delivered. (Refer to "Information and Process Control System to Support Stabilization and Safety, 'MICREX-NX'" on page 27).

The "MICREX-VieW" is a control system for medium and small scale operations, and this series provides a lineup of systems that meet various scale and cost requirements.

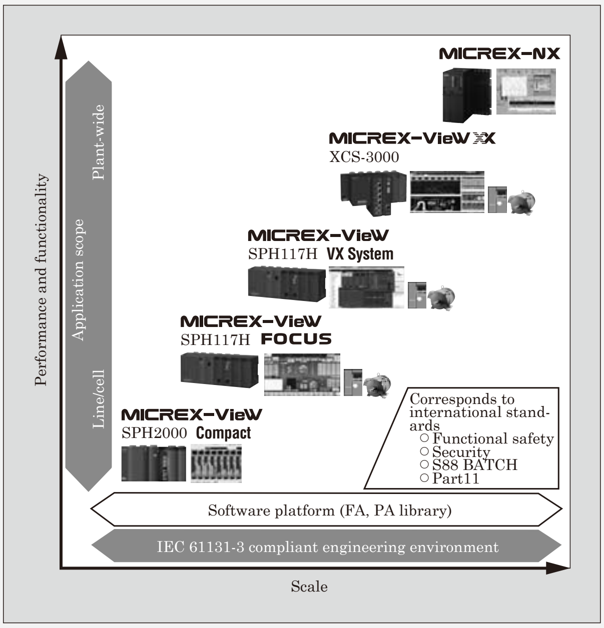

Fig.3 Fuji Electric's monitoring control system position map

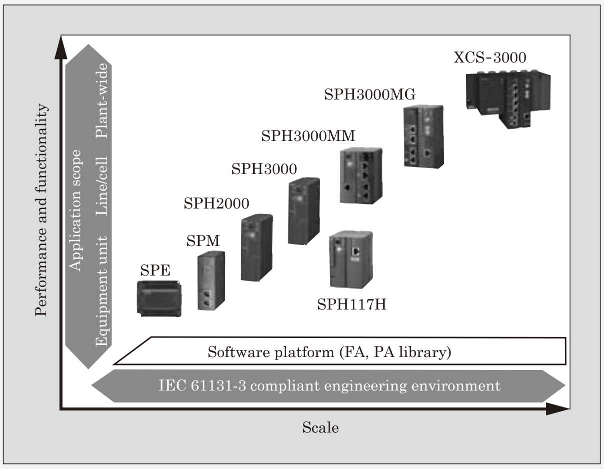

Fig.4 Fuji Electric's controller position map

In addition, we have developed the "MICREX-VieW XX (Double X)" and added it to our lineup. This product has been built on a control system platform that maintains compatibility with existing systems, while also providing the latest operation and engineering functions. This is a highly reliable system capable of making the controller, network, I/O, HMI, database and other individual devices redundant in duplicate as necessary. (Refer to "Small- and Medium-Scale Monitoring and Control System to Realize Inheritance and Evolution of Customer Assets, 'MICREX-VieW XX'" on page 33, and "Latest Operation and Engineering Functions of Small- and Medium-Scale Monitoring and Control System, 'MICREX-VieW XX'" on page 38.)

Figure 4 shows the controller position map that makes up the control system layer. We have a lineup that meets the application scope, scale, and cost of our customers ranging from components to systems capable of advanced redundancy. Our lineup can be applied to a wide variety of applications such as single machine control, line control that performs high-speed and high-precision synchronous operation of inverters and motors, turbine control, continuous process control and batch process control. All controller engineering environments are compliant with IEC 61131-3 international standards, and software has been created to be compatible with other products. (Refer to "Integrated Controller Realizing Machine Control and Advanced Motion Control, 'MICREX-SX Series'" on page 43.)

3.4 Advanced control technologies

For safe and optimized control of factory facilities and plants, various control technologies have been developed.

Fuji Electric has developed various technologies while focusing on the following core technologies in order to make advanced automatic control possible. As prediction and diagnosis technologies, we have developed our own original neural network technology, as well as the multivariate statistical process control technology; as optimization technologies, we utilize mathematical programming and meta-heuristics*3; as control technologies for stably operating plants, we have developed technology for multi-variable model predictive control, as well as a control performance monitoring technology that diagnoses the structural deterioration of plant control functions. However, there are many cases in which skilled personnel are required to respond to non-steady states such as abnormalities and plant start-ups and shutdowns. Therefore, the matter of inheriting technologies is becoming an issue for many of our customers. There is a trend of increased interest in data analysis technologies in which large amounts of historical data measured at plants are analyzed and the analysis results are used to respond to non-steady states. Fuji Electric has been developing solutions to these types of problems through our multivariate statistical process control abnormality diagnosis technology, quality estimation technology that utilizes the partial least-square method and skilled personnel operation pattern analysis technology via pattern mining. (Refer to "Data Analysis Technology in Plant Control" on page 21.)

3.5 Environmental measurement technologies

Fuji Electric has a lineup of industrial gauges that include pressure and differential pressure transmitters, flowmeters, water level gauges, recorders, and controllers. In addition to these products, we continue to work to develop other environmental measurement technologies and products.

In order to carry out recovery and reconstruction after the Fukushima Daiichi Nuclear Power Station accident, there has been increasing need for a wide variety of radiation equipment and systems. Fuji Electric has been developing radiation monitoring technologies for over 40 years and has been able to quickly respond to this need. We have developed technologies for a wide range of applications including lightweight, compact and easy-to-use personal dosimeters and portable body surface radiation monitors, and environmental radiation measurement technologies such as transportable monitoring posts and a wide range of dose monitoring devices, as well as the miniature and portable devices for depth direction soil radiation concentration distribution monitoring. We have also developed food radiation measurement systems for which expertise and pre-processing are not required. These types of developments have helped us contribute to safe and secure radiation monitoring activities.

Efficient fossil fuel burning is one of effective measures to reduce CO_2 emissions. Furthermore, the reuse of the discharged gas is also an effective measure. In order to achieve these types of goals, Fuji Electric is working to develop laser gas analyzer technology. Since the analysis time is extremely fast at 1 to 5 seconds, we are able to remarkably improve the precision of combustion and exhaust gas recovery control, allowing us to contribute greatly to reducing CO_2 emissions. (Refer to "Cross Stack Laser Gas Analyzer Contributing to Energy Conservation, 'ZSS'" on page 49.)

In addition, we have developed a MEMS applicable vibration sensor, and by using this, we have been able to develop and offer a structural health monitoring system (SHM) for diagnosing the structural safety of aging buildings and buildings subject to earthquakes. (Refer to "Structure Health Monitoring System Using MEMS-Applied Vibration Sensor" on page 54.)

3.6 Service technology

For our customers, it is a very important matter to be able to continue the long-term use, to the greatest extent possible, of production facilities that have been fully amortized. Fuji Electric has expanded its life cycle service to support stable and efficient operations in order to help solving the various issues related to aging facilities. In order to do this, it is essential to have diagnosis technology for each facility. We have developed a diverse range of diagnosis technologies including diagnosis technology of high-voltage circuit breakers and oil-immersed and molded transformers, as well as on-line diagnosis technology for rotating machines. At the same time, we are also working on an on-line monitoring technology that carries out diagnosis via a wireless network so that customer facilities can be diagnosed without having to suspend operations.

4. Future Outlook

Instrumentation and control technology has been conventionally applied mostly to process control systems. It was used for the partial optimization of "manufacturing" and its performance indicators included control functions, performance, reliability and initial investment cost. However, the application range of the instrumentation and control technology has greatly expanded and the

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***3: Meta-heuristics**

This refers to a basic framework of algorithms designed to accommodate both specific problems in optimization problems as well as generic purposes. When modifying values from the initial values of solutions, the behavior of organisms are mimicked as well as physical phenomena in order to obtain optimal values.

technology is now required to deal with vertical solutions ranging from manufacturing execution systems (MES) to supply-chain management systems (SCM). As a result, its performance indicators have also changed to place emphasis on overall optimization (TCO reduction) and facility and equipment life cycle costs. We are now being asked to go to the limits in offering new proposals and services based on our customer needs.

In order to meet these needs, we need to further accelerate integration between instrumentation and control technology and IT. By utilizing virtualization and big data analysis technology, we have been able to progress in developing solution technologies such as simulations, operation support, maintenance, and safe and secure proposals, as well as technology for control system security.

5. Postscript

Based on global market and technological trends, we have introduced the current status and future outlook of Fuji Electric's instrumentation and control technologies.

In the future, we will continue to enhance and expand our instrumentation and control technologies so that they become the basis of Fuji Electric's industrial solutions for providing a stable energy supply, energy savings, safety and security and environmental measures.

Reference

(1) Kurotani, K., Todaka, Y. Current Status and Prospects of Measurement and Control Technologies. FUJI ELECTRIC REVIEW. 2012, vol.58, no.1, p.2-8.

Instrumentation and Control System Solutions to Support Stable Operation, Energy Efficiency and Environmental Conservation

SHOBAYASHI Naoki* KOIDE Tetsuya* INAMURA Yasuo*

ABSTRACT

Stabilization and sophistication of operation, improvement of energy efficiency and environmental conservation are common issues shared by customers in various fields. To address these issues, Fuji Electric makes full use of its 60-plus years of experience with instrument to offer instrumentation and control system solutions. In the steel industry, they support stable operation of iron mills, improvement of energy management efficiency and stable production of high-quality products. In the chemical, food and pharmaceutical industries, they facilitate high-mix low-volume production, safe and stable operation, preventive maintenance and ensured product manufacturing records. In addition, they contribute to safe and stable operation and environmental measures in garbage processing plants, boiler facilities and cement plants.

1. Introduction

Fuji Electric's instrumentation and control technologies were launched in 1951 when we released measuring equipment such as flow meters and gas analyzers, and they have been developed into panel instrumentation where the measuring equipment are combined with receiving instruments and adjusting instruments. Fuji Electric delivered a computer control system in 1963 for the first time in the instrumentation industry, and launched its first distributed control system (DCS) in 1975, having a history that spans over 60 years so far. Throughout our history, we have been considering, "What issues are our customers facing?" and "How Fuji Electric can solve these issues?" and have actually provided instrumentation and control systems as solutions for the customers. Specific issues addressed include stabilization and sophistication of operation, improvement of energy efficiency and environmental conservation.

In this paper, we will introduce the solutions Fuji Electric has offered for the steel, chemical, food and pharmaceutical industries and incineration processes.

2. Instrumentation and Computer System Solutions in Steel Industry

Fuji Electric has delivered a variety of instrumentation and control systems for steel plants, from pig iron making through steelmaking, rolling and process lines, contributing to stable operation, energy efficiency and environmental conservation in steelworks.

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2.1 Surrounding circumstances

The steel industry, which produces materials for other industries and construction materials, is one of Japan's key industries. In recent years, we have been experiencing huge environmental changes such as the rapid economic advance of China and mergers and reorganizations of domestic manufacturers. In order to maintain and enhance its international competitiveness and make further progress under such conditions, the steel industry is facing urgent needs to positively incorporate domestic demand, actively develop new demand overseas and improve production efficiency.

2.2 Issues encountered by industry and Fuji Electric's solutions

(1) Stabilized operation of converters

An oxygen converter gas recovery (OG) system, part of a converter, is shown in Fig. 1. In the OG system, linz-donawitz converter gas (LDG), which is generated in the process of a refining reaction in a converter, is recovered in a gas holder without being burned. LDG is high-temperature and combustible gas whose main ingredient is CO and it contains much dust. It is used as fuel for facilities in steelworks. OG systems have risks of explosion due to air inflow, deteriorated

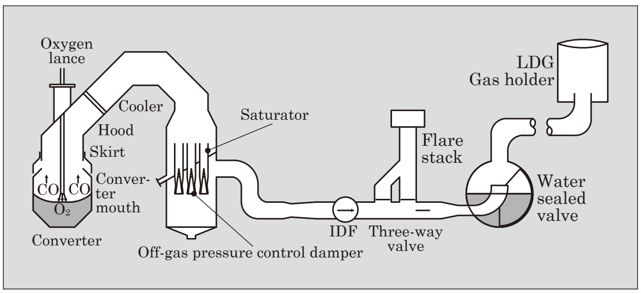

Fig.1 Outline of OG system

energy recovery rate due to the issuing of LDG and environmental contamination due to a leak of poisonous gases containing dust. To prevent such risks, it is necessary to restrict disturbances to the minimum level to keep the pressure at converter mouth (P0) constant.

Fuji Electric is providing new control of P0 (NCP0), an instrumentation and control system, as a solution to such challenges. The NCP0 is a control system where, in addition to an optimal regulator, an adoptive regulator such as disturbance pattern judgment and hunching detection is adopted and a feed forward regulator based on estimated flow values of gas generated in an oxygen converter is combined. This system makes it possible to automatically change control gains and various parameters used for the control of disturbances, thereby minimizing the fluctuation of process gains, furnace pressure and gases generated in an oxygen converter.

(2) Enhanced energy operational efficiency

Various types of energies used in steelworks are generally classified into purchased energy, such as city gas, oxygen and electric power, and by-product energy, such as by-product gases, steam and electric power. The most important tasks in energy management at steelworks are to control a balance between demand and supply through optimally operating energy and to minimize useless consumption of energy.

As solutions to such challenges, Fuji Electric provides “Steel EMS package” (see Fig. 2), a solution package of demand/supply forecasting (visualized future) and optimization (realization of energy-efficient operation)[1].

With this demand/supply forecasting system, energy fluctuations will be estimated based on track record data gained from DCS, operation plans according to manufacturing execution system (MES) and manufacturing plan data. This will enable operators to perform energy-efficient operation according to the estimated energy demand and supply from a few minutes ahead through a few days ahead.

In addition, with this optimization system, energy cost will be minimized through the particle swarm optimization (PSO) method, the latest metaheuristics optimization technology, based on the data estimated by the demand/supply forecasting (plant-by-plant and energy-by-energy data). This PSO method will make it possible to extract optimal operation patterns for in-service facilities based on the collected track record data. With the conventional method, it was difficult to adjust the operation patterns in the event of an unintended operation or an operation method change. In contrast, with this PSO method, we can find optimal solutions, and this makes it possible to maintain a balance between demand and supply and minimize useless consumption of energy.

(3) Stable manufacturing of high-quality products

The tasks for overall steelworks include stabilized operation, securing of product quality and enhancement of energy efficiency. Detailed management of quality information, precise analysis of collected information and minimization of downtime at the time of updating a system are required for a computer control system. Fuji Electric offers quality information management systems and operation analysis systems as an approach to these tasks.

(a) Quality information management system

As a quality information management system in steel process lines, we provide the process data collection system (PDCS) package. With this package, the length quality data of coil products will be collected from each sensor and managed with appropriate resolution. This package will precisely record conditions during coil manufacturing, thereby enabling stable operation and securing product quality.

(b) Operation analysis system

Analyzing the operation track record data collected by PDCS will identify operation factors affecting product quality. Fuji Electric is providing the following systems as operation analysis systems contributing to stable manufacturing.

(i) Bayesian analysis system

Bayesian analysis system is a system developed based on a Bayesian network utilizing a probabilistic inference algorithm in which a complicated relation between an effect and its cause is denoted by conditional probability. By analyzing past operation track records with this system, we will identify significant factors in a manufacturing

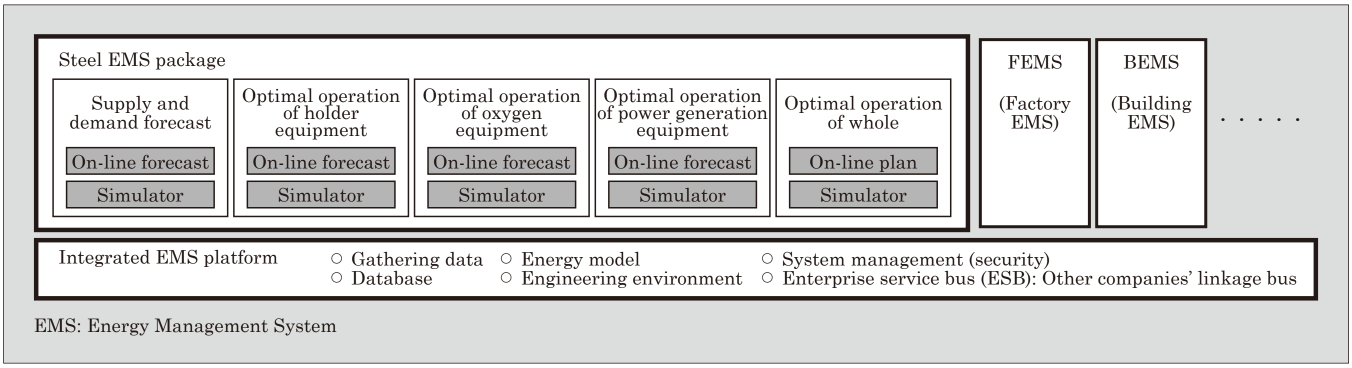

Fig.2 Steel EMS package

process which may affect product quality.

(ii) "MainGATE MSPC"

By using multivariate statistical methods, MainGATE MSPC will detect abnormalities which cannot be detected merely with the setting of upper/lower limits, and identify key factors which will affect product quality most to improve the quality.

(c) Effective updates of computer systems

It becomes difficult to enhance or remodel computer systems for stable operation when the production of existing hardware is discontinued. Therefore, they must be renewed in a shorter span compared to other control devices.

Fuji Electric is providing an updating technology utilizing virtualization, which makes it possible to easily install new functions at the time of replacing an existing system with new hardware. This system has the following functions to make operation tests easy, and they contribute to effective updates of computer systems:

- ○ Simultaneous parallel operation of old and new computer systems
- ○ Comparison of results output from old and new computer systems

With this updating system, we can cut down the cost and duration required for updating to half and replace an old system with a scalable one while securing product quality.

3. Instrumentation System Solutions in Chemical, Food and Pharmaceutical Industries

3.1 Surrounding circumstances

In spite of the fact that the chemical, food and pharmaceutical industries are producing products indispensable for our daily life, they are facing difficult conditions: skyrocketing raw material costs in recent times; a decline in domestic demand due to the falling population; declining birth rate and aging of society; and diversified needs of consumers, etc. For those reasons, competitiveness needs to be further enhanced. Furthermore, as a result of the reorganization of chemical corporations in Europe and the U.S.A., international competition is being intensified.

In addition to the need to ensure safe and stable operation, domestic plants are facing problems of aging operators and a reduction in their number.

3.2 Issues encountered by industry and Fuji Electric's solutions

Common issues shared by the chemical, food and pharmaceutical industries and Fuji Electric's solutions for them will be described here.

(1) Accommodation for high-variety low-volume manufacturing

As a measure to respond to stagnant demand, diversified needs of users and rising raw material costs, high-variety and low-volume manufacturing is being applied. Under such circumstances, it is necessary to establish a manufacturing system which can easily accommodate the addition and change of products.

In order to solve this issue, Fuji Electric is providing ISA 88-compliant recipe management system as a batch control system for high-variety and low-volume manufacturing. This system can be installed in "MICREX-NX," Fuji Electric's DCS. With this system, we can promptly and adequately respond to changes of recipes in association with the addition of product or improvements in products. An example of MICREX-NX's recipe management functions is shown in Fig. 3.

Moreover, we have developed "HEART," an engineering tool which makes it possible to create software with the use of general-purpose OA software (Excel, Visio*1). By using this tool, we can unify the management of specifications and software and realize its in-house manufacturing, thereby reducing the running cost required in association with product improvement and making it possible to promptly release new products.

(2) Safe and stable operation

We used to be dependent on operators with experience and skills for safe and stable operation so as to stably supply products. In order to respond to the declining number of experienced operators in the future, applying machinery and systems to secure safety and enhance stable operation is required.

In recent years, starting with Europe, there have been increasing tendencies to promote activities intended to secure safety for whole components and facilities through new safety-securing methods which are based on specifications regarding functional safety and mechanical safety (safety design, safety approval and safety management). These activities are attracting attention in Japan, too.

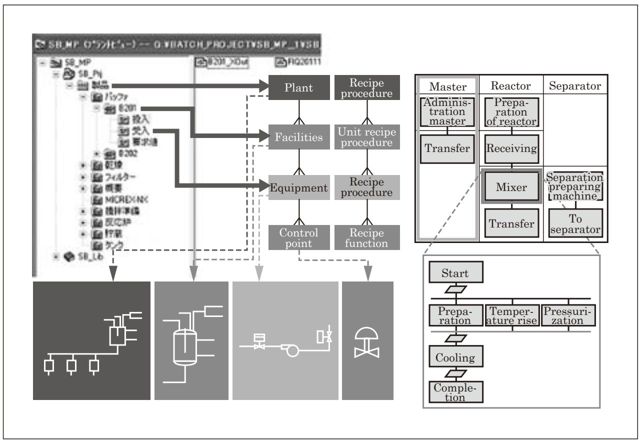

Fig.3 Example of MICREX-NX's Recipe management functions

*1: Excel, Visio: A trademark or a registered trademark of Microsoft Corp., U.S.A.

Fuji Electric is providing safety instrumented systems to secure safety at manufacturing sites. The safety instrumented systems protect humans, the environment and facilities from unexpected accidents or troubles at plants. MICREX-NX's safety instrumentation system corresponds to SIL 3, a safety integrity level.

With the introduction of the safety instrumented systems, facilities will be shut down in the event of safety-related abnormalities without being damaged. In this way, it becomes possible to restart the facilities without problems, and this contributes to stable operation, too.

(3) Preventive maintenance

Improvement and preventive measures against a variety of issues are being implemented at manufacturing sites. However, in some cases, events that show signs of trouble may not be revealed, which could result in sporadic failures or accidents. It is necessary to predict or estimate such unrevealed events to prevent failures and accidents, and thus production downtime should be minimized.

Fuji Electric's MainGATE MSPC will detect abnormalities which cannot be detected merely with the setting of upper/lower limits. By comprehending signs of troubles according to correlations among various events generated at workplaces, this system will contribute to preventive maintenance, accident prevention and minimized production downtime.

(4) Saving of product manufacturing record

In product manufacturing, saving manufacturing process records (traceability) and making use of them for improvement are important tasks.

Fuji Electric's MICREX-NX is compatible with ER/ES*2 including FDA21 CFR Part11*3 to secure traceability of manufacturing processes at plants. With this system, the necessary data will be recorded digitally, which makes it easy to save and manage the data.

4. Instrumentation and Computer System Solutions in Combustion Process

Instrumentation system solutions for Combustion processes at garbage disposal facilities, boiler facilities and cement plants will be described here.

4.1 Surrounding circumstances

(a) Garbage incinerator plants

Garbage incinerator plants have an extremely high public nature and are required to treat general waste in a stable and effective manner. In addition, there is increasing social demand for environmental countermeasures and utilization of waste heat.

(b) Boiler facilities

After the Great East Japan Earthquake, the importance of electric power supply and the securing of power have been reaffirmed. As a result, the demand for safety and stable operation has been increased further in areas from boilers at thermal power plants of a very public nature through heat supplying-type thermal boilers to supply heat and electric power within factory.

(c) Cement plant

The Basic Environment Plan of the Ministry of the Environment states that our ideal society is a sustainable one. In the cement industry, too, with the aim of achieving this goal, efforts for a sustainable society, including global warming countermeasures and effective use of waste and by-products, are required.

4.2 Issues encountered by industry and Fuji Electric's solutions

(1) Safe and stable operation

The challenges to overcome for safe, stable, efficient and effective operation of plants and facilities are as follows.

(a) Garbage incinerator plant

In order to treat waste in a stable and effective manner, it is necessary to comprehend precisely the overall operation circumstances of facilities.

(b) Boiler facilities

In accordance with turbine load, etc., prompt and effective supply of high-temperature and high-pressure steam is required.

(c) Cement plant

Stable and product-feature-based production of high-quality cement products is required.

As a solution to such tasks, Fuji Electric is providing "MICREX-VieW XX" that enables safe and stable operation. Features of the system are:

- ○ High-speed and highly reliable system
- ○ Up-to date monitoring function with drastically improved usability
- ○ Cross-sectionally integrated component, including aspects from measuring, driving, power generation, energy management system (EMS) through factory automation (FA) and process automation (PA) (systems from high-speed control through process automation systems are integrated into the same component)
- ○ High-efficiency engineering function
- ○ Globally capable
- ○ Inheriting of customer's existing properties (Hardware & Software)

We are developing solutions for various incin-

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*2: ER/ES: Regulations regarding electronic records and electronic signatures used at the time of applying for approval or permission for using pharmaceutical and food products.

*3: FDA 21 CFR Part11: Regulations established by the Food and Drug Administration (FDA). Requirements to be observed regarding electronic records and electronic signatures used at the time of applying for approval of sales of pharmaceutical and food products are specified there.

eration processes with MICREX-VieW XX and control packages.

(a) Garbage incinerator plant

MICREX-VieW XX enables the integration of electric, instrumentation and computer systems. With this system, we can precisely comprehend overall operation circumstances of garbage disposal facilities, from extra-high-voltage electric distribution facilities through incinerators and control computers. Thus, we will be able to find abnormalities of facilities within the plant at an early stage and promptly remove the causal factors to restore operation, thereby achieving safe and stable operation.

A configuration example of a garbage disposal facility system with MICREX-VieW XX is shown in Fig. 4.

(b) Boiler facilities

With the MICREX-VieW XX system, the functions of turbine govenor control device, high-speed control device, and boiler control device, instrumentation and control system, are implemented via the same component. Coordination between the boiler control and turbine control functions will be enhanced as a result, and this enables sophisticated boiler/turbine cooperative control. Consequently, a boiler can supply steam in accordance with the level of turbine load more promptly in an effective and stable manner.

(c) Cement plant

Fuji Electric is providing the following packages for production facilities at cement plants, and these packages will promote stable production of a variety of high-quality cement products:

(i) Raw material ratio control depending on the type of cement products (limestone, auxiliary material)

(ii) Raw material formulation-adjustment control based on analysis data gained from X-ray fluorescence analyzers

(iii) Ratio and delivery control of clinker, gypsum and mixture depending on the type of cement product

(2) Environmental countermeasures and measures to alleviate environmental impact

In order to protect the environment, which is a social requirement, it is necessary to comply with the exhaust gas regulations. Furthermore, taking measures to further alleviate environmental impact such as CO_2 reduction is our task.

(a) Garbage incinerator plant

To promote the neutralization of toxic HCI contained in exhaust from garbage incinerators, slaked

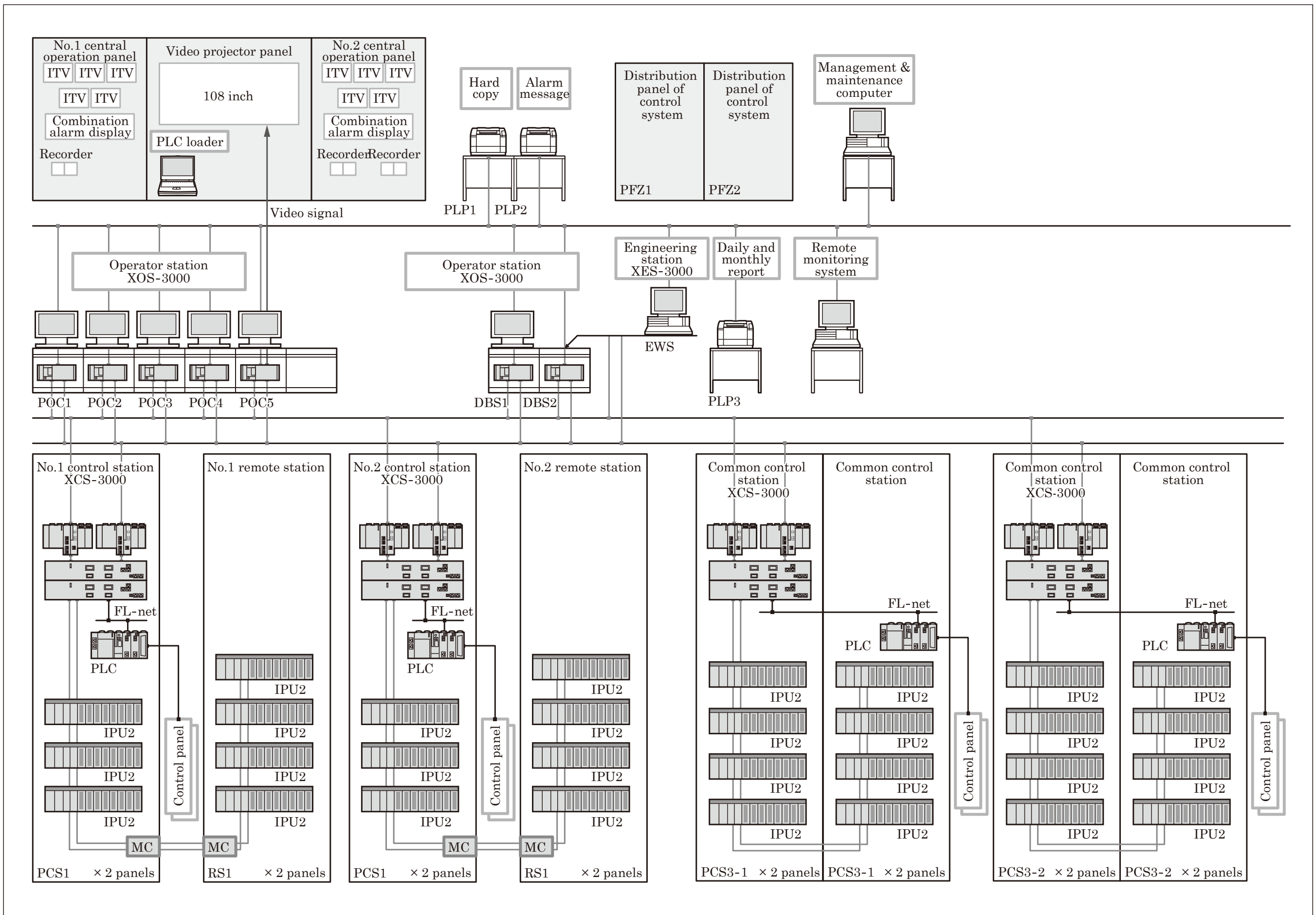

Fig.4 Configuration example of a garbage disposal facility

lime is injected in accordance with its concentration. As a device to detect the concentration, Fuji Electric is providing laser gas analyzers. Conventional infrared gas analyzers require two to three minutes until the measurement after the collection of exhaust gas. Therefore, redundant time control and sample PI control had been implemented to prevent hunching during the concentration control. On the other hand, the laser gas analyzer can measure the concentration at high speed, within one to five seconds, which enables real-time control and further decreases the HCI concentration in exhaust.

(b) Boiler facilities

(i) By controlling CO in exhaust with high-speed response raiser-type CO analyzers and controlling O2 in exhaust with zirconia O_2 analyzers, exhaust heat loss can be reduced and the fuel consumption of a boiler can be lowered, resulting in a CO_2 emission reduction.

(ii) In some boilers where the by-product gas and by-product oil generated from factory can be used as fuel. By automatically selecting a boiler of higher efficiency (if there are two or more boilers) based on by-product fuel generation prediction and model prediction, and by automatically controlling the amount of by-product fuel in an optimal way, we will minimize operation cost and reduce CO_2 emissions.

(c) Cement plant

In cement plants, waste is positively reused as sources for heat energy and sewage sludge as cement raw materials, which helps reduce environmental impact.

However, when waste is used as fuel, it becomes necessary to monitor exhaust, because the components of the waste fluctuate greatly. As a solution to this, Fuji Electric is providing high-temperature and high-dust-concentration exhaust analyzers to be installed on exhaust stacks.

5. Postscript

We have outlined instrumentation and control system solutions contributing stable operation, energy saving and environmental conservation.

We, Fuji Electric, will do our best to offer our customers solutions for safe and stable operation, cost reduction and environmental countermeasures by making use of our integrated abilities which can provide systems from software to heavy electrical machinery through a one-stop service.

Reference

(1) Narumi, K. et al. "Steel EMS Package" Optimizing Energy Management at Steelworks. FUJI ELECTRIC REVIEW. 2013, vol.59, no.3, p.165-169.

Drive Control System Solution Utilizing High-Speed Controller and Large-Capacity Network

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ABSTRACT

Recently, in the field of plant control, higher-speed control response and high-speed processing of massive data are demanded of drive control systems for improving product quality and stabilization and achieving efficient operation. Fuji Electric meets these demands by enhancing the functionality of system components and increasing the speed and capacity of networks. Applications include solutions for press machines, steel processing lines and metal rolling mill. In steel processing lines, the maintenance tools are integrated by making use of the inverter transparent connecting function which allows remote monitoring and operating inverters in order to streamline its maintenance.

1. Introduction

Improved product quality as well as stabilization and streamlining of operation are required in the field of machine control of metal processing, printing, etc. and in the field of plant control of iron manufacturing, nonferrous metal manufacturing, papermaking, etc. What is necessary to achieve them is faster control response and high-speed processing of massive amounts of data. It is also important to flexibly establish a system capable of resolving these issues while maintaining ease of engineering.

For example, multi-axis motion control in the field of machine control requires highly accurate synchronization, and thus multiple actuators must be synchronized with one another and controlled with an accuracy of several microseconds. In the field of plant control, the number of I/O points of a whole plant is as many as tens of thousands, and it is necessary to connect multiple controllers by way of a network for processing massive amounts of data at high speed. To this end, the network is required to be capable of handling massive amounts of data at high speed.

This paper introduces solutions, combining features of a high-speed controller and a large-capacity network, to the requirements and issues of two categories of drive control systems - "machine control system" designed to control actuators used for metal processing, printing, etc. with high accuracy and "plant control system" intended for high-speed processing of massive amounts of data in such fields as steelmaking and papermaking.

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2. Trends in Drive Control Systems

Drive control systems consisting mainly of drive control units, such as controllers and inverters, are required to meet demands for "improved manufacturing quality," "improved production efficiency," "stabilization of operation," "streamlining of maintenance" and "visualization of operation," which are growing year by year; and the development of system components with more sophisticated functions and the increase in network speed and capacity is accelerating to meet these demands.

2.1 System components

Fuji Electric has developed the "SPH3000MM" equipped with two high-speed field buses and the "SPH3000MG" integrating the high-speed, large-capacity control network "SX-Net," to offer systems that supports various operation scales and requirements, from machine control systems to plant control systems. (see Fig. 1)

(1) High-speed field bus "E-SX bus"

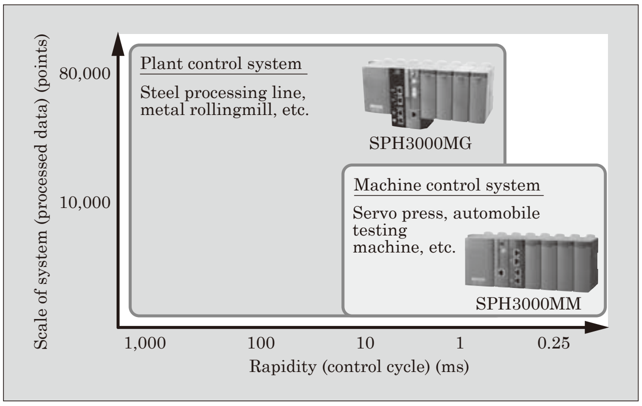

Fig.1 Application ranges of "SPH3000MM" and "SPH3000MG"

The “E-SX bus” is a high-speed, large-capacity field bus with considerably higher performance than the conventional “SX bus.” The functions and performance of the E-SX bus and those of the SX bus are compared in Table 1. The E-SX bus can ensure highly accurate motion control because the data output timing inside the bus can be synchronized.

(2) High-speed, large-capacity control network “SX-Net”

The SX-Net, which is based on gigabit Ethernet*[1], is a high-speed, large-capacity control network capable of synchronizing controllers with an accuracy of ±80 µs. Synchronous control among controllers can improve the accuracy of plant control. The main specifications of the SX-Net are shown in Table 2.

(3) High-speed, high-accuracy controller “SPH3000MM”

The SPH3000MM is a high-speed, high-accuracy controller equipped with two CPUs, each of which is mounted with the E-SX bus. Parallel processing by the two CPUs helps achieve high-speed computations and, at the same time, establish a simple but expandable control system. The two CPUs can operate in synchronization with each other with an accuracy of ±3 µs and are appropriate for highly accurate synchronous control among actuators for multi-axis motion control, etc.

(4) High-speed, large-capacity network controller “SPH3000MG”

The SPH3000MG controller, which contains the SX-Net and the E-SX bus, supports high-speed, large-capacity networks. Although it was impossible for conventional systems to synchronize network-connected controllers, systems using the SX-Net-connected SPH3000MG can synchronize controllers. The SPH3000MG has an improved computation processing speed (minimum command execution time: 5 ns) and ensures higher accuracy of plant control, backed by synchronous control among controllers and high-speed processing.

(5) Data collection/analysis assisting package software “f(s) NISDAS 7”

“f(s) NISDAS 7” is package software that assists data collection/analysis and it is capable of collecting internal data from controllers or inverters at high speed. This package software contributes to the “visualization of operation” of large-scale, complicated systems with the fastest data collection speed of 1 Kwords/ms. An application example of a system installed with f(s) NISDAS 7 is shown in Fig. 2.

Table1 Comparison of functions and performance between “E-SX bus” and “SX bus”

Item	E-SX bus	SX bus	Comparison
Number of I/O points	65,536	8,192	8 times
Transmission rate	100 Mbits/s	25 Mbits/s	4 times
Tact cycle	250 µs or over	500 µs or over	Twice
Tact accuracy	1 µs or less	100 µs	More than 100 times
Synchronization inside bus	Yes (±1 µs or less)	No	–

Table 2 Main specifications of “SX-Net”

Item		Specification
Number of connectable units		126
Transmission rate		1 Gbits/s
Transmission method		Common memory, message communication
Minimum scan cycle		500 µs
Common memory	Data area size	128 Kwords (64 words × 2,048 blocks)
	Refresh cycle	8 Kwords/1 ms (when 16 stations are set)

*1: Ethernet is a trademark or registered trademark of Fuji Xerox Co., Ltd.

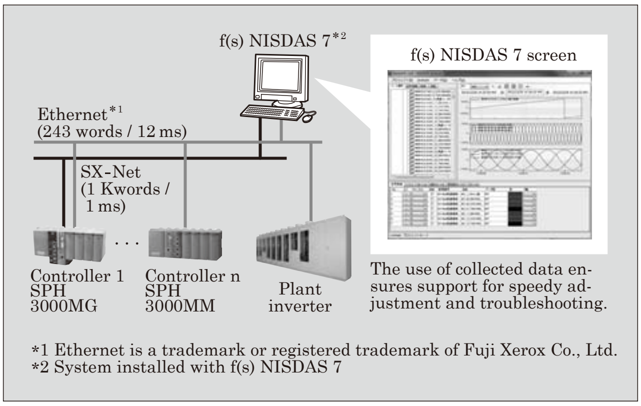

Fig.2 Application example of “f(s) NISDAS 7”

2.2 Machine control system

A machine control system uses two or more sensors or actuators for sequence control or motion control. High-speed, high-accuracy motion control, in particular, is required to improve productivity or quality.

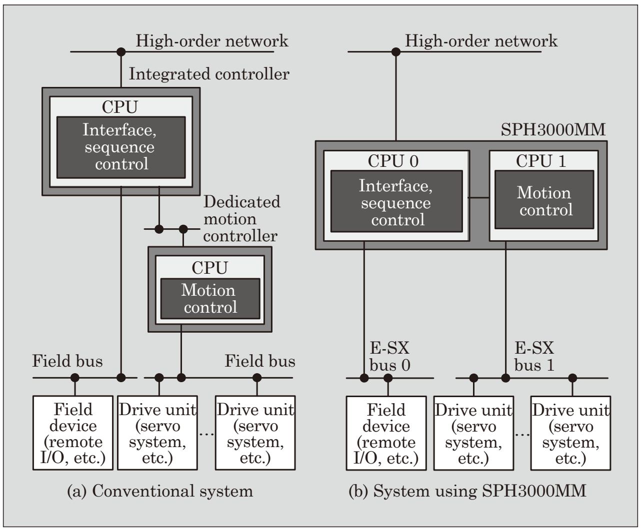

Fig.3 Conventional system and system using “SPH3000MM”

A comparison between a conventional system and a system using the SPH3000MM is shown in Fig. 3. The conventional system used a dedicated controller for motion control, and controlled the entire equipment with the aid of an integrated controller. On the other hand, using SPH3000MM enables to construct a system with only one controller because one of its CPUs performs motion control while the other is available for sequence control or control of communication with another system. In addition, motion control by both CPUs makes it possible to control up to eight axes at a control cycle of 250 µs. As has been described, a machine control system having expandability can be constructed with the SPH3000MM.

2.3 Plant control system

A plant control system connects multiple controllers and operation/monitoring devices via a control network, and links several dozen to hundreds inverters and sensors to an individual controller through a field bus. The control network of a plant control system is required to offer a higher speed and a larger capacity than ever before. This is because plant data is increasing in size in response to the enhancement of production efficiency and the visualization of operation. It is also desirable that controllers, which are installed in dispersed locations, be synchronously controlled to improve manufacturing quality.

The SPH3000MG and the SX-Net can ensure not only communication among high-speed, large-capacity controllers but also synchronous control among controllers, which has been difficult to realize conventionally. What is more, each controller can easily refer to the memory on the network because the SX-Net adopts a common memory system. The combination of the SPH3000MG and the SX-Net can thus provide the control network with enhanced speed and increased capacity as well as higher accuracy of the plant control system through synchronous control among controllers.

3. Application Examples

This section introduces a machine control system for a pressing machine as an application example of the SPH3000MM. A plant control system for a steel processing line and that for a metal rolling line are also described as application examples of the SPH3000MG.

3.1 Machine control system for pressing machine

A large-size pressing machine for automobile steel sheets is designed to form panels for automobile bodies, doors, etc. and required to have higher panel formability and energy-saving. On a mechanical press, panels are formed by the descending energy of the flywheel and the slide driven by the main motor. Much of this energy was absorbed by the air cushion and the locking cylinder making up the cushion device and discharged as heat. In addition, air cushion had difficulty in controlling cushion load speedily and flexibly, which affected panel formability.

Fuji Electric developed a large-capacity servo system suitable for cushion control as a solution to these issues, and achieved both improved panel formability and reduced power consumption of the press process.

(1) System configuration

The configuration of a machine control system for a large-size pressing machine for automobile steel sheets is shown in Fig. 4. This system adopts the SPH3000MM as the controller governing the entire system, high-performance vector control type inverter "FRENIC-VG," which can be connected to the E-SX bus, as inverters, and a newly developed large-capacity, low-inertia servomotor as the motors for driving the cushion. The specifications of the servomotor are shown in Table 3, and its appearance is illustrated in

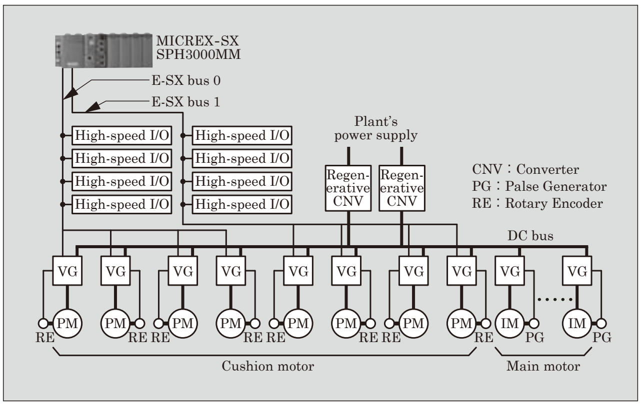

Fig.4 Configuration of machine control system for large-size pressing machine for automobile steel sheets

Table 3 Specifications of servomotor

Item	Specification
Type	Indoor, totally closed, water-cooled-type permanent magnet synchronous motor
Rating	110 kW, 1,600 min^{-1}
Overload capacity	300%, 10 s or over
Moment of inertia	0.19 kgm^2

Fig.5 Large-capacity low-inertia servomotor

Fig. 5.

This system achieves high-speed, high-accuracy synchronous control with combination of the SPH3000MM and a general-purpose inverter, not an expensive, complicated dedicated motion controller. It is characterized by the following:

(a) ease of connection to higher-order controllers or controllers of other manufacturers, regardless of the network type; and

(b) ease of system modifications or additional installation of I/O points.

(2) Improving panel formability

To improve panel formability, the cushion load must be controlled in a speedy, flexible manner. It is, therefore, necessary to synchronize the eight servomotors for driving the cushion with high accuracy and instantaneously output accurate torque.

Connecting the SPH3000MM and the eight FRENIC-VGs to the E-SX bus makes it possible to control the torque of the eight servomotors speedily and flexibly with a control cycle of 500 μs and a synchronization accuracy of ±3 μs or less. Torque errors attributable to the effect of temperature, etc. and torque pulsation caused by the eccentricity of the encoder are reduced by the torque compensation functions (optional) provided with the FRENIC-VGs, resulting in a significant improvement in torque control accuracy.

(3) Reducing the power consumption of the press process

Both the FRENIC-VGs for driving the main motor and those for driving the cushion motor are of a DC distribution type and connected to the regenerative converters by their common DC buses. With this configuration, it becomes possible to supply the energy recovered by the cushion motor directly to the power-running*2 main motor or regenerate this energy to the plant's supply. As a result, the power consumption of the press process can be greatly reduced.

3.2 Plant control system for steel processing line

A processing line for treating ferrous and nonferrous materials, such as heating, pickling, plating or coating them, consists of several hundred motors, inverters, valves and sensors. The number of I/O points of this control system exceeds 40,000. Streamlining of maintenance and the visualization of operation are important to such a large-scale process, and these demands are becoming more advanced. Fuji Electric established a new processing line control system to resolve these issues.

A configuration example of the new processing line control system is shown in Fig. 6. The SPH3000MG is adopted as the controller governing each section and the controller for the inverters (DMC: drive master controller), and the SX-Net is used to connect the controllers. The DMC is a standard package developed for processing lines and features the following:

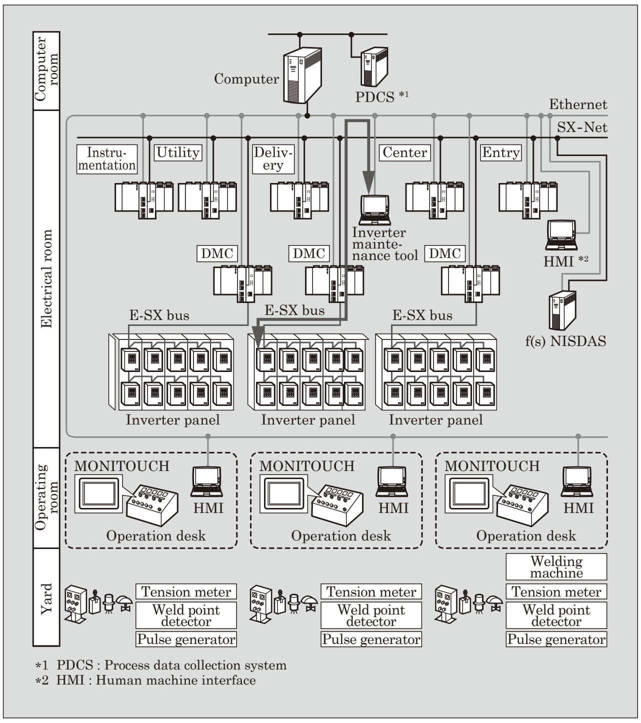

Fig.6 Configuration example of new processing line control system

(a) Connectability to the E-SX bus and the SX-Net

(b) Ability to control up to 64 inverters

(c) Speed control with a master controller, tension control, diameter computation and other necessary functions for the processing line as standard functions

(1) Streamlining of maintenance

In this system, the DMCs and the inverters are connected via the E-SX bus. One DMC can control up to 64 inverters and thus helps reduce the number of controllers for the inverters.

In addition, by connecting a personal computer installed with an inverter maintenance tool and the DMCs via Ethernet, DMC-controlled the inverters can be remotely monitored and operated via the controllers and the field bus. This inverter transparent connection function eliminates the need for maintenance lines or dedicated terminals for inverters and enables the user to set control parameters, trace back failures and trace control data in real time on a remote personal computer.

(2) Visualization of operation

A system installed with f(s) NISDAS 7 is connected to the SX-Net connecting the controller governing each section and the DMCs. Thus, massive amounts of data handled and processes in the plant can be speedily collected with a single system, allowing to visualize the status of the plant in depth.

*2: Power running: Conveying the power of the motor to the machine for acceleration

3.3 Plant control system for metal rolling mill

A metal rolling mill is equipment for producing steel products to be used for construction materials, bridges, etc. and is a plant that requires high-speed control performance to improve productivity and product quality. Its control system is made up of many sensors and actuators, their control units, operation units and monitoring systems. A configuration example of a metal rolling line control system is shown in Fig. 7. This line features split shear cutting control as an example of utilizing the high-speed control performance of the SPH3000MG.

The split shear is equipment installed on the outlet side of the rolling mill to divide and cut rolled materials. Its cutting accuracy affects product yield, which is required to be several dozen mm even at a finish rolling speed in excess of 20 m/s.

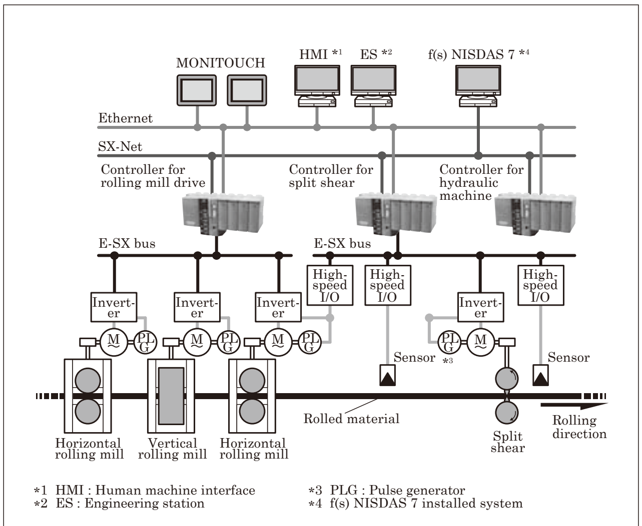

Fig.7 Configuration example of metal rolling mill line control system

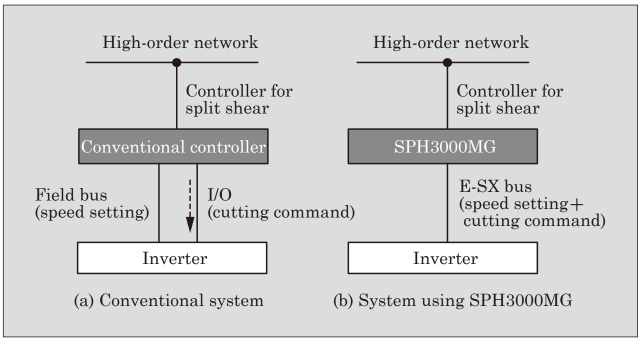

Fig.8 Conventional system and system using “SPH3000MG”

A comparison between a conventional system and a system using the SPH3000MG is shown in Fig. 8. The conventional system output the speed setting by the field bus and cutting commands by I/Os separately to the inverter to achieve the required cutting accuracy. The SPH3000MG and an E-SX bus-compatible inverter provided with a high-speed field bus transmission function integrate all commands to the inverter into the E-SX bus.

At the same time, faster throughput from the detection of rolled materials by a sensor to the output of commands to the inverter is achieved by adopting high-speed I/Os supporting the E-SX bus.

4. Postscript

This paper described drive control system solutions in combination with high-speed controllers and large-capacity networks. These solutions are expected to contribute to the manufacturing of quality products and the stabilization and streamlining of operation, which are required of mechanical equipment and plant systems. Fuji Electric is committed to further expanding the applications of these controllers and networks to resolve the issues confronting manufacturing sites.

Data Analysis Technology in Plant Control

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ABSTRACT

For safe and optimized control of factory equipment and plants, various control technologies has been developed. Fuji Electric is developing technologies for analyzing massive data measured in plants and making effective use of them. Fault diagnosis technology by means of multivariate statistical process control can be used for recognizing faults in manufacturing processes accurately to improve the operation rate. In addition, quality estimation technology based on the partial least squares method using manufacturing process information leads to improved quality and yield. Furthermore, log analysis technology by pattern mining can be used for analyzing past data and making tacit knowledge into explicit knowledge, thereby assisting operators.

1. Introduction

Diverse technologies are being developed for the purpose of ensuring the safe and optimized control of factory equipment and plants. These technologies include prediction technologies, which collect and analyze measured data to predict the future behavior of plants, fault diagnosis technologies intended to discover faults at an early stage, technologies for optimizing the energy efficiency of energy supply plants, and control technologies that enable plants to operate in a stable manner.

Fuji Electric Co., Ltd. has developed the following technologies: Original neural network technology as core technology for prediction and fault diagnosis; metaheuristics optimization technology, such as particle swarm optimization (PSO) suitable for mathematical programming and nonlinear large-scale optimization problems; PID control technology; model prediction control technology for multivariable systems; and control performance monitoring technology that monitors deterioration of control performance resulting from changes in the characteristics of the object controlled(1).

With the sophistication of these technologies, an increasing number of plants in various fields are introducing automatic control. On the other hand, the startup and shutdown of plants and response to unusual states, such as faults, still rely on the judgment of experienced operators in many cases. Drawing attention as an approach to advanced automation of plants is data analysis technology, which analyzes massive volumes of data measured at plants and utilizes them for improving operations, improving manufacturing quality and responding to unusual states.

This paper presents an overview of trends in plant control technology and describes what Fuji Electric's data analysis technology is like.

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2. Trends in Plant Control Technology

2.1 Demands for data analysis technology in view of plant control

To maintain the quality of products manufactured at plants, upper and lower limits are set on process variables that will affect the quality of products to determine whether there is any problem with the quality. However, since multiple process values are in correlation with one another, it is difficult to conduct correct diagnosis by monitoring any single variable. In addition, for a process in a normal condition with great variation in process values, proper lower and upper limits are difficult to set. For this reason, technology that enables us to conduct diagnosis with consideration given to the correlation between multiple variables is required.

In connection with the improvement of the yield and quality of products, the quality of finished products needs to be evaluated, and if any quality-related problem is found, such measures as equipment adjustment must be taken. However, this approach will give rise to defective lots because it evaluates finished products. What is needed as a solution to this issue is technology capable of preventing defective products by estimating the quality of products prior to completion and taking measures against expected problems.

Startup and shutdown of plants and response to unusual states must also be performed by field personnel. However, it takes field personnel time to respond to faults because they have less experience in faults and the number of experienced operators is on the decrease. Plant operations are carried out according to manuals to a certain degree, but some manual operations are performed in different ways depending on the operator. Therefore, technology capable of realizing optimum operations in response to different situations is required. In case of a fault, operators will be swamped with alarms, which will be displayed on the history monitoring screen of the distributed control system (DCS), and they will become unable to determine each of them, making it difficult to identify the fault. To deal with these issues, it is desired today that measurement trend data, alarm data, operation log data and log data on manual operations collected at plants be analyzed and utilized to assist plant operations.

2.2 Trends in related technologies

When it comes to activities of societies engaged in plant data analysis technologies, the 143rd Committee on Process Systems Engineering of the Japan Society for the Promotion of Science conducts workshops organized by universities, user companies and vendor companies, such as "Alarm Management (2008 to 2010)" and "Soft Sensors (2010 to 2012)," compiled study results on issues confronting user companies and the latest technological trends. In the Institute of Electrical Engineers of Japan, the Electronics, Information and Systems Society has the "Technical Committee on Technological Survey of Use of Big Data (2012 to 2014)" and the "Technical Committee on Survey of Data-based Adaptive Smart Systems (2012 to 2014)," which are actively committed to surveys and research of technologies for analysis and use of data. The Society of Instrument and Control Engineers presented a feature article titled "Data-driven Control-New Approaches and New Horizons" in its journal "Measurement and Control" in 2013. As described thus far, many organizations have been actively devoting their energy to data analysis technologies for the last several years.

3. Fuji Electric's Commitment to Data Analysis Technology

3.1 Approaches to use of data analysis technology

It is important to enhance productivity by having the stable operation of a plant and improving manufacturing quality and yield. Thus, Fuji Electric takes the following three main approaches to the development of data analysis technology:

(a) improving the operation rate through accurate fault diagnosis of the manufacturing process;
(b) estimating product quality based on information obtained during manufacture and thereby improving quality and yield; and
(c) assisting operators in running the plant by analyzing past data and turning tacit knowledge into explicit knowledge.

We are developing fault diagnosis technology backed by multivariate statistical process control (MSPC) for (a), quality estimation technology adopting the partial least squares for (b), and log analysis technology based on pattern mining for (c) (See Fig. 1).

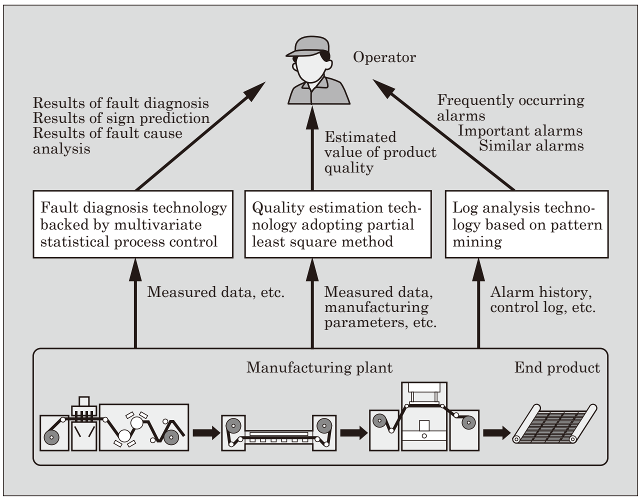


Fig.1 Approaches to use of data analysis technology

3.2 Fault diagnosis technology backed by multivariate statistical process control

Statistical process control means monitoring the operating state of the production process using a statistical method. It is a technique for preventing products that are nonconforming to specifications and thereby improving productivity.

Univariate statistical process control (USPC), which has been widely applied, is a technique for diagnosing faults by setting upper and lower limits, or control limits, on each process variable that significantly affects quality. However, if process values considerably vary, it is difficult to properly control upper and lower limits on variables even if the production process concerned is normal because the method for controlling these upper and lower limits has the precondition that the production process in normal state is working in a stable manner. MSPC, as opposed to USPC, is a technique capable of effectively monitoring a large number of variables, which affect one another in a complicated manner, by considering the correlation between these variables (see Fig. 2).

Next, we describe principal component analysis (PCA)*1, which is a technique of MSPC. Following steps are taken when applying PCA to fault diagnosis:

(a) Taking normal sample from a collected sample.
(b) Performing PCA with normal data to model the characteristics of the normal data.
(c) Setting a threshold on two indices used to evaluate the degree of divergence of the measured

*1: PCA: Principal component analysis. It is the method of taking characteristics from a massive amount of data by compiling the amount of information into orthogonal principal components based the correlation between many variables.

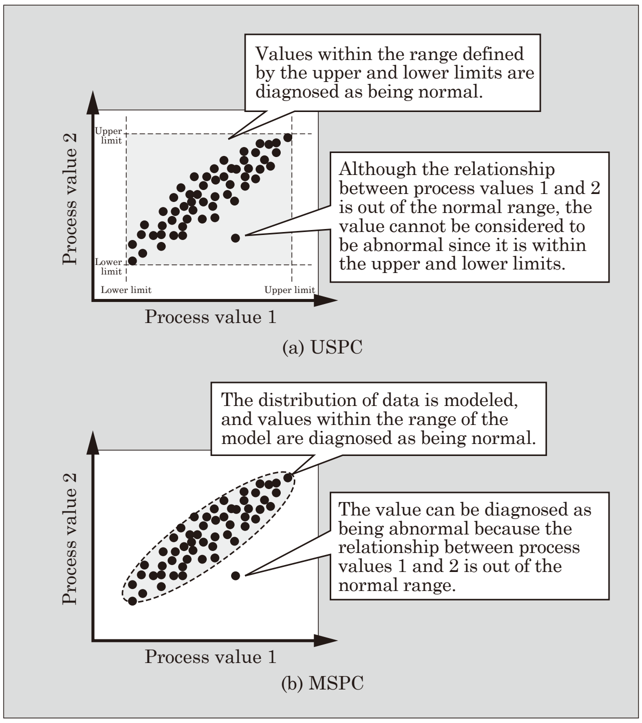


Fig.2 Comparison of fault diagnosis between USPC and MSPC

data from the normal model, Q statistic*2 and T^2 statistic*3.

The Q statistic and T^2 statistic are calculated using the measured data, and the values are diagnosed as being abnormal if they exceed the thresholds. The Q statistic and the T^2 statistic are calculated by Equation (1) and Equation (2), respectively.

$$Q = \|x - \hat{x}\|^2 = \sum_{n=1}^{N} (x_n - \hat{x}_n)^2 \quad \cdots\cdots (1)$$

Q: Q statistic
$\hat{x}$: Approximate value of input variable x on PCA model
N: Number of variables

The Q statistic is the index for evaluating the deviation from the correlation between the modeled data variables had and it can detect abnormality in the correlation between the variables.

$$T^2 = \sum_{m=1}^{M} \frac{t_m{}^2}{\sigma_{t_m}{}^2} \quad \cdots\cdots (2)$$

T^2: T^2 statistic
t: Principal component score
σ_{t_m}: Standard deviation of the mth principal component score
M: Number of principal components

*2: Q statistic: Degree of deviation of the correlation between variables from the normal state.

*3: T^2 statistic: Degree of deviation of amplitude from the normal state although the correlation between variables is maintained.

The T^2 statistic corresponds to the distance from the average to each sample within the principal component space obtained by compressing original variables, and represents the degree of divergence from the average of the model. Consequently, even if the correlation between variables is maintained, abnormalities attributable to the fact that values themselves are large can be detected. An example of the application of PCA to fault diagnosis is shown in Section 4.1.

3.3 Quality estimation technology adopting partial least square method

Quality estimation is a technology that, with the aid of a multivariate analysis method, models the correlation between the manufacturing process and product quality based on the operating state of the process and the set values of manufacturing conditions and consequently estimates product quality in the middle of manufacturing. If the quality of the end product can be estimated in the middle of manufacturing, measures, such as parameter or system adjustments, can be taken to prevent the occurrence of defective products. Therefore, quality estimation technology can make a contribution to the achievement of stable quality and improved yield.

Even if there are many input variables, partial least squares (PLS*4) makes it possible to easily create a model using all input variables as they are, unlike a multi-regression analysis model, which requires input variables to be narrowed down in preliminary analysis. PLS thus helps significantly reduce the time required to create a model. PLS is very effective for processes with particularly many input variables and processes with multicollinearity.

Following steps are taken when applying PLS to quality estimation.

(a) Collecting production conditions, process values and quality values.
(b) Carrying out PLS using the collected values and creating a PLS model based on the relationship between quality and the production conditions and the process values.
(c) Performing a simulation with different production conditions to find conditions that improve quality.
(d) During diagnosis, sequentially estimating product from the production conditions and the pro-

*4: PLS: Partial Least Squares. PLS is a kind of modeling technique developed in the field of economics. A proper model can be obtained even if there is multicollinearity because for input variables that are correlated with one another, they are aggregated into intermediate variables and then output variables are expressed. Multicollinearity means that input variables cannot be properly modeled by general multi-regression analysis when input variables are strongly correlated with one another.

cess values.

An estimated value of quality based on a PLS model can be calculated from Equation (3).

$$\hat{y} = Q\ (W^{\mathrm{T}}P)^{-1}W^{\mathrm{T}}x \quad \cdots\cdots\cdots \quad (3)$$

$\hat{y}$: Estimated value of quality
x: Input variable
W: Weighting matrix
P, Q: Coefficient matrices relating to input variable and output variable

An example of the application of PLS to quality estimation is shown in Section 4.2.

3.4 Log analysis technology based on pattern mining

Pattern mining means extracting "a pattern of a phenomenon fulfilling a constraint such as events, motion, operation or alarm," which exists frequently in a database. Recently, many monitoring control systems have been designed to give operators messages and, at the same time, save event logs as log data whenever such events as alarms, operations by operators, and actions by automatic control occur. Log data, in many cases, includes the times of occurrence and types (alarm, operation, control action) of events and the contents of messages and is accumulated as text data listed in time sequence.

By applying pattern mining to this log data, characteristic patterns corresponding to various situations can be extracted. Using these patterns enables us to embody improvements as shown below toward the achievement of optimum operation.

(1) Reducing unnecessary alarms

By extracting consecutive alarm patterns, in which only specific alarms occur, or patterns of the occurrence of notification alarms that do not need any operation, unnecessary alarms can be reduced through, for example, the aggregation of alarms.

(2) Automating routine operations

By extracting patterns of combinations of operations relative to the occurrence of alarms, operations can be automated as routine operations.

(3) Turning operation know-how into explicit knowledge

By extracting the operation patterns of experienced operators, operation know-how can be turned into explicit knowledge or automated. In addition, when multiple groups of operators working in shifts operate the plant, they can share operation know-how different among the groups by, for example, extracting the operation pattern of each group against the same alarm.

(4) Fault factor analysis

By extracting the patterns of the occurrence of events, including the occurrence of faults that should be noted, it is possible to analyze the factors and process of the occurrence of faults.

The log analysis flow of a control system adopting pattern mining is shown in Fig. 3. Below are the main items of log analysis.

(a) Data selection: Selecting the subject range from all data
(b) Preprocessing: Dealing with missing data
(c) Data conversion: Coding and aggregating data
(d) Serial pattern analysis: Carrying out pattern mining
(e) Filtering: Filtering the analysis result
(f) Pattern extraction: Extracting the analysis pattern

4. Application Examples

4.1 Fault diagnosis by PCA

What is particularly important to maintain the performance of a thermal power plant is to discover faults with the turbine shaft. This section cites an example of the application of PCA to turbine shaft fault diagnosis.

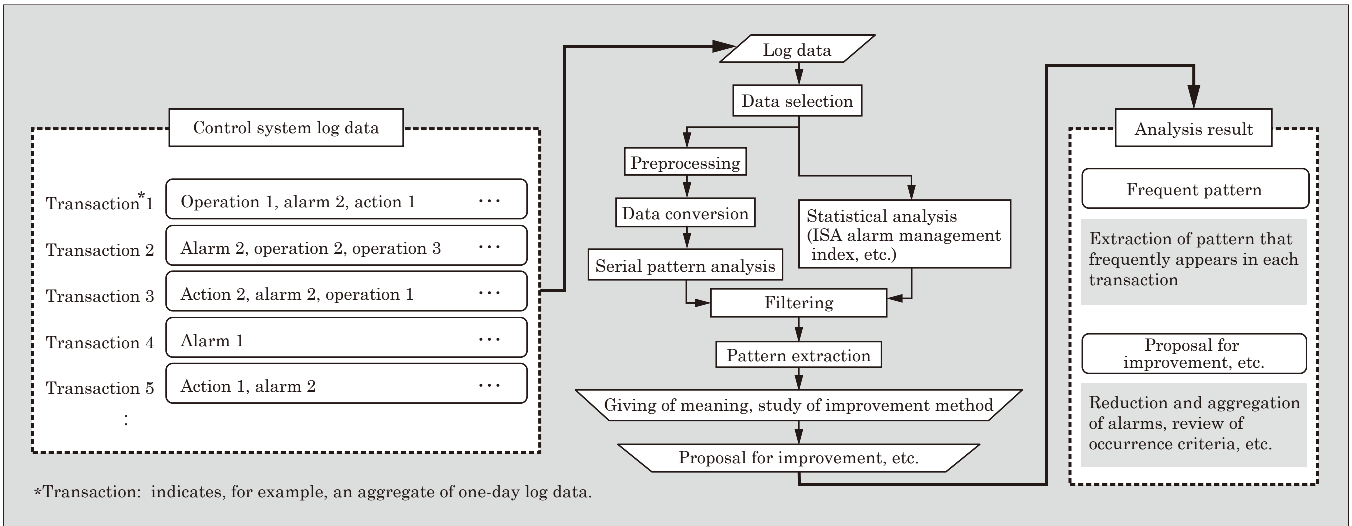


Fig.3 Log analysis flow of control system

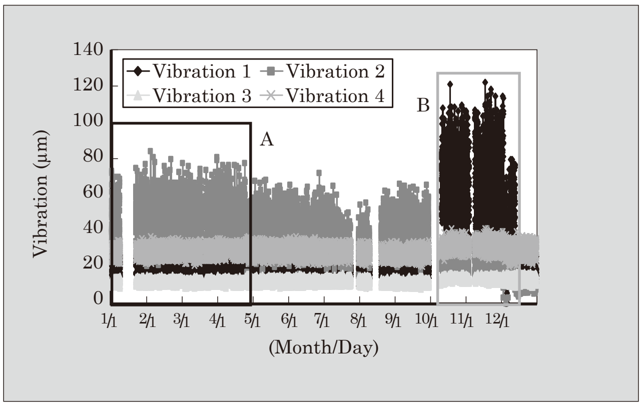


Fig.4 Vibration data on turbine shaft

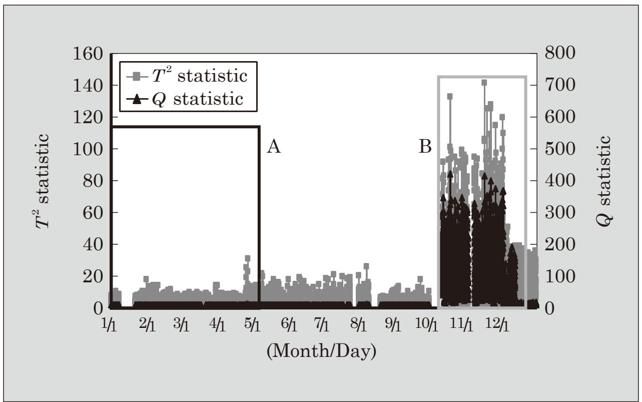


Fig.5 Analysis results of vibration data by PCA

In conventional control based on upper and lower limits, vibrations in excess of 120 µm are considered abnormal, but there is a possibility that faults cannot be detected when the value is 120 µm or lower. An example of vibration data is shown in Fig. 4. Area B is the period showing abnormal measured data because of sensor fault. Most of the data in this period was at or below the fault judgment threshold, 120 µm, and it is difficult for conventional upper/lower limit checks to detect abnormal data. PCA evaluation results of the Q and T^2 statistics by creating a PCA model based on normal data (see area A in Fig. 4) are shown in Fig. 5. The Q and T^2 statistics in area B were much larger than those in the other areas and helped detect abnormal vibrations.

4.2 Quality estimation by PLS

This section presents an example of quality estimation by PLS in a film formation process for thin-film photovoltaic cells. Based on the results of experiments performed by changing many manufacturing conditions, the relationship between the parameters of the manufacturing conditions and the conversion efficiency representing product quality was modeled by PLS.

The photovoltaic cell consists of about ten layers. The film formation process (see Fig. 6) uses about ten parameters of manufacturing conditions for the formation of each film, including temperature, pressure, film

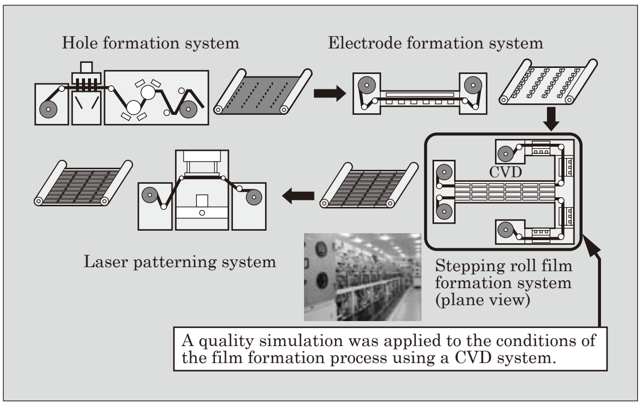


Fig.6 Film formation process for thin-film photovoltaic cell

formation time, film formation speed, film thickness, and doping level, and about 100 parameters in total for the formation of all films. These parameters are correlated with one another, and whenever any manufacturing condition is changed, the other ones correlated with the changed condition also need to be changed accordingly.

There are about 100 parameters in total for the formation of all films. These parameters are correlated with one another, and whenever any manufacturing condition is changed, the other ones correlated with the changed condition also need to be changed accordingly.

We conducted manufacturing experiments by gradually changing 30 of these about 100 parameters, which greatly affects product quality. A PLS model was constructed using data on the 115 obtained samples. The relationship between two main variables and conversion efficiency is shown in Fig. 7. In the figure, the dots are measured data, and the plane is the quality characteristic plane based on the PLS model, indicating that the distribution of the actual data can be approximated. The figure shows that higher efficiency is desirable, and that efficiency can be improved by changing the parameters of the manufacturing condi-

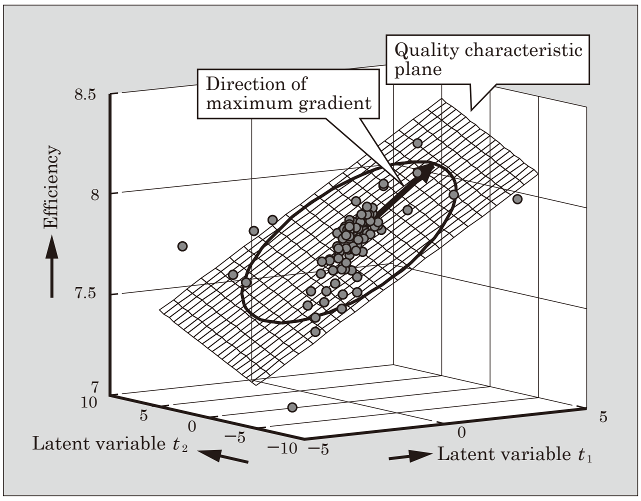


Fig.7 Example of quality estimation

tions in the steepest gradient direction (maximum gradient direction) of the plane.

5. Postscript

This paper described fault diagnosis by multivariate statistical process control, quality estimation technology adopting the partial least squares, and log analysis technology based on pattern mining as data analysis technologies for plant control. Of these technologies, log analysis technology based on pattern mining is in the process of being developed toward early practical use.

We are determined to establish more advanced, sophisticated technologies through application to actual plants and consequently make a contribution to the realization of a society offering a higher level of safety and efficiency.

Reference

(1) Kurotani, K., Todaka, Y. Current Status and Prospects of Measurement and Control Technologies. FUJI ELECTRIC REVIEW. 2012, vol.58, no.1, p.2-8.

Information and Process Control System to Support Stabilization and Safety, "MICREX-NX"

SHINO Junichiro*　SUZUKI Takehiro*　ONO Kenichi*

ABSTRACT

In control systems supporting production sites, information integration with a host system, integration with a safety-related system, strengthening of security, and the like are progressing. In such a situation, on the other hand, there is much equipment which is approaching an updating time, and it is required for succession of established property, technical innovation, and correspondence to an international standard. Fuji Electric has marketed the latest version V8.0 of information and process control system "MICREX-NX" with many delivery track records onto the market. It is a system which supports the stability and safety of plant operation with Adoption of wide screen and Windows 7, The screen design which increase visibility and operability, alarm management, security devices and safety instrumented system which are able to meet the international standards, and so forth.

1. Introduction

Control systems, which have supported production fields, are in the process of undergoing information integration with manufacturing execution and management systems and carrying out unified control of equipment and integration with safety systems. In addition, enterprises are stepping up their efforts to enhance security. Under these circumstances, production equipment about to be renewed requires a system that is adaptable to future creative technological breakthroughs while taking over existing assets.

In October 2013, Fuji Electric Co., Ltd. released the new version, V8.0, of the information and process control system "MICREX-NX," which contributes to the stable and safe operation of plants, in order to improve the safety of obsolete production equipment and, at the same time, help customers achieve stable plant operation. Since its first release in 2004, MICREX-NX has been introduced in more than 250 systems mainly in the fields of steel, chemical engineering, pharmaceutical industry and water treatment.

This paper describes the main features of the information and process control system "MICREX-NX."

2. Overview of "MICREX-NX"

MICREX-NX, among the line of Fuji Electric's control systems, is intended for controlling medium- and large-scale processes and is capable of supporting solutions compatible with many international standards such as engineering, alarm management, safety systems, control system security, batch systems and electronic records. Figure 1 shows system configurations based on MICREX-NX.

A standard system consists of an operator station (OS), which is a human machine interface (HMI), an automation system (AS), which is a controller, a process input/output module (ET200M) and an engineering system (ES). Each piece of the equipment is connected to an open network or private network via a switching hub for industrial use (SCALANCE). A dedicated personal computer for industrial use is used for the OS and the ES, and it is provided with a wide display and compatible with Windows 7*[1], and it offers a screen design combining improved visibility and usability.

MICREX-NX offers a high degree of scalability, which makes it possible to expand system configurations step by step in response to the expansion or processing capability enhancement of steel, chemical engineering, water treatment and other plants, and can be integrated with an information system covering production to management or a safety system. MICREX-NX also comes with migration products with which existing assets can be taken over.

MICREX-NX is characterized by, and provides in each phase of the life cycle, from system design to operation, maintenance and renewal, scalability adaptable to the expansion of plants, a unified engineering environment, streamlined maintenance work by cutting-edge monitoring control and equipment management functions, advanced security and safety conforming to international standards.

* Industrial Infrastructure Business Group, Fuji Electric Co., Ltd.

*1: Windows 7 is a trademark or registered trademark of Microsoft Corporation, U.S.

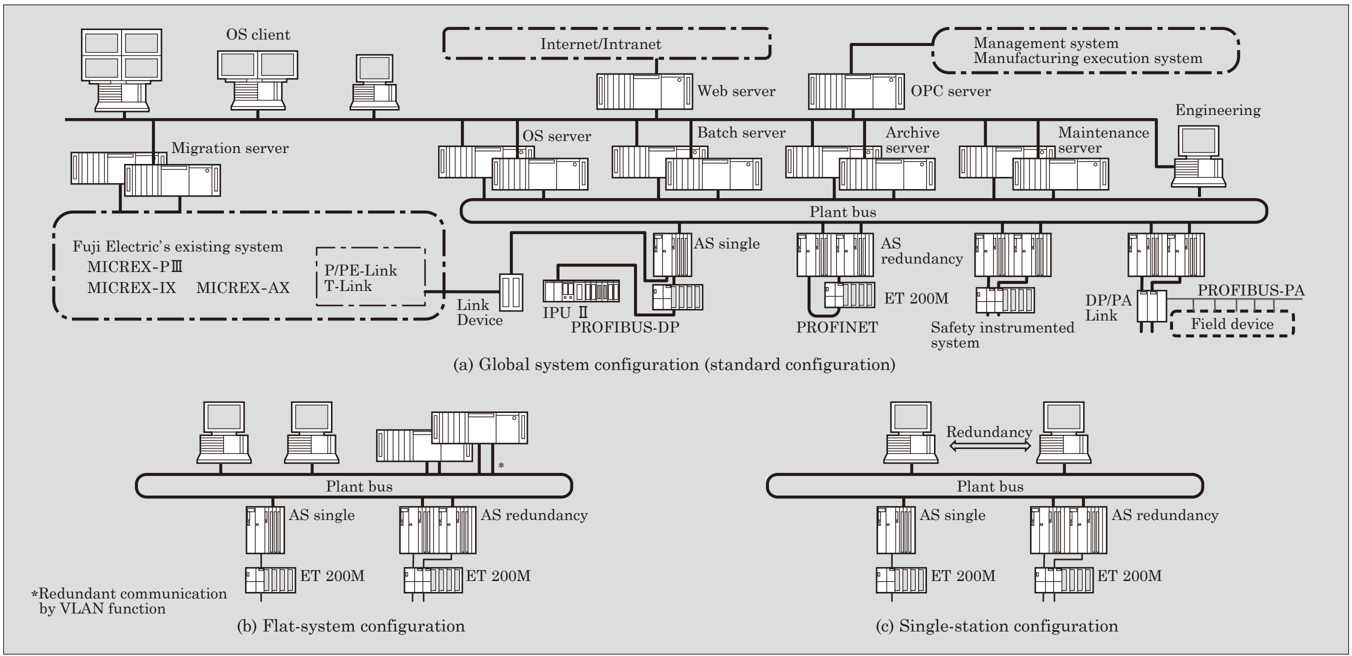


Fig.1 System configurations based on "MICREX-NX"

3. Features of "MICREX-NX"

3.1 System architecture with high expandability

(1) A variety of CPUs

For the AS, the core of MICREX-NX, a series of four types of CPUs with different processing capacities is available. A proper CPU can be selected according to the number of input/output loops or the size of application software.

(2) Diverse system configurations

MICREX-NX offers three system configuration patterns so that a system with high cost performance ratio can be constructed according to the scale of each plant. (see Fig. 1)

(a) Global system configuration

The global system configuration is the standard configuration for medium- and large-scale systems. A single system can accommodate up to 12 servers, to each of which up to 32 clients can be connected. All configurations can have redundancy. Connecting a wide variety of optional equipment also provides a system with extremely high expandability, such as longer data archive, monitoring via a web server and linkage with a host computer.

(b) Flat system configuration

The flat system configuration is intended for medium- and large-scale systems and features high cost performance ratio. This configuration is made flat by overlapping the plant bus and the terminal bus in the global system configuration by means of information technology. With the flat system configuration, the network line or SCALANCE can be shared, and such advantages as the reduction of equipment, communication cables and wiring work cost can be expected.

(c) Single-station configuration

The single-station configuration is for medium-scale systems. A single OS is endowed with engineering, data processing and monitoring operation functions. Although this configuration is compact in size, it can make the HMI and AS redundant.

(3) Complete redundancy configuration

MICREX-NX can make the HMI, AS, network and I/Os redundant, and we call this configuration the complete redundancy. The MICREX-NX's system switching function for AS redundancy, in particular, is superior to existing systems of Fuji Electric and systems of our competitors. Many controllers are designed to immediately switch their systems if any failure occurs to any of their communication routes. In the contrast, MICREX-NX, in the event of a failure

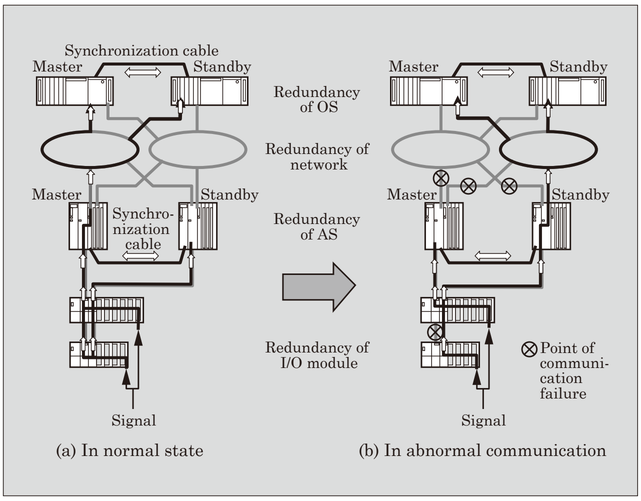


Fig.2 Concept of system switching by complete redundancy

occurring on multiple communication routes, utilizes a standby system AS to enable the operation system AS to continue operating, sending and receiving data through a normal communication route; this results in reducing the amount of switching of the AS in operation. The concept of system switching by complete redundancy is shown in Fig. 2. In other words, MICREX-NX can be said to be robust against multiple failures and extremely high in availability.

3.2 Various network connection patterns

(1) Inheritance of existing assets

For example, the energy center of a steel plant, which is generally large in scale, may require phase-in renewal. The expansion or renewal of a control system imposes a very heavy burden on the user. We offer solutions that enable users of our distributed control system (DCS) transition to the latest MICREX-NX while making effective use of their existing assets at the time of partial renewal or expansion.

DPCS-F, which is an existing control network, an FL-net compliant LAN and T-Link and P/PE-Llink used as networks for PIOs can be connected to the MICREX-NX by means of dedicated migration components (gateway or link device). This allows accessing to any existing controller from the OS, send and receive information between old and new controllers, and input and output data between existing PIOs. These features help users make the most of their existing assets and, at the same time, achieve long, stable operation.

(2) Support for open networks

It is a long time since I/O networks, field networks, information networks and so on for control systems were made open. MICREX-NX supports open networks, including PROFIBUS*[2]-DP, PROFINET*[3], MODBUS*[4], FOUNDATION Fieldbus*[5] and As-i. As a result, field equipment fulfilling users' requirements or network functions can be selected and adopted, and system configurations can be provided with a higher degree of flexibility.

With regard to OPCs used for communication with host systems, MICREX-NX is compatible not only with conventional OPC-DA, A & E and HDA but also with OPC-UA featuring high communication security.

3.3 Variety of information and process control packages

More and more international standards concerning tools and applications for control systems are in the process of being established, and such tools and applications are now part of user-specified requirements. These international standards include IEC 61131-3 covering engineering tools, ISA S88.01 concerning batch systems, ISA 18.2 and IEC 62682 (under examination) defining alarm management, and IEC 61508 defining functional safety. MICREX-NX provides tools and packages conforming to these international standards.

(1) Engineering tool

MICREX-NX supports five languages (LD, FBD, SFC, ST/SCL, IL) compliant with the international program language standard, IEC 61131-3, and users can make effective use of their past program assets.

For continuous control engineering, a dedicated editor, continuous function chart (CFC), is available. CFC enables users to design layouts and terminal-to-terminal wiring simply by dragging and dropping various function blocks (FBs) and set operating condition parameters with ease.

(2) Batch system

The batch system of MICREX-NX visualizes hierarchical structures compliant with ISA S88.01. (see Fig. 3) This batch system makes it easy to reflect designs in systems, grasp them, and change combinations of recipes. The progress of processes can be constantly monitored on the monitoring screen by linking with a dedicated editor for sequence control sequential function chart (SFC). In addition, when the batch system is used in combination with a route control package, optimum transfer can be realized even if piping or transfer conditions are complicated. The batch system is also compatible with FDA 21 CFR Part 11*[6] and ensures traceability (electronic signatures, electronic records, audit trails) with the aid of a package such as

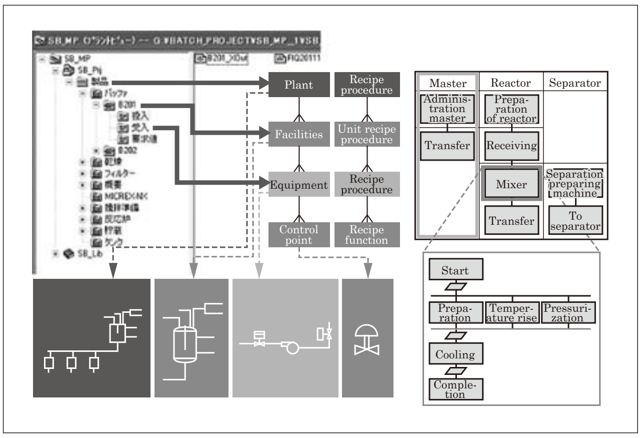


Fig.3 Visualization of batch system

*2: PROFIBUS is a trademark or registered trademark of PROFIBUS User Organization.

*3: PROFINET is a trademark or registered trademark of PROFIBUS User Organization.

*4: MODBUS is a trademark or registered trademark of Schneider Automation, Inc., France.

*5: FOUNDATION Fieldbus is a trademark or registered trademark of Fieldbus Foundation.

*6: FDA 21 CFR Part11: Regulations established by the U.S. Food and Drug Administration (FDA). Matters to be observed regarding electronic records and electronic signatures used at the time of applying for approval of sales of pharmaceutical and food products are specified there.

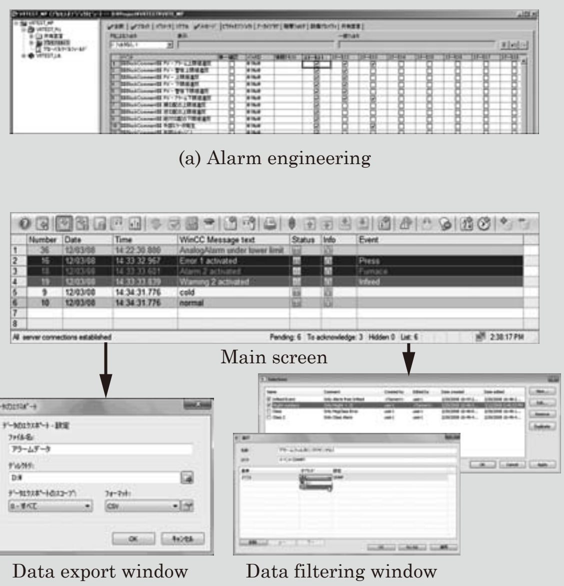
SIMATIC Logon, Version Cross Manager or Version Trail.

(3) Alarm management system

As the first step toward realizing plant safety, it is important to accurately monitor and manage the operating state of the plant and information about the occurrence of alarms. Many of the past alarm handling and issuing systems were designed to simply classify alarms into “high level,” “medium level,” and “low level.” As a result, plant operators overlooked important states in the deluge of alarms and could not keep track of what dangerous state occurred to which piece of equipment, causing latent risks of the plant to multiply.

MICREX-NX is capable of breaking down priorities of alarms of each class into 16 levels in addition to the conventional three classes of alarms (see Fig. 4). If, for example, a problem occurs at a plant and causes a serious failure on multiple devices, alarms that are more important will be reported preferentially to the HMI. On the alarm display screen, a variety of filtering functions, with which necessary alarms can be retrieved from accumulated information, are available. These alarms can also be searched not only based on the abovementioned classes or priority conditions but also by equipment. With the aid of the export function, operators can store and manage detailed information about alarms in CSV format and, at the same time, facilitate the identification and analysis of trends in alarms. The function of temporarily controlling unnecessary alarms that are frequently issued during maintenance or inspection helps operators locate true alarms without fail.

The alarm management function of MICREX-NX can reduce risks in the plant operation.



(a) Alarm engineering

(b) Alarm screen

Fig.4 Alarm engineering and alarm screen

(4) Asset management

Asset management placing emphasis on maintenance is important to enable a control system to operate for many years in a stable manner. Companies have started introducing asset management aiming to improve the effect of a control system while reducing maintenance costs of the equipment making up the control system.

Asset management provided by MICREX-NX can offer, through a dedicated maintenance station, state monitoring, diagnosis, and integrated management of the OS, AS, ET200M, SCALANCE and individual components of field devices. For example, it visualizes on the screen the diagnostic status determined by the system, identification information and diagnostic messages about components, the type and current progress of maintenance operations, etc. These functions ensure effective preventive maintenance and help to reduce work time, prevent failure to perform diagnosis, and improve the operating rate of and ensure long and stable operation of the control system.

3.4 Security of control systems

The security of a control system must be maintained from the standpoint of availability, integrity and confidentiality. In parallel with the establishment of the security standard IEC 62443 Series, Japanese companies are working hard to protect the security of their control systems. MICREX-NX features the following security-related functions:

(1) Protection of operation and engineering

HMI makes it possible to set detailed access rights (scope of equipment that can be monitored, operation and setting ranges, etc.), including a password, individually for each log-on ID, allowing system operation in a flexible manner in response to the user’s needs.

The user application for control systems is capable of preventing unintended changes to the software logic and the leak-out or falsification of important control know-how by further transforming software logic created by CFC into FBs and protecting the generated FBs with a password. This user application, if installed with an additional software package, also enables operators to manage and check change history, including version numbers, as well as the users who accessed the system.

(2) Connection to virtual private network (VPN)

As plant facilities are becoming gigantic or their decentralization (construction of local or overseas facilities) is accelerated and IT is further developing, wide-area networking, remote monitoring and maintenance of control systems have become easy. This situation consequently forces us to introduce measures against tapping on networks, intrusion into systems and information falsification to the control system.

MICREX-NX uses SCALANCE S (VPN or firewall construction module), which is a dedicated security product, to reduce the risk of tapping, intrusion and falsification. SCALANCE S protects data exchanged through communication between facilities with a robust encryption protocol (IPsec). Up to 128 VPN routes can be established, and therefore, it is possible to construct a network among multiple facilities. Enabling the firewall can strongly block unauthorized access from outside.

(3) Anti-virus measures

MICREX-NX protects control systems from virus threats, which are increasing and becoming more serious year by year, with two means. One is conventional virus-scan-type software. It entails operation-related issues, such as heavy burdens on the system and the necessity to update virus patterns as appropriate. The other is a function called white listing. White listing means protecting the system from adverse effects of all viruses, whether known or unknown, by registering software and applications when the system is clean before it is infected with a virus as a “white list,” and controlling all operations of unregistered software and applications. Unlike the virus-scan-type software, white listing does not need frequent updating of pattern definitions and, at the same time, can prevent damage by new viruses. It can also minimize burdens on the system because it does not require constant scanning.

(4) Third party-certified system

Achilles Certification, which is a third party certification system for control system security, qualifies products, such as controller components, that maintain a specified high level of communication security robustness. MICREX-NX can build a high-security control system consisting of components qualified as Level 2 by Achilles Certification.

3.5 Integration of control and safety

MICREX-NX serves not only as a process control system but also as a safety instrumented system (SIS). Fuji Electric markets the system as “MICREX-NX Safety.” An integrated-type SIS, MICREX-NX Safety is characterized by the following features:

(1) Both safety instrumentation and process control can be achieved with one AS

In general, the SIS and the DCS are separately configured. MICREX-NX Safety can achieve a concurrent configuration of the SIS and the DCS with a single AS besides a separate configuration and ensure safety levels up to SIL 3 in any configuration.

By applying to the AS a dedicated system for realizing a safety control function, a protection mechanism different from the DCS is extended to the AS and enables it to function as the SIS. However, this feature is applicable only to ASs supporting redundancy. Software for the SIS and that for the DCS are theoretically separated from each other and run while maintaining independence. This is the technology Fuji Electric realized for the first time in the world, and certified by the German certification body, TÜV SÜD.

(2) Engineering of both the DCS and the SIS is feasible with one ES

Engineering by MICREX-NX Safety uses the same hardware and engineering tools used by the DCS. That is, both the DCS and the SIS can be designed with one ES. The SIS is provided with a different password lock function from that of the DCS to prevent changes being made to the SIS application software by personnel other than the person in charge of the SIS design. Safety Matrix, which is an engineering tool exclusively for the SIS, is capable of automatically generating safe the SIS application software simply by entering information about input signals, logic conditions and output signals on the tabular form screen (see Fig. 5).

(3) Monitoring is possible with one HMI

The operating state of the SIS is generally monitored by the HMI of the DCS. However, it is anticipated that operators may not take a thorough emergency response if only the operating state of the SIS, which works in case of emergency, is displayed on the regular monitoring screen. Nevertheless, designing a dedicated screen capable of displaying the operate state of the SIS in an easy-to-understand manner as needed incurs a heavy burden.

MICREX-NX has the function of displaying on the HMI a screen of the same design as the screen of Safety Matrix. On the matrix screen using various colors, the operator can immediately identify which sensor is activated, what logic judgment is based on, and to what equipment a signal was output, in connection with the safety function that has just operated.

(4) Configuration of a safety function loop

The safety I/O module of MICREX-NX Safety can establish duplication or redundancy (1oo2, 2oo2, 2oo3, etc.) in combination based on the safety level of input/output equipment in any position (see Fig. 6). With

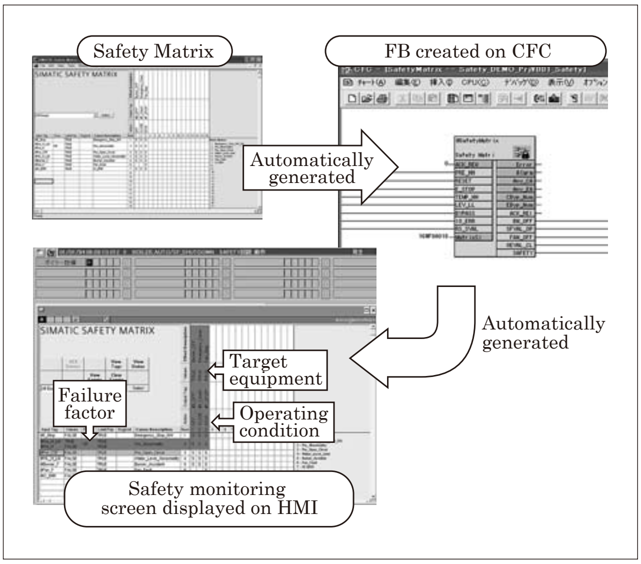


Fig.5 Automatic generation of SIS application software by Safety Matrix

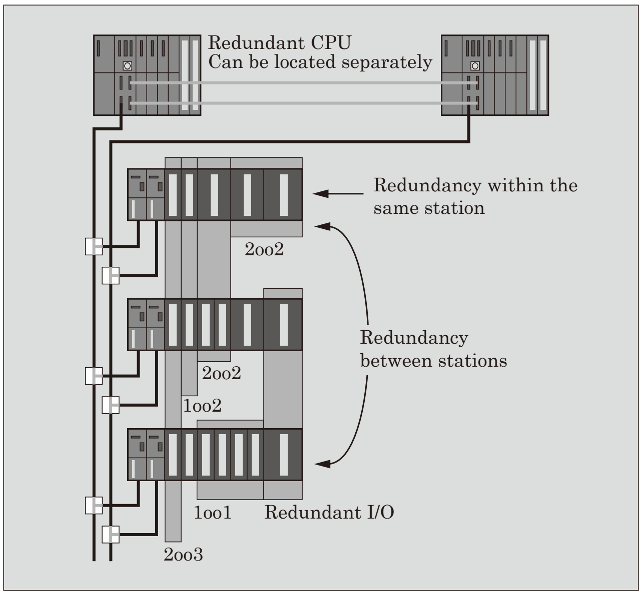


Fig.6 SIS redundancy configuration

this configuration, operators can respond to multiple concurrent failures, or reduce failures attributable to common causes.

4. Postscript

This paper described the characteristic functions of the information and process control system “MICREX-NX” that combines various technologies and solutions to help plants operate in a stable and safe manner.

In Japan, existing plants will be further expanded or refined, and the role of monitoring control systems will become more important accordingly. In particular, commitments compliant with international standards such as active adoption of safety systems, protection of system security and alarm management are expected to increase and accelerate.

We are committed to pushing forward with system development to keep MICREX-NX as the information and process control system capable of offering solutions to issues confronting customers.

Small- and Medium-Scale Monitoring and Control System to Realize Inheritance and Evolution of Customer Assets, “MICREX-VieW XX”

NISHIWAKI Toshiyuki* FUJITA Fumihiko* NAGATSUKA Kazuhito*

ABSTRACT

The “MICREX-VieW XX” small- and medium-scale monitoring and control system allows users to continue using the screen and program assets of existing facilities and realizes a connection with existing networks in updating of customer facilities. Screens and programs can be efficiently created by the vertically and horizontally integrated engineering environment. In addition, the compact, high-performance and high-reliability controller with abundant built-in communication interfaces and high-speed, high-capacity dual I/O bus allows users to build a dual system with no common portion. Continuous operation is possible even in a multiple-fault mode and high reliability is realized.

1. Introduction

In Japan, there has been an increasing need to upgrade aged equipment and systems brought about by lack of investment in industrial and social infrastructure resulting from the so-called lost two decades after the bubble economy burst. In the instrumentation control field, systems are required to inherit operations and perform segmented upgrades of facilities, as well as supporting the mix of old and new systems while allowing for long-term and continuous operations.

Furthermore, the steady expansion of capital investment centering on overseas developing nations such as China and regions in Southeast Asia has led to an increased demand for stable production facilities, improved production efficiency and ease of operations.

Fuji Electric is meeting these industrial and social infrastructure needs through the development of its “MICREX-VieW XX (Double XX),” medium- and small-scale monitoring control system that standardizes control system architecture. This paper describes the features and main functions of the system.

2. Control System Platform

Fuji Electric has developed a control system platform that is capable of widely applying to our monitoring control systems. It consists of the control system layer, software library layer and engineering environment.

The control system layer consists of a database, controller, I/O equipment and HCI (human communication interface) ,equipped with a migration system, that allows asset utilization of past products, thus providing the control system layer with a sufficient functionality and performance that can be applied to a wide range of fields including our specialized instrumentation control and electric control fields.

The software library layer consists of a group of software that maximizes the functionality and performance of sensors and actuators, and a system template and other features that minimize system cost and lead-time.

Control technologies are packaged on the control system platform, which combines these two layers with the engineering environment, with applications installed. These packages can then be applied individually to various Fuji Electric control system fields.

3. Position of “MICREX-VieW XX”

Figure 1 shows Fuji Electric’s monitoring control system position map. The monitoring control system covers a wide range from line and cell control via small-scale systems to plant-wide control via large-scale systems. The “MICREX-NX” can apply to the entirety of plants and factories and has been constructed as a large- and medium-scale monitoring control system suited to chemical, pharmaceutical, water treatment and iron and steel energy centers that require conformity to international standards such as functional safety standards and FDA 21 CFR Part 11*1. The MICREX-VieW Series consists of a diverse application lineup including the “MICREX-VieW XX,” “MICREX VieW VX System,” “MICREX-VieW FOCUS”

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*1: FDA 21 CFR Part11: Regulations established by the U.S. Food and Drug Administration (FDA). Matters to be observed regarding electronic records and electronic signatures used at the time of applying for approval of sales of pharmaceutical and food products are specified there.

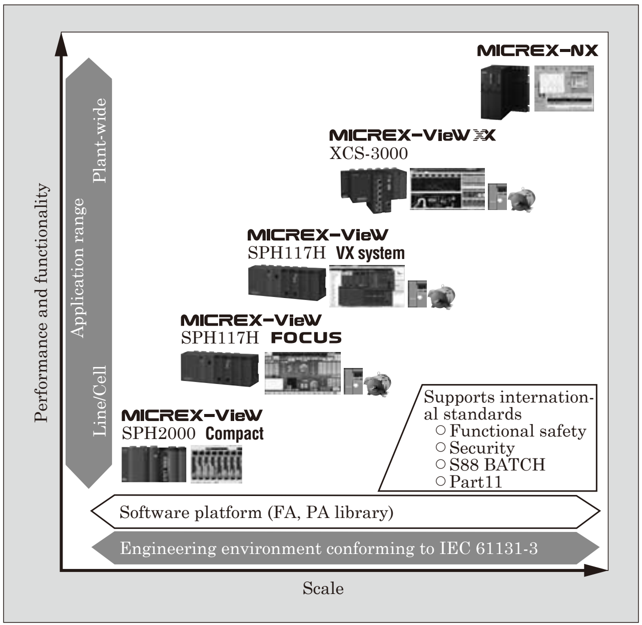

Fig.1 Fuji Electric's monitoring control system position map

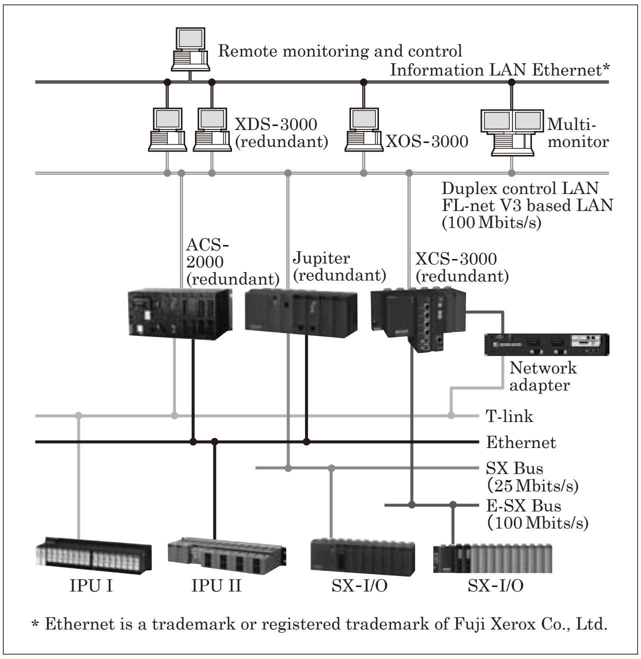

Fig.2 Configuration example for the "MICREX-VieW XX" system

and "MICREX-VieW Compact."(1)

The engineering environment of the MICREX-VieW Series is compliant with the IEC 61131-3 international standard. This series can be applied to the monitoring control system engineering of all types of systems, whether small-scale or large-scale, in the factory automation (FA) and process automation (PA) fields. In addition, the control system layer has common system architecture and integrates engineering tools, applications and displays, as well as to improve compatibility, scalability and flexibility.

The MICREX-VieW XX construct a medium- and small-scale monitoring control system that can be applied to a wide range of applications, such as line control, cell control, process lines and steel rolling in the electric control field, as well as cement, power generation and waste processing in the instrumentation control field.

4. "MICREX-VieW XX"

The MICREX-VieW XX comes with the following functionality in order to achieve the "inheritance and evolution of customer assets" in various fields such as the instrumentation control and electric machine control fields.

(a) A complete duplex database to prevent data loss
(b) A compact, high-performance, highly reliable controller that has rich built-in communication interfaces
(c) A duplex high-speed, large capacity I/O bus
(d) Functions that enable the inheritance of display and program assets
(e) A network connection that can connect with existing systems and easily be scaled in the future
(f) Vertically and horizontally integrated engineering functions for effective production of displays and programs
(g) PC-based HCI with better operability

Figure 2 shows a configuration example of the MICREX-VieW XX system. The system uses a FL-net V3 based duplex control LAN, and the system consists of stations including existing equipment, a duplex database, maximum 16 operator stations, and maximum 30 duplex controller stations. Furthermore, the I/O equipment can connect to the following I/O network:

(a) "E-SX Bus": 1 line
(b) T-link for connecting IPU I: up to 4 lines
(c) Ethernet*2 for connecting IPU II: up to 2 lines

In addition, the existing control network PE link and DPCS-F connection are available.

4.1 Highly reliable system

As shown in Fig. 3, the MICREX-VieW XX achieves a highly operable and reliable system by having duplex database, power sources, base board, controller components, control network, E-SX Buses, integrated type I/O devices, network adapters, mounted network card and network lines. Furthermore, when using IPU II, duplex I/O devices can also be configured. Since this duplex system has no common components, continuous operation of the system is possible in multiple failure modes.

The redundancy method of the MICREX-VieW XX is a warm-standby method that equalizes application data and performs failure monitoring mutually by connecting the running controller and standby controller

*2: Ethernet is a trademark or registered trademark of Fuji Xerox Co., Ltd.

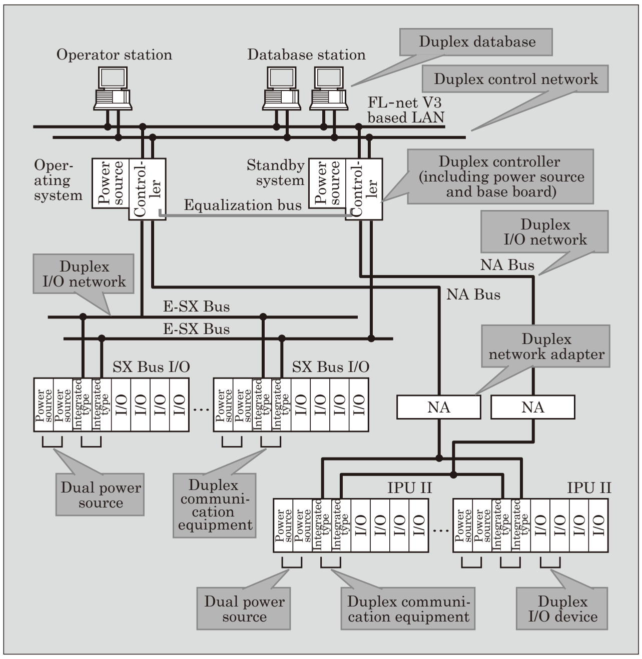

Fig.3 Configuration of a highly reliable system

via the equalization bus. If a failure were to occur to the running controller, it would switch to the standby controller in no more than 400 ms, allowing the system to continue its operations. Since the running controller summarizes the relevant controller system states and broadcasts it to the higher-level HCI, system supervisors will recognize system alarms.

Since the communication performance of the equalization bus had been slow in conventional system, the possible amount of equalization data was small in comparison with the data region of the application program. Therefore, it became necessary to sort data for equalization, and this caused poor productivity compared with when creating single system application programs. The new system enabled the equalization of all data regions (up to 2,386 Kwords) that the application program uses by expanding the data transfer performance of the equalization bus between the running and standby systems. This eliminates the need to sort equalization data, and since the application program can be created without any sense of duplex configuration, this enhancement improves quality while reducing engineering man-hours.

4.2 Application on existing control system replacement

Figure 4 shows the replacement of existing control systems. To perform replacing existing control systems in stages, the system is designed with following measures to provide continuous usage of assets:

(a) Inheriting customer assets

Screens and program applications can be converted to the new systems.

(b) Continued use of support tools

Support tools and controllers have a common hardware interface to keep connection between existing systems and new systems.

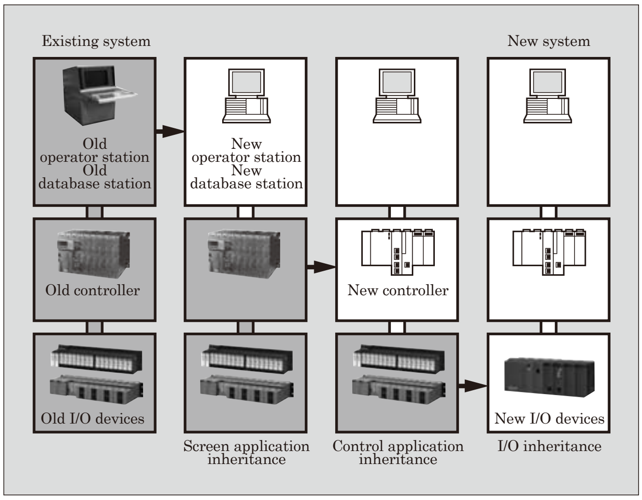

Fig.4 Example of existing system upgrade

(c) Connection to existing networks

New systems can connect to existing I/O networks by a network adapter, therefore realizing continuous use of user assets which have long life-time such as network cable or I/O equipment.

These measures give users the ability to upgrade their facilities partially at all levels of the system. Users can use the new hardware to inherit application assets. Furthermore, by inheriting and continuing to use the same engineering tools and monitoring displays as the existing systems, the conventional operability can be maintained "as is," making continued operation possible.

4.3 Continuity with FA field

In the FA field, the "MICREX-SX Series" is being employed widely in control systems ranging from machine control to advanced motion control. (Refer to "Integrated Controller Realizing Machine Control and Advanced Motion Control, 'MICREX-SX Series'" on page 43.) The MICREX-VieW XX has high similarities to the MICREX-SX Series controller, and it has following features:

(a) The support tool conforms to the programming language of the IEC 61131-3 international standard, and the library such as function blocks can be used in common.

(b) In many cases, plant control applications are built with linkage operation of higher process control and lower sequential control, and the integrated engineering station supports both application programs of higher level and lower level by the same support tool.

(c) The "MICREX-SX" I/O devices and communication interface equipment are used in common via the E-SX Bus. The system has cost benefits since spare parts of various devices that are needed in process control and sequence control can be shared.

4.4 Characteristics of each component

(1) Compact, high-performance and highly reliable controller

Figure 5 shows the exterior of the "XCS-3000," and Fig. 6 shows the standard configuration of the "MICREX-VieW XX." The XCS-3000, shown in system configuration in Fig. 6, is a controller which performs control program execution, duplex control network and data equalizing via a single unit. By taking advantage of high-density packaging and natural cooling technology, it has a compact housing with external dimensions of W145.0 × D69.8 × H113.1 (mm), equipped with a 1 Gbits/s Ethernet-based duplex control network, an equalization bus and network adapter bus. Furthermore, XCS-3000 has a 100 Mbits/s Ethernet-based E-SX Bus, general Ethernet interface and USB interface. In addition, it provides a built-in SD memory card slot that supports up to 2 GB for storing application program data.

(a) With a multi-processor architecture, it is capable of parallel execution of network processing and application program data processing. These following functions expand capability to apply to the range of medium- and small-scale systems.
  ○ High-speed execution function: as fast as 8 ns per basic instruction
  ○ Large memory capacity: program 512 Ksteps
  ○ Data: 2,368 Kwords
  ○ I/O: up to 4,096 words

(b) It has a duplex line control network that is capable of high-speed and large capacity data transmission, using 1 Gbits/s Ethernet. Additionally, by implementing the equalization transmission protocol that performs 512 Kword of transfer of equalization data within 70 ms, it is possible to construct a high-reliable system which has improved throughput and high-speed execution cycle.

Fig.5 "XCS-3000"

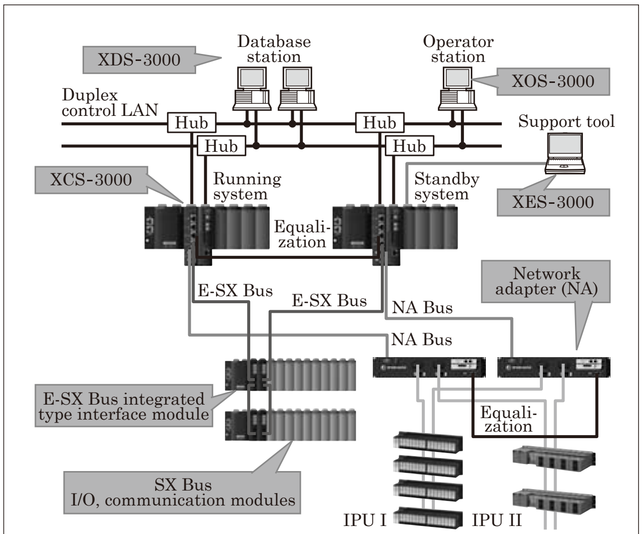

Fig.6 Standard system configuration of the "MICREX-VieW XX"

(2) I/O devices

XCS-3000 provides connection to integrated type interface modules that implement duplex E-SX Bus protocol based on 100 Mbits/s Ethernet technology at the physical layer. As shown in Fig. 6, it is possible to configure a large capacity and high-speed duplex I/O bus for achieving high reliability, enabling to use various SX Bus-connected I/O device or communication device via E-SX Buses. Furthermore, by using the network adapter, the IPU-II that is process automation I/O device is available to achieve higher reliability of I/O equipment itself. The IPU II, an integrated type I/O device, has redundant power supply, backbone bus, communication interface and I/O.

(3) Network adapter (NA)

The network adapter, as shown in Fig. 6, connects with the controller via the NA Bus that has a block transfer protocol capable of high-speed data transfer on 1 Gbits/s Ethernet. The NA body is equipped with a total of six slots, and the implementation of various communication cards allows it to connect with existing Fuji Electric original network products such as IPU I, IPU II, DPCS-F and PE link or with open networks.

The data refresh performance of the NA Bus is 10 ms at the maximum in control networks as well as in I/O networks. In addition, the NA body also has duplex configuration to ensure high reliability.

These features allow applications of the controller to adopt a common specification for various networks, and in addition to connecting to existing networks, it becomes easy to scale networks in future expansion.

(4) Software tool

The MICREX-VieW XX is equipped with the highly operable operator station "XOS-3000," the reliable and open database station "XDS-3000" and integrated engineering station "XES-3000." IEC 61131-3 compliant "SX-Programmer" (Expert) support tool is used for controller support, which allows various operations such as the creation of application programs, the setting of system definition parameters, the diagnosis of failures and the monitoring of operations. (Refer to "Latest Operation and Engineering Functions of

Small- and Medium-Scale Monitoring and Control System, 'MICREX-VieW XX'" on page 38).

5. Postscript

By applying the "MICREX-VieW XX" medium- and small-scale monitoring and control system, it is possible to construct a high speed, high precision, and highly reliable system, and enables customers to continuing using their existing assets. This system contributes to the high quality production of products and stable and efficient operation required by various plant systems.

We are committed to expand the functionality of control systems continually to solve the issues faced at manufacturing sites.

Reference

(1) Fukuzumi, M. et al. "MICREX-VieW" for Small and Medium-scale Monitoring and Control System Platforms in Energy & Environmental Fields. FUJI ELECTRIC REVIEW. 2012, vol.58, no.1, p.14-20.

Latest Operation and Engineering Functions of Small- and Medium-Scale Monitoring and Control System, "MICREX-VieW XX"

SATO Yoshikuni* KITAMURA Sumio⁑ HINATA Kazuhito*

ABSTRACT

The small- and medium-scale monitoring and control system "MICREX-VieW XX" is equipped with the latest functions as follows. The "XOS-3000" operator station achieves high operability with a multi-window platform MPF. The "XDS-3000" database station is capable of data analysis using relational database (RDB) and duplex configuration with no data missing. The "XES-3000" engineering station allows high-efficiency, high-quality engineering by the integrated TAG and variable database and simulation feature that eliminates the need for the actual equipment.

1. Introduction

The "MICREX-VieW XX (Double X)" small- and medium-scale monitoring and control system comes equipped with the highly-operable operator station "XOS-3000," the reliable and open database station "XDS-3000" and integrated engineering station "XES-3000." In this paper, we will describe the functions and features of these devices, and give information on control system security based on recent trends.

2. Operation Functions

2.1 High-operability via the multi-window of the operator station "XOS-3000"

To provide operators of the MICREX-VieW XX with user-friendliness and high operability, the multi-window platform "MPF" was developed. The MPF has many display functions such as a multi-window display for simultaneously showing individual monitoring windows and a multi-display that utilizes multiple display screens. Operators can easily arrange the screens to meet their purposes such as increasing the size of the screens they want to monitor the most and decreasing the size of screens that provide supplemental information (see Fig. 1). Furthermore, the screen window layout can be saved and restored.

The MICREX-VieW XX generally uses a 27-inch 1,920×1,080 resolution display. Operators want to enlarge or reduce the screen display freely depending on the distance from the screen and room lighting on to ensure that it is always "easy to see." This functionality is achieved in the MPF by utilizing vector format drawing based on windows presentation foundation (WPF) technology. The operator can freely zoom-in and zoom-out by using the "pan and zoom panel" (see Fig. 2) to adjust the screen arbitrarily so that it is easy to view.

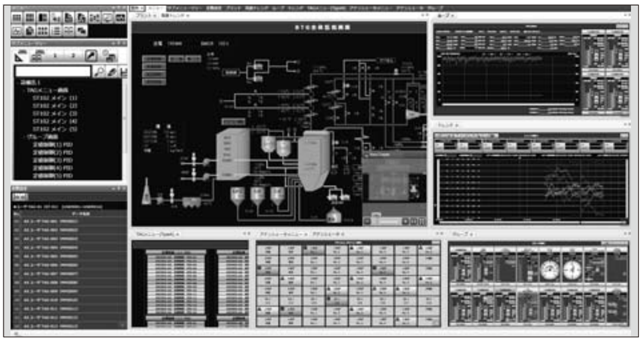

Fig.1 Example of multi-window display

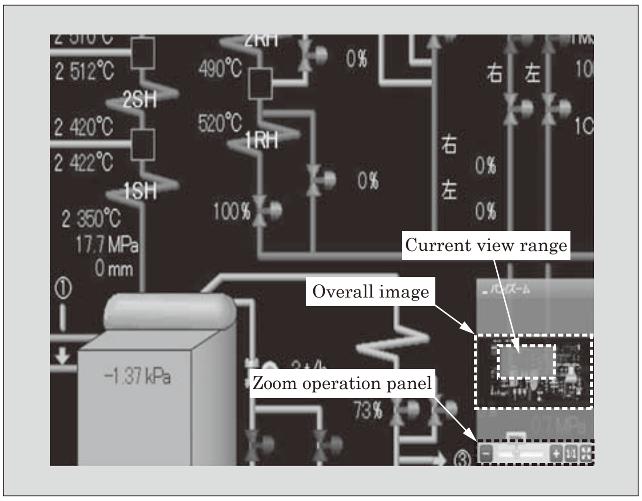

Fig.2 Pan and zoom panel

* Corporate R&D Headquarters, Fuji Electric Co., Ltd.
⁑ Industrial Infrastructure Business Group, Fuji Electric Co., Ltd.

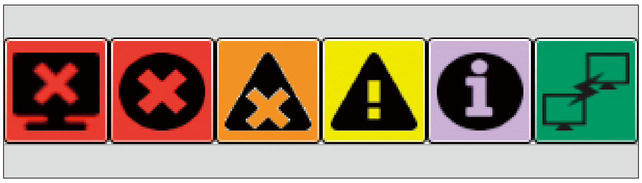

Fig.3 Example of icon display

2.2 Visibility and operability of the "XOS-3000"

The operator station XOS-3000 carries out the design of the operation screen to ensure visibility and operability with consideration given to the arrangement of the graphics and window, as well as the operation and color scheme of the keyboard and mouse.

The basic colors used on the monitoring operation screen have been decided based on the Color Universal Design. Colors used on the screen are classified by accent colors and base colors, adopting a standard color pattern with consideration given so that no false recognition arises due to differences in each color perception. In addition, the screen uses only black, white, and the other basic six colors, and by maintaining a sufficient contrast between the characters on the screen and background colors, the display is easy to view and helps to ease the fatigue that comes with long-time use.

In order to make the screen easy to identify, high visibility icons are used, by avoiding indication only by characters or colors to express their meaning (see Fig. 3).

2.3 High-maintainability of the "XOS-3000"

The MICREX-VieW XX combines the functionality that customers need so that they can create a system for their purposes. This is done through highly independent operation whereby application software is treated as "add-ins" in the MPF. (see Fig. 4)

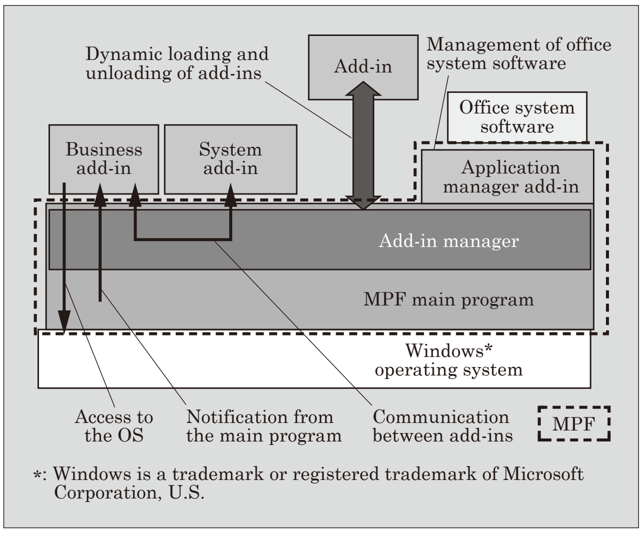

Fig.4 "MPF" structure

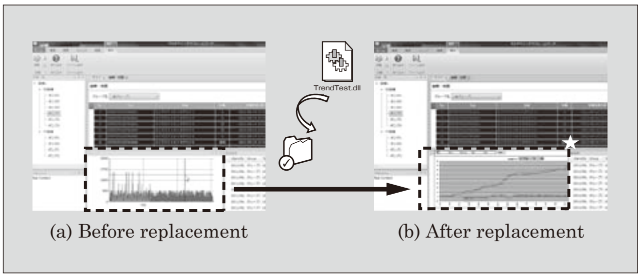

Fig.5 Online update of add-ins

Furthermore, when maintenance is required such as when adding display functions or performing updates, these actions should be done while minimizing the effects on plants that operate 24-hours a day. The MPF allows operators to install, update and remove add-ins while the system is running (see Fig. 5).

2.4 Highly reliable "XDS-3000" database station

Each of the stations that constitute the MICREX-VieW XX differs from common client-server configuration as an information system. Each is independent of the others and provides a robust way to acquire plant information through communication with the controller.

Among these components is the XDS-3000 database station that collects series (historical) data such as plant trend data, report data and at times of alarm, thus carrying out unitary management and making the station essential for performing analysis. Historical data is any important record information that arises while the plant is operating, for which defects must not occur as a result of accidents that may happen to the system.

The XDS-3000 forms a duplex system with two stations, one running and another as a standby. This ensures continuous operation based on a security and high reliability.

The historical data collected by the station on the operation side of the XDS-3000 is stored in a relational database (RDB), and equalization is continuously implemented through RDB mirroring to the standby station. Therefore, if the station in standby is shut down temporarily, the historical data during the shutdown will be automatically equalized with the standby station after it restarts, ensuring that defects in the historical data do not occur.

By making use of the features of an RDB, the XDS-3000 is able to provide users with search and display functionalities in their desired conditions. The RDB can be accessed by Structured Query Language (SQL), providing the operator with the ability to analyze with various database keys such as the time of the data, plant facilities, and information sources. In addition, the XDS-3000 can promote the effective use of data by users in the safety-ensured environment described in Chapter 4.

3. Engineering Functions

3.1 "XES-3000" integrated engineering station

The XES-3000 integrated engineering station is a unit to optimally engineer the MICREX-VieW XX for the plant. As is mentioned in Section 3.2, this station provides an integrated engineering environment that combines various tools focusing on the integrated TAG database.

3.2 Vertical and horizontal integrated engineering

(1) Integrated database

TAGs*1 and variables of XOS-3000, which is the human communication interface (HCI), and the controller "XCS-3000" in the engineering of this system are integrated by the database in the system without any overlapping definitions for each application software project. Even the TAGs and variables that span vertically (between the HCI and controller) and horizontally (between each station of the controller), access can be made anywhere inside the system via the integrated database. Doing this sets the system free from the transmission processing between each station of the controller and from the shared operation of the HCI and controller, which has been traditionally a troublesome task. This type of easy, highly efficient and high-quality engineering contributes to reduction in man-hours.

(2) Integrated cross-referencing

The system is also integrated entirely with respect to cross-referencing. Quick implementation can be made across the HCI and controller of follow-up studies when an abnormality arises during testing or operation, as well as of studies on the range of influence that requires confirmation when adding, modifying or deleting TAGs or variables (see Fig. 6).

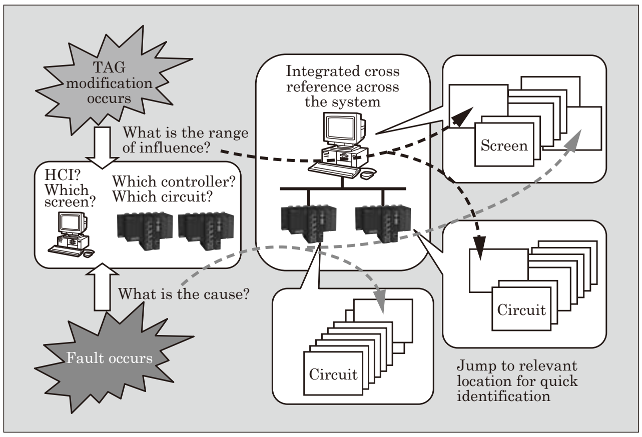

Fig.6 Integrated cross reference

*1: TAG is a unique symbol defined for controlling measurement objects.

3.3 Automatic generation of control software through the specification description

The engineering tool "HEART" is able to automatically generate control software from software function specifications created in general-purpose office automation (OA) software such as Excel*2 or Visio*3. Engineering support is available for all stages of development from determination of specification, design, testing, local adjustments, through maintenance. The tool has the following features:

(1) Specification editing

Since editing can be done in the user's familiar OA software, the tool has the advantage of reducing the burden on users during implementation, as well as making it easy to use in the engineering of customers.

Instrumentation flow, interlock block diagram (IBD), sequential function chart (SFC), time charts, etc. have all been provided as ways of describing the control function specifications, allowing the user to create the specifications using expressions that suit the desired form of control. With regards to drawings, in addition to Excel and Visio's excellent editing functions, HEART also comes with its own set of unique editing functions such as drag and drop from a group of function symbols prepared by HEART, as well as a clickable toolbar. Therefore, users can edit more easily and efficiently than creating the specifications in Excel or Visio alone. Furthermore, when there are places for which the control content is difficult to understand, HEART provides the ability to insert bubble comments and images, making it possible to have the same descriptions that as the information that is normally used in creating the specifications. In addition, it also takes advantage of the merits of general-purpose software and allows users to confirm the specifications created in Excel or Visio by e-mail, thus helping customers reduce the number of meetings that they need to have.

Furthermore, the software provides a wealth of evolving functionality including segmentation of control functions created by users and speeding up utility functions that can be used when inputting variable information during editing. These functions provide traditional property input methods as well as other methods such as cross references and drag and drop from a variable list.

(2) Monitoring functions

After downloading the control software created in HEART to the controller, monitoring of the execution state of the controller (on and off state of bits and analog values) can be done according to the created control function specifications. Furthermore, values can be

*2: Excel is a trademark or registered trademark of Microsoft Corporation.

*3: Visio is a trademark or registered trademark of Microsoft Corporation.

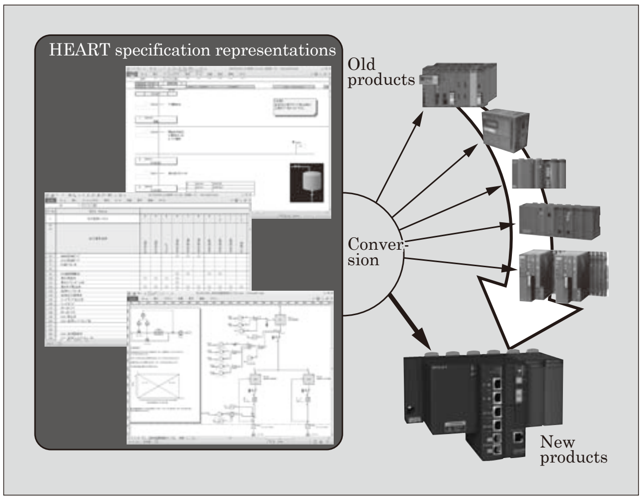

Fig.7 Engineering inheritance via “HEART”

written for the controller memory, which is effective in studying abnormalities during debugging and operation.

When using HEART, modifications and changes during testing and on-site adjustment are carried out on the specifications themselves. Therefore, specification follow-up to match up with the software modifications and changes is no longer necessary, and this eliminates mismatch between the specifications and the software due to follow-up description mistakes.

(3) Inheritance of engineering

The control function specifications created in HEART can be converted to the control software of various controllers. It supports various existing controllers such as the “ACS-2000,” “ACS-250,” “MICREX-SX,” “MICREX-Jupiter” and “MICREX-NX.”

In addition to supporting the MICREX-VieW XX controller XCS-3000, it also inherits high efficiency and high quality engineering. HEART can also be effectively utilized when migrating from previous products (see Fig. 7).

3.4 Simulation functions

The MICREX-VieW XX comes equipped with the “VieW System Simulator” (see Fig. 8). Even if the user has not prepared actual equipment such as a controller and I/O module, operation verification of the monitoring control system can be carried out easily through the use of a PC alone, thus allowing users to perform operation verification for the user-created program as well as coordinate operations between the controller and the monitoring and operations of the XOS-3000. In addition, since there will be frequent downloads to the controller while modifying the program during the initial stages of design, the use of a simulator allows users to shorten transfer time and also efficiently carry out operation verification. Table 1 shows the operation environment of the simulator.

(1) Modeling of multiple controller configurations

The simulator can be operated while simultaneously modeling configurations of multiple controllers connected by a control LAN. Modeling is also carried out for the data memory of the control LAN that connects multiple controllers and communicates plant data with the XOS-3000. This simulator alone can carry out operation verification of monitoring operation screens that target multiple controllers as well as data linkage between the controllers. It is possible to implement simulation for up to 8 controllers at once on a single PC.

(2) Ease of switching between the simulator and actual equipment

By simply changing the XOS-3000 connection from the simulator control LAN to the actual control LAN, it is possible to switch from the PC simulation to the actual equipment. This has the merit of improving the development efficiency of customer systems.

When carrying out display and controller engineering for the MICREX-VieW XX in separate locations both domestically and abroad or even when sharing the tasks within an organization, it is possible to carry out operation verification of the system by using the actual equipment and simulator separately as needed. If the system is small-scale, it is possible to perform all system simulations using a single PC.

(3) Modeling of large-scale systems

When performing modeling of large-scale systems, loads are distributed by connecting multiple PCs to

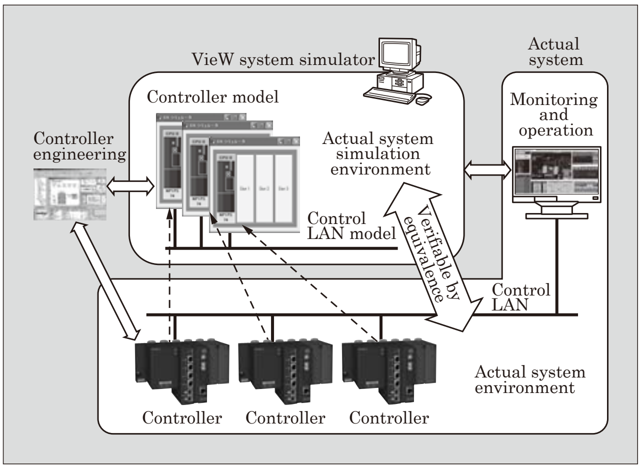

Fig.8 Simulation functions

Table 1 Simulation operation environment

Functions	Specifications
Compatible products	SPH300 Series, SPH2000 Series, SPH3000 Series, XCS-3000
CPU	8 per configuration
P/PE	8 per configuration
Control LAN	FL-net, SX-Net
I/O	Supports I/O expansion, compatible with E-SX bus I/O
System memory support	Free-running counter, cause of failure bit, application abnormality detection
Connection HCI	XOS-3000, POD

Ethernet*4, using the data memory sharing functions in the control LAN model and carrying out data linkage. For example, in the case of HCI, it is easy to implement simulation of the controller on a separate PC. This makes it possible to carry out highly reproducible simulations, including responses, even in large-scale systems.

4. Control System Security

4.1 Trends in Japan and abroad

Starting with the Stuxnet attack virus, which targeted Iranian nuclear facilities in 2010, cyber attacks of control systems have been on the rise, and this has created a sense of urgency regarding security measures for control systems. Under these circumstances, third-party certification of security based on the IEC 62443 international standards has begun overseas, and there are now cases starting to appear where certification is becoming a procurement requirement in plants.

Even in Japan, the Control System Security Center (CSSC) was established in April 2012 under the guidance of the Ministry of Economy, Trade and Industry as an institution for evaluating and certifying control system security based on the IEC 62443 international standards in order to ensure the security of critical infrastructure and improve international competitiveness.

4.2 Security evaluation and certification

The preparation of international standards has been making progress to meet control system security requirements, and an environment is being developed that can apply evaluation and certification of security as a common standard. Fuji Electric participates in the IEC/TC65/WG10, which is a domestic council of IEC 62443, as well as participates as a joint enterprise cooperative in CSSC in order to support the creation of a security evaluation and certification scheme for control systems, and to improve Japan's international competitiveness in the control system market.

In light of these circumstances, we have created the MICREX-VieW XX as a system that ensures security by developing it with an eye toward the importance of security from the design stages in order to provide users with a safe and secure system to achieve stable plant operations.

In the future, we plan to obtain certification as soon as the international standard based security certification system commences operations to provide users of the MICREX-VieW XX with a system that ensures safety.

5. Postscript

In this paper, we provided an overview of the latest operation functions and engineering functions of the "MICREX-VieW XX" small- and mediun- scale monitoring and control system, as well as described some of its operation and security features.

As a manufacturer, it has been our duty to continuously pursue improvements in operability and engineering efficiency. We are committed to continue providing our customers with high-quality systems that accurately meet their needs and ensure their satisfaction.

*4: Ethernet is a trademark or registered trademark of Fuji Xerox Co., Ltd.

Integrated Controller Realizing Machine Control and Advanced Motion Control, "MICREX-SX Series"

ISHII Yasushi*

ABSTRACT

The "MICREX-SX" Series of integrated controller line allows engineering consistently conforming to the international standard IEC 61131-3 from small- to large-scale systems. This is expected to accelerate componentization of software and dramatically improve the efficiency of control system development. Various types of control ranging from machine control to multi-axis, high-speed and high-precision motion control can be realized by connecting with Fuji Electric's drive products via a network. As main examples, motion control in combination with a servo amplifier and vector inverter and steel process line control are described.

1. Introduction

Fuji Electric has been developing and selling programmable logic controller (PLC) for factory automation (FA) and machine control fields since the 1970s. In this paper, we will describe our "MICREX-SX Series" integrated controller that realizes the control of general industry's machines, monitoring control, such as printing machines and packaging machines, and that also enables motion control. In particular, we will describe the "SPH3000MM" and "SPH3000MG," which are suited for large-scale plant control, for example, in the manufacture of iron and steel and paper products.

2. Overview of "MICREX-SX Series"

2.1 Overall picture of "MICREX-SX Series"

Figure 1 shows the overall picture of the MICREX-SX Series. Controllers for use in control operations are evolving dramatically as a result of the high-performance and high-functionality of CPUs and networks, the evolution of programming support tools, and the integration with IT. The main features of the MICREX-SX Series are its high-speed control and openness (conforming to safety standards of various countries, utilizing a common programming language, and compatible with various open networks). The MICREX-SX Series corresponds to control content, scale and requirement performance, providing a lineup ranging from low-priced modules suitable for small-scale systems to high-performance modules suited to large-scale systems.

The engineering environments of the MICREX-SX Series are consistently integrated into a globally acceptable engineering environment (Expert, a software tool conforming to IEC 61131-3) regardless of the system scale, making it possible to create original application software via an internationally standardized programming environment.

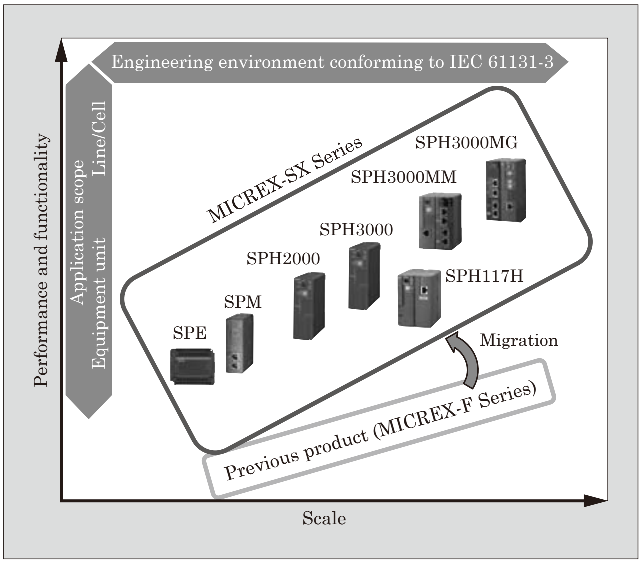

Fig.1 Overall picture of "MICREX-SX Series"

Furthermore, it also comes with a hardware upgrade tool and application software conversion tool to support the smooth migration of customer assets constructed with older products.

2.2 Features of "MICREX-SX Series"

(1) Improvement in the development efficiency of application software

One of the big issues often mentioned when constructing a control system is the increase in the number of man-hours required for the development of application software. The MICREX-SX Series responds

* Industrial Infrastructure Business Group, Fuji Electric Co., Ltd.

to this issue by making full use of a function block and block engineering via a programming tool that conforms to the IEC 61131-3 international standard, thus improving development efficiency through layering and segmenting software. The result is that software development man-hours can be greatly reduced up to 50% compared to conventional controllers. This type of software creation engineering environment can be used consistently via this Series.

(2) High-speed bus direct-connection system

Figure 2 shows an example of a high-speed bus direct-connection system. The MICREX-SX Series allows customers to easily use a servo amplifier, inverter and HMI (human machine interface) to construct a system, making it easy to obtain a motion control system or instrumentation control system.

In general motion control systems and instrumentation control systems, both a dedicated CPU module and support tools are required. However, the MICREX-SX makes it possible to execute sequence control, motion control and instrumentation control using a single CPU module and one support tool. This is possible because the CPU module has high-speed performance and the sequence control, motion control and instrumentation control can be created using an IEC 61131-3 programming environment.

(3) Ethernet connection

In recent years, communication via Ethernet*1 is being used to respond to the increasing number of monitoring control points. In the MICREX-SX Series, Ethernet is provided as standard in the CPU module, and in addition to this, it also comes with standard protocols such as FTP. In addition, in order to respond to a wider range of applications, it also has a variety selection of I/O modules, communication modules and software parts. Furthermore, it is enhanced with a hardware upgrade tool and application software conversion tool to support migration from older products, and it has an operating environment that is familiar to users of the older products. Figure 3 shows an example

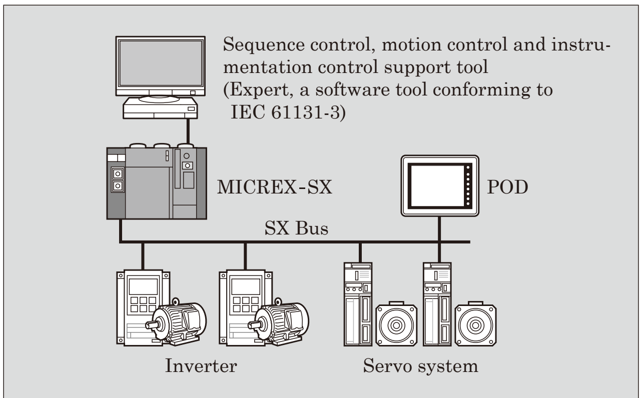

Fig.2 High-speed bus direct-connection system

*1: Ethernet is a trademark or registered trademark of Fuji Xerox Co., Ltd.

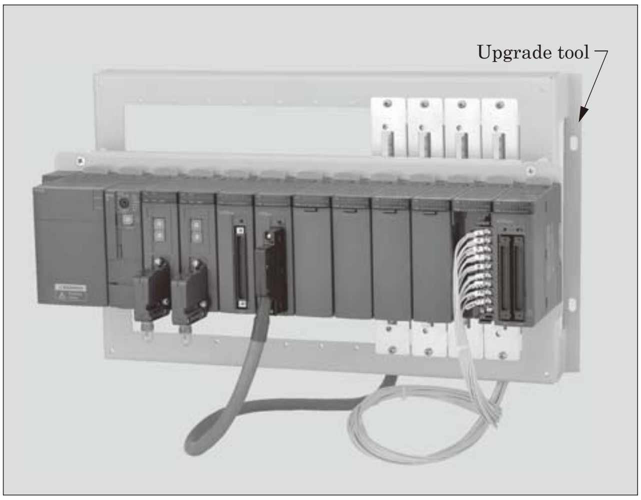

Fig.3 Example of upgrade tool

of the upgrade tool. By using this tool, users can replace older products with the MICREX-SX Series while using the wiring of existing facilities as-is, allowing customers to reduce the number of man-hours needed for the migration..

2.3 Features of "SPH3000MM"

The machine control field, which requires high-precision control performance, makes use of the SPH3000MM equipped with a 2-system "E-SX Bus." E-SX Bus is an original protocol network developed by Fuji Electric that applies 100-Mbits/s Ethernet technologies on the physical layer.

SPH3000MM inherits all of the current features of the MICREX-SX Series, while also coming with the functions shown below. It is a high-speed and high-precision controller that enables high-speed and high-precision motion control and realizes large-scale systems.

(1) High-speed I/O via the E-SX Bus's 25-μs response performance

The E-SX Bus is a complex motion control bus for actualizing a large capacity I/O data transfer function, message communication function, loop-back function and high-speed and high-precision synchronized communication function required in the drive solutions of main SPH3000MM applications.

(a) It can be applied to a diverse range of systems from small to large scale, providing a total extension of 1 km at 100 meters between stations with a maximum of 238 connected stations, as well as a maximum I/O size of 4,096 words (8 times larger previous MICREX-SX Series models).

(b) When connecting 32 I/O devices, it is possible to achieve high-precision synchronous control at ±1 μs or less.

(c) Application execution has been taken into account with respect to I/O data capacity, which is capable of 67 words at a maximum control

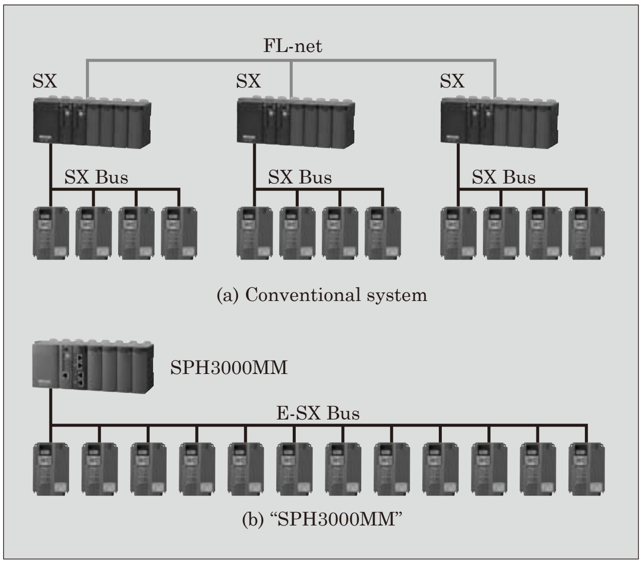

Fig.4 System configuration comparison

cycle speed of 0.25 ms and 512 words at 1 ms. It can do refresh processing of up to 4,096 words in 3 ms, making it capable of high-speed control even in large-scale systems.

The SPH3000MM comes equipped with a 2-system E-SX Bus, and even when connecting 32 I/O devices to each E-SX Bus system, the synchronization of the output timing of each of the systems can be kept ±3 µs or below. At a maximum control cycle speed of 0.25 ms, it is possible to carry out multi-axis motion control using up to 8 axes (4 axes × 2 systems).

(2) High-speed arithmetic functions with a maximum speed of 9 ns per instruction

By combining the arithmetic engine with high-compression compiler technology, it achieves a maximum execution performance speed of 9 ns per instruction, and in addition to this, control cycle tolerance is kept ±1 µs or below, providing it with a smaller deviation compared to conventional products.

(3) Synchronized execution between the application programs of 2 arithmetic engines

The CPU module of SPH3000MM adopts architecture of 2 arithmetic engines. The arithmetic engines between the 2 systems are connected by an internal synchronized bus, and execution cycle synchronization is performed with a precision of ±1 µs or less between arithmetic engines. Because of these features, systems that were forced to split up the system configuration due to performance reasons in conventional products can be simplified by using SPH3000MM (see Fig. 4).

2.4 Features of "SPH3000MG"

SPH3000MG equipped with "SX-Net" is used in plant control that requires high-speed and large capacity control communication. SX-Net is an original common-memory protocol network developed by Fuji Electric that applies gigabit Ethernet. (Refer to "Drive Control System Solution Utilizing High-Speed Controller and Large-Capacity Network" on page 16) The SPH3000MG inherits the features of the existing MICREX-SX Series. It is a high-performance and large capacity controller that meets the demands of the following functions.

(1) Equipped with the high-speed and large capacity control network SX-Net

SX-Net is a time-fixed network protocol that performs sequential communication processing according to established cycles of time. Participating stations broadcast their own data to all the other stations within the transmission timing set to each station. By doing this, the overall system can share data on SX-Net via a common memory, and each station can carry out control design without being conscious of the application network. The data update cycle can be chosen within a range of 0.5 to 30 ms depending on the number of stations and the data capacity of the common memory, and common memory data received and transmitted via broadcasts can be used in a data region of up to 128 Kwords.

In addition, the master station on the SX-Net network can send synchronization frames to the participating stations to correct the transmission timing, which in turn, allows other stations to correct cycle discrepancies with the master station based on the synchronization frame information and received timing that was sent from the master station, making it possible for each station to have accurate synchronization.

(2) Equipped with the high-speed and high-precision motion control bus E-SX Bus

As mentioned in Section 2.3, the mounting of an E-SX Bus allows for high-speed and high-precision motion control with an I/O refresh performance of 512 words per ms (based on 32 stations).

(3) High-speed I/O response through synchronized execution of user applications between controllers via SX-Net and the E-SX Bus

SPH3000MG mounts SX-Net and the E-SX Bus on the front of the module and the existing main "SX Bus" on the rear of the module. By making the most of this integrated module structure, synchronization between SX-Net and the E-SX Bus as well as arithmetic cycle synchronization is performed.

The SX-Net data update cycle enables integral multiplication settings for the E-SX Bus control cycle, and when SPH3000MG is connected with SX-Net, it can correct the control time of the E-SX Bus based on the synchronization frames sent by the master station. By doing this, SX-Net, the E-SX Bus and the arithmetic cycle of applications can all be synchronized, enabling synchronization of the output timing of multiple and separately controlled devices to be within a precision of ±80 µs. Furthermore, it makes it easy to use a distributed controller to configure a large-scale, high-precision application that needs to synchronize and process the control timing and control data in an entire system.

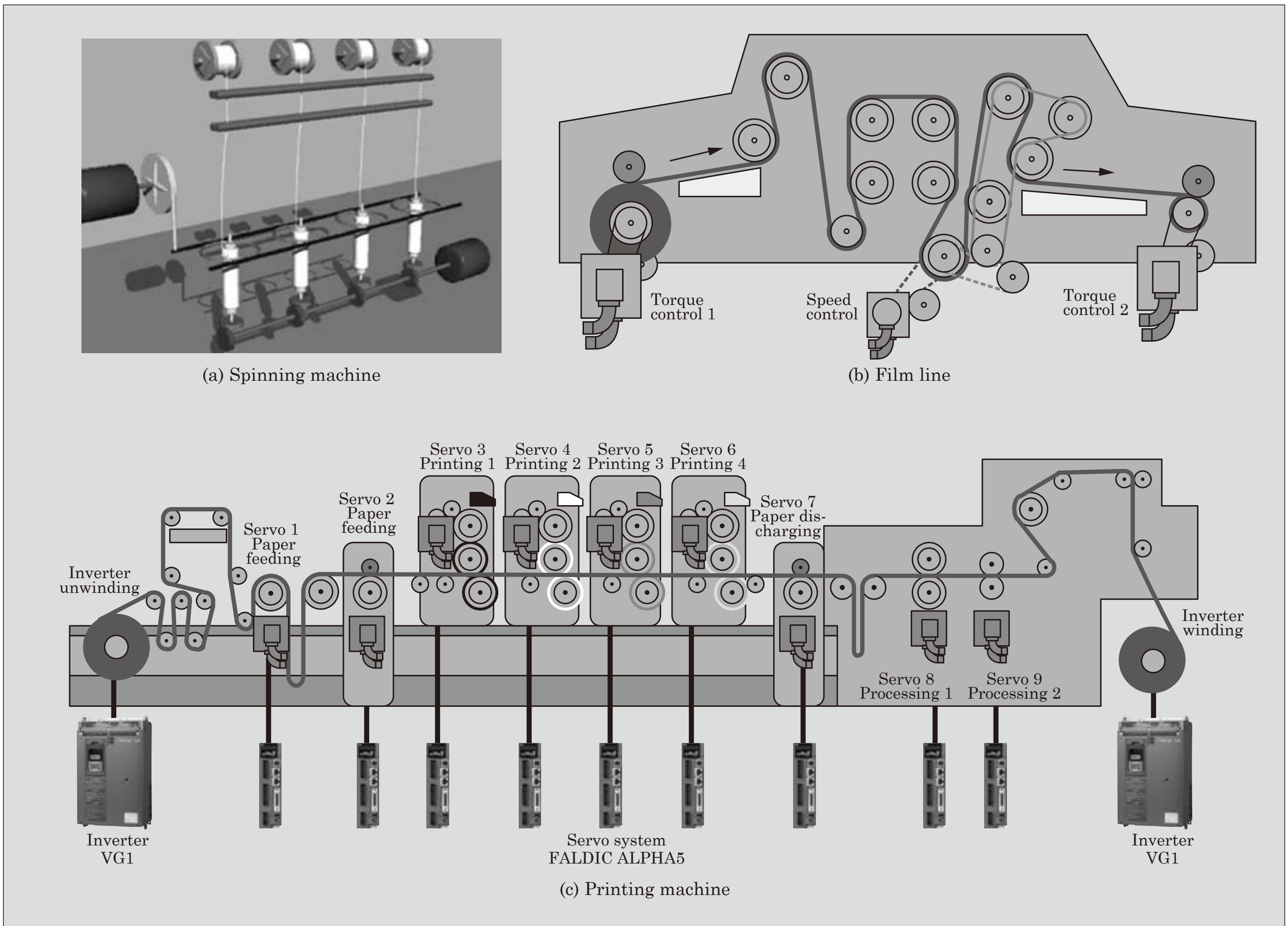

Fig.5 Example of motion control application

3. Application Examples

3.1 Motion control applications via "SPH3000MM"

(1) Combination with a servo amplifier

As examples of applications that require high-speed and high-precision synchronous motion control, the SPH3000MM has been used for pillow packaging machines and spinning machines, multicolor printing machines, flying shear cutters and film lines (see Fig. 5).

Motion control systems that adopt SPH3000MM can be configured as synchronous systems with a total of 8 axes (4 axes per bus system) and a speed of 0.25 ms, allowing for high-speed and high-precision motion control as a general-purpose controller. During the control cycle of 0.25 ms, 0.12 ms are secured to execute the application software, and it is also possible to set up high-precision position control including synchronization control and interpolation control. By segmenting these types of controls as a function block, it is possible to improve quality and reduce application software development man-hours through reuse.

For multicolor printing machines, sectional synchronous control is now possible without the need for a main axis, thereby replacing the conventional main axis that was used for synchronous control. Conventionally, for an axis that acted as a virtual main axis, a driven axis that controlled processes such as paper feeding, multicolor printing and paper discharging carried out high-precision synchronization. Doing this allowed for the high-speed processing of high-precision color printing without any printing irregularities. In order to achieve a printing precision of 0.015 mm or less at a printing speed of 300 m/min, there needed to be synchronization precision of 3 µs or less. By using the SPH3000MM, the bus systems can be flexibly divided to correspond to the functions of customer facilities. For example, one system can be used for the virtual main axis, paper feeding and paper discharging, while the other system can be used for the multicolor printing. By doing this, high-speed and high-precision synchronous application software can be easily constructed.

Figure 6 shows an example of an "E-SX Bus" compatible motion control system configuration being applied to these machines. Machine control is possible through the use of the SPH3000MM, Fuji Electric's servo amplifier "ALPHA5 Series" (an E-SX Bus compatible version is under development) and

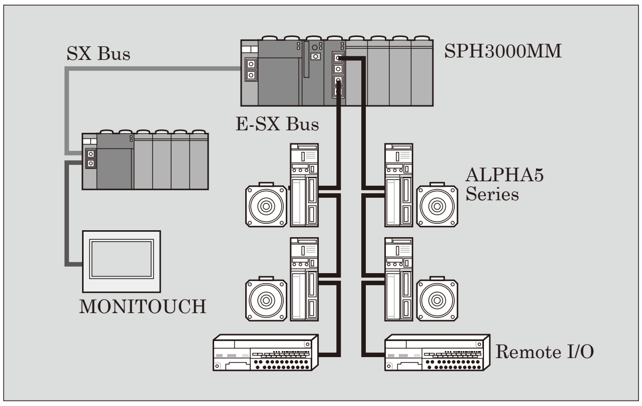

Fig.6 Example of an "E-SX Bus" compatible motion control system configuration

POD "MONITOUCH" (HMI).

(2) Combination with vector inverter

As examples of combining the control system with a vector inverter*2, SPH3000MM has been used for crane systems, film lines, wiredrawing machines, iron and steel processing lines, etc. Figure 7 shows an example of a wiredrawing machine and Fig. 8 shows an example of a mill pressure control system for an iron and steel processing line.

In both instances, SPH3000MM made it possible to achieve the high-speed and advanced control needed in tension control and steady strain control. Crane systems can be configured with several tens of vector inverters. In such a case, high-speed execution processing utilizing SPH3000MM and the performance of the E-SX Bus enable a set up that meets system requirements via a single controller as shown in Fig. 4(b).

Since the state of materials that pass through rolling mill rolls changes every moment, optimized control is necessary while measuring the states of materials and equipment via various detectors in order to control

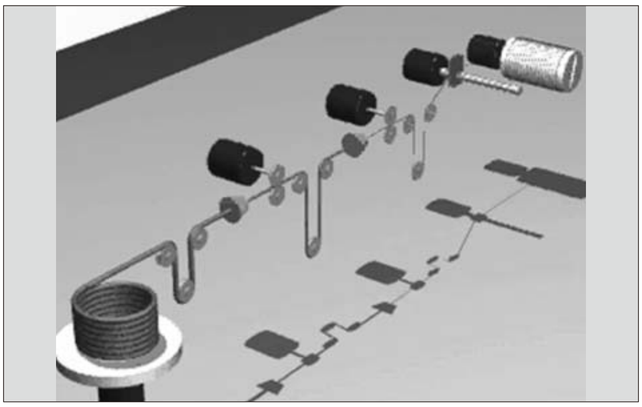
Fig.7 Example of wiredrawing machine

*2: Vector inverter: This is an inverter whose output current is adjusted to the current proportionate to the load applied through vector arithmetic, allowing for a high and low speed motor torque, high-precision and high-speed control, etc.

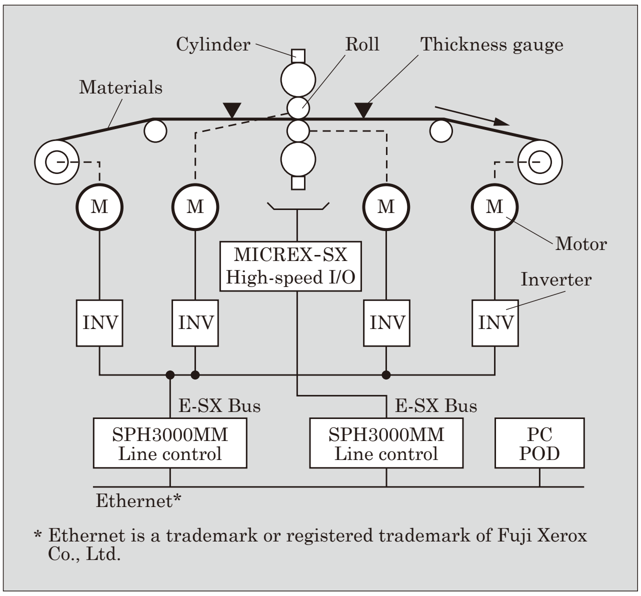

Fig.8 Example of mill pressure control system

the prescribed thickness. To do this, it is very important to accurately reflect the information sent from the detectors. The requirements of control device are as follows:

(1) High-speed and accurate input from the detectors (magnetic sensor, absolute encoder, etc.)
(2) High-speed arithmetic and high-speed cycle times
(3) High-speed synchronous output of the commands to the actuator

Conventionally, control functions were narrowed down by using a dedicated control device to ensure the processing speed. In SPH3000MM systems, in addition to the high-speed arithmetic, the high-speed and high-precision synchronization functions of the E-SX Bus and the high-speed output of the detectors and actuator make it possible to maintain a high-speed while also achieving advanced control with few restrictions on the narrowing down of control functions(1).

3.2 Application of "SPH3000MG" to iron and steel process line

As an application example, Fig. 9 shows a control system for an iron and steel process line. The system is configured with multiple solenoid valves, detectors, monitoring and operation devices and drive devices that drive hundreds of electric motors. In order to convey steel sheets at an appropriate speed and tension, it is required to have tension control, load balance control and high-precision speed matching control for the electric motors and attain a control cycle of several dozen milliseconds and an I/O scale of tens of thousands of points. This type of system must meet the following three requirements:

(a) Scalability corresponding to the system scale
(b) High-speed connection with distributed equipment
(c) High-speed and large capacity collection of con-

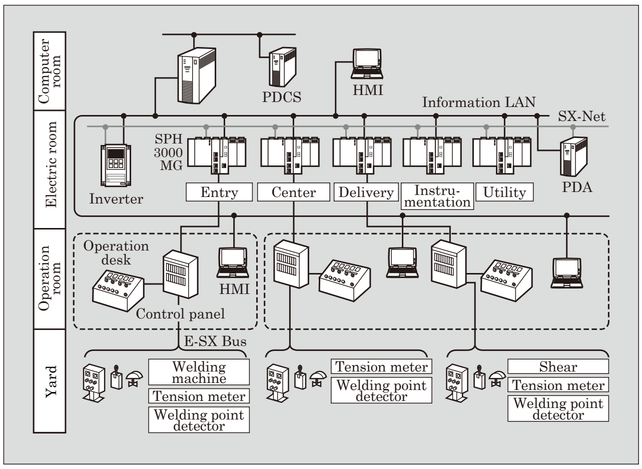

Fig.9 Application example of iron and steel process line

trol data

SPH3000MG can make use of the assets of the previous products of the MICREX-SX Series. By utilizing the diverse I/O modules, etc. of existing products, it is possible to construct a flexible system.

4. Postscript

By utilizing the "MICREX-SX Series," it is possible to implement various applications related to machine control. In particular, adoption of the "E-SX Bus" equipped "SPH3000MM" and "SX-Net" equipped "SPH3000MG" makes it possible to construct a high-speed, high-precision and large-scale motion control system. We believe that the information presented in this paper can contribute to the high-quality manufacture of products and stable and efficient operation required in various plant systems and machine facilities and equipment.

We are committed to continuing to expand the range of applications of controllers to solve the issues faced at manufacturing sites.

Reference

(1) Nishimura, E. et al. "E-SX Bus" & "SPH3000MM" Promising High-speed, High-precision Motion Control. FUJI ELECTRIC REVIEW. 2012, vol.58, no.1, p.21-25.

Cross Stack Laser Gas Analyzer Contributing to Energy Conservation, "ZSS"

KONISHI Hideyuki* KANAI Hideo* OGAWA Takaharu*

ABSTRACT

Fuji Electric has been developing gas analyzers that contribute to overall energy conservation of processes. Cross stack laser gas analyzers are capable of high-speed response because they are directly installed in flues for measurement and are suited for control aimed at energy conservation. Fuji Electric has developed a technology that allows a device to measure two components, though this was conventionally limited to one component, and commercialized the world's first cross stack laser gas analyzer for two-components (O_2+CO): "ZSS". Instrumentation air is available as the purge gas for O_2 measurement, and the analyzer features improved environmental resistance, or resistance to inhibitory substances in the measured gas. Application to the converter and combustion control processes of steel plants is expected.

1. Introduction

With the aim of restricting global warming and creating a sustainable society, renewable energy is becoming prevalent, but we are facing many challenges in achieving stable supply and cost. On the other hand, the development of shale gas and shale oil are progressing, and the production amount of these fossil fuels is predicted to increase. Against such background, it is estimated that fossil fuels will remain the dominant source of primary energy for a while.

In order to reduce CO_2 emissions in the whole of society, our task is to make efforts for the effective utilization of fossil fuels. That is required also from the viewpoint of energy conservation. As regards "utilization," not only the reduction of fuel consumption but also the "reuse" of it should be considered. In addition, a comprehensive reduction of fossil fuels, including toxic materials generated in the processes of fossil fuel incineration and their treatment energy, have to be taken into consideration.

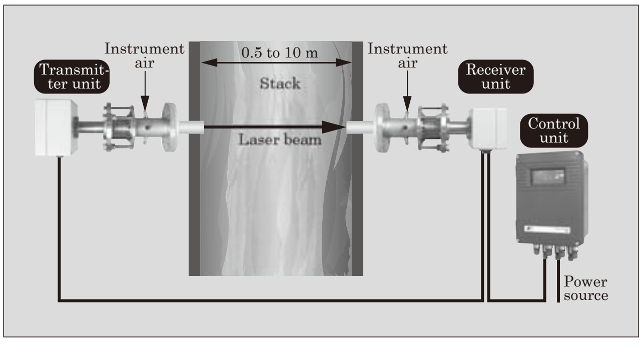

Fig.1 "ZSS"

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Fuji Electric has been developing gas analyzers that contribute to the comprehensive conservation of energy in processes from such a point of view.

This time, we have developed cross stack laser gas analyzers "ZSS," one unit of which can measure two components, oxygen (O_2) and carbon monoxide (CO), at the same time (see Fig. 1).

2. Market of Gas Analyzers for Processes

Almost 60 years ago, Fuji Electric started manufacturing infrared gas analyzers for the first time in Japan. They have been applied in many fields, particularly for the monitoring of the atmosphere in incinerators used in steelmaking processes and thermal treatment processes, helping to enhance the quality of the process products.

With air pollution becoming a focus of attention as a social problem, we have been providing analyzers for the monitoring of toxic gases emitted from factories and business establishments, making a contribution to the improvement of environmental issues in Japan. The demand for environmental measurement is estimated to increase further in China, where air pollution is a serious problem, and in India and other countries in the Middle East, where there is concern about similar environmental issues.

On the other hand, in Japan, Europe and the U.S.A., where systems to monitor toxic gas emissions have already established, because the generated toxic gases are removed through after treatment, their demand is shifting to restricting generation of the toxic gas itself and reducing resources and energy necessary for the after treatment, that is, comprehensive energy conservation. The cross stack laser gas analyzer, released by Fuji Electric in 2007, the first time as a Japanese corporation, is installed directly in flues for measurement and is characterized by its high-speed response. That is why it is optimally suited for control applications aimed at conserving energy, and its market is expected to expand in the future.

3. Measurement Principle and Product Features

3.1 Measurement principle

The measurement principle of ZSS is shown in Fig. 2. Each gas component has its own wavelength range where it absorbs light. ZSS uses only one absorption line out of several tens to several hundreds of lines for concentration measurement, and the tunable laser element that can be adjusted to produce a wavelength around the selected absorption line is to be used. For instance, a laser element producing a wavelength of around 0.760 to 0.765 μm is used for O_2 concentration meters, while for CO concentration meters a laser element producing a wavelength of 1.580 to1.583 μm or 2.330 to 2.335 μm is used depending on the measurement range.

The electrical current range of a laser element is adjusted so that it can sweep a range of wavelengths around the absorption line used for measurement, and the laser element is driven with a modulated (e.g., 10 kHz) signal (1f). This modulated laser beam is projected toward a target gas to be measured and the transmitted beam is received with a photodiode. When the target gas exists in the flue, a signal (2f) having twice the frequency (20 kHz) of the modulated signal (1f) will be contained in the received signal. The intensity of the amplitude of 2f is proportional to the concentration of the target gas, and this property is utilized for measurement.

3.2 Product features

ZSS has features that are the most suitable for steelmaking processes and incineration processes.

(1) Measurement of two components with a single unit

The external appearance of ZSS is almost the same as conventional devices, but two types of laser element, for O_2 and CO, are integrated in it. The ZSS has its original optical system where laser beams projected from each laser element are combined on the same axis.

Furthermore, the photo acceptance unit which is sensitive to wavelengths of both O_2 and CO is installed on the receiving unit to streamline the structure of the device, and this makes it easy to adjust the optical axis (see Fig. 3).

Conventionally, it has been necessary to install two units for measuring O_2 and CO. Mounting flanges had to be installed on two points in a flue and the optical axes had to be adjusted individually. In contrast, since the ZSS has a structure with two laser components in one unit, one set of procedures such as the installation of a mounting flange and the adjustment of an optical axis is enough. Consequently, it will reduce not only the manufacturing cost but also the installation cost and easies maintenance afterwards, producing significant merits for users.

(2) Use of instrument air

The installation environment for ZSS in incineration processes is shown in Fig. 4. When installing laser

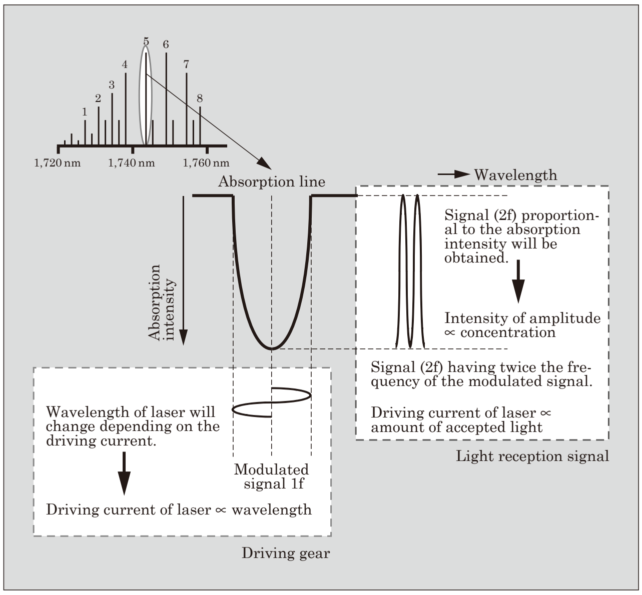

Fig.2 Measurement principle of “ZSS”

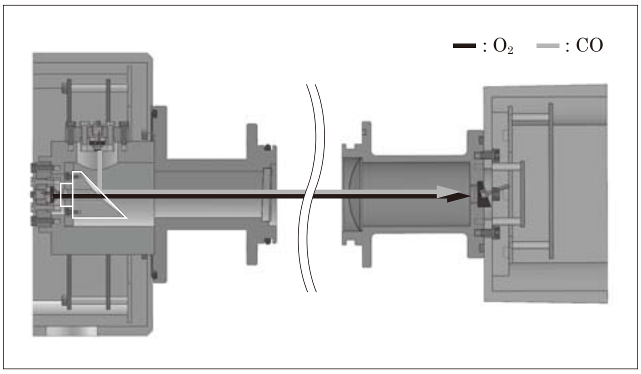

Fig.3 Structural drawing of two-component analyzer (O_2 concentration meter+CO concentration meter)

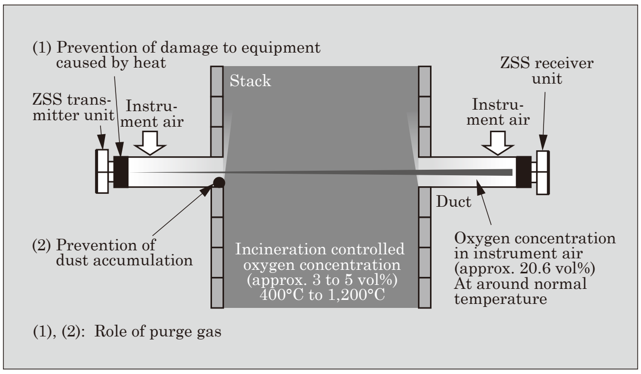

Fig.4 Installation environment for “ZSS” in incineration processes

gas analyzers in incineration processes such as in garbage incineration plants, in order to prevent measurement failures due to the accumulation of dust in ducts and the damage of equipment caused by heat (700 °C to 1,200 °C) in furnaces, purge gas flow in the ducts should be maintained continuously. If instrument air is adopted as purge gas, the O_2 concentration in the purge gas will interfere with the O_2 concentration in the flue, becoming an impediment to precise measurement. The O_2 concentration in instrument air is 20.6 vol%, while the O_2 concentration in the furnace subject to the control is 3 to 5 vol%. Therefore, a sufficient SN ratio will not be achieved.

For those reasons, for O_2 concentration meters of laser gas analyzers, nitrogen is commonly used as the purge gas. However, with the exception of the steel industry, there are few installations which have a nitrogen supply system. Moreover, introducing a laser gas analyzer using nitrogen gas requires several millions of yen annually for the nitrogen gas supply system in general.

In order to solve this problem, taking note of the temperature difference between the gas in a flue and purge gas, Fuji Electric considered that if a wavelength (absorption line) which is hardly absorbed by O_2 at around normal temperature but well absorbed by O_2 at high temperature is used, the interference of O_2 contained in the purge gas will become negligible. However, at high temperature the kinetic energy of molecules will increase and, consequently, the absorption intensity will become lower in general. Actually in many absorption lines, the higher the temperature became, the smaller their absorption intensity became. After investigating numerous absorption lines, we have discovered an absorption line which has the intended gas temperature response at around 760 nm and confirmed that it had an absorption intensity which allows O_2 gas to be measured. In this way, even with the use of instrument air as purge gas, it became possible to precisely measure the O_2 in a furnace, without suffering interference from the O_2 in the air.

(3) Enhanced environmental resistance (measures for resistance against inhibitory substances)

When adopting laser gas analyzers as O_2 and CO concentration meters in incineration processes or combustible gas recovery processes at outlets of converters at garbage incineration plants, the effects of inhibitory substances such as a high amount of dust and water droplets become a problem.

If there are many inhibitors, they will interfere with the device's laser beam and its intensity will be deteriorated, resulting in a measurement failure due to the decrease in the SN ratio. Moreover, inhibitory substances fluctuate greatly in these facilities. In some cases, the amount of accepted light becomes insufficient or, to the contrary, output power becomes saturated, and these will hinder continuous measurement.

By incorporating a function to automatically optimize reception gain depending on the amount of accepted light, Fuji Electric has developed an analyzer which can surely perform measurements even in the event of a great fluctuation in the amount of inhibitors. Furthermore, the time required to sample data once is reduced to one-tenth compared to the conventional devices. In this way, this analyzer can diminish the strain in accepted waveform caused by fluctuations in the light amount during data sampling, and, at the same time, significantly reduce the effects of inhibitory substances by increasing the number of times data is sampled.

4. Application Examples

Examples of ZSS application will be described here. In every case, the effectiveness of this device has been verified through field tests.

4.1 Enhancement of combustible gas recovery rate in converter processes

In converter processes at steel plants, as shown in Fig. 5, in order to oxidize and remove impurities from molten iron produced in blast furnaces, a huge amount of O_2 is blown into the molten iron. As a result of a reaction with O_2, a great amount of CO_2 and CO will be generated. Since CO is a combustible gas, recovering it as a fuel material in gas holders and reusing it as a fuel for incineration at other processes will contribute to energy conservation and help reduce CO_2 emissions in overall processes in steelmaking. In addition, if O_2 remains in the gas to be stored in gas holders, it may cause an explosion. That is why monitoring is required. Therefore, by measuring the O_2 concentration and controlling valves, gases with high O_2 concentration are exhausted, while combustible gases whose concentration becomes sufficiently low are recovered.

The magnetic O_2 concentration meters, which have been used conventionally for this process, require gas sampling devices. Since the response speed of an entire device will differ depending on the distance from the sampling point and the structure of gas sampling devices, it takes 30 seconds to 3 minutes, in general. Longer response time means loss of opportunities to recover combustible gases. Applying the high-speed

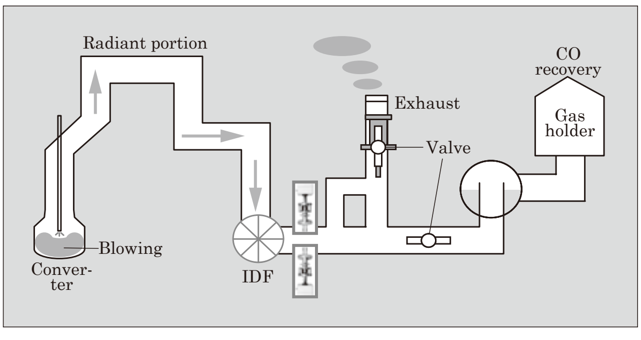

Fig.5 Schematic diagram of converter process

Table 1 "ZSS" effects on combustible gas recovery

Response speed of conventional model	30 sec.	1 min.	1 min. 30 sec.	2 min.	3 min.
Combustible gas recovery increased rate	2.7%	6.1%	9.4%	12.7%	19.4%
Annual economic effects	13.68 million yen	30.91 million yen	47.46 million yen	64.36 million yen	98.32 million yen

Size of converter:
○ Converter capacity: 250 t/charge (15 min./charge)
○ Annual gross output of steel: 1.4 million tons (per converter)
○ Amount of heat recovered: 200,000 kcal/t (C heavy oil cost: calculated at 1.81 yen/1,000 kcal)

response ZSS will effectively help to improve the recovery rate of combustible gases.

The results of a trial calculation of the economic benefits related to recovering combustible gas by implementing ZSS is shown in Table 1. If the response speed of a magnetic O_2 concentration meter used for combustible gas recovery in a converter is 30 seconds to 3 minutes, the economic benefits gained from the improved combustible gas recovery by switching from a magnetic O_2 concentration meter to ZSS becomes 13 million yen or more annually. Installation cost can be recovered in half a year as a moderate estimate.

Moreover, if the concentration of CO in recovered gas is not sufficiently high, even when its O_2 concentration is low, the recovered gas cannot be reused. By directly measuring the CO concentration, it becomes possible to upgrade the quality of combustible gas to be recovered.

In this way, in addition to securing safety by monitoring the O_2 concentration, which has been performed for some time, introducing the ZSS has made it possible to conserve energy by improving the recovery rate of reusable combustible gases.

4.2 Optimization of incineration efficiency in incineration processes

An incineration control system is required in various processes such as in boilers for industrial use, garbage incineration plants and industrial furnaces.

The relation between the air ratio and incineration efficiency in incineration processes is shown in Fig. 6. The air ratio refers to the ratio of actual amount of air to the theoretical amount of air. With an adequate air ratio, fuel is combusted completely, and this enables the highest incineration efficiency and sufficiently reduces the generation of nitrogen oxide (NO_x) and sulfur oxide (SO_x) as a result. Accordingly, as shown in Fig. 7, optimized incineration can be secured by measuring the O_2 concentration and feeding back the results to the system.

However, the air ratio in an actual incinerator is not consistent, being affected by the structure and temperature of the furnace. Even when the O_2 concentration at the measurement portion is controlled

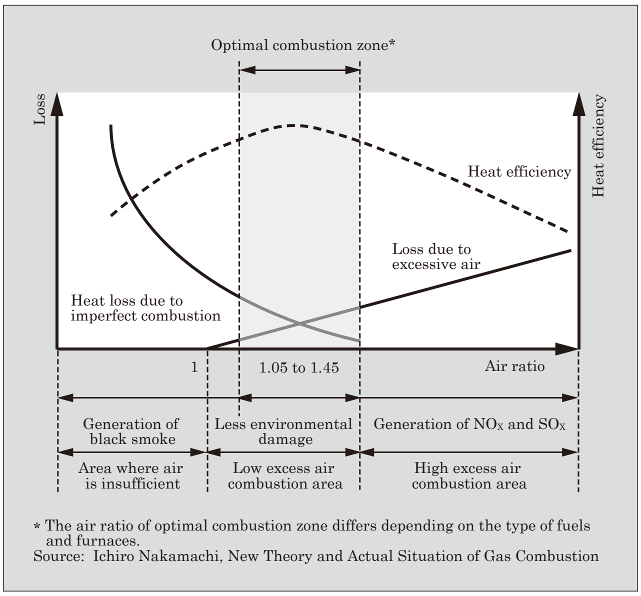

Fig.6 Relation between air ratio and incineration efficiency

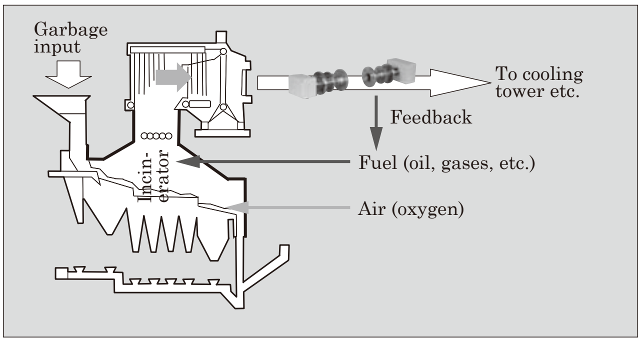

Fig.7 Schematic diagram of incineration process (example of incinerator)

adequately, some degree of imperfect combustion is inevitable. Figure 6 shows how the amount of heat loss increases rapidly when combustion is imperfect. In addition, CO and black smoke are also generated. That is why the occurrence of imperfect combustion should be restricted also from the viewpoint of environmental conservation. For these reasons, incinerators are generally operated at an excess O_2 ratio compared to the optimal air ratio. On the other hand, although the increased amount is not as much as in the case of imperfect combustion, excess air also becomes a cause of heat loss. Therefore, the O_2 concentration should be minimized as much as possible to enhance the incineration efficiency.

By measuring not only O_2 but also CO at the same time and performing incineration control, the optimal air ratio will be achieved. If ZSS is used soon after incinerator to measure the exhaust, CO can be detected immediately. In this way, this system will simultaneously reduce the ratio of excess air and CO emissions as much as possible.

Introducing ZSS makes it possible to optimize the incineration efficiency and contribute to further energy conservation as a result.

5. Postscript

In this paper we have outlined the cross stack laser gas analyzer "ZSS" that contributes to energy conservation. By achieving the measurement of two components (O_2+CO), it becomes possible to apply this system to process control. We intend to acquire explosion-proof certification to expand its application area. This structure with meters for two components is applicable also for other component combinations. We will develop this system further while considering market needs.

We are determined to work on the development of gas analyzers that contribute to comprehensive energy conservation in processes.

Structure Health Monitoring System Using MEMS-Applied Vibration Sensor

SAKAUE Satoru*   MURAKAMI Keizo*   KITAGAWA Shinji*

ABSTRACT

Recently, studies have come to be increasingly energetically conducted on structure health monitoring (SHM), which involves diagnosis of the structure performance of buildings based on response waveforms to earthquakes and microtremors. Fuji Electric has commercialized a vibration sensor that applies micro-electro-mechanical systems (MEMS) and a primary diagnosis monitoring system that makes use of the sensor. Use of the MEMS-applied vibration sensor instead of a servo acceleration meter allows building of low-cost systems. At present, for the purpose of practical application of the SHM system, Fuji Electric is conducting research and development for estimating an index (feature quantity) that represents the soundness of buildings.

1. Introduction

In Japan, many of social infrastructures represented by bridges, tunnels and expressways constructed one after another in the period of rapid growth have existed for 40 to 50 years and are obviously aging. Japan is an earthquake-prone country, and seismicity is required on buildings. To maintain the performance of these social infrastructures and buildings and increase their longevity, inspections and maintenance must be performed at a proper timing. In case of a disaster, it is necessary to conduct primary diagnosis to instantaneously determine the soundness of buildings and inform users of whether they must evacuate from them.

In the past, visual inspections by engineers were the main inspections of structure, and it was difficult for engineers to carry out all works because there were many number and types of structure constructed. In recent years, there has been increasing demand for preventive maintenance, which is intended to detect abnormalities early and take action to increase the longevity of buildings.

In this situation, structure health monitoring (SHM), which, by means of such sensor technology as acceleration sensors, diagnoses the structural performance of buildings from response waveforms to earthquakes and microtremors (constantly produced faint vibrations that people do not feel) has been introduced. Research and development of SHM was conducted mainly by universities and research institutions. With the increase of social capital stock and the occurrence of great earthquakes and infrastructure accidents, and progress of with low-cost acceleration sensors applying micro-electro-mechanical systems (MEMS) as well as diagnosis technology, SHM systems adopting SHM technology for evaluating the soundness of structure are expected to rapidly develop.

In 2012, Fuji Electric commercialized a MEMS-applied vibration sensor for measuring acceleration and a primary diagnosis monitoring system adopting this sensor and is committed to further carry out research and development of SHM systems. This paper outlines an SHM system for buildings and its element technologies.

2. Structure Health Monitoring System

2.1 Overview

An SHM system refers to a system for evaluating the soundness of structure from response waveforms of earthquakes and microtremors by installing acceleration sensors, etc. on them, in order to provide users with information for safety and security. This system consists of the functions of data acquisition, primary diagnosis in case of an earthquake, analysis (state estimation), diagnosis, provision of diagnosis results and accumulation and management of SHM information (see Fig. 1).

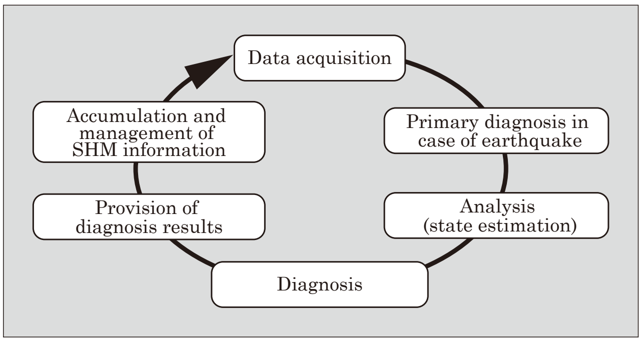

Fig.1 Functional configuration of SHM system

* Corporate R&D Headquarters, Fuji Electric Co., Ltd.

Fuji Electric has been participating in the Structure Health Monitoring Consortium*1 under the initiative of Keio University developing SHM systems. The development covers a system covering steps from data acquisition to primary diagnosis and a system responsible for analysis (state estimation) and accumulation and management of SHM information.

The features of Fuji Electric's SHM systems are shown below.

(a) The SHM system can carry out multi-point measurements using low-cost sensors.
(b) The SHM system can immediately provide the diagnosis result of the soundness of the building after an earthquake occurs.
(c) The SHM system can collect analog data besides acceleration and make it available for diagnosis.

(1) Primary diagnosis monitoring system

Fuji Electric developed and commercialized a primary diagnosis monitoring system in collaboration with Toda Corporation. A configuration example of the primary diagnosis monitoring system is shown in Fig. 2. This system consists of vibration sensors, a vibration recorder, information monitors and a LAN connecting them. What is required for analysis by SHM is time-synchronizing data. To ensure highly accurate time synchronization between the sensors, the vibration recorder distributes extremely accurate time to the vibration sensors, and also serves as a simplified diagnosis server to collect the acceleration data measured by the vibration sensors and compute the seismic intensity and displacement of the building in real time. Based on these computation results, the primary diagnosis monitoring system displays information about the seismic intensity and estimated soundness of the building for safety and security on the information monitors.

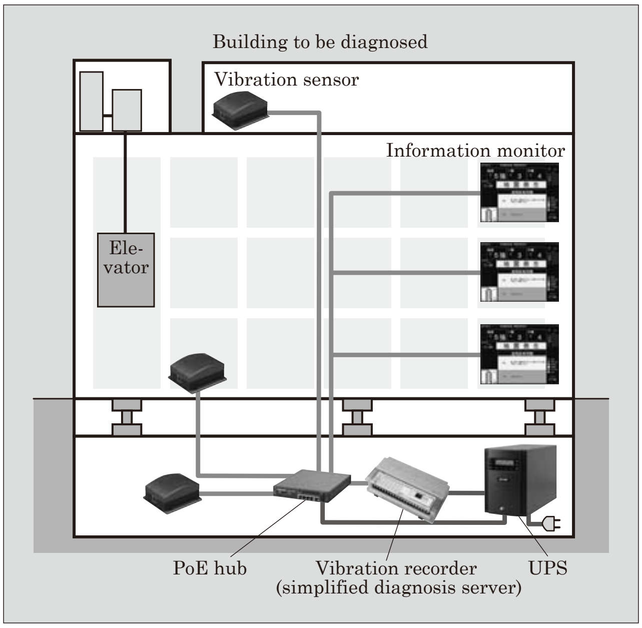

Fig.2 Configuration example of primary diagnosis monitoring system

*1: URL: http://www.mita.sd.keio.ac.jp/consortium/index.html

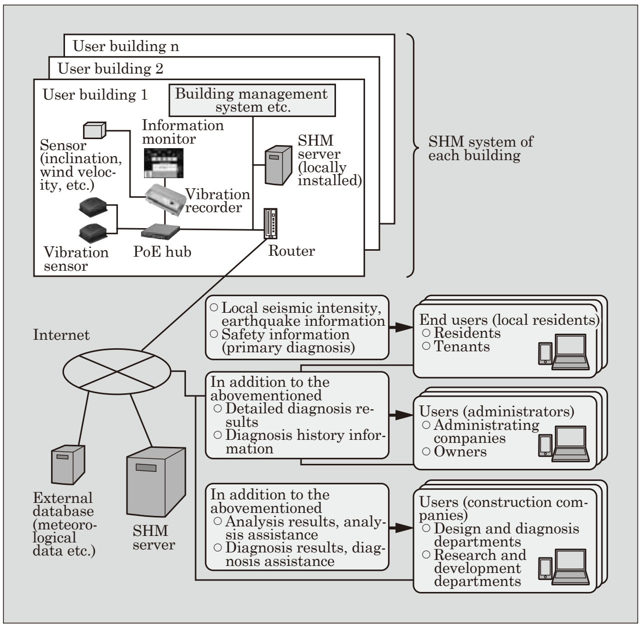

Fig.3 Configuration example of cloud-type SHM system

(2) Fuji Electric's SHM system

Based on the SHM system developed by Keio University, Fuji Electric is developing an SHM system that will be applicable to a wider range of fields with the aid of vibration sensors and vibration recorders. This system is capable of diagnosing and evaluating structure from various aspects by collecting analog data, such as inclination, wind direction and velocity and temperature, in addition to acceleration (digital data) from vibration sensors, in synchronization with time. Such data can be collected in a vibration recorder, diagnosed and evaluated in a sophisticated manner on a locally installed SHM server. As shown in Fig. 3, the SHM system can also provide many users with information for safety and security and information about effective maintenance at lower cost by switching the SHM server to cloud-type services installed in a data center, etc.

2.2 Functions and services

(1) Primary diagnosis service

The SHM system conducts diagnosis using data measured inside the building, and provides information about building diagnosis for determining the soundness of the building on an information monitor or by broadcasting just after the occurrence of an earthquake. A screen example of the information monitor is shown in Fig. 4.

(2) Analysis (state estimation) and information accumulation and management services

The SHM system removes noise from measured data, adds metadata, and estimates an index (feature

* Developed in collaboration with Toda Corporation.

Fig.4 Screen example of information monitor

quantity) representing the soundness of the structure concerned. In addition, it manages measured values, analysis (state estimation) results, diagnosis results and other data in a proper manner for the maintenance and management of the structure and provides users with them in visualized form.

2.3 Application example

The consortium has installed an SHM system in an apartment building constructed in Tokyo and conducted test operation.

Three vibration sensors and a vibration recorder for temporarily recording data measured by the vibration sensors are installed inside the building, and data measured during microtremors and earthquakes is transmitted via the Internet to the SHM server installed inside Keio University. This data and analysis results will be provided on web screens. A display example of acceleration data and that of power spectrum analysis results are shown in Fig. 5 and Fig. 6, respectively.

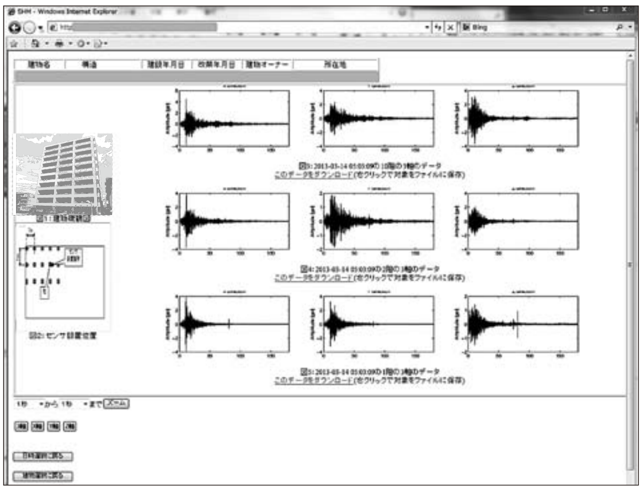

Fig.5 Display example of acceleration data

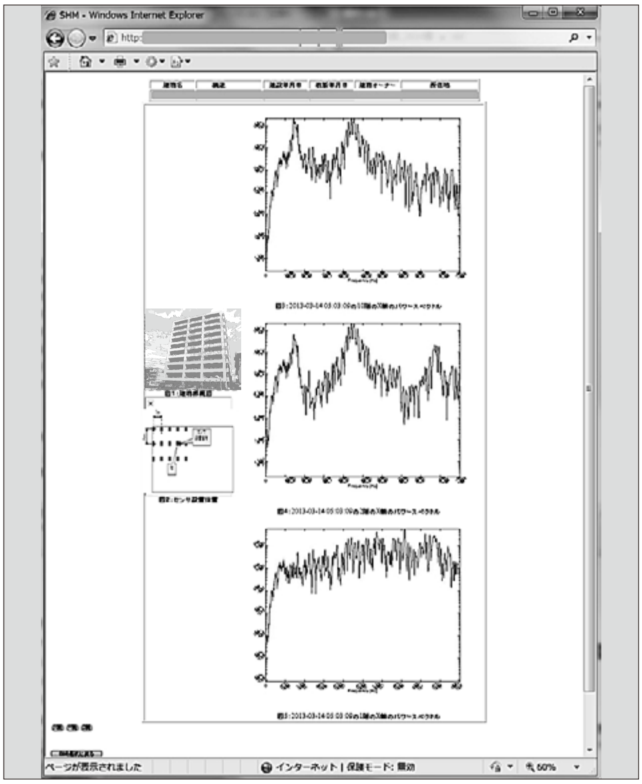

Fig.6 Display example of power spectrum analysis results

Also installed inside the apartment building selected for the test operation is an SHM system equipped with an expensive conventional servo-type accelerometer. The results of the test operation showed that the data measured by the vibration sensor was equivalent to the data collected by the servo-type accelerometer. This fact verifies that an SHM system using low-cost vibration sensors can be constructed.

3. Element Technologies of Structure Health Monitoring System

3.1 Vibration sensor

The appearance of a vibration sensor is shown in Fig. 7, and its specifications are listed in Table 1. The vibration sensor is equipped with an electric-capaci-

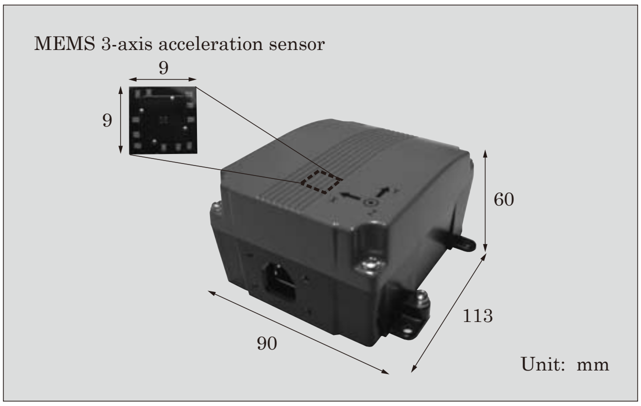

Fig.7 Vibration sensor

Table 1 Specifications of vibration sensor

Item	Specifications
Detection direction (number of axes)	3 components (X, Y and Z axes)
Measurement range	±2,000 Gal*
Resolution	X and Y axes: 0.02 Gal, Z axis: 0.07 Gal
Frequency range	0.1 to 50 Hz
Sampling frequency	200 Hz (can be set on 100 Hz)
Time synchronization	Within 1 ms
Power source	PoE supply: 48 V, 4 W

*: Gal is the unit of acceleration; 1 Gal = 0.01 m/s²

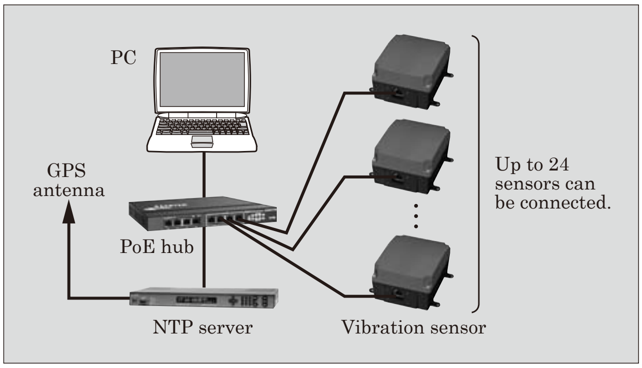

Fig.8 Connection example of vibration sensors

tance-type MEMS 3-axis acceleration sensor, which was originally developed to measure microtremors required for the SHM system and has a sensitivity covering low-frequency and low-acceleration regions, and its peripheral circuit.

A connection example of vibration sensors is shown in Fig. 8. Up to 24 vibration sensors can be connected to a personal computer via a PoE hub*2. These vibration sensors transmit acceleration data on the X, Y and Z axes together with time data. Since the SHM system requires time-synchronizing data for analysis, the NTP protocol or another protocol is used to keep the synchronization error between the vibration sensors within ±1 ms. Once an IP address is set to each vibration sensor prior to installation, it will automatically start communication simply by connecting an LAN cable to it, making other setting operations no longer necessary at the time of installation.

3.2 Analysis technology

To enable the SHM system to diagnose and evaluate the soundness of the structure concerned, an index appropriate for the purpose of diagnosis needs to be estimated. Various analysis technologies are required for primary diagnosis and analysis (state estimation) because the value of the diagnosis index will be estimated from the values measured by sensors.

*2: PoE hub: Hub capable of supplying the power by means of an Ethernet communication cable.

Table 2 Diagnosis indices and representative sensors to be used for SHM system

Object to be measured	Example of diagnosis index	Representative sensor to be used for measurement
Overall level	Decrease in frequency of primary mode	One or more acceleration sensor in whole object
Layer* level	Decrease in frequency of each order mode	Acceleration sensors installed on multiple layers
	Local increase in inclination of mode shape	Acceleration sensors installed on multiple layers
	Decrease in layer rigidity	Acceleration sensors installed on multiple layers (Mass of each layer, inter-layer displacement gauge)
	Maximum story drift in excess of threshold	Acceleration sensors installed on multiple layers (Mass of each layer, inter-layer displacement gauge)
	Interleaving frequency	Three acceleration sensors
	Maximum deformation, cumulative deformation, cumulative energy	Acceleration sensors installed on multiple layers
	Others	Acceleration sensors installed on plural layers
Component level	Torsional mode	Two or more acceleration sensors installed on the layer concerned
	Others	AE sensor, strain gauge, etc.

* Layer: Story of a building

Examples of diagnosis indices to be used for SHM systems and representative sensors to be used for measurement are shown in Table 2.

(1) Analysis technology that realizes primary diagnosis

In primary diagnosis, the maximum acceleration and maximum story drift of all stories are estimated as soundness indices in order to evaluate the soundness of the building concerned just after the occurrence of an earthquake. Here, the maximum story drift is calculated by integrating acceleration data twice. In this step, various pieces of data are preprocessed and integrated in the frequency region to stabilize integration. In concurrence with this, the soundness indices of all stories are estimated by evaluating the acceleration response of the stories not installed with the sensors based on information about the mode (amplitude pattern of vibrations at the natural frequency) of the building concerned. An example of estimation results is shown in Fig. 9. Through such analysis, diagnosis can be conducted only with several vibration sensors without installing a vibration sensor on all stories.

The maximum acceleration, a soundness index, in excess of the threshold indicates the possibility of damage to the inside of rooms by moving furniture and equipment and to equipment piping, anchors, etc. The

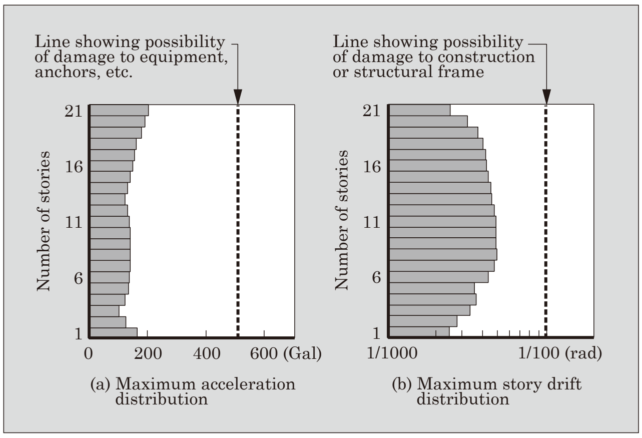

Fig.9 Estimation example of maximum acceleration and maximum story drift in primary diagnosis

maximum story drift exceeding the threshold presents the likelihood that the soundness of the structural frame will be impaired.

Such information will be useful for making decisions such as whether or not to conduct a damage investigation preferentially from the stories with higher maximum acceleration or maximum story drift. Set these thresholds with structure design information, etc. about each building concerned taken into account.

(2) Analysis technology for state estimation

Using measured acceleration data, obtain the natural frequency, mode and other vibration characteristics, and then estimate the state of the building from changes in the characteristics. To estimate the state of a building, construct a physical or mathematical model that is best suited to the object to be measured. Correctly determining the orders and parameters of a model expressing the system concerned (building concerned in this case) from input/output data is generally called system identification. The SHM system determines the structure of the model and estimates its parameters by conducting system identification with the acceleration of the first floor as the input and the acceleration of the top floor as the output. The system then estimates the vibration characteristics of the building concerned from these estimation results.

In diagnosis, the soundness of the building can be evaluated based on, for example, a change (decrease) in the estimated natural frequency.

It should be noted that the accuracy of the system identification mentioned above will vary with the set orders of the model or the quality of the data to be used for identification. To avoid this variance, these parameters will be automatically determined by applying an optimization algorithm that uses the orders of the model and the data processing parameters to be used for identification as decision variables and identification accuracy as an evaluation function. In addition, an interactive interface is adopted to enable users to adjust identification parameters, and the combination of this interface and the abovementioned optimization algorithm achieves practical-state estimation.

4. Postscript

This paper described the structure health monitoring system using MEMS-applied vibration sensors.

Fuji Electric has commercialized a primary diagnosis monitoring system capable of diagnosing the soundness of buildings just after the occurrence of an earthquake, and has been providing information useful for subsequent decision-making. Fuji Electric is also conducting research and development for the practical use of SHM systems. As the first step, we will construct a system that will provide experts in structures with information necessary for diagnosis, such as analysis results, in a timely manner. We are determined to establish soundness indices based on measured data accumulated in the system, achieve automatic diagnosis, and, above all, make the system applicable to social infrastructure, such as bridges and tunnels, and thereby contribute to the safety and security of society.

In the process of establishing the SHM system, we were given suggestions and guidance from Professor Mita of the Faculty of Science and Technology at Keio University. We also received advice from Toda Corporation and member companies of the consortium. We would like to express our heartfelt thanks to all of them.

Indirect External Air Cooling Type Energy-Saving Hybrid Air Conditioner for Data Centers, "F-COOL NEO"

OGA Shunsuke* TAKAMATU Takeshi* TAKAHASHI Masaki‡

ABSTRACT

To improve the energy efficiency of air conditioners in data centers, in which heat generation is dramatically increasing due to improved performance and higher-density of servers, systems that make use of outside air cold, which is natural energy, are being adopted. Fuji Electric has developed a hybrid air conditioner "F-COOL NEO" combining indirect external air cooling, which is less susceptible to the effect of dust and corrosive substances contained in external air, and vapor compression refrigeration cooling. F-COOL NEO automatically controls the operation ratio of the two types of cooling according to external air temperature and a cooling load. As a result of evaluation, it has been verified that high efficiency can be attained of the amount of power consumption throughout the year approximately 1/3 that of general air conditioners.

1. Introduction

In recent years, the amount of heat generated by servers used in data centers has increased dramatically as a result of the higher performance and higher density of the servers. The server-generated heat is typically cooled by air conditioning, and this creates a cooling burden throughout the year. In order to improve the energy efficiency of the air conditioning, the introduction of external air cooling using the cold energy of external air, which is natural energy, is being promoted. External air cooling is categorized as either a direct method in which the cold energy source of the external air is captured directly, or an indirect method in which the external air is passed through a heat exchanger to capture only the cold energy. Fuji Electric has developed the "F-COOL NEO" hybrid air conditioner that combines an indirect-type external air cooling (indirect external air cooling) system, which is less susceptible to moisture, dust and corrosive substances contained in the external air, with vapor compression-type refrigeration cooling.

The F-COOL NEO maximizes energy savings by automatically controlling the operating percentages of external air cooling and refrigeration cooling throughout the year according to the external air temperature that changes by season and by night and day, and according to the cooling burden, and is able to achieve high efficiency with an annual power consumption that is about one third of usual air conditioners.

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‡ Corporate R&D Headquarters, Fuji Electric Co., Ltd.

2. Features and Configuration

Table 1 shows the specifications of the F-COOL NEO. There are 2 models with rated cooling capacities of 25 kW and 40 kW.

Except for the time when starting up or when settings are changed, air can be supplied (blown) in the range of 18°C to 35°C with an accuracy of ±1 K with respect to the setting. Moreover, the air supply rate for the 25 kW model can be set in the range of 2,500 to 10,000 m^3/h and for the 40 kW model can be set in the range of 2,500 to 12,000 m^3/h. Additionally, the temperature control range can be controlled with greater accuracy than the previous ±2 K, and accordingly, if an upper limit value is defined and settings made so as not to exceed this value, then the temperature can be set to a higher value and energy can be conserved.

Figure 1 shows the configuration of the F-COOL NEO. The F-COOL NEO is an internal/external integrated unit that contains both an indirect external

Table 1 "F-COOL NEO" specifications

Item	Specification	
	FCA-25	FCA-40
Cooling method	Indirect external air cooling (antifreeze solution) + Compression refrigerator cooling (R410 A)	
Rated cooling capacity	25 kW	40 kW
Rated supply air flow	7,450 m^3/h (control range: 2,500 to 10,000)	8,500 m^3/h (control range: 2,500 to 12,000)
Supply air temperature setting	18 °C to 35 °C	
Supply air temperature accuracy	±1 K	
External dimensions	W1,200×D2,000×H2,500 (mm)	W1,200×D2,000×H2,700 (mm)

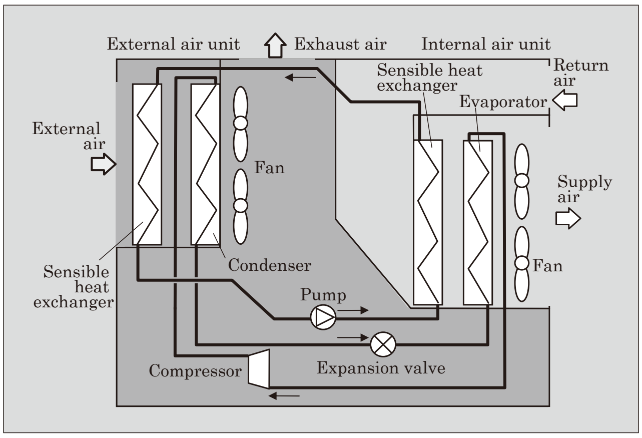

Fig.1 "F-COOL NEO" configuration

air cooling unit and a refrigeration cooling unit. The server-side air (internal air) and the cold energy source of air outdoors (external air) are separated inside the device, and there is no conduction of air. The indirect external air cooling unit provides both the internal air unit and the external air unit with a sensible heat exchanger, and brine coolant (antifreeze) is circulated by a pump to transport the external cold energy.

The refrigeration cooling unit operates to maintain the temperature of the supply air when the external air temperature is high and the capacity of the external air cooling is insufficient. The refrigeration cooling unit has an internal air unit that is provided with a vaporizer, and an external unit that is provided with a condenser, compressor and an expansion valve. Additionally, R410A is used as the refrigerant.

3. Operational Control to Realize Energy Savings

Indirect external air cooling has a high efficiency because it cools by the power of a pump and fan, without using a compressor. However, the cooling capacity is dependent on the external air temperature, and therefore the capacity decreases when the temperature of the external air increases. When the capacity of the indirect external air cooling unit is insufficient, the refrigeration cooling unit will operate to provide supplemental capacity, but the efficiency will decrease due to the operation of the compressor. Therefore, in order to realize energy saving operation with a minimal decrease in efficiency, automatic control is implemented to select an appropriate operating mode from among the multiple operating modes provided to support various operating conditions, and then the operation switches to the selected operating mode so as to maximally utilize external air cooling.

Figure 2 shows a schematic diagram of the burden sharing for indirect external air cooling and refrigeration cooling. The horizontal axis is the external air temperature normalized so that the external air cooling capacity becomes 0 when the temperature of the return air is the temperature of the external air. In other words, the capacity limit of external air cooling decreases as the temperature difference between return air and external air becomes smaller.

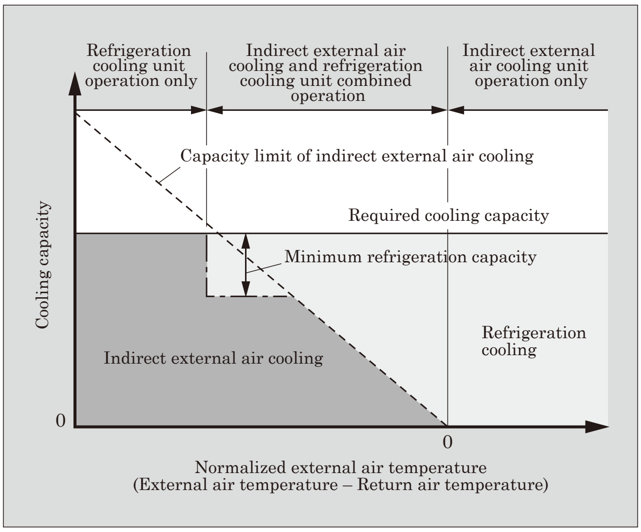

Fig.2 Schematic diagram of burden sharing for indirect external air cooling and refrigeration cooling

(1) Indirect external air cooling unit operation only mode

If the capacity of the indirect external air cooling unit is sufficient with regard to the cooling burden, the indirect external air cooling unit will operate by itself.

(2) Combined operating mode of the indirect external air cooling unit and the refrigeration cooling unit

If the capacity of the indirect external air cooling unit falls below the cooling burden, the refrigeration cooling unit compensates for the shortfall. However, because the refrigeration cooling unit of the F-COOL NEO does not have a mechanism for controlling the cooling capacity to the minimum capacity or less, the capacity of the indirect external air cooling unit is adjusted so as not to exceed the cooling burden.

(3) Refrigeration cooling unit operation only mode

Under the condition that the external air temperature is higher than the return air temperature and the cooling capacity cannot be provided by indirect external air, the refrigeration cooling unit will operate by itself.

One of the abovementioned operating modes (1), (2) and (3) will be selected automatically according to the cooling burden and the external air temperature, but the control of the devices will become discontinuous at the time when changing modes, and so that the temperature of the supply air does not fluctuate, multiple sub-modes with different control methods are provided within each operating mode.

4. Evaluation of Energy Savings

4.1 Test equipment

A characteristics evaluation of the F-COOL NEO was performed using the test equipment shown in

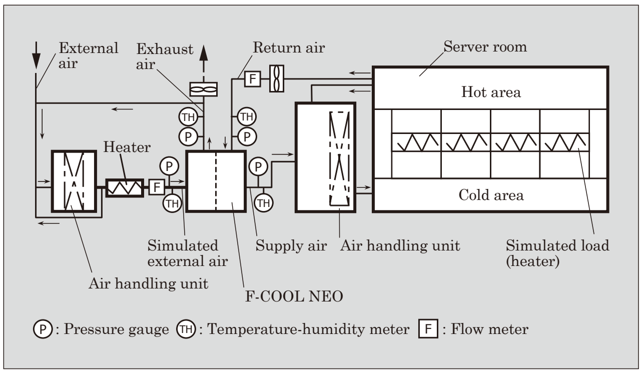

Fig.3 Test equipment

Figure 3.

At the internal air side, the amount of heat generated is controlled by a simulated load (heater) in a server rack installed in the server room, and the return air from the server room is fed to the F-COOL NEO and an air handling unit. A temperature-humidity meter and a pressure gauge are provided both before and after the F-COOL NEO. Additionally, a fan and a flow meter are provided upstream from the F-COOL NEO, and the external static pressure is maintained to be constant while the return air flow is controlled.

At the external air side, a simulated year-round external air condition is created by an air handling unit and a heater, and then fed to the F-COOL NEO. As in the case of the internal air side, a temperature-humidity meter and a pressure gauge are provided both before and after the F-COOL NEO. Additionally, a flow meter is provided upstream from the F-COOL NEO, and the flow rate of an air handling unit for external air is adjusted to maintain the external static pressure at a constant value, and to control the simulated external air flow rate.

Power consumption is measured by connecting a power meter to the power supply pin of the F-COOL NEO, and the cooling capacity is calculated from the air humidity and flow rate at the internal air side inlet and outlet.

4.2 Characteristics of external air cooling

Figure 4 shows the result of measurements of the cooling capacity of external air cooling by itself under the condition where the return air temperature, supply air flow rate and external air flow rate are all constant. The measurement results of a sensible heat exchanger alone in an equivalent evaluation apparatus are also shown in the figure.

Under the condition of constant return air temperature, the cooling capacity varies linearly with the external air temperature, and the cooling capacity drops as the external air temperature rises. Accordingly, when the external air temperature is high and the external air cooling capacity is low, the capacity must be supplemented by the refrigeration cooling unit in order to maintain the rated cooling capacity.

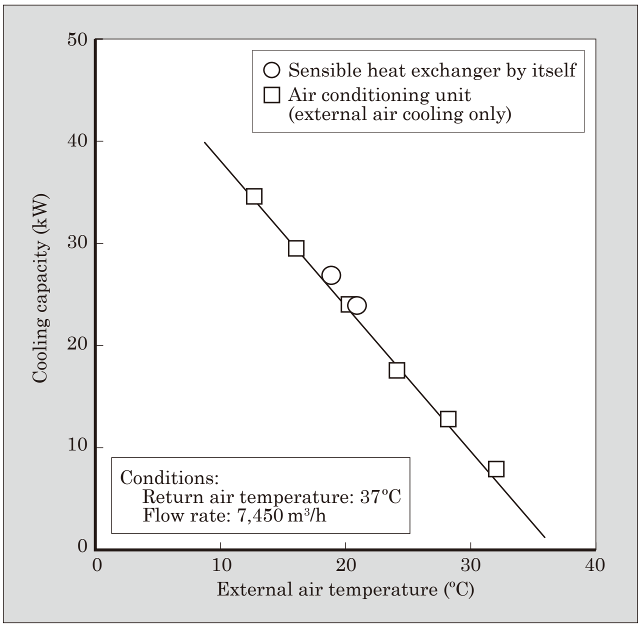

Fig.4 External air cooling characteristics

4.3 External air temperature dependence

Using simulated external air, the external air temperature was varied and characteristics were measured. While operating at the rated cooling capacity of 25 kW, the power consumption of all the equipment was measured, and coefficient of performance (COP) was computed from Equation (1).

$$\mathrm{COP} = \frac{\text{Cooling capacity}}{\text{Equipment power consumption}} \quad \cdots\cdots (1)$$

Cooling capacity: Computed from the inlet/outlet enthalpy difference at the internal air side
Equipment power consumption: 15 minute average value of the equipment power consumption

Figure 5 shows the power consumption and the COP calculation results and measurement results. At 19°C or less, the indirect external air cooling unit operates alone, and the power consumption is about one fifth that of refrigeration cooling unit operation only at 37°C or higher. In the intermediate temperature range, there is combined operation of the indirect external air cooling unit and the refrigeration cooling unit, and the power consumption is also in-between that of indirect external air cooling operation only and refrigeration cooling operation only, and the advantageous effect of external air cooling is obtained. Moreover, the power consumption and COP calculation results are nearly the same as the measured values.

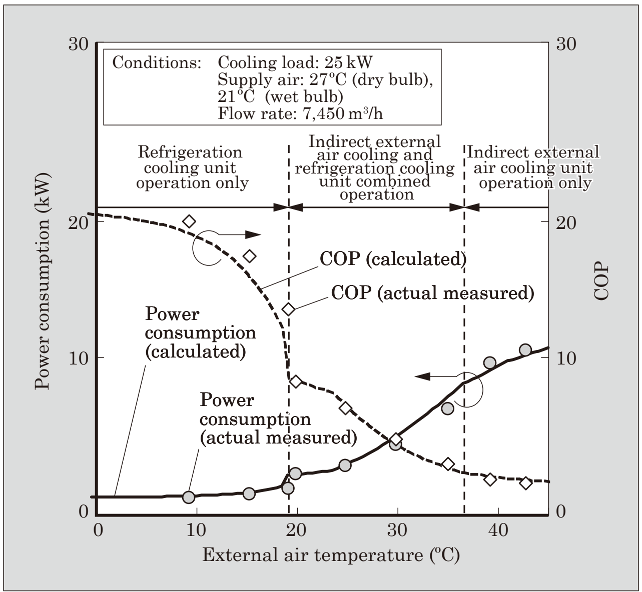

Fig.5 Power consumption, COP calculation results and measurement results (FCA-25)

5. Continuous operation evaluation at simulated data center

5.1 Evaluation equipment

As the evaluation equipment, a module-type simulated data center and the F-COOL NEO were installed in combination, and continuous operation was carried out in a semi-external environment (see Fig. 6). The heat source was controlled by a simulated load (heater) provided inside the simulated data center, and the total amount of heat was cooled with the F-COOL NEO.

5.2 Operating mode switching evaluation

When switching between indirect external air cooling unit operation only and combined operation of the indirect external air cooling and refrigeration cooling units, as shown in Fig. 2, the share of the cooling capacity becomes discontinuous, and therefore a sub-mode that changes the method of device control is provided to smooth the capacity sharing. Figure 7 shows the transition from indirect external air cooling operation only to combined operation at a rated load. When the external temperature rises, establishing the condition for transitioning to the combined operation mode, the compressor starts operating, and at that time the cooling capacity is controlled by the rotating speed of the pump. The temperature of the supply air becomes slightly disturbed for about 15 minutes after transitioning, but the accuracy is maintained within 1K.

Figure 8 shows the transition from combined operation to indirect external air cooling operation only at a rated load. When the external air temperature

Fig.6 Evaluation equipment

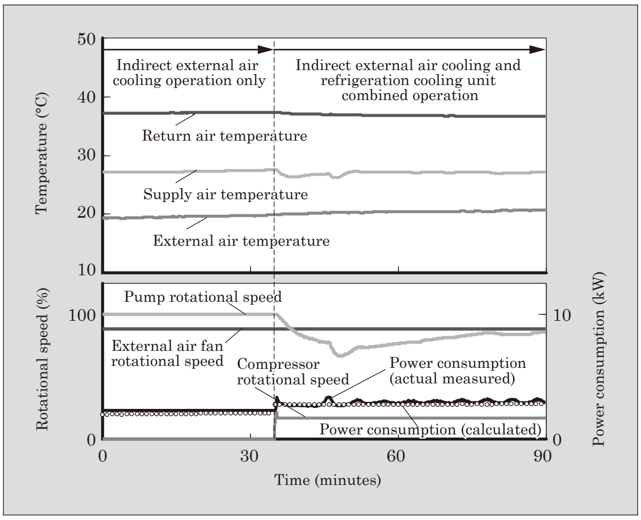

Fig.7 Operation mode switching (Indirect external air cooling unit operation only → Combined operation)

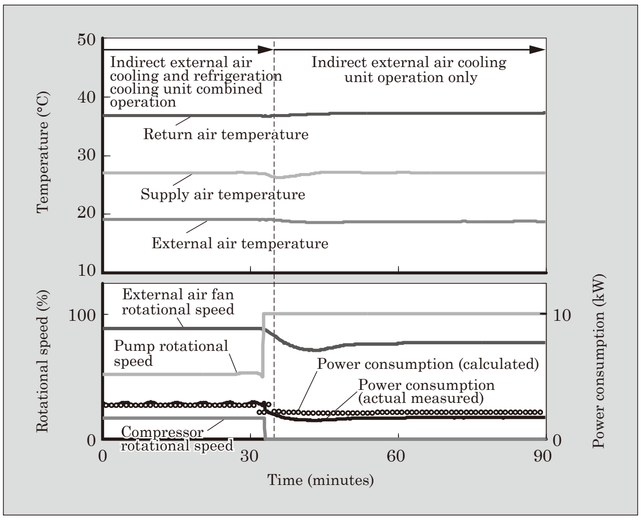

Fig.8 Operating mode switching (Combined operation → Indirect external air cooling unit operation only)

drops, establishing the condition for transitioning to the indirect external air cooling operation only mode, the rotating speed of the pump is controlled and then the compressor is stopped, and at that time the cooling capacity is controlled by the rotating speed of the external air fan.

The change in power consumption while transitioning operating modes and the values computed for each one-minute are shown in Figs. 7 and 8. The measured values are on close agreement with the calculated values, and the computation method is also considered to be effective for time-series variations.

6. Evaluation of annual efficiency

6.1 Measurement of power consumption

Figure 9 shows the changes in power consumption at rated load operation during a summer day in the simulated data center. The power consumption fluctuates with changes in the external temperature during the day, but the temperature of the supply air is maintained constant. In addition, the power consumption estimated from the hourly external air temperature matches the trend of the measurements. Table 2 compares the measured and estimated values of power consumptions. The measurement of the amount of power consumed in one day closely agrees with the estimated value.

6.2 Estimation of annual efficiency

Figure 10 shows the calculation results of annual energy consumption using 2009 hourly meteorological data from the Tokyo observatory of the Japan

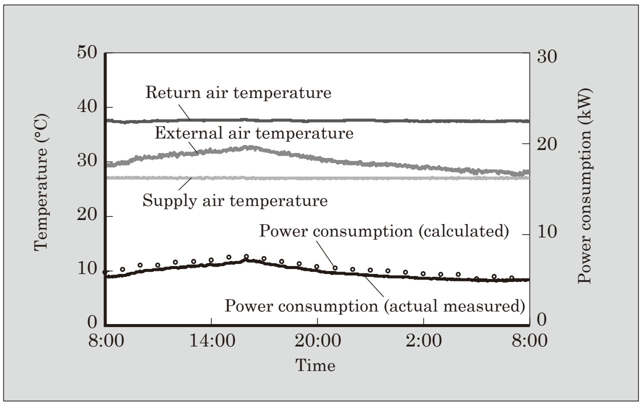

Fig.9 Power consumption during rated load operation for one summer day

Table 2 Power consumption and COP

		Thermal load (GJ)	Power consumption	COP
Daily operation (2009 summer, Tokyo)	Measured	2.20	117 (kWh/day)	5.2
	Calculated	2.16	126 (kWh/day)	4.8
Annual operation (2009 , Tokyo)	Calculated	788	21,009 (kWh/year)	10.4

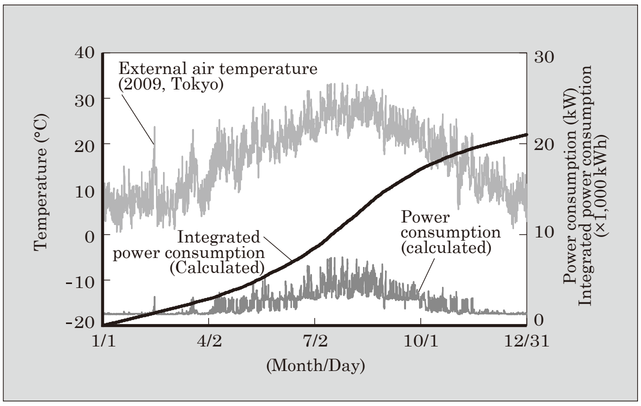

Fig.10 Power consumption during rated operation in 2009

Meteorological Agency. Additionally, Table 2 shows the calculation results of the annual COP using Equation (2). The annual COP for the Tokyo region was 10.4.

$$\text{Annual COP} = \frac{\text{Annual amount of cold energy generated}}{\text{Annual power consumption}} \quad \cdots\cdots (2)$$

This value is significantly larger than the annual COP in the range of 3 to 4 of a package air conditioner for general computation use. By using the F-COOL NEO, it was confirmed that the amount of power consumption could be reduced to about one third.

7. Application to Modular data centers

When constructing a data center, the module concept is a key point in terms of minimizing the initial investment and achieving early operation, energy savings and scalability. In order to reduce the investment burden and shorten the construction period (3 months) through step-by-step construction with a standardized housing, air conditioning, power supply and the like, Fuji Electric has developed and commercialized a “built-in block system” modular data center. This module is configured from a server block, UPS block, power receiving block and an electricity self-generating block. Figure 11 shows the server block and the UPS block. The server block is configured from a server rack hous-

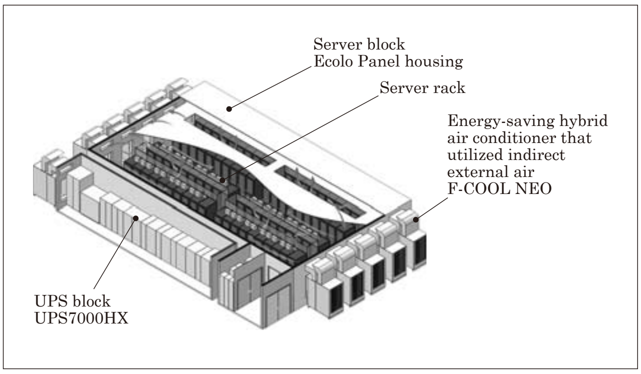

Fig.11 Modular data center

ing made from “Ecolo Panel” prefabric building material that Fuji Electric used in constructing convenience stores, electric power distribution equipment that distributes power to the server rack via a bus duct, and the F-COOL NEO that cools the server load. This basic block can house 80 server blocks and is provided with high thermal insulation and high earthquake resistance (980 Gal). The F-COOL NEO is installed in the outer periphery of the housing, and the cooling air supplied to the server rack is vented out from the interior walls of the housing, and air that has been warmed by the server rack is returned from above the ceiling to the F-COOL NEO. The UPS block use a Fuji Electric-made UPS “UPS7000HX” having an efficiency of 97% to boost the efficiency of the power supply equipment. Additionally, the monitoring and control of basic modules is performed by the data center energy management system “F-DMS,” and labor savings and remote operation are achieved. Investment can be optimized by gradually added equipment in response to the demand for these modules. Figure 12 shows a bird’s-eye view of a data center in which four sets of basic modules were installed.

Fig.12 Bird’s-eye view of data center site

8. Postscript

This paper has described the “F-COOL NEO” hybrid air conditioner that combines an indirect external air cooling unit which utilizes natural energy with a vapor compression-type refrigeration cooling unit. This air conditioner is not only for data centers and is also suitable for the precision machining field, and the food and pharmaceutical fields in which cooling air conditioning with clean air is needed throughout the year.

In the future, we intend to continue working to achieve energy savings through optimal operation control in response to fluctuations in the cooling load.

Fuel Tank Pressure Sensor for Vehicles, “EPL11E-GM”— Pressure Sensor for Fuel Leak Detection

SHINODA Shigeru*

Amid the trends toward greater vehicle safety and reduced burden on the environment, vehicles are required to have built-in on-board diagnostics (OBD) systems that utilize electronic control to detect fuel leakage from the fuel tank system. In response to these trends, Fuji Electric commercialized a tank pressure sensor (pressure sensor for fuel leakage detection) in 2007.

Electronic control of vehicles has advanced, and electronic control units (ECUs) have come to be used for not only the engine control system, but also the power train system, body control system, information communication control system, and so on, and electromagnetic compatibility (EMC) has been demanded in regard to the noise generated by these control systems. In response to such market needs, Fuji Electric has developed the “EPL11E-GM” fuel tank pressure sensor for vehicles that maintains the external dimensions of previous products while realizing improved EMC performance with a chip capacitor for noise removal embedded within the package.

This paper describes relative pressure applications and gauge pressure applications of the EPL11E-GM.

Table 1 “EPL11E-GM” basic specifications

Item	Specification
External dimension	15.6×11.5×6.6 (mm)
Absolute maximum voltage*1	16 V
Absolute maximum pressure	50 kPa
Storage temperature	−40 °C to +130 °C
Working temperature	−30 °C to +120 °C
Working pressure*2	±6.666 kPa
Output range	0.5 to 4.5 V
Interface	Pull Up ≥ 300 kΩ Pull Down ≥ 100 kΩ
Diagnostic ranges*3	<0.2 V, 4.8 V<
Sink current	1 mA
Source current	0.1 mA
Pressure error	<3.0%F.S.
Temperature error	<1.5 times
EMC immunity	ISO 11452-2 (100 V/m, CW, 10 kHz to 2 GHz) ISO 11452-4 (100 m, CW, 1 MHz to 400 MHz) ISO 7637 (Level IV)

*1: <1 min
*2: Relative voltage and full-scale voltage may be changed optionally
*3: Detection of a broken VCC line or broken VOUT line, detection of a broken GND line

1. Features

Figure 1 shows the external appearance and Table 1 lists the basic specifications of the EPL11E-GM.

Fuji Electric’s tank pressure sensor is based on the concept of “compact high reliability” and fully leverages the advantages of one-chip technology. Amid requests for stronger EMC performance, the EPL11E-GM continues the conventional technique of integrating a sensing unit and signal processing unit into a single chip, while incorporating an externally attached chip capacitor to improve EMC immunity, all within a compact package.

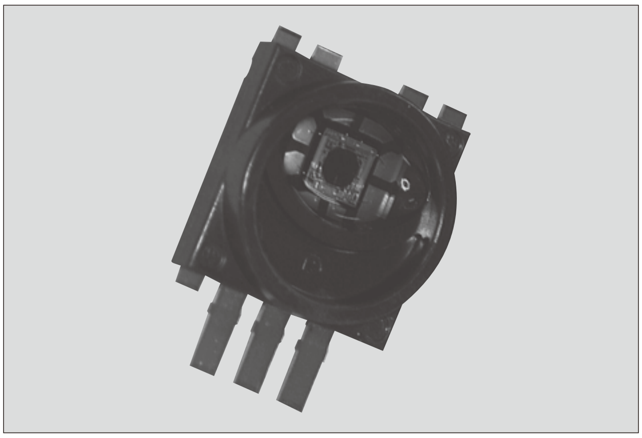

Fig.1 “EPL11E-GM”

2. Product Configuration

The tank pressure sensor is, in principle, a piezoresistor-type* pressure sensor, and is configured as a single-chip that incorporates a sensor unit, amplifier circuit, characteristic adjusting circuit and EMC protective elements.

The sensor unit consists of a diaphragm formed with micro electro mechanical systems (MEMS) technology, and piezoresistors that are arranged on top of the diaphragm. The diaphragm deforms in response to pressure, and as a result, the resistive value changes. This change in resistive value is converted into an electrical signal that can be used to sense the pressure.

* Electronic Devices Business Group, Fuji Electric Co., Ltd.

*: Piezoresistor: A resistor that changes its resistive value according to mechanical stress

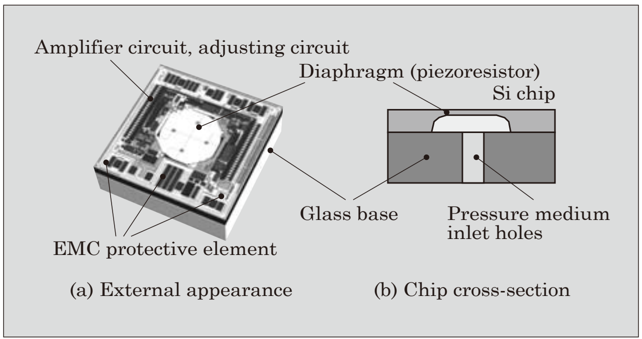

Fig.2 Pressure sensing unit

Figure 2 shows the pressure sensing unit of the EPL11E-GM. At the time when an IC is fabricated on the diaphragm, piezoresistors formed from diffusion wiring are also fabricated, and a Wheatstone bridge is configured from four piezoresistors. The diaphragm is processed with high accuracy by Fuji Electric's proprietary 3D etching technology to achieve a rounded shape, and ensures resistance to overpressure and high sensitivity as a result of high-precision thin film processing technology.

The chip in this product is formed with an amplifier circuit for boosting the output from the diaphragm sensor unit and an adjusting circuit for compensating the sensor characteristics. The chip is also equipped with a protective element for protecting the complementary metal-oxide-semiconductor (CMOS) circuitry in the sensor from surge current generated by the engine control system of the vehicle, static electricity in the assembly process, external electromagnetic radiation, and so on.

Moreover, in order to measure relative pressure or gauge pressure corresponding to atmospheric pressure, a glass base is provided for the pressure sensing unit and inlet holes for the pressure medium are formed in the back of the package. In order to reduce thermal stress from the package, internal stress from the junction layers, and the like, the glass base is formed with an electrostatic bonding process to ensure a highly reliable airtight structure.

The sensitivity of the EPL11E-GM is 200 to 300 mV/kPa, which is about 10 times more sensitive than the 10 to 40 mV/kPa range of Fuji Electric's flagship low pressure sensor products. In the design of the chip for the EPL11E-GM, the gain of the amplifier circuit was increased, and the diaphragm design was optimized to enhance accuracy and sensitivity, and to provide pressure resistance.

Additionally, with the same external dimensions as Fuji Electric's standard package for low-pressure sensors, the EPL11E-GM package is provided with pressure medium inlet holes for relative pressure to realize a compact size.

3. EMI Noise Immunity

High immunity to EMI noise is a feature of the EPL11E-GM. Two types of noise tests were carried out in conformance with ISO 11452, and the favorable results shown in Figs. 3 and 4 were obtained.

(a) RF immunity test (antenna radiation test)

(b) Bulk current injection (BCI) test

Ample noise immunity was confirmed based on the low output fluctuation of ±20 mV or less, which is 0.5% of the 4,000 mV output range.

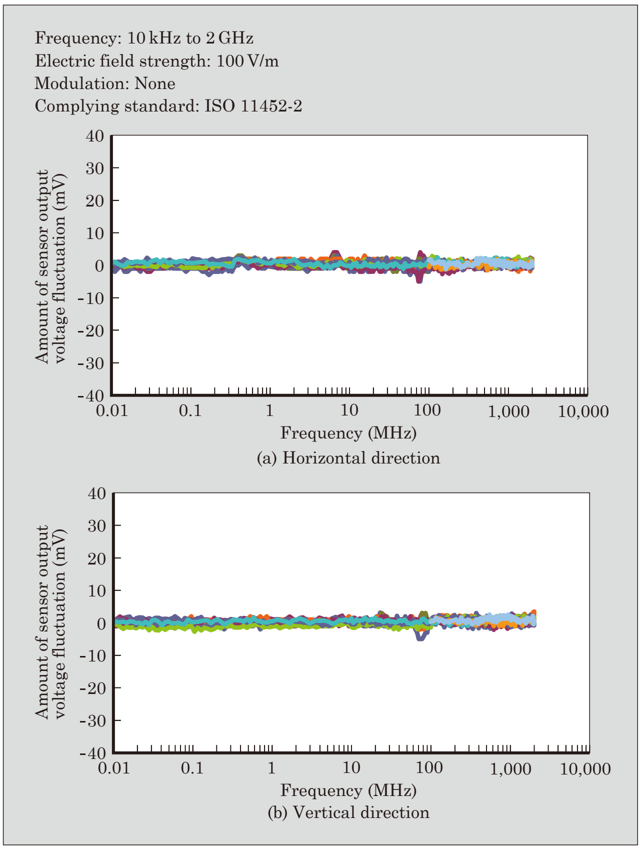

Fig.3 RF immunity test (antenna radiation test) results

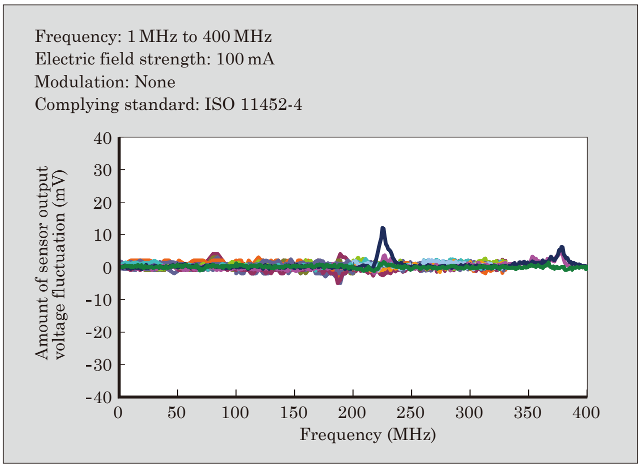

Fig.4 Bulk current induction (BCI) test results

Launch time

June 2014

Product Inquiries

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“V Series” IPM — Medium Capacity and Compact Package, “P636 Package”

MINAGAWA Kei* **TERASHIMA Kenshi***

In recent years, device miniaturization has been required not just of motor drive devices such as general-purpose inverters and servo controllers, which are the main applications for intelligent power modules (IPMs), but also in the air conditioner and photovoltaic power generation power conditioner (PCS) markets as well. As a result, there is rising demand for IPMs to be more compact in size and to provide higher output current.

In response to these market requests, Fuji Electric is planning to commercialize a new medium-capacity (600 V/50 to 100 A, 1,200 V/25 to 50 A) compact package IPM as an addition to its current lineup of “V-series” IPMs.

This paper describes the features and technological background of the medium capacity, compact package “P636 Package.”

1. Features

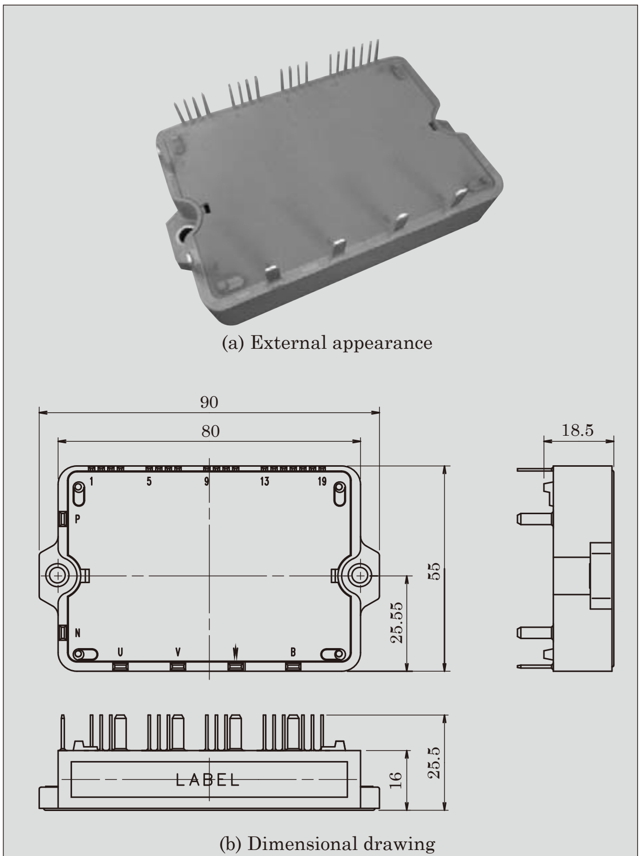
Figure 1 shows the external appearance of the P636 package, and Table 1 lists the product lineup. The P636 package is the world’s first lineup of medium capacity IPMs with rated current of 600 V/100 A, 1,200 V/50 A in a compact package with external dimensions of W90×D55×H18.5 (mm). These products will enable devices to be made smaller and will increase the degree of freedom in device design.

(1) Miniaturization

The P636 package footprint is 54% smaller than the current V-series IPM “P630 package” and 26% smaller than the existing medium-capacity Econo-IPM “P622 package.”

(2) Optimization of overcurrent protection level

The overcurrent protection level was optimized in order to support greater maximum load current to a



(a) External appearance

(b) Dimensional drawing

Fig.1 “P636 Package”

Table 1 “P636 package” lineup

Voltage	Rated current		Model		Built-in functions				
	Inverter unit	Brake unit	6 in 1	7 in 1	IGBT drive circuit	Control power supply undervoltage protection	Chip overheat protection	Over-current protection	Alarm output (upper & lower arms)
600 V	50 A	30 A	6MBP50VFN060-50	7MBP50VFN060-50	○	○	○	○	○
	75 A	50 A	6MBP75VFN060-50	7MBP75VFN060-50	○	○	○	○	○
	100 A	50 A	6MBP100VFN060-50	7MBP100VFN060-50	○	○	○	○	○
1,200 V	25 A	15 A	6MBP25VFN120-50	7MBP25VFN120-50	○	○	○	○	○
	35 A	25 A	6MBP35VFN120-50	7MBP35VFN120-50	○	○	○	○	○
	50 A	25 A	6MBP50VFN120-50	7MBP50VFN120-50	○	○	○	○	○

* Electronic Devices Business Group, Fuji Electric Co., Ltd.

device. Compared to the overcurrent protection level of 1.5 times the rated current for the P622 package, the overcurrent protection level for the P636 package has been increased to 2.0 times the rated current.

(3) Built-in braking element

The device ratings cover the medium-capacity ranges of 600 V/50 to 100 A and 1,200 V/25 to 50 A. The inclusion of a built-in braking element, despite the small package size, eliminates the need for an externally attached braking element.

2. Background Technology

(1) Reduction of thermal resistance through use of high heat-dissipating insulative substrate

The miniaturization of the package made it necessary to improve the heat dissipation performance and to prevent temperature rise due to the concentration of heat and thermal interference from the power chip. Therefore, instead of the aluminum (Al_2O_3) insulative substrate used in the existing P622 package, a high heat-dissipating aluminum nitride (AlN) insulative substrate has been newly used.

Table 2 compares the thermal resistance of the P622 package and the P636 package for the same elements rated at 100 A/600 V. The P636 package has approximately 20% lower thermal resistance than the P622 package.

(2) Reduction of generated loss and EMI noise

In order to suppress the temperature rise of power chips, not only must the thermal resistance be reduced, but the generated loss must also be reduced.

Figure 2 compares the results of simulations of generated loss during PWM inverter operation of the P622 package and the P636 package at 600 V/100 A. In the case where a carrier frequency of 5 kH is the operating condition, the P636 package, with the application of a 6th generation insulated gate bipolar transistor (IGBT) optimally designed for IPM-use, generates approximately 10% less loss that the P622 package that uses a previous generation IGBT.

As shown in Fig. 2, the conduction loss of the IGBT and FWD account for approximately 60% of the total generated loss. A tradeoff relation exists between the "conduction loss and turn-off loss of the IGBT" and the "conduction loss, turn-on loss and recovery loss of the FWD." Accordingly, in order to reduce the IGBT and

Table 2 Comparison of thermal resistance for same rated element at 600 V/100 A

Item	"P622 package" inverter unit		"P636 package" inverter unit	
	IGBT	FWD	IGBT	FWD
Thermal resistance max. (°C/W)	0.36	0.67	0.30	0.52
Percent reduction (%)	–	–	17	22

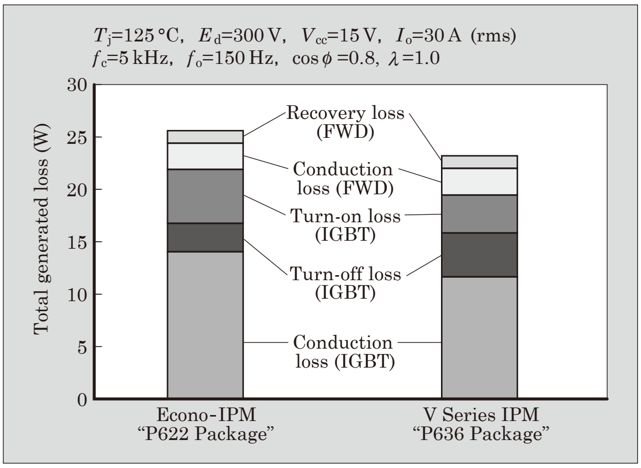


Fig 2 Comparison of simulated total generated loss at 600 V/100 A

FWD conduction loss, which are the dominant sources of loss among the generated loss, we reconsidered the points of application on the IGBT's $V_{ce(sat)}$ and the FWD's V_F tradeoff curve.

Additionally, a tradeoff relationship also exists between generated loss and EMI noise. With the P636 package, in order to reduce EMI noise while reducing generated loss, as a result of the reconsideration of the optimal points of the above-mentioned tradeoff relationship, the voltage rise dv/dt at the time of switching was reduced and, as shown in Fig. 3, the EMI noise was suppressed.

(3) Increased output current

By reducing the P636 package's thermal resistance (IGBT unit) by 17% and generated loss by 10% compared to the P622 package, the output current value at the same $\Delta T_{j\text{-}c}$ (temperature between the chip and case) could be increased by 30%. As shown in Table 3, for example, the output current value at which $\Delta T_{j\text{-}c}$ becomes the same is 30 A (rms) for the P622 package, but could be increased to 39 A (rms) for the P636 package.

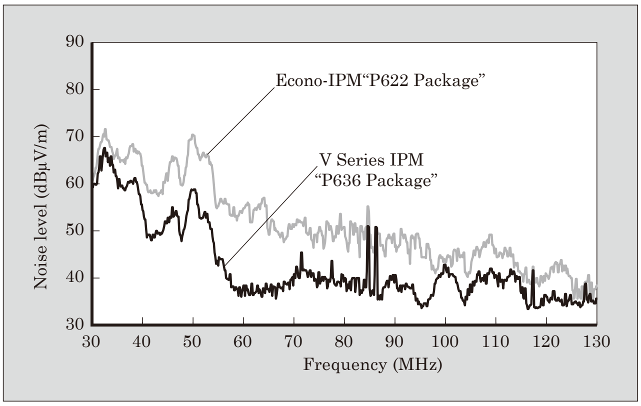


Fig.3 EMI noise comparison (relative comparison test results)

Table 3 Comparison of applied current and temperature rise at 600 V/100 A

T_j=125 °C, E_d=300 V, V_{cc}=15 V, f_c=5 kHz, f_o=150 Hz, cosϕ=0.8, λ=1.0

Product	Output current (rms) (A)	IGBT			FWD		
		Total loss (W)	Thermal resistance max. (°C/W)	$\Delta T_{j\text{-}c}$ (°C)	Total loss (W)	Thermal resistance max. (°C/W)	$\Delta T_{j\text{-}c}$ (°C)
Econo-IPM “P622 package”	30	21.9	0.36	7.9	3.7	0.665	2.5
V series IPM “P636 package”	30	19.5	0.30	5.8	3.7	0.52	1.9
	39	26.0	0.30	7.8	5.0	0.52	2.6

30% increase

2.1 °C decrease

0.6 °C decrease

Launch time

600 V class: August 2014

1,200 V class: December 2014

Product Inquiries

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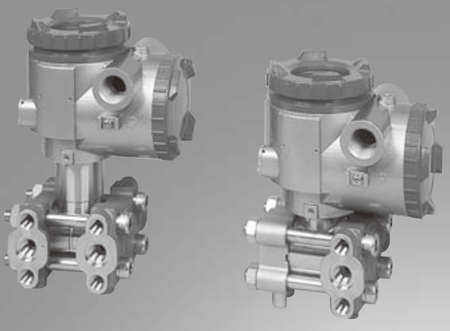
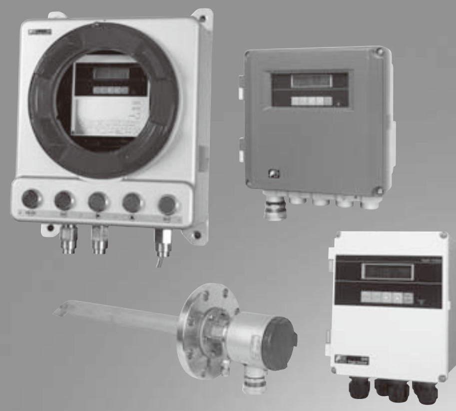
Fuji's Measurement Instruments

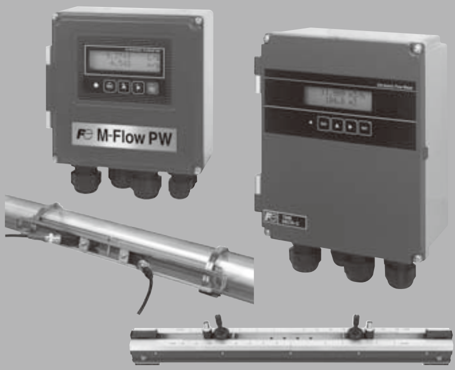


Electronic Transmitters

Laser Gas Analyzers



Zirconia Oxygen Analyzers



Ultrasonic Flowmeters

Gas Analyzers for Stack Gas

Temperature Controllers

Portable Type
Ultrasonic Flowmeters

Infrared Gas Analyzers

Recorders

Fuji Electric

Innovating Energy Technology

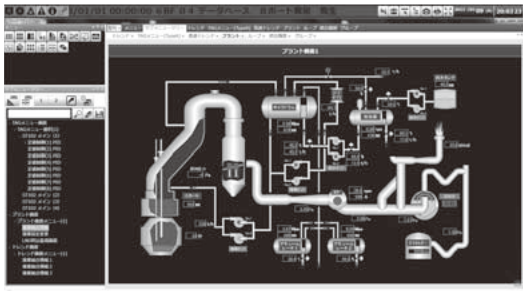
Fuji Electric
Innovating Energy Technology

Small- and Medium-Scale Monitoring and Control System

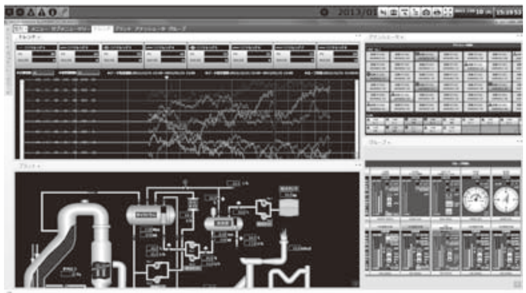
MICREX-VieW XX

Features

- **Innovative HCI* operation**
- **High performance, high reliability**
- **Small sized, large capacity controller**
- **High speed control LAN**
- **High efficiency engineering**
- **Inheritance of existing system assets**



New HCI plant screen (image)

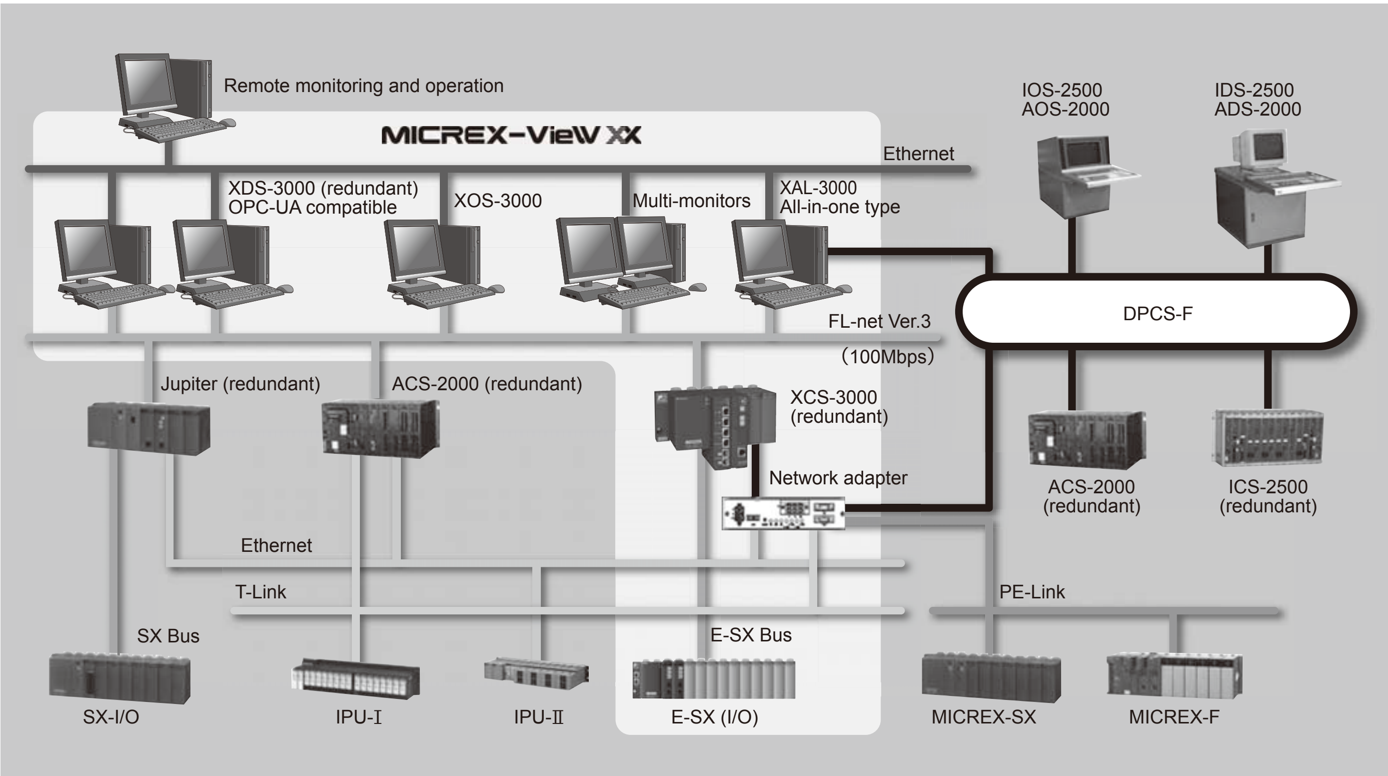


Screen size and position can be adjusted by user needs

Small- and medium-scale monitoring and control system "MICREX-VieW XX" combines high reliability technology, based on Fuji Electrics' many delivery records of monitoring and control systems as a background, and environmental durability technology cultivated in FA field. This is the new monitoring and control system that provides a seamless connection between the control system and shop floors.
In "MICREX-VieW XX," HCIs, controllers, power supplies, networks, and the like can be built as duplex systems as needed, providing users with a high reliability system according to the scale of their facilities.
It has high compatibility with Fuji Electric existing systems, allowing users to upgrade their facilities (migration) by making most of their hardware and software assets.
In addition, it can operate as the common system platform with integrating components for various industries or fields, from PA to FA, including measurement, drives, power generation, energy management systems (EMS).

*HCI: Human Communication Interface

Example of basic system configuration



Overseas Subsidiaries

* Non-consolidated subsidiaries

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we develop products that maximize energy
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