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"

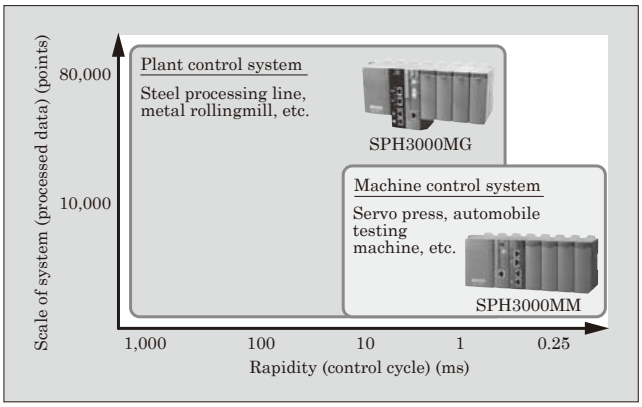

Fig.1 Application ranges of "SPH3000MM" and "SPH3000MG"

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.

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.

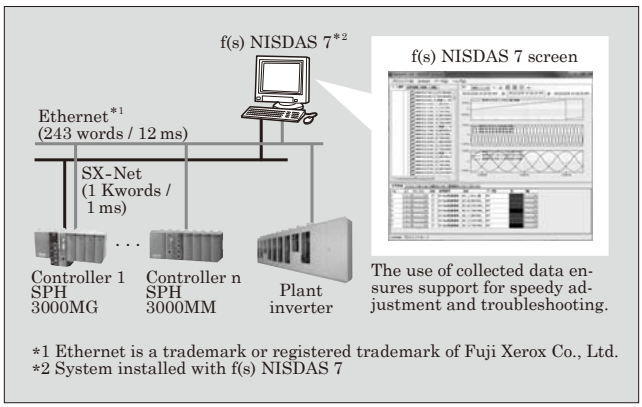

Fig.2 Application example of "f(s) NISDAS 7"

(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.

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.

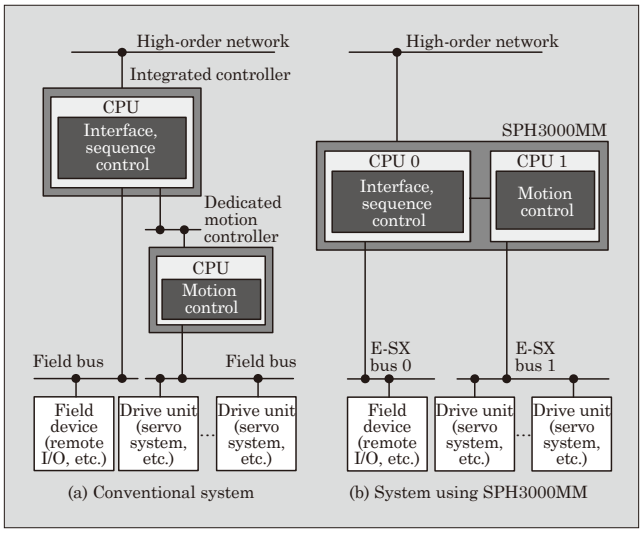

Fig.3 Conventional system and system using "SPH3000MM"

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

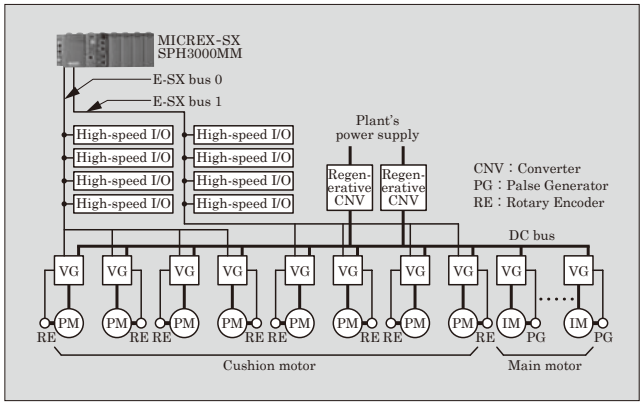

Fig.4 Configuration of machine control system for large-size pressing machine for automobile steel sheets

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:

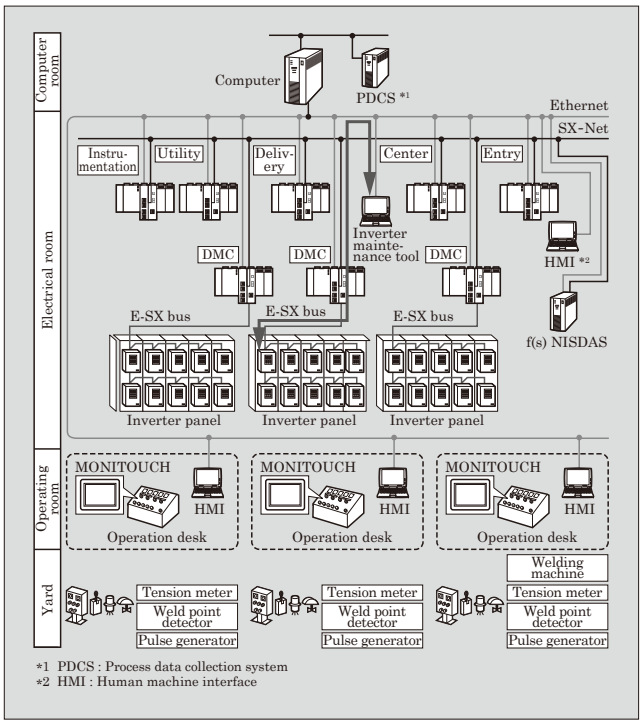

Fig.6 Configuration example of new processing line control system

(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.

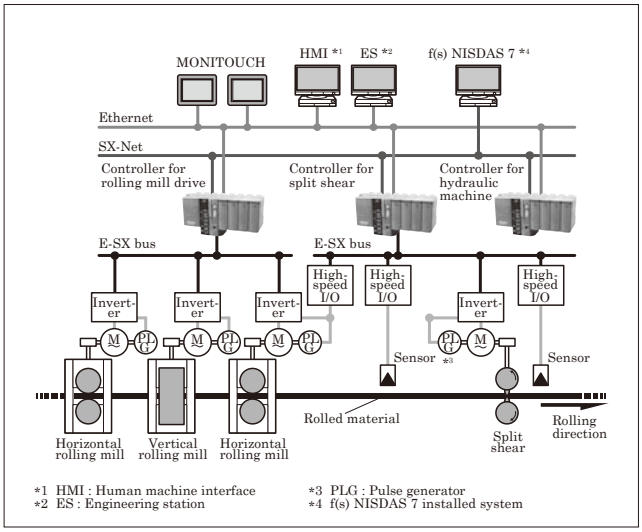

Fig.7 Configuration example of metal rolling mill line control system

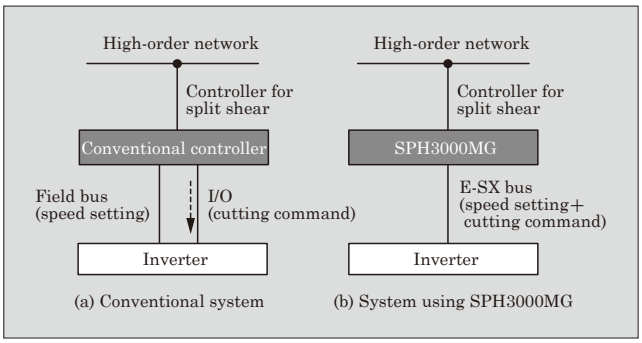

Fig.8 Conventional system and system using "SPH3000MG"

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.