4-in-1 Modules with Ratings of 1,700 V / 75-200 A

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Power conversion devices, especially insulated gate bipolar transistor (IGBT) modules, are widely used as core devices in power conversion system that convert electrical energy between AC and DC or vice versa. IGBT modules are required to have not only high performance and high reliability, but also features contributing to simplified equipment design work and equipment downsizing. In addition, they must also have characteristics that are suitable for circuit systems of various applications.

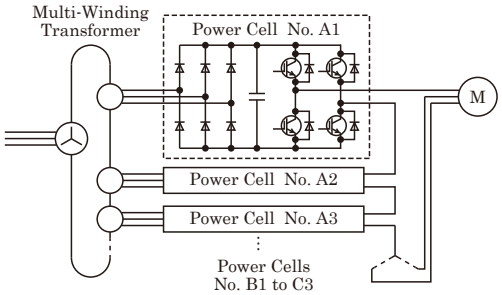
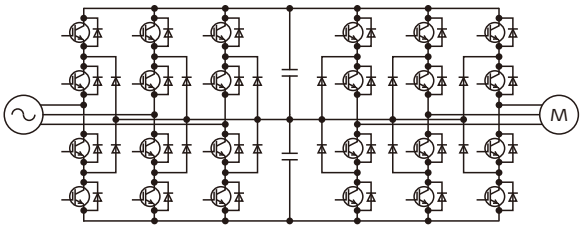
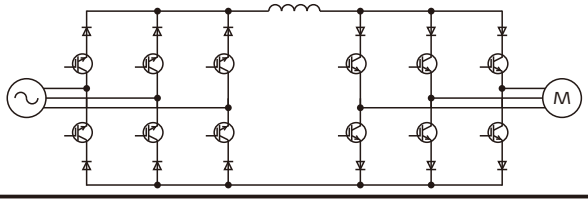
This paper describes a newly developed 1,700-V/75- to 200-A 4-in-1 module optimized for the circuit configuration of medium-voltage inverters.

1. Features

Medium-voltage inverters are power converters that control output voltage and frequency, designed for high input voltages of 690 V or higher. They are used in a variety of fields, including metal processing, chemical plants, and natural gas and fossil fuel mining. Table 1 shows circuit systems of medium-voltage inverters. Among these circuit systems, the series-connected multi-stage unit type occupies nearly 60% of the global market share, primarily in China, due to its simple configuration and easy maintenance features. In the future, it is expected to continue to be a mainstream medium-voltage inverter.

Conventional series-connected multi-stage unit type medium voltage inverters combine two 2-in-1

Table 1 Medium-voltage inverter circuit systems

	Circuit example	Features	Applicable module	Market share percentage and primary regions of use
Series-connected multi-stage unit type		○ Simple topology ○ Easy maintenance ○ Output adjustable according to the number of series ○ Input transformer required (High cost)	1,700 V/75–1,200 A 2-in-1 module	60% Worldwide (China, etc.)
3-level type		○ With no transformer ○ Complex topology	3.3 kV/800–1,500 A 4.5 kV/400–1,500 A HPM	30% Europe and the U.S.
Current source type		○ Reverse blocking diode required (High loss)	6.5 kV/400–1,500 A Press Pack (GCT)	10% Europe and the U.S.

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‡ Fuji Electric (Shenzhen) Co., Ltd.

modules and one converter diode module. In contrast, the newly developed 1,700-V 4-in-1 module, as shown in Figs. 1 and 2, optimizes the input rectifier circuit and output inverter circuit, and incorporates a three-phase rectifier circuit, H-bridge circuit, and thermistor in one package. Since an inverter unit can be configured with only one of these modules and passive components, the unit can be easily multi-leveled. By providing the product as a single package, the footprint of the module has been reduced by 54%.

The newly developed 1,700-V 4-in-1 modules are lined up in the same packaging up to 75 A to 200 A, as shown in Table 2.

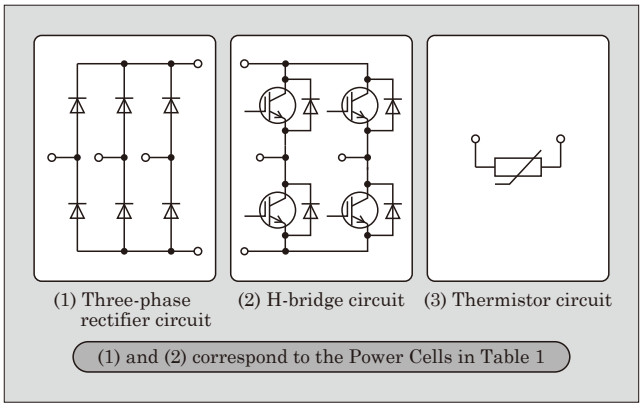

Fig.1 Equivalent circuit diagram

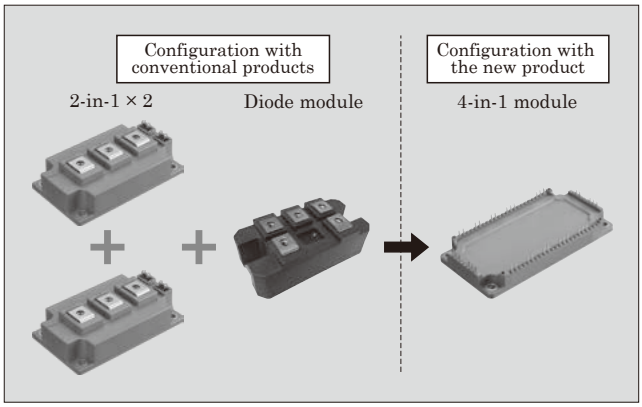

Fig.2 Comparison of medium-voltage inverter module configurations

Table 2 Lineup of the 1,700-V 4-in-1 module

Rated voltage (V)	Rated current (A)			
	75	100	150	200
1,700				
Appearance EconoPIM™*	(Unit: mm) 62 122			

* EconoPIM™ is a trademark or registered trademark of Infineon Technologies AG

2. Applied Technologies

2.1 Heat concentration reduction through layout optimization

Since the footprint has been reduced by 54% as described in Chapter 1, the module's thermal density has increased. Therefore, one of the technical challenges in the development of this product was to suppress the rise in chip temperature caused by thermal interference between adjacent chips.

The new product uses the 7th-generation freewheeling diodes (FWDs) to reduce power loss during inverter operation, thereby suppressing the rise in temperature of the module and making it possible to mount a 4-in-1 circuit in a single package, instead of the conventional configuration of two 2-in-1 packages.

To suppress the temperature rise, this module has an optimal chip arrangement to minimize the effect of thermal interference between chips. Figure 3 shows the result of temperature analysis using the finite element method. This result has demonstrated that when all built-in chips are producing heat at the same time, under the most severe conditions, the maximum temperature of the IGBT chip is 142.6°C. The maximum temperature of this module is less than 5% higher than 136°C, the average of all chips. The results confirm that the temperature of one chip does not rise excessively even when the heat generation density increases.

2.2 Higher reliability through the use of 2,200-V converter diodes

Considering the use of medium-voltage inverters in areas with an unstable power supply, it is necessary to improve the overvoltage withstand capacity to external surge voltages, and the input surge current withstand capability to surge currents generated during recovery from instantaneous voltage drops. Therefore, we have developed a converter diode with a withstand voltage of 2,200 V, exceeding the module's withstand voltage of 1,700 V, as well as surge current withstand. Figure 4 shows a comparison of the surge current withstand

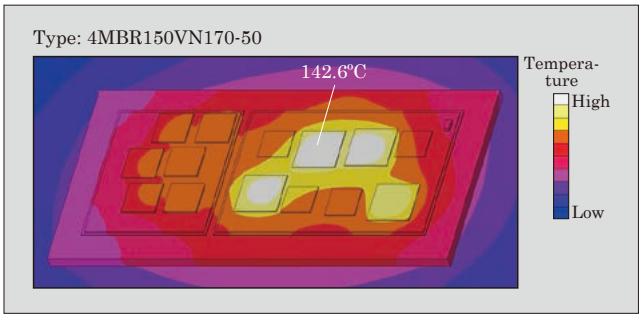

Fig.3 Result of temperature analysis using the finite element method (total phase heat generation)

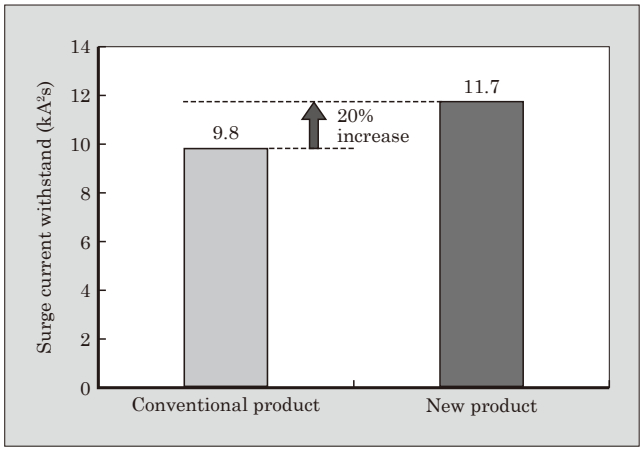

Fig.4 Results of a comparison of surge current withstand (T_{vj} = 150°C)

capacity of the conventional module and the new product module. Compared with the conventional module, the withstand capacity has been increased by 20% and achieved higher reliability.

3. Application Examples

Figure 5 shows the comparison data of the dissipation loss on a medium-voltage inverter that uses the newly developed 4-in-1 module with the conventional 2-in-1 module. The newly developed 4-in-1 module (4MBR150VN170-50) demonstrated a 3% reduction in generated loss compared to the conventional 2-in-1 module (2MBI150VH-170-50). As a result, it is possible to install a 4-in-1 module with a footprint 54% smaller than conventional models without changing

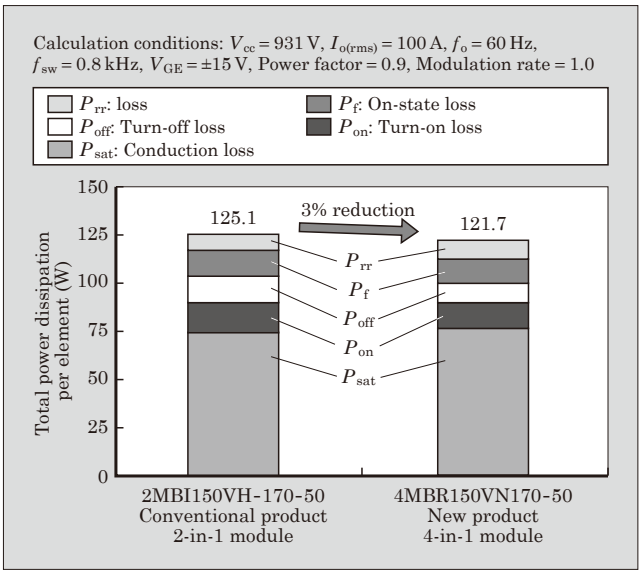

Fig.5 Results of a comparison of generated loss

the inverter's peripheral components, contributing to the miniaturization of the entire system.

Launch Date

April 2021

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