Approaching Power Switching Perfection with IGCTs – Integrated Gate-Commutated Thyristors

IGCT type 5SHY 55L4500 – 91 mm, 4.5 kV

The IGCT is a snubberless gate-controlled turn-off switch which turns off like an IGBT but conducts like a thyristor with the lowest conduction losses. Fig. 1 shows turn-off at 3000 A. GCTs are the only high power semiconductors to be supplied integrated into their gate-units. The user thus only needs to connect the device to a 28 – 40 V power supply and an optical fibre for on/off control. Because of the topology in which it is used, the IGCT produces negligible turn-on losses. This, together with its low conduction losses, enables high frequency operation formerly unobtainable by high power semiconductors.

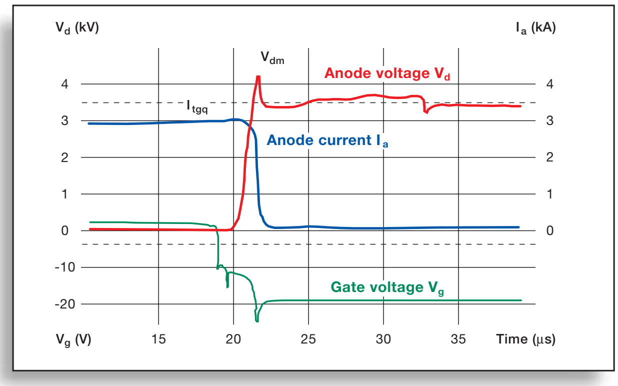

Fig. 1
IGCT turn-off exhibits same waveform and losses (E_{off}) as Transistor

Applications

The Integrated Gate-Commutated Thyristor is the latest power switching device for demanding High-Power applications such as:

- MVD (Medium Voltage Drives)
- Marine Drives
- Traction
- Co-generation
- WindPower Converters
- STATCOMs
- DVRs (Dynamic Voltage Restorers)
- VAR SPEED (AC excitation systems)
- BESS (Battery Energy Storage Systems)
- SSB (Solid State Breakers)
- DC Traction Line Boosters
- Traction Power Compensators
- Induction Heating

The IGCT is now used in a multitude of applications due to its versatility, efficiency and cost-effectiveness as can be seen from a selection of references at the end of this document. Due to their low on-state voltages, they achieve the lowest running costs by allowing inverter efficiencies greater than 99.6% to be achieved.

As can be seen in Table 2, IGCTs are available as reverse conducting (RC), asymmetric and reverse blocking (RB) devices allowing them to be used in both AC and DC circuits (e.g. in voltage and current source inverters). Additionally, they can be used in self, line or load-commutated applications for both parallel and series resonant inverters in, for instance, induction heating furnaces because of their ability to operate as ”zero t_Q”, highly interdigitated, fast, high voltage thyristors.

Fig. 3
Standard IGCT sizes

The low losses allow hard-switched operating frequencies of up to 600 Hz for 6.5 kV devices and 1 kHz for 4.5 kV devices in the steady state and over 25 kHz in burst mode.

Fig. 2
Basic IGCT inverter circuit

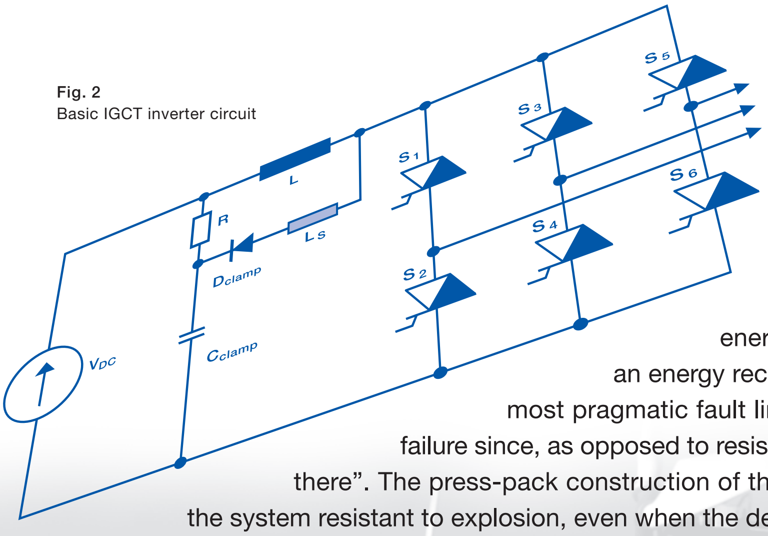

Fig. 2 illustrates the basic IGCT VSI topology. It can be seen that diode commutation is controlled by inductance L and not by turn-on modulation as would be the case with IGBTs. Though turn-on modulation is a practical approach with low voltage transistors, the engendered losses are excessive at high voltages. The clamp circuit of Fig. 2 eliminates turn-on energy in the semiconductor by storing it in L. This energy is then either dissipated in R or recycled by an energy recovery circuit (not shown). The inductance is the most pragmatic fault limitation technique in the event of catastrophic failure since, as opposed to resistors and fuses, it has the merit of ”already being there”. The press-pack construction of the IGCT, combined with the inductance, makes the system resistant to explosion, even when the device’s surge rating is exceeded.

Turn-off dv/dt is also not gate-controlled but programmed at the device manufacturing stage by anode design and lifetime engineering. The absence of dv/dt and di/dt control functionality simplifies gate-unit design and allows a high degree of standardisation. Fig. 3 shows currently available device calibres.

Some sixty publications exist on the use of IGCTs in many of the applications previously listed and these can be downloaded from the ABB website (www.abb.com/semiconductors). Table 1 summarises the essential documents relating to the application of IGCTs.

Title	Document number
Applying IGCT Gate Units	5SYA2031
Applying IGCTs	5SYA2032
Recommendations regarding mechanical clamping of Press-pack High Power Semiconductors	5SYA2036
Failure Rates of IGCTs due to Cosmic Rays	5SYA2046
Field measurements on High Power Press-pack Semiconductors	5SYA2048
Voltage ratings of high power semiconductors	5SYA2051
Specification of environmental class for pressure contact IGCTs - OPERATION	5SZK9107
Clamp circuit with energy recovery	Patent N° DE 199 42 258 A 1

Table 1 – Principal applications documents

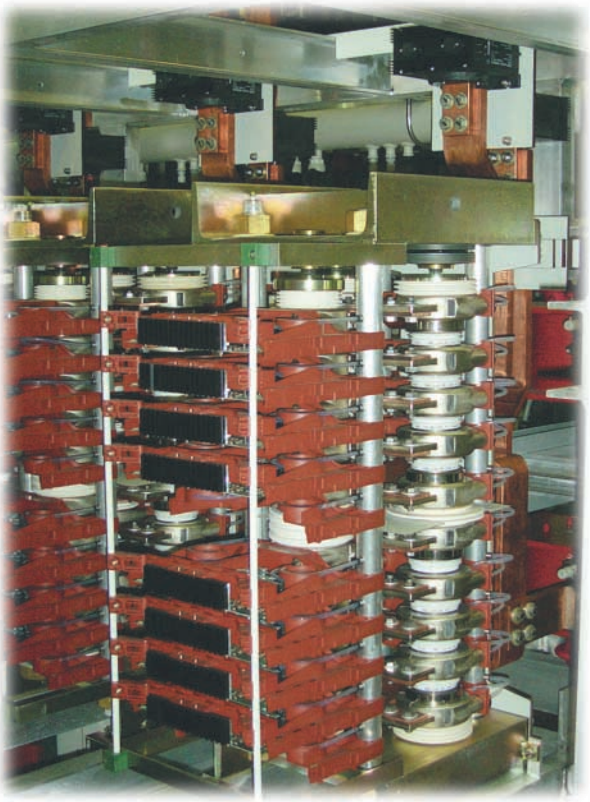

Fig. 4
Power Electronic Building Block with 27 MW/m^3 power density

Outlook

The expansion of power electronics into the new fields of Energy Management, Renewable Energy Sources and Co-generation is driving semiconductor requirements towards higher frequency, higher voltage and higher efficiency while increasing demands for reliability and lower costs. The IGCT is capable of still higher currents, voltages and frequencies without series or parallel connection and the first of such products will appear in 2007 as "**H**igh **P**ower **T**echnology" devices, see Table 2 below. This latest family of IGCTs exhibit 50% higher turn-off capability than standard devices.

Growing markets for reverse blocking devices are leading to the expansion of the product range with new devices scheduled for production in 2008 ([5]). 10 kV devices are now also in development.

Within 10 years of its introduction, the IGCT has established itself as the power device of choice for high power at high voltage by meeting the needs of a growing and demanding Power Electronic Market. Single inverters of over 15 MW can now be realised without series or parallel connection achieving the highest inverter power densities in the industry. The use of series connection has already produced 100 MW inverters with first generation devices and for future installations, e.g. in Utility STATCOMs, powers of up to 300 MW are envisioned.

Product Range

Type		Reverse Conducting				Reverse Blocking				Asymmetric
V_{DRM}	Si ø	38 mm	51 mm	68 mm	91 mm	38 mm	51 mm	68 mm	91 mm	91 mm
3.3 kV		/	/	/	/	/	/	/	/	TBD
4.5 kV		340 A	640 A	1100 A	2250 A	/	/	/	/	[1] 4000 A
4.5 kV		/	/	/	/	/	/	/	/	[2] 3800 A
4.5 kV		/	/	/	/	/	/	/	/	[3] 4000 A
4.5 kV		/	/	/	/	/	/	/	/	[4] 5500 A (HPT)
5.5 kV		275 A	520 A	910 A	1820 A	/	/	/	/	[5] 5000 A (HPT)
6.0 kV		/	/	/	/	/	800 A	/	/	3000 A
6.5 kV		/	/	/	/	[4] 400 A	[5] 800 A	[5] 1500 A	TBD	[4] 4200 A (HPT)
10 kV		/	/	TBD	TBD	/	/	/	/	[6] 3000 A

Table 2 – Product Range

Legend:

[1] standard

[2] high frequency

[3] low on-state

[4] production in 2007

[5] production in 2008

[6] production in 2010

References

No.	Application	Project	Supplier	IGCT Type	Year
1	Intertie (100 MW)	Swb Synor GmbH Stadtwerke Bremen (D)	ABB (CH)	Asymmetric	1996
2	Intertie (2 x 66 MVA)	e-on Netz Bayernwerke, Karlsfeld (D)	Adtranz / ABB (CH)	Asymmetric	1999
3	MVDs (0.3 – 5 MW)	ACS1000	ABB (CH)	Reverse Conducting	1998
4	DVR (4 MW)	Singapore	ABB (CH)	Asymmetric	1997
5	Interties (2 x 19 MVA)	DB Energie GmbH (D)	ABB (CH)	Asymmetric	2001
6	MVD (1.5 MW)	Silcovert H+	ASI Robicon (I)	Asymmetric	1998
7	MVD (5.3 MW / 14 krpm)	Silcovert H+	ASI Robicon (I)	Asymmetric	2000
8	BESS (18 MVA)	National Power (UK)	ABB (CH)	Asymmetric	2000
9	DVR (2 x 22 MW)	Israel	ABB (CH)	Asymmetric	2000
10	MVD (5 – 27 MW)	ACS 6000	ABB (CH)	Asymmetric	1999
11	MVD (0.3 – 5 MW)	PowerFlex 7000	RA (CAN)	Reverse Blocking	2000
12	SSB (4 kVDC / 16 kA)	RFX Fusion Torus	ASI Robicon (I)	Asymmetric	2004
13	Traction drive (3 MW)	HST SOKOL Moscow – St. Petersburg	RAO, "VSM", SET Corp. (RUS)	Asymmetric	2001
14	Chopper	SMES	American Superconductor (USA)	Asymmetric	1999
15	Intertie (2 x 19 MVA)	DB Energie GmbH (D)	ABB (CH)	Asymmetric	2001
16	MVD (9 MW)	Silcovert GN	ASI Robicon (I)	Asymmetric	2000
17	Wind Power (1 MW)	Unity PF Converters	Gamesa (E)	Reverse Conducting	2001
18	BESS (18 MVA)	TVA Columbus, MS	ABB (CH)	Asymmetric	2002
19	Choppers, VSI, SSB (64 MW)	RFX Fusion Reactor	ASI Robicon (I)	Asymmetric	2001
20	Pulse Power (6 MW)	Medical	Jaeger Toennies (D)	Reverse Conducting	2001
21	Wind Power (2 – 5 MW)	Unity PF Converters	ABB (CH)	Rev. Conducting / Asym.	2006
22	Trolley Bus Chopper (300 kW)	Hradec Kralove (CZ)	Skoda Ostrov & Polovodice (CZ)	Reverse Blocking	2002
23	MVD (1.5 MW)	SER Drives	Int'l. Electronics (E)	Asymmetric	2002
24	MVD (1 MW)	MYVF-6000	Ming Yang (PRC)	Reverse Conducting	2002
25	MVD (10 MW)	Steel Mill	Aritime (PRC)	Asymmetric	2003
26	MVD (2 MW)	General Purpose	Nanjing Drives (PRC)	Reverse Conducting	2004
27	MVD (5 – 24 MW)	ACS 5000	ABB (CH)	Reverse Conducting	2005
28	Co-generation (10 MW)	Unity PF Converters	Energomash (RUS)	Asymmetric	2006
29	STATCOM (50 MVA)	VAR Compensation	Xu Ji (PRC)	Asymmetric	2006
30	Step down chopper	Traction line booster	NIIEFA-Energo (RUS)	Asymmetric	2006
31	Rotary Intertie (12 MW)	Slip frequency controller	ABB (CH)	Asymmetric	2006
32	STATCOM (2 x 13 MVA)	Reactive power compens.	ABB (CH)	Asymmetric	2006
33	Chopper (0.7 MW)	HST "Sokol"	VSM (RUS)	Asymmetric	1999
34	Chopper (1 MW)	EMU EM2I	Spetsremont (RUS)	Asymmetric	1999

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