7th-Generation "X Series" 1,700-V/800-A RC-IGBT "Dual XT" Modules for Industrial Applications

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In recent years, there has been increasing expectations that power electronics technology will further contribute to efficient energy usage and energy saving, and play an important role in achieving a sustainable society. In particular, the demand is growing for power semiconductors as key devices of power conversion equipment used for various applications, such as the industrial, automotive, and renewable energy applications.

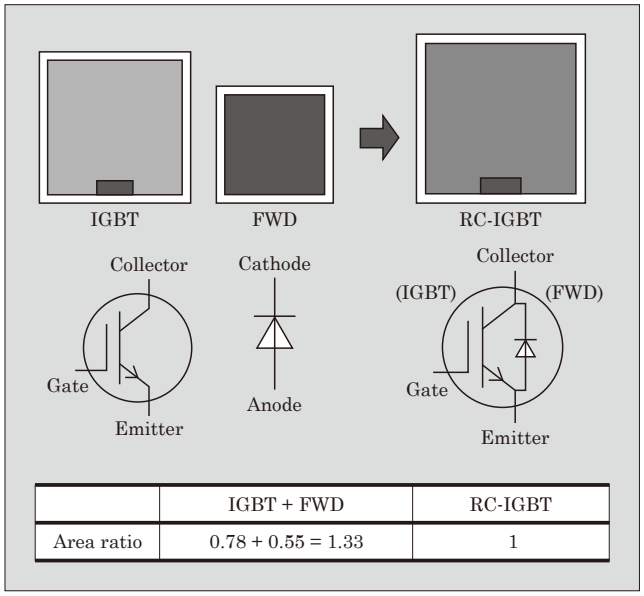
Fuji Electric has made many technological innovations to reduce the size, lower the power dissipation, and improve the reliability of insulated gate bipolar transistor (IGBT) modules, contributing to the miniaturization, cost reduction, and performance of power conversion systems by helping them become smaller, more efficient and reliable. Our latest 7th-generation "X Series" IGBT modules achieve even lower power dissipation, higher reliability, and higher power density, by innovating in chip and packaging technology.

In addition, we have also developed reverse-conducting IGBTs (RC-IGBTs), which combine 7th-generation IGBT and free-wheeling diode (FWD) functions into a single chip to create a line-up of the X Series RC-IGBT module for industrial applications. This line-up has even higher power density and higher reliability than conventional IGBT modules, which combine IGBT and FWD chips. Moreover, the current rating has been increased to 800 A, compared with the previous maximum current rating of 600 A.(1)

1. Characteristics of RC-IGBTs

Figure 1 shows the schematic and equivalent circuit diagrams of the X Series RC-IGBT for industrial applications. In inverters that are used as power conversion equipment, two types of semiconductor chips, IGBT and FWD, are connected in anti parallel (IGBT + FWD system). In contrast, an RC-IGBT integrates the IGBT and FWD functions into a single chip.

Since RC-IGBTs incorporate the functions of an IGBT and FWD into a single chip, the chip area of RC-IGBTs is larger than that of individual IGBTs and FWDs at the same rated current. Therefore, they have better heat dissipation and lower thermal resistance than conventional chips. At the same time, the chip area of an RC-IGBT is smaller than that of the combined chip area of an IGBT and FWD. Therefore, an RC-IGBT can provide a higher rated current for the same chip area. By taking advantage of these features, we have increased the output of IGBT modules while maintaining the same package size.



	IGBT + FWD	RC-IGBT
Area ratio	0.78 + 0.55 = 1.33	1

Fig.1 Schematic and equivalent circuit diagrams of the "X Series" RC-IGBT for industrial applications

2. Product Line-Up

Figure 2 shows the line-up, product appearance,

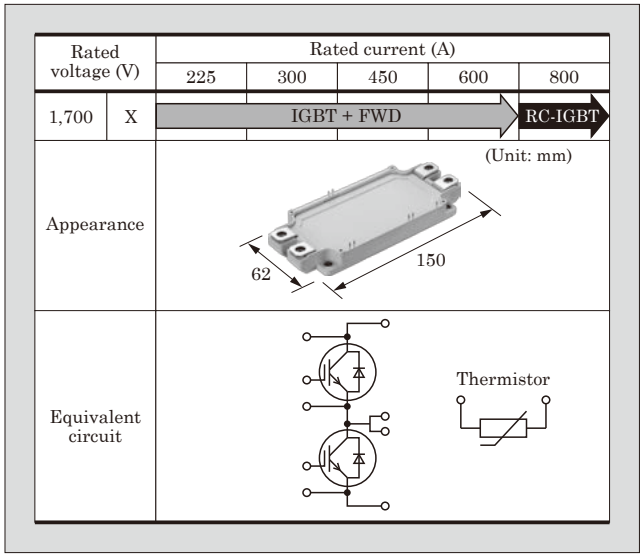


Fig.2 Line-up of the 1,700-V "Dual XT" modules

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and equivalent circuit of the newly added X Series 1,700-V RC-IGBT "Dual XT" modules for industrial applications. Customers can select the most suitable module for their application.

3. Features of the 7th-Generation "X Series" 1,700-V/800-A RC-IGBT "Dual XT" Modules for Industrial Applications

(1) Reduction of ΔT_{vj} chip virtual junction temperature

Wind power conversion systems, which are considered to be one of the most important sources of renewable energy, widely use IGBT modules with a rated voltage of 1,700 V. Figure 3 shows a schematic diagram of a wind power conversion system. The rotation of the wind turbine causes the generator to produce AC power and the generator-side power conversion equipment converts it into DC power. The DC power is reconverted to AC power by the power conversion equipment on the grid side.

During this process, the generator-side power conversion equipment, which converts the rotation of the wind turbine into electrical energy, can have a large temperature time variation ΔT_{vj} during low-frequency operation of 1 to 10 Hz, shortening the lifetime of the RC-IGBT module in the power cycle.

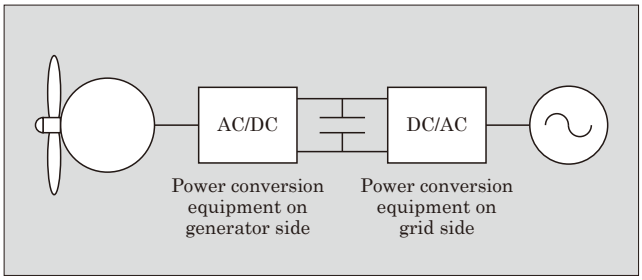

Fig.3 Schematic diagram of wind power conversion system

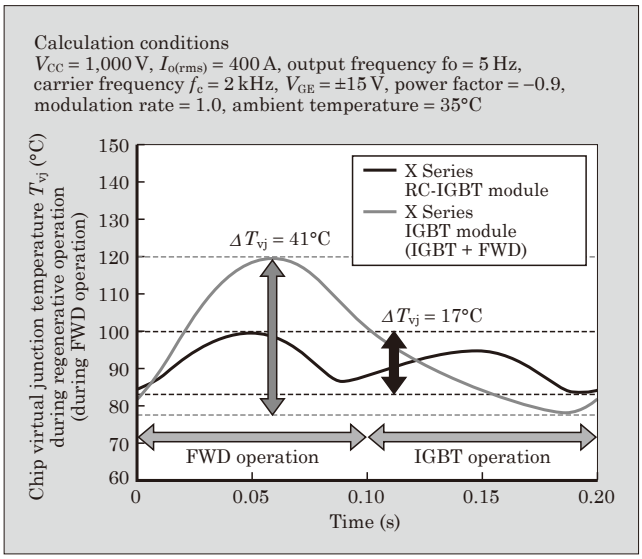

Fig.4 T_{vj} calculation results during low-frequency operation

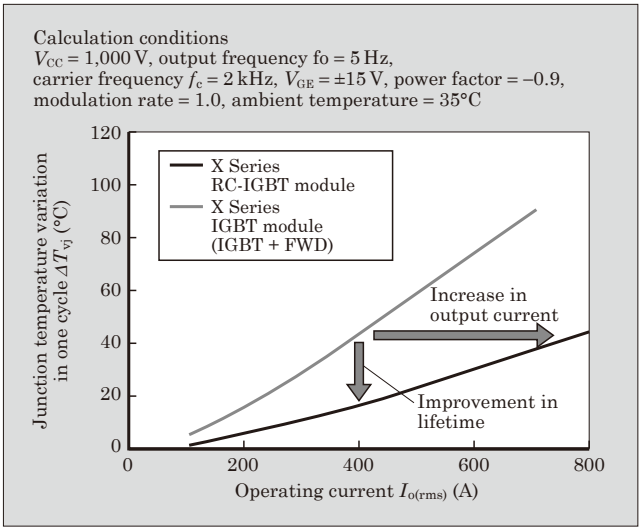

Fig.5 ΔT_{vj}–I_o calculation results during low-frequency operation

Figure 4 shows the calculation result of the chip virtual junction temperature change T_{vj} in one cycle of low-frequency operation during regenerative operation. In conventional IGBT modules with the IGBT + FWD system, the IGBT and FWD chips alternately generate heat, and the ΔT_{vj}, in one cycle, was 41°C. In contrast, the X Series RC-IGBT module has reduced the lower maximum chip virtual junction temperature T_{vjmax} due to the larger RC-IGBT chip area improving heat dissipation. Moreover, the IGBT and FWD regions in an RC-IGBT chip alternately generate heat, increasing the minimum chip virtual junction temperature T_{vjmin}. As a result, the X Series RC-IGBT module has significantly improved ΔT_{vj} to 17°C, which reduces the amount of thermal stress variation applied to the aluminum wire and solder.

(2) Output current and power cycle life improvement

Figure 5 shows the calculation results of ΔT_{vj} and output current I_o at low-frequency operation. The X Series RC-IGBT module for industrial applications can have the significantly lower ΔT_{vj} than the conventional X Series IGBT module with the IGBT + FWD system at the same output current. This means that under the same power conversion conditions, thermal stress variation decreases with reductions in the IGBT module's temperature variation. Moreover, under the same power cycle life time conditions that means same ΔT_{vj} conditions, the X Series RC-IGBT module can output higher current than the conventional IGBT + FWD system, as shown in Fig. 5. In case of ΔT_{vj} is 41°C, the X Series RC-IGBT module for industrial applications can expand 1.8 times output current of power conversion systems compared with using the conventional IGBT + FWD modules.

References

(1) Ebukuro, Y. et al. 7th-Generation "X Series" RC-IGBT "Dual XT" Modules for Industrial Applications. FUJI ELECTRIC REVIEW. 2021, vol.67, no.4, p.242-246.

Launch Date

October 2021

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