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HIGH-FREQUENCY INVERTER FOR HIGH-SPEED INDUCTION MOTOR FRENIC 5000H

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1 FOREWORD

In recent years energy saving, power saving and freedom from maintenance for installed equipment and machineries are much clamored for, consequently, AC variable speed operating technique through use of an inverter has developed in a large scale. In particular, the diffusion of transistor inverter adopting power transistors of high controllability in their main circuits is something to be wondered at. Since the power transistors are easy to carry out high-speed switching, the miniaturization of the equipment as well as rendering them lighter in weight and obtaining of higher reliability are possible.

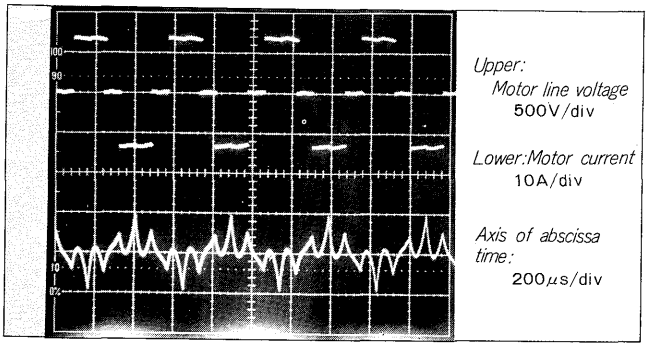
On the other hand, in the market, the demand for motors that turns stably with high speed, aiming at improvement of productivity, uniforming the finished surfaces, improvement of working accuracy for betterment of product quality and product performance together with energy and power saving quality, are increasing everyday.

With these backgrounds, Fuji Electric has pushed forward for developing and manufacturing high-frequency inverters and serialized small-sized, high-performance and high-reliability high-frequency inverter FRENIC 5000H. Following are the description on the specifications of that products.

2 SPECIFICATIONS AND PERFORMANCE

Table 1 shows the standard specifications of 5000H. The capacity range of the inverter is from 2 to 12 kVA and applicable to high-speed induction motors of less than 7.5 kW. Rated frequency selection range is from 240 to 5,000 Hz, and this means that in the bipolar motor, it is equivalent of 14,000 to 300,000 rpm rotating speed if we are to disregard the slipping. Also, variable-speed operation in the range of 1:20 against the selected rated frequency is possible. With three-phase 200 V power supply, rated maximum voltage is 200 V in effective value. The output waveform is a square wave (PAM system) with a width of 120 °el. *Fig. 1* shows the output waveform. In order that the apparatus can be applied for all sort of high-speed motors, the setting of V (voltage) and f (frequency) can be made stepless and independently. Soft start/soft stop time limit is from 3 to 30 seconds and it can be set independently and by internal switching over, the time limit can be extended up to the maximum of 200 seconds. As for the operation, the standard practice is for one-direction operation, but through internal setting switchover, reverse operation also is possible.

Fig. 1 Output waveform FRENIC 5000H



The protective function of the inverter relies on maximum frequency limiting, stall prevention, inverter interruption and stopping at the time of detection of abnormalities in the inverter (cooling fan overheat, overcurrent, decelerating time abnormal, power supply failure, outer equipment failure) so that the reliability of the inverter is much enhanced.

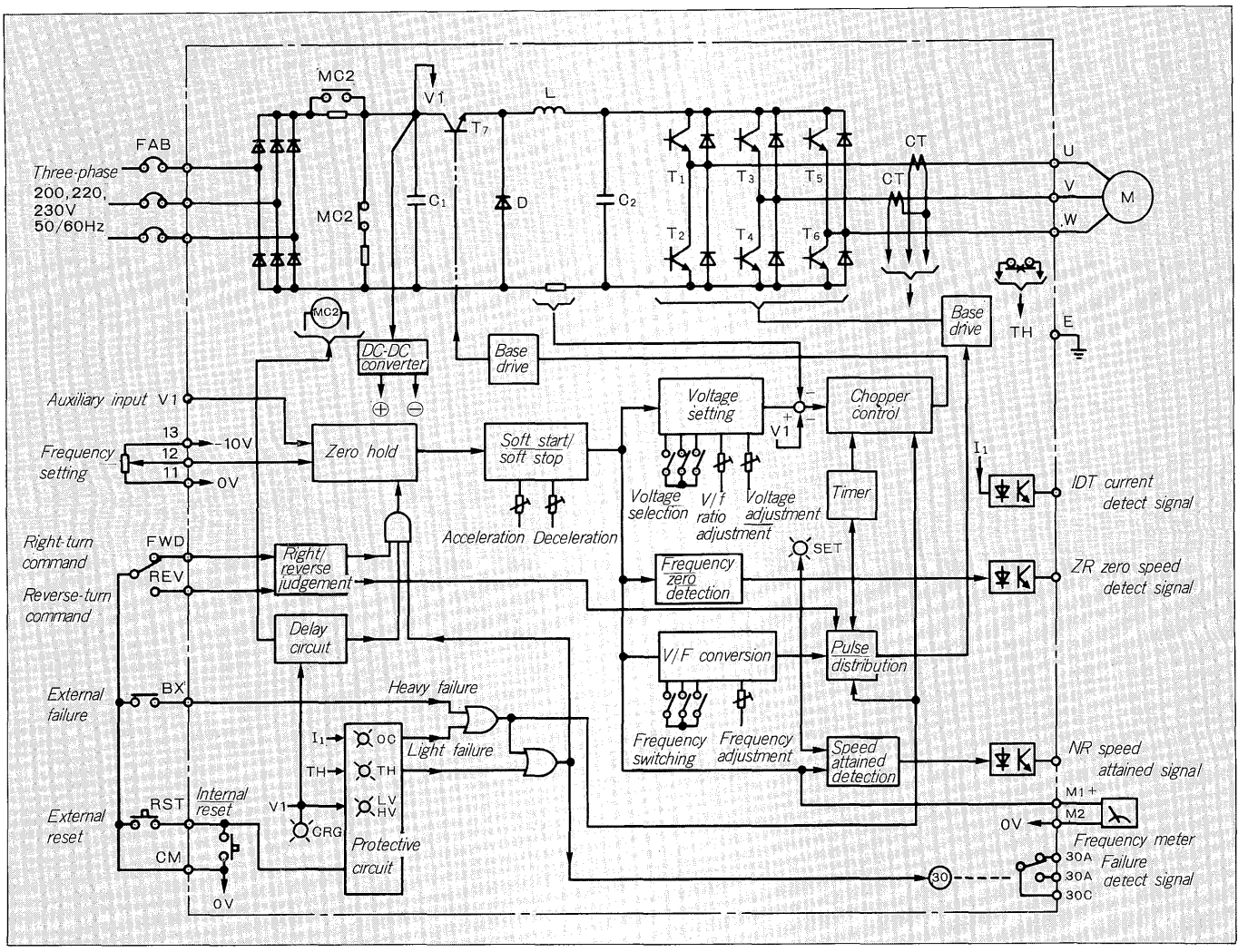
As the additional function of the inverter, the inverter can sent out speed attained signal, speed-zero signal, current detection signal and failure detected signal. With these, the control process is made easier and that is a great advantage in composing a system.

As for the structure type, there are two series of types available, namely: standard unit type and cubicle type. All of these two aim at miniaturization of their shape.

3 COMPOSITION AND OPERATION OF CIRCUITS

Fig. 2 shows 5000H inverter unit. The outline of its operation is as described in the following.

Fig. 2 Circuit composition of FRENIC 5000H



3.1 Main circuit

The three-phase 200 V current of the power supply is converted into DC current by a rectifier and turns into variable-DC voltage source in chopper unit consisting of transistor T_7 and reactor L. This voltage is converted into variable-frequency three-phase AC in the inverter unit consisting of transistors T_1 to T_6, and is supplied to high-speed induction motor. By setting the switching frequency of the chopper unit to higher than 10 kHz, the equipment is miniaturized and its operating noise is reduced.

3.2 Control circuit

The control circuit is divided, approximately, into the following units: chopper control unit for controlling the voltage, inverter control unit for controlling frequencies, and protective circuit unit for protecting the equipment.

(1) Chopper control unit for controlling the voltage is provided with a current limiting circuit so that the equipment is safely operated without need for stopping it when an overcurrent occurs.

(2) Inverter control unit is provided with a high-precision *V/f* converter and a circuit dividing its output into three-phase signal.

(3) As the protective circuit, it has various functions indicated in *Table 1*, providing the equipment with highly reliable operations.

4 FEATURES

In 5000H equipment, a variety of fruits of new technology are incorporated. The main features are as follows.

(1) High-speed switching technique of power transistor

This is base current saving type feature in which collector catch diodes are applied for high-speed base drive, a circuit with insulating function through the use of a photo coupler is adopted. (*Fig. 3*) By this system, more than 10 kHz frequencies are easily obtained as the switching frequency.

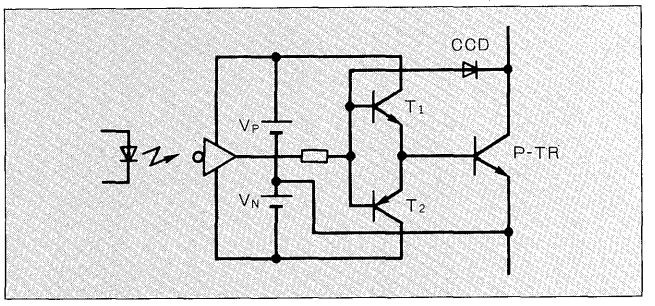
(2) Miniaturization of control power supply by DC-DC converter

By utilizing a DC-DC converter, a stabilized power supply for various insulated types of use as control circuit, base drive circuit, etc. is obtained. This power supply unit

Table 1 Standard specifications of FRENIC 5000H

Inverter models		FRN 002H	FRN 003H	FRN 006H	FRN 008H	FRN 012H	Remarks
Motor output applied (max)		1.2 kW	2.2 kW	3.7 kW	5.5 kW	7.5 kW	
Rated output current		6 A	9 A	16 A	24 A	36 A	
Input	Voltage and frequency	Three-phase 200 ~ 230 V 50/60 Hz					When single phase input, rating will be decrease.
	Permissible variation	Voltage: 180 ~ 253 V, Frequency: ±5 Hz					
Output	Voltage (max)	Three-phase 200 V ±5% (with supply voltage more than 200 V, only)					
	Frequency (max)	240 ~ 5,000 Hz					
Control system		Square-wave PAM control					Even when output is released, operation is possible.
Frequency control range		1 : 20 (ex. when max. 240 Hz, 12 ~ 240 Hz) (ex. when 5,000 Hz, 250 ~ 5,000 Hz)					
Frequency precision		±0.5% or less when input voltage fluctuates ±10%					
		±0.5% or less at the ambient temperature of 25 ±10 °C					
V (voltage)/*f* (frequency) ratio		Setting possible as desired, *V*/*f* intensifying or weakening possible (*V* and *f* independently settable)					
Overcurrent resistance		120% for one minute					
Soft start/soft stop		3 ~ 30 s (independently settable)					Option max. 200 s.
Operation system		Unidirectional operation					Option, reversible operation possible
Speed setting signal		DC 0 ~ −10 V (input impedance 20 kΩ) DC 0 ~ +10 V (input impedance 20 kΩ)					
Braking		During deceleration for stopping, for completely stopping, at minimum-speed operation, DC braking circuit will operate. During the DC braking, current limiting level and braking time can be adjusted.					Option: Braking by regenerative power discharge resistance
Converter efficiency		More than 90%					
Cooling system		Self cooling	Air cooling				
Protective function	Maximum frequency limit	Input setting voltage is limited so as no voltage higher than maximum frequency setting voltage should not be applied.					
	Stall prevention	During overcurrent and overvoltage suppression, control is made for preventing the motor from stalling.					
	Inverter interruption	Inverter will be stopped at cooling fin overheated, overcurrent, decelerating time defective (regenerative overvoltage), power supply abnormal, external equipment failure, etc. (individual LED indication), and when abnormalities are detected, signal will be issued from contact (contact c, AC 250 V, 2 A).					
	Momentaneous current interruption	At current interruption, operation will stop and operation will restart upon receiving operating command after current restoration.					
	Display (LED lighting)	(1) Smoothing condenser residual voltage indication (2) During the inverter interruption protective operation, individual display will be made. (3) Operation display.					
Environment	Location	Indoors, altitude: 1,000 m or less There should be no corrosive gas, oil mist nor dust.					
	Ambient temperature	−10 ~ +50 °C					
	Ambient humidity	20 ~ 90% RH (no condensation tolerated)					
Construction		Wall hanging type					
Option		(1) Scot connection transformer for two-phase output (2) Three-phase single winding transformer for output raising (3) Reversible operation unit (4) Soft start (soft stop) extension unit (5) Regenerative power discharge registance braking					
Output signal	Rotation constant speed signal	When set frequency coincides with output frequency, the signal will be sent out by open collector.					Open collector specifications: VCE: 35 V IO : 50 mA
	Zero speed signal	When the output frequency is lowered to 1/30 or less than the maximum set frequency, the signal is output by open collector.					
	Current detect signal	When inverter current surpasses the set value, the signal is output by open collector. (However, no signal will be output during the accelerating/decelerating period.)					
	Abnormality detect signal	When inverter protective function operates, the signal is output by the contact (contact c).					Contact capacity: AC 250 V, 2 A

Fig. 3 Base current saving type high-speed base drive circuit



occupies only about 1/2 of space, when compared with that of conventional transformer types.

(3) Stable and high-performance PAM control system

For the motor magnetic sound during the operation and for rendering the output frequency higher, a PAM system that can change the voltage peak value is adopted.

(4) Control system by voltage control chopper

For chopper control unit, a momentaneous value control system whose response is quick and precision is high, is adopted, so that a stable drive is attained.

5 SCOPE OF APPLICATION

The fields in which high-frequency inverters are applied at present are, mainly, the following.

(1) Internal grinding machines and jig grinding machines
(2) Semi-conductor cutting and working mills
(3) High-speed drilling machines
(4) Face moulding machines
(5) Centrifugal separators
(6) Pumps
(7) Wood working machines

However, even in these fields, still there are many equipment that carry out high-speed operations by means of pulleys. From now on, in order to improve the productivity, precision in the work and freedom from maintenance, it is believed that progress toward making the equipment high-speed direct drive system will be pushed forward, and in particular, the highly standardized high-frequency inverters will be more and more popular.

6 OUTER VIEW

The standard constructions are available in two types: unit type and cubicle type whose outer views are shown in *Figures 4* and *5*.

The cubicle type includes devices necessary for driving motors including an interface with external equipment, and it is an ideal type for controlling the equipment as a single unit.

Fig. 4 Standard unit

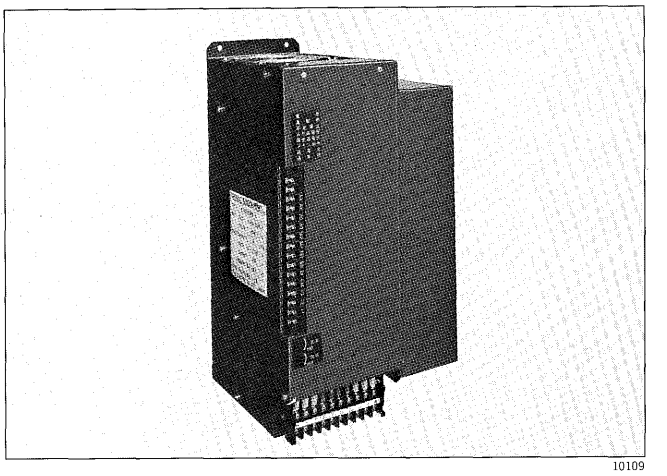


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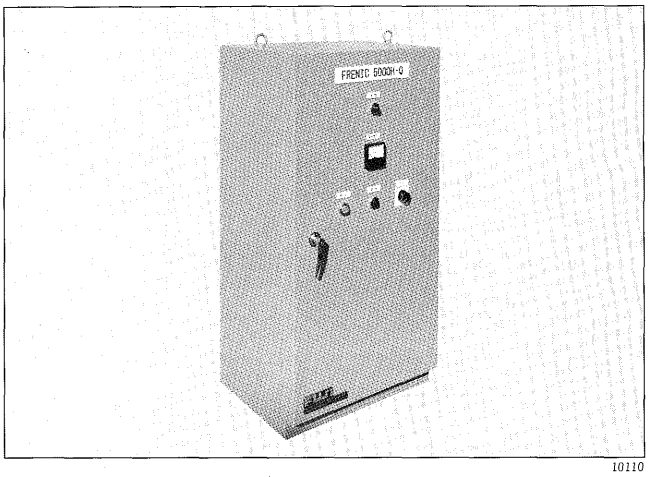
Fig. 5 Cubicle type unit



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7 SUMMARY

It is expected that the field of application for the high-frequency inverters will be expanding more and more together with the ever increasing demands for higher precision for installed equipment and for improvement in productivity. The high-frequency inverters have only come to their early phase of diffusion and basing on the data acquired in the field, they need to be improved on their performance and specifications. We are planning yet to expand the serialization of their capacities and standardization of their types.