

Determination of SCR Characteristics using TYN612

Md. Moyeed Abrar

Assistant Professor, Department of CSE, Khaja Banda Nawaz College of Engineering Kalaburagi,

Abstract— A thyristor is one of the most widely used and an important power semiconductor device. They are extensively used in power electronic circuits owing to its many salient features. Thyristors are operated as bistable switches, operating from non-conducting state to conducting state. From switching point of view, thyristors can be assumed as ideal switches for most applications, but practical thyristors exhibit certain characteristics and limitations. Silicon controlled rectifier is the first thyristor device. The state of the art presented in the paper is the determination of Silicon controlled rectifier characteristics (SCR) using the SCR device TYN612. The SCR characteristics are a plot between the Anode to Cathode voltage versus the Anode current keeping the Gate current fixed.

Keywords— Thyristor, Power semiconductor device, Bistable switches, Silicon controlled rectifier, SCR device TYN612, Anode to Cathode voltage, Anode current, Gate current

I. INTRODUCTION

Power electronics is fundamentally based on the switching of the power semiconductor devices. With the significant rise in power semiconductor technology, the switching speed of the power devices and the power handling capabilities have improved to a greater extent. Thyristors are manufactured almost exclusively by diffusion. The manufacturers use various gate structures to control the di/dt , turn on time and turn off time. Silicon controlled rectifier (SCR) is the first thyristor developed in the late 1957. Depending on the physical construction, turn on and turn off behaviour, thyristors can be broadly classified into nine categories: Phase control thyristors (SCRs), Fast switching thyristors (SCRs), Gate turn off thyristors (GTOs), Bidirectional triode thyristors (TRIACs), Reverse conducting thyristors (RCTs), Static induction thyristors (SITHs), Light activated silicon controlled rectifiers (LASCRs), FET controlled thyristors (FET-CTHs) and MOS –controlled thyristors (MCTs). SCR possesses an important property of controlled turn ON and uncontrolled turn OFF. Pulse gate requirement, bipolar voltage withstanding capability and unidirectional current capability are some of the desirable features of SCR [1].

In this paper the determination of the SCR characteristics is presented using a simple circuit design. The rest of the paper is organized into sections as follows: section II illustrates the silicon controlled rectifier overview. Section III focuses on the system design. Results and discussion are reported in section IV. Finally section V summarizes the paper and presents the concluding remark.

II. SILICON CONTROLLED RECTIFIER OVERVIEW

A. Construction of Silicon controlled Rectifier

A PNPN diode consists of four alternate layers of P-type and N-type materials as shown in fig.1. The P-type and N-type semiconductor regions on the extreme are called Anode and the cathode respectively.

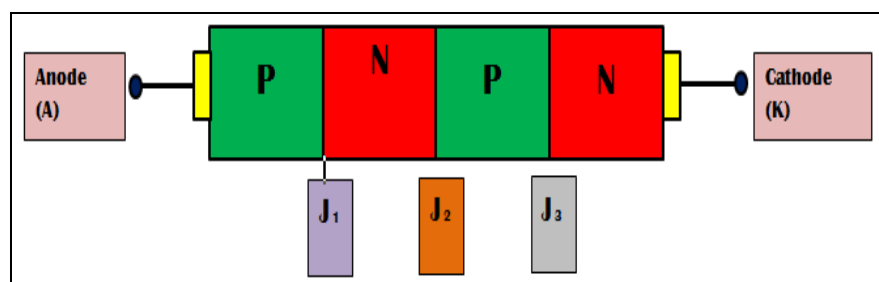


Fig. 1 Construction of a PNPN diode

The construction of a Silicon controlled rectifier (SCR) is almost identical as that of a four-layer diode with the only difference that the connection to one of the inner layers adjacent to the cathode layer is brought out to exercise control over the switching characteristics of the device. Thus, an SCR has three terminals namely, Anode, Cathode and the Gate. The control terminal is the gate terminal, gate cathode to be more precise. Fig. 2 shows the circuit symbol of an SCR.

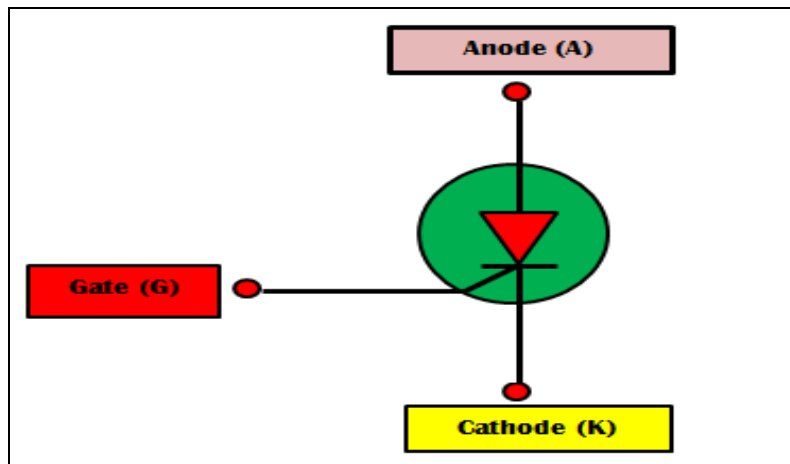


Fig.2 Circuit symbol of SCR

Considering the PNPN diode to be equivalent to back to back connection of a PNP and an NPN transistor, it can be seen that the gate terminal is nothing but the base terminal of the NPN transistor as shown in fig. 3.

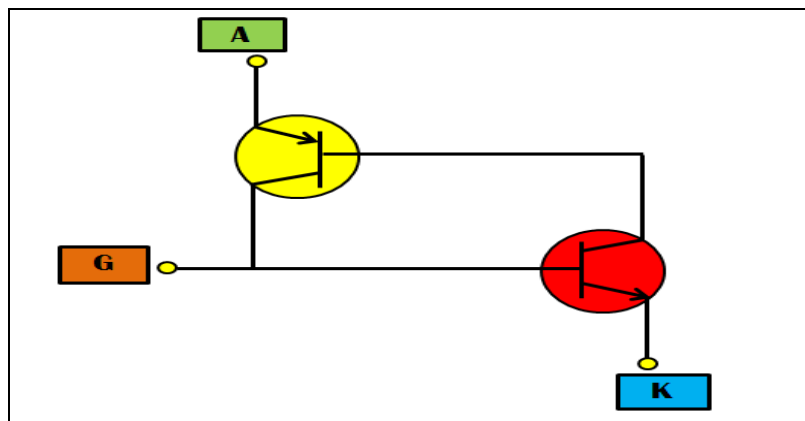


Fig.3 Gate terminal equivalent to base terminal of NPN transistor.

The control action of the gate terminal in the case of an SCR functions as follows. A momentary pulse applied to the gate terminal increases the base current of the NPN transistor initiating a regenerative feedback action. This regenerative feedback action ultimately drives both the transistors to saturation causing switching ON action of the device even if the anode to cathode voltage were less than the break-over voltage. The anode to cathode voltage at which the device can be triggered to the ON-state is a function of the gate trigger current. In other words, magnitude of trigger current required to turn the device ON depends upon the anode to cathode voltage. Larger gate current can trigger the device ON for a lower anode-to-cathode voltage.

In the case of SCR, only the cathode gate is available. If the anode gate is also made available, then the device is referred to as the Silicon-controlled switch (SCS). In other words, SCS is a four-layer PNPN device where connection to all the four layers is available. The characteristics of the device are essentially the same as those of an SCR. Fig. 4 shows the circuit symbol of SCS [2], [3].

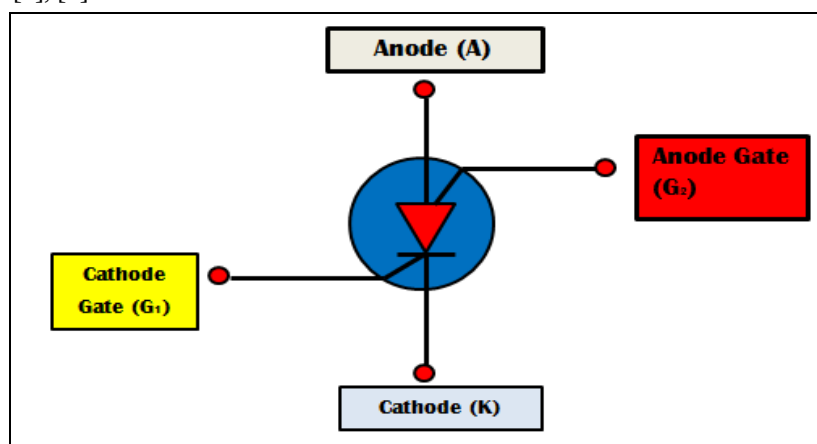


Fig. 4 Circuit symbol of SCS

B. V-I characteristics of SCR

In the case of SCR, one can plot a family of characteristics in the first quadrant for different values of gate current as shown in the fig. 5. As it is clear from the family of characteristic curves, the break-over voltage reduces with increase in gate trigger current. In other words, as the anode-to-cathode voltage reduces, the magnitude of the gate current required triggering the device to the ON-state increases. The V-I characteristics in the third quadrant is almost identical as that in the case of a PNP diode.

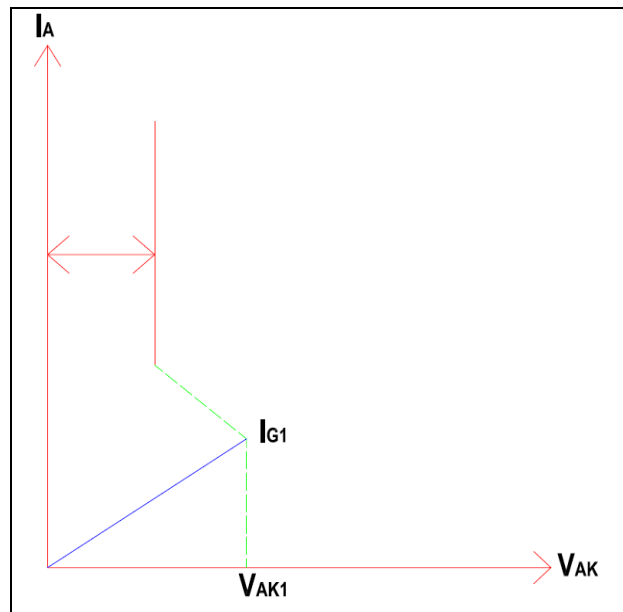


Fig.5 V-I Characteristics of SCR

C. Gate Triggering Characteristics of SCR

The gate triggering characteristics of SCR are a plot of gate voltage V_G versus gate current I_G . As the cathode gate circuit of an SCR is nothing but a forward-biased PN junction, the characteristics curve resembles the one for a forward-biased PN junction diode. The gate trigger voltage V_{GT} is the gate-to-cathode voltage required to trigger the device to the ON-state and gate trigger current I_{GT} is the forward biased current flowing in the gate cathode circuit. Furthermore, it should be known that the P-type and N-type semiconductor materials constitute the gate and cathode regions respectively in an SCR and should be lightly doped.

Owing to light doping, there is a spread in the V-I characteristics even for a given type of SCR. This spread is shown in fig. 6 by the characteristic curves 1 and 2. In addition, there are minimum and maximum values of gate voltage that can be applied to the device. Similarly there are minimum and maximum values of gate current too. Yet another requirement that needs to be fulfilled is that of the power dissipation. There is always a rated gate power dissipation specified for the SCR which should not be exceeded. This is also depicted in fig. 6. All these requirements together define the operating area for the gate trigger circuit. This operating area has been shown by shading in fig. 6. The boundary specified by the power dissipation is for the average value of the gate power dissipation. A relatively higher dissipation may be permitted for shorter pulse durations.

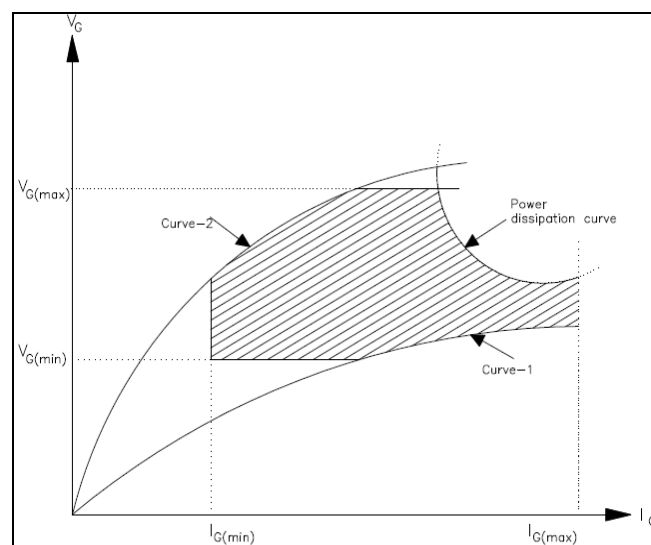


Fig. 6 Gate triggering characteristics of SCR

Higher gate-trigger currents yield faster turn-on. But the faster turn of the SCR is also not without problems. If the rate of rise of the ON-state current (di/dt) exceeds the critical value of $(di/dt)_c$, the device could get damaged due to creation of localized hot spots. It may be mentioned here that the above discussion is valid for all the devices of the thyristor family with gate control [2], [3].

III. SYSTEM DESIGN

A. Hardware Design

The Based on the hardware design and system specifications, the circuit schematic for the system is as shown in fig. 7

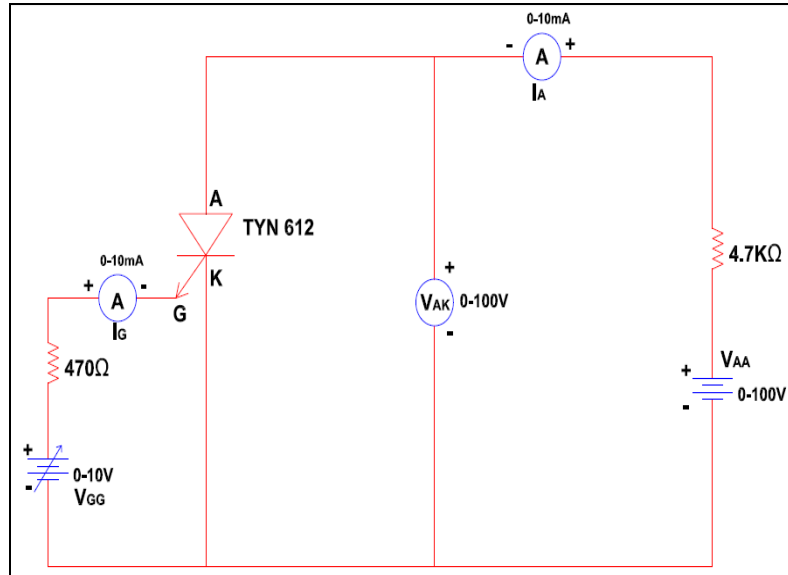


Fig.7 Circuit schematic for the designed system

B. System Specifications

The system specifications for the designed system are illustrated in table 1.

TABLE I
SYSTEM SPECIFICATIONS

SL. NO	SPECIFICATIONS
1.	Domain: Power Electronics
2.	Digital IC trainer kit/ Breadboard
3.	Power supply : Battery (DC regulated power supply)
4.	SCR: TYN 612
5.	Resistors : 470 Ω, 4.7K Ω
6.	Multimeters (4)
7.	Single stranded wires, connecting probes, patch cord, crocodile clips.
8.	Software : MATLAB
9.	Applications of SCR: Motor control, Industrial and domestic lighting, heating, static switching.

C. TYN 612 SCR Overview

The TYN series SCR is available in through hole or surface mount packages, they provide an optimized performance in a limited space area. The 12A SCR series SCR is suitable to fit all modes of control found in various applications such as overvoltage crowbar protection, motor control circuits in power tools and kitchen aids, inrush current limiting circuits, capacitive discharge ignition and voltage regulation circuits. Apart from this they are intended to be used for general purpose switching and phase control applications. These devices can also be interfaced directly to microcontrollers, logic integrated circuits and other low power gate trigger circuits[4]. The salient features of the TYN 612 SCR device are

1. Blocking voltage to 600Volts.
2. 12 Amperes of on-state RMS current.
3. Ultra low gate trigger current.

Fig. 8 shows the circuit symbol of SCR TYN 612

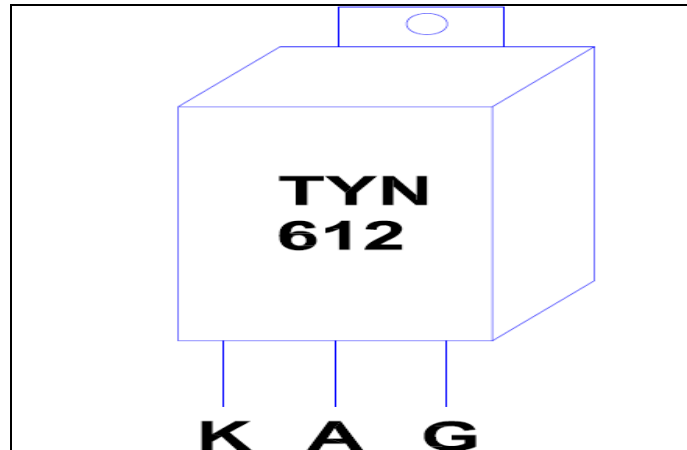


Fig. 8 Circuit symbol of TYN 612 SCR

The TYN 612 SCR used in the system is shown in fig.9.

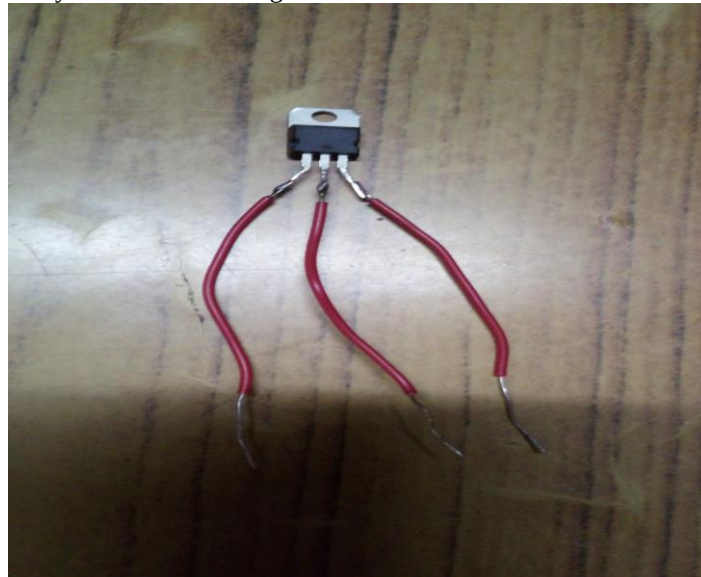


Fig. 9 TYN 612 SCR

D. System set up

The experimental set up was done in Power electronics laboratory. According to the hardware design the required components were taken and the resistors were checked using a Multimeter. The SCR device TYN612 with its three terminals Gate (G), Cathode (K), and Anode (A) was smoothly placed on the breadboard. The system was rigged as per the circuit schematic on a breadboard and power supply was switched on to get the required results. The DC Regulated power supply used in the system set up has two voltage sources in the form of a dual battery as shown in Fig. 10. The photographic view of the system set up is depicted in fig. 11.



Fig. 10 DC Regulated power supply

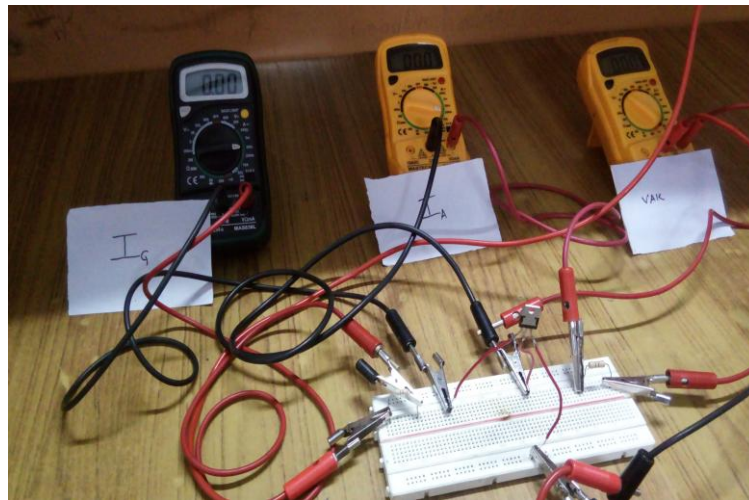


Fig. 11 Photographic view of the system set up

IV. RESULTS AND DISCUSSION

The gate current I_G was set to a fixed value of 3.60 mA by varying the voltage source V_1 of the dual battery. Voltage source V_2 was slowly varied in order to get the variations in anode current I_A and anode to cathode voltage V_{AK} . The corresponding values of anode current I_A and anode to cathode voltage V_{AK} were noted down. The same procedure was repeated with gate current fixed to 3.75mA and the corresponding values of anode current I_A and anode to cathode voltage V_{AK} were noted down. The results obtained for anode current I_A and anode to cathode voltage V_{AK} are tabulated in table 2.

TABLE III
EXPERIMENTAL VALUES OF RESULTS OBTAINED

Sl.No	$I_{G1} = 3.60 \text{ mA}$		$I_{G2} = 3.75 \text{ mA}$	
	V_{AK1} in Volts	I_{A1} in mili amps	V_{AK2} in Volts	I_{A2} in mili amps
1.	0.5	0.0	0.5	0.0
2.	0.6	0.2	1.0	0.2
3.	0.7	0.3	1.5	0.2
4.	1.0	0.3	0.9	0.6
5.	0.7	0.5	0.7	0.7
6.	0.7	0.7	0.7	0.8
7.	0.7	0.8	0.7	0.9
8.	0.7	0.9	0.7	1.0
9.	0.7	1.0	0.7	1.1
10.	0.7	1.2	0.7	1.2
11.	0.7	1.3	0.7	1.4

The fig. 12 and 13 shows the photographic view of results for one of the values of V_{AK} and I_A when I_G set to 3.60 mA.



Fig. 12 Gate current I_G set to 3.60 mA.

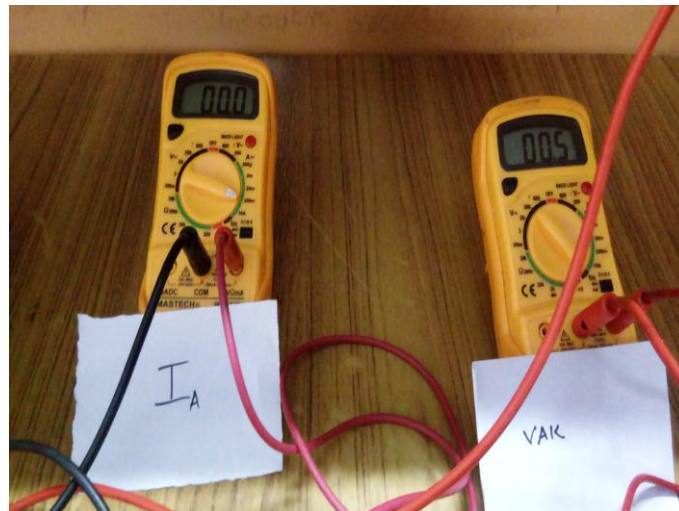


Fig. 13 One of the values of V_{AK} and I_A when I_G set to 3.60 mA.

Lastly, fig. 14 and 15 shows the photographic view of results for one of the values of V_{AK} and I_A when I_G set to 3.75 mA.



Fig. 14 Gate current I_G set to 3.75mA.

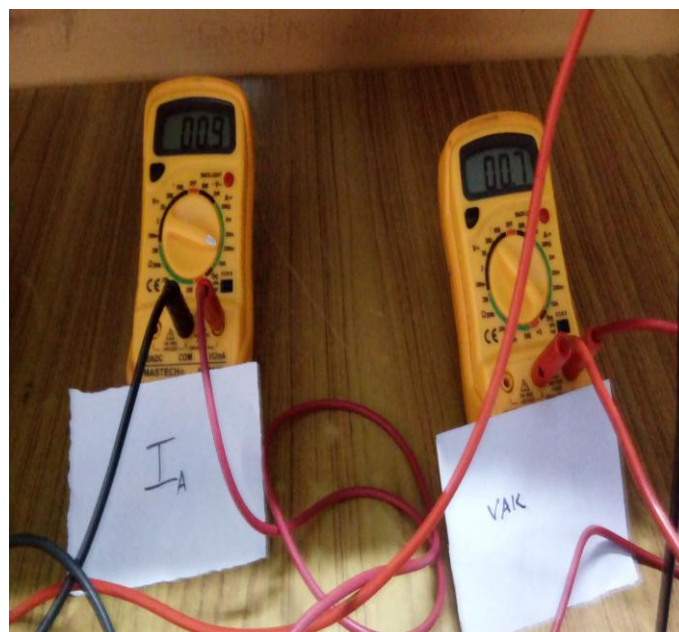


Fig. 15 One of the values of V_{AK} and I_A when I_G set to 3.75 mA.

The SCR characteristics were plotted by using the readings obtained from the experimental results tabulated in table 2. The SCR characteristics are a plot between the Anode to cathode voltage V_{AK} versus the Anode current I_A keeping the Gate current I_G fixed. MATLAB software tool was used for plotting the result in graphical form as illustrated in fig. 16.

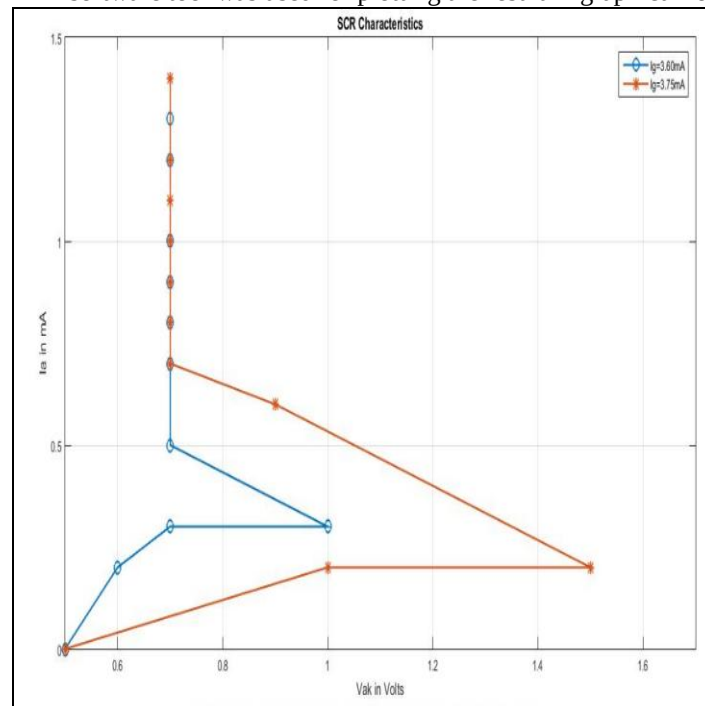


Fig. 16 Graphical form of the result

In the graph of figure m, the Anode to cathode voltages V_{AK} are plotted on x-axis and Anode current I_A are plotted on y-axis.

V. CONCLUSION

The circuit for obtaining the SCR characteristics was designed and implemented using SCR TYN612. From the experimental results it can be concluded that keeping the gate current I_G fixed, as the voltage V_2 was increased steadily then there was a rise in the values of Anode to cathode voltage V_{AK} as well as the Anode current I_G . After a certain increase in voltage V_2 it is observed that the Anode to cathode voltage V_{AK} was reduced and then became constant whereas the Anode current was increased. This is evident from the results displayed in the tabular column. The circuit which is used to determine the output characteristics is quite simple, easy to design requiring few components and requires less cost. Furthermore the designed system is very stable and reliable and easy to use and implement.

REFERENCES

- [1] Muhammed H Rashid, *Power Electronics circuits, devices and applications*: pp. 104-114, Prentice Hall of India Pvt. Ltd, 2002.
- [2] Anil K Maini, Varsha Agarwal, *Electronic devices and circuits*: pp. 227-229, Wiley India Pvt. Ltd, 2009.
- [3] Albert Malvino, David J Bates, *Electronic Principles*: pp. 526-534 Tata Mc Graw- Hill Education Private Ltd, 2007.
- [4] A datasheet on *TN12, TS12 and TYNx12 series* by ST Microelectronics, pp.1/10, September 2000.
- [5] Bin Wu; Mehdi Narimani, "Multipulse SCR Rectifiers", *Wiley IEEE press* 2017, pp. 480.
- [6] Chun-Yu-Lin, Yi-Han Wu, Ming-Dou Ker, "Low- Leakage and Low- Trigger voltage SCR Device for ESD protection in 28-nm High-k Metal Gate CMOS process" *IEEE Electron Device Letters*, vol.37, Issue 11, November 2016. pp. 1387-1390.
- [7] You-Li, Junjun-Li, Robert Gauthier, "Junction engineering for SOI SCR triggering and performance improvement", *IEEE conference proceedings on Electrical Overstress/Electrostatic Discharge Symposium*, Tucson AZ, USA, 7-12 September 2014.
- [8] Qiu Yinggui, "Research on the energy measurement model of SCR transfer" *IEEE 6th International conference on Information Management, Innovation Management and Industrial Engineering*, vol.1, 2013.

ACKNOWLEDGEMENT

First of all I would like to thank Almighty Allah by the grace of whom I reached the stage of completion of this work. This avenue has been a turning point in my career to mold me into a thorough and dynamic Professional. My sincere thanks to the Management of esteemed institution Khaja Banda Nawaz College of Engineering for their inspiration and support.

BIBLIOGRAPHY



Md. Moyeed Abrar is working as Assistant Professor in the department of Computer science and engineering of Khaja Banda Nawaz college of Engineering, Kalaburagi Karnataka since 2014. He has done his B.E in Electrical and Electronics from P.D.A college of Engineering affiliated to Visvesvaraya Technological University, Belagavi Karnataka. He has completed his M.Tech in Digital Electronics from Appa Institute of Engineering and Technology affiliated to Visvesvaraya Technological University, Belagavi, Karnataka. He has excellent technical skills and is a versatile and dynamic professional. He has also published several papers in various reputed International Journals. His research areas of interest are Power and Energy systems, Digital circuits and logic design, Microprocessors and Microcontrollers, Power electronics, control systems, Electrical machine design and IOT.