UDC 621.314.5:621.382.3:621.313.333

TRANSISTOR INVERTER FRENIC5000G7/P7 FOR GENERAL USE

Yoshitaka Fujiwara
Shinobu Kawabata
Masaru Yamazoe

1. FOREWORD

The FRENIC5000G5/P5 Series inverter for general use with magnetic flux control and instantaneous current limiter has been highly evaluated as a trip-free high performance inverter which operates smoothly ever since it was introduced. However, the demand for high precision and multiple functions, functions which communicate with a personal computer, programmable controller (PC) and other high level controllers, etc., centered about the FA field, in the general use inverter market are getting stronger. Trip-free operation under all conditions, including instantaneous power failure, is a demand common to a wide field of applications.

To meet these demands, Fuji Electric has promoted multi-functionalization by all-digital control, including operability, and development of high precision technology and high-speed speed sensor-free torque calculation technology and serial interface and other technology and developed the new series FRENIC5000G7/P7 inverter. This new series is outline here.

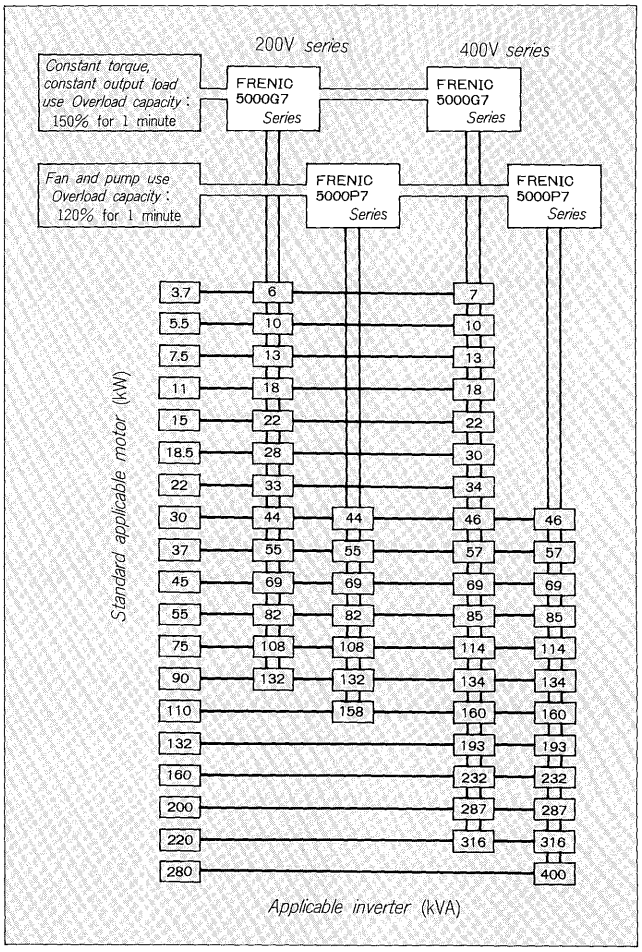
2. OUTLINE AND FEATURES

The composition of the new series is shown in *Fig. 1.* The FRENIC 5000G7 Series is designed for constant torque load use and has an overload capacity of 150% for 1 minute. The FRENIC 5000P7 Series pursues economy for fan, pump, and other variable torque loads and has an overload capacity of 120% for 1 minute. Since an abundant capacity series is available for both 200V and 400V systems, an entire system can be constructed on a consistent concept. The most economical inverter for the motor capacity can be chosen.

An outer view of the inverter is shown in *Fig. 2.* Its design concept is unified with that of its sister product FVR-G7 Series. A unique structural design allows simple use with panel external cooling systems by removing the mounting adapters at the back and moving them to an intermediate position of the unit. Outside the dimensions are approximately 30% smaller than old models.

The main features are:

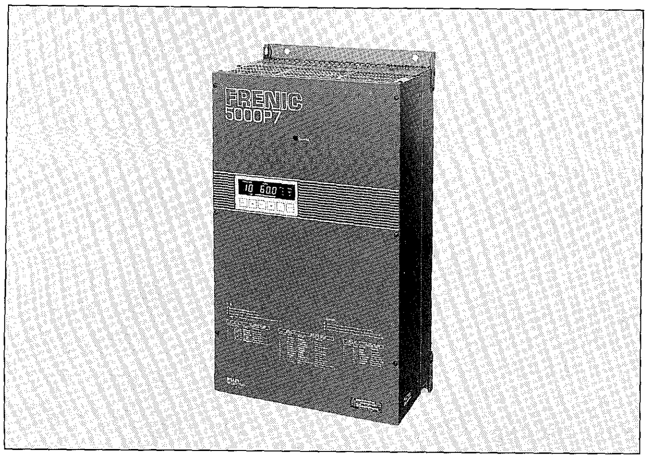
Fig. 1 FRENIC5000G7/P7 model composition



(1) Trip-free inverter with torque limiting

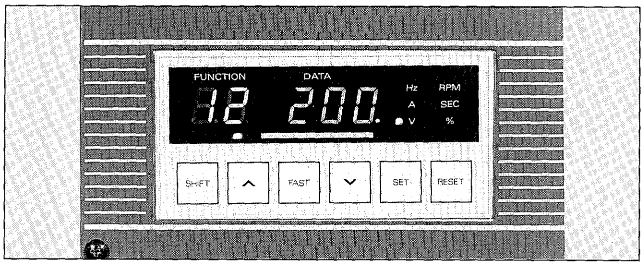
The modes for which it is easiest to make an inverter trip are overcurrent by starting operation with acceleration time set abnormally short, overcurrent by precipitate overload during constant speed operation, regenerative overvoltage and overcurrent by interference with other loads by machine shaft, regenerative overvoltage by deceleration

Fig. 2 Inverter



AF89-786

Fig. 3 Keypad panel



AF89-788

time setting mistake, and overcurrent at temporary stopping and restarting for instantaneous power failure.

Conversely, for overcurrent modes, high-speed calculation torque limiting control operates and the frequency is controlled while maintaining maximum torque and operation is continued. Moreover, when the inverter do the line starting when the motor is stopped or freely rotating, the inverter is overcurrent tripped most easily, but tripping can be prevented by operation of the instantaneous current limiting circuit.

For the regenerative overvoltage mode, operation is continued while limiting the regeneration power by selecting automatic deceleration control. Even when the deceleration time was set to the shortest time, the deceleration time is extended automatically.

(2) Smooth rotating and stable motor speed

Since sinusoidal PWM with magnetic flux control is used over the entire capacity range, torque pulsations are suppressed under all operating conditions and the unstable current phenomena is eliminated.

Moreover, since high-performance slip compensation based on output torque calculation is used, stable speed operation relative to load fluctuations is possible. The amount of the slip compensation can be freely set to match the slip characteristics of the motor.

(3) Simple parameters setting

The keypad panel is shown in *Fig. 3*. 7-segment digital LEDs are divided into 2 digits function code display and four digits data display. The data is indicated real number display with units and erroneous setting is prevented. Since the number of functions is large due to extensive multifunctionalization, function selection uses a method which selects a number for each digit. Furthermore, the function section uses green LEDs and the data section uses red LEDs to avoid erroneous identification of the numbers. The bottom half is the keypad. Innovations have been made so that setting can be performed by simple key operation.

3. SPECIFICATIONS AND CIRCUIT CONSTRUCTION

The standard specifications are shown in *Table 1* and the circuit construction is shown in *Fig. 4*. Typical new specifications from among these are described.

(1) Widening of power supply voltage and output voltage ranges

Standard correspondence to 200-230V for 200V class and 380-460V for 400V class is possible. Since the output voltage setting can be changed over a wide range, optimum setting can be performed even for specially designed motors. Moreover, to make standard application to 380V, 4-pole motor possible, the rated current was reviewed.

(2) Multistep speed operation

Multistep speed operation is possible by using the 3 bits signls of control terminals X1, X2, and X3. Besides the frequency set by analog signal from the outside, 7 frequencies can be preset as internal settings.

(3) Acceleration/deceleration time switching operation

Four acceleration and deceleration times can be selected by using the 2 bits signals of control terminals RT1 and RT2. Its range of application is wide, including use at manual inching operation and when the load inertia changes substantially.

(4) Various operation monitor signals

Besides frequency meter output, running signal (RUN), frequency equivalence signal (FAR), frequency level detection signal (FDT), overload early warning (OL), undervoltage stop (LV) which is output when the inverter was stopped by an undervoltage, etc. are provided as inverter operation status signals. These are effective when the entire system is controlled by a high-level controller while checking the inverter operation status. Open collector output standard, but it can be converted to contact signal by using an optional relay output unit.

(5) Frequency setting by analog signal

Three kinds of inputs, input terminals 11-12-13 by voltage signal or variable resistor and voltage signal input V1 and auxiliary input by current signal C1 are provided, the same as the old series. However, the input was made such that the current signals and voltage signals are not effective simultaneously and are switched by external signal AUT. Next, in addition to use as the addition/subtraction input for the main setting input (12-11), when auxiliary input V1 is used independently, an analog signal of both polarities can be input and reversible operation can be performed.

(6) Data link with high-level controller

Table 1 FRENIC5000G7/P7 standard specifications

Inverter			FRENIC5000G7	FRENIC5000P7
Output rating	Inverter capacity	200V class	6 to 132kVA	44 to 158kVA
		400V class	7 to 316kVA	46 to 400kVA
	Overload capacity		150% for 1 minute (inverse time characteristic)	120% for 1 minute (inverse time characteristic)
	Voltage	200V class	3-phase 3-wire system 200–230V	
		400V class	3-phase 3-wire system 380–460V	
	Maximum frequency		50 to 400Hz	
Power source	Voltage/ frequency	200V class	3-phase 3-wire system 200V/50Hz, 200–230V/60Hz	
		400V class	3-phase 3-wire system 380–420V/50Hz, 400–460V/60Hz	
	Allowable variation		Voltage: +10 to –15%, voltage imbalance rate: Within 3%, frequency: ±5%	
Control specifications	Control system		Sinusoidal PWM with flux control	
	Output frequency range		0.5 to 400Hz (starting frequency 0.5 to 5Hz possible)	
	Output frequency stability	Standard	Analog setting: ±0.2% of maximum frequency (at 25°C ±10%)	
		Option	Digital setting: ±0.01% of maximum frequency (–10 to +50°C)	
	Frequency setting resolution	Standard	Analog setting: ±0.1% of maximum frequency	
		Option	Digital setting: ±0.002% of maximum frequency	
	Voltage/ frequency characteristic (V/f)	200V class	Voltage: 160 to 230V, frequency: 50 to 400Hz	Voltage and frequency can be adjusted independently.
		400V class	Voltage: 320 to 460V, frequency: 50 to 400Hz	
	Torque boost		21 selectable modes and automatic energy-saving operation	
	Acceleration/deceleration characteristic		Acceleration/deceleration time: 0.2 to 3,600 sec. Linearity acceleration/deceleration: 4 patterns, Non-linear acceleration/deceleration: 2 patterns	
	Braking torque	Standard	Regenerative braking: 10 to 15% DC braking: Operating frequency 0 to 10sec., voltage 0 to 10%	
		Option	Dynamic braking: 100% (braking duty 5%ED)	
	Accessory functions		Torque limiting control, automatic deceleration control, instantaneous current limiting, slip compensation control, multistep frequency selection, restart after instantaneous power failure, UP-DOWN control, back up sequence from line to inverter operation, automatic acceleration/deceleration operation, jump frequency, reversible operation with signal polarity, high or low limiters, bias frequency	
Protection functions			Stall prevention, overcurrent, overvoltage, undervoltage, instantaneous power failure, inverter overload, inverter overheating, motor overload (electronic thermal OL relay trip), external fault (external thermal OL relay trip, etc.), CPU error, short circuit for output terminal, ground fault protection for inverter (option), incoming surge.	
Operation	Frequency setting signal		Potentiometer or voltage input: DC 0 to ±10V (DC 0 to ±5V), current input: DC 4 to 20mA	
	Input signal		Forward command, reverse command, 3-wire control, multistep frequency selection, UP-DOWN control, acceleration/deceleration time selection (4 steps), coast-to-stop command, switching operation from line to inverter, interlock for load side switch, external alarm input, alarm reset input, ground fault protection input	
	External output signals	Relay output	Inverter running output signal (NO), alarm (SPDT)	
		Open collector output	In-operation signal, frequency equivalence, frequency level detection, overload early warning, undervoltage alarm	
Display	Frequency meter output signal		Analog: DC 0 to +10V, digital pulse frequency: (6 to 100) x output frequency	
	Keypad panel LED display	Running	Output frequency, reference frequency, synchronous speed, output current, output voltage, machine speed, input/output signal check	
		Setting	Function codes and data display	
		Fault	OC1: Overcurrent during acceleration, OC2: Overcurrent during deceleration, OC3: Overcurrent during running at constant speed, OU: Overvoltage, LU: Undervoltage, OL1: Inverter overload, OH1: Inverter overheating, OH2: External fault, CPU error, running condition (8 data) at time of fault, fault history (immediately preceding 3 faults)	
	LED display (charge lamp)		Lit by DC intermediate circuit voltage	

Two options cards which communication with and control the inverter from a personal computer, PC, or other high-level controller are available. *Table 2* outlines their specifications. Both communicate by using serial signals, but use of the two cards must be selected to match the different communication systems. The personal computer interface card conforms to RS-422 and RS-485 interface standards and the PC interface card can be connected to the Fuji Electric MICREX-F Series T-link.

The information which can be communicated is almost the same for both.

(a) Exchange of signals corresponding to signals which are input and output from terminals during operation.

Fig. 4 Inverter circuit composition

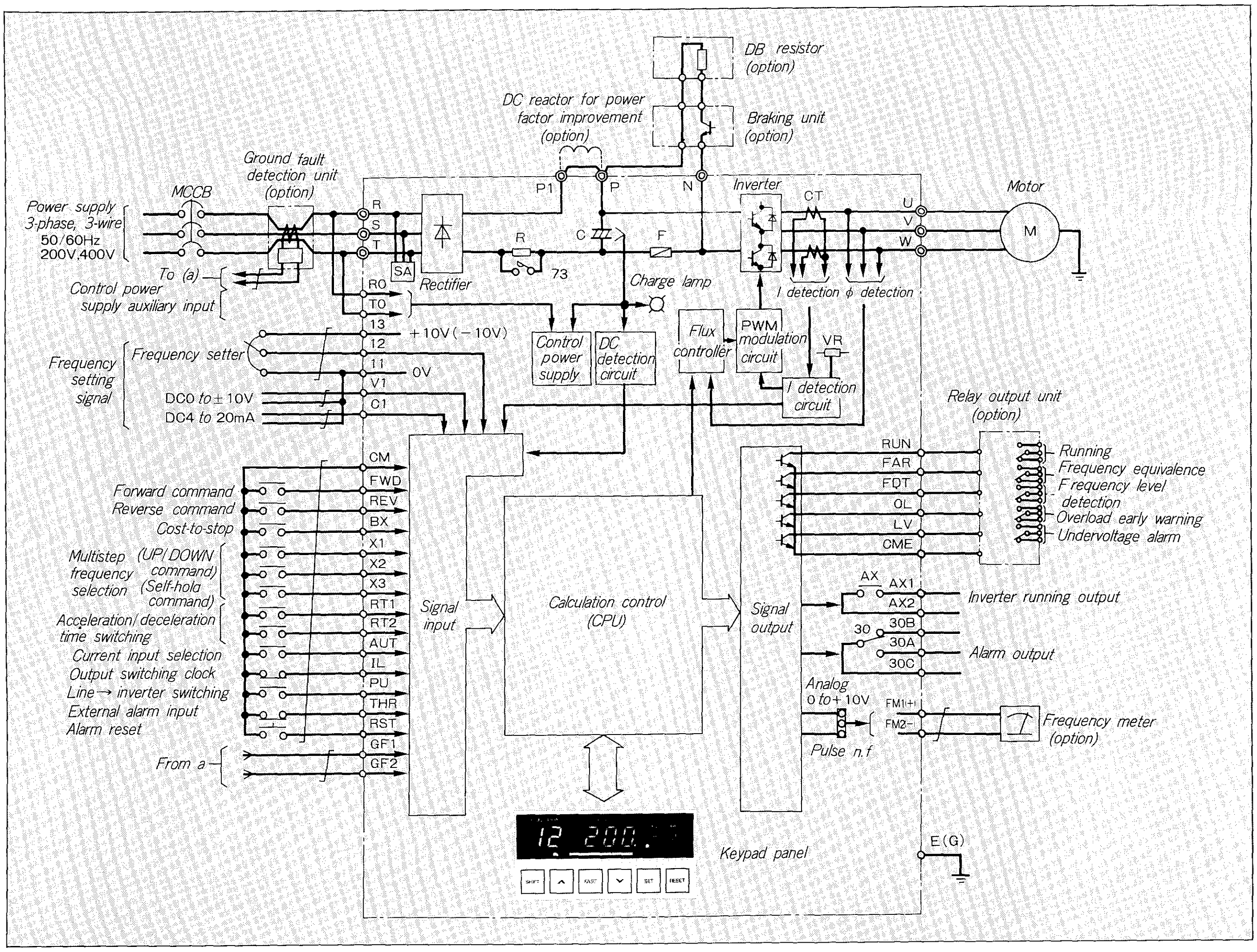


Table 2 Serial interface card outline specifications

Item	Specification		
Application	Personal computer		PC
Type	OPC II-RS		OPC II-TL
Applicable computer	Computer with RS-422, RS-485 interface For RS-232C interface, use is possible by connecting a converter.		MICREX-F Series
Interface specification	RS-422	RS-485	T-link
Number of connectable units	Max 10	Max 31	Max 12
Transmission speed	Selected from the following 19,200 (baud) 1,200 (baud) 9,600 600 4,800 300 2,400		500kbps/sec (refresh time 10ms)
Connection cable	Shielded twisted-pair cable		Shielded twisted-pair cable

Fig. 5 Torque limiting control circuit block diagram

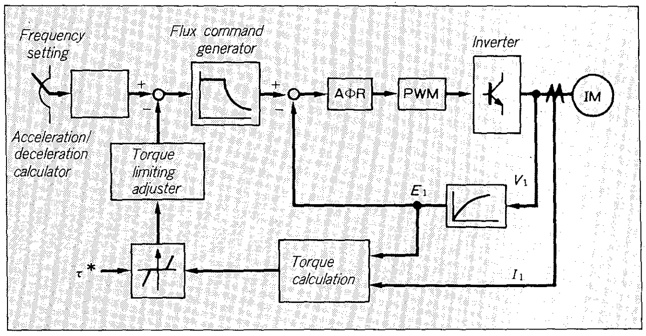


Fig. 6 Example of torque calculator static characteristic

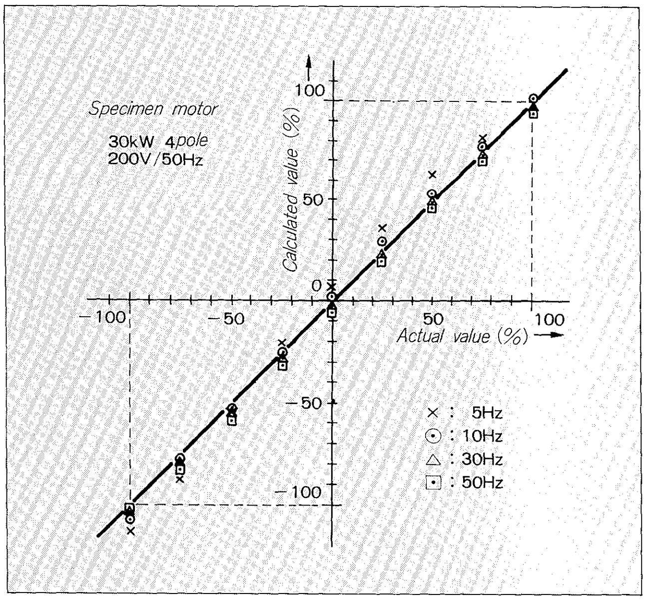
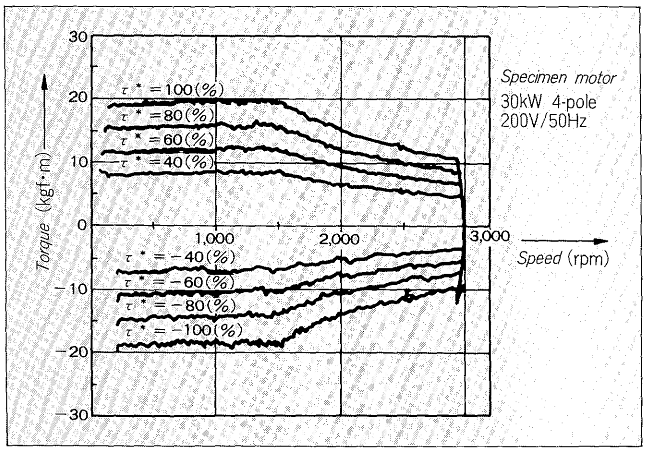


Fig. 7 Example of speed-torque limiting characteristic



(b) Various parameters monitoring and setting modification.
(c) Frequency setting by 16-bit digital signal.
(d) Monitoring of output frequency, output current, etc. by 16-bit digital signal, etc.

Fig. 8 Example of torque limiting boost dependence characteristic

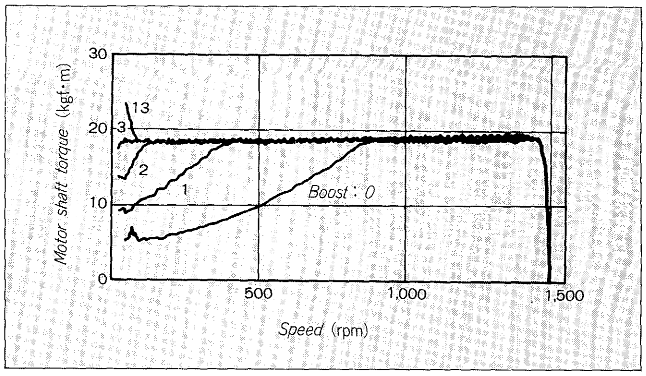
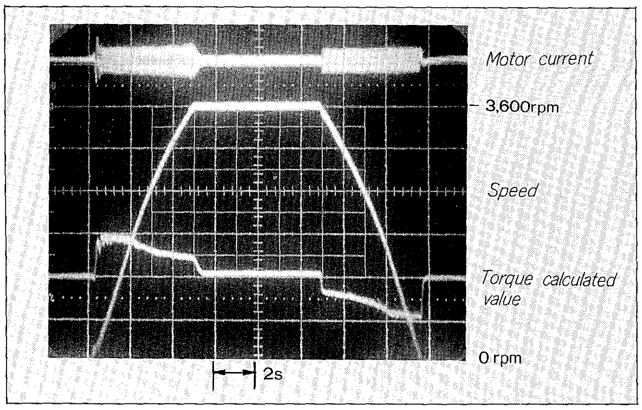


Fig. 9 Example of acceleration/deceleration by torque limiting characteristic



4. OPERATION CHARACTERISTICS

The operation characteristics are introduced centered on the technology newly used.

(1) High-speed torque limiting control

The torque limiting control block diagram is shown in *Fig. 5.* The part from the torque calculator to the torque limiting controller is the newly developed part.

The torque value is calculated from the inverter output voltage, output current, and motor primary winding resistance. The calculated torque is compared to the actual torque in *Fig. 6.* It can be seen that a good characteristics is obtained over a wide frequency range.

The torque calculation result is compared to the value τ set by key operation and the output of the acceleration/deceleration calculator is compensated through the torque limiting adjuster and as a result, the torque limiting operation is performed.

Figure 7 is the speed-torque characteristic when the torque limiting value was set to various values. The torque limiting value of the driving mode indicated by plus and the braking mode indicated by minus can be set independently. In the range of the constant power characteristics of the base speed and higher, the limiting value also uses a constant power characteristic.

Figure 8 is the torque limiting characteristics when torque limiting was set to 100% and the torque boost

Fig. 10 Example of impact load characteristic

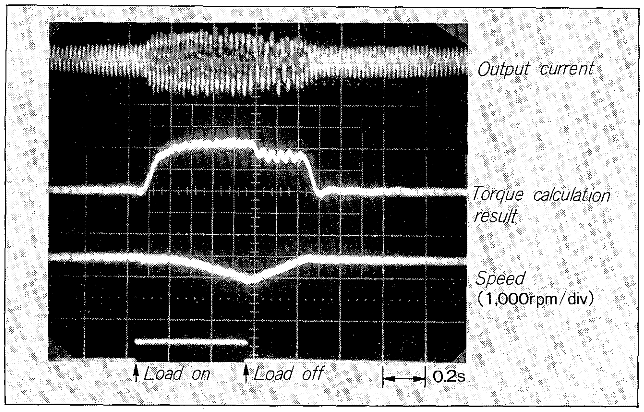


Fig. 11 Example of slip compensation control static characteristic

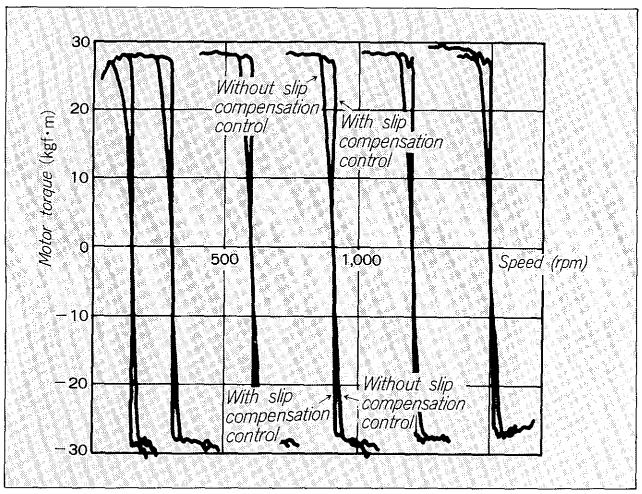
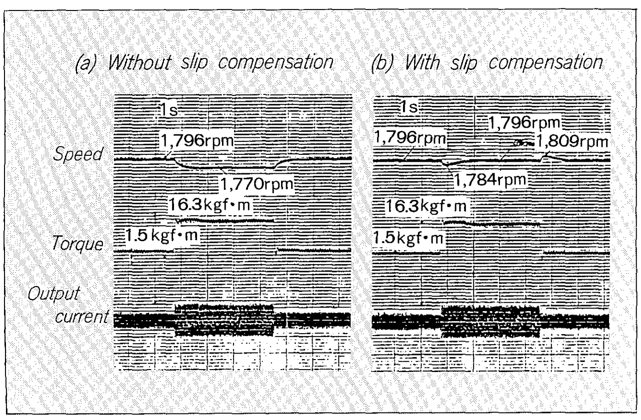


Fig. 12 Example of slip compensation control dynamic characteristic



set value was changed. Since the maximum value of the output torque is limited at setting of the weak characteristics of data codes 0 ~ 2, control by torque calculation is ineffective.

Figure 9 is an oscillogram which shows a torque limiting control dynamic characteristic example. This is the acceleration/deceleration characteristic when an inertia load of 5 times the motor rotor GD^2 was connected and the acceleration and deceleration times were set to 0.2 second. The actual acceleration and deceleration times are

Fig. 13 Example of direct-on-line motor starting characteristic

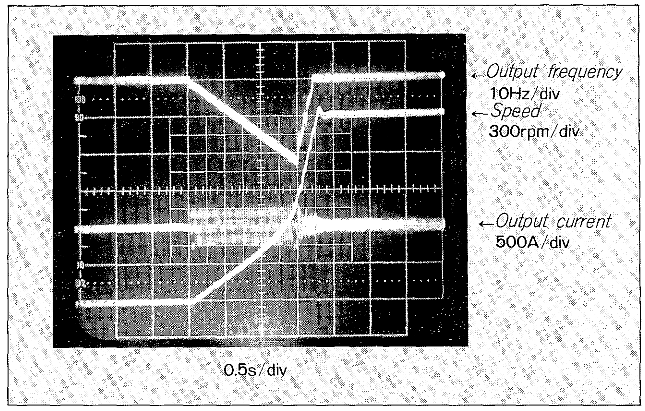
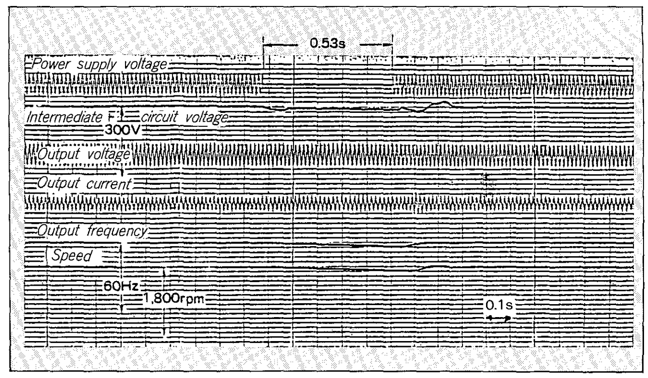


Fig. 14 Example of restart after instantaneous power failure operation



extended automatically according to the torque limitter value. Since the output torque changes according to the constant output characteristic over the 1,800 to 3,600 rpm non-linear acceleration and deceleration are done automatically.

Since this operation tracks the changes automatically even when the load torque and GD^2 load change, the acceleration/deceleration time can be set without being afraid of trip.

Figure 10 shows another dynamic characteristic of torque limiting control.

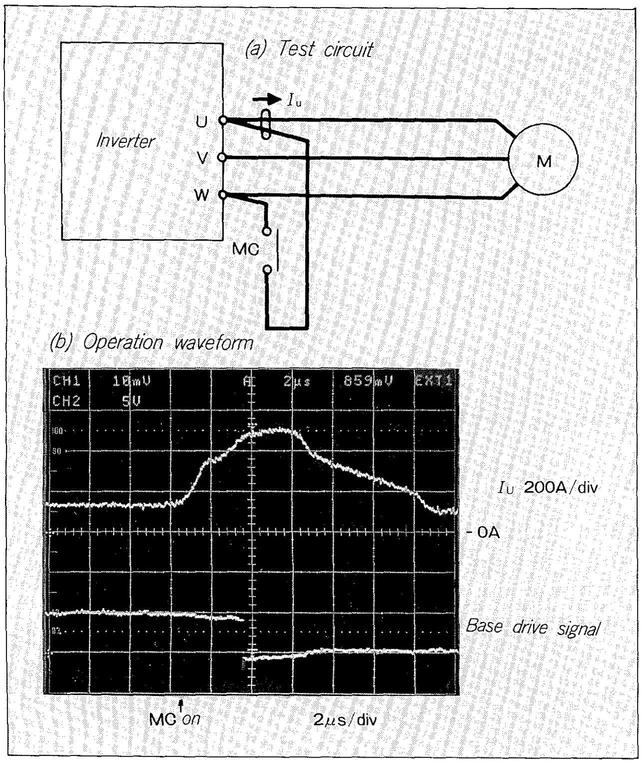
This is an oscillogram when an overload for a short time (about 0.5 sec.) was given during constant speed operation. The torque limiting is held while dropping the speed. If the overload is canceled, the motor is quickly re-accelerated up to the reference speed. This function allows economical application of the inverter to presses and others repetitive impact loads.

(2) High-performance slip compensation control

High-performance slip compensation control was made possible by using the torque calculation result.

Figure 11 shows the slip compensation static characteristic. The two curves at each speed shows the difference of the speed torque characteristic with and without slip compensation. A very good compensation characteristic is shown in both the drive and braking zones. *Figure 12* shows the slip compensation control dynamic characteristic. The characteristic with and without slip compensation

Fig. 15 Example of short-circuit protection characteristic



for 100% load torque changes. With slip compensation, the speed recovers quickly and the absolute value of the speed drop is also small. This operation characteristic is extremely effective for the drive equipment of multistory parking lot, etc. whose load torque changes a lot and which speed stability.

Since the amount of the slip compensation can be easily changed by setting, its optimum value can be set not only for standard motors, but also be specially designed motors.

(3) Instantaneous current value limiting control

Generally, with general-purpose inverters, since the output current increases abruptly when the load side switch is closed while the inverter is running and a motor direct-on-line mode was generated while the motor is stopped or coasting to a stop, overcurrent tripping frequently occurs.

Since the FRENIC5000G7/P7 series is equipped with a high-speed instantaneous current limiting circuit, it can follow this sufficiently. *Figure 13* shows the starting characteristic when a stopped motor is placed directly on line for an inverter running at 50Hz. While current limiting is being done, the output frequency drops and when the frequency matched to the speed is reached, instantaneous current limiting operation is reset and the frequency is quickly recovered to the original output frequency by sudden acceleration operation.

(4) Continuous operation at instantaneous power failure

Figure 14 shows the oscillogram when an instantaneous power failure was generated at light load. The voltage of the DC intermediate circuit starts to drop at the power supply power failure. That is, when a power failure is detected, the inverter shifts to the low power regenerative mode and the DC voltage is recovered while dropping the frequency and operation is held. The size of the regenerated low power matched to the amount of power consumed by the control circuit is preset and the motor is decelerated at a slightly steeper slope than the natural deceleration by load of the motor and waits for the power to recover. For a large inertia load, ample operation can be continued even for an instantaneous power failure of 2 to 3 seconds.

In the past, for an instantaneous power failure, an option card was used and the output of the inverter stopped at a power failure and the operating motor was pulled in at power recovery. However, since the new system shifts to the recovery acceleration mode simultaneously with power recovery, the speed drop is small and shock-free recovery operation is possible. This function is standard with the new series.

(5) Output short circuit protection

Figure 15 shows the oscillogram of a running inverter short circuit test. After the overcurrent detection level (= 234A) is reached, a base off signal is generated in about 2μs, the short circuit current begins to attenuate 2μs later. In this way, short circuit protection of the entire capacity series was made possible by the technology of high-speed detecting and high-speed base off and the use of a new element with a built-in current limiting circuit for short circuit and other abnormal currents.

For ground fault protection, a zero phase current detection option is available as shown in the connection diagram of *Fig. 4.*

5. CONCLUSION

The newly developed transistor inverter FRENIC 5000G7/P7 for general-purpose was outlined above. The needs of the times were met and performance and reliability were improved, functions were increased, and size and weight were substantially reduced by using much new technology. This series is expected to be used in a wider field of application as the successor of the FRENIC 5000G5/P5 Series. The popularity of the inverter is increasing and the places where it is active as an important component in large FA systems is also increasing. The need for ease of coping with automation and for improved reliability, and improved maintainability, establishment of an after service organization, and elimination of environmental noise and signal trouble, improved safety and other operation continuity is extremely high. We are confident that the inverters of this new series can amply meet the expectations of such market.

On the other hand, the advance of power electronics and the microcontroller, and its application technology is something to watch. Backed by these new technologies, we will continue our efforts to supplies inverters which can meet new needs in the future.