

The Work-Horse of Power Conversion: Phase Control and Bi-directionally Controlled Thyristors



Since its introduction in the 1960s, the phase control thyristor has been the back-bone of the high power electronics industry. Its field of application ranges from small DC-drives rated at a few kW, to converters for HVDC (High Voltage DC transmission) of several GWs. Even though fast and asymmetric thyristors have been replaced by turn-off devices, the Phase Control Thyristor (PCT) remains, thanks to its ease of operation and low losses, the device of choice for many high power applications.

Due to the growing demand for energy efficiency, the thyristor remains at the heart of much of the equipment needed for energy transmission and distribution, as it allows the best performance in terms of cost, reliability and efficiency. For these reasons, ABB not only maintains its existing thyristor range but continues to improve and enlarge it with devices for today's needs and the needs envisaged for tomorrow.

The ABB PCT product range, see Table 1, includes press-pack devices with ratings of 1600 – 8500 V and 350 – 6100 A used in demanding applications such as HVDC, FACTS and DC-drives. These components have been used in very large numbers over very many years, setting benchmark reliability records.

Product Range for Phase Control Thyristors

Part number	Voltage V_{DRM} (V)	Current I_{TAV} (A)	Current I_{TSM} (kA)	T_{VJM} (°C)	Thermal resistance R_{thjc} (K/kW)	Mounting Force (kN)	Housing
5STP 10D1601	1600	969	15.0	125	32	10	D
5STP 07D1800	1800	730	9.0	125	36	10	D
5STP 09D1801	1800	932	13.7	125	32	10	D
5STP 09D2201	2200	862	12.0	125	32	10	D
5STP 06D2800	2800	620	8.0	125	36	10	D
5STP 08D2801	2800	793	10.6	125	32	10	D
5STP 04D4200	4200	470	6.4	125	36	10	D
5STP 04D5200	5200	440	5.0	125	36	10	D
5STP 03X6500 ¹⁾	6500	350	4.5	125	45	10	X
5STP 20F1601	1600	1901	27.3	125	16	22	F
5STP 18F1800	1800	1660	21.0	125	17	22	F
5STP 18F1801	1800	1825	26.2	125	16	22	F
5STP 17F2201	2200	1702	25.5	125	16	22	F
5STP 16F2800	2800	1400	18.0	125	17	22	F
5STP 16F2801	2800	1512	23.6	125	16	22	F
5STP 12F4200	4200	1150	15.0	125	17	22	F
5STP 08G6500 ²⁾	6500	720	11.8	125	22	22	G
5STP 34H1601	1600	3370	49.0	125	10	50	H
5STP 27H1800	1800	3000	47.0	125	10	50	H
5STP 30H1801	1800	3108	47.0	125	10	50	H
5STP 29H2201	2200	2855	45.0	125	10	50	H
5STP 24H2800	2800	2625	43.0	125	10	50	H
5STP 27H2801	2800	2670	43.0	125	10	50	H
5STP 18H4200	4200	2075	32.0	125	10	50	H
5STP 17H5200	5200	1975	29.0	125	10	50	H
5STP 12K6500	6500	1370	21.9	125	11	50	K
5STP 33L2800	2800	3740	60.0	125	7.0	70	L
5STP 28L4200	4200	3170	52.0	125	7.0	70	L
5STP 25L5200	5200	2760	42.0	125	7.0	70	L
5STP 18M6500	6500	1800	32.0	125	9.0	70	M
5STP 45N2800	2800	5080	75.0	125	5.7	90	N
5STP 38N4200	4200	3960	60.0	125	5.7	90	N
5STP 34N5200	5200	3600	55.0	125	5.7	90	N
5STP 26N6500	6500	2810	45.0	125	5.7	90	N
5STP 12N8500	8500	1200	35.0	90	5.7	90	N
5STP 50Q1800	1800	6100	94.0	125	5.0	90	Q
5STP 45Q2800	2800	5490	75.0	125	5.0	90	Q
5STP 38Q4200	4200	4275	60.0	125	5.0	90	Q
5STP 34Q5200	5200	3875	55.0	125	5.0	90	Q
5STP 57U4200	4200	5710	97.5	125	4.0	135	U
5STP 52U5200	5200	4120	82.5	110	4.0	135	U
5STP 42U6500	6500	3430	71.4	110	4.0	135	U

¹⁾ Also available in D housing

²⁾ Also available in F housing

Table 1

The Bi-directionally Controlled Thyristor

Since many medium and high voltage applications use anti-parallel connected thyristors as AC controllers, ABB has introduced the Bi-directionally Controlled Thyristor (BCT) which consists of two monolithically integrated anti-parallel thyristor functions on one silicon wafer. The two thyristor halves are, unlike TRIACs, individually triggered and have a separation region enabling the design of high voltage devices with the dynamic capability of discrete devices. Fig. 1 shows a cross-section of the BCT's silicon wafer.

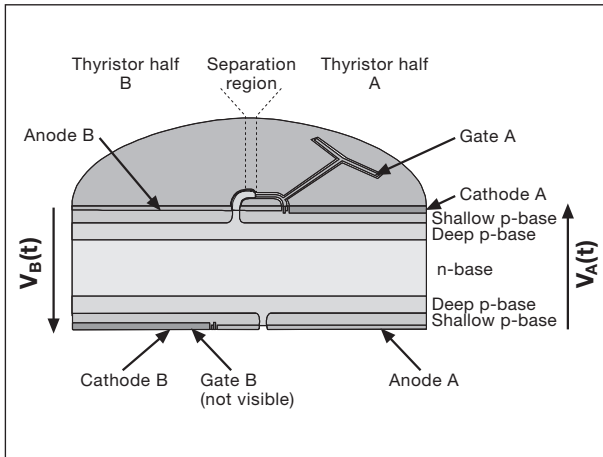


Fig. 1 Cross-section of a BCT

The BCT is designed, manufactured and tested using the same philosophy, technology and equipment as the well established PCT thus reaching the same levels of performance and reliability as experienced with the PCT. This enables manufacturers of equipment for applications such as SVC, 4-quadrant DC-drives and soft starters to reduce part count and equipment size without jeopardizing reliability and performance by introducing the BCT instead of a conventional solution with PCT. Examples show volume improvements and part counts reductions for equipment with BCT in the magnitude of 25% compared with equally rated PCT-solutions.

The BCT product range includes 2 wafer sizes available in 3 different housings with ratings 2800 – 6500 V and 3120 – 5840 A as can be seen in Table 2. The ratings I_{TSM} , and R_{thjc} are given for one “thyristor-half” of the device. I_{RMS} is the rms-current for a device operating in an AC-switch application.

Product Range for Bi-directionally Controlled Thyristors

Part number	Voltage V_{RM} (V)	Current I_{RMS} (A)	Current I_{TSM} (kA)	T_{VM} (°C)	Thermal resistance R_{thjc} (K/kW)	Mounting Force (kN)	Housing
5STB 24Q2800	2800	5840	43	125	10	90	Q
5STB 24N2800	2800	5400	43	125	11.4	90	N
5STB 18N4200	4200	4260	32	125	11.4	90	N
5STB 17N5200	5200	4000	29	125	11.4	90	N
5STB 13N6500	6500	3120	22	125	11.4	90	N
5STB 25U5200	5200	4400	42	110	8	135	U
5STB 42U6500	6500	3510	30	110	8	135	U

Table 2

Voltage rating definitions

The development of high-voltage thyristors has led to increased values of dissipated power in the off-state (due to the higher voltages) even if the leakage currents themselves have remained at similar levels to devices with lower blocking capability. This can cause problems when such devices are characterised and measured in outgoing inspection at elevated temperature (e.g. 125°C) because the *whole device* is heated to a constant temperature (not just the junction) and no temperature gradient exists to sink the generated heat away from the junction, resulting in

thermal runaway during testing. Here the applied voltage causes a leakage current and the product ($V \times I$) heats the device. As the device gets hotter, leakage current increases exponentially and so, also, does the heating. If the cooling of the device is not adequate, the device will get progressively hotter and will ultimately fail. This is in strong contrast to real-world applications where the junction temperature may indeed reach a maximum value of 125°C but the case temperature never exceeds, say, 110°C, allowing leakage current losses to be cooled away across the temperature gradient between junction and case.

A more realistic method of measuring power semiconductor is to have a sinusoidal 50 or 60 Hz wave of peak value V_{DWM}/V_{RWM} and to superimpose a narrow pulse of amplitude V_{DRM} as per Fig. 2. This pulse corresponds to repetitive voltage peaks as typically caused by commutation transients (though the RC-circuit limiting them should be designed to give a peak voltage below rated V_{DRM} and V_{RRM}).

By using this method, the voltage capability is tested at application-like conditions and in conformance with international standards, without thermal run-away. This method of rating is applied to ABB's high voltage thyristors, $V_{DRM}/V_{RRM} > 4500$ V. In the data sheets, the level for V_{DWM}/V_{RWM} is selected as the maximum expected working voltage for a device chosen according to the recommendations in Application Note 5SYA2051 "Voltage ratings for high power semiconductors".

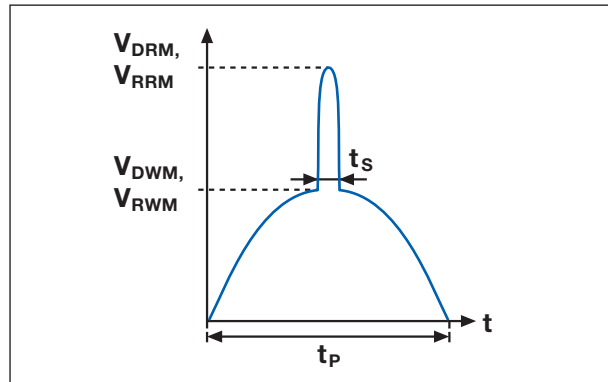


Fig. 2 Voltage definitions for high voltage PCTs and BCTs

Documentation

Device datasheets are available from the ABB website (www.abb.com/semiconductors). Additional documentation required for the reliable application of Phase Control and Bi-directionally Controlled Thyristors is available at the same site and is summarised in Table 3. The environmental specifications are available upon request.

Document Title	Document number
Phase control thyristors, sections 1 - 5	
BCT application note	5SYA2006
Design of RC-snubbers for phase control applications	5SYA2020
Gate drive recommendations for phase control thyristors	5SYA2034
Recommendations regarding mechanical clamping of high power press pack semiconductors	5SYA2036
Field measurements on high power press pack semiconductors	5SYA2048
Voltage definitions for PCT and BCT	5SYA2049
Voltage ratings of high power semiconductors	5SYA2051
Specification of environmental class for pressure contact diodes, PCTs and GTO, storage	5SZK9104
Specification of environmental class for pressure contact diodes, PCTs and GTO, transportation	5SZK9105

Table 3 – Principal applications documents

Outlook

Although Turn-off devices such as IGCTs and IGBTs have been introduced in certain applications formerly dominated by PCTs, the need for efficient energy transmission and distribution solutions secures the position of the PCT as the back-bone of power electronics. New products continue therefore to be developed, with 6" devices planned for 2008.

Recent developments, such as static breakers, have opened new fields of application for both PCTs and BCTs. These new markets, in addition to the growing traditional applications such as HVDC, will ensure the PCT's pivotal position in power conversion for many years to come.

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