

FRENIC-Multi Series General-purpose Compact-size Inverters

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1. Introduction

With recent background of increasing demand in general-purpose inverter market such as powerfulness for conveyance machines and energy-savings for fan and pump applications, there are growing needs to improve performance and multi-functionality for small and medium-size variable-speed inverter applications, as well as to reduce size and cost.

Newly developed FRENIC-Multi series is Fuji Electric's core line of general-purpose inverters. So that these inverters are suitable for use in any industry or application field, FRENIC-Multi series has been designed to have high performance, multi-functionality, improved environmental friendliness, ease of maintenance, and use, enhanced protection functionality, harmonization with peripheral equipment, conformance to overseas standards, etc., and is positioned as a global product for wide range of uses throughout the world.

This paper introduces these features.

2. Environment Harmonization Design

2.1 Conformance to RoHS directive

As a result of the enforcement of WEEE*¹ and RoHS directives*² of European Union (EU), the concept of environmentally harmonized products are spreading throughout various countries in the world. Although general-purpose inverters are currently exempt from RoHS directive, due to rising environmental awareness in the marketplace, FRENIC-Multi series will not exceed specified content levels of six limited hazardous substances [lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl (PBB), and polybrominated diphenyl ether (PBDE)]. Also, client who requests compliance with green procurement are recently increasing, therefore Fuji Electric is preparing so that we can respond quickly in case the information of existence and content of any of those six hazardous substances is requested.

*1: WEEE is Waste Electrical and Electronic Equipment.

*2: RoHS directive is restriction on the use of certain hazardous substances in electric and electronic devices.

2.2 Long-life design of limited-life parts

In previous models, periodic replacement of DC bus capacitors, electrolytic capacitors on the printed circuit board, and cooling fan was recommended every 3 to 7 years, as these parts have a limited service life. Since these parts were designed to have longer service lives and their layouts were optimized in FRENIC-Multi series, to prolong the equipment maintenance cycle time, their designed lives extended to 10 years under the conditions of 40°C inverter ambient temperature and 80 % continuous load operation. Also, in order to prevent incidents of sudden equipment stoppage, service life information can be viewed on keypad display, and when some parts approach the end of its service life, warning signal is output as a transistor-level signal that is sent to upper-level controller or the like to encourage part replacement before any problems occur.

3. Abundant Model Varieties

Figure 1 shows the appearance of FRENIC-Multi series, and Table 1 lists the varieties of models in this series. Newly developed FRENIC-Multi series succeeds previous FVR-E11S series and adds 11 kW and 15 kW models to 3-phase 200 V and 400 V series, and offers a wider range of capacities.

Additionally, models with built-in pulse generator (PG) feedback card, built-in electromagnetic compatibility (EMC) filter, and built-in RS-485 card have been developed as semi-standard series in order to provide wider user selection. Figure 2 shows an example of the model with built-in RS-485 card.

4. High Performance and Multi-functionality

4.1 Dynamic torque-vector control (with flux estimation)

Dynamic torque-vector control is a control method based on an equation that describes induction motor voltage. In this method, output current and motor constants are used to calculate the optimal output voltage command value and estimated slip value in real-time to enable high-speed response and stable operation in response to abrupt load changes.

Fig.1 Appearance of the FRENIC-Multi series



Table 1 Model varieties of the FRENIC-Multi series

Model type		Varieties	
Standard		3-phase 200 V	0.1/0.2/0.4/0.75/1.5/2.2/ 3.7/5.5/7.5/11/15 kW
Semi-standard	Built-in EMC filter	3-phase 400 V	0.4/0.75/1.5/2.2/3.7/ 5.5/7.5/11/15 kW
	Internal PG feedback card	Single-phase 200 V	0.1/0.2/0.4/0.75/1.5/ 2.2 kW
	Internal RS-485 card		

Fig.2 Internal RS-485 card



FRENIC-Multi series adds the functions of flux axis difference compensation based on the estimated flux and excitation current compensation by means of flux regulator to enable stable output for large starting torques of 200 % or greater. Moreover, an online tuning function can be used to perform primary resistance compensation and secondary resistance compensation to minimize speed fluctuation that is accompanied with motor temperature change.

Fig.3 Speed vs. torque characteristics

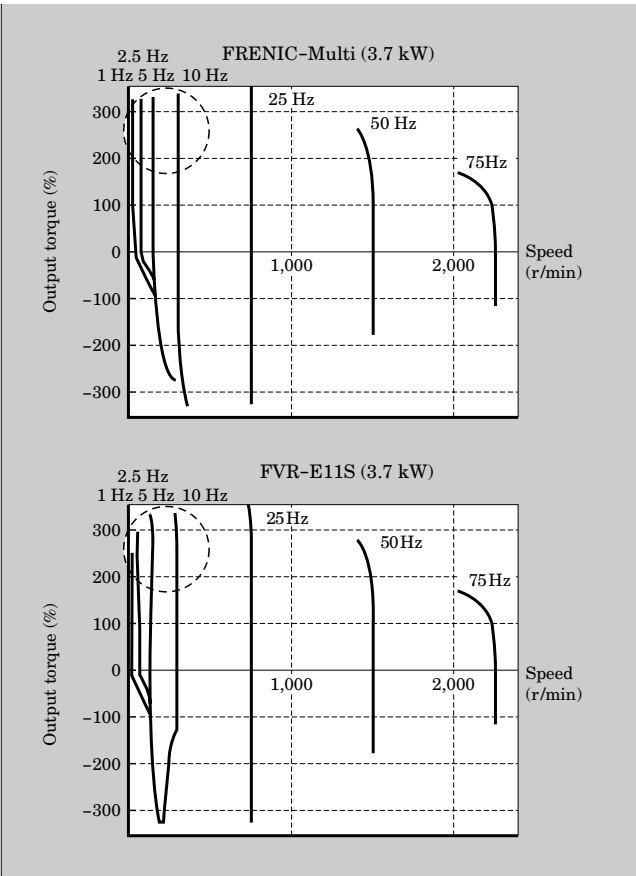


Fig.4 Step load response

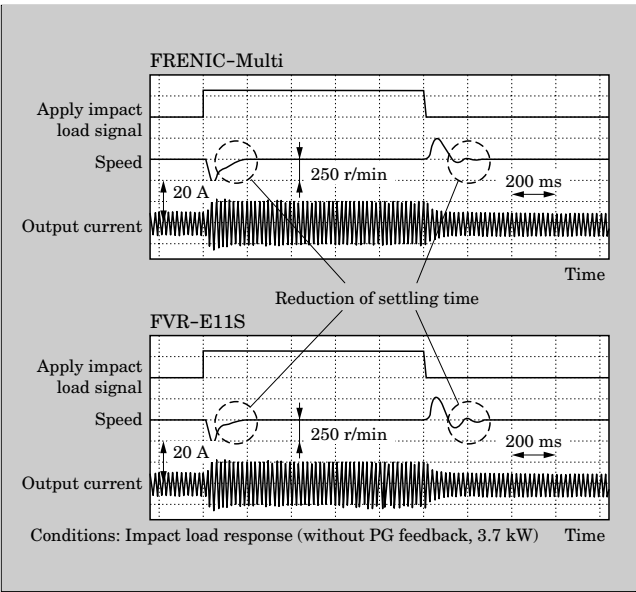
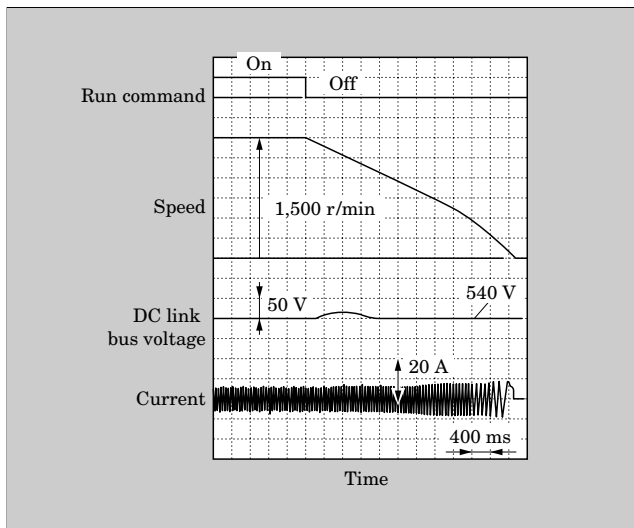


Figure 3 shows the speed versus torque characteristics and Fig. 4 shows the step load response characteristics of FRENIC-Multi compared to FVR-E11S. In the low-speed region, FRENIC-Multi series is capable of stable torque output over a wide range, and even in response to step loads, FRENIC-Multi series exhibits

Fig.5 Regenerative avoidance control



less fluctuation in motor speed and shorter settling time to recover the original speed.

4.2 Regeneration avoidance control

With FRENIC-Eco series inverters for fan and pump applications, regeneration avoidance control regulating DC link bus voltage to constant value is used where DC link bus is monitored during deceleration, and the deceleration time is automatically extended if the voltage is greater than a certain value. On the other hand FRENIC-Multi series, uses a highly responsive torque limiting method well suited for horizontal and vertical conveyance applications. With torque limiting method, braking torque is calculated instantaneously, and if it reaches the suppression level, deceleration time is extended automatically to prevent tripping due to overvoltage.

Figure 5 shows an example of regeneration avoidance control characteristics. By detecting the braking torque and controlling the output frequency, voltage increases of DC link bus are suppressed.

4.3 Overload stop function

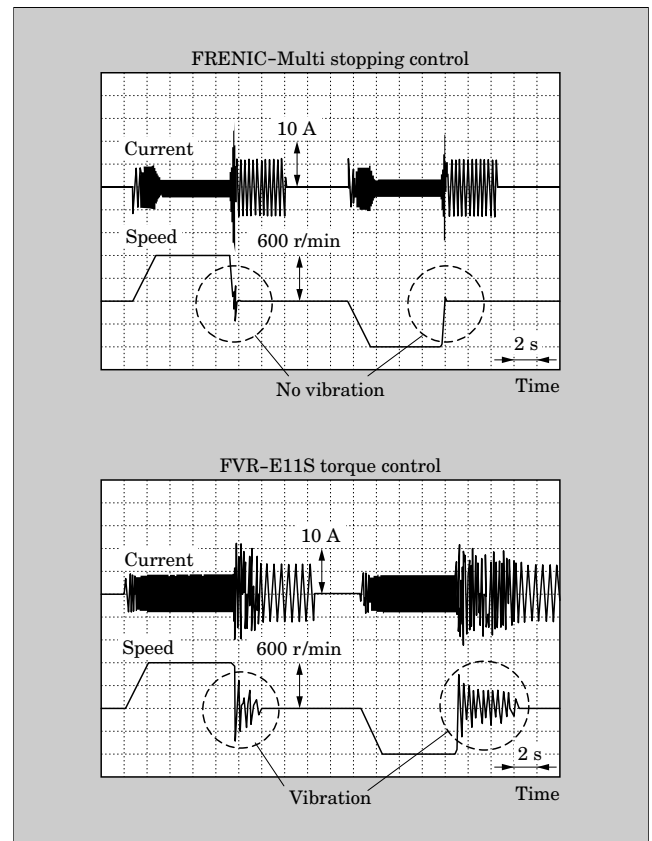
Because sudden load changes are detected based on changes of torque or output current, inverter can provide any one of the following operations.

- Coast-to-stop
- Deceleration stop
- Control to stop

Control to stop is an essential function for horizontal and vertical conveyance. It decelerates the motor based on the torque estimated by the torque limit method, and after deceleration operation is switched to current control from torque limit, generates a holding torque and waits to apply the brake.

Figure 6 shows characteristics of this control to stop operation function. FRENIC-Multi series maintains a constant torque after hit-and-stop, and in

Fig.6 Control to stop characteristics



contrast to FVR-E11S series, motor rotational characteristics are free from vibration.

4.4 Brake signal for vertical conveyance

In vertical conveyor systems, in order to prevent work-piece from falling, a mechanical brake is usually applied to hold the work while conveyor is stopping.

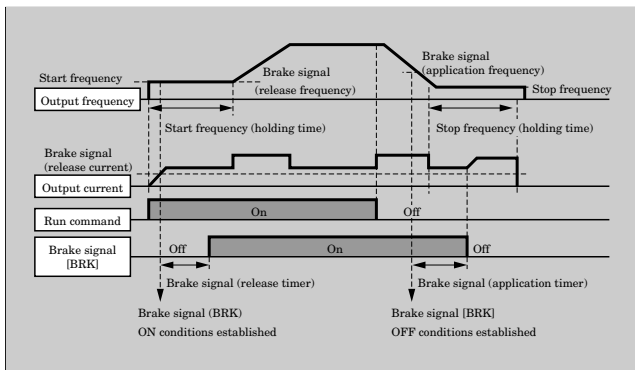
With FRENIC-Multi series, a transistor-level brake signal output is provided, and brake signal apply/release timer, braking signal released frequency/current, and brake signal injection frequency are added to function codes. Combination of these settings with starting frequency, starting frequency holding time, stop frequency, and stop frequency holding time, enable optimal system configuration that does not burden drive system or brake for vertical conveyance applications.

Figure 7 shows an example of timing chart for the brake signal.

4.5 Torque and current limiting operation

Since FRENIC-Multi series is equipped with two limiting methods of torque limiting (drive and braking), current limiting, optimal limiting operation can be selected in accordance with each system. Torque limiting regulates actual torque, therefore it is best suited for protecting drive system. Current limiting regulates output current and can be used for thermal

Fig.7 Timing chart for brake signal



protection of the motor and system, and for load limiting.

4.6 PG feedback control

For the first time in the inverter industry, Fuji has developed optional PG interface control for lower-end models, which was originally developed for high-end models. Installation of PG interface card in FRENIC-Multi series enables use of the following functions and has significantly expanded the range of applications.

(1) Speed control based on PG feedback

Since speed control is more accurate than slip compensation control based on estimated torque, and speed control based on PG feedback is expected to improve positioning accuracy of conveyance machines and measurement accuracy of measurement machines.

(2) Position control based on pulse detection

PG feedback control application to conveyance machines makes it possible to control work position. Position control signal terminals and function codes are provided so that sophisticated position control system can be configured with ease. Figure 8 shows an example of a timing chart of position control. In this example, constant feed marking system controls conveyor feed rate at constant value after detecting the passage of work piece on the conveyor.

(3) Frequency setting using pulse train

Pulse train from control device such as programmable controller can be used to set frequency. Moreover, following operation can be performed by inputting pulse signal from the PG attached to main motor.

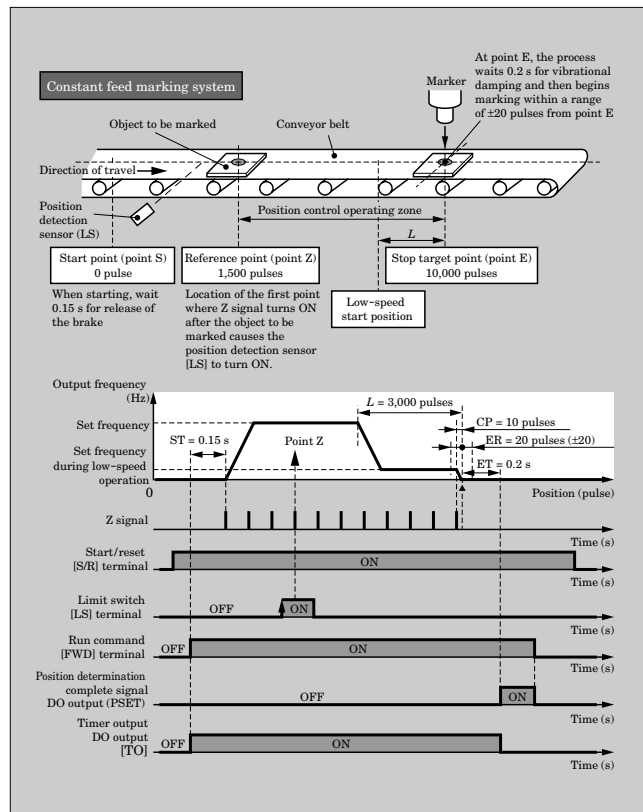
4.7 Maintenance functions

Following maintenance information of the inverter can be monitored via keypad or by data transmission.

- (1) Capacity of DC bus capacitor
- (2) Cumulative operation time of electrolytic capacitors on printed circuit board
- (3) Cumulative operation time of cooling fan
- (4) Cumulative inverter operation time

As FRENIC-Multi series was designed with attention to peripheral equipment, monitoring of the following information is additionally provided to facilitate

Fig.8 Timing chart for position control



equipment maintenance.

- Cumulative motor operation time
- Number of times motor has started

The above information provides a guideline for the user to replace consumable parts related to equipment operation. By implementing preventative maintenance, trouble-free and stable system operation can be achieved.

5. Simple Operation, Simple Wiring, Space Savings

5.1 Removable keypad

With previous FVR-E11S series, keypad was attached to the inverter unit with screws. However, with FRENIC-Multi series, the keypad can be easily removed with simple one-touch operation. Additionally, when a rear cover, which is packaged with the inverter is attached to the keypad, it can be mounted on the control panel of the enclosure, to enable remote operation. In case of remote operation, keypad and inverter connection is possible with commercially available LAN cable (straight cable for 10BASE-T/100BASE-TX) by one-touch connection.

5.2 Removable interface board

Interface board is designed to be removable in order to simplify wiring operations. Optional PG interface card and the RS-485 communication card

have similar dimensions and are installed in the same way as the standard interface board, so that various optional specifications can be supported by only replacing the standard interface board with an optional card.

5.3 Side-by-side mounting

When several numbers of inverters are used, space-saving design of control panel is allowed by the side-by-side mounting of multiple inverters (of 3.7 kW or less).

6. Conclusion

Features of high-performance and compact FRENIC-Multi series inverters have been described. All inverter models in this series are intended for use in general applications, throughout the world, and were developed by incorporating Fuji Electric's proprietary technology and techniques. In the future, Fuji Electric intends to apply its performance and functions of FRENIC-Multi series to various machine and equipment, and to expand the range of applications.





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