The IGBT Module for Three-Level Bidirectional Switch Type Inverter

Authors: Satoshi Kawabata*, Hiroki Muraoka* and Ayumi Maruta*

1. Introduction
Three-level inverters inherently have higher efficiency than the standard two-level configuration. This paper presents an insulated gate bipolar transistor (IGBT) module that integrates bidirectional switches for three-level bidirectional switch type inverter applications. By employing Mitsubishi Electric’s newest 6th-generation IGBT, this product helps users simplify the circuit configuration and improve its efficiency.

2. Product Concept
We have developed this product based on the concept of Mitsubishi Electric’s newest 6th-generation IGBT with the goal of integrating bidirectional switches for three-level inverters into the conventional NF Series package.

3. Product Specifications
Figures 1 and 2 respectively show the outline view and circuit diagram of the module.

Fig. 1 Outline

Fig. 2 Circuit diagram

The 6th-generation IGBT has a wide operating temperature range up to the maximum junction temperature of 175°C, which is 25°C higher than that of the 5th-generation IGBT of 150°C, and thus provides users with more flexibility of temperature design.

In the three-level bidirectional switch topology, the voltage applied to each IGBT during the switching period is generally one-half that of the two-level topology. However, considering high-voltage applications, the chip was designed to have a breakdown voltage of 1,200 V. This also gives a margin against a surge voltage induced by the circuit wiring inductance and applied to the chip.

These features provide an easy-to-design device for the users.

4. Circuit Configuration of Three-Level Inverter

4.1 Features
Figure 3 illustrates various circuit configurations of electric power inverters. Figure 3 (a) through (c) shows the standard two-level, three-level neutral point clamped (NPC), and three-level bidirectional switch topologies, respectively. The two-level circuit gives an output voltage with a stepwise change equal to the direct current voltage of E, whereas the three-level topologies give a stepwise change of E/2, which provides an output voltage closer to a sine wave, and thus the size of filter circuit can be reduced. A breakdown voltage of the elements for the three-level NPC topology can be one-half that of the two-level topology, and thus the three-level NPC topology is a suitable configuration for high-voltage power converters. For improved efficiency, however, the three-level bidirectional switch topology is more advantageous than the NPC topology.

In the NPC configuration, at an output voltage of P (or N), the current passes through the elements Q11 and Q12 (or D13 and D14), whereas in the bidirectional switch configuration, it is only Q11 (or D14), that is, the number of elements that the current passes through is one half, and thus the conduction loss can be reduced.

4.2 Loss of Three-Level Bidirectional Switch Type
Figure 4 shows a relative comparison of the IGBT loss between two circuit configurations, where the direct current voltage, output current and switching frequency are the same. The loss in the two-level configuration is dominated by switching loss, accounting for about 70%. In contrast, in the three-level bidirectional switch configuration, the voltage applied during the switching...
period becomes E/2, which significantly reduces the switching loss and hence the total loss by about 35%.

5. Application Examples

The three-level bidirectional switch configuration with the 6th-generation IGBTs was applied to the converter and inverter of an uninterruptible power supply (UPS). The efficiency was improved by about 2% compared to the two-level circuit configuration with the 5th-generation IGBTs. Figure 5 shows a relative comparison of the conversion efficiency.

![Fig. 5 Equipment efficiency curve at 400 V/500 kVA](image)

The three-level bidirectional switch type inverter has achieved high efficiency of over 96% in the load factor range from 20% to 100%, and the maximum efficiency is over 97%, which is about 2% higher than that of the standard two-level type inverter.

6. Conclusion

Mitsubishi Electric's newest 6th-generation IGBTs and three-level bidirectional switch configuration are expected to help improve equipment efficiency. With continuous product development, we will enhance the lineup of the 6th-generation IGBTs to enable users to simplify their circuit configurations.