Latest Technology for General-Purpose Inverters and Servo Systems

SAKAI Toshiaki † **IMOTO Hiroyuki** †

ABSTRACT

General-purpose inverters are used in a wide range of industrial fields, including transportation machinery, air conditioners, and machine tools. Fuji Electric offers a lineup of new products that meet various needs. We have realized easy system construction with auto tuning and vector control for synchronous drive system, and enforced energy savings and reduced electric power for air conditioning dedicated inverters using temperature difference constant control and estimated end pressure control functions, and lined up a new product expanding the range of applications to high-speed and multi-axial control for high-performance vector control inverters. For servo systems, we have developed new products that realize optimal adjustment through application-specific auto tuning and enrich replacement methods from older models, as well as packaged products designed for ease of use.

1. Introduction

The market for general-purpose inverters and servo systems appeared to have recovered from the recent economic downturn precipitated by the collapse of the Lehman Brothers, but due to the Great East Japan Earthquake occurring in 2011 as well as the effects of monetary tightening in China, is still in the bottom of the trough. Market requests for not only improved performance, but also for improved ease of use of these drive equipment are increasing. This paper introduces the latest technologies of general-purpose inverters, based on technical trends, to meet such market demands, and also describes several application examples.

2. Production Lineup

2.1 General-purpose inverters

Figure 1 shows Fuji Electric's product lineup of general-purpose inverters.

Fuji Electric provides five series of general-purpose inverters: the "FRENIC-Mini," "FRENIC-Multi," "FRENIC-Eco," "FRENIC-MEGA" and the vector control type "FRENIC-VG." The main features and uses of these products are shown in Table 1.

2.2 Servo systems

Figure 2 shows Fuji Electric's product lineup of servo systems.

The "ALPHA5 Smart Series" has been developed as a functionally limited version of the "ALPHA5 Series." With capacities ranging from 0.05 to 3 kW and a frequency response of 1,500 Hz, the ALPHA5 Smart Series provides the same performance as the ALPHA5 Series, but by limiting its functions, such as by removing a USB terminal, realizes an advantage in terms of price. This product is intended primarily for deployment overseas.

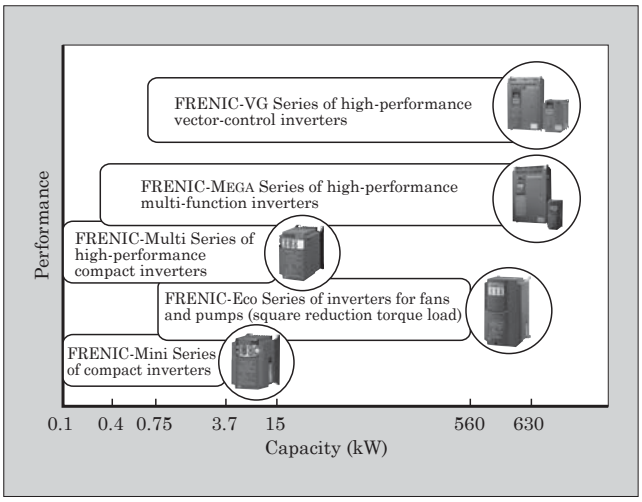

Fig.1 Fuji Electric's product lineup of general-purpose inverters

Table 1 Features and uses of general-purpose inverters

Inverter series name	Main features and uses
FRENIC-Mini	Compact size for variable speed control of 3.7 kW or less
FRENIC-Multi	Compact size for variable speed control of 15 kW or less, for constant torque load
FRENIC-Eco, FRENIC-Eco Plus	Standard size for variable speed control of 560 kW or less, for square reduction load
FRENIC-MEGA	Standard size for variable speed control of 630 kW or less, for constant torque load
FRENIC-VG	High-performance vector-control inverter of 630 kW or less

† Fuji Electric Co., Ltd.

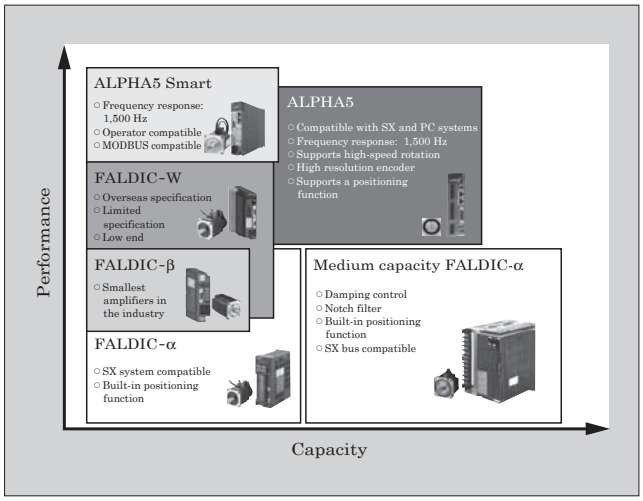

Fig.2 Fuji Electric's product lineup of servo systems

3. Latest Technology for General-Purpose Inverters and Examples of Their Application[1]

General-purpose inverters are used for the variable speed control of three-phase induction motors. In recent years, with application to synchronous motors and support of application-specific control functions, there has been an increased variety of models.

3.1 "FRENIC-MEGA Series" of synchronous drive systems

An IPM motor containing an internal permanent magnet in the rotor of a motor has low loss and enables smaller size and higher efficiency. An overview of Fuji Electric's synchronous motors is shown in Table 2.

The synchronous motors of each series are driven by a single inverter with sensorless vector control or with sensor vector control. In typical inverters for induction motors and inverters for synchronous motors, the following points differ significantly depending on the presence of a motor magnet.

(1) Auto tuning of synchronous motors

In the vector control of synchronous motors, information of the electrical parameters of a motor (armature resistance, inductance and back electromotive force) is necessary. When driving a synchronous motor with an inverter, the type and capacity of the motor can be specified, and all the other electric parameters will be set automatically.

Additionally, by performing auto tuning for the motors, electrical parameters can be read from the inverter. This allows a synchronous system of maximum efficiency to be constructed easily.

(2) Vector control of synchronous motors

Even if the electrical parameters of a synchronous motor have been set, the actual rotation angle of the motor (magnetic pole location) must be known. With sensorless vector control, a sensor is not used and therefore the magnetic pole location is detected at motor startup. According to the magnetic pole location, alternating magnetic flux is generated with high-frequency waves oriented in a fixed direction so that the shaft does not rotate inside the motor, and estimation calculations are performed based on the value of current flowing in the windings. In the case of sensor vector control, once the magnetic pole location is detected, the motor will be able to output maximum torque from its stopped state to the rated rotational speed. For this reason, synchronous motors can be used in the fields where conventional DC motors have been applied, such as extruders.

Table 2 Overview of Fuji Electric's synchronous motors

Series	Capacity range	Shape	Efficiency level	Control method
GNS type	5.5 to 200 kW	Induction motor compatible	IE4	Sensorless vector control
GNP type	5.5 to 90 kW	Induction motor compatible	IE4	
GNB type	5.5 to 540 kW	Compact	IE3	
GNF type	5.5 to 425 kW	Compact	IE3	Sensor vector control

3.2 "FRENIC-Eco Plus" dedicated inverter for air conditioning

The method of using an inverter with an induction motor driven by a commercial power supply and reducing the rotational speed to save energy is well known. Additional energy savings and a further reduction in power usage can be achieved with an autonomous control-type "FRENIC-Eco Plus" inverter. This inverter has functions for temperature difference constant control and estimated end pressure control, and realizes the optimal control for fans and pumps. Display settings can be specified in units of flow rate and pressure.

(1) Temperature difference constant control

In air-conditioning equipment such as refrigerating machines, the temperature difference between the inlet and outlet may be controlled to be constant. If the temperature difference becomes constant, rather than circulating cooling water unnecessarily, the rotational speed of the motor can be reduced to save energy. As shown in the application example of Fig. 3, the FRENIC-Eco Plus has two temperature sensor inputs, and this temperature difference can be held constant.

Figure 4 shows measured values of power consumption as a result of constant temperature difference control. In particular, the significant reduction in power consumption during the winter is the result of a lower cooling water temperature due to the outside temperature, and because the cooling water is not circulated unnecessarily.

(2) Estimated end pressure control

In the case where water is delivered by a pump, a method exists for maintaining constant pressure (water pressure) at the end terminal of the path. The wa-

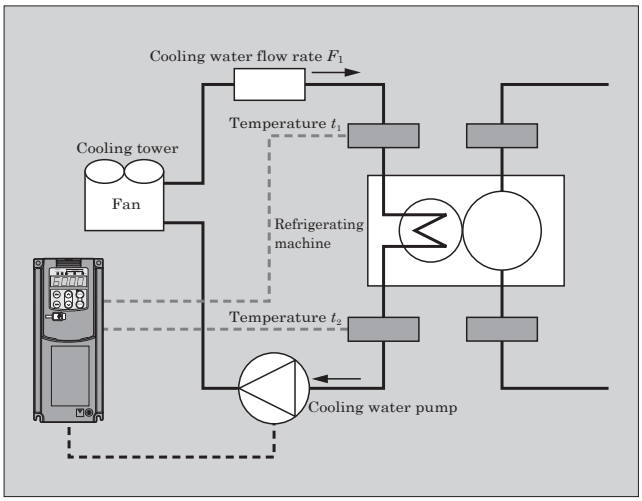

Fig.3 "FRENIC-Eco Plus" application example

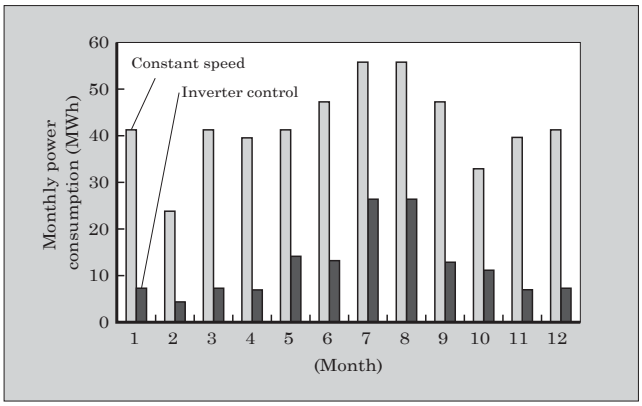

Fig.4 Measured power consumption as a result of temperature difference constant control

ter pressure decreases due to pipe resistance along the path to the end terminal. Because the pipe resistance for water is closely correlated with the flow rate, the flow rate and pressure characteristics are recorded in the inverter and are used in controlling the rotational speed of the pump. Consequently, operation that is significantly more energy-efficient than constant discharge pressure (constant pressure at the pump outlet) control can be realized. Estimated end pressure control, which does not require a pressure sensor at the end terminal, enables simplification of the installation work and can be used to configure a maintenance-free system.

With the FRENIC-Eco Plus, proportional control and constant temperature and pressure control can additionally be selected, and a system configuration other than the conventional simple PID control is possible. This is the only example in Japan of a commercialized autonomous control-type inverter that does not require an additional regulator.

3.3 "FRENIC-VG" high-performance vector-control inverter

The FRENIC-VG Series has 600 Hz frequency response, and supports not only a 1,024 pulse encoder that is compatible with conventional models, but also a 17-bit serial encoder (131,072 pulse resolution) that is used with servo systems. Various systems can be configured with the following control methods.

(1) Precise synchronous control

In the case where a single machine is driven by multiple motors, the amount of rotation of each motor must be in agreement at all times, including when decelerating or accelerating. With the FRENIC-VG Series, precise synchronous control can be configured easily with a "MICREX-SX" programmable controller and an "E-SX bus." The "SPH3000MM" CPU module of the MICREX-SX has a minimum tact time of 0.25 ms, and tact fluctuation of less than 1 μs. For this reason, synchronicity is fully ensured on the position control side, and the machine-side moment of inertia, the position adjustment system and the speed adjustment system affect the synchronous precision.

The E-SX bus is a system that features a 100M bits/s communication rate, maximum separation between stations of 100 m, and a total length of up to 1 km. Even in a large capacity precise synchronous control system, an inverter and a motor can be arranged freely with few restrictions relating to the layout on the control board. Figure 5 shows a system configuration of the E-SX bus.

(2) Multi-axis control

Semiconductor manufacturing equipment and metal processing equipment require many types of motion control, including spindle control, traverse control, dancer control, PTP positioning control, winding control, and the like. Motor control comprises the categories of positioning control, speed control and torque control, but there are also many devices in which these are mixed. With the MICREX-SX system, programs can be incorporated that mix these types of control, and there are few restrictions on the number of control spindles. Because both vector inverters and servo inverters can be connected directly to the SX bus system, mixed systems ranging from the 0.05 kW minimum capacity of a servo system to the 630 kW maximum

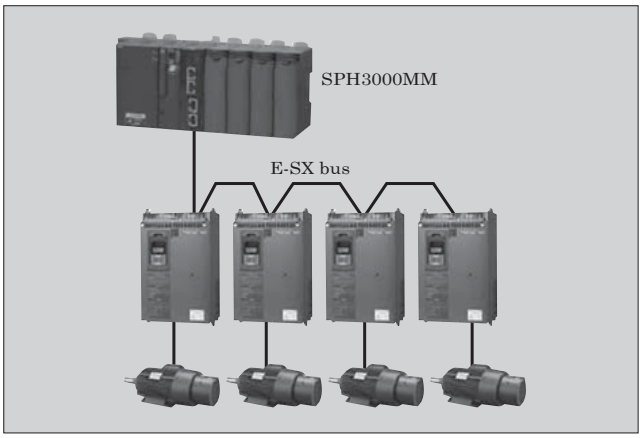

Fig.5 System configuration of E-SX bus

capacity of a vector inverter can be constructed easily.

The SX bus is a system that features a 25 Mbits/s communication rate, maximum separation between stations of 25 m, and a tact time of 1 ms. A high-speed communication interface (SX bus interface) is available for general-purpose inverters and other devices.

4. Latest Technology of the "ALPHA5 Smart Series" of Servo Systems and Application Examples

The latest technology used in the "ALPHA5 Smart Series" and an application example of a packaging machine that uses a programmable operation display (POD) and a MICREX-SX controller are described below.

(1) Individual tuning modes selectable for each application

In a servo system, internal gain must be adjusted in order to drive the associated mechanical system optimally. Previously, adjustment was typically performed by auto tuning. In the case of belt driving with a long travel distance, however, resonance or vibration may occur midway during the travel, requiring an engineer to adjust the parameters one-by-one. The adjustment of equipment of overseas customers required a significant amount of time just to reach the overseas site, and a quick response was not possible in some cases.

With the ALPHA5 Smart Series, in order to solve these problems, rules for optimal adjustment with individual tuning modes selectable for each application have been established. Figure 6 shows a block diagram of the individual tuning modes that are selectable for each application. The ALPHA5 Smart Series automatically changes its internal gain adjustment depending on the machinery configuration, and in addition to auto tuning, is provided with three other modes: interpolation operation, short cycle time operation and trace operation. The tuning setting method changes according to the type of mechanical system (ball screw, belt, and the like), and can be selected by the customer according to the application or the type of mechanical system. Because many electrical engineers are usually in charge of making the adjustments, this series has adopted a method for selecting the tuning mode according to the application.

(2) Parameter conversion technology using a PC loader

The previous method for replacing an older machine with a new machine had been to read out the parameter data, and then transfer that data to the new machine. This method required an operator to check the parameter values one-by-one, convert the values to the corresponding parameter values of the new machine and set the parameters accordingly, but there was a risk of notational errors or of conversion mistakes. As long as a single machine was targeted for replacement, the parameters could be checked and the replacement completed. When tens of spindles are to be replaced with a single system, however, the parameter conversion work becomes very time-consuming, and the likelihood of a mistake increases. Accordingly, it was necessary to proceed with caution, and a tremendous amount of time was required.

Consequently, Fuji Electric created a new parameter conversion tool. Figure 7 shows the PC loader screen of the parameter conversion tool. Using this tool, the parameters readout from an older machine can be converted directly to the parameters for a new machine, thus allowing the parameter conversion task to be completed simply by transferring the parameters after conversion to the new machine.

Because humans are not involved in the conversion process, the possibility of mistakes occurring is nearly zero, and even in cases of a large number of spindles, parameter replacement can be accomplished reliably within a short amount of time. This function is intended to provide compatibility with older machine models.

(3) Example application to packaging machine

Packaging machinery can be broadly classified into the three categories of vertical intermittent motion, vertical continuous motion and horizontal continuous motion. Each type can be used to package surface

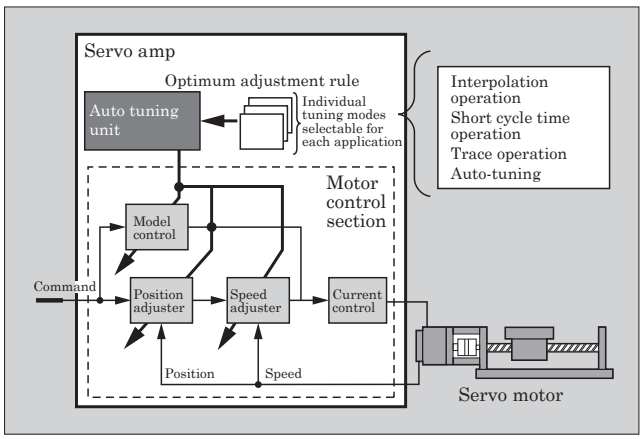

Fig.6 Modes selectable for each application

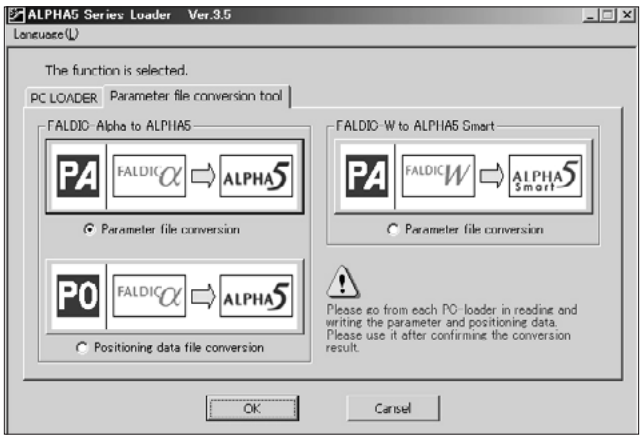

Fig.7 PC loader screen for parameter conversion tool

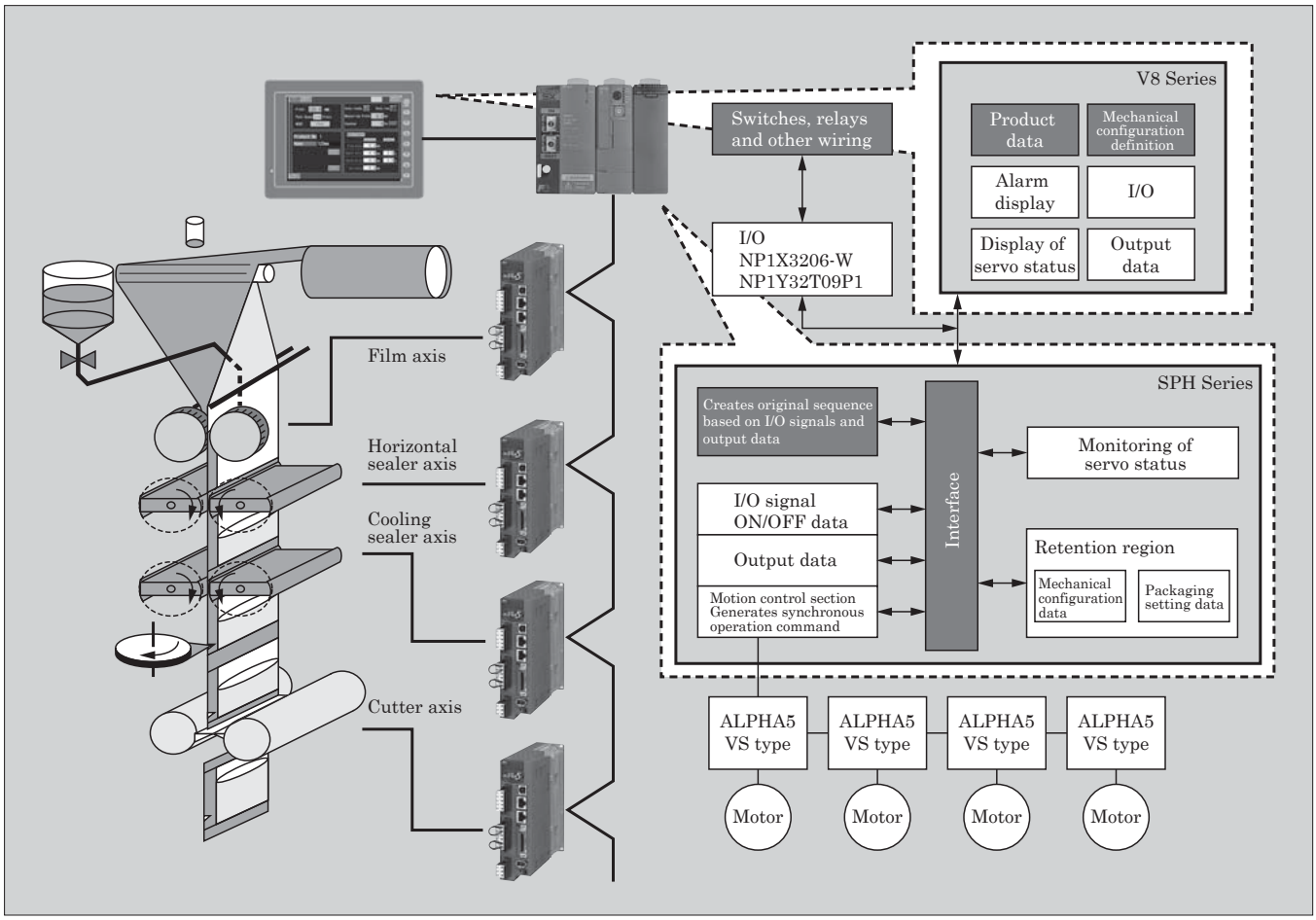

Fig.8 Example application to vertical packaging machine using a software package

sheets for plastic bottles, powder for medicine and bread, and the like.

Fuji Electric has extensive experience and expertise in control technology in Japan. In addition to providing close technical support to its customers, so that overseas customers can easily construct a system themselves, Fuji Electric has incorporated its control system expertise into a software package so as to be able to provide systems that do not require constant monitoring.

Figure 8 shows an example application to a vertical packaging machine. This system is configured from a POD, a MICREX-SX controller and a 4 axis servo system, and is used for packaging powders such as medicines, and liquids such as food flavorings.

Previously, in order to control this vertical packaging machine, it had been necessary to create a POD screen and a MICREX-SX program. With the POD, screens for product data settings, mechanical configuration definitions (required for each servo system axis), I/O settings, and the like had to be created. Additionally, with the MICREX-SX, programs for I/O data, motion control unit, mechanical configuration setting data, and the like had to be created, and the development thereof required a tremendous amount of time.

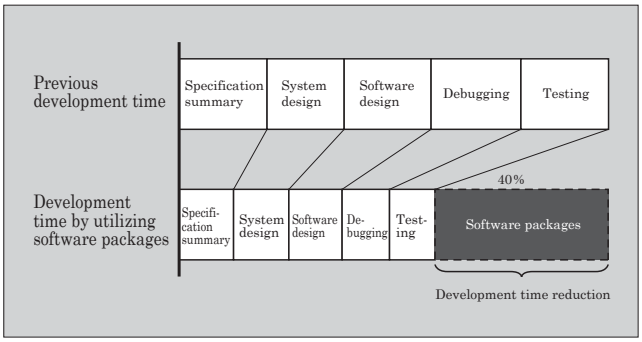

Fig.9 Comparison of development times when creating programs

The newly created software package incorporates a motion control unit for controlling the servo system and can be applied directly. Customers only have to create the remaining specific programs for their packaging machines. By providing a specific software package for packaging machines, the time required for development has been reduced by approximately 40% compared to that of conventional development (see Fig. 9).

Furthermore, for machinery manufacturers attempting to enter overseas markets for electronically-controlled packaging machines, system construction

had presented a barrier to entry in the past, but this method has brought the benefit of enabling easy construction, even if developing such a system for the first time. A software package tailored to a certain industry such as this is a breakthrough accomplishment of Fuji Electric.

5. Postscript

This paper has introduced the latest technology of general-purpose inverters and servo systems, and has described examples of their applications.

General-purpose inverters are expected to become further tailored to individual applications through combination with highly efficient synchronous motors and the provision of energy-saving and power reducing functions. For servo systems, rather than simply improving motor control performance, the provision of a system capable of realizing a function for suppressing machine vibration and of shortening the startup time of the machinery itself is needed. Fuji Electric intends to continue to develop products that fully meet these needs.

Reference

(1) SAKAI, T. et al. Latest Technology for General-purpose Inverters and Servo Systems. FUJI ELECTRIC REVIEW. 2009, vol.55, no.4, p.154-161.