FRENIC-Mini Series Compact Inverter

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1. Introduction

General-purpose inverters are utilized in a wide range of applications for such uses as increasing the energy efficiency of fan pumps and increasing the labor saving and automation of industrial equipment. General-purpose inverters range from a series for simple variable-speed use to a series that utilizes sophisticated vector control, and are selected according to the required performance and functionality of the application.

The new developed FRENIC-Mini Series was designed to achieve compact size and low price, and has realized a level of performance and functionality at a low price, suitable not only for simple variable-speed use, but also for applications such as conveyance and transportation machinery which had formerly required top-tier models. Moreover, through environmental considerations such as the noise reduction and the partial adoption of lead-free solder as well as improved maintainability and longer life, this series was conceived to be a global product that can be used widely throughout the world.

Features of the FRENIC-Mini Series are introduced below.

Fig.1 External view of FRENIC-Mini Series

2. Wide Variety of Models

Figure 1 shows the external view of the FRENIC-Mini Series. The newly developed FRENIC-Mini Series is the successor to the former FVR-C11 Series and has kept the same external dimensions.

In consideration of suitability for global markets, a 3-phase 400 V series, which did not exist for former models, has been added.

Moreover, in order to cover various customer applications, a built-in EMC (electromagnetic compatibility) filter type, built-in braking resistor type, and a type compatible with RS485 communication have been

Fig.2 Built-in EMC filter type and built-in braking resistor type

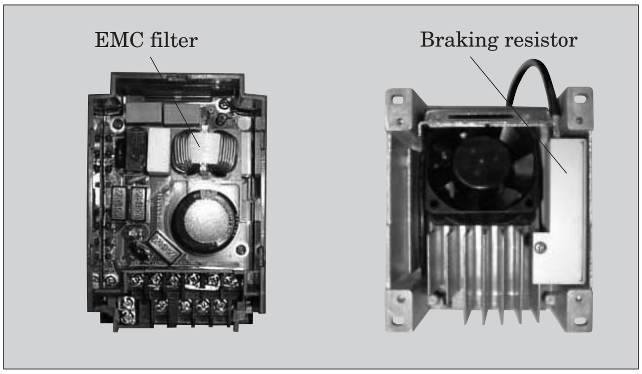


Table 1 Variety of FRENIC-Mini Series models

Item		Varieties	
Power supply voltage	1	Single-phase 100 V	0.1/0.2/0.4/0.75 kW
	2	Single-phase 200 V	0.1/0.2/0.4/0.75/1.5/2.2 kW
	3	3-phase 200 V	0.1/0.2/0.4/0.75/1.5/2.2/3.7 kW
	4	3-phase 400 V	0.4/0.75/1.5/2.2/3.7 kW
EMC filter	1	None	All models
	2	Built-in type	All models except single-phase 100 V
Built-in braking resistor	1	None	All models
	2	Built-in type	1.5/2.2/3.7 kW (3-phase 200 V/400 V)
RS-485 compatible	1	None	All models
	2	Same package	3-phase 200 V/400 V

: Additional models and functions

developed as quasi-standard models in this series. (See Fig. 2.) In the past, these features had only been available as options.

Table 1 lists the model varieties.

In contrast to the former series which had 17 models, the FRENIC-Mini Series has been expanded greatly to 58 models to accept wide range of customer needs.

Just increasing the number of models would lead to a drastic increase in the types of component parts. However, because the FRENIC-Mini Series was designed to standardize the common components, and function allocation was optimized for structural units such as the control board and power supply board, this series was realized with almost no increase in the number of such units.

3. Technology for High Performance

Simple torque vector control was developed to enhance the torque characteristics of small-capacity general-purpose inverters, and to provide automatic energy-saving, stall prevention and other functions that are demanded by the market. As a result of the ratification of the Kyoto Protocol, an international accord to thwart global warming, the energy-saving effect of inverters has been attracting attention, and even small capacity inverters are being provided with energy-saving functions.

Simple torque vector control has enabled powerful operation to be realized at low-speed and made possible the application of inverters to conveyance and transport machinery and mixers. Moreover, the energy-saving function has made it possible for fan pump applications to achieve even higher efficiency. Figure 3 shows a control block diagram.

3.1 Simple torque vector control

An induction motor flux estimator operating by means of *V/f* control enables the constant application of an appropriate voltage, regardless of the load, and the generation of smooth, large torque even at low-speed. Consequently, a starting torque of 150 % (at 5 Hz) was achieved.

Figure 4 illustrates the speed vs. torque characteristics. Slip compensation control enables highly responsive and stable operation to be achieved in response to load fluctuations (step loads).

Figure 5 illustrates the dynamic characteristics during slip compensation.

Moreover, voltage control performance was enhanced and motor instability at low speed was improved to approximately 1/2 compared to our former models. Figure 6 illustrates the dynamic characteristics of motor instability at low speed.

3.2 Automatic energy-saving function

Torque is calculated from estimated values of the flux estimator of Fig. 3 and from the induction motor current. Because an appropriate voltage can be applied to the induction motor in accordance with the

Fig.3 Control block diagram

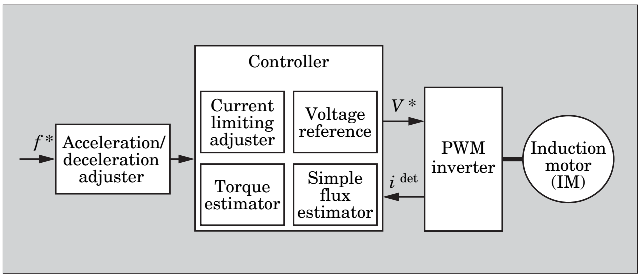


Fig.4 Speed vs. torque characteristics

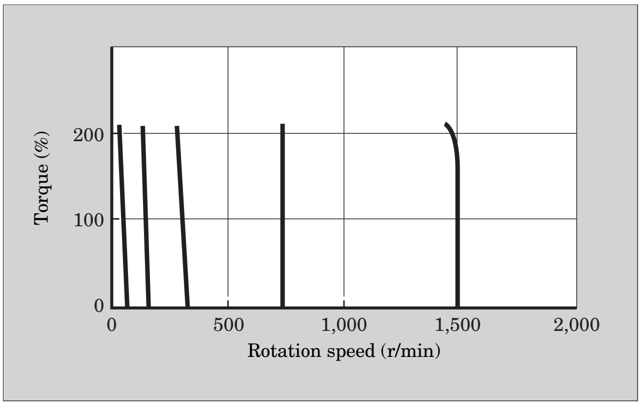


Fig.5 Dynamic characteristics during slip compensation

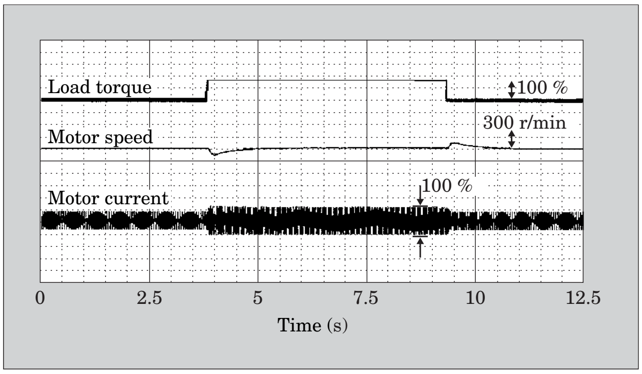


Fig.6 Dynamic characteristics of motor instability at low speed

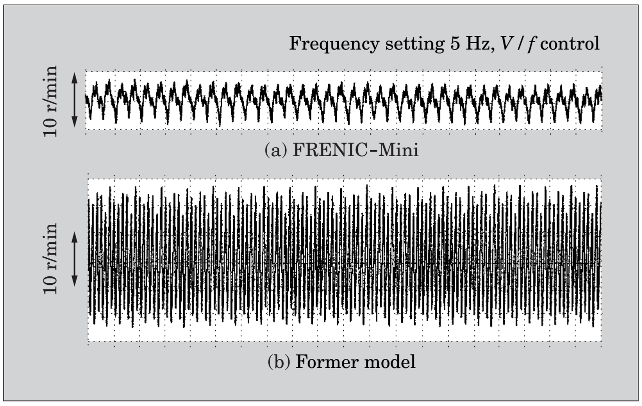


Fig.7 Energy-saving characteristics

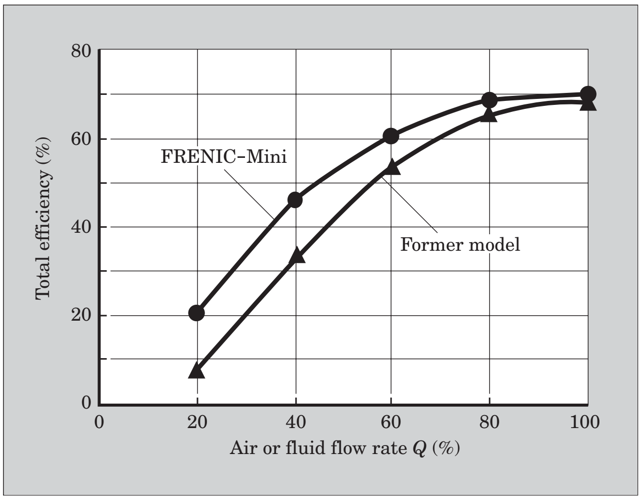
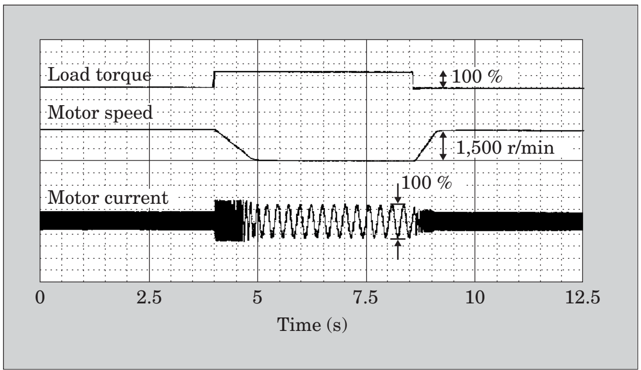


Fig.8 Dynamic characteristics of current limiting function



load, the induction motor efficiency can be kept at its optimal state. Figure 7 illustrates the energy-saving characteristics.

3.3 Highly responsive current limiting function

A highly responsive current limiting function is provided so that operation can continue at impact load torque without tripping. This function and the slip compensation control described in paragraph 3.1 have advanced the application of inverters to conveyance and transportation machinery.

Figure 8 illustrates the dynamic characteristics of the current limiting function.

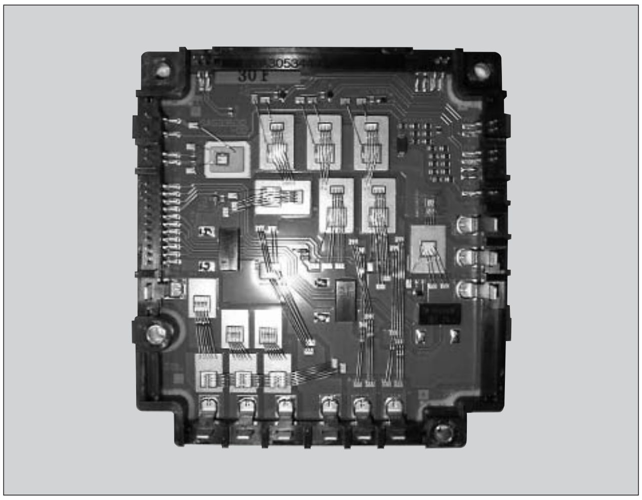
4. Environmental Considerations

4.1 Reduction of EMC noise

The noise generated by an inverter may cause other devices to malfunction in some cases, and for this reason, the reduction of generated noise is an important issue.

The main cause of inverter generated noise is the switching of the IGBT (insulated gate bipolar transistor) element and of the control power supply FET (field effect transistor) in the main circuit. Other types of noise include conductive noise that is transmit through

Fig.9 IGBT module using lead-free solder



the stray capacitance between modules and wiring and ground, and radiative noise generated by electromagnetic waves.

Former inverter models have implemented noise reduction measures, for example, by lowering the voltage change rate *dV/dt* of the IGBT in the main circuit.

The FRENIC-Mini Series employs such noise-reducing schemes as a structure that cuts off the transmission path for the FET of the control power supply.

Moreover, in former models, a noise reducing EMC filter was an optional external attachment. But an internal EMC filter has been developed for the FRENIC-Mini Series in compliance with the European EMC standard (EN61800-3).

4.2 Use of lead-free solder

Lead is an environmentally harmful material and its use will be restricted in Europe beginning in 2006. Therefore, it will not be possible to use lead in the future.

An IGBT module that utilizes lead-free solder was developed for the new FRENIC-Mini Series. (See Fig. 9.)

The use of lead-free solder enables better thermal resistance and power cycle characteristics than in the past.

5. Enhanced Maintainability

5.1 Longer service life of cooling fan

The inverter contains internal parts which have finite service lives, such as a cooling fan, DC bus capacitor, electrolytic capacitor on the printed circuit board, etc. It is recommended that these parts be replaced periodically.

In former models, the recommended standard replacement interval was 3 years for the cooling fan, 5 years for the DC bus capacitor and 7 years for the

Table 2 Criteria for judging part replacement based on "maintenance information"

Part to be replaced	Criteria
DC bus capacitor	Capacitance is 85 % or less of value when shipped
Electrolytic capacitor on printed circuit board	61,000 or longer cumulative run time
Cooling fan (applicable motor rating : 1.5 to 3.7 kW)	61,000 or longer cumulative run time

electrolytic capacitor on the printed circuit board. The cooling fan had the shortest service life.

However, to use an inverter for 10 years, for example, would require that the cooling fan be replaced 3 times, resulting in an increase in the frequency of maintenance work.

The FRENIC-Mini Series uses a long-life cooling fan (designed for a lifespan of 7 years at 40°C) having a standard replacement interval that is the same or longer than that of the DC bus capacitor. This reduces the amount of replacement work.

5.2 Service life diagnosis function

The DC bus capacitor has a finite service life, and its electrostatic capacity decreases as the remaining lifespan becomes shorter. This decrease in capacitance varies widely according to usage conditions such as the ambient temperature and load conditions and cannot be determined solely from the number of years of usage.

In order to judge when part replacement is necessary, the FRENIC-Mini Series automatically performs an internal computation of the discharge time of the DC bus capacitor when the power is turned off and displays the percentage decrease from the initial value.

Moreover, cumulative run time for each of the other finite service life components, the electrolytic capacitor of the control power supply and the cooling fan, may be referenced from the "maintenance information" via the keypad.

Table 2 shows the criteria for judging the part replacement of each finite service life component.

Further, when these finite service life components reach the criteria of Table 2, they are judged to have reached the end of their useful life and this decision may be output from a transistor as a lifespan forecast signal.

6. Advanced Functionality

6.1 Keypad function

The keypad of the former FVR-C11 series was chiefly for setting monitor functions such as frequency and functions that determined inverter operation, but the keypad of the FRENIC-Mini Series utilizes a menu mode to dramatically increase the quantity of displayable information, which includes maintenance and alarm information.

Table 3 Displayable information in the menu mode

Menu No.	Menu	LED display	Description
1	Function code, Data setting	1.F_ _ to 1.y_ _	Sets function codes and data
2	Function code, Data verification	2.rEF	Displays only function codes that have been changed from their factory defaults
3	Drive monitoring	3.oPE	Displays operating information required for maintenance or testing
4	I/O checking	4.i_o	Displays external interface information
5	Maintenance information	5.CHE	Displays maintenance information including cumulative run times
6	Alarm information	6.AL	Displays alarm history and the operation information at the time when the alarm occurred
7	Data copying (requires a remote keypad)	7.CPy	Reads/writes/verifies function codes and data

Table 3 lists the contents corresponding to each menu number in the menu mode.

In addition to the functionality of the FVR-C11 Series, the FRENIC-Mini Series has added individual menus for function code and data verification, drive monitoring, I/O checking, maintenance information, and alarm information.

The drive monitoring function allows the display of 10 types of data including output current, the maintenance function allows the display of 12 types of data such as cumulative run time, and the alarm information function allows the display of 19 types of data including the output frequency generated when an alarm occurs.

Moreover, in contrast to the former series, which was capable of storing only information from the prior alarm occurrence, the FRENIC-Mini Series is able to store information from the past four alarm occurrences. Such information is useful for analysis of the event when trouble occurs.

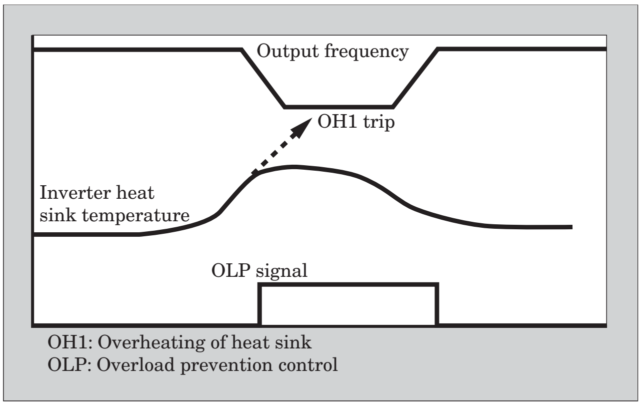
In addition to the standard keypad, a remote keypad is provided optionally. Also, LEDs (light emitting diodes) for unit display and to indicate the operating status, and a data copying function have been added to the standard keypad.

6.2 Overload prevention control function

In an application where operation is continuous, such as a fan pump, it may be undesirable in some cases to halt operation to protect the equipment, even when the inverter becomes overheated due to load and ambient temperature conditions.

The overload prevention control function is a newly

Fig.10 Overload prevention control function



developed function that, as shown in Fig. 10, operates before the inverter trips due to cooling fan heating or inverter overloading, to automatically lower the output frequency of the inverter in order to avoid tripping.

7. Conclusion

Features of the FRENIC-Mini Series of compact inverters have been presented above.

For the highly price-competitive inverter class of 3.7 kW and below, the development of the FRENIC-Mini Series has broadened the range of possible applications to include uses that require one-class higher performance, and global applications are anticipated.

Fuji Electric will continue to actively incorporate new technology and functions, and will strive to develop even better products for the future.