

The next stage in power semiconductors

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Recent design innovations have resulted in a new power semiconductor that can switch with the speed of an Insulated Gate Bipolar Transistor and conduct like a Gate Turn-Off thyristor. With such a device, drive and inverter manufacturers can make lower cost, more efficient controls for motors in medium-voltage applications.

Engineers at ABB Semiconductors, recently developed a new type of power switch with an architecture combining the best features of an Insulated Gate Bipolar Transistor and a Gate Turn-Off thyristor. Called the Integrated Gate Commutated Thyristor (IGCT), the new solid-state switch is for medium-voltage applications from 2 to 6.9 kV, with maximum ratings to 4,000 A. According to ABB en-

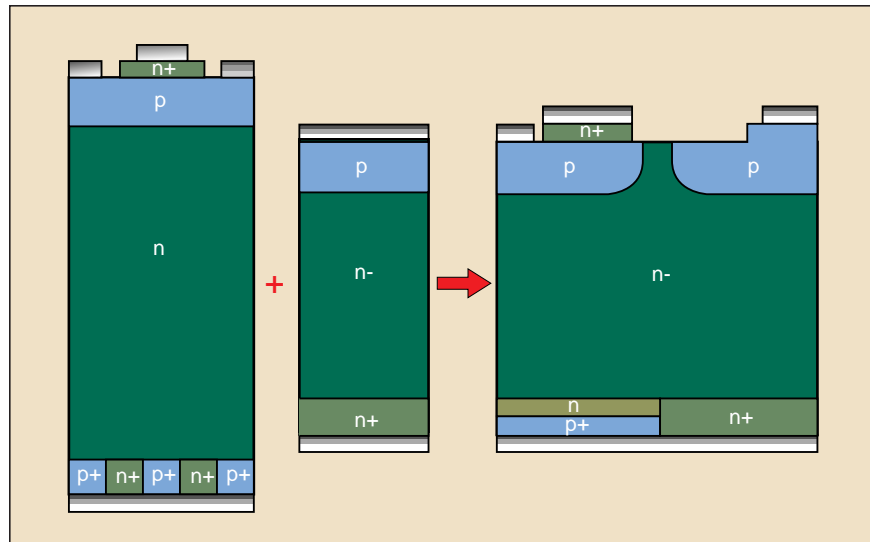


Figure 1 — Integrating a GTO thyristor with a diode produces what ABB engineers call a Gate Commutated Thyristor (GCT). The transparent emitter and buffer layer of the GCT accommodates a thin *n*-base permitting snubberless operation.

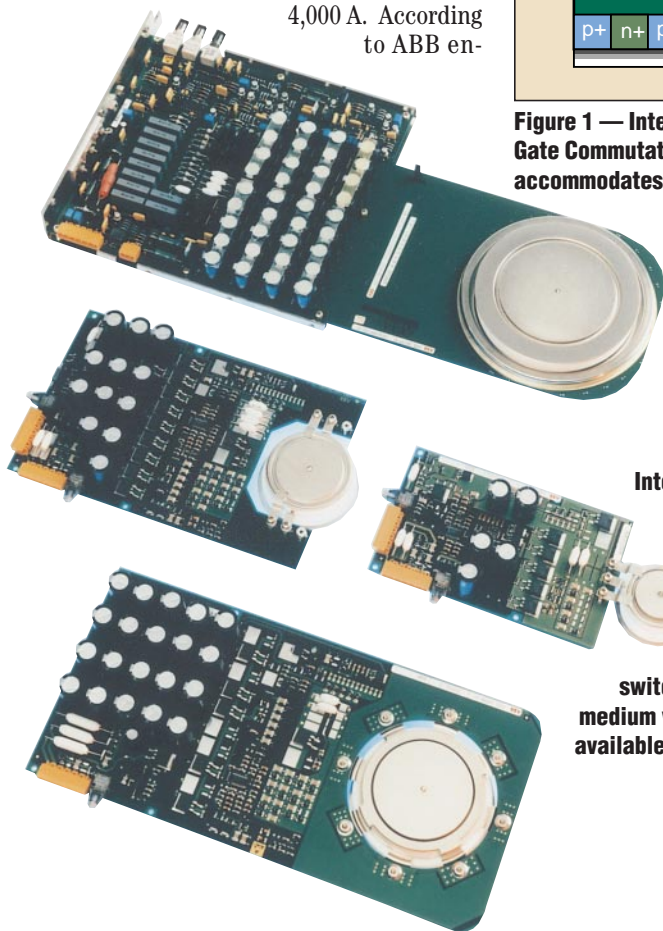
gineers, IGCTs are well suited for drives that:

- Control water or air flow from large spinning fans.
- Produce high starting torque such as that needed in steel mills.
- Control power to ac locomotive drives.
- Operate induction furnaces.

A switch is born

Since the invention of the transistor, engineers have been searching for the “ideal” solid-state power switch — a fast device with low losses and high current and voltage ratings.

Most semiconductor researchers have concentrated on transistor-type devices, such as IGBTs with their rugged turn-off capabilities, and thyristor devices, such



Integrated Gate Commutated Thyristors (IGCTs), from ABB Semiconductors, switch like IGBTs and conduct like GTOs. The new devices can switch up to 10 MW of power at medium voltage levels and are available for 2.3, 4.16, and 6.9 kV.

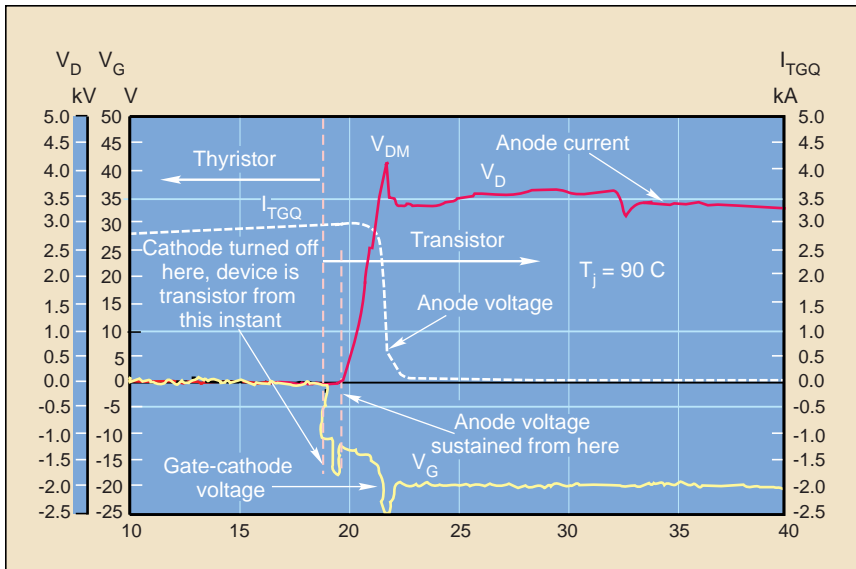


Figure 2 — In the IGCT, turn-off occurs after the device changes to a transistor mode of operation. Up to 4,000 A/ μ s can be commutated with a 20-V gate.

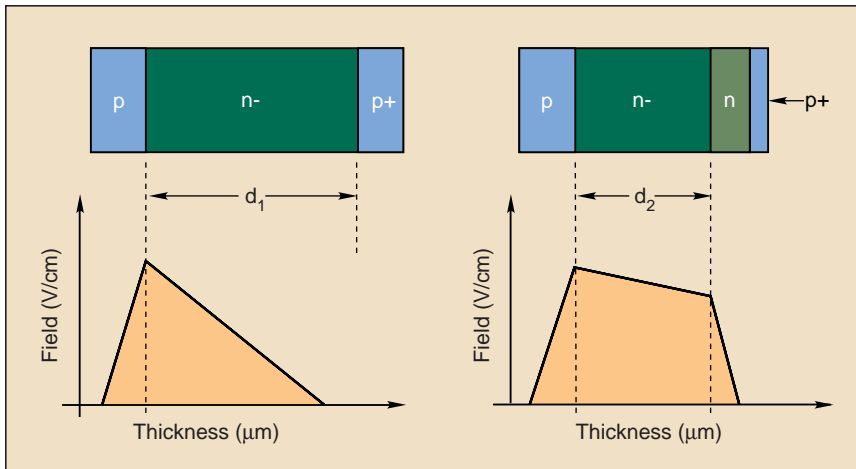


Figure 3 — The electric field in a blocking junction has a triangular distribution. With the addition of a buffer layer the electric field is more uniform, letting the device block the same voltage, but more efficiently because the silicon can be made thinner.

| Relative power semiconductor characteristics | | | | | |
|--|---------|---------------------------------|------------|----------------|---------------------|
| Type | Speed | Gain | Efficiency | Control method | Max. rating, A |
| GTO | Medium | Medium | Low | Current | 10,000 (snubbered) |
| IGBT | Fast | High | High | Voltage | 2,000 (unsnubbered) |
| IGCT | Fastest | Turn-off, low; conduction, high | High | Current | 4,000 (unsnubbered) |

as GTOs with their low conduction losses. But both structures have drawbacks. IGBTs have high conduction losses; GTOs are slow and require additional circuitry. (For more on GTOs and IGBTs, see "Power semiconductors for A-S drives," PT Design, 2/96, p. 66, or visit www.ptdesign.com on the Internet.)

It was while working on enhancements to GTOs and IGBTs when engineers at ABB took the first step toward IGCTs. They developed a GTO-type device that they named a Gate-Commutated Thyristor (GCT), Figure 1.

When GTOs change from a conducting state to a blocking state (turn-off), they go through an indeterminate state where they are neither a regenerative thyristor nor a transistor. This state is sometimes referred to as the GTO phase. This phase requires snubber circuits to reduce the rate at which voltage is reapplied to the circuit. To eliminate the need for snubbers, ABB engineers added very low inductance gate circuits to shunt all anode current out of the gate circuits and away from the cathode, Figure 2. The cathode shuts off within 1 μ sec and is not involved in the turn-off process.

When this happens, the IGCT effectively converts to a transistor with no base drive, turning off with high dv/dt . This is why it can operate without a snubber, like a MOSFET or an IGBT.

Device innovations

What makes IGCTs possible are several design innovations, including low inductance gate connections, the addition of a buffer layer in the semiconductor, use of a transparent emitter, and reverse conduction.

The addition of a buffer, Figure 3, reduces the required silicon wafer thickness by about 40% while still allowing high blocking voltages. This correspondingly reduces conduction and switching losses.

Previous GTO technology used anode shorts to provide a path for stored charges to leave the wafer during turn-off. IGCTs use transparent emitters instead. A transparent emitter is a thin and

weakly doped anode that's permeable to electrons. Electrons can cross without emission, as if the anode were shorted. This technique reduces trigger currents by almost one order of magnitude over conventional GTOs.

Antiparallel diodes are included on the same wafer as the switch and create a reverse conducting device, which significantly reduces inverter cost. The use of buffer layers and transparent emitters let engineers reduce the thickness of the diode without compromising its performance.

The combined result of all these innovations is a device that operates at over 500 Hz, versus the 250 Hz of earlier power devices at full rated current. (The thermal capabilities of the IGCT limit its frequency.) Total turn-off time is less than 4 μ sec, compared to about 50 μ sec for GTOs and 3 μ sec for IGBTs. The IGCT has lower conduction loss for devices rated 1.8 kV and higher.

Among the benefits of IGCTs is that engineers can choose the rate of switching to match the application. In a motor drive system, for example, this means that a designer can choose faster switching to obtain better system efficiency, or slower switching to improve inverter efficiency through reduced losses.

IGCTs also make possible other designs that have not been feasible in the past. With these devices, engineers do not have to design around IGBT and GTO trade-offs, which often impose limits on starting torque and regeneration ability. And they can expect to save at least 30% in overall system costs.

But these new switches will not replace IGBTs and GTOs in all applications. According to ABB, it is unlikely that manufacturers will develop IGCTs for low-voltage. One reason is that researchers may have reached the limits of silicon thinness. IGBTs also offer several benefits IGCTs can't match at economically lower voltages, such as low gate drive cost and gate control of short circuit conditions. ■