Bar and shape steel rolling mills are constantly required of stable operations. Thus the equipment needs high information processing capability and high speed control to improve productivity, as well as highly accurate processing to increase yield. Fuji Electric has delivered electrical equipment and drive control systems for use in the rolling mills of combined mill plants outside Japan. To achieve high productivity and stable operations, its control systems, mainly comprise inverters and controllers, are interlinked with high precision via high-speed networks. Moreover, to provide timely support from Japan, remote maintenance support systems are installed in the systems to continuously collect and inspect operating and control data.

1. Introduction

A joint venture of a Japanese steel company and an Indonesian company constructed a combined mill*1 plant in Indonesia, which is capable of manufacturing bar and shape steel products in one line. Fuji Electric has delivered electrical equipment and a drive control system for rolling mills to that plant.

What is always required of bar and shape steel rolling mills is stable operation, that is, automatic operation with less down time, high-efficiency operation and automatic operation with the minimum labor required. Such operation needs a capacity to process large volumes of information and high-speed control to improve productivity as well as highly accurate processing to increase yield. To meet this needs, Fuji Electric provided a drive control system mainly comprised of inverters and controllers to process large volumes of information in accurate and high-speed manner and interlinked them with high precision via a network including a high speed field bus.

Data such as control values of the individual drive units, positions of machines and behavior of detection targets are constantly collected by “f(s)NISDAS” high-speed data collection and analysis support system to help analyze operation conditions and control states promptly. In addition, a remote support system is constructed to grasp the conditions on site from Fuji Electric in Japan, a remote location, via the Internet.

2. Overview of Rolling Mill

A rolling mill is equipment that heats billet materials (rectangular bars of steel) and rolls them using a combined mill to make them into bar or shape steel products. Major facilities include a furnace, 18 continuous rolling mill stands, crop and dividing shears, cooling bed, straighteners, cold shear and finishing facility.

Products made by this equipment are mainly construction materials and various types of products can be manufactured such as deformed bar steel (in 12 sizes), round bar steel (in 8 sizes), L-shaped steel (in 15 sizes), channel steel (in 5 sizes) and flat steel (in 19 sizes). Figure 1 shows an overall view of the rolling mills.

3. Electrical Equipment and Drive Control System for Rolling Mills

In order to achieve high-productivity operation that satisfies the specifications required by the cus-
tomer, we have built electrical equipment including about 500 motors (total output of 26 MW), 14 transformers and 42 operation panels and a drive control system composed of 105 sets of inverters and 7 controllers.

3.1 Motors
As the main mill motors for rolling mills, we consolidated about 20 inverter-driven induction motors into 4 sets of specifications for delivery. Table 1 shows the number of the delivered main mill motors by application and capacity.

(a) Applicable standard
   JEC-2137-2000
(b) Cooling system
   700- to 1,100-kW motor: IC416 (frame surface cooled with independent component)
   1,500-kW motor: IC666 (with motor-mounted independent heat exchanger using surrounding medium)

Figure 2 shows an appearance of a representative 700-kW main mill motor. The 900-kW and 1,100-kW models have the same appearance.

3.2 Drive unit
We have provided inverters for industrial plants with the DC intermediate circuit using a common power supply. Two types of inverters are used according to the capacity: “FRENIC4400VM5R” with an 800-V AC output 3-level IGBT inverter (see Fig. 3) and “FRENIC4000VM5R” with a 400-V AC output IGBT inverter (see Fig. 4).

Table 1 Number of motors delivered for each rolling area

<table>
<thead>
<tr>
<th>Motor rating</th>
<th>700 kW</th>
<th>900 kW</th>
<th>1,100 kW</th>
<th>1,500 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,000 min⁻¹</td>
<td>900 min⁻¹</td>
<td>1,800 min⁻¹</td>
<td>750 min⁻¹</td>
</tr>
<tr>
<td>Rough rolling</td>
<td>4 units</td>
<td>1 unit</td>
<td>1 unit</td>
<td>–</td>
</tr>
<tr>
<td>Intermediate rolling</td>
<td>2 units</td>
<td>1 unit</td>
<td>2 units</td>
<td>1 unit</td>
</tr>
<tr>
<td>Finish rolling</td>
<td>–</td>
<td>1 unit</td>
<td>4 units</td>
<td>3 units</td>
</tr>
</tbody>
</table>

Figure 2 Appearance of 700-kW main mill motor

Figure 3 “FRENIC4400VM5R”

Figure 4 “FRENIC4000VM5R”

(1) Features of inverters for industrial plants
A DC intermediate circuit system using a common power supply, receiving and sending powering*2 energy and regenerative energy through a DC common bus, contributes to high-efficiency operation of plants.

For the converters of rolling mills, we have introduced 12-phase rectification diode converters to reduce harmonics on the power supply side.

To improve maintainability, the equipment is designed to allow all maintenance to be done from the front side of the panel. A touch panel with an LCD display is provided on the front side, facilitating monitoring and maintenance operations.

Support tools provided include analog output for charting, a PC loader and a high-speed data collection system.

(2) “FRENIC4400VM5R” 3-level IGBT inverter
This 800-V AC common power supply inverter suppresses harmonics and torque pulsation via 3-level PWM control and reduces adverse effects on the motor and machinery. The special specifications for this application are described as follows.

*2: Powering: A state in which power of the motor is transmitted to the load
(a) Parameter switching function

For this application, combination stands are provided that switch between 2 types of motors using one rolling stand. The conventional configuration includes one inverter for one main mill motor. However, for this application, a configuration using one inverter for switching and driving between 2 motors with different specifications has been employed to streamline the system and save labor for maintenance. To achieve this, we have expanded the setting range so that control parameters for 2 types of motors can be set in the inverter so that the product can be operated by switching between parameters.

(b) Driving of shear using the “FRENIC4400VM5R”

Conventionally, 400-V AC inverters were generally used to drive auxiliary motors. The configuration for this application includes 800-V AC inverters to drive crop shears for cutting the leading and following ends of the steel material and dividing shears for cutting the steel material into a fixed length, which need relatively large motor output. These inverters are connected to the DC intermediate common power supply for driving the rolling mill. This not only decreases the output current but also reduces the number and capacity of converters as a whole, resulting in reduced cabling and panel space saving. The crop and dividing shears employ a newly developed small-capacity (650 kVA) inverter, which has the optimal capacity for the equipment.

(3) “FRENIC4000VM5R” stacking low-voltage IGBT inverter

This is a 400-V AC common power supply inverter, and models of 300 kVA or smaller, applying a plug-in mounting unit system, can incorporate up to 12 units per panel. Units with different capacities and vector control and V/F control modes can be stored together, which achieves space saving useful for applications with many small-capacity inverters for plants.

The cooling design uses a common fan on the ceiling for each panel, instead of providing a cooling fan for each unit. This reduces the number of fans, which are consumable replacement parts, contributing to less maintenance work.

(4) Measures against harmonic leakage current

To control the harmonic DC current leakage resulting from IGBT device switching and prevent electrolytic corrosion of the motor bearings and mechanical bearings coupled with the motors, we have taken the following measures based on the JIS Standard.

(a) The variable-speed drive system employs the IT system, which has high-voltage and low-voltage transformers for input and insulates the system from the ground.

(b) The transmission system also uses the IT system.

(c) The power cable connecting the inverters and motors has both ends of the shield grounded, and a motor frame ground is provided on the inverter side. This results in a configuration with star-shaped equipotential bonding between devices on the secondary side of the high-voltage and low-voltage transformers.

### 3.3 Drive control system

(1) System configuration

Figure 5 shows the system configuration of this application. This system employs the “MICREX-SX SPH3000MG,” Fuji Electric’s latest controller equipped with the “SX-Net” high-speed network and the “E-SX bus” high-speed, large-capacity control network for high-precision control of the rolling mills, which require high-speed operation. We have built a system that accommodates a wide range of scales and needs from machine control systems to rolling control systems by synchronizing multiple controllers and successfully improving productivity. We have also integrated f(s)NISDAS, a PDA system for collecting operation and control data at high speed. This provides a capability to monitor the operation and control states. Furthermore, in order to provide prompt support from a site in Japan, we have integrated a remote maintenance support system to allow data and control programs to be monitored remotely.

(2) Control equipment

(a) “E-SX bus” high-speed, large-capacity field bus

The E-SX bus is a high-speed, large-capacity field bus with the performance of the conventional SX-bus significantly improved. Data output timing in the E-SX bus can be synchronized, allowing high-precision control. Table 2 shows a performance com-

![Fig.5 System configuration](image-url)
With plant control systems, the volumes of plant data are increasing along with improvements in production efficiency and visualization of operation. Accordingly, control networks are required to offer high-speed and large-capacity features more than ever. To improve manufacturing quality, it is preferable to have distributed controllers synchronized for control.

The control system of this plant is composed of 7 units of the MICREX-SX SPH3000MG and 3 HMI terminals. These devices are connected via the control network and tens to hundreds of inverters and sensors are connected with individual controllers via the field bus. Use of the MICREX-SX SPH3000MG and SX-Net not only allows high-speed, large-capacity communication between controllers but also achieves synchronous control between controllers, which was difficult in the past. In addition, the SX-Net uses a common memory system, making it easier for the individual controllers to reference memory in the network. In this way, by using the MICREX-SX SPH3000MG and SX-Net, the speed and capacity of the control network can be increased and the accuracy of the plant control system can be improved by synchronizing between controllers.

Throughput from the detection of steel material to be rolled to issuance of an instruction to an inverter has been improved by using the MICREX-SX and high-speed I/O modules and inverters compatible with the SX bus. This has successfully enhanced the precision of control functions we have offered so far, including impact speed drop suppression and minimum tension control, to improve the rolling quality.

(2) Remote maintenance support

For new construction projects outside Japan, remote maintenance support is essential for improving productivity to perform centralized management of control information covering the entire plant and provision of prompt support from Japan. Accordingly, in addition to collecting data from controllers and HMI devices, f(s)NISDAS can collect data from drive units by linking the “plusFSITE” data communication module in this plant. In this way, by using the MICREX-SX SPH3000MG and SX-Net, the speed and capacity of the control network can be increased and the accuracy of the plant control system can be improved by synchronizing between controllers.

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3.4 Plant control

(1) High-speed, high-precision control with the “MICREX-SX SPH3000MG”

With plant control systems, the volumes of plant data are increasing along with improvements in production efficiency and visualization of operation. Accordingly, control networks are required to offer high-speed and large-capacity features more than ever. To improve manufacturing quality, it is preferable to have distributed controllers synchronized for control.

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3.5 Other equipment

(1) Transformers

For the main transformers, we have adopted a zigzag connection for the primary winding to reduce harmonics on the power supply side and achieve 24-phase rectification together with rectification by the diode converters. This has successfully reduced harmonics.
generated on the power supply side.

As the auxiliary transformers, we have delivered oil-immersed transformers of FUJI TUSCO Co., Ltd. of Thailand (total capacity: 12,300 kVA).

(2) Controlboards

The local operation panels, individual protection panels for group-driven motors, distribution switch-panels and motor control center (MCC) have been designed and manufactured in Southeast Asia with adequate quality management provided from Japan. This has ensured a quality equivalent to that of manufacturing sites in Japan and proven to be a new option in Fuji Electric’s engineering for steel industry in Southeast Asia.

4. Postscript

This paper has described the latest electrical equipment and drive control system for bar and shape rolling mills outside Japan. In addition to those mentioned in this paper, technologies for devices and equipment offered by Fuji Electric are developing on a daily basis and evolving rapidly. Furthermore, with opportunities to deliver electrical equipment for rolling mills overseas expected to increase even more, we intend to further work on reinforcing remote maintenance support.
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Innovating Energy Technology

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