

FUJI HIGH POWER GTO THYRISTORS

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1 INTRODUCTION

In development of new types of power semiconductor devices, power electronic technology is accomplishing a new innovation. Fuji Electric has developed and commercialized Gate Turn Off (GTO) thyristors having a gate turn-off capability in order to make high power converter equipments smaller in size and lighter in weight as to enhance their efficiency and performance, thus, expansion of their field of application is expected.

Immediately following the development of an asymmetrical GTO Thyristor (Type: EFT23-45) of the highest voltage current ratings in the world of 4.5 kV/3,000A used for inverter and chopper equipments for driving large-capacity motor, Fuji Electric has newly developed reverse-blocking 4.5 kV/3,000A GTO thyristors (Type: EFT06-45 and EFT26-45) for applying them to high voltage high current breaker and converter equipments requiring reverse blocking voltage. Also, Fuji Electric has succeeded in developing and commercializing a reverse conducting 2.5 kV/2,000A GTO thyristor (Type: EHS21-25) with arrangement of GTO thyristor and antiparallel diode on the same chip, thus promoting enhancement of functionality

of GTO thyristors.

This report introduces features, ratings and characteristics of asymmetrical and reverse blocking 4.5 kV/3,000A GTO thyristors, and reverse conducting 2.5 kV/2,000A GTO thyristor.

2 ASYMMETRICAL GTO THYRISTOR

The asymmetrical GTO thyristor has, as shown in Fig. 1 (a), an asymmetrical junction structure, and an anode short structure is adopted for reducing the switching loss.

Table 1 shows the ratings and characteristics. As shown in the table, the controllable current is as large as 3,000A and this is the largest class of interrupting capability while the turn off time is 25 μ s.

3 REVERSE BLOCKING GTO THYRISTOR

The reverse blocking GTO thyristor has a junction structure as shown in Fig. 1 (b) and has the reverse blocking capability equal to 4.5 kV off-state voltage. The outer view is shown in Fig. 2.

As shown in Table 2, there are two types in recently

Fig. 1 Structure of GTO thyristors

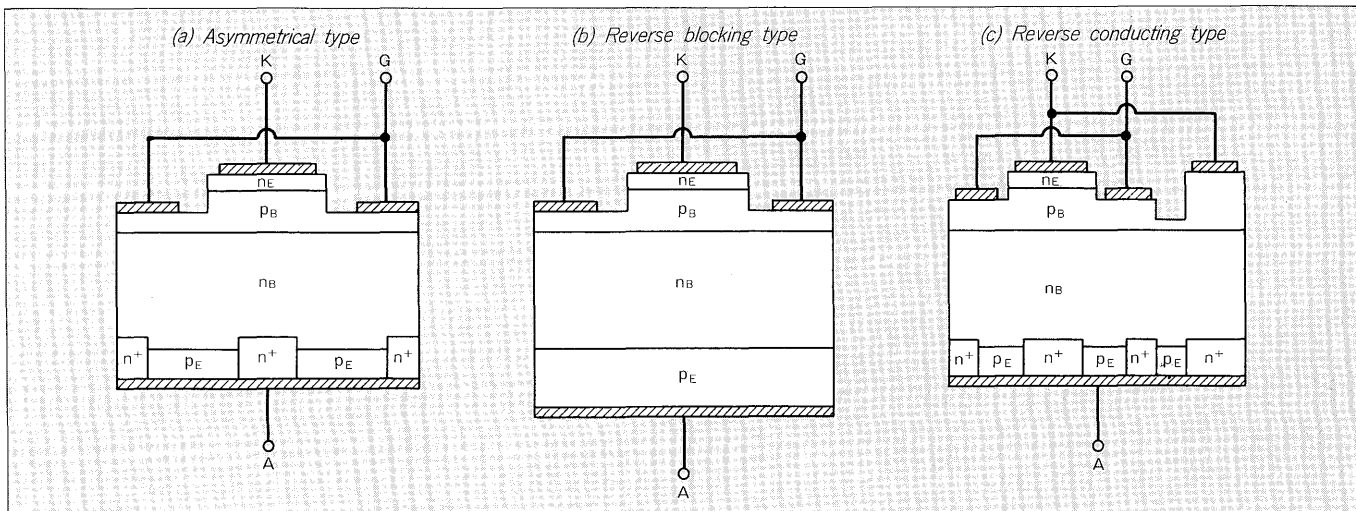


Table 1 Ratings and characteristics of asymmetrical 4.5 kV/3,000A GTO thyristor

Item	Symbol	Unit	EFT23-45
Off-state voltage	V_{DRM}	V	4,500
Reverse voltage	V_{RRM}	V	20
Controlable current	I_{TGQM}	A	3,000
Effective current	$I_{\text{T(RMS)}}$	A	1,000
Surge current	I_{TSM}	A	16,000
Critical di/dt	di/dt	A/ μs	300
Reverse gate voltage	V_{RGM}	V	20
Junction temperature	T_{j}	$^{\circ}\text{C}$	$-40\sim 125$
Storage temperature	T_{stg}	$^{\circ}\text{C}$	$-60\sim 125$
Mounting force		kg	$4,000\pm 400$
On-state voltage	V_{TM}	V	3.5
Critical dv/dt	dv/dt	V/ μs	1,500
Gate trigger current	I_{GT}	A	3.0
Turn on time	t_{gt}	μs	10
Turn off time	t_{gq}	μs	25
Thermal resistance	$R_{\text{th(j-f)}}$	$^{\circ}\text{C/W}$	0.015

Fig. 2 Reverse blocking 4.5 kV/3,000A GTO thyristor

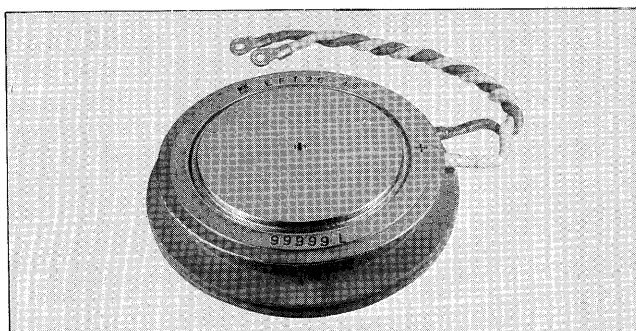
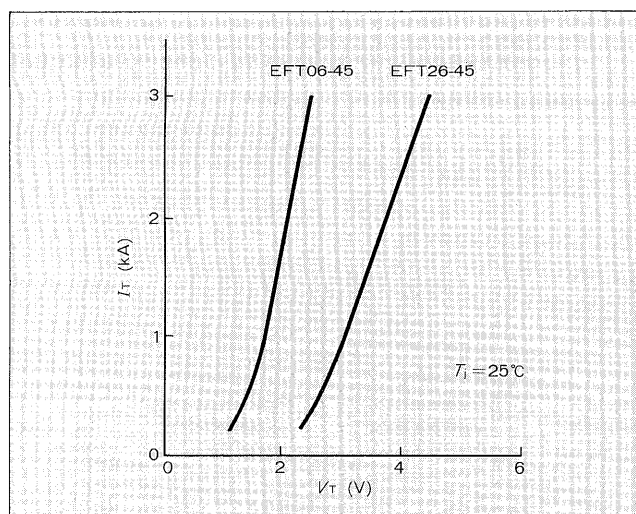


Fig. 3 On-state current/voltage characteristics



developed reverse blocking GTO thyristors. The first type (Type: EFT06-45) has been developed for breakers, having

Table 2 Ratings and characteristics of reverse blocking 4.5 kV/3,000A GTO thyristors

Item	Symbol	Unit	EFT06-45 (High current type)	EFT26-45 (High speed type)
Off-state voltage	V_{DRM}	V	4,500	4,500
Reverse voltage	V_{RRM}	V	4,500	4,500
Controlable current	I_{TGQM}	A	3,000	3,000
Effective current	$I_{\text{T(RMS)}}$	A	1,400	1,000
Surge current	I_{TSM}	A	16,000	14,000
Critical di/dt	di/dt	A/ μs	300	300
Reverse gate voltage	V_{RGM}	V	20	20
Junction temperature	T_{j}	$^{\circ}\text{C}$	$-40\sim 125$	$-40\sim 115$
Storage temperature	T_{stg}	$^{\circ}\text{C}$	$-60\sim 125$	$-60\sim 125$
Mounting force		kg	$4,000\pm 400$	$4,000\pm 400$
On-state voltage	V_{TM}	V	2.5	4.5
Critical dv/dt	dv/dt	V/ μs	1,500	1,500
Gate trigger current	I_{GT}	A	1.0	1.5
Turn on time	t_{gt}	μs	10	10
Turn off time	t_{gq}	μs	30	25
Thermal resistance	$R_{\text{th(j-f)}}$	$^{\circ}\text{C/W}$	0.015	0.015

Fig. 4 Turn on waveform

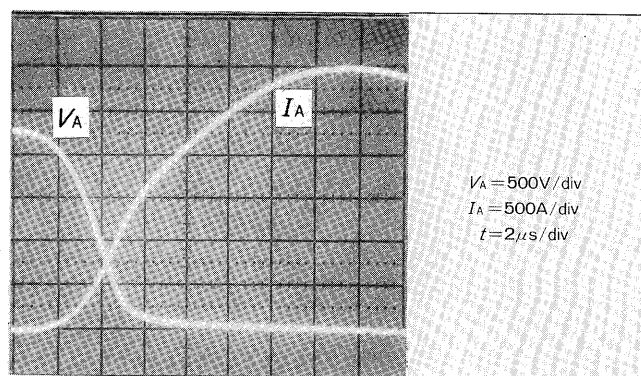
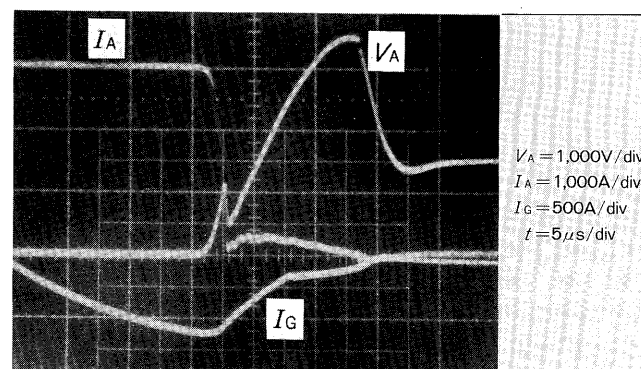


Fig. 5 Turn off waveform



an on-state voltage as low as 2.5 V/3,000A so that it can flow an effective current as high as 1,400A. The second

type (Type: EFT26-45) has been developed for applying to converter equipments, having been suitably doped with lifetime killer, so that the turn off time is as short as 25 μ s, thus reducing the switching loss. Fig. 3 shows on-state current voltage characteristics while, Fig. 4, turn on waveform. In two types, that is, both EFT06-45 and EFT26-45, the value of di/dt is 300A/ μ s, and the turn on time is less than 10 μ s. Fig. 5 shows turn-off waveform of high-speed type EFT26-45. The anode current of 3,000A is interrupted within 25 μ s. For high-current type EFT06-45, the turn off time is less than 30 μ s.

4 REVERSE CONDUCTING GTO THYRISTOR

The reverse conducting GTO thyristor has a structure

Fig. 6 Reverse conducting 2.5 kV/2,000A GTO thyristor

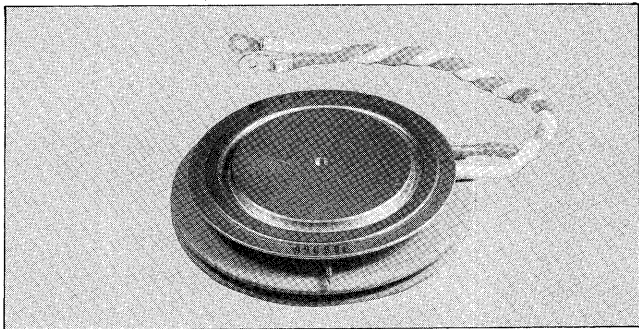


Fig. 7 Outer view of an element

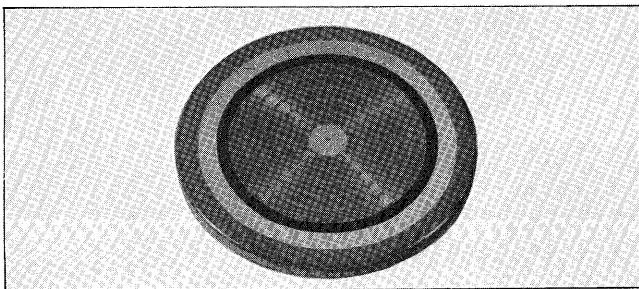
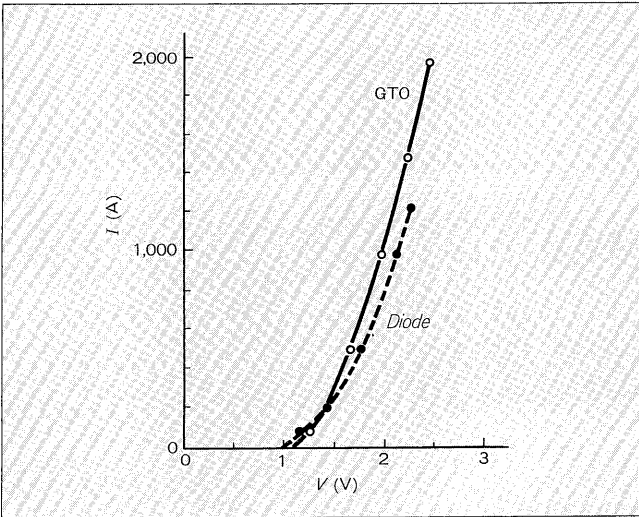


Fig. 8 On-state current and reverse current/voltage characteristics



of GTO thyristor combined with anti parallel diode, whose structure in section is as shown in Fig. 1 (c). The outer view of the case is shown in Fig. 6 and that of element, in Fig. 7. In the inner circumference of the element, GTO thyristor is arranged, while in the outer circumference, diode is arrayed. There is a groove between GTO unit and diode unit, thus the two units are electrically insulated one from another.

Table 3 shows the ratings and characteristics. Fig. 8 shows on-state and reverse current/voltage characteristics of GTO unit and diode unit. The on-state voltages for both are less than 2.5V at the current of 1,000A. Fig. 9 shows turn on waveform, Fig. 10, turn off waveform, and Fig. 11, commutating waveform. By optimum application of separation technique for GTO unit from diode unit, di/dt of

Table 3 Ratings and characteristics of reverse conducting 2.5 kV/2,000A GTO thyristor

Item		Symbol	Unit	EHS21-25
Off-state voltage		V_{DRM}	V	2,500
Controlable current		I_{TGQM}	A	2,000
Effective current	GTO	$I_{T(RMS)}$	A	600
	Diode	$I_{R(RMS)}$	A	600
Surge current	GTO	I_{TSM}	A	7,000
	Diode	I_{RSM}	A	7,000
Critical di/dt		di/dt	A/ μ s	300
Gate reverse voltage		V_{RGM}	V	20
Junction temperature		T_j	$^{\circ}$ C	-40~125
Storage temperature		T_{stg}	$^{\circ}$ C	-60~125
Mounting force			kg	3,000 \pm 300
On-state voltage	GTO	V_{TM}	V	2.5/1,000A
Reverse voltage	Diode	V_{RM}	V	2.5/1,000A
Gate trigger current		I_{GT}	A	2.0
Gate trigger voltage		V_{GT}	V	0.9
Turn on time		t_{gt}	μ s	10
Turn off time		t_{gq}	μ s	25
Reverse recovery current		I_{rr}	A	250
Commutating dv/dt		$(dv/dt)_c$	V/ μ s	500
Thermal resistance	GTO	$R_{th(j-f)}$	$^{\circ}$ C/W	0.03
	Diode	$R_{th(j-f)}$	$^{\circ}$ C/W	0.04

Fig. 9 Turn on waveform

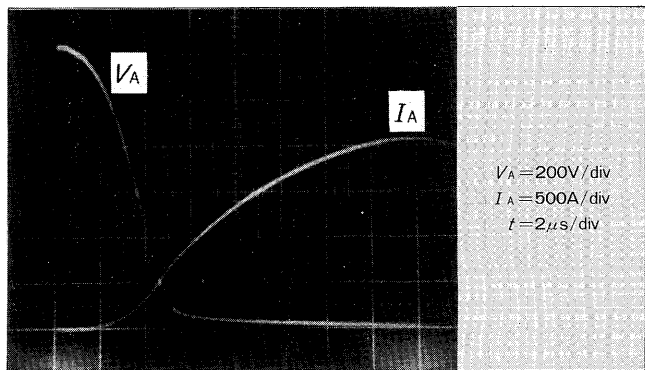


Fig. 10 Turn off waveform

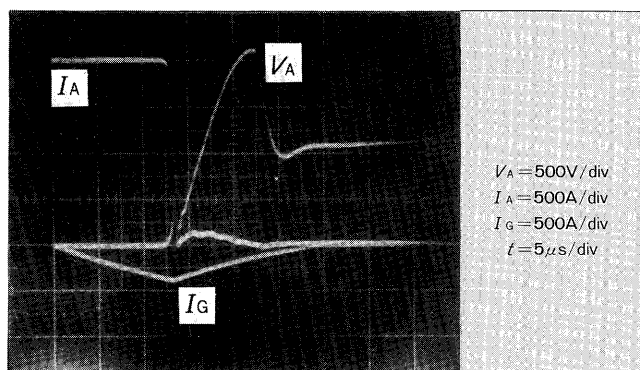
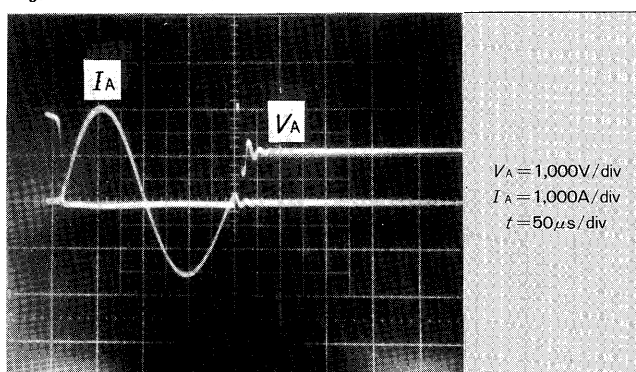


Fig. 11 Commutating waveform



300A/ μs , turn on time of 10 μs , turn off time of 25 μs , and commutating dv/dt of 500V/ μs are attained without deteriorating the off-state voltage of 2.5 kV. By placing these elements into practical use, an advance in miniaturization of inverter equipment is expected to progress another leap forward.

5 CONCLUSION

We have summarized the present situation in development of GTO thyristors for high power application in our company, Fuji Electric. By developing 4.5 kV/3,000A asymmetrical and reverse blocking GTO thyristors and 2.5 kV/2,000A reverse conducting GTO thyristor, we expect that application field for power converter equipments will be expanded still more.