Early-Time Turn-on Characteristics of a High Current Thyristor

L.D. Roose and G.J. Rohwein
High Power Electromagnetics Dept.
Sandia National Laboratories
P.O. Box 5800, MS-1153
Albuquerque, NM 87185-1153

Abstract

Studies and experiments aimed at increasing the turn-on speed of high current thyristors^{1,2,3,4} have been carried out in recent years to meet an expanding need in the pulsed power field for switches with high peak power handling capacity and high pulse repetition rate capability. The present tests were conducted to measure the early-time turn-on characteristics of ABB 2003-45A02 thyristors and to determine whether special triggering techniques could raise the safe turn-on rate to the 100,000 A/ μ s range which would qualify it for applications such as direct drive accelerator circuits. Results were encouraging. With these devices and special triggering techniques a maximum turn-on rate of 65,373 A/ μ s and a peak current of 19,040 A were recorded at a pulse repetition rate of 5 Hz.

Introduction

Because of their high current carrying capacity, high power thyristors are used in numerous switching applications such as motor controllers power converter circuits, and pulse discharge systems. Their principal limitation for pulsed power applications is turn-on speed (di/dt) which, for most conventional thyristors, ranges between less than 500 A/ μ s to roughly

1,100 A/ μ s when triggered in the normal mode. With enhanced triggering techniques, however, some conventional thyristors will turn on at rates exceeding 40,000 A/ μ s¹. In some cases, turn-on rates over 100,000 A/ μ s⁵ have been recorded. At these and higher rates, many more potential thyristor applications exist. One such application is commercial pulsed accelerators which typically generate pulses of 1-to-2 MV, 5,000 to 10,000 A with 50-to-100 ns duration. Pulse repetition rates range from tens to hundreds of hertz. In these circuits, switches must turn on fast enough for a current rise of 15-to-30 ns.

From the standpoint of switching, all of these requirements except pulse duration and rise time can currently be met by high power thyristors. The present tests were conducted on two ABB HCT 2003-45A02 thyristors (Fig. 1) to evaluate their fast pulse capability. These devices have a manufacturers rating of 4.5 Kv, 18KA/ μ s, 80 KA peak sinusoidal current.

Fig. 1 ABB High Current Thyristor

Discussion

The ABB HCTs were tested only in a fast pulse mode. In this mode, fast rise time, low energy per pulse, and narrow pulse width are of primary importance.

This work was supported by the U.S. Department of Energy under Contract DE-AC04AL85000.

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

Two trigger sources with different rise times were used for these tests. Each trigger source was provided with three different capacitor values (0.1-0.2-0.4 μ F) and operated over a range of voltages from

Fig. 2 SCR Switched Trigger Circuit

200-to-600 volts. One trigger source was a simple SCR-switched capacitor discharge circuit (Fig. 2) that delivered a single unipolar pulse with a voltage rise time of 70ns and a current rise of about 300ns (Fig s. 3A and 3B). The other was a

Fig. 3A Gate Voltage from SCR Trigger Circuit V= 50v/div, T= 500ns/div.

Fig. 3B Gate Current from SCR Trigger Circuit I=100A/div, T=1μs/div.

MOSFET-switched circuit (Fig. 4) that

Fig. 4 MOSFET Switched Trigger Circuit

provided a longer duration but lower gate voltage and current due to higher on-state resistance of the MOSFETS (Fig s. 5A and 5B). The voltage rise was ~ 15ns and the

Fig. 5A Gate Voltage from MOSFET Trigger Circuit V=20V/div, T=500ns/div.

Fig. 5B Gate Current from MOSFET Trigger Circuit I=50A/div, T=1μs/div.

current rise ~ 300ns. The SCR-circuit produced slightly higher peak current (4%)

but 17% higher (di/dt) (Fig. 6), indicating that high initial peak gate current dominates turn-on rate. However, turn-on delay time is measurably different for each triggering condition as shown by the time spread in traces on Figs. 6 and 7.

Fig. 6 Anode Current with SCR (upper) and MOSFET (lower) Trigger Circuits. $I=4000A/div$, $T=500ns/div$.

Differences in di/dt for the two trigger sources in the 3-to-4.5 Kv range are indicative only and do not represent device limits. Since current rise in this range is limited also by circuit inductance which was approximately 31 nH. In the low voltage ranges, however, turn-on was very much device and trigger energy limited as shown by the anode voltage fall and current traces recorded for 1kV (Fig. 8).

The peak current reached by the circuit at 4.5 Kv was 19,040A which had a

rate of rise (10 to 90%) of 65,373 A/μs.

Fig. 7 Anode Voltage Fall triggered with SCR (upper) and MOSFET (lower) circuits. $V=1000v/div$, $T=500ns/div$.

Fig. 8 Anode Voltage Fall (upper) and Current (lower) for 1kV MOSFET triggered tests. $V=200v/div$, $I=400A/div$, $T=500ns/div$.

Fig. 9 Time Relationships between Peak Current, Anode Voltage Fall and Gate Voltage and Current.
T=500ns/div.

All tests were run at a 5 Hz rep rate except for a 10-minute run at 3.8 Kv, 10 Hz during which the first thyristor failed. The other thyristor failed at 4.5 Kv, 5 Hz after prolonged test runs. Due to the device failures, long-term endurance runs could not be made. These tests will be necessary to determine the safe operating conditions for high rep rate operation.

Conclusion

The early-time turn-on characteristics of ABB 20H4501 thyristors have been measured over a range of 0.5-to-4.5 Kv at a pulse repetition rate of 5 Hz. Results show a strong dependence on triggering current in the lower ranges but minimal dependence above 4 Kv.

References:

1. G.J. Rohwein, L.D. Roose, W.M. Portnoy, "Characterization of High Power Thyristors", Proceedings of the 10th IEEE Pulsed Power Conference, June, 1995.
2. E.R. Ramezani, A. Welleman, J. Siefken, "High Peak Current, High di/dt Thyristors for Closing Switch Applications", ABB Report, Lenzburg, Switzerland and Pittsburgh, PA 15235-5900.
3. M. Jung, W. Mayerhofer, M. Edele, Oogstir, T. Schweizer, E. Zegfand, E. Ramezani, "Test of Fast SCR's as Spark Gap Replacement", DLR Institut Für Technische Physik, Stuttgart, Germany, and ABB Semi Conductors AG, Lenzburg, Switzerland.
4. J.L. Hudgins and W.M. Portnoy, "Fast Transient Behavior of Thyristor Switches", Proceedings of the 16th IEEE Power Electronics Specialists Conference, Toulouse, France, pp. 458-462, June, 1985.
5. J.L. Hudgins and W.M. Portnoy, "High di/dt Pulse Switching of Thyristors", IEEE Transactions on Power Electronics, Vol. PE-2, pp. 143-148, April, 1987.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ROUTING
SEQUENCE

STOP	ORG.	NAME	COMMENTS OF RECIPIENT			
MS-1152	9323	M.T. Buttram, Mgr.				
MS-0175	13214	Classification Review				
MS-0161	11500	Patent & Licensing				
MS-0619	12615	Printing Media (formerly Tech. Pubs.)				
MS-1153	9323	Vicki Walker, OAA				
FROM Vicki Walker for: G.J. Rohwein MS-1153			ORG. 9323	BLDG. 962	PHONE 845-7010	DATE 06/20/96

SENDER'S REMARKS 96-0500C "Early Time Turn-On Characteristics of a High Current Thyristor"

TJS CAMERA & 1 HOUR PHOTO
12611 MONTGOMERY NE
SPACE A6
ALBUQUERQUE NM 87111
505-299-5338
5317884388730659

5317884388730659 0000
DATE 06/18/96 TIME 06:48 PM

ITEM: 019 VIS SALE
ACCT: 4851278807858273 EXP: 9784
RESP: AUTH/TKT 017877

TOTAL: \$48.19

I AGREE TO PAY ABOVE TOTAL AMOUNT
ACCORDING TO CARD ISSUER AGREEMENT
(MERCHANT AGREEMENT IF CREDIT VOUCHER)
TOP COPY MERCHANT BOTTOM COPY CUSTOMER

[Signature]
SIGNATURE
THANK YOU

#17-51

Thank you
Call again

06-18-96
21

716.	X	
	0.09	@
05*	*6444.	TX TM
	*3.75	TX
	*68.19.	MS TL
	*68.19	CG TND TL
1d	*0.00	
736.0g		
#17-54		