JIS College of Engineering
(An Autonomous Institution)
Department of Electrical Engineering

POWER ELECTRONICS LAB MANUAL

Exp-1. Study of characteristics of an SCR

AIM:

To obtain the V-I characteristics of SCR (Silicon Controlled Rectifier).

APPARATUS REQUIRED:

SL. No, Apparatus, Range, Type, Quantity.

1. Two continuously variable DC Regulated Power Supplies of 0-1v and 0-30v.

Specification of Regulated Power Supply :

Input Voltage : 230v ± 10% AC, 50 Hz.

Load Regulation : ± 0.2%

Line Regulation : ± 0.05%

Ripple : Less than 3mv R.M.S.

Protection : Against Short Circuit & Over Load

2. Three meters measure Voltage & Current are mounted on front panel & connections brought out on 4mm Sockets.

(i) Two Ammeter of Dual range(0-30mA/ 0-1.2A) & (0-200µA).

(ii) One Voltmeter of Dual range 0-30V/0-1.2V.

3. SCR (2P4M) placed inside the cabinet and connections are brought out on sockets.

BRIEF THEORY:

An SCR is a three terminal, four layer latching device. The three terminals are anode, cathode and gate. When the anode is more positive w.r.t the cathode, junctions j1, j3 are forward biased and the junction j2 is reverse biased. Only a small leakage current flows through the device. The device is said to be in the forward blocking state or OFF state. When the anode to cathode voltage is increased to break-over value, the junction j2 breaks down and device starts conducting. The anode current must be more than a value known as latching current in order to maintain the device in the ON state. Once SCR starts conducting, it behaves like a conducting diode and gate has no control over the device.

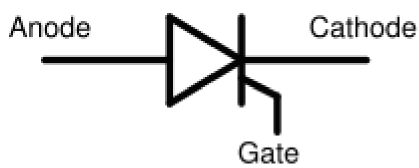


Fig.1 Schematic Symbol

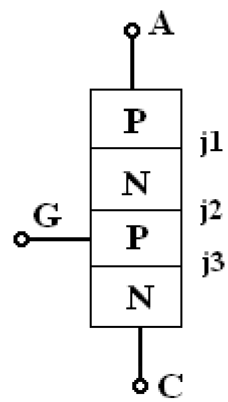
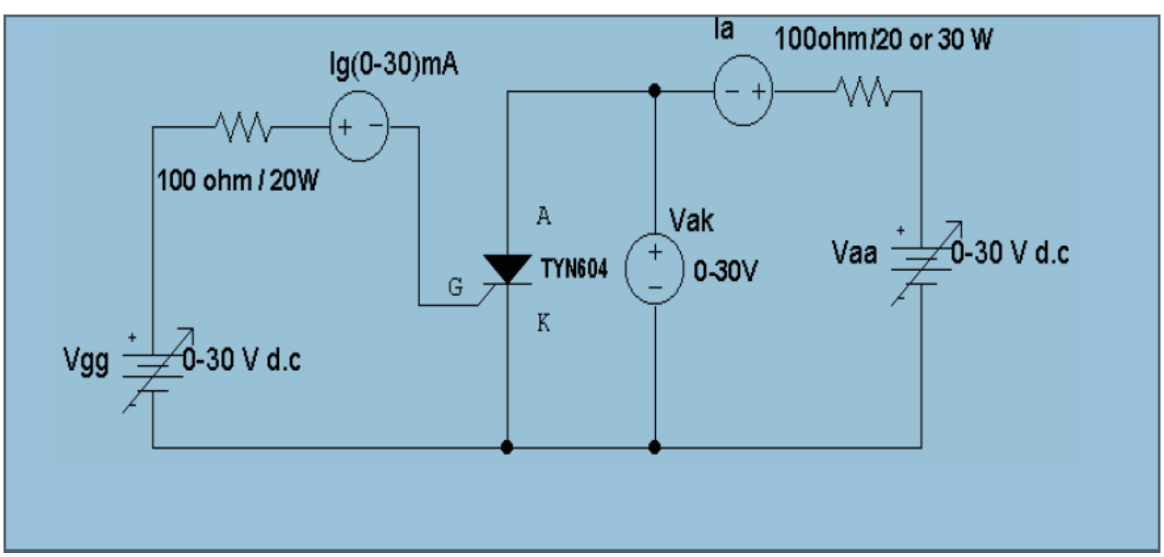


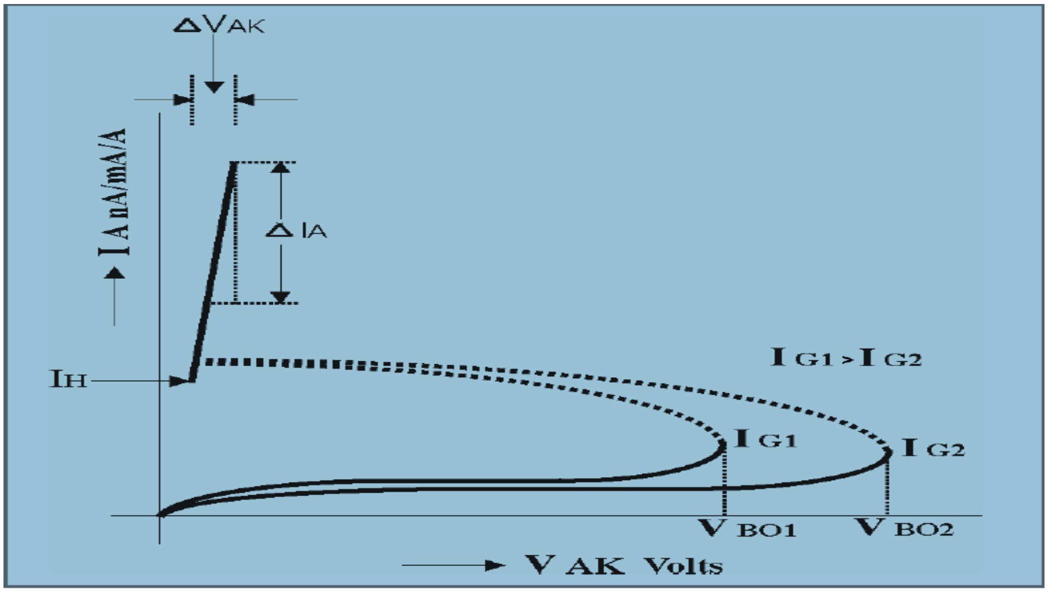
Fig.2 Block Construction

The device can be turned OFF only by bringing the device current below a value known as holding current. The forward voltage drop across the device in the ON state is around one volt. When the cathode voltage is made positive w.r.t the anode voltage the junction j2 is forward
biased and the junction's j1 and j3 are reverse biased. The device will be in the reverse blocking state and small reverse leakage current flows through the device. The device can be turned ON at forward voltages less than break over voltage by applying suitable gate current.

CIRCUIT DIAGRAM :



MODEL GRAPH :



EXPERIMENTAL DATA:

SL.NO	I_G = mA (For 'OFF STATE')	I_G = mA (For 'ON STATE')		
	V_{AK} (V)	I_A (mA)	V_{AK} (V)	I_A (mA)

RESULT :
Thus the forward V-I characteristics of SCR have been determined experimentally. Write down your observation and draw the curve of above characteristics.

DISCUSSION:

ANSWER THE FOLLOWING QUESTIONS:

1. What is thyristor family?
2. What are the different family members of thyristor devices?
3. What are the different modes of an SCR?
4. Define Latching current (IL).
5. Define Holding current (IH). Which will be larger either IL or IH?
6. What are the conditions for 'Turn-ON' of an SCR.

Exp-2. Study of the characteristics of Triac

AIM:
To obtain the V-I characteristics of TRIAC for both forward and reverse biased conduction.

APPARATUS REQUIRED:
i. Two continuously variable overload & short circuit protected DC regulated power supplies of 0-3v for Gate Current and 0-30v for MT1 & MT2 are provided in ME 552,ME 552D & ME 552P.

Input Voltage	: 230 V ± 10% AC, 50 Hz
Load Regulation	: ± 0.2%
Line Regulation	: ± 0.05%
Ripple	: Less than 3 mv R.M.S.
Protections	: Against Short Circuit & Over Load

ii. Three meters to measure voltage & current are mounted on front panel & connections brought out on sockets.

iii. Triac (BT136) is mounted inside the cabinet and pin connection are brought out at terminals/sockets.

BRIEF THEORY:
A TRIAC is a bidirectional thyristor (it can conduct in both directions) with three terminals. It is used extensively for control of power in AC circuit. When in operation, a TRIAC is equivalent to two SCRs connected in anti-parallel. Its three terminals are usually designated as MT1, MT2 and gate.

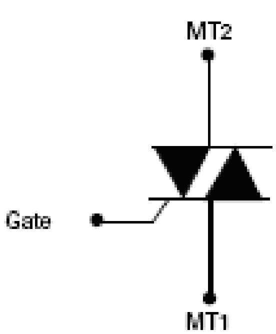


Fig.1 Schematic Symbol

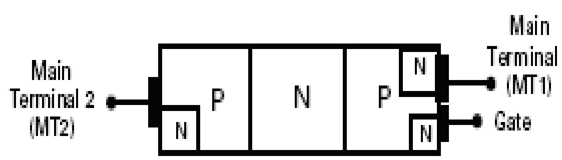
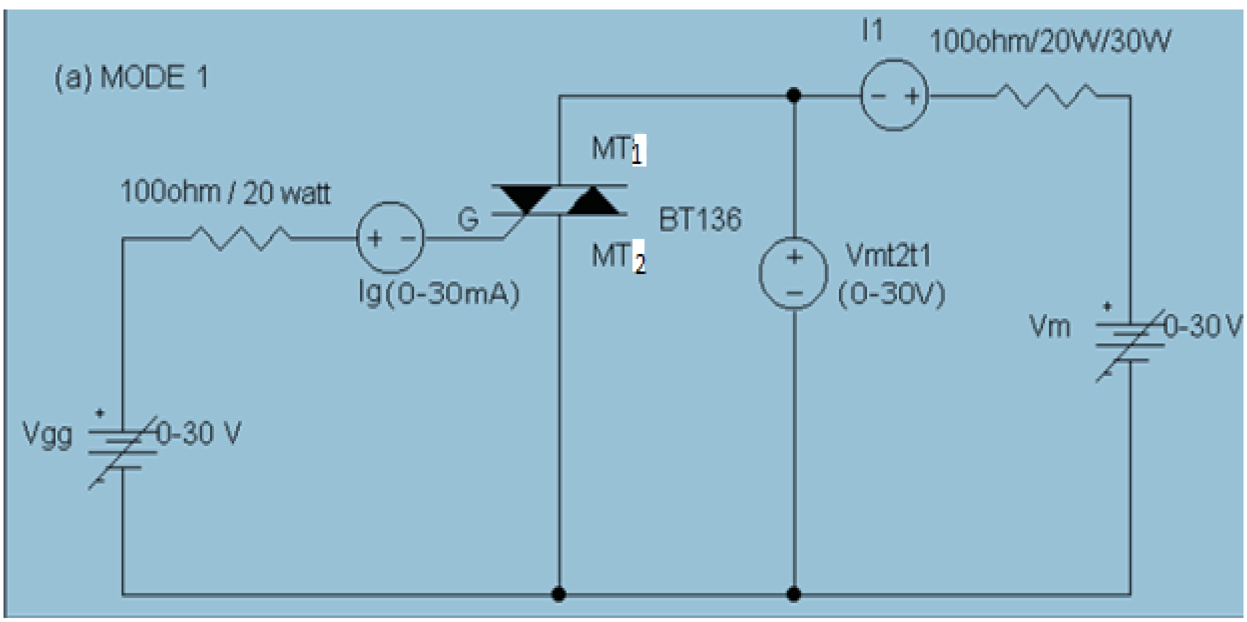


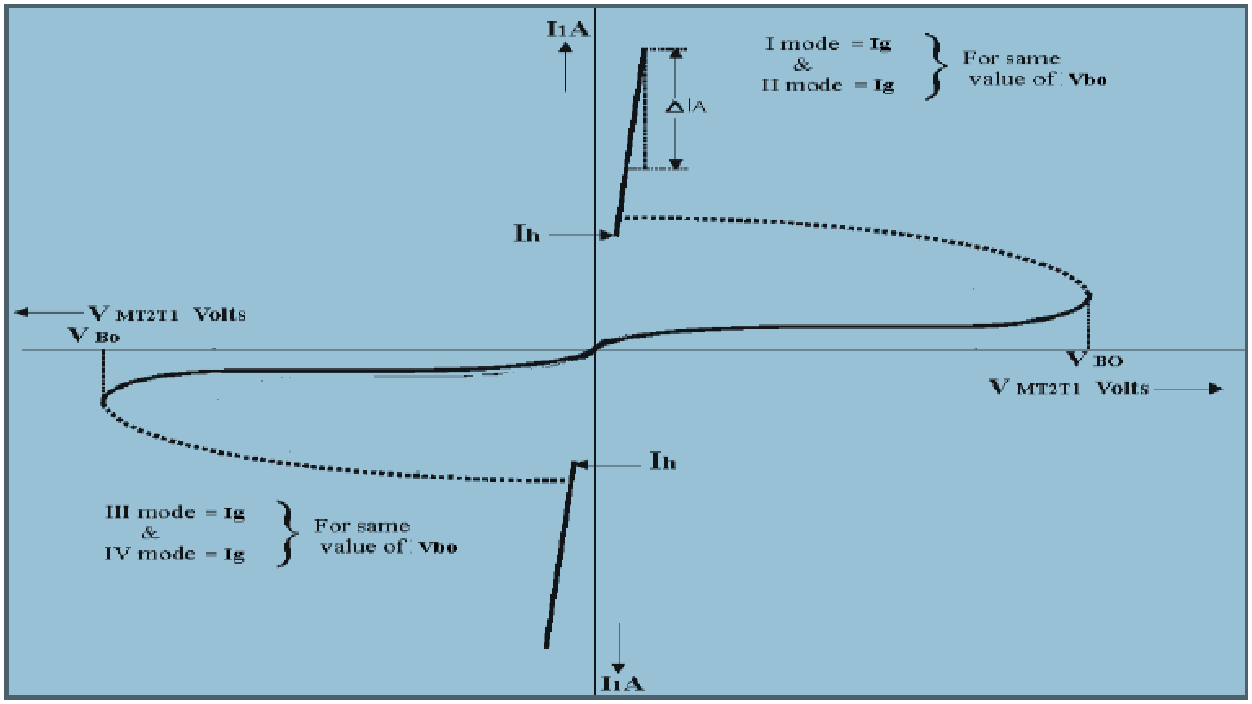
Fig.2 Block Construction

The V-I characteristics of a TRIAC is based on the terminal MT1 as the reference point.
The first quadrant is the region wherein MT2 is positive w.r.t MT1 and vice-versa for the third quadrant. The peak voltage applied across the device in either direction must be less than the break over voltage in order to retain control by the gate. A gate current of specified amplitude of either polarity will trigger the TRIAC into conduction in either quadrant, assuming that the device is in a blocking condition initially before the gate signal is applied. The characteristics of a TRIAC are similar to those of an SCR, both in blocking and conducting states, except for the fact that SCR conducts only in the forward direction, whereas the TRIAC conducts in both the directions.

CIRCUIT DIAGRAM



MODEL GRAPH



EXPERIMENTAL DATA:

FORWARD CHARACTERESTICS:

SL. No	AppliedVoltage,$V_{MT1-MT2}$ (v)	Conduction Current, $I_{MT1-MT2}$ (mA)

REVERSE CHARACTERESTICS:

SL.No	AppliedVoltage,$V_{MT1-MT2}$(V)	Conduction Current $I_{MT1-MT2}$(mA)

RESULT:

DISCUSSION:

ANSWER THE FOLLOWING QUESTIONS:

1. What is TRIAC?

2. Write down some applications of TRIAC.

3. How does a TRIAC work?

4. What are the differences between SCR and TRIAC?

Exp-3. Study of different triggering circuit of an SCR

AIM:

To obtain the RC triggering circuit of SCR.

APPARATUS REQUIRED:

S.No.	APPARATUS	RANGE	TYPE	QUANTITY
1	CRO	20 MHz		1
2	R.P.S	(0-30)V		1
3	DRB			1
4	Transformer	230/24V		1
5	Load	100Ω,2A		1
6	Voltmeter	(0-15)V	MI	1

COMPONENTS REQUIRED:

S.No.	ITEM	RANGE	TYPE	QUANTITY
1	SCR		2P4M	1
2	Capacitor	104μF		2
3	Resistor	1K,2.2K,0.1K 10K,22K		1 1
4	Diode		IN4007	2

Theory :

The conversion of SCR state from OFF state to ON state may be done in several ways.

These are

i. Forward voltage triggering
ii. dv/dt triggering
iii. Temperature triggering
iv. Light triggering and
v. Gate triggering

Among all the method of triggering the SCRs, gate triggering is the most commonly used to turn on the device as this method accurately tends itself for turning on the SCR whenever the device is in need of conduction state. Gate triggering is not only efficient but also a reliable method.

Here, diode D_1-D_4 form a full wave bridge. Full wave output voltage may be obtained by using RC full wave trigger circuit. Initially, the capacitor C charges to a low positive value which is almost zero.The capacitor is set to this minute positive voltage with upper plate positive and lower plate negative by the SCR gates clamping action. SCR gates triggered only when it reaches a voltage of about E_{gt}, and the reactified voltage appears across load. V_d appears across load as $E_{0.}$ The value of RC may be calculated by using the empirical formula as follows.

$$RC \geq 50\ T/2 \cong 157/\omega$$

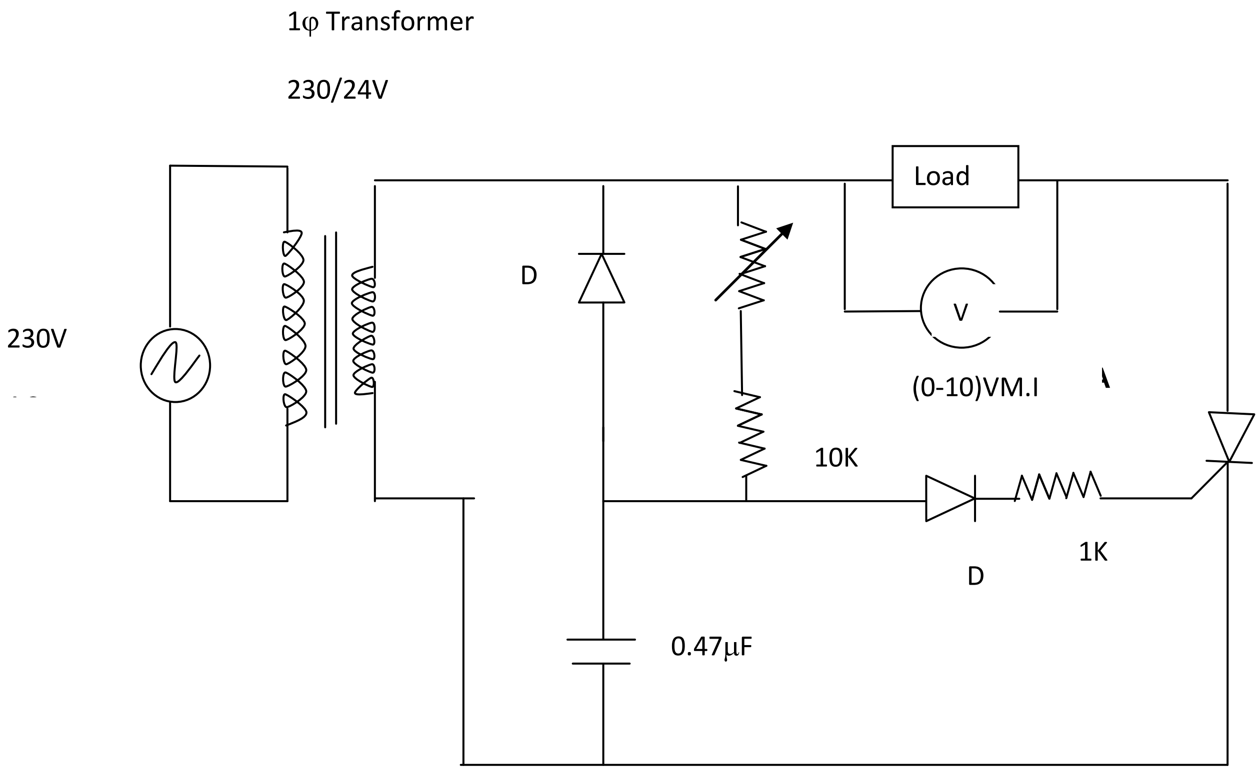
Value of R is given as

$$R << E_s - E_{gt} / I_{gt}$$

PROCEDURE: (RC-TRIGGERING)

1. Make the connections as per the circuit diagram.
2. Switch on the power supply.
3. Note down the output waveform across the load for different triggering angles of SCR using a CRO.
4. Repeat the procedure for various resistor values of potentiometer.
5. Switch off the power and remove the connections.

CIRCUIT DIAGRAM (RC-TRIGGERING):

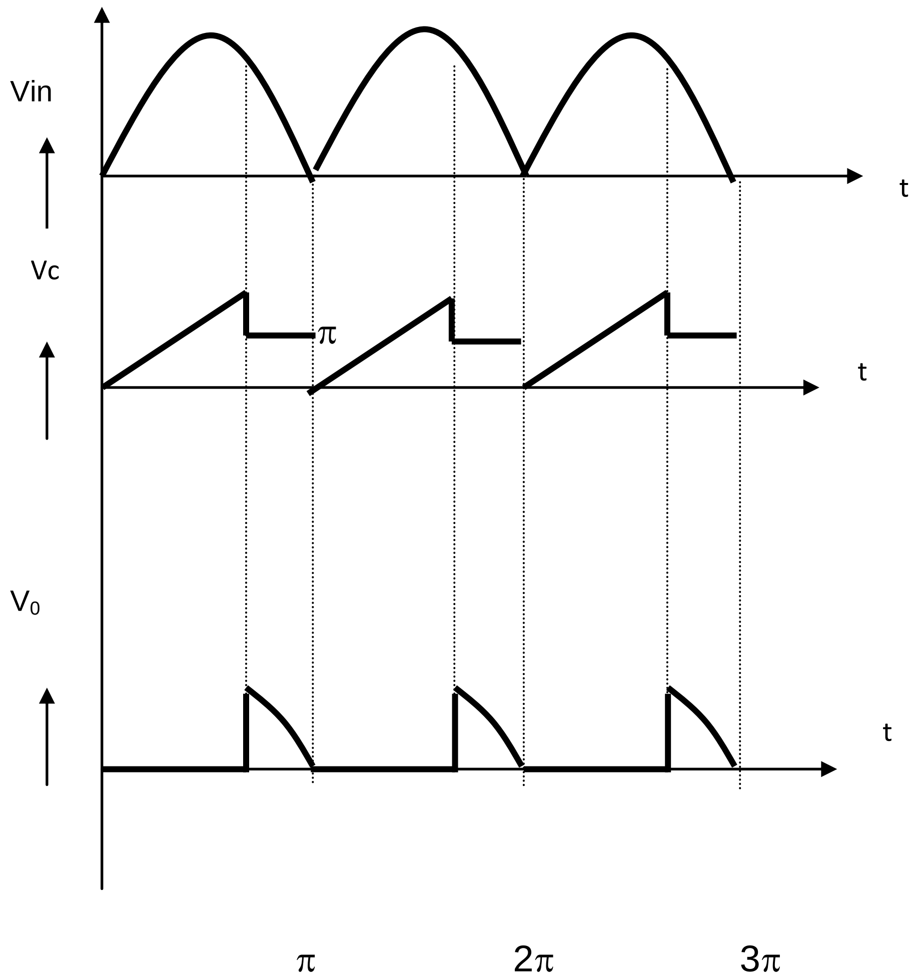


EXPERIMENTAL DATA:

(For, RC-TRIGGERING):

SL. No.	Input Voltage (V)	Input Cycle Time (ms)	Resistance Value (K Ω)	O/P Voltage V rms (V)	Voltage Across (Anode- Cathode) V rms (V)

MODEL GRAPH (RC-TRIGGERING):



RESULTS:

Thus the RC triggering circuit for SCR was constructed and its output waveforms were plotted for different triggering angles of SCR.

DISCUSSION:

Exp-4. SIMULATION OF AC TO DC HALF CONTROLLED CONVERTER (SEMICONVERTER) USING PSIM

AIM:

To construct a single phase half controlled Converter (Semi Converter) and plot its output response.

THEORY:

Single phase half controlled converter uses two thyristors are at the same potential as shown in circuit diagram. Gates can be connected and only a single gate pulse is required to trigger these SCRs. There are two modes of operations.

Mode 1: During the positive half cycle of the supply voltage, thyristor T_1 and diode D_1 are in the forward biased condition. When a gate signal to thyristor $T_{1,}$ it starts conducting and the load current flows through the path. The load current continues to flow until the thyristor gets commutated by the reversal of source voltage at the instant $\omega t = \pi$.

Mode 2: During the negative half cycle of the supply voltage, thyristor T_2 and diode D_2 are in the forward biased condition. When the thyristor T_2 is triggered at an angle, it starts conducting and load current flows through the path.

Observe that the load current direction in this mode is same as that of load current direction in the previous mode. In both the modes, it is clear that power flows from source to load.

FORMULAE: Derivations for average dc output voltage of both R & RL Load:

V_{dc} (Theortical) = $\frac{2}{2\pi}\int_{\alpha}^{\pi} Vm\ Sin\ wt\ dwt$

$= \frac{2Vm}{2\pi}[- coswt]_{\alpha}^{\pi}$

$$= \frac{2V_m}{2\pi} [-\cos \pi + \cos\alpha]$$

$$V_{dc} \text{ (Theoretical)} = \frac{V_m}{\pi}[1+\cos\alpha]$$

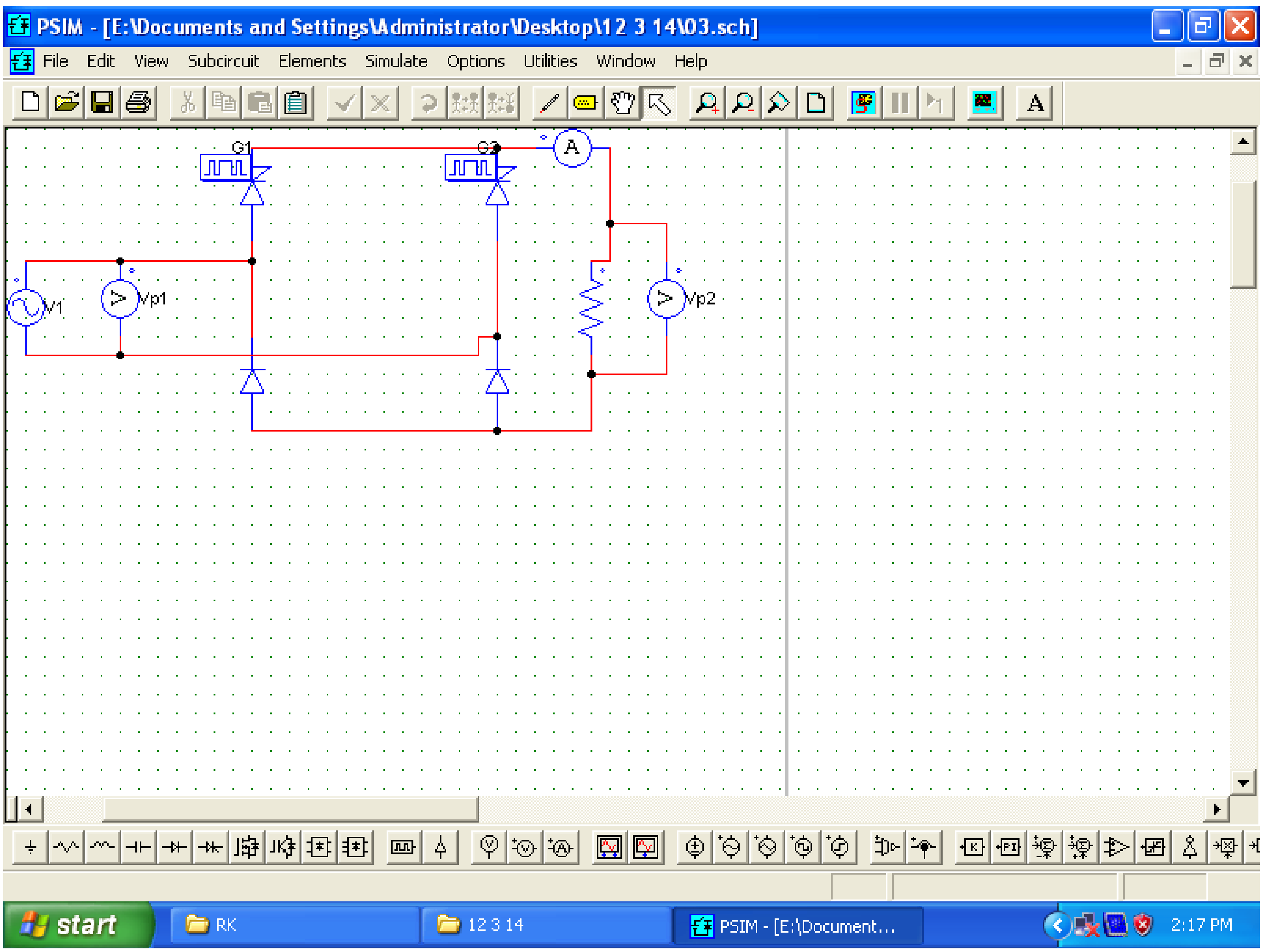
α - Firing angle (Degree)

$V_m = \sqrt{2}\, V_s$

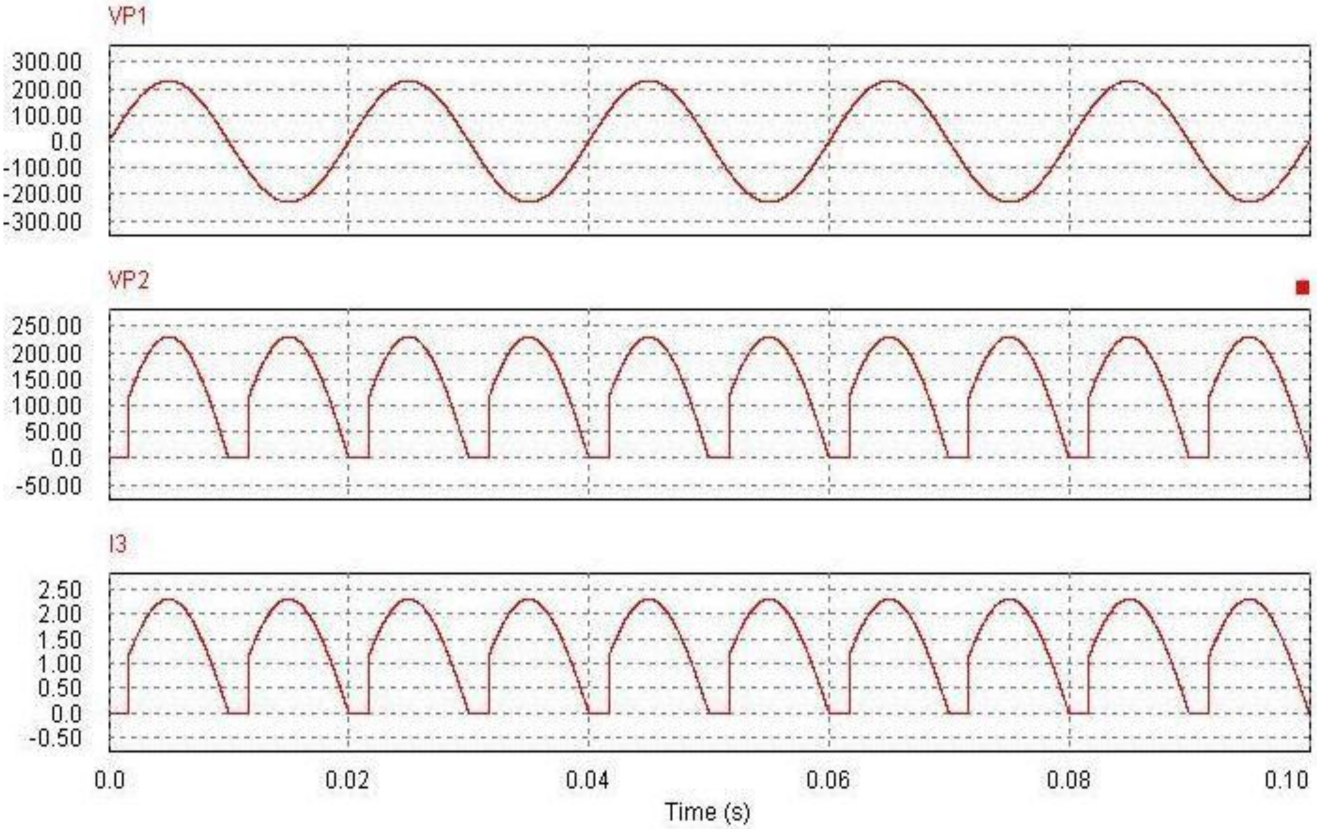
Vm - Peak Voltage (Volt);

Vdc – Average Output voltage (Volt)

CIRCUIT DIAGRAM :



MODEL GRAPH:



EXEPERIMENTAL RESULT:

Thus a single-phase half controlled converter was constructed and their Output waveforms were plotted.

DISCUSSION:

QUESTIONS:

1. What is the condition for load current should be discontinuous?

2. ***What is the output ripple voltage frequency of three phase half wave converters?***

3. What are the two modes of operation present in the three phase half controlled rectifiers?

4. What is the use of freewheeling diode present in the three phase half controlled rectifiers?

5. What is the condition for the output voltage should be negative?

Exp-5. SIMULATION OF SINGLE PHASE FULLY CONTROLLED CONVERTER USING PSIM

AIM:

To construct a single phase fully controlled Converter and plot its response. Also find out the average value, peak value and rms value of different voltages and currents.

THEORY:

The single phase fully controlled convertor using four thyristors (T_1 , T_2 , T_3 , T_4).There have two mode of operations.

Mode 1: During the positive half cycle of the supply voltage, The thyristors T_1 and T_2 are in the forward biased condition and the thyristors T_3 and T_4 are in the reverse biased condition. To ensure simultaneous firing of T_1 , T_2 pair and T_3 , T_4 pair during positive and negative half cycle of the voltage respectively they should be triggered from same firing circuit. In this mode, T_1 and T_2 conducts.

Mode 2: During the negative half cycle of the supply voltage, the thyristors T_3 and T_4 are triggered simultaneously at an instant $\pi + \alpha$. With this, the thyristors T_1 and T_2 are commutated by the negative line voltage which reverse biased them through the thyristors T_3 and T_4 respectively. In this mode, T_3 and T_4 conducts.

FORMULAE USED:

$$V_{dc}\text{ (Theortical)} = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin wt \, dwt$$

$$= \frac{2V_m}{2\pi}[-\cos wt]_{\alpha}^{\pi+\alpha}$$

$$= \frac{2V_m}{2\pi}[-\cos(\pi+\alpha) + \cos\alpha]$$

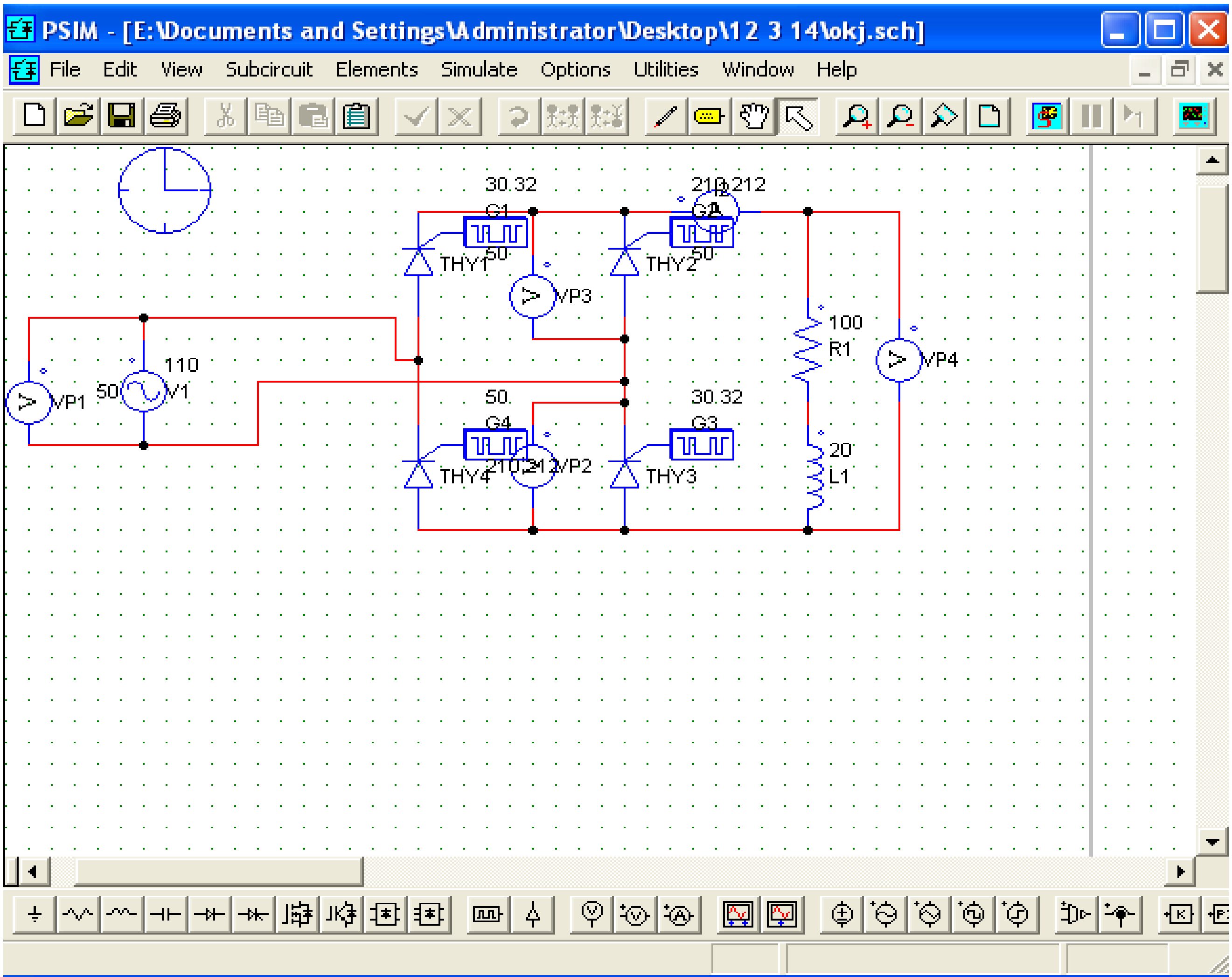
$$V_{dc}\text{ (Theortical)} = \frac{2V_m}{\pi}[\cos\alpha]$$

Where α - Firing angle (Degree)

Vm - Peak Voltage (Volt); $V_m = \sqrt{2}\, V_s$

Vdc – Average Output voltage (Volt)

CIRCUIT DIAGRAM:



OUTPUT & RESULT:

Draw the output graph across the load and find out the peak value, rms value, average value of output voltage and current across the load.

DISCUSSION:

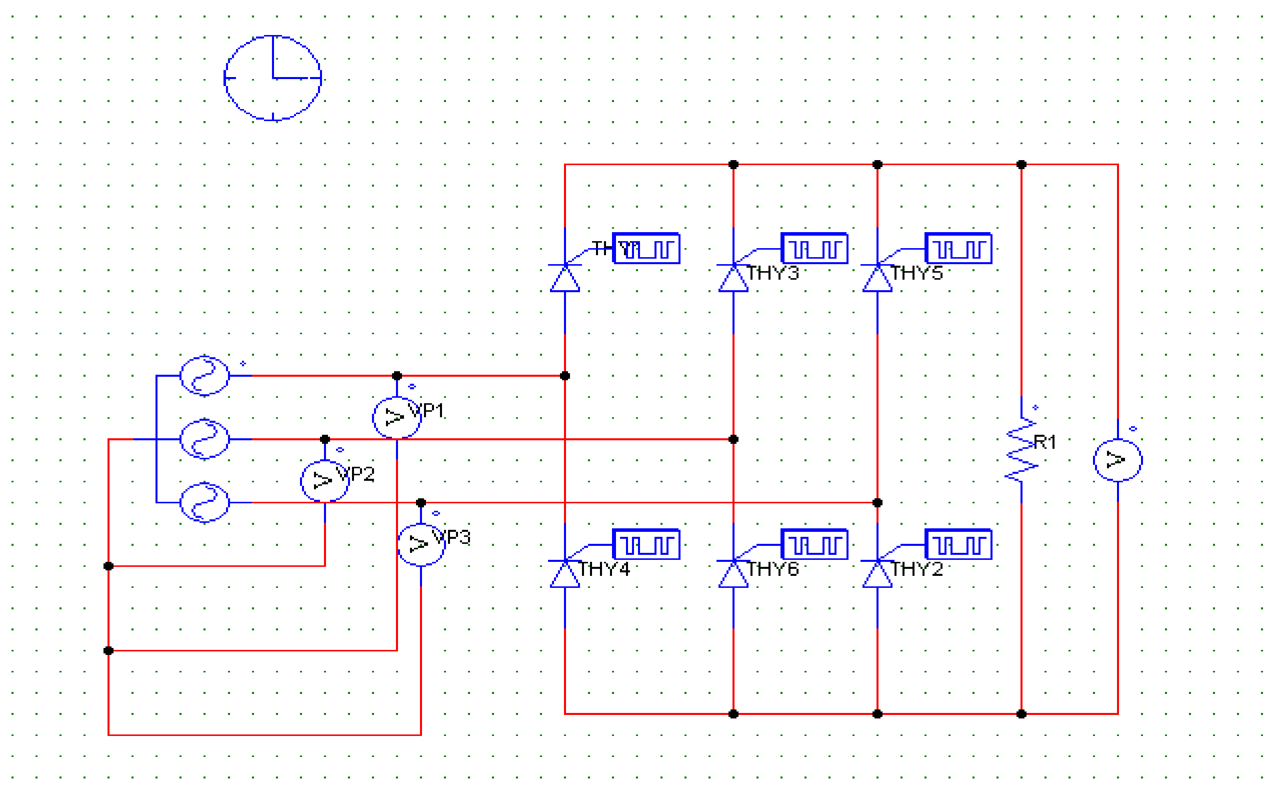
Exp-6. SIMULATION OF THREE PHASE FULLY CONTROLLED RECTIFIER USING PSIM

THEORY:

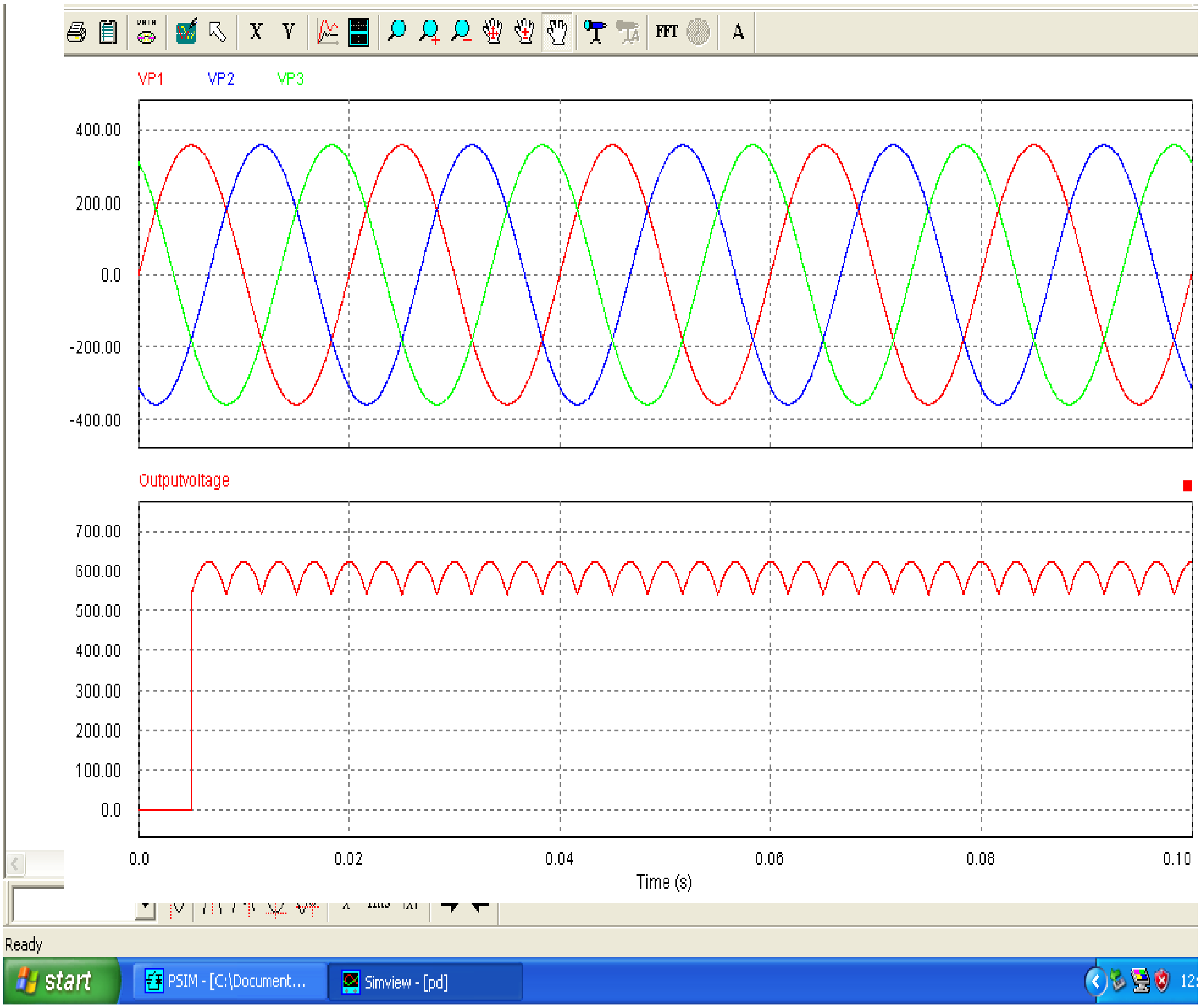
A three-phase fully-controlled bridge rectifier can be constructed using six SCRs. The bridge circuit has two halves, the positive half consisting of the SCRs T1, T3 and T5 and the negative half consisting of the SCRs T2, T4 and T6. At any time, one SCR from each half conducts when there is current flow. The SCRs are triggered in the sequence T1, T2, T3, T4, T5, T6 and T1 and so on. When the SCRs are fired at 0^0 firing angle, the output of the bridge rectifier would be the same as that of the circuit with diodes. For instance, it is seen that D1 starts conducting only after $\theta = 30^0$. In fact, it can start conducting only after $\theta = 30^0$, since it is reverse-biased before $\theta = 30^0$. The bias across D1 becomes zero when $\theta = 30^0$ and diode D1 starts getting forward biased only after $\theta = 30^0$.

For $\alpha = 0^0$, T1 is triggered at $\theta = 30^0$, T2 at 90^0, T3 at 150^0 and so on. For $\alpha = 60^0$,T1 is triggered at $\theta = 30^0 + 60^0 = 90^0$, T2 at $\theta = 90^0 + 60^0 = 150^0$ and so on. Note that positive group of SCRs are fired at an interval of 120o. Similarly, negative group of SCRs are fired with an interval of 120^0. But SCRs from both the groups are fired at an interval of 60^0. This means that commutation occurs every 60^0, alternatively in upper and lower group of SCRs. Each SCR from both groups conducts for 120^0.

CIRCUIT DIAGRAM:



MODEL GRAPH:



FORMULAE USED:

Average output voltage,

$V_o = (3\sqrt{3}\ V_m / \Pi) * \cos\alpha$

Where,

V_m = Peak phase voltage, Volts
α = Firing angle, degrees

RESULT:

Draw the waveform of supply voltage, ouput voltage across the load, load current. Also find out the average and rms value of all these parameters.

DISCUSSION:

ANSWER THE FOLLOWING QUESTIONS:

1. What is a three phase controlled rectifier?

2. What are the advantages of three phase controlled rectifier over three phase uncontrolled rectifier?

3. What are the classifications of three phase controlled rectifier?

4. What are the advantages of six pulse converter?

5. Derive the expression for average output voltage of three phase full converter.

6. What are the effects of source inductance in the controlled rectifiers?

7. What is the effect of freewheeling diode in case of inductive load?

Exp-8 : Study of performance of PWM Inverter using MOSFET/IGBT as switch of 3 phase Induction Motor (simulation)

THEORY :

In Pulse Width Modulation (PWM) method, a fixed dc input voltage is given to inverter and a controlled ac output voltage is obtained by adjusting the ON and OFF period of inverter components. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is modulated to obtain controlled inverter output voltage and to reduce its harmonics content. Different PWM techniques are as under

1. Single-pulse modulation (SPM)
2. Multiple-pulse modulation (MPM)
3. Sinusoidal-pulse modulation (SPM)

In PWM inverters, forced commutation is essential. The three PWM techniques listed above differ from each other in the harmonics content in their respective output voltages. Mostly in industrial application sinusoidal-pulse modulation is used to control three phase induction motor.

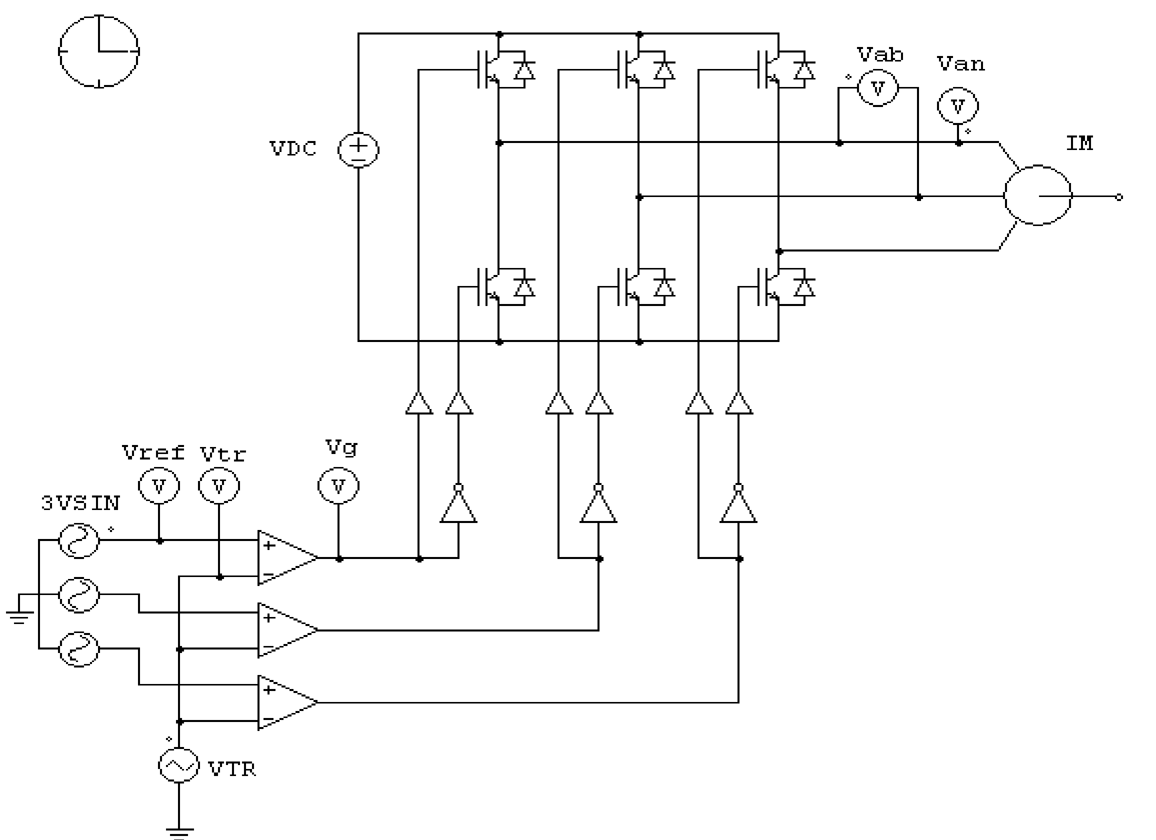
In SPM several pulses per half cycle are used as in case of MPM. In MPM the pulse width is equal for all pulses but in SPM pulse width is a sinusoidal function of angular position of pulse in a cycle. In SPM a high frequency triangular carrier wave v_c is compared with a sinusoidal reference wave v_r of desired frequency. The intersection of v_c and v_r waves determines the switching instants and commutation of the modulated pulse as shown in fig. The carrier and reference waves are mixed in a comparator. When sinusoidal wave has magnitude higher than triangular wave, comparator output is high, otherwise it is low.

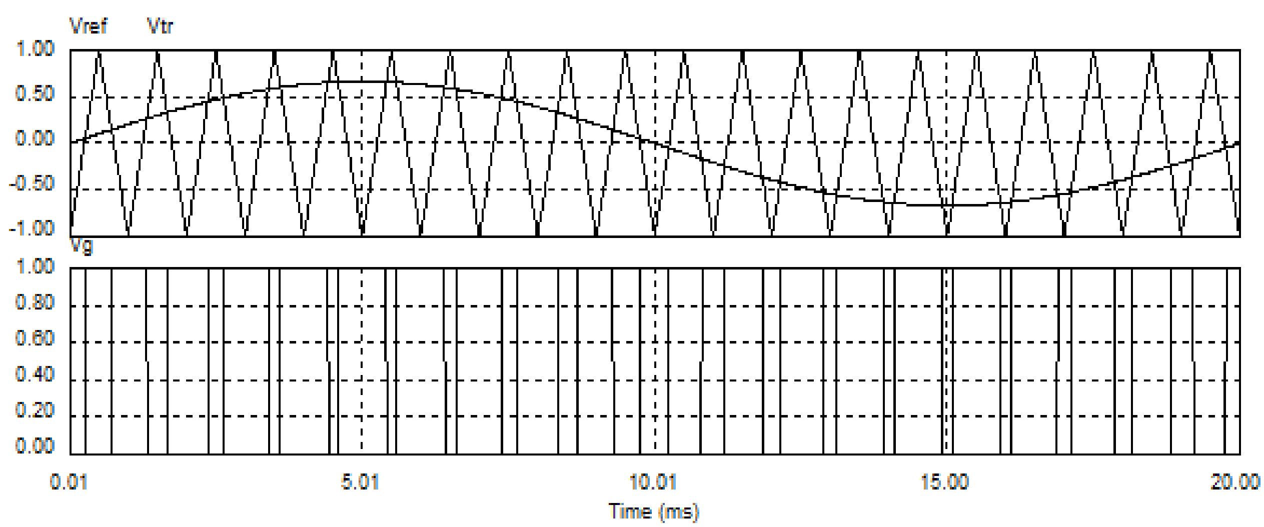
The fundamental component in the output phase voltage of PWM inverter operating with sinusoidal PWM is given by

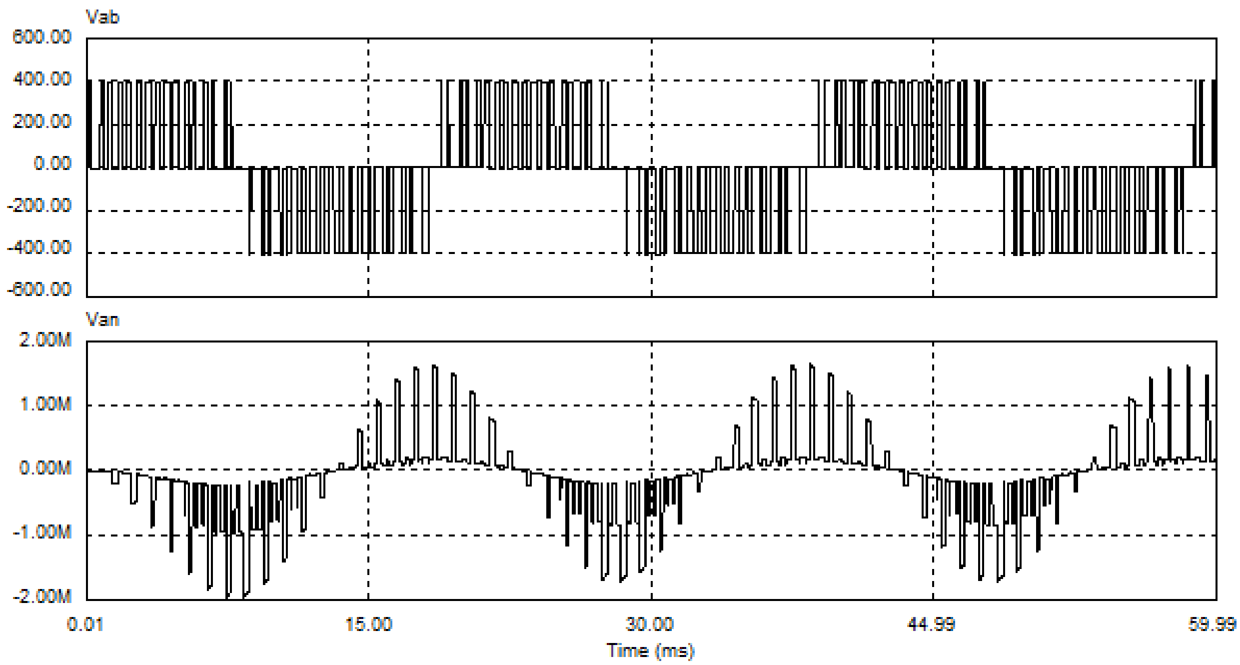
$$V_{ph} = m\frac{V_{dc}}{2\sqrt{2}}$$

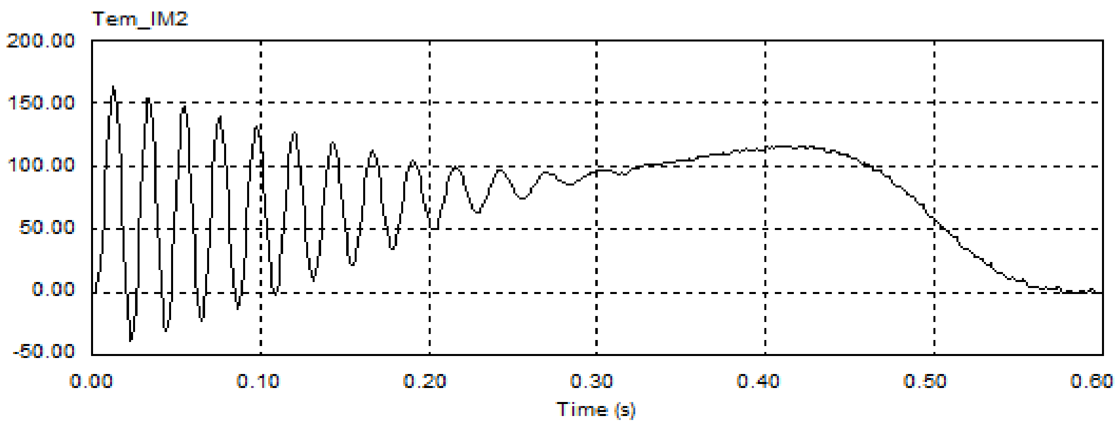
Where m is the modulation index. The ratio of peak amplitude of reference and carrier wave i.e. V_r/V_c is called modulation index (MI). The MI controls the harmonic content of output voltage waveform.

CIRCUIT DIAGRAM FOR PSIM :









PROCEDURE :

1) Open the PSIM software and construct the circuit of half-controlled single phase rectifier.
2) Use the "element" icon to get all the relevant components or devices.
3) Reset the parameters of different devices by double clicking over them as specified below :

Device	*Description*	*Parameters*
IM	Induction Motor	R_s = 0.183, L_s = 0.0015, R_r = 0.277, L_r = 0.0022, L_m = 0.0538, MI = 0.0165, P = 4, All Flags = 1.

VDC	DC voltage source	Amplitude = 400
IGBT 1-6	IGBT switches	All parameters = 0
VSIN3	3 ph sinusoidal voltage source	V (line-line-rms) = 0.816, Frequency = 50 Init. Angle (phase A) = 0
VTR	Triangular voltage source	Vp-p = 2, Frequency =1000, Duty Cycle = 0.5, DC Offset = -1, Tstart = 0

4) Connect voltmeter as shown in the fig.
5) Now click 'simulation control' icon for transient analysis. Set the parameters with suitable values like Time Step = 1E-005, Total Time = 0.6, Print Time = 0, Print Step = 1, All Flags = 0.
6) Then click "run simulation" for simulation process. Graphical window will appear.
7) Observe the waveforms of the following: Reference and Carrier wave (Vref, Vtr), Vab, Van.
8) Also observe the waveforms of electromagnetic torque (Tem_IM).
9) Record the all above waveform in graph paper.

DISCUSSION :