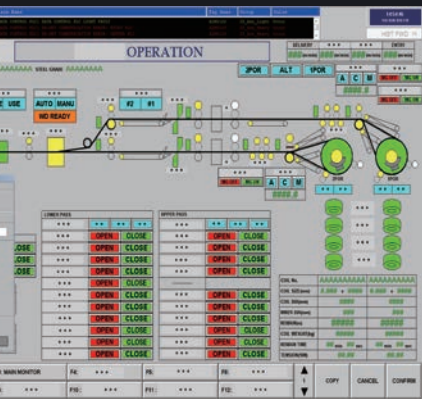
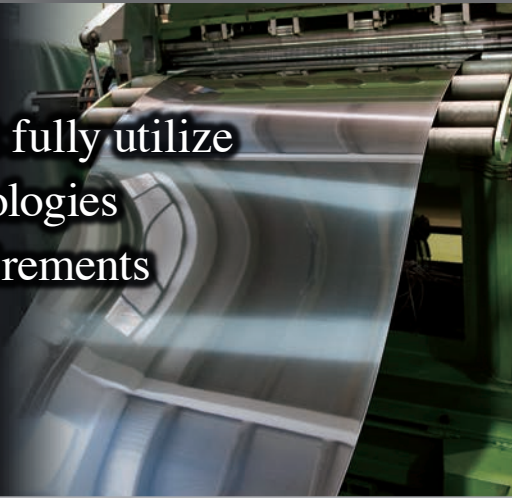


Steel Plant Processing Line Control Systems

Optimal systems that fully utilize our innovative technologies to meet various requirements and ensure reliable and stable operation



Fuji Electric fully utilizes its innovative technologies development—to contribute to stabilizing operations, maintenance for steel plant processing lines.

Steel plants of today require the use of the latest in power electronics technology, advanced big data analysis technology, AI, and IoT in order to stabilize and support their operations, and reduce maintenance. Fuji Electric has been building systems that integrate these innovative technological elements and our accumulated expertise with the aim of improving control technology. We have been meeting the requirements of various clients and contributing to the stable operation of steel plant processing lines by continually providing optimal control systems that fully utilize our innovative technologies.

Contributing to improvements in product quality, plant operating ratio, and safety

Stable operations

- Improvements in reliability and control accuracy of electrical equipment through increased speed and functionality of motors, drive devices, and programmable controllers (PLCs)
- System construction that utilizes a rational division of functions for each control device
- Support for easy replacement with new components

Supporting stable operations and production through predictive maintenance and visualization

Reduced maintenance

- Easy maintenance by monitoring equipment operations and utilizing data
- Predictive maintenance that contributes to productivity improvements and reduced downtime
- Support for remote maintenance environments

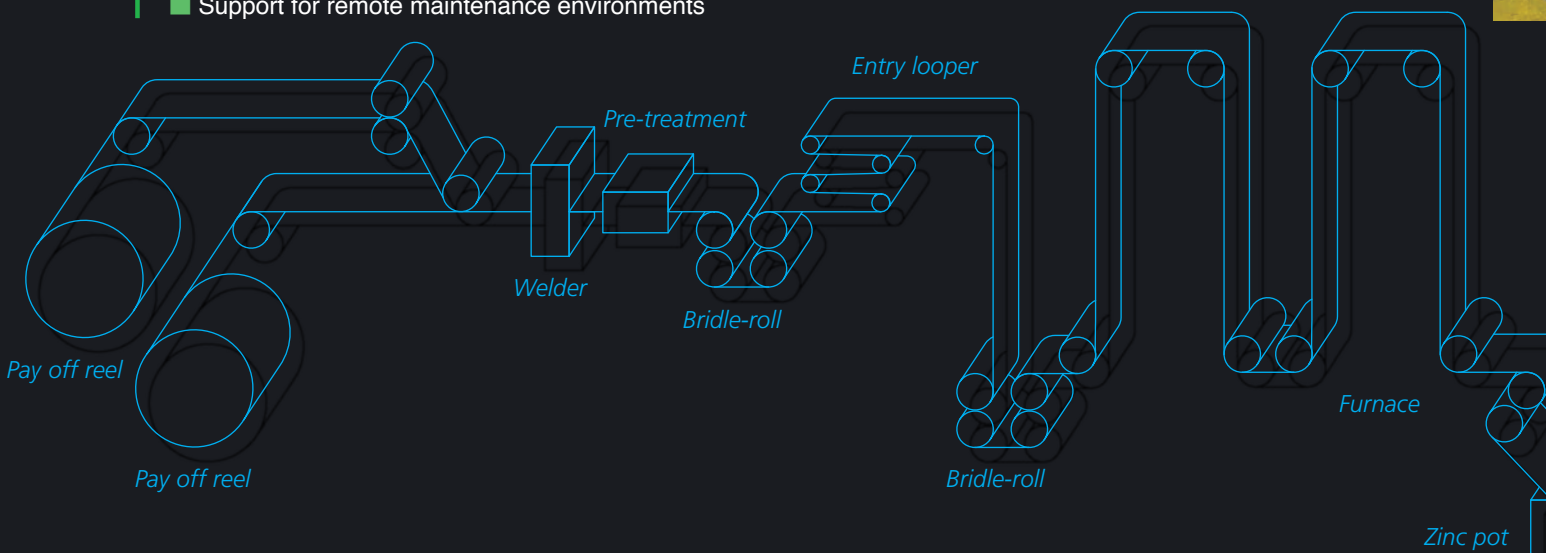
Supporting stable operation by facilitating and unifying operations

Operation support

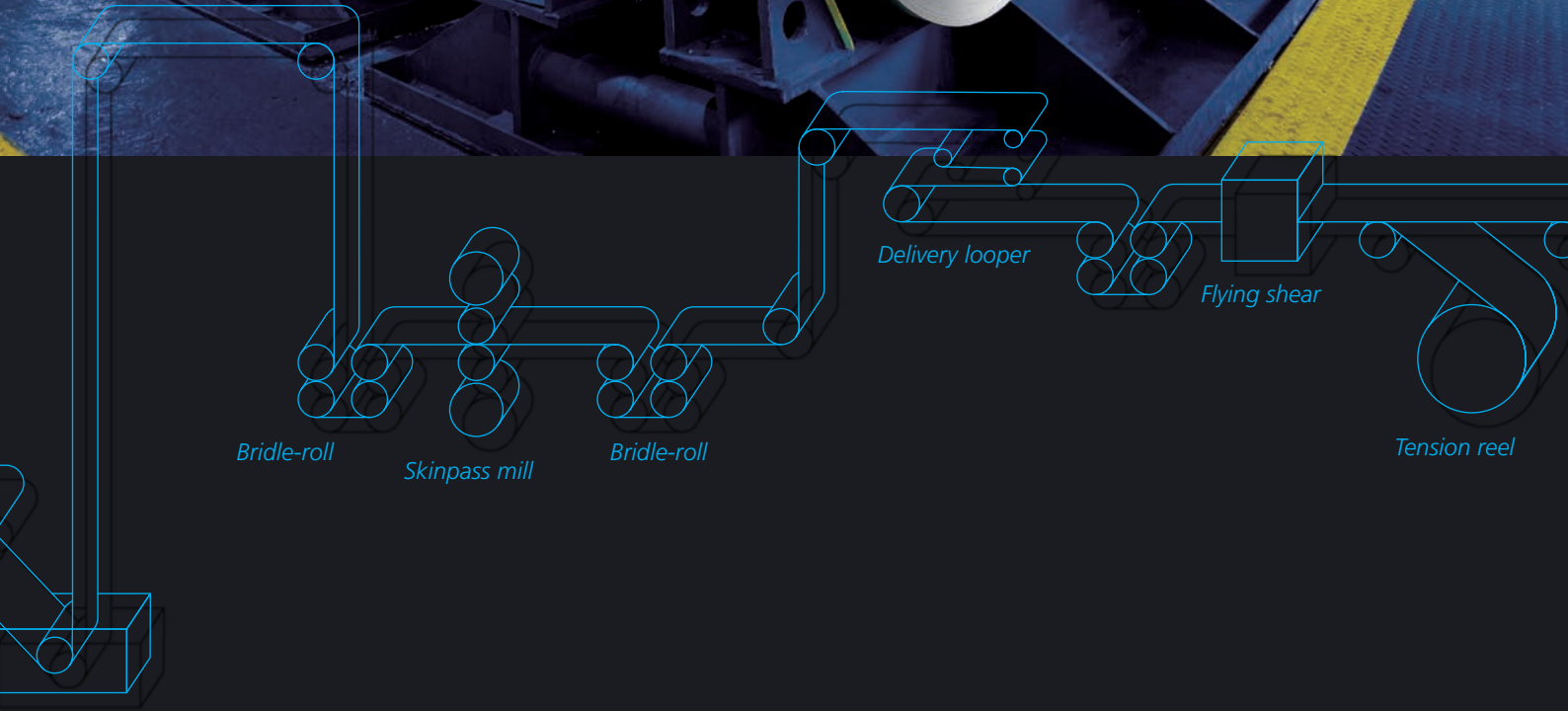
- Visualization of operating conditions and failure occurrences, improvement of operator guidance functions
- Full operational support tools
- Support for optimal operation decision-making through advanced big data analysis technology (use of deep learning technology)
- Providing an offline operation support environment that can handle shakedown testing of rebuilt parts and new operators (under development)

Configuration components

- High-speed motor controller: MICREX-VieW XX XCS-3000 Type E
- Common power supply multi-stage inverter: FRENIC 4000 VM6/FM6
- DDC thyristor Leonard for plants: LEONIC-M700/M Compact



—from control and information technology to system providing operational support, and reducing



Stable operation -Threading control (speed control)-

Unevenness will occur and lead to a deterioration of product quality if the threading material vibrates due to speed fluctuations in a steel plant processing line.

Fuji Electric's processing line control systems for steel plants enable the stable production of high-quality products by means of high-precision speed control.

Stable ASR* system high-speed response

The high-speed response of the automatic speed regulator (ASR) system is reduced by torsional vibrations between the motors and rolls, torque pulsation due to the universal joints, and vibration of the tension system through the material.

As a countermeasure, we equip the drive devices with a shaft vibration suppression observer. The drive system uses a programmable logic controller (PLC) equipped with a tension vibration suppression observer function that

enables a response speed of 20 rad/s for the ASR system.

During the droop speed control of the helper rolls under load, mechanical shaft moment of inertia disturbs the roll alignment. As a countermeasure, we equip the control system with a forcing torque compensation function and an automatic speed regulator (ASR) automatic gain compensation function to enable more precise and uniform speed control accuracy.

*ASR:Automatic Speed Regulator

Maintaining the high-speed response of the ASR system by suppressing mechanical shaft resonance

Formerly, when shaft resonance occurred in the helper drive system, if the resonance frequency was near the cutoff frequency of the ASR system, the gain had to be reduced at the expense of the ASR system response. To solve this, we installed a minimum dimension shaft torque observer in the inverter, and this makes it possible to suppress the shaft vibration.

◎Figure 1 shows the effect of shaft vibration suppression correction.

◎Figure 2 shows the control block diagram when the minimum dimension shaft torque observer is mounted on the inverter.

Fig. 1 Shaft vibration suppression correction effect

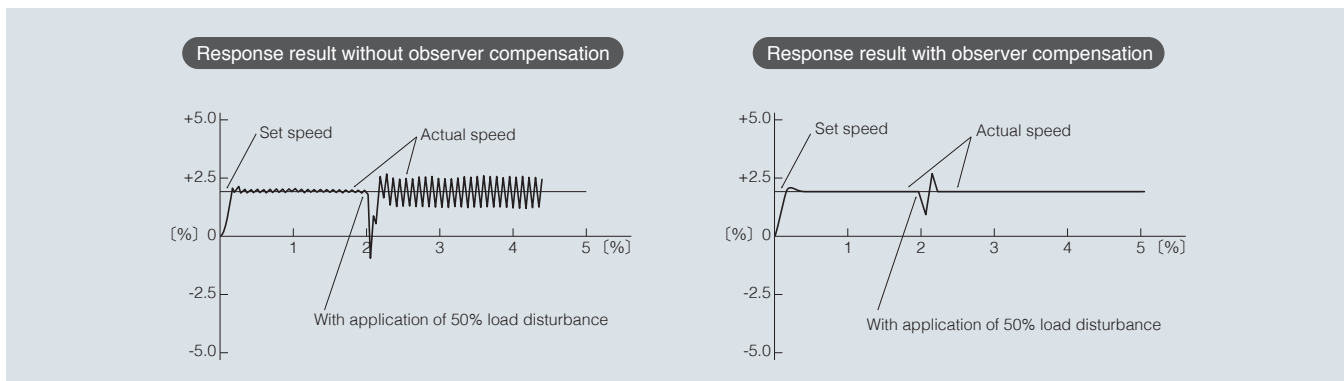
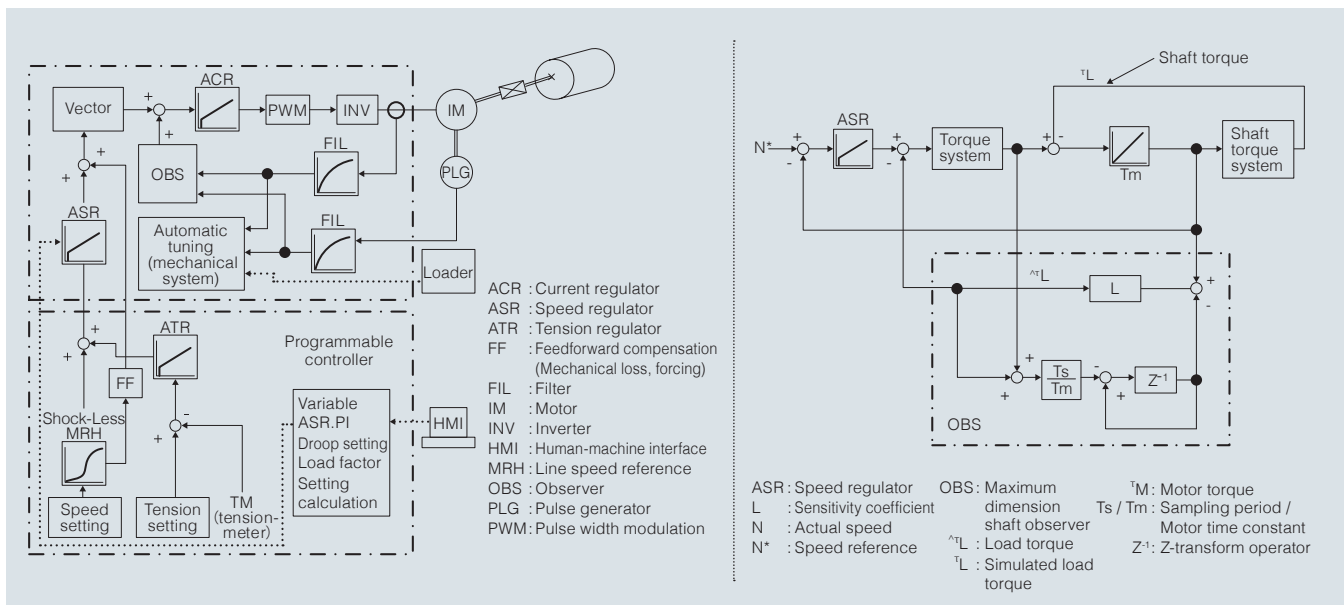


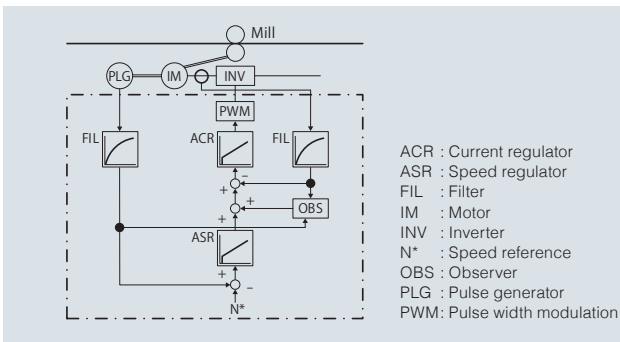
Fig. 2 Inverter drive system with mechanical shaft resonance countermeasures



Contributing to stable operation and improved quality by suppressing motor speed fluctuations

The speed of the motors driving the rolls in a rolling mill may fluctuate when the threading material is caught in the rolls and this may cause the shape of the threading material to deteriorate. We minimize this by having the load torque estimated by the observer and feedforward that estimated value to the controller as the current setting to suppress the speed fluctuation of the motors. This contributes to stable operation and improved quality (see Fig. 3).

Fig. 3 Motor speed fluctuation suppression control



Equipped with various standard control functions

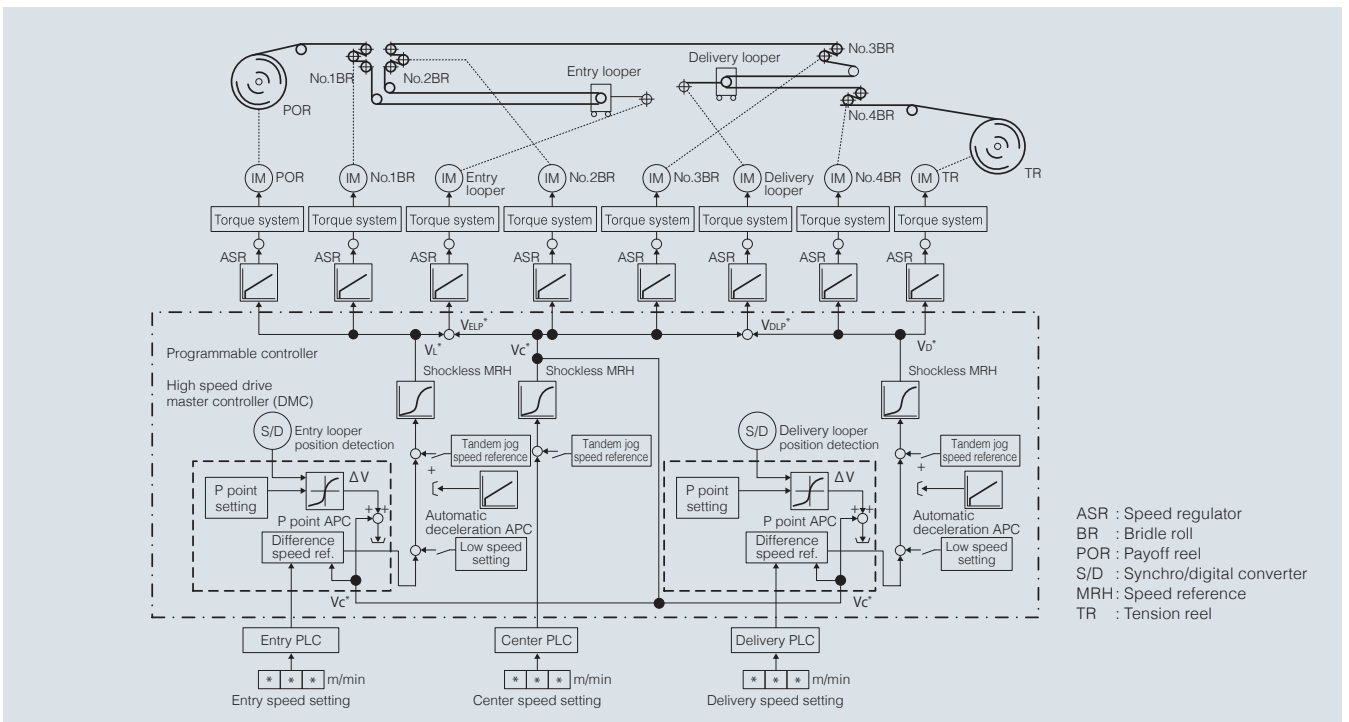
The following functions such as reel take-up and rewind control functions are included as standard functions in the software. These functions can be easily set and monitored on the operation screen, which enables stable operation.

- Coil external shape calculation
- Reel speed calculation
- Plate thickness calculation (least squares method)
- Line speed calculation
- Forcing torque calculation
- No-load loss compensation calculation
- Rolling thickness compensation calculation
- Remaining length calculation
- Tail end stop control calculation, etc.

Speed reference system for processing

The line speed is controlled by the software shown in the block diagram in Fig. 4. This system is equipped with various standard control functions such as the high speed drive master controller package (DMC), which enables the high-speed control of a large number of drive devices and motors and results in stable operation.

Fig. 4 Speed reference system for processing



Stable operation -Threading control (Tension control)-

Heat buckles (wrinkles) and meandering of the threading material occur in a steel plant processing line due to the expansion and contraction of the threading material caused by the temperature and load fluctuations of each device. Tension control is important for suppressing this problem and ensuring stable operation.

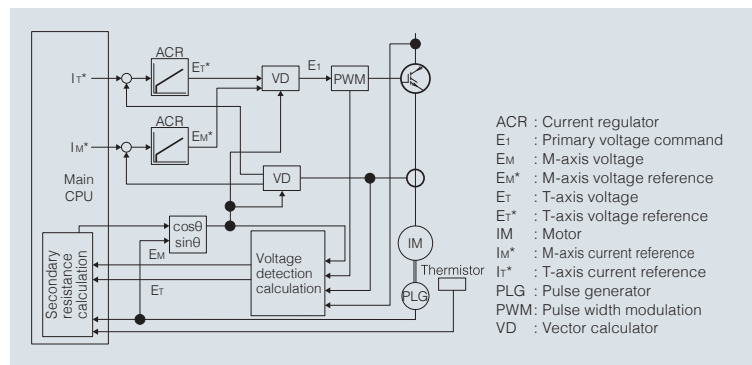
Fuji Electric's processing line control systems for steel plants enable stable production of high-quality products by means of high-precision tension control.

High-precision torque controlling PWM inverter controller ensures stable operation and quality

Improving the response of the current control system is necessary in order to improve the accuracy and response of the torque control. The current must follow the command value closely, both transiently and constantly, in order to produce the desired torque. For this purpose, our processing line control systems use a high-precision torque controlling pulse-width modulation (PWM) inverter controller. (See Fig. 5).

This controller does not directly control the AC current, but rather constantly adjusts the magnetizing current and torque current, which are DC values. This method detects the voltage of the above-mentioned voltage model from the on/off signal and current polarity of the inverter by utilizing the features of voltage-type PWM.

Fig. 5 High-precision torque controlling PWM inverter



Applying modern control theory to control tension vibration and prevent disturbance

Tension vibration due to the eccentricity of the winder roll and the winding step causes disturbance at the central section and skin path mill.

To prevent these problems, we have introduced closed-loop tension control based on the observer tension estimate and tension vibration suppression control by feedforwarding the observer output to the ACR (see Fig. 6).

Figure 7 shows the effect of the tension vibration suppression correction.

Fig. 6 Tension vibration suppression control

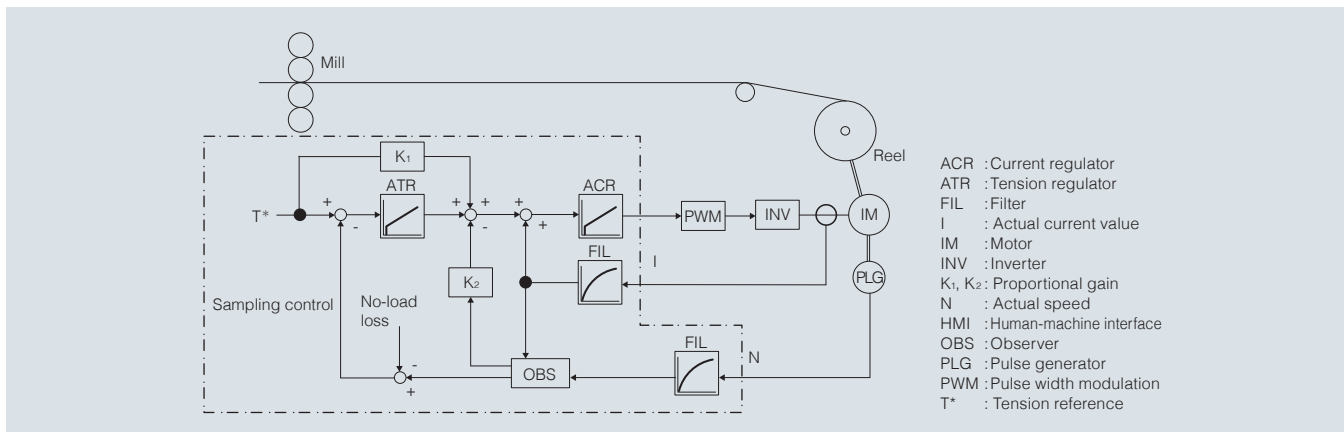
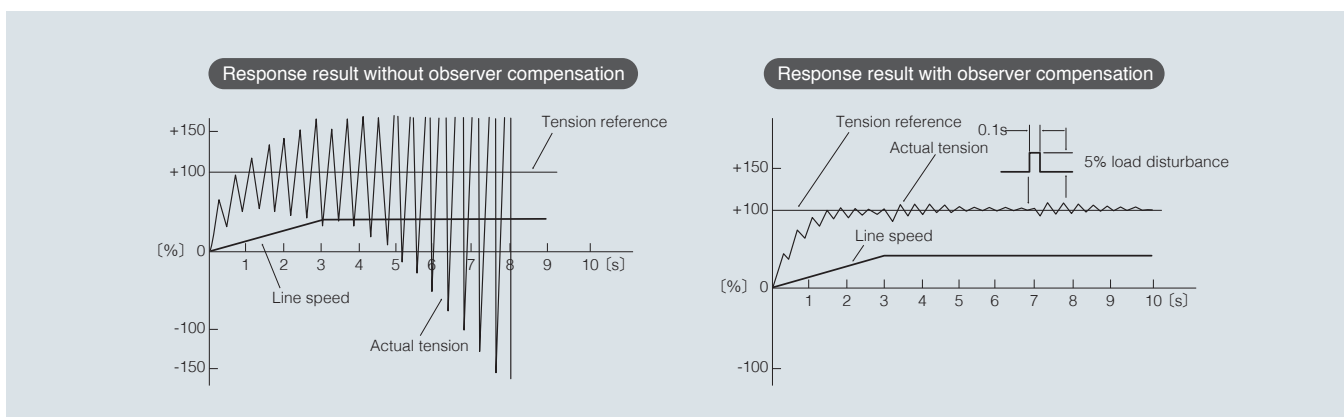


Fig. 7 Shaft vibration suppression correction effect



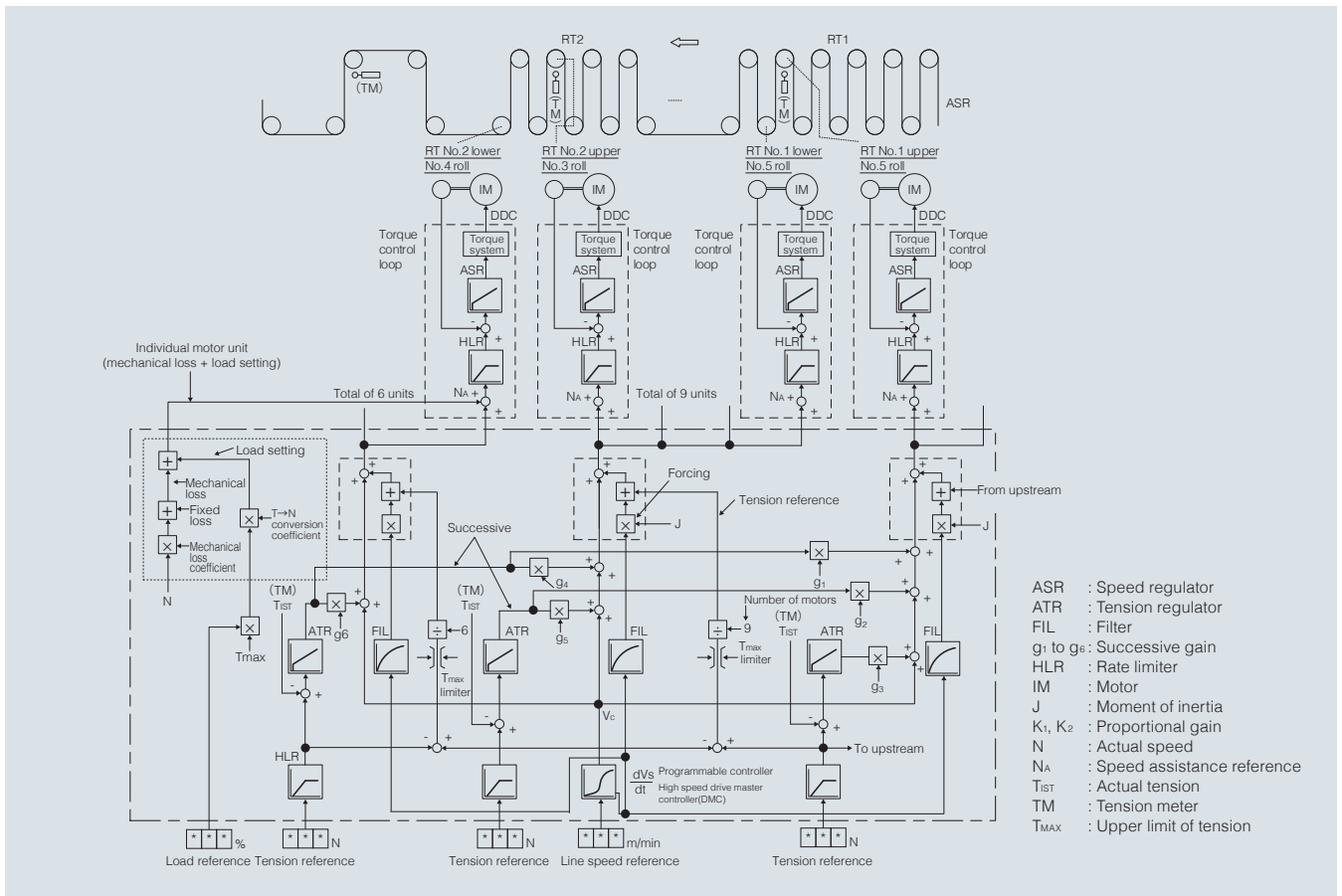
Preventing various furnace failure factors through in-furnace tension control

High-precision tension control in the furnace is required to prevent meandering of the threading material, heat buckling, plate width fluctuation, and strip breakage.

Our systems utilize cascade control that corrects the output value of each tension controller by feedforwarding to the rear line helper drive devices in the form of a successive loop, centering on the line master drive devices.

In addition, we equip the bridles on the entry and delivery sides of the furnace section with impact drop compensation observers as a measure against load fluctuations in order to reduce the influence on the inside of the furnace caused by tension fluctuations from the loopers (see Fig. 8).

Fig. 8 In-furnace helper roll tension control



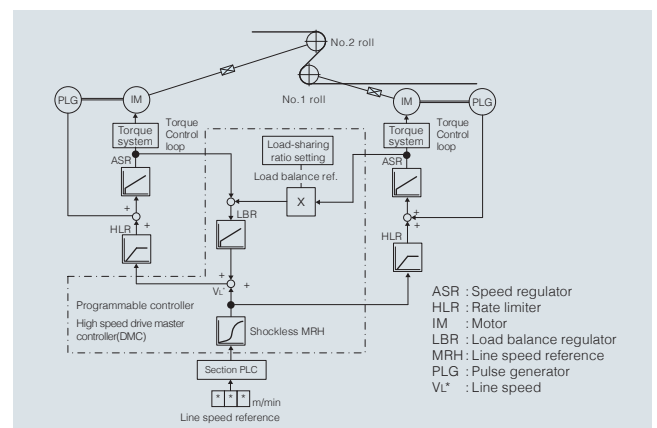
Using load balance control to maintain the torque of multiple rolls at a constant ratio

For the equipment like the bridle rolls that transports the threading material with tension before and after n rolls as a load, we stabilize the quality by controlling the torque of the motors that drive each roll and keeping the torque at a constant ratio.

If there are two or more ASRs (drooping = 0%) on a tight line, one of the ASRs must have an outer loop. Here, LBR* is the outer loop.

This load sharing ratio is determined based on the capacity ratio and tension expansion ratio of the motors (See Fig. 9).

Fig. 9 Load balance control



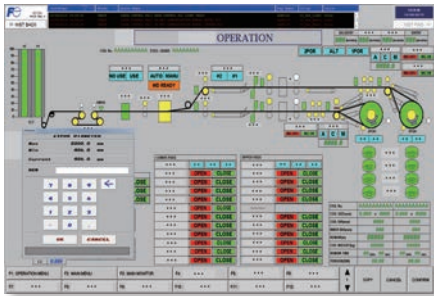
*LBR: Load Balance Regulator

Operation support

Plant operations sometimes have issues with technology transfer and productivity improvement. Fuji Electric solves these issues by providing high-quality, client-friendly steel plant processing line control systems that effectively utilize big data from plants and our abundant software assets.

Easy-to-operate HMI systems contributing to productivity improvement

In addition to our proprietary dedicated screens for operation and maintenance of steel plant processing lines that are displayed on human-machine interfaces installed at the processing line operator's stations and in the electrical rooms, we have a large amount of highly reliable operation support screens and functions available for processing lines in steel plants. We also provide support for optimal operation decision-making using advanced big data analysis technology. All of these features help to make clients' operations easy and improve their productivity.



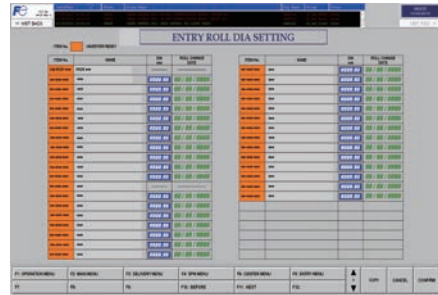
Functions for displaying and setting information necessary for operation and to announce abnormalities in electrical equipment in an easy-to-understand way.



Screen displaying the tension setting and actual tension value of each part.



Screen displaying a list of all failures in the order of their occurrence.

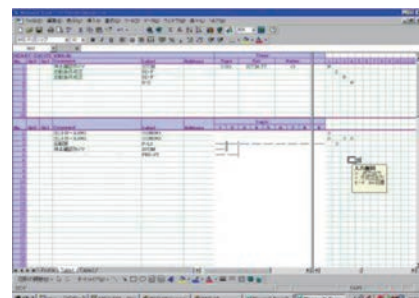
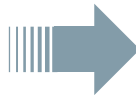


Screen and functions for setting roll diameter management, an essential operation for maintaining uniform speed of the line drives.

Contributing to the leveling of operation technology by visualizing conditions using our Heart-Excite condition table

A condition table is monitoring software that supports the operations of the plant. Logical calculations such as operating conditions, startup conditions, and transition conditions are displayed in tabular format. This makes it possible to provide an easy-to-understand display of the system execution status, operation and startup interlocks, etc. to the line operator. Use of this software enables the conditions during plant operation to be visualized and contributes to the transfer of technology and the improvement of productivity.

CONDITION	PANEL NAME	POS.	High speed(DS) Extraction		Low speed(DS) Extraction	
			MAN	AUTO	MAN	AUTO
OPL I/O Panel Solenoid valve power UV (DC100V)						
OPL AUX Panel Absocoder power UV						
OPL Insulated AMP Panel AMP power UV						
Lower WR shift: Ready	IP06189					
Main circuit SW [ON]						
WR chock lift DS (South) [UP END]	PXMUL_08	→				
WR chock lift DS (North) [UP END]	PXMUL_09	→				
Main depression Lubrication position [Reduction position within 0~3mm]		→				



Condition table in use as an add-on to the Expert programming support tool.

Reduced maintenance

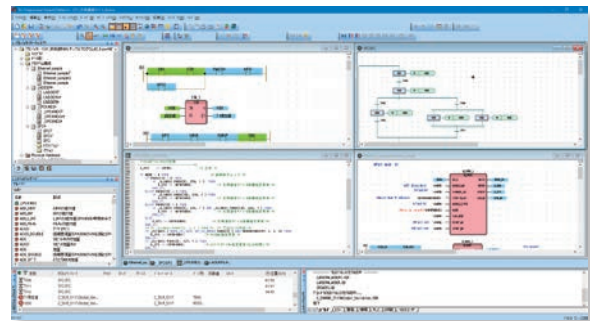
Daily maintenance of numerous mechanical equipment, motors, and drive equipment is essential for reducing downtime and improving the operating ratio of the line equipment. Fuji Electric's processing line control systems for steel plants have a variety of services and tools available to contribute to maintenance reductions for our clients.

Expert (D300win) programming support tool for programmable controllers makes programming easy to do for the given purpose and application

Expert (D300win) is a programming support tool for Windows that complies with the international standard IEC 61131-3 (JIS B 3503). Programming for each program organization unit (POU) and worksheet makes it possible to create a structured design by dividing each function and process. In addition, the ST language is similar to the C language, and this enables the creation of programs using the same method as on a personal computer for complicated calculations which a ladder logic language is not good at.

Features

- **Mixed language description**
All five types of program expressions (IL, LD, FBD, ST, SFC) specified in the standards are supported.
- **Excellent document functions**
- **Simulation functions**
- **Functional module support functions, MONITOUCH linkage functions**

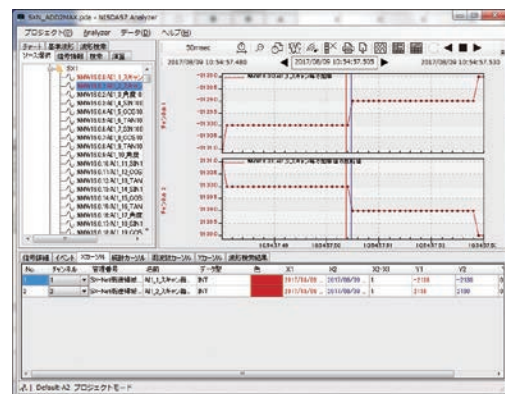


Providing a variety of support from equipment to operation monitoring and maintenance. Fuji Electric's proprietary f(s) NISDAS7 data collection and analysis support packaged software

Our f(s) NISDAS7 is packaged software that runs on personal computers and collects and analyzes data from programmable controllers (PLCs) and inverters. This software can be used for various purposes such as the start-up of production equipment, operation monitoring, and maintenance. The f(s) NISDAS7 software collects data in 1 ms from a PLC. The data is saved to a recording device at the same time as it is collected and displayed on the chart screen in real time.

In addition, since data is saved using the recording device of a personal computer, data can be saved continuously as long as recordable space is available. And data collection can also be started and stopped by a trigger signal in the collected data. This allows the collection of only the required data, and enables efficient use of the recording device.

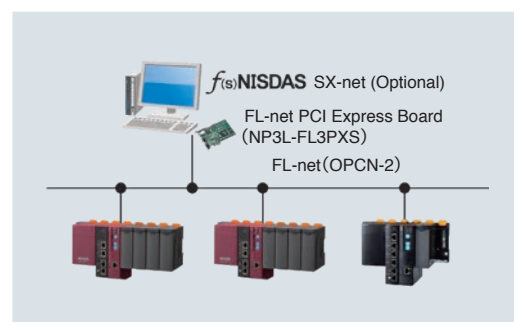
Additionally, utilizing big data collected from equipment by f(s) NISDAS7 with Fuji Electric's analytics and AI technology will lead to predictive maintenance for inverters, motors, and parts. And this will contribute to improved productivity and reduced downtime.



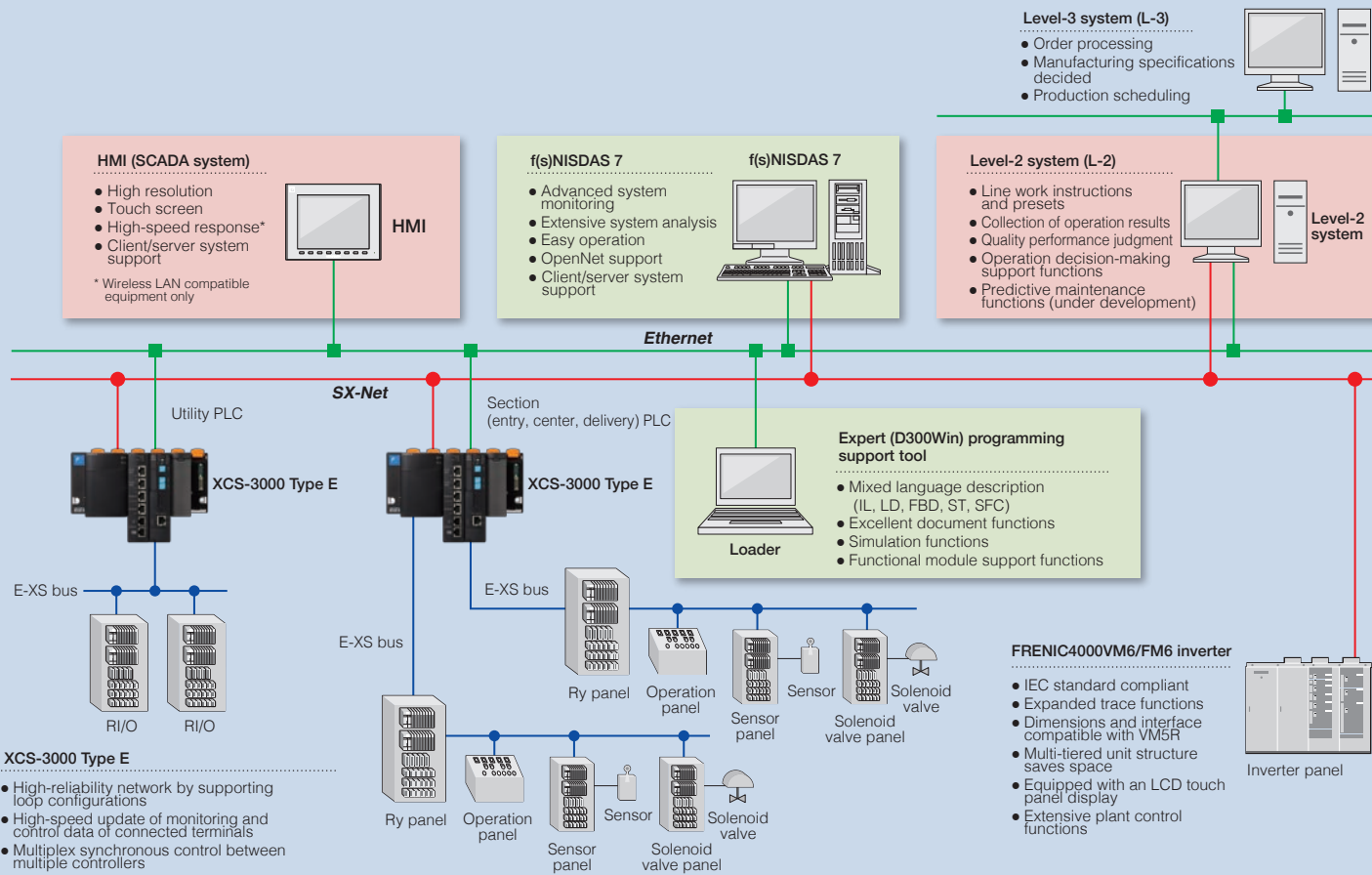
Features

- **Advanced system monitoring**
Collect data from multiple PLCs, inverters, etc. to a single personal computer.
- **Extensive system analysis**
Data can be analyzed on the spot in a timely manner while it is being collected. Data can also be analyzed at a later time.
- **Easy operation**
Easy and clear operation.
- **Easy to adopt and highly expandable**
Supports open networks and client/server systems.
- **Support and service**
Strong support is available for setup.

System configuration



System configuration



Configuration components

Electric high-speed controller enabling high-speed updating of large-capacity monitoring and control data

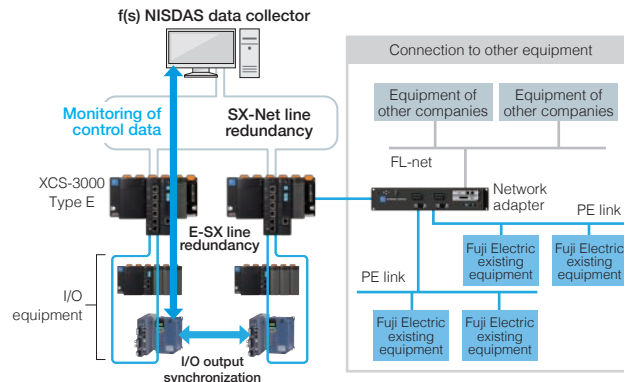
MICREX-View XCS-3000 Type E

MICREXX CS-3000 Type E controller provides high speed and reliability for applications in electric power application plants. The operating status of the production equipment can be monitored and controlled with high reliability maintained, while updating a large volume of monitoring and control data at high speed.

Fuji Electric's proprietary large-capacity, high-speed control network and high-speed I/O network technology enable a monitoring and control system that seamlessly connects the control system to the site.

Features

- Supports loop configurations for high network reliability and redundancy for SX-Net (high-speed control network communication) and E-SX bus (high-speed I/O network communication). This controller features both high speed (1 Gbps) and high reliability which enable operation to continue at single locations even if the network is disconnected.
- High-speed updating of monitoring and control data of connected terminals, with high-speed batch updating of monitoring and control data enabled for all devices (up to 128) on the network regardless of the scale of the equipment by increasing the transmission capacity.
- Multiplex synchronous control between multiple controllers, with multi-axis synchronization control enabled by synchronously controlling I/O stations under multiple different controllers on SX-Net.

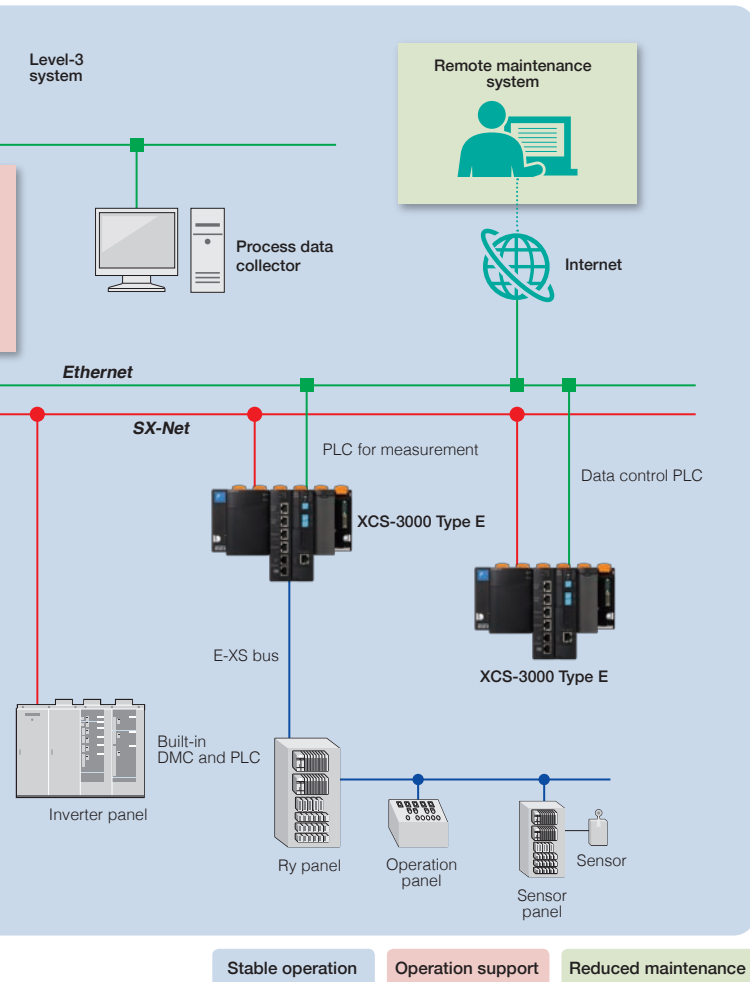


Software

Fuji Electric has refined the control function software for steel plant processing lines and provides high-quality software that has a proven track record. We can meet the diverse requirements of each client and provide fine-tuned control by customizing the standard software.

■ List of steel plant processing line control functions

Item	Category	Control function application name
1	Master controls	Speed and tension control
2		Diameter calculation and diameter correction
3		Automatic deceleration and automatic acceleration
4		Load balance control
5		Elongation rate control
6		High-speed drive control
7	Individual controls	Handling control
8		Mode setting
9		Ancillary equipment control
10		Tandem jog control · Individual jog control
11	Overall controls	Welding point tracking control
12		Data control
13	HMI	Line information display and setting
14		Line alarm management
15	L-2	Line information display and setting
16		PDI and HMI management
17		Operation decision-making support functions
18		Predictive maintenance functions (under development)



Common power supply system, multi-stage stacking inverter with further improved high performance and high reliability

FRENIC4000VM6/FM6

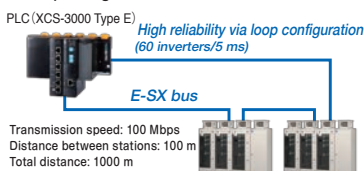
This PWM inverter for plants features space savings, high performance, and high functionality. We have additionally improved its high performance and reliability for compatibility with the VM5R/FM5R models.

Features

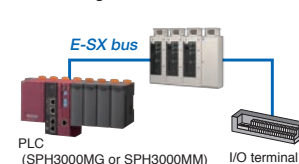
- Enhanced safety in compliance with IEC standards* and new JIS standards.** This can be widely installed at overseas plants. It is also compliant with the JIS standards revised in July 2019 following the enforcement of the Industrial Standardization Law.
- Supports ultra-high-speed E-SX bus network groups and various transmission connections (optional).
- Expanded trace functions. Usability has been improved, and the low-speed tracing functions expand the sampling range before and after the occurrence of a failure. In addition, various other functions have been added, such as Excel output of charts and 1-ms real-time chart display on the loader.

* IEC standards (available soon): IEC 60204-1:2016, IEC61800-3:2017, IEC61800-5-1:2007+A1/2016
 ** New JIS standards: JIS B 9960-1:2019, JIS C 61800-5-1:2016, JIS C 4421:2008

■ Loop configuration



■ Bus configuration



LEONIC-M700/M Compact DDC thyristor Leonard for plants

LEONIC-M700/M Compact

This DDC DC variable speed control device can be utilized in all types of industrial fields, including steel plant processing lines.

Features

- Full digital configuration provides high-precision speed control and high-speed response performance.
- Easy interface (using T-link, SX bus, PROFIBUS, etc.) to connect to higher-level controllers (PLCs).
- Using the PC loader system (optional) greatly improves ease of maintenance.
- Existing analog interfaces can also be used.
- Software switching of the control method is possible to suit the application requirements.
- Equipped with power failure protection functions.



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