“FRENIC-MEGA (G2) Series” High-Performance, Multifunctional Inverters

TAKAMI, Yuichi* **YAYAMA, Takahiro*** **YAMAZAWA, Kotaro***

ABSTRACT

General-purpose inverters have been recently expanded to various applications, and in addition to enhancing control performance, they are being required to improve energy saving, environment resistance, and preventive maintenance. Our newly developed “FRENIC-MEGA (G2) Series” improves control performance through faster processing and advancements in our proprietary motor control technology. It also enhances energy saving capability supporting PM motor drive as standard and environmental resistance complying with JIS C60721-3-3 and Class 3C2 of IEC 60721-3-3. Its functions for traceback, predicting product life for maintenance, and customizable logic allow it to be used for various applications.

1. Introduction

In recent years, the performance and function of general-purpose inverters have greatly improved, and their application versatility is on the increase, ranging from simple variable speed drives to machine tools and horizontal or up-down conveyance machinery. For these applications, Fuji Electric has offered the “FRENIC-MEGA (G1) Series.” To respond to user requests for further improvements in performance and function, we have developed the “FRENIC-MEGA (G2) Series” high-performance, multifunctional inverters.

2. Overview of “FRENIC-MEGA (G2) Series”

Figure 1 shows the external appearance of the FRENIC-MEGA (G2) Series, and Table 1, the model line-up. This Series offers various communication options, which look ahead to Internet of Things (IoT), and also expanded functions corresponding to FA systems, while securing the compatibility with the FRENIC-MEGA (G1) Series, which are the conventional models.

Fig.1 “FRENIC-MEGA (G2) Series”

Table 1 “FRENIC-MEGA (G2) Series” model line-up

Classification of model	Power supply voltage	Output
Basic	Three-phase 200 V	0.4 to 90 kW
	Three-phase 400 V	0.4 to 630 kW
EMC filter built-in	Three-phase 200 V	0.4 to 90 kW
	Three-phase 400 V	0.4 to 630 kW
DC reactor built-in	Three-phase 200 V	30 to 55 kW
	Three-phase 400 V	30 to 55 kW
Communication option	DeviceNet*1, CC-Link*2, PROFIBUS-DP*3 T-Link, SX-Bus, EtherNet/IP*1 PROFINET-RT*3, MODBUS*4 TCP EtherCAT*5, CANopen*6	

*1 DeviceNet and EtherNet/IP are trademarks or registered trademarks of ODVA, Inc.
*2 CC-Link is a trademark or registered trademark of Mitsubishi Electric Corporation.
*3 PROFIBUS-DP and PROFINET-RT are trademarks or registered trademarks of PROFIBUS User Organization.
*4 MODBUS is a trademark or registered trademark of Schneider Automation,Inc.
*5 EtherCAT is a trademark or registered trademark of Beckhoff Automation GmbH.
*6 CANopen is a trademark or registered trademark of CAN in Automation.

Furthermore, the models for the applications working under heavy breaking loads, such as up-down conveyance machinery, are available as a built-in brake circuit type as standard and have increased the output to 55 kW (200-V model)/75 kW (400-V model) from the conventional 22 kW. In addition, the upper limit of the operating ambient temperature has been increased to 55°C from the conventional 50°C. Moreover, meeting

* Power Electronics Systems Industry Business Group, Fuji Electric Co., Ltd.

the environmental resistance criteria of class 3C2*1, JIS C60721-3-3/IEC 60721-3-3, the inverters are equipped with improved maintenance functions, including traceback and life forecast of the built-in insulated gate bipolar transistor (IGBT) module.

3. Performance and Functions of "FRENIC-MEGA (G2) Series"

3.1 Control performance

Through the use of the ever-faster micro controller unit (MCU) and the further advance of Fuji Electric's own motor control technologies that have been cultivated, the FRENIC-MEGA (G2) Series has achieved a current response of 1,000 Hz or more and a speed response of 200 Hz or more as shown in Figs. 2 and 3. They both are twice as fast as the conventional responses.

This reduces the effects of disturbance on the machine and enables us to respond to higher performance requirements. These improvements contribute to the reduction of travel vibration during the up-down transportation of elevators and the like and also to the stabilization of the processing quality of wire drawing machines, printers, etc.

The FRENIC-MEGA (G2) Series has achieved higher motor control technology, as following examples.

(1) Zero-speed torque in the sensorless control of PM motors

The sensorless vector control of conventional permanent magnet synchronous motors (PM motors) is not capable of stable speed estimation at low speeds and it is thereby difficult to generate torque at zero speed. For this reason, we had a challenge in product applicability except for fans, pumps and such other equipment that do not require drive in the low-speed region. To solve this, we have adopted a new control method, which makes the speed estimation in the low-speed region possible by superimposing a high frequency onto the fundamental frequency used for motor drive. This method has enabled a torque generation of 100% or more in the very-slow and zero-speed regions as shown in Fig. 4 and has increased the applicability to low-speed conveyors, etc.

(2) Great reduction in the auto searching*2 time of induction motors

In the induction motor, the residual voltage*3,

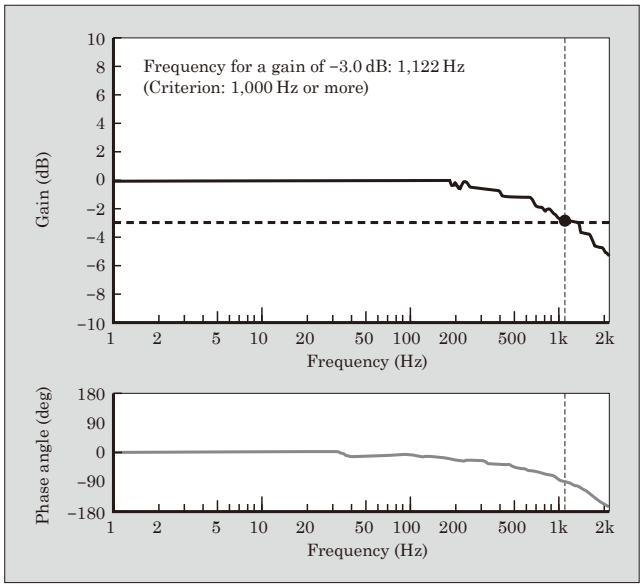


Fig.2 Current responsibility

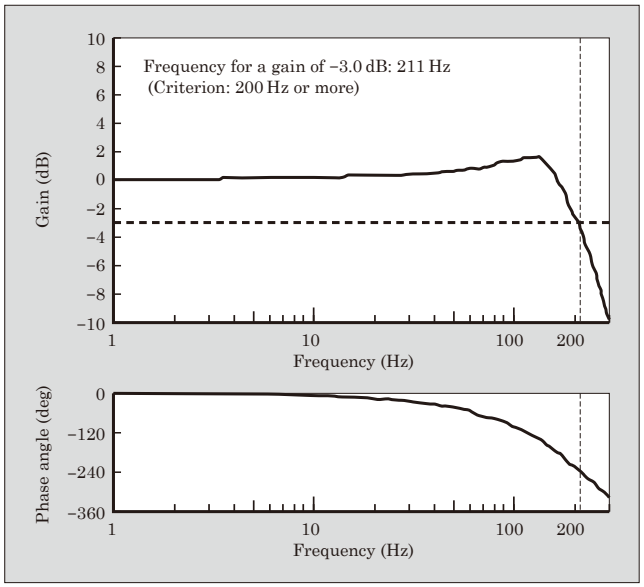


Fig.3 Speed responsibility

*1 Class 3C2: Locations with normal levels of contaminants experienced in urban areas with industrial activities scattered over the whole area or with heavy traffic

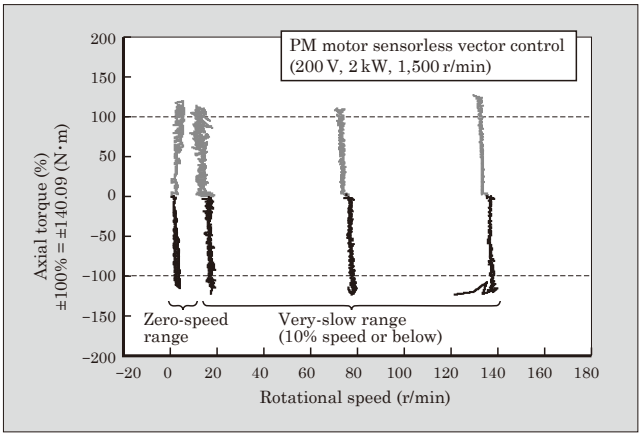


Fig.4 Speed-torque characteristics in the low-speed region

*2 Auto searching: Function that automatically searches for idling motor speed and carries out a restart

*3 Residual voltage: Voltage induced on the motor's winding side due to the residual magnetic flux of the motor's iron core and the motor's rotational speed Residual voltage is higher when the number of motor rotations is higher.

which occurs in the motor when an instantaneous power interruption or such causes the inverter output to stop when in operation, attenuated by being consumed in the motor's secondary conductor (squirrel-cage). Generally, this residual voltage is more resistant to attenuate when motor capacity is greater. The conventional method of auto searching is susceptible to residual voltage and so needed a wait until the residual voltage has sufficiently attenuated. With the application of PM motor control technologies, we have developed a new method, in which a zero-voltage condition is produced two times within a very short period of time when the residual voltage, which occurs immediately after inverter output shuts off by an instantaneous power interruption, is still high. We can estimate the rotational speed by detecting the changes in short-circuit current vector during the process. As shown in Fig. 5, this method has achieved the reduction of wait time before the start of speed estimation and also the reduction of time for frequency stabilization by improving the accuracy of speed estimation results. The time for completing a auto searching process is thereby shortened to 1.5 s, which is faster than the conventional result of 11 s, reducing the downtime caused by an instantaneous power interruption. In addition, to give due consideration to ensuring the operation of auto searching, this control method switch back to the conventional method automatically when the short-circuit current after the application of zero voltage does not flow sufficiently because of a quick attenuation of residual voltage.

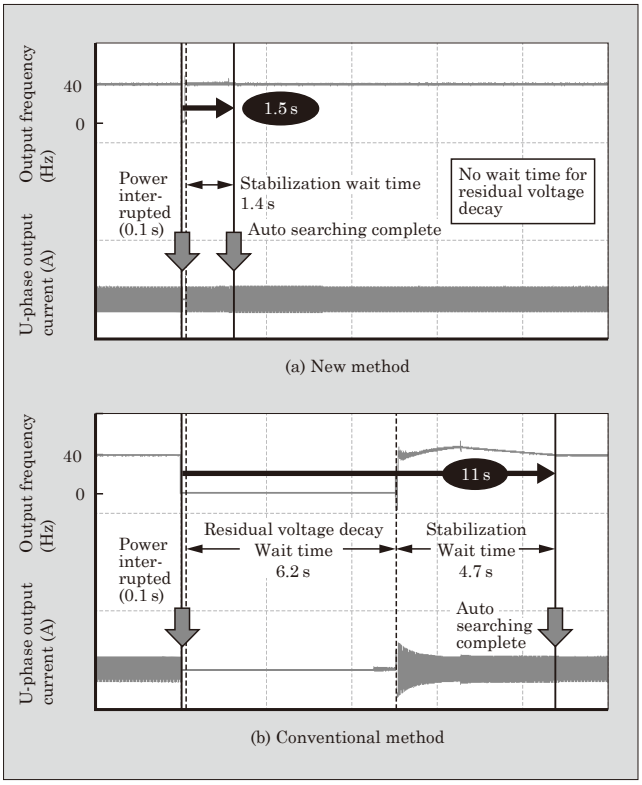


Fig.5 Auto searching time comparison (400 V, 315 kW)

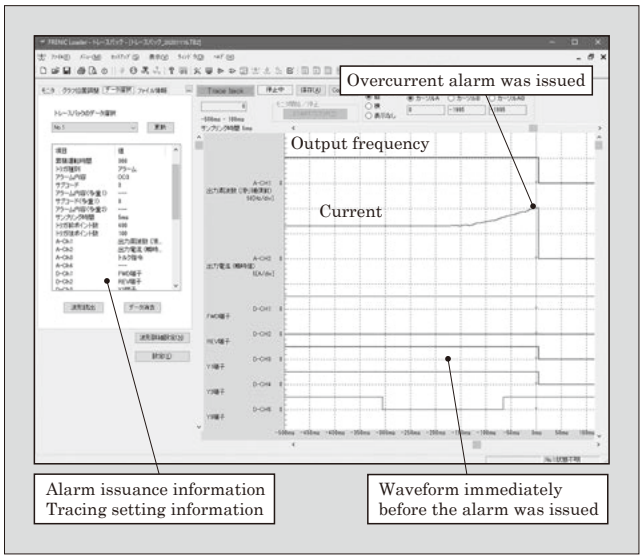


Fig.6 Traceback function using the PC support tool "FRENIC-Loader 4"

3.2 Traceback function

We have included the traceback function to facilitate the failure analysis when alarms occur. The traceback function retrieves and records the chronological data of inverter statuses before and after each alarm is issued. By the combined use of the new multifunction keypad (see Chapter 4), data with dates added can be saved up to 100 data items in a microSD*4 card. Saved data can be read using the PC support tool "FRENIC-Loader 4" (download free of charge from Fuji Electric's web site*5). Figure 6 shows an example of waveforms recorded immediately before and after an alarm was issued using the traceback function. As this example shows, users can later on analyze the information recorded before and after alarms are issued.

3.3 Preventive maintenance and predictive maintenance functions

As shown in Table 2, the FRENIC-MEGA (G2) Series offers enriched functions for preventive maintenance and predictive maintenance as well as the newly added functions for predicting the lifetime of the IGBT module and for issuing the alerts for cooling capability declines.

(1) Life forecast of the IGBT modules

The lifetime of the IGBT modules, which are important components of the inverter, is estimated based on the inverter's operating conditions (cumulative totals of load, temperature, etc.) to alert the user of the need to perform maintenance before the lifetime is

*4 microSD is a trademark or registered trade mark of SD-3C LLC.

*5 URL for the free download of "FRENIC-Loader 4" from Fuji Electric's web site (available in Japanese) https://www.fujielectric.co.jp/products/inverter/frenic-megag2/download/

Table 2 Preventive maintenance and predictive maintenance functions

Classification	Function
Preventive maintenance	Cumulative operation time
	Time of voltage application to main circuit capacitor
	Time of voltage application across capacitors on the printed circuit board
	Operation time of cooling fan
	Cumulative operation time of motor
	Motor activation count
Predictive maintenance	Diagnosis of main circuit capacitor capacitance
	IGBT lifetime prediction (New)
	Alerts for cooling capability declines (New)

reached.

(2) Alerts for cooling capability declines

The decline in the cooling capability of the inverter, which is caused by clogged cooling fins, etc., is estimated based on the in-inverter temperature measured by the temperature sensor to alert the user of the need to perform cleaning or inspection.

3.4 Customizable logic function

The customizable logic function is the simple programmable logic controller (PLC) function incorporated in the inverter and has the expandability for desired functions with a user-created program uploading to the inverter. This function, which was equipped on the FRENIC-MEGA (G1) Series, has been evolved in its own function as it has gone through many models. With the FRENIC-MEGA (G2) Series, the function has been strengthened in the maximum program size and available functions as shown in Table 3 and now allows the user to create more flexible and complex programs by adding user parameters and user alarms.

Table 4 shows some examples of functions implementable using the customizable logic function of the FRENIC-MEGA (G2) Series as well as the required number of program steps and execution cycles.

The conventional customizable logic function of the FRENIC-MEGA (G1) Series uses single execution cycles to carry out processing since it handles only digital signal processing and also the number of steps handled is not many. With the addition of analog operation, setting parameter access, and more other features, the FRENIC-MEGA (G2) Series allows the user to add more complex and sophisticated functions.

On the other hand, if such sophisticated functions are executed in a single cycle, the performance of the entire functions is reduced due to increases in computation time. To resolve this issue, the FRENIC-MEGA (G2) Series has been equipped with the multi-task function that executes a program in divided multiple cycles. This has made optimal programming possible; for example, the operation and speed commands that affect the device's response or the machine's takt time are switched in a cycle of a 1 ms while, at the same time, complex data processing is carried out in a cycle of 20 ms.

Furthermore, programming can be performed using the simple method in which the user directly edits the setting parameters for the inverter or using the FRENIC-Loader 4 that allows the user to drag and drop block diagram symbols to arrange and connect them as shown in Fig. 7 so that the user can easily create programs with no need of any sophisticated programming technique even when the program to be worked on is sophisticated and large.

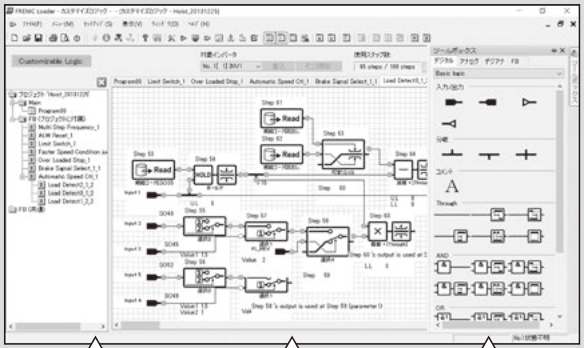
Table 3 Comparison of main specifications of customizable logic function

Item	FRENIC-MEGA (G2) Series	FRENIC-MEGA (G1) Series (Conventional models)
Maximum program size (Number of program steps)	260	10
Signals processed	Digital signals Analog signals	Digital signals
Main function	[Total of 113 types] Logical operation, timer, Analog operation, Selector, Filter, Bit extraction, Function code operation	[Total of 54 types] Logical operation, timer
User parameter	60	None
User alarm	5	None
Minimum execution cycle	1 ms	2 ms
Multi-task	Supported (5 in parallel)	Not supported
Programming environment	PC support tool "FRENIC-Loader 4"	None (Direct parameter edits only)

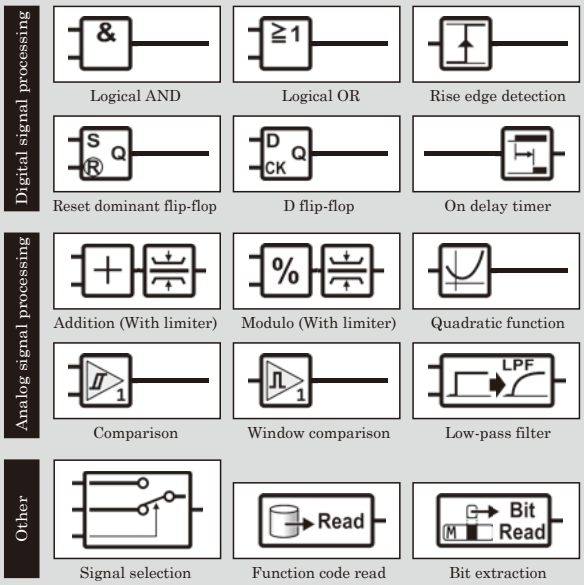
Table 4 Example functions implementable by customizable logic

Application device	Number of program steps	Execution cycle*1
Wire drawing machine	113	20 ms
Winder	180	20 ms
Wire strander	20	2 ms
Hoist	85	10 ms
Spinning machine (Traverse)	91	10 ms
Solar pump	200	20 ms

*1 Minimum execution cycle when multi-task function is not used



(a) Program edit screen



(b) Examples of available function symbols

Fig.7 Programming using the PC support tool "FRENIC-Loader 4"

4. New Multi-Function Keypad

The FRENIC-MEGA (G2) Series is equipped with a keypad of seven-segment five-digit LED display as with the conventional Series. In addition, the new multi-function keypad shown in Fig. 8 is also available as an option. It offers a great visibility with the use of a large LCD screen and supports Japanese characters (*hiragana*, *katakana* and *kanji*) and other 19 languages. As other features, it can save traceback data into a microSD card and add clock data to alarm history using the clock function. Using a smart device, on which the Mobile Loader application is installed for Bluetooth*6 connection, the user can make the settings of function codes (setting parameters of the inverter) and monitor the operating status of the inverter when

Fig.8 External appearance and Bluetooth connection of the new multi-function keypad

Fig.9 Water resistance test scene of the new multi-function keypad

the inverter is placed in a location where its keypad display is difficult to see.

Furthermore, the new multi-function keypad, which is compliant with IP55 in resistance to dust and water, can be installed on the panel door surface that may be subjected to dust, water splashes, etc. (see Fig. 9).

5. Improved Environmental Resistance

In recent years, there has been a growing demand for the environmental resistance to hydrogen sulfide (or sulfide gas), sea salt aerosol, etc. Figure 10 shows the external appearance of the printed circuit board used for the FRENIC-MEGA (G2) Series. Using a highly environmentally resistant material to coat the printed circuit board, the coating area has been extended from the conventional partial coating to the entire surface coating.

Furthermore, we examined the correlation in the influences of corrosive gas defined in IEC 60721-3-3 between experiments and corrosion simulations that

*6 Bluetooth is a trademark or registered trade mark of Bluetooth SIG, Inc.

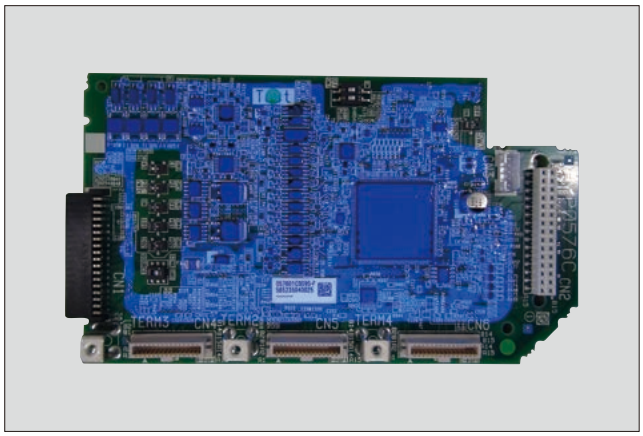


Fig.10 Printed circuit board of “FRENIC-MEGA (G2) Series”

used the Corrosion Analyzer of OLI Systems, Inc., the U.S.A., and predicted the progression of corrosion. With the exploitation of the results, this prediction served well to improve the environmental resistance of the inverter.

All of these have assured that the FRENIC-MEGA (G2) Series is compliant with the class 3C2 requirements defined in JIS 60721-3-3/IEC 60721-3-3.

6. Postscript

In this paper, we have presented the “FRENIC-MEGA (G2) Series” high-performance, multifunctional inverters. The FRENIC-MEGA (G2) Series can support a wider range of devices and applications than with the conventional general-purpose inverters. Fuji Electric will continue to make efforts to commercialize general-purpose inverters that satisfy market demands.

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