690-V Inverters Equipped with SiC Hybrid Module "FRENIC-VG Stack Series"

SATO, Kazuhisa*   TAKANO, Makoto*   NOMURA, Kazuki*

ABSTRACT

Fuji Electric offers 690-V stack type of the "FRENIC-VG Series" that has the highest-level performance in the industry. The 690-V inverters have seen high demand from the marine industry, overseas chemical plants, mining and water treatment facilities and their conventional capacities were between 90 and 315 kW. Now capacities from 355 to 450 kW have been added to the lineup. Incorporating a SiC hybrid module with low power dissipation prevents the product from becoming larger due to capacity enlargement, and keeps the product width to 220 mm. Connecting multiple stacks in parallel makes it possible to drive multi-winding motors up to 2,700 kW. Having a direct parallel connection enables large-capacity single-winding motors to be driven up to 1,200 kW.

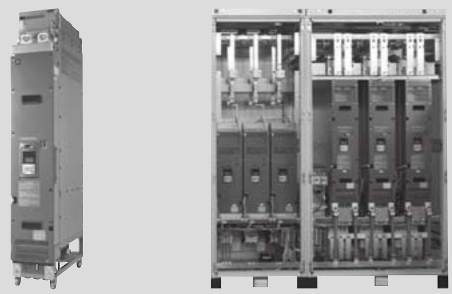
1. Introduction

In recent years, for inverters used in large-scale facilities, such as steel plants and large-sized cranes, there has been increasing demand for larger capacity, improved responsiveness and enhanced precision, as well as space saving and ease of maintenance for installation and replacement work.

To meet these needs, we added 400-V stack-type inverters to the industry's top performing "FRENIC-VG Series"(1) line-up in FY2012. Furthermore, in June 2014, we released 690-V stack-type inverters, which were in high demand in vessel equipment, overseas chemical plants, mining and water treatment facilities Figure 1 shows the applications of the products.

This time, we have added the types from 355 to 450 kW in capacity to the 690-V line-up, which originally consisted of the types from 90 to 315 kW in capacity. We have been able to increase the capacity while preventing the inverters from increasing in size by utilizing low-loss SiC hybrid modules. The product's external appearance and an installation example in the panel are shown in Fig. 2.

Fig.1 Uses of 690-V inverter "FRENIC-VG Stack Series"



(a) External appearance (b) Installation example in the panel

Fig.2 690-V inverter "FRENIC-VG Stack Series"

This paper describes the SiC hybrid module and the "FRENIC-VG Stack Series" of 690-V inverters equipped with the modules.

2. SiC Hybrid Module

The SiC hybrid module incorporated in 690-V stack-type inverters with capacities from 355 to 450 kW is configured with SiC-Schottky barrier diodes (SiC-SBDs) and Si-insulated gate bipolar transistors (Si-IGBTs). It utilizes Fuji Electric's SiC-SBD chip, which has a 1,700-V withstand voltage, and a 6th-generation "V Series" IGBT chip. The external appearance and circuit configuration of the SiC hybrid module are shown in Fig. 3.

2.1 Features of the SiC hybrid module

The SiC hybrid module utilizes SiC-SBD, which is a unipolar device with no minority carrier injec-

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

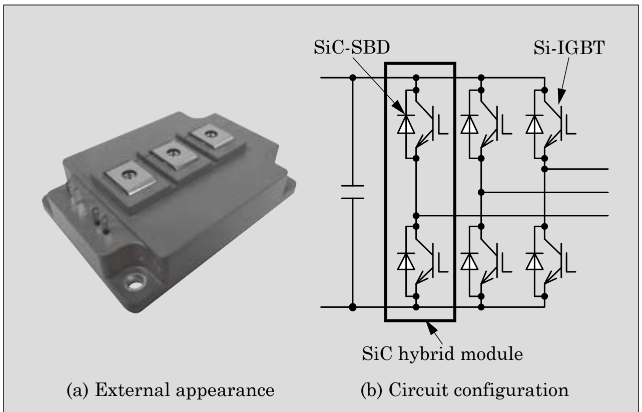


Fig.3 SiC hybrid module

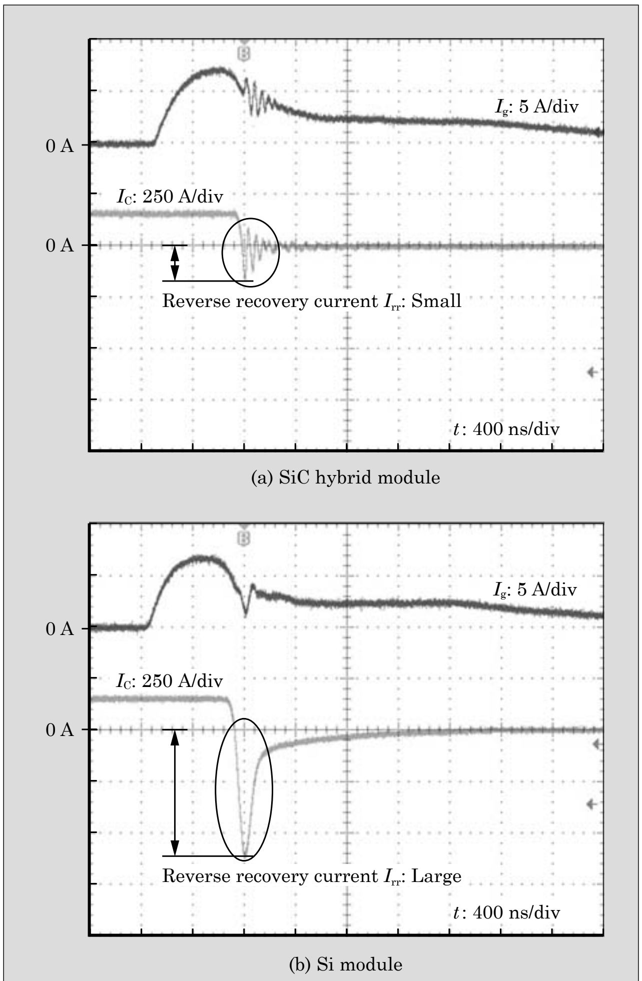


Fig.4 Module reverse recovery current waveform

tion, and therefore, it is characterized as generating almost no reverse recovery loss E_{rr} during switching operations. Figure 4 shows the reverse recovery current waveform of the module. Reverse recovery current is much lower in the SiC hybrid module when compared with conventional Si modules. Furthermore, the reduction in reverse recovery current also leads to reduced turn-on loss E_{on} for opposing arm IGBT.

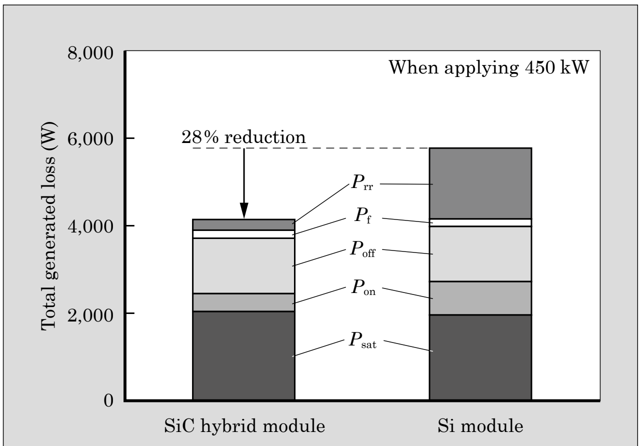


Fig.5 Total generated loss of module

Figure 5 shows a comparison of the total generated loss of an Si module and SiC hybrid module when mounted on a 450-kW stack. The P_{rr} of the SiC hybrid module is approximately 85% less than that of the Si module, while P_{on} is approximately 45% less. Total generated loss has been reduced by 28%, which enables size reduction of equipment and capacity increase.

2.2 Challenges and measures for SiC hybrid module applications

SiC hybrid modules perform switching at a higher speed than Si modules. Thus, when the devices connect in parallel, their appropriate current sharing is needed to operate stably. Furthermore, reducing and equalizing inductance and matching impedance are required to suppress oscillation and reduce EMC noise.

Therefore, we have optimized the current sharing and matched the impedance of the module to that of the gate drive circuit by utilizing an electromagnetic analysis simulation of the wiring inductance (see Fig. 6), thereby allowing the switching while suppressing gate oscillation.

In addition, inverters for overseas markets need to comply with the standards enforced by each export destination. In particular, the following measures are taken to comply with emission noise regulations set

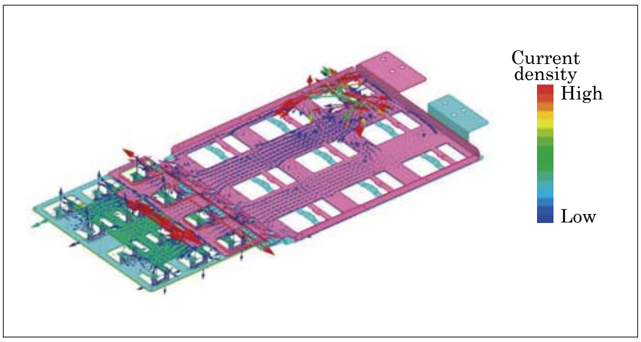


Fig.6 Example of electromagnetic analysis simulation of wiring inductance

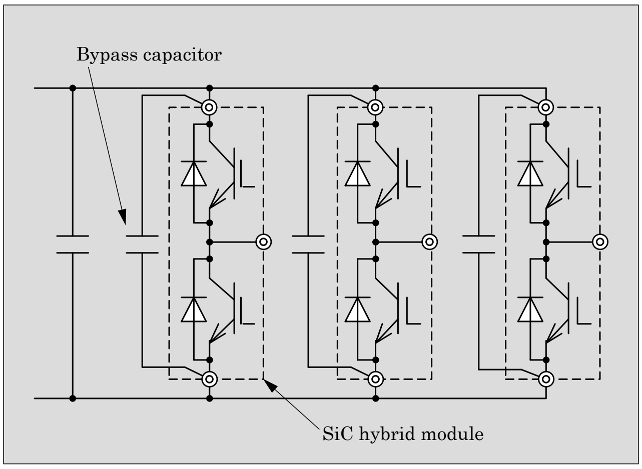


Fig.7 Bypass capacitors connected to SiC hybrid module

forth in the EN61800-3 EMC standard.

Since the SiC hybrid module performs high-speed switching, emission noise generated by the inverter increases. Conventional countermeasures for emission noise include incorporating the inverters into a panel and inserting zero-phase reactors (common mode reactor) into the output cables of inverters. However, such countermeasures taken outside the inverter are not effective enough to reduce the emission noise increased by using the SiC hybrid module.

On the other hand, the amount of emission noise is proportional to the size of the loop (emission area) in which a noise current flows; therefore, implementing measures near the noise source is effective to reduce the size of the loop. Consequently, the FRENIC-VG Stack Series has achieved noise reduction by connecting in parallel bypass capacitors that have good frequency characteristics as close as possible to the noise generating SiC hybrid module (see Fig. 7).

3. 690-V Inverter “FRENIC-VG Stack Series”

3.1 Product lineup

Figure 8 shows the line-up of the 690-V inverter “FRENIC-VG Stack Series.” Depending on the type of application, it is possible to select an inverter, PWM converter, filter stack or diode rectifier as a stack with an identical shape. The addition of the new SiC hybrid module equipped inverters that have single unit capacities from 355 to 450 kW has expanded the line-up of inverters in this series to support capacities from 90 to 450 kW. In order to meet the needs of further increased motor output, output capacity can be expanded by either using a high capacity multi-winding motor with split windings or by connecting stacks in parallel.

The FRENIC-VG is capable of driving a multi-winding motor with a maximum of 6 windings and supporting capacities of up to 2,700 kW. Furthermore, stacks can be connected in parallel without using a current limiting reactor, enabling it to configure a direct parallel connection system that drives high-capacity single winding motors. This direct parallel connection system, as shown in Fig. 9, is capable of driving high-capacity single winding motors of up to 1,200 kW by connecting up to 3 stacks in parallel via a motor ter-

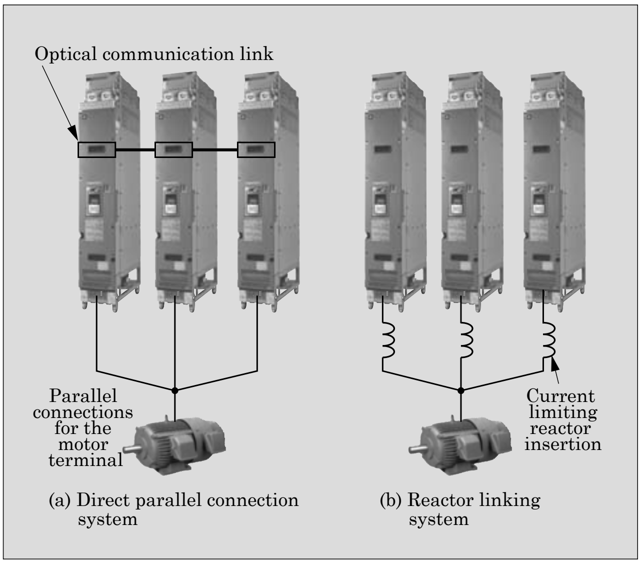


Fig.9 Stack parallel connection system

Shape	Series	Configuration	Specification (Application load)	Standard application motor capacity (kW) (50 / 100 / 500 / 1,000 / 5,000)
Stack	Inverter “FRENIC-VG”	Single unit	MD (LD)	90 (110) – 450 (450); Direct parallel connection system 1,200 (1,200); Multi winding motor driving system 2,700 (2,700)
	PWM converter “RHC-D”*	Single unit	MD (LD)	132 (160) – 450 (450); Transformerless 1,200 (1,200); Transformer insulation system 2,700 (2,700)
	Filter stack “RHF-D”*	Single unit	–	160 – 450
	Diode rectifier “RHD-D”	Single unit	MD (LD)	220 (250) – 450 (450); Parallel connection system 2,000 (2,000)

*Planned to be released in FY2015

Fig.8 Line-up of 690-V inverter “FRENIC-VG Stack Series” minal.

However, the difference between output voltages of the stacks causes an error current (cross current). Conventionally, cross current was suppressed through current limiting reactor insertion. The FRENIC-VG controls cross current by using control software without a current limiting reactor. This cross current suppression control and internal inductance of the output power lines make it possible to connect stacks in parallel.

3.2 Features of the stack-type

(1) Standardization of product width

The 690-V inverter FRENIC-VG Stack Series has a standardized stack width of 220 mm to increase ease of installation in panels, thereby achieving space saving and a total cost reduction.

In particular, stacks with capacities from 355 to 450 kW come equipped with SiC hybrid modules, as mentioned in Chapter 2, and as a result, total generated loss has been reduced by 28% compared with Si module based products. The inverter has thereby enabled the cooling component of the module to keep the volume the same as the previous products, while maintaining a stack width of 220 mm.

As shown in Fig. 10, the conventional configuration of the 690-V inverter with a capacity of 450 kW required two 250-kW stacks directly connected in parallel. In contrast, the 450-kW stack equipped with SiC hybrid modules is operates with only a single unit, thus greatly contributing to reducing the size of the panel.

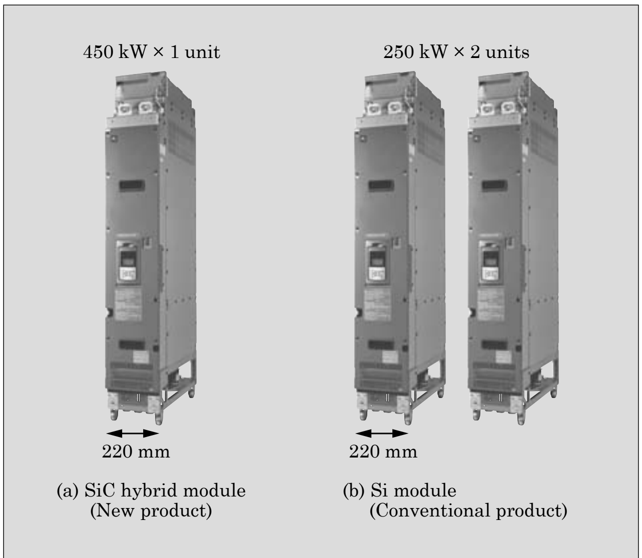


Fig.10 Space Savings based on SiC hybrid module application

(2) Selection of converter based on application needs

The stack-type differs from all-in-one unit types in that it is configured with the converter and inverter allocated to separate stacks.

By doing this, it is possible to select the converter based on application needs, as well as select the diode rectifier for applications that do not have regenerative power, or the PWM converter for applications that require regenerative power or harmonic suppression.

(3) Space savings via DC distribution

Since the inverter is made with the converter and inverter separated at a DC circuit part, a multi drive can be configured by using DC distribution system that aims to transfer energy between DC buses. This makes it easy to reduce the capacity of the converter and configure a high-capacity system, achieving space saving of the panel.

(4) Improved maintainability

The time for replacing inverters in important facilities is needed to be reduced when in trouble or equipment upgrade.

The stack-type comes with a caster drawer structure and replacement lifter greatly reduces work time compared to the conventional unit-type systems.

4. Postscript

This paper described the “FRENIC-VG Stack Series” of 690-V inverters equipped with SiC hybrid modules.

We plan to continue expanding the field of application for the 690-V inverter system by increasing the number of parallel connections in the direct parallel connection system through expansion of the control software for cross current suppression control.

References

(1) Tanaka, M. et al. “FRENIC-VG,” a High-Perfor-mance Vector-Control Inverter. FUJI ELECTRIC REVIEW. 2012, vol.58, no.4, p.154-159.

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