FRENIC-Eco Series Inverters for Fan and Pump Applications

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1. Introduction

Reflecting the growing awareness of global environmental conservation throughout the world in recent years, and as represented by the enforcement of Kyoto Protocol, there is a demand for energy savings and conservation in order to reduce CO_2 emissions that cause global warming. In fan and pump applications in heating, ventilation and air-conditioning systems (HVAC) and the like, substantial energy savings have been realized through the use of inverters. In such applications, the use of inverters is already widespread, and marketplace requirements for improved functionality and higher performance have recently increased.

In response to those requirements, newly developed FRENIC-Eco series was specifically designed for fan and pump applications, and realizes improved ease-of-use with the most suitable functions, performance and options for use with fans and pump, as well as compact size and low cost by optimized design using semiconductor devices in the main circuit. Moreover, since FRENIC-Eco series is environmentally friendly and complies with standards for example designed for long-service life and low noise, and conforming to EU's RoHS directive*1, it is positioned as global product that can be used throughout the world.

This paper describes the features of FRENIC-Eco series.

2. Abundant Model Varieties

Figure 1 shows the appearance of FRENIC-Eco series, and Table 1 lists its model varieties.

To provide wide range of capacities for use in applications ranging from home-use pumps to ventilation systems in tunnels, 3-phase 200 V series from 0.75 to 75 kW and 3-phase 400 V series from 0.75 to 220 kW were developed as standard models. In addition to these standard models, a series with built-in DC reactor for suppressing harmonics in power supply, a series with built-in electromagnetic compatibility (EMC) filter for reducing electromagnetic noise, and a waterproof (IP54) series for use in wet environments (such as pump applications) have also been developed as semi-standard models.

To simplify maintenance, Fuji Electric has also developed inverter support loader software that enables function code setting, operation monitor, test run, and the like on PC.

To improve ease of use, optional interface cards such as LONWORKS*2, DeviceNet*3, RS-485, and relay output as well as, optional multi-function keypad

Fig.1 Appearance of FRENIC-Eco series

Table 1 Variety of FRENIC-Eco series models

Item	Varieties	
Standard Type	3-phase 200 V	0.75 to 75 kW (90 to 110 kW)
	3-phase 400 V	0.75 to 220 kW (280 to 500 kW)
DC reactor (DCR) built-in type	3-phase 200 V	0.75 to 75 kW
	3-phase 400 V	0.75 to 75 kW
EMC filter built-in type	3-phase 200 V	0.75 to 15 kW
	3-phase 400 V	0.75 to 15 kW
Waterproof type (IP54 enclosure)	3-phase 200 V	0.75 to 45 kW
	3-phase 400 V	0.75 to 90 kW

( ) are intended to be lineup in series.

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

having built-in copying function with improved operation and display capabilities, and external cooling attachment moving rear heat source to outside the control panel to reduce panel size have been developed.

3. Environmental Design

3.1 Energy-savings operation function

Previous energy-savings operation function used a control method that minimized motor loss in accordance with load condition. Newly developed FRENIC-Eco series, however, utilizes a new control method that minimizes both amount of electric power consumed by the inverter itself (inverter loss) and the motor loss. Figure 2 compares characteristics of "inverter + motor" efficiency vs. motor output when using previous method, new method of energy-savings operation, and no energy-savings operation. New method is capable of achieving energy savings in several percent greater than that in previous method.

3.2 RoHS compliance

Even though general-purpose inverters are presently excluded from the EU's RoHS directive, FRENIC-Eco series is steadily advancing toward conformance with RoHS directive in consideration of growing environmental awareness in the marketplace.

3.3 Noise reduction including peripheral devices

By insulated gate bipolar transistor (IGBT) switching in main circuit and field-effect transistor (FET) switching in control power supply, inverter generates conducted noise that travels through stray capacitance with respect to ground and radiated noise that travels as electromagnetic waves, and these may cause incorrect operation in other peripheral devices. FRENIC-Eco series implements the following measures to reduce noise generation.

(1) Reducing voltage fluctuation (dv/dt) of main circuit's IGBT
(2) Use of a structure that cuts off noise conduction path of control power supply FET
(3) Use of a structure that reinforces chassis ground shield

Additionally, the product line has been expanded to include semi-standard series having built-in EMC filter, which conforms to EU's EMC standard (EN61800-3).

3.4 DC reactor built-in type

FRENIC-Eco models with built-in DC reactor (0.75 to 75 kW) are added as to semi-standard series. Since models of motor ratings 22 kW and below also contain built-in zero-phase reactor and capacitive filter, they conform to 2004 version of "Public Building and Construction Standards" issued by Japan's Ministry of Land, Infrastructure and Transport. Models of motor ratings 30 kW and above can conform to that standard by adding zero-phase reactor.

3.5 Easier maintenance

In order to reduce maintenance labor involved in replacing parts of already installed equipment, all limited life parts used in inverter are designed to have an optimal layout (heat countermeasure) and selected from long life parts, to achieve longer design service life. Table 2 lists design service life of various parts in case of 40°C inverter ambient temperature and 80 % load condition of inverter rated current.

Moreover, by storing and displaying following maintenance information to keypad or by sending it to upper-level system, enhance of equipment reliability and simple maintenance can be performed.

- ○ capacitance of main circuit
- ○ cumulative operating time of electrolytic capacitors on printed circuit board
- ○ cumulative operating time of cooling fan
- ○ cumulative operating time of inverter
- ○ cumulative operating time of motor
- ○ number of times started

3.6 Easy replacement of cooling fan

As cooling fan used in FRENIC-Eco has long life, it

*2: LONWORKS is a registered trademark of Echelon Corp. in the US and other countries.

*3: DeviceNet is a registered trademark of the Open DeviceNet Vender Association (ODVA).

Fig.2 Efficiency with and without energy-savings operation function

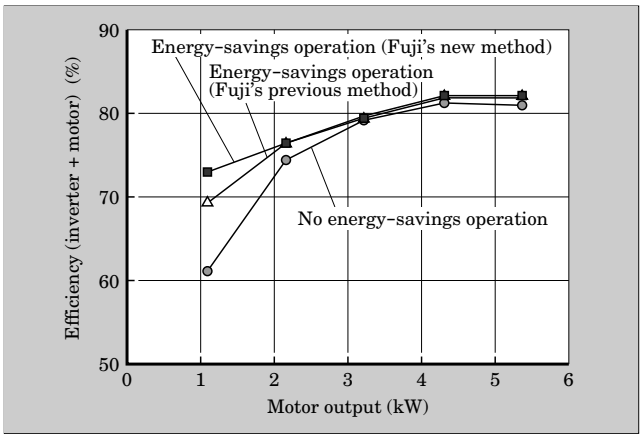


Table 2 Design service life of aging parts

Part name		Design service life
Main circuit capacitor		10 years
Electrolytic capacitor on the printed circuit board		10 years
Cooling fan	30 kW or below	10 years
	37 kW or above	7 years

Load condition : 80 % of output rated current
Ambient temperature : 40°C

has low likelihood of requiring replacement. Moreover, its structure allows easy replacement in the case of failure.

7.5 to 30 kW models can be replaced with simple one-touch operation, and 37 kW and larger models can be replaced from the front panel of the inverter, without removing inverter from control panel. Figure 3 shows cooling fan replacement procedure.

4. Optimal Functions for HVAC

4.1 Current output of analog monitor

Previously, information such as output frequency or output current was 0 to 10 V analog voltage output signal. With newly developed FRENIC-Eco series, such information can also be output as a 4 to 20 mA current signal, which is commonly used as instrumentation signal. Therefore, even in cases where control line wires are long and 4 to 20 mA is required, there is no need for an external device such as a voltage-current converter.

4.2 PID control function

In fan and pump applications, tasks such as control of temperature, flow rate, and pressure are performed by proportional, integral, derivative (PID) function of inverter or by an external PID regulator. Since newly developed FRENIC-Eco series is equipped with enhanced PID control function that supports multiple mode of manual speed commands, alarm output function, low water-flow stop function, and an anti-reset windup function that prevents PID control overshoot, it is suitable for various fan and pump applications. Figure 4 shows a block diagram of PID control function.

4.3 Commercial switching sequence

For fan and pump applications, inverter often operates on commercial power supply mode at or near the commercial frequency, and drives in cases where its frequency is required less than commercial frequency, to improve efficiency. Moreover, in cases where it is not possible to stop equipment that is using inverter, operation may be continued by changing over to commercial operation when inverter issues an alarm stop or fails.

In these cases, the changeover between commercial and inverter operation was traditionally implemented by external sequence control circuit outside the inverter. Since FRENIC5000G11S/P11S series housed a portion of that external circuitry inside the inverter, it simplifies external sequence circuit. As FRENIC-Eco series additionally provides automatic changeover internal sequence to commercial operation in response to an alarm stop initiated by inverter protection function, it enables further simplification of external circuitry.

4.4 Pick-up function

FRENIC-Eco series is equipped with pick-up function that uses high-speed current control function same as in FRENIC-Mini series. With this function, even when idling fan, turning by natural convection or the like, is started by inverter, smooth pick-up is possible regardless of motor's direction of rotation.

Figure 5 shows characteristics of idling motor started by pick-up function.

4.5 Power monitor function

Monitoring information of amount power consumption (kW), cumulative power consumption (kWh) and cumulative power rates (price in local currency per

Fig.3 Replacement of cooling fan (7.5 to 15 kW)

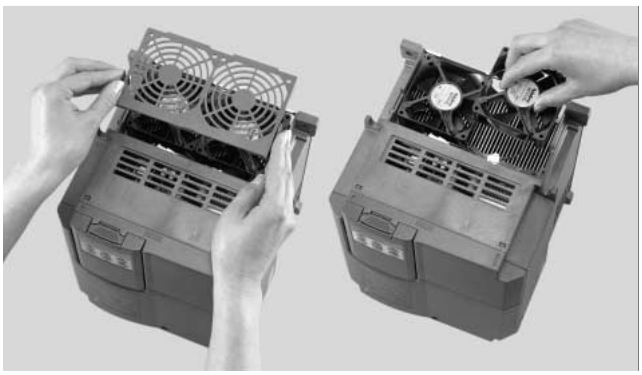


Fig.4 Block diagram of PID control

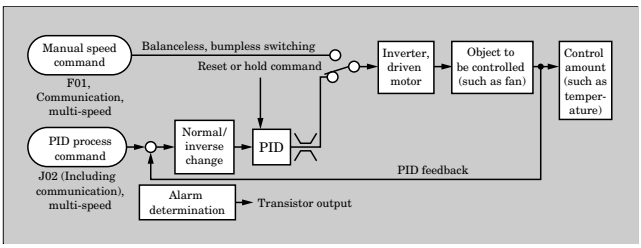
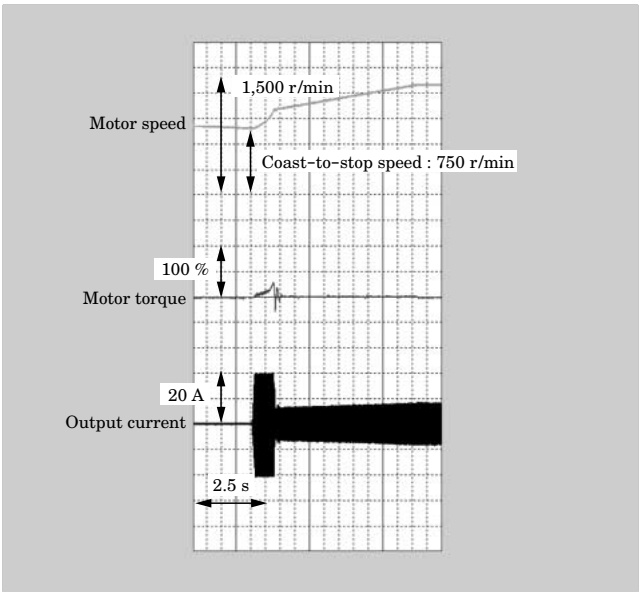


Fig.5 Characteristics of a motor started by the pick-up function



kWh) is displayed on keypad, or is transmitted to an upper-level system to enable power monitoring of whole system consisting of other devices such as inverters.

4.6 Analog input monitor function

By analog input monitor function provided in FRENIC-Eco series, where signals such as flow rate or temperature in air conditioning equipment are connected to the inverter's analog input pins, and conversion factors to convert those signals into physical values such as temperature and pressure are preset, those values can be displayed synthetically on the inverter's keypad or transmitted to an upper-level system, without requiring the use of dedicated flow meters or pressure gages.

5. Options

5.1 Multi-function keypad

FRENIC-Eco series is provided with a keypad as standard equipment, and this keypad provides the capability for remote operation. As an option, multi-function keypad featuring a backlight liquid crystal display (LCD) and large 5-digit 7-segment light-emitting diode (LED) display is also available. Figure 6 shows the appearance of this multi-function keypad. Special features of multi-function keypad are listed below.

(1) Can be attached to inverter unit instead of standard keypad (allows remote operation via a LAN cable)
(2) A "REM/LOC" switch key makes it possible to switch between remote operation via external operation commands, or local operation with inverter unit
(3) Can store and read out function codes for up to 3 inverters
(4) Communication debug function enables testing and verification of transmission data

Fig.6 Appearance of multi-function keypad

(5) Capable of information display up to the last 4 generated alarms, and capable of setting and verifying function code data

5.2 Network options

To communicate with upper-level controller, Fuji Electric provides interface cards that support LONWORKS and DeviceNet. Since LONWORKS is well suited for building networks, it realizes flexible system

Table 3 Functions of inverter support loader software

Name of function	Description
Function code setting	Reading, editing and comparison of function code data, term searches, user settings, etc.
Operation monitor	I/O monitor, system monitor, alarm monitor, meter display
Multi-monitor	Simultaneous monitoring of two or more inverters
Test run	○ Run/stop and frequency setting can be entered at the loader for starting test run. ○ Monitoring of the operation status (such as the output frequency)
Real-time trace	Arbitrary data can be monitored in real time.
Other	Communications setting, connection setting

Fig.7 Function code setting screen

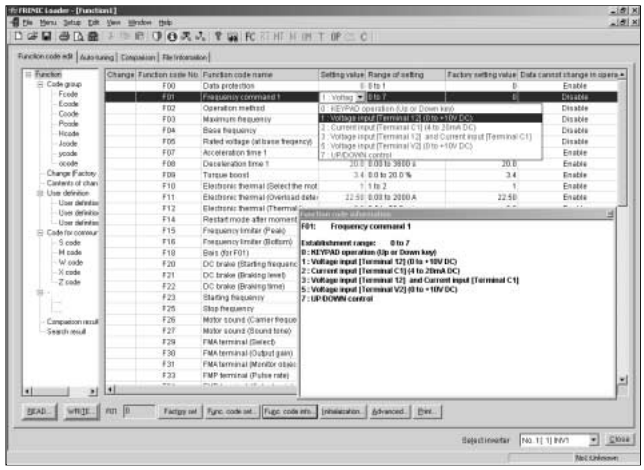
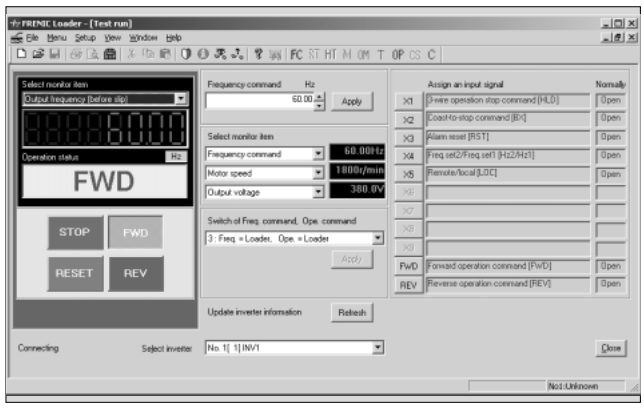


Fig.8 Test run screen



for building's internal control such as air conditioning. In the future, Fuji Electric intends to provide interface cards that support various other networks such as PROFIBUS-DP*4 and CC-Link*5.

5.3 Inverter support loader software

Inverter support loader software that runs on Windows*6 is available to support function code setting, operation monitoring, test runs and the like.

Table 3 lists function of the inverter support loader software, Fig. 7 shows an example screenshot of function code setting, and Fig. 8 shows an example screenshot of test run.

6. Main Circuit Technology

FRENIC-Eco series uses suitable main circuit semiconductor devices matched to variable torque characteristic of fan and pump applications.

Moreover, smaller size and lower cost are realized through the use of newly developed low-thermal resistance metal circuit board (7.5 to 15 kW), where ceramic circuit board was used internally in the past, and the use of power module that integrates the converter unit and inverter unit previously separated.

Additionally, electromagnetic analysis and simulation techniques were used to design internal bus bar that connects main circuit's IGBT and capacitor. Since as a result, shape of the internal bus bar and layout of IGBT device and the main circuit's capacitor are optimized, it enables inductance reduction of the internal wiring and a uniform distribution of current, and realization of more compact size and lower cost for snubber circuit and main circuit's capacitor.

7. Conclusion

Features of FRENIC-Eco series inverter for fan and pump (variable torque load) applications have been described above. These inverter models feature enhanced functions and performance for fan and pump applications in order to achieve significant energy savings, and are specifically-designed products that will develop further use of inverters. Looking ahead to future trends of fan and pump market, Fuji Electric intends to continue to create products that satisfy the needs of the marketplace.

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*4: PROFIBUS-DP is a registered trademark of the PROFIBUS User Organization.

*5: CC-Link is a registered trademark of the CC-Link Association.

*6: Windows is a registered trademark of Microsoft Corp. in the US and other countries.