Current Measurement Inside Press Pack IGBTs

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1. Introduction
As large-capacity system equipment that support the infrastructure, power conversion equipment used in industry, power, and railway applications require superior reliability. They must also be compact and cost-effective. Traditionally, the thyristor and GTO (Gate Turn-Off) thyristor have generally been used as devices in large-capacity equipment, but recently, the IGBT (Insulated Gate Bipolar Transistor) has come into greater use. Fuji Electric has developed for commercial use a press pack IGBT, which is a high-withstand-voltage, large-current device. Figure 1 shows a press pack IGBT.

The press pack IGBT is designed to carry larger currents by the connection of multiple IGBT chips and diode chips in parallel inside a package. When chips are connected in parallel, the balance of the current through each chip becomes important.

This paper presents a technology that measures the current during switching. Measuring is accomplished with a current sensor mounted on each of the chips inside a press pack IGBT package.

2. Target Specifications for Measurement of Current inside a Package
To examine the current balance of each chip inside a press pack IGBT package, which has a pressure-welded structure, the current must be measured directly with a current sensor mounted on each of the chips inside a press pack IGBT package.

Table 1 lists the target specifications for a current sensor embedded into a chip. The target specifications are outlined below.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Target Value</th>
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<tbody>
<tr>
<td>Isolation voltage</td>
<td>2.5kV</td>
</tr>
<tr>
<td>Frequency band</td>
<td>250kHz</td>
</tr>
<tr>
<td>Outline shape</td>
<td>24.7 × 24.7mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>2.1mm or less</td>
</tr>
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</table>

3. Characteristics of the Prototype Current Sensor
We used a Rogowskii coil for the current sensor. Because the Rogowskii coil does not use magnetic material, its outline can be made smaller. Furthermore, because this coil detects the current according to Ampere’s contour integral law, it is not susceptible to external magnetic fluxes.

3.1 Structure
Figure 2 shows the prototype current sensor. The basic structure of the prototype current sensor shown in Figure 2 was a rectangular toroidal coil with 300 turns of one layer of polyester wire (φ0.2mm) closely wound around an insulating core with a 1.0 × 1.0mm cross-section. The final step was epoxy-molding to make a current sensor with a thickness 2.0mm and an outline shape of 24.7 × 24.7mm.
3.2 Frequency Characteristics

Figure 3 shows the frequency characteristics of the prototype current sensor. We designed it so that the center of the frequency band was 250kHz, which was the target specification. The frequency band is from 5kHz to 1.3MHz.

Fig.3. Frequency characteristics

3.3 Evaluation of Actual Waveforms

Figure 4 shows the results of current measurement during turn-off. As the comparison in the figure of the measurement results of the prototype current sensor and the sensor currently used in the switching test makes clear, the turn-off waveforms from the measurements match. This result shows that the performance of the prototype current sensor is equivalent to current sensors now in use.

Fig.4. Current measurement waveform evaluation

3.4 Effects of External Magnetic Fluxes

Chips are connected in parallel inside a press pack IGBT package, which is a large-current device. We evaluated the effects of external magnetic fluxes, generated by the current of adjacent chips, on the current sensor.

The evaluation was performed by placing the prototype current sensor near the current to be interrupted and measuring the current level detected by the prototype current sensor when the current was interrupted. Figure 6 shows the results of measurement. The current change detected by the current sensor, which was caused by the external magnetic fluxes, with respect to the breaking current of 160A was 2% or less. This result shows that the prototype current sensor can measure current accurately without being affected by external magnetic fluxes.

It is clear from the above measurements that the prototype current sensor satisfies the target specifications.

Fig.5. Testing the effects of external magnetic fluxes

4. Results of Current Balance Measurement

We measured the current of each chip by mounting the prototype current sensor on each chip inside the press pack IGBT package. Figure 7 shows the configuration we developed for current measurement in which chips and current sensors were placed inside a press pack IGBT package.

Fig.7. Configuration for current measurement
Figure 8 shows the test circuit configuration. We conducted the switching test by mounting the prototype current sensor inside the test device package as shown in Figure 8. During the switching test, we measured the current of each chip by setting the breaking current of the overall press pack IGBT package to 1,800A.

We verified whether the current of each chip measured by the prototype current sensor was accurate. Figure 9 shows the waveforms obtained by totaling the currents detected by each prototype current sensor and those obtained by measuring the current of the entire package using a conventional current sensor. As Figure 9 makes clear, the waveforms match and the current of each chip can be measured accurately.

5. Conclusion
This paper presents a technique that measures the current of each chip during switching with a current sensor mounted on each chip inside a press pack IGBT package.

Taking full advantage of current-measurement technique, we intend to continue our work in making power devices more reliable. We also plan to apply the current-measurement technique presented here to power conversion equipment.

References
