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

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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.

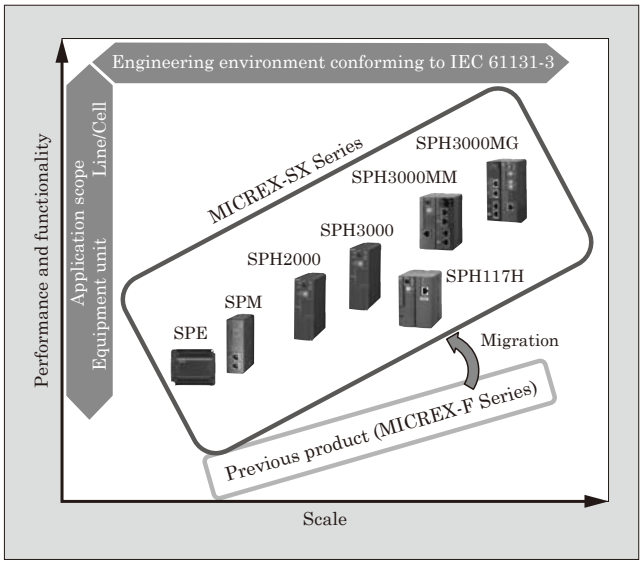

Fig.1 Overall picture of "MICREX-SX Series"

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

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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

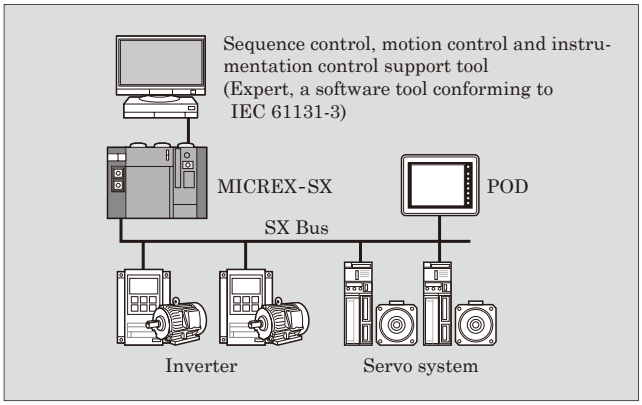

Fig.2 High-speed bus direct-connection system

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

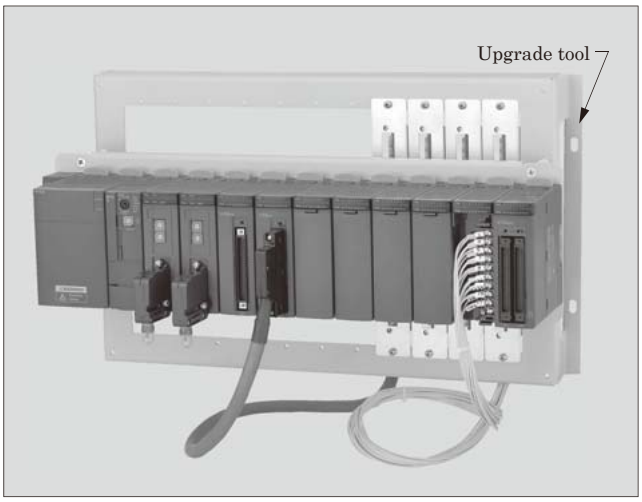

Fig.3 Example of upgrade tool

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

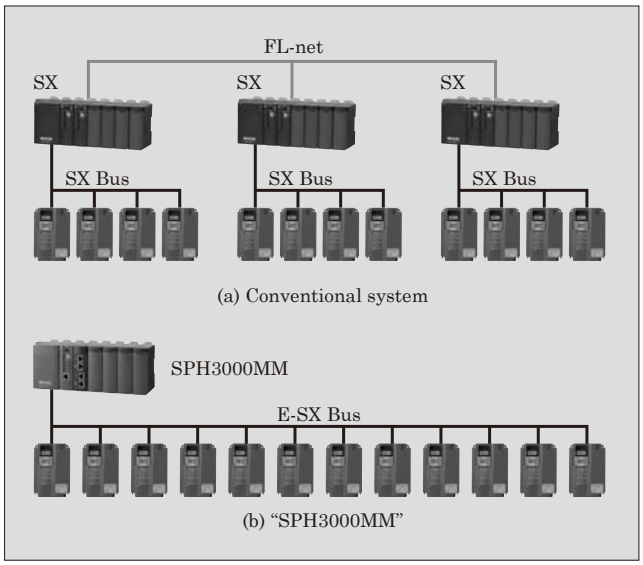

Fig.4 System configuration comparison

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.

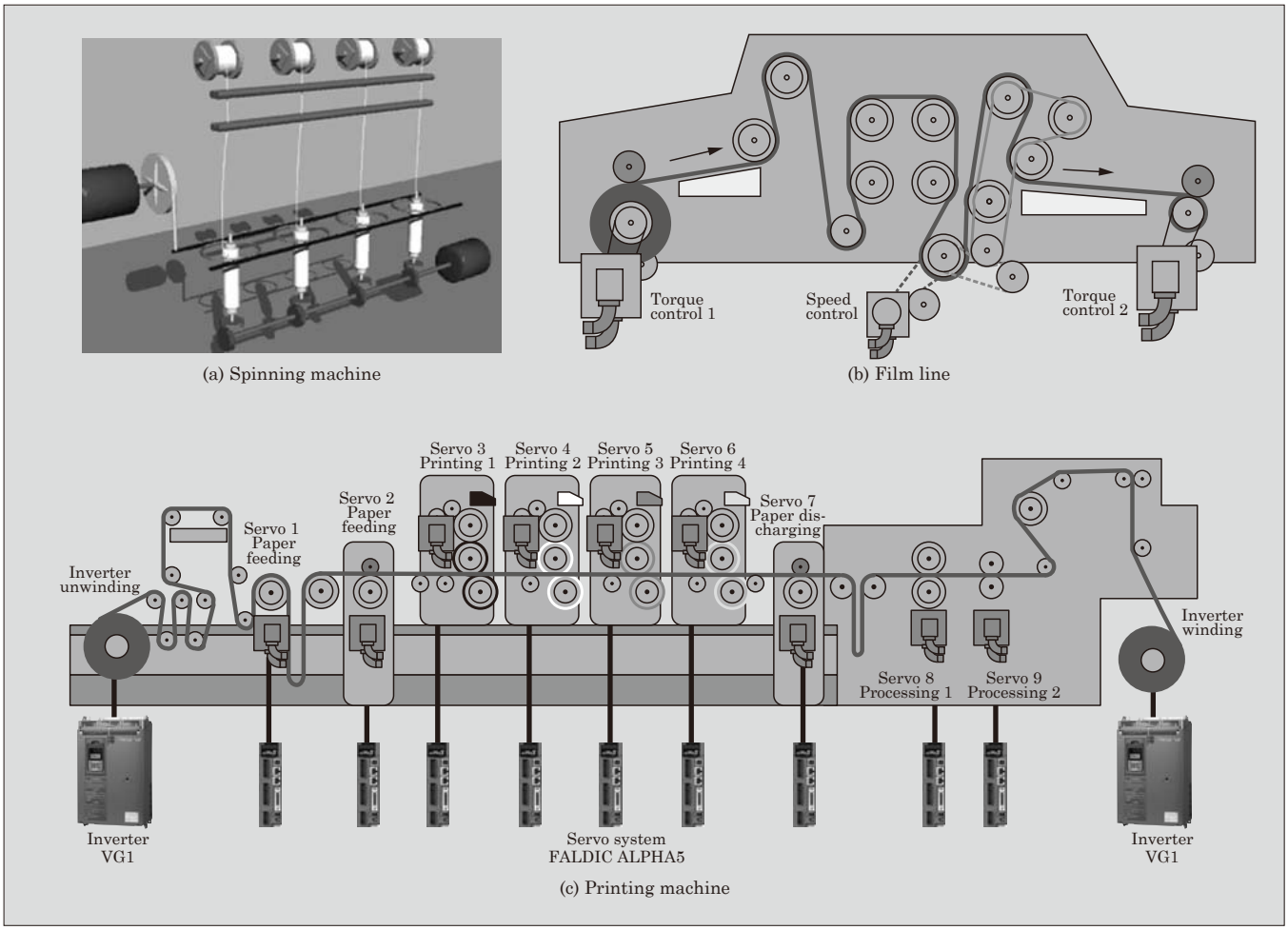

Fig.5 Example of motion control application

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

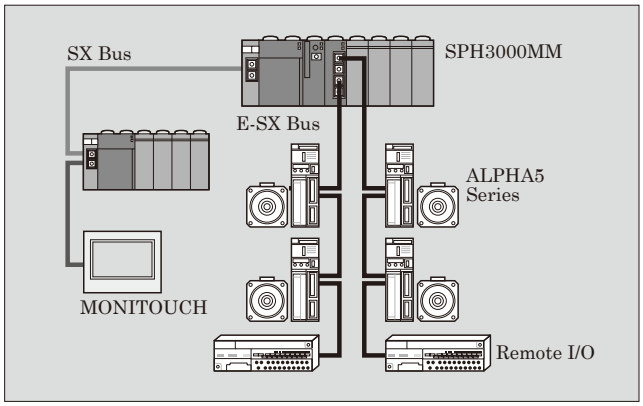

Fig.6 Example of an "E-SX Bus" compatible motion control system configuration

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

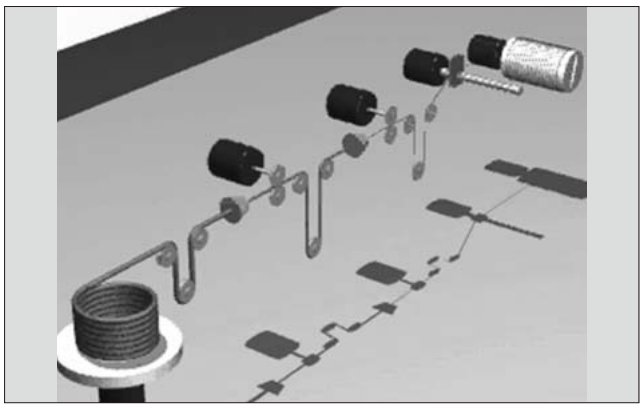

Fig.7 Example of wiredrawing machine

*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.

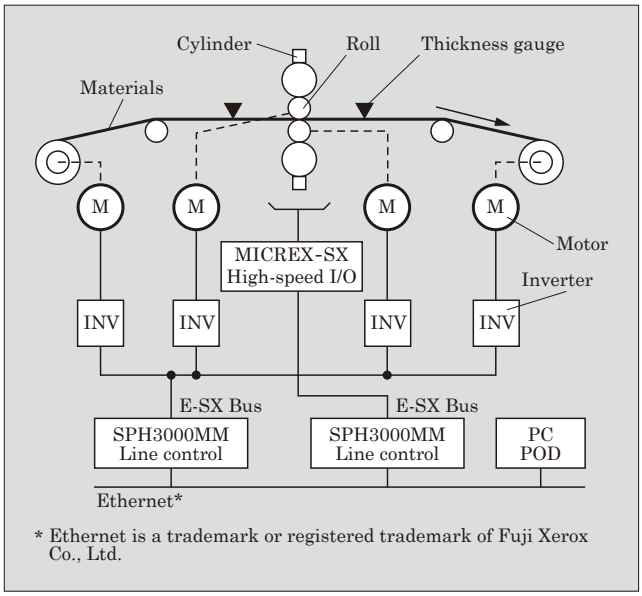

Fig.8 Example of mill pressure control system

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-

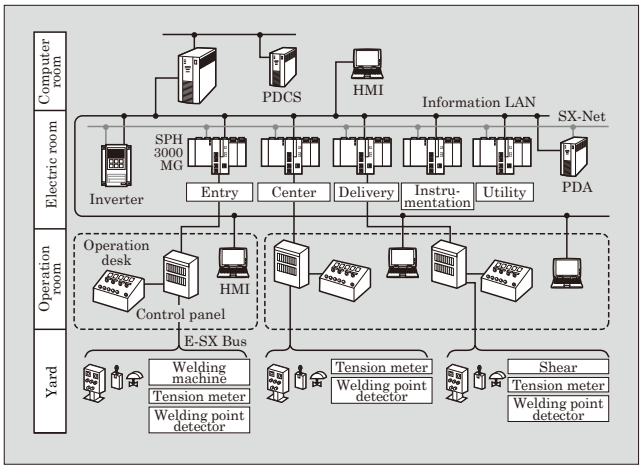

Fig.9 Application example of iron and steel process line

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.