FRENIC5000G11S/P11S Series, the Latest General-Purpose Inverters

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1. Introduction

Supported by a wide-range of users, the development of general-purpose inverters over the past ten years has been remarkable. The standard series began with simple *V/f* control, and now has achieved high performance with controls for magnetic flux, torque and efficiency. Consequently, general-purpose inverters can be used in applications that previously required dedicated inverters.

The FRENIC5000G9S/P9S series had satisfied market needs as the highest-class inverters with regards to function, performance, quality and price. However, due to the enlarged application range, still higher performance is required. The FRENIC5000G11S/P11S series being introduced here is the latest product series, and uses the most advanced technology.

2. Main Features and Specifications

Table 1 shows the basic specifications, and main features are described below.

(1) Powerful control with dynamic torque-vector control

A RISC (reduced instruction set computer) processor is utilized as the CPU (central processing unit) to improve the response and control calculation speed of important input signals for stopping accuracy and positioning. If a frequency of 0.5Hz has been set, high starting torques of 200% for 22kW or less and 180% for 30kW or more can be achieved. High-speed torque limiting for stopping with a stopper and a press to avoid regenerative braking, etc. are equipped as standard. The inverter can be utilized in a wide range of applications such as a rapidly changing load with tripless control.

(2) Wide range of model configurations

The FRENIC5000G11S series is for general industry and the FRENIC5000P11S series is for squared torque load such as fans, pumps, etc. The FRENIC 5000G11S series includes a 200V system ranging from 0.2kW to 90kW and a 400V system ranging from 0.4kW to 400kW. The FRENIC5000P11S series includes a 200V system ranging from 5.5kW to 110kW and a 400V system ranging from 5.5kW to 500kW. Compared with the conventional series, these series have a wide capacity range provided by enhanced capacity of the unit construction. Therefore, inverters can be selected as appropriate for a particular application.

(3) Environment-friendly inverter

To increase the range of noise suppression measures, a review of heat loss reduction and cooling design for inverters of 30kW or more was performed, and the upper limit of the carrier frequency has been raised. Measures such as utilization of a half-resonant type low-noise control power supply system and soft switching to suppress *dV/dt* of the IGBT (insulated gate bipolar transistor) in the main circuit reduce the effect of noise to peripheral devices such as sensors. Furthermore, in the low carrier mode, which is effective against noise, tone change by a non-periodic carrier frequency can soften the grating noise. The inverter is equipped with terminals for connecting a DC reactor that can suppress higher harmonics, and is equipped with a European EMC (electromagnetic compatibility) compliance filter.

(4) Circuit configuration

Figure 1 shows the circuit configuration. A newly developed control technology using a digital AVR (automatic voltage regulator) and newly designed gate array improved the output waveform of the inverter, and decreased motor wow to 1/2 that of conventional units. In inverters of 1.5kW or more, an auxiliary control power supply is equipped as standard, and error output signals can be maintained even if the main circuit power supply is interrupted. For the main circuit, a dedicated IPM (intelligent power module) was developed, improving the reliability for short-circuit protection, etc.

(5) Compliance with international standards

To comply with international markets, the inverter has been approved by UL (America), cUL (Canada), TÜV (Germany) and CE marking (Europe). The keypad panel supports 6 languages: Japanese, English, French, German, Italian and Spanish. Chinese is also supported as an option.

(6) Abundant functions

Table 1 Basic specifications

Item			FRENIC5000G11S		FRENIC5000P11S	
Output ratings	Rated capacity	200 V series	0.2 to 22 kW	30 to 90 kW	5.5 to 22 kW	30 to 110 kW
		400 V series	0.4 to 22 kW	30 to 400 kW	5.5 to 22 kW	30 to 500 kW
	Voltage	200 V series	3-phase 200 V/50 Hz 200 V, 220 V, 230 V/60 Hz			
		400 V series	3-phase 380 V, 400 V, 415 V, (440 V)/50 Hz 380 V, 400 V, 440 V, 460 V/60 Hz			
	Overload capability		150% of rated current for 1 min		110% of rated current for 1 min	
			200% for 0.5 s	180% for 0.5 s		
	Rated frequency		50, 60Hz			
Input ratings	Phases, Voltage, Frequency	200 V series (3-phase)	200 V to 230 V, 50/60 Hz	200 V to 220 V, 50Hz 200 V to 230 V, 60Hz	200 V to 230 V, 50/60 Hz	200 V to 220 V, 50Hz 200 V to 230 V, 60Hz
		400 V series (3-phase)	380 V to 480 V, 50/60 Hz	380 V to 440 V, 50Hz 380 V to 480 V, 60Hz	380 V to 480 V, 50/60 Hz	380 V to 440 V, 50Hz 380 V to 480 V, 60Hz
	Voltage/frequency variations		Voltage: +10 to –15%, Frequency: +5 to –5%			
	Momentary voltage dip capability		When the input voltage is 165 V (400 V series: 310 V) or more, the inverter can be operated continuously. When the input voltage drops from the rated voltage to below 165 V (400 V series: 310 V), the inverter can be operated for 15 ms. The smooth recovery method is selectable.			
Output frequency	Adjustment	Maximum frequency	50 to 400 Hz		50 to 120 Hz	
		Base frequency	25 to 400 Hz		25 to 120 Hz	
		Range of output frequency	0.1 to 400 Hz		0.1 to 120 Hz	
		Carrier frequency	0.75 to 15 kHz (different depending on capacity)			
	Accuracy		Analog setting: ±0.2% of maximum frequency (at 25±10°C) Digital setting: ±0.01% of maximum frequency (at –10 to +50°C)			
	Setting resolution		Keypad panel setting: 0.01 Hz (99.99 Hz or less), 0.1 Hz (100 Hz or more) Analog setting: 1/3,000 of maximum frequency, link setting: 1/20,000 of maximum frequency, 0.01 Hz			
Control	Control method		*V*/*f* control, dynamic torque vector control , vector control with PG (G11S only)			
	Torque boost		Automatic torque boost, manual torque boost,			
	Starting torque		200% (22 kW or less) (at dynamic torque control)		50%	
			180% (30 kW or less) (at dynamic torque control)			
Braking	Braking torque (not using option)		150% (0.75 kW or less)	10 to 15%	20%	10 to 15%
			100% (7.5 kW or less)			
			20% (22 kW or less)			
Enclosure (IEC60529)			IP40	IP00	IP40	IP00
Cooling method			Natural cooling (0.75 kW or less), Fan cooling (1.5 kW or more)		Fan cooling	

A PID (proportional, integral and differential) function, which performs feedback control for temperature control with a fan or pressure and flow rate control with a pump, is equipped, and the changeover sequence to a power distribution line is partly integrated into the inverter to simplify peripheral circuitry. Furthermore, many new functions are provided such as the following: a function that continues operation by consuming inertia energy of the motor and load at a power failure, a function that decelerates and stops the motor, an automatic energy-saving function to operate the motor at minimum loss, and a function to switch a fan on and off depending on the temperature of the cooling fins.

Since serial transmission (RS485) capability is equipped as standard, system compatibility with various open buses (optional) is facilitated.

By installing a PG (pulse generator) feedback card, real vector control is possible, and the inverter can be used in even higher performance applications.

3. Control System

The control system developed for FRENIC5000G11S/P11S, including operation characteristics will be described below.

3.1 Dynamic torque-vector control

Fuji Electric's original "dynamic torque vector control" system was newly developed and features remarkably improved dynamic characteristics compared to conventional "torque-vector control".

The system configuration is shown in Fig. 2. By detecting output voltage of the inverter and making the voltage a sinusoidal wave with the digital AVR, a small rotational fluctuation of about 5r/min (p-p) is

Fig.1 Circuit configuration

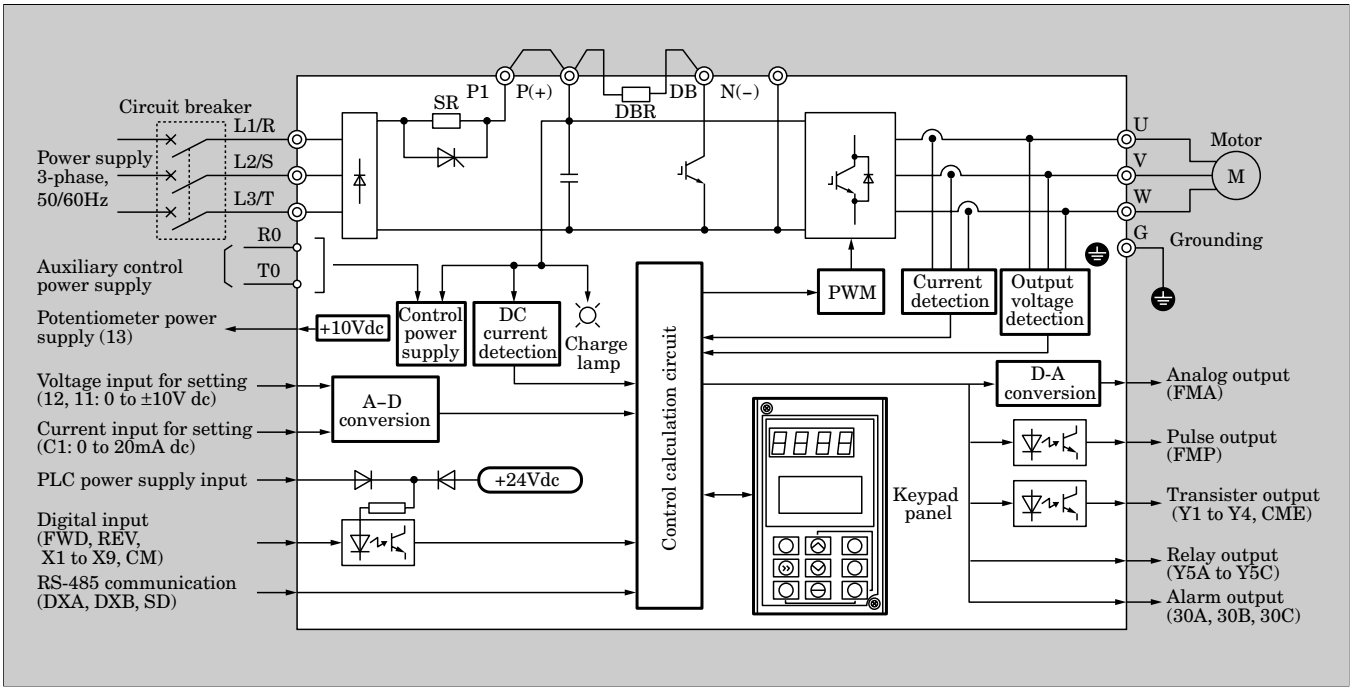


Fig.2 System configuration

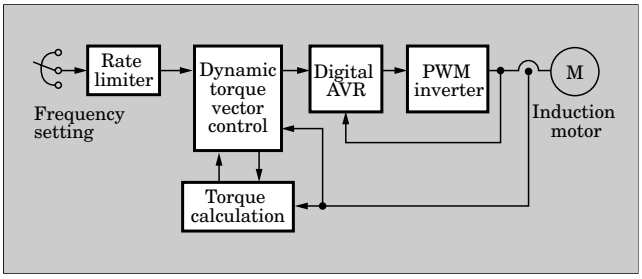
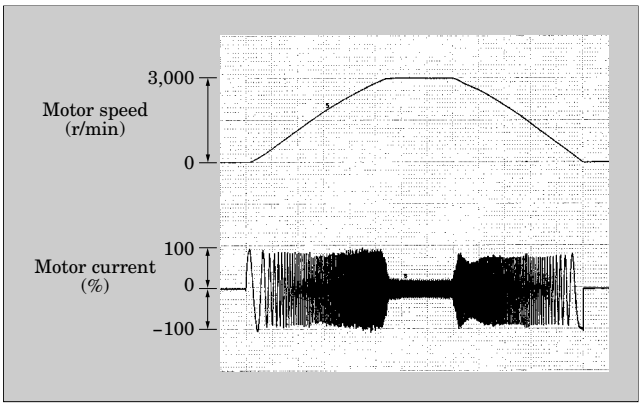
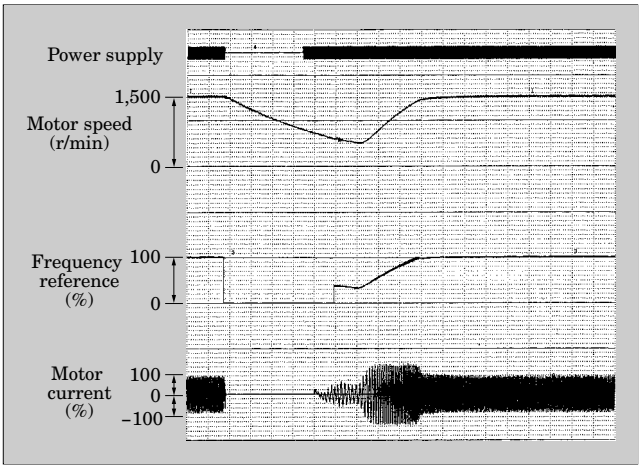


Fig.3 Acceleration/deceleration characteristics



realized at 1Hz operation. The torque calculation accuracy is improved with this digital AVR and accurate torque calculation becomes possible even at the ultra low speed of 0.5Hz. With dynamic torque-vector control, the stability and response are also improved at acceleration/deceleration and rapid load change.

Fig.4 Operation characteristics after an instantaneous power interruption (flying start)



3.2 Acceleration and deceleration characteristics

Figure 3 shows acceleration and deceleration operation characteristics using a torque limiting function. The torque limiting function operates immediately after the start of deceleration, and the speed variation and current overshoot are suppressed. Since a new torque limiting method is utilized in which the deviation between the torque limit value and generating torque in the motor is made to be zero, the acceleration and deceleration time can be shortened.

With this function, machine tools, which require reduced gear noise and the shortest acceleration and deceleration, and conveyance machinery, which require high-frequent operation, can be smoothly accelerated and decelerated or forward and reverse operated.

Fig.5 Motor speed vs temperature variation

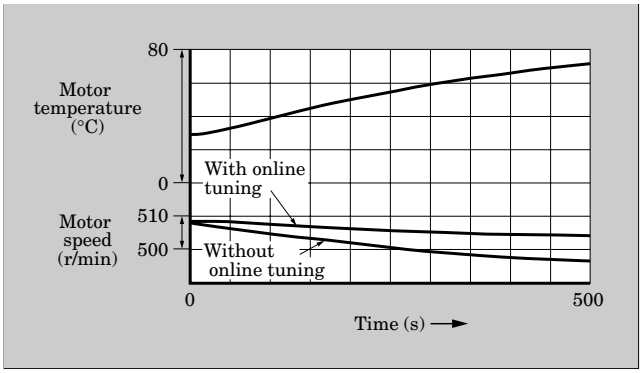
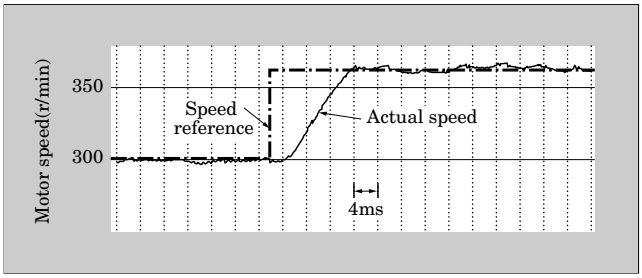


Fig.6 Response at step speed setting (Vector control using speed sensor)



3.3 Flying start

The control system is equipped with a flying start function whereby a free-running motor can be smoothly restarted without shock.

This function detects the rotating speed and direction by self-excited oscillation of the motor and inverter that is induced by positive feedback of the motor current. Figure 4 shows operation waveforms in the case of restarting after an instantaneous power interruption. The operation smoothly restarted without rush current.

Since the speed can be correctly detected even if the rotating direction is reversed, this function can be used effectively to start the reverse rotating fans.

3.4 Auto-tuning function

Various motors are used with general-purpose inverters. Control constants must be adjusted to correspond to the motor in use to effectively utilize the ability of dynamic torque-vector control. Therefore, in addition to the conventional off-line auto-tuning function, the control system is also equipped with a new on-line auto-tuning function that adjusts the control constants according to changing motor constants during operation. Figure 5 shows operation characteristics when using the on-line tuning function. Even if the motor slip fluctuates due to temperature change, it is possible to maintain an approximately constant rotating speed. This facilitates applications such as fluid mixing machines, commercial-use washing machines, etc.

Fig.7 Appearance of keypad panel

3.5 Vector control with speed sensor

Vector control with speed sensor can be realized by installing a “PG feedback card” in the main body of a motor with PG. Since this can control the torque, application to printing machines, winding machines, etc. are possible. In Fig. 6, a waveform of the response at step speed setting is shown. The response to an input signal is only several milliseconds due to the high-speed CPU.

4. Keypad Panel

The keypad panel has been refined and made more usable than previous models. Its operability not only succeeds that of previous inverters, but is also backward compatible with other inverters. Figure 7 shows the appearance of the keypad panel, and its features are described below.

(1) LED/LCD display

The LED display can selectively display 13 types of data such as settings, output frequency, current, voltage, power consumption, and data at the PID control. The LCD display is enlarged and is provided with an operation guide display for manual-less operation. A scrolling display is used for explanation of the operation keys.

(2) Operation keys

The number of operation keys has increased from the conventional keypad panel, and with these keys, the motor can be operated in forward and reverse directions from the keypad panel. Furthermore, changeover of jogging mode and changeover of operation command (terminal/keypad panel) can be performed by key operation on the keypad panel, eliminating the need for changeover in a remote control room.

(3) Frequency setting

The frequency setting is displayed in the LED display part, but the value can be also set as a process value (e.g. pressure) during PID control, in addition to frequency or line speed, and the control value of the object to be controlled can be recognized at a glance.

(4) Abundant functions

The following functions can be set with this keypad panel in addition to the operation functions, monitoring functions and function setting functions.

(a) I/O check (tester function)
In addition to the analog/digital input and output tester function of the conventional inverter unit, the input and output of the option card can also be checked.

(b) Maintenance
To verify operation status of the equipment, maximum current, r.m.s current and average braking power can be checked from the operation patterns.
Accumulated operation time, inverter internal temperature, maximum current and DC link circuit voltage can be displayed and verified as maintenance information for the equipment. In addition, the life expectancy information of inverter components that wear out, such as the main capacitor, capacitor mounted on the printed circuit board and cooling fan, can also be displayed.

(c) Copying function
A function to copy function data is provided in the keypad panel, and can be simply set up.

5. Conclusion

In this paper, we have presented an overview of the general-purpose inverter FRENIC5000G11S/P11S newly introduced to the market. This inverter has characteristics and functions that considerably exceed those of conventional inverters, and can be applied to a wide range of applications. We, at Fuji Electric, will continue to improve inverter characteristics and functions, including application to new fields, and to develop general-purpose inverters in response to market needs.