IGCT Technology — A Quantum Leap for High-power Converters

Low losses, small size, reliable, modular and cost-effective — uncompromising implementation of IGCT technology creates medium-voltage converters with entirely new characteristics.

Horst Grüning

From the very beginning, the development of power semiconductors was nothing more than a search for the ideal switch. The lowest on-state and commutation losses, the highest possible commutation frequency and a simple drive circuit were and still are what is needed in practice. From the transistor and Darlington to the IGBT, low-voltage applications have benefited all the way along while the medium-voltage user could only look on — GTO's and more GTO's, nothing else was in sight. Then at last, the IGBT's grew bigger … would they make the grade?

ABB Switzerland has explored a new avenue of development with the aim of exploiting the advantages of the IGBT for higher powers while retaining the strengths of the GTO as far as possible.

Thus the GCT (gate commutated thyristor) grew from the GTO — at first with an improved drive and a new gate connection and then with a new housing, new-technology wafer, monolithically integrated diodes, hybrid integrated drive, a much simplified power circuit and much more. We now find the potential of the new device to be so large that we are convinced we have found a worthy successor for the GTO.

The secret of the GCT

The key to success was in the GTO itself. More precisely, the only thing wrong with it was an enormous control problem. A typical turn-off response is shown in Fig. 1. Because of the demand for high turn-off amplification, the GTO passes through a region during the transition from the conducting (thyristor) to the non-conducting (transistor) states when both anode voltage and cathode current are impressed (red background). As with a mechanical switch, however, a four-layer device can only assume one of two stable states — on and off. The transition tends to instability and has to be got through as quickly as possible and be supported by snubber

Interdisciplinary development

Know-how from many disciplines is essential to develop high-power converters. This is where low-power electronics for the control circuit, silicone technology for the power semiconductors, metallurgy and ceramics for the hermetically sealed semiconductor housing, power electronics for the main circuit, conductors and cooling and mechanical engineering for the layout and construction all converge. The circuits of GTO converters are complex and a feature of their development is the many interfaces that were necessary.

IGCT megawatt converters of a piece

GCT's have a low-inductance drive circuit and for this reason conduct evenly. Poor compromises are eliminated, development and design become clearer and scalable, the ditches between the disciplines involved are bridged, R&D becomes coordinated — a converter of a piece is created.

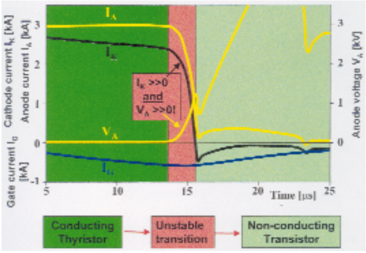

Fig. 1: Typical turn-off characterstic of a 4.5 kV, 3 kA, GTO

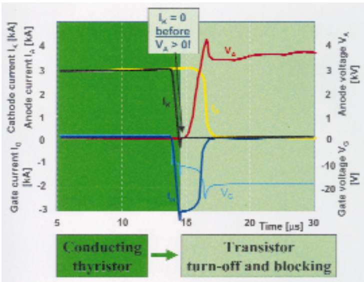

Fig. 2: Typical turn-off characterstic of a 4.5 kV, 3 kA, GTO

circuits. The basic principle of the GCT resolves these problems, because the device now has what is referred to as a hard drive (Fig. 2), i.e. instead of dI_G/dt @ 50 A/µs, $dI_G/dt \geq$ 3000 A/µs is applied to the gate. The current is thus switched from the cathode to the gate (hence the name GCT) before any appreciable change in the distribution of the charge between the gate and the anode can be observed. The conductivity and therefore the low anode voltage remain unchanged for as long as this charge (plasma) exists. The device thus changes directly from the thyristor to the transistor mode and turns off as a consequence just as stably, fast and without the help of a snubber circuit as an IGBT (insulated gate bipolar transistor).

1st. step towards an IGCT converter — a low-inductance drive

The rate-of-change of the drive is critical for the operation of the GCT. The cathode current has to be turned off in less than 1 µs, otherwise the device moves into the unstable part of the characteristic. This corresponds to $dI_G/dt \geq$ 3000 A/µs for a 3 kA GCT and proportionally more or less for other types. The voltage needed results for a given inductance of the gate circuit, respectively the inductance for a given gate voltage.

On the other hand, a simple, reliable and cost-effective drive unit is only possible at low voltages. An ideal voltage is –20 V, because the gate can withstand this voltage after turn-off. The permissible leakage inductance for interrupting 3 kA is 6 nH or less which is only 1/50 of the usual value for a GTO. It was possible to achieve this value by adopting a coaxial configuration of the device connection and a multi-layer connection to the power output of the drive (Fig. 3).

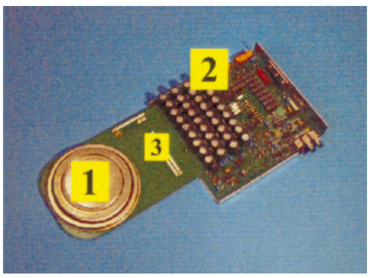

Fig. 3: 4.5 kV, 3 kA, IGCT (integrated gate commutated thyristor).
The GCT (1) and the gate unit (2) form a single part. The PCB (3) connects the GCT and the drive.

2nd. step towards an IGCT converter — optimum silicone technology

The so-called hard drive solves the GTO's drive problem. This actually also improves a standard GTO wafer and the GCT manufacturer no longer has to compromise when designing the wafer in order to obtain the desired switching characteristic. The GCT wafer can be much thinner than GTO wafer and this smoothes the way to the utilisation of plasma engineering techniques. GCT's generate for this reason much lower losses than GTO's (Fig. 4).

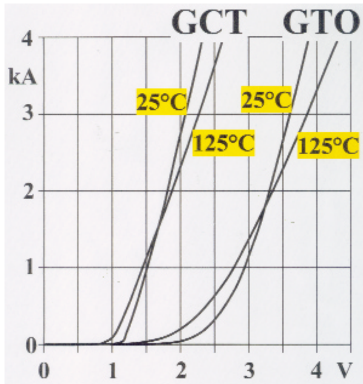

Fig. 4: A comparison between GTO 5SGA 40L4501 and GCT 5SGY 35L4502. The commutation losses of both devices are approximately the same.

3rd. step towards an IGCT converter — higher converter integration and linear sizing with current

IGCT technology applies two levels of integration: monolithic on the wafer and hybrid for the periphery of the GCT.

In many cases, the anti-parallel diodes can be integrated monolithically (Fig. 5). This eliminates the diode stack and associated heavy current connections.