LABORATORY MANUAL

POWER ELECTRONICS LAB

B.Tech. (Electrical Engineering), 5^{th} Semester

Department of Electrical Engineering
Veer Surendra Sai University of Technology,
BURLA

Vision

To be recognized as a center of excellence in education and research in the field of Electrical Engineering by producing innovative, creative and ethical Electrical Engineering professionals for socio-economic development of society in order to meet the global challenges.

Mission

Electrical Engineering Department of VSSUT Burla strives to impart quality education to the students with enhancement of their skills to make them globally competitive through:

M1. Maintaining state of the art research facilities to provide enabling environment to create, analyze, apply and disseminate knowledge.

M2. Fortifying collaboration with world class R& D organizations, educational institutions, industry and alumni for excellence in teaching, research and consultancy practices to fulfil 'Make in India' policy of the Government.

M3. Providing the students with academic environment of excellence, leadership, ethical guidelines and lifelong learning needed for a long productive career.

Program Educational Objectives

The program educational objectives of B.Tech. in Electrical Engineering program of VSSUT Burla are to prepare its graduates:

1. To have basic and advanced knowledge in Electrical Engineering with specialized knowledge in design and commissioning of electrical systems/renewable energy systems comprising of generation, transmission and distribution to become eminent, excellent and skilful engineers.

2. To succeed in getting engineering position with electrical design, manufacturing industries or in software and hardware industries, in private or government sectors, at Indian and in Multinational organizations.
3. To have a well-rounded education that includes excellent communication skills, working effectively on team-based projects, ethical and social responsibility.
4. To have the ability to pursue study in specific area of interest and be able to become successful entrepreneur.
5. To have broad knowledge serving as foundation for lifelong learning in multidisciplinary areas to enable career and professional growth in top academic, industrial and government/corporate organizations.

LIST OF EXPERIMENTS

1. Familiarization with power electronics components. (SCR, IGBT, MOSFET, GTO, BJT) & Draw the V-I Characteristics of SCR with different gate currents.
2. Study of Single phase half wave converters with R and R-L loads with and without freewheeling action.
3. To study single phase AC regulator using TRIAC (R & R-L Loads)
4. To study different triggering circuits for thyristors (Cosine Law & UJT Triggering)
5. Study of single Phase full wave converters with R and R-L loads with and without freewheeling action
6. To study the characteristics of three phase diode rectifier (R & R-L Loads)

COURSE OUTCOMES:

Upon completion of this course, students will demonstrate the ability to:

CO1. Demonstrate power electronics components and their V-I Characteristics.

CO2. Produce waveforms across the loads and switches.

CO3. Implement triggering circuits for power electronic devices.

CO4. Demonstrate operation of AC-DC and AC-AC converters.

CO5. Demonstrate operation of Inverter circuits.

Experiment 1

AIM OF THE EXPERIMENT:

Study of V-I characteristics of SCR with different gate currents.

APPARATUS REQUIRED:

Sl.No.	Name of the Items	Type	Range	Quantity
1.	SCR	T1508	25A,1200V	1nos.
2.	Ammeter	MC	(0-20)mA,(0-2.5)A, (0-75) mA	3
3.	Voltmeter	MC	(0-250)V,(0-2)V	3
4.	Rheostat	Toshniwal	220Ω2.8A, 145Ω 2.8A	2
5.	Two Way Key			1
6.	Decade Resistance		(0-999)KΩ	1
7.	Patch Chords & wires			few

THEORY:

OFF MODE: when anode is positive w.r.t. cathode (without any gate signal) the S.C.R. is forward biased and it is in forward blocking state or off-state. Only leakage current of mA value will flow through the device.

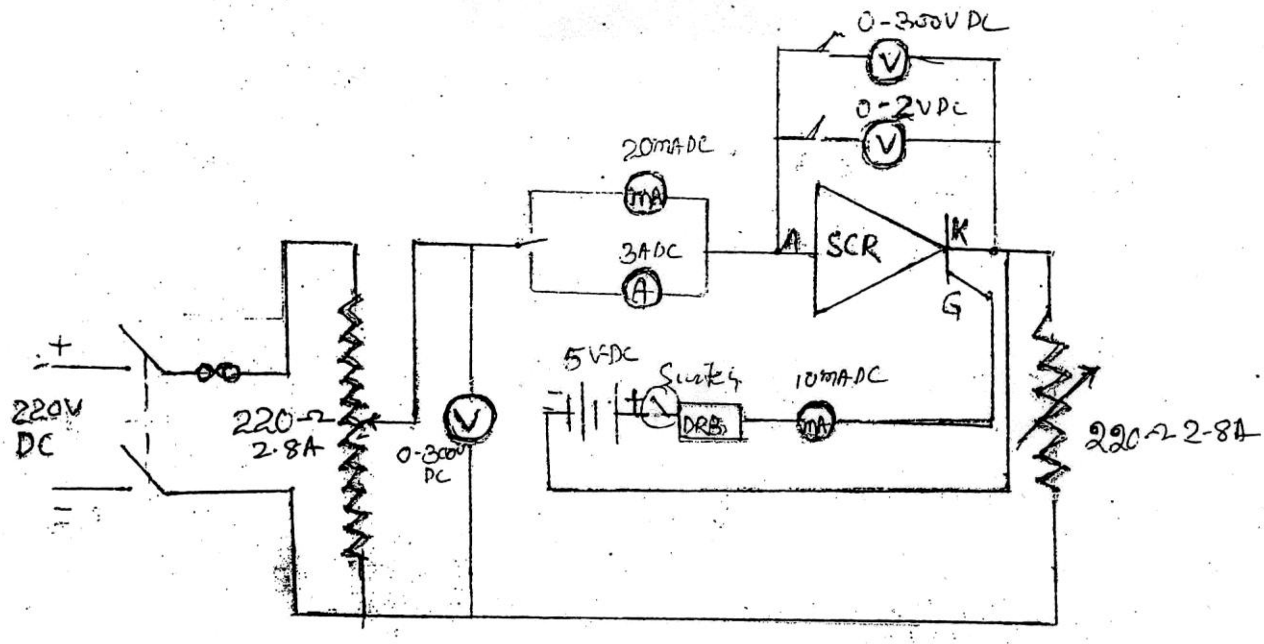
When anode is made negative with respect to cathode, the SCR is reversed biased and is in reverse blocking state. Only leakage current flows through the device.

CONDUCTION MODE:

When SCR is forward biased (without gate signal) and voltage across it is gradually increased the leakage current will increase and at a particular voltage VB (break over voltage) large forward current flow from anode to cathode and is controlled by the external impedance. The voltage drop across the device will decrease to the ohmic drop of the device, and the device is in conducting state or on state. The anode to cathode voltage is now decreased; the device will continue to stay on. Only when the current become less than holding current (at small input forward voltage / connecting high impedance in the circuit) the device will go to blocking state.

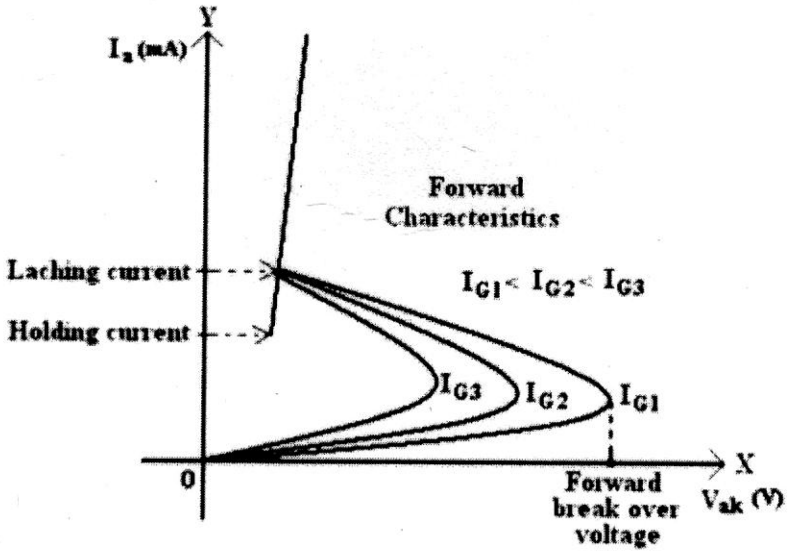
When the SCR is forward biased and gate signal is given (gate positive w.r.t. cathode) the SCR will conduct at reduced applied voltage. The characteristic is given in the following figure.

Circuit Diagram for V-I characteristics of SCR



MODEL GRAPH:

VI CHARACTERISTICS OF SCR



PROCEDURE:

1. Connections are made as per circuit diagram.
2. Initial voltage across anode to cathode (Vak) make zero with the help of rheostat.
3. Connect the two way keys in such that low current and high voltage rating ammeter and voltmeter respectively to the circuit.
4. Now slowly increase the anode to cathode voltage (Vak) by varying the rheostat till the thyristor gets turned On, with the indication that anode to cathode voltage decreases to its on state voltage drop and anode current increases. If the thyristor will not conduct then apply gate current to 14mA by varying the decade resistant.
5. Now switch off the DC supply and connect the two ways key in such that high current and low voltage rating ammeter and voltmeter respectively were connected to the circuit then switch on the DC supply.
6. Note the values of voltmeter (Vak) which is the break over voltage and the anode current (Ia) which is the latching current value.
7. Further, increase the anode current (Ia) in steps by varying the anode to cathode (Vak) and note the readings.
8. Now reduce the Anode to cathode (Vak) till the thyristor is turned off and find the holding current.
9. Now change the gate current and repeat the same procedure from 2 to 8.
10. Finally, a graph of anode current Vs anode to cathode voltage is plotted for various gates current.

PRECAUTIONS:

1. Before setting each the gate current, keep the anode to cathode voltage (V_{ak}) as zero.
2. Keep the load resistance at maximum point.
3. Initially choose the higher range ammeter and voltmeter to check the break over voltage.

TABULATION FOR V-I CHARACTERISTICS OF SCR

Sl.No	**Ig.=1**			**Sl.No.**	**Ig.=2**		
1	V_i	V_{ak}	I_a	1	V_i	V_{ak}	I_a
2				2			
3				3			
4				4			
5				5			

CONCLUSION:

DISCUSSION QUESTIONS

1. What is latching current?
2. What is break over voltage?
3. What is forward bias and reverse bias?
4. What is holding current?

Experiment 2

AIM OF THE EXPERIMENT:

Study of Single phase half wave converters with R and R-L loads with and without freewheeling action.

APPARATUS REQUIRED:

Sl.No.	Name of the Items	Type	Range	Quantity
1.	SCR module with protection	25TTS12	25A,1200V	1nos.
2.	SCR Triggering Kit	--	--	--
3.	Isolation Transformer		230/230V	1
3.	Ammeter	MC	0-3A	1
4.	Voltmeter	MC	0-250V	1
5.	Rheostat	Toshniwal	220Ω2.8A,13Ω7.9A	2
6.	Inductor		120mH,4A	1
7.	CRO		30MHz.	1
8.	CRO Probe		1:1, 1:10	2
9.	Patch Chords & wires			As Req.

THEORY:

Following diagram is based on R-C phase shift. When R is changed, firing angle also changes ranging from 0 to 180^0. But when this is subjected to thyristor as gate pulse, wide range variation of firing angle connects is achieved. (Firing angle = phase angle). After α = 90, amplitude of the gate pulse may not be sufficient to turn on. So to obtain wide range of firing angle, it is totally dependent upon the peak value of gate pulse.

FORMULA USED:

FOR R - LOAD

1. Average DC output voltage V_{dc} is

$$V_{dc} = \frac{V_m}{2\pi}(1+\cos\alpha)$$

2. RMS output voltage is V_{rms}

$$V_{rms} = \frac{V_m}{2}\left[\frac{1}{\pi}\left(\pi-\alpha+\frac{\sin 2\alpha}{2}\right)\right]^{½}$$

FOR RL – LOAD

3. Average DC output voltage V_{dc} is $$V_{dc} = \frac{V_m}{2\pi}[\cos\alpha - \cos\beta]$$

4. RMS output voltage is V_{rms} $$V_{rms} = \frac{V_m}{2}\left[\frac{1}{\pi}(\beta - \alpha) - ½(\sin 2\beta - \sin 2\alpha)\right]^{½}$$

5. Rectification efficiency $$\%\eta = \frac{V_{dc}^2}{V_{rms}^2}$$

6. From factor $$FF = \frac{V_{rms}}{V_{dc}}$$

7. Peak inverse voltage $$PIV = V_m$$

8. Ripple factor $$RF = \sqrt{FF^2 - 1}$$

9. Power factor $$PF = \frac{1}{\sqrt{2\pi}}\left(\pi - \alpha + \frac{\sin 2\alpha}{2}\right)^{½}$$

Where

V_m = maximum or peak voltage in volts $\sqrt{2V_i}$

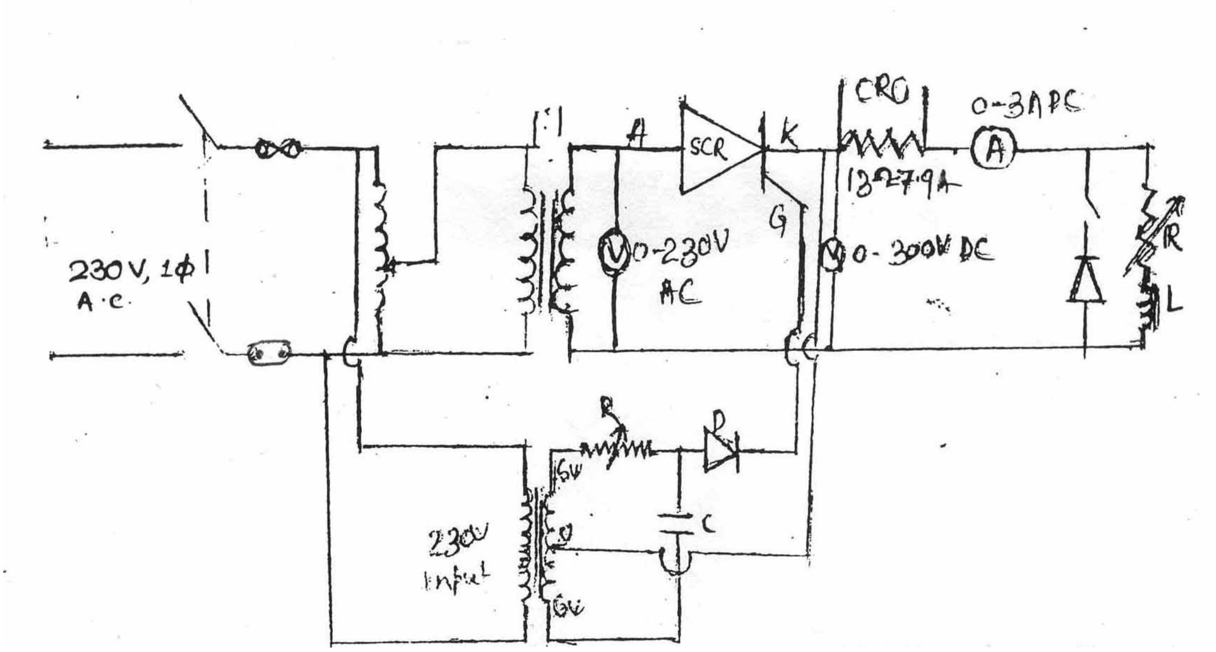
V_i = Supply voltage in volts

α = Firing angle

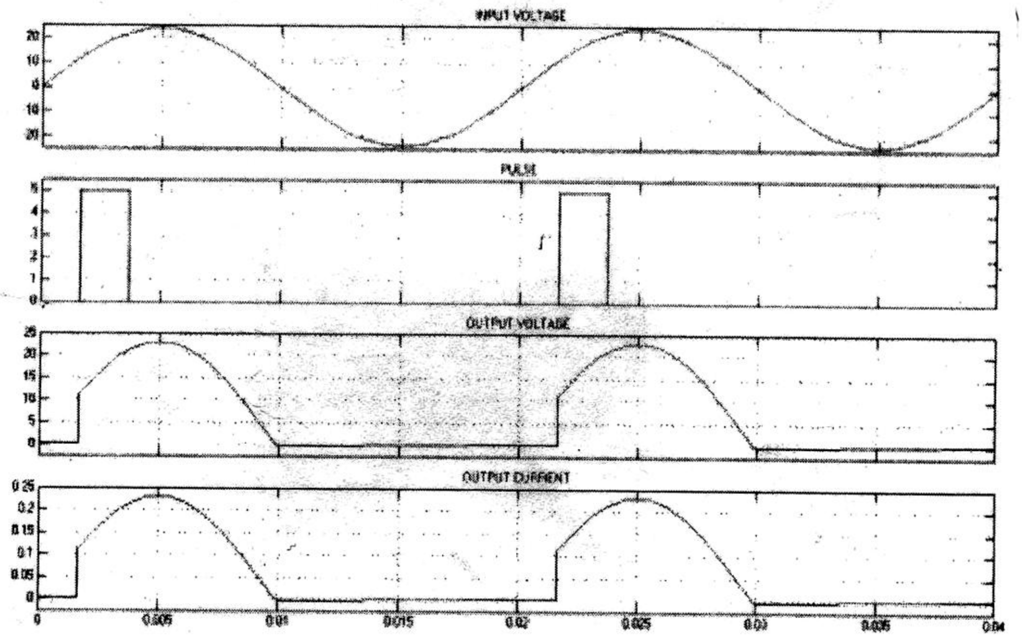
β = Extinction angle

γ = conduction angle = β - α

Circuit Diagram for Single phase half wave controlled converters



Single Phase Half Wave Rectifier Wave forms with R-Load



OBJECTIVE:

Observe the load voltage at different firing angle. Trace the load voltage waveform corresponding to firing angle with/without free-wheeling diode. Find the load voltage theoretically experimentally.

Also observe waveform across the different components.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Switch on the triggering circuit.
3. Switch on the supply and keep the input supply voltage at 100V.
4. By varying the potentiometer, vary the firing angle provided in the panel board from 0-90^0.
5. Trace the different voltage and current waveform for different firing angles.
6. Follow similar procedure for the R-L loads with and without free wheeling diode.
7. Output voltage is calculated for each step and the readings are tabulated.
8. Readings are taken from voltmeter and ammeter for various observations and finally calculate the error.

TABLE

For R-Load

Sl.No.	Firing angle α^0	Practical Vavg.(V)	Practical Iavg.(A)	Reading from CRO		% error in	
				Voltage	Current	Voltage	Current
1							
2							
3							
4							

For R-L Load at β=

(With FD & without FD)

Sl.No.	Firing angle α^0	Practical Vavg.(V)	Practical Iavg.(A)	Reading from CRO		% error in	
				Voltage	Current	Voltage	Current
1							
2							
3							
4							

CONCLUSION:

DISCUSSION QUESTIONS:

1. What are the types of converter in power electronics?
2. What is firing angle?
3. What is freewheeling diode?
4. What is the effect on Power factor?
5. How the extinction angle β can be known theoretically?

Experiment 3

AIM OF THE EXPERIMENT

Study of single phase AC regulator using TRIAC with R and R-L loads.

APPARATUS REQUIRED:

Sl.No.	Name of the Items	Type	Range	Quantity
1.	TRIAC module	BT13600	4A,600V	1
2.	Isolation Transformer		230/230V	1
3.	Ammeter	MI	0-2.5A	1
4.	Voltmeter	MI	0-250V	1
5.	Rheostat	Toshniwal	220Ω2.8A,13Ω7.9A	2
6.	Inductor		Fan Motor	1
7.	CRO		30MHz.	1
8.	CRO Probe		1:1, 1:10	2
9.	Patch Chords & wires			few

THEORY:

OBJECTIVE:

Measure the firing angle, corresponding voltage and current across R and R-L load. Trace the wave forms of voltage and current. For various value of α, calculate the theoretical RMS voltage and current and determine the % error.

FORMULA USED:

The RMS output voltage is $$V_{oRMS} = V_s\left[\frac{1}{\pi}\left(\pi - \alpha + \frac{\sin 2\alpha}{2}\right)\right]^{1/2}$$

Where α =Firing angle

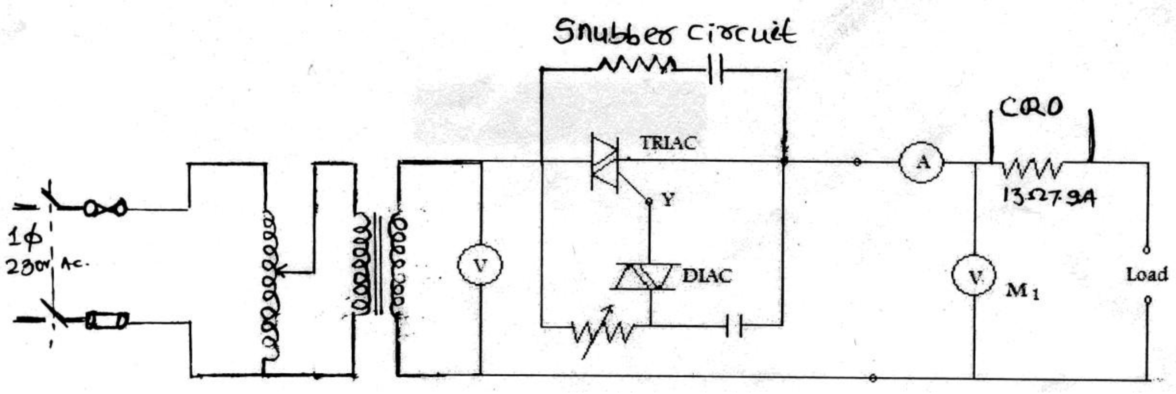
V_s = Source voltage

$$\%\ \text{error} = \frac{V_{rms(th)} - V_{rms(\exp t)}}{V_{rms(th)}} \times 100$$

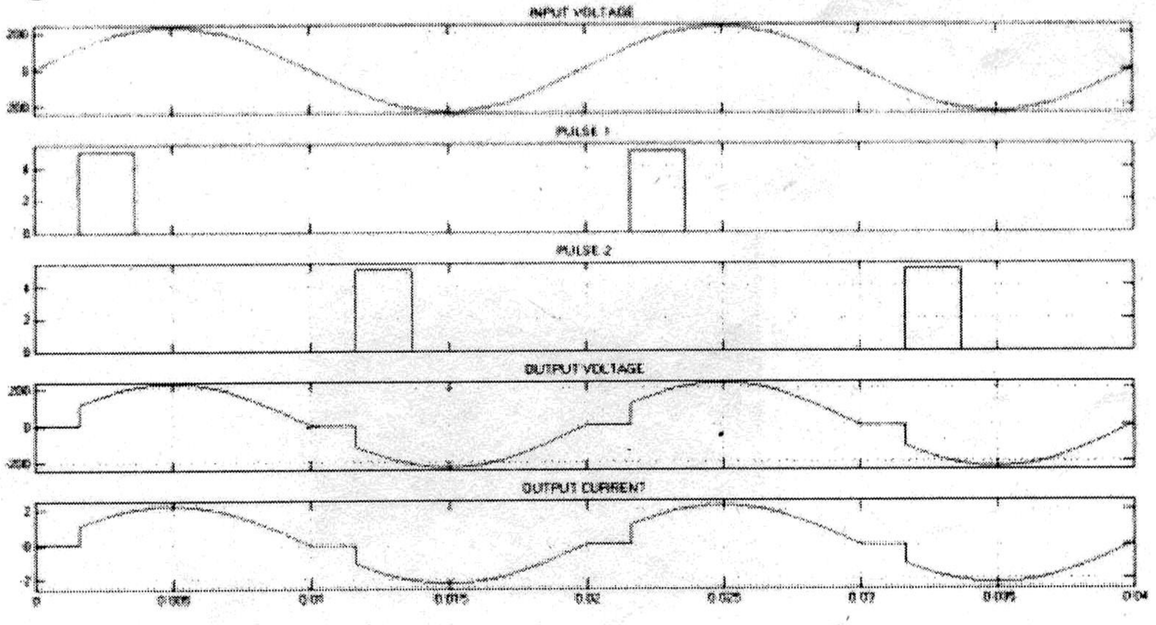
PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Load the resistance to its full position.
3. Switch on the 230V A.C. supply and adjust the variac to 220V.
4. By varying the potentiometer, vary the firing angle and for each step note down the firing angle, ammeter, voltmeter reading and the output waveforms for R & R-L load separately.
5. Finally the output wave form is plotted and theoretical RMS voltage and current is calculated.

Circuit Diagram of TRIAC for single phase AC regulator



Single -Phase A.C. Phase controller with R- Load



TABULATION FOR SINGLE PHASE AC REGULATOR

***(i)** For R- Load*

Sl.No	Firing angle α^0	Voltmeter Reading	Ammeter reading	Voltage from CRO	Current from CRO	% error in voltage.	% error in current
1							
2							
3							

***(ii)**For R-L Load*

Sl.No	Firing angle α^0	Voltmeter Reading	Ammeter reading	Voltage from CRO	Current from CRO	% error in voltage.	% error in current
1							
2							
3							

CONCLUSION:

DISCUSSION QUESTIONS

1. What is bidirectional device?
2. What is bipolar device?
3. What is the number and range of the given Triac?
4. What type of firing and commutation are used here?
5. How do you change the firing angle?
6. Draw the symbol of Triac.

Experiment 4

AIM OF THE EXPERIMENT

Study of different methods of triggering of thyristors.

(i) UJT controlled method.

(ii) Cosine Law controlled method.

APPARATUS REQUIRED:

Sl.No.	Name of the Items	Type	Range	Quantity
1.	UJT triggering module			
2.	Cosine Law triggering module			
7.	CRO		30MHz.	1
8.	CRO Probe		1:1	2
9.	Patch Chords & wires			few

THEORY:

(i) <u>UJT controlled method.</u>

230V AC is stepped down to 6V AC. It is fed to Z.C.D. (Zero crossing detector) to get square wave output with same frequency when emitter base junction of UJT. (i.e. Capacitor changing voltage) reaches peak voltage (V_P – nV_z). The uni-junction breaks down. The capacitor discharge voltage across the resistor is fed to an amplifier, which is mainly to amplify insufficient output of UJT for turning on a thyristor.

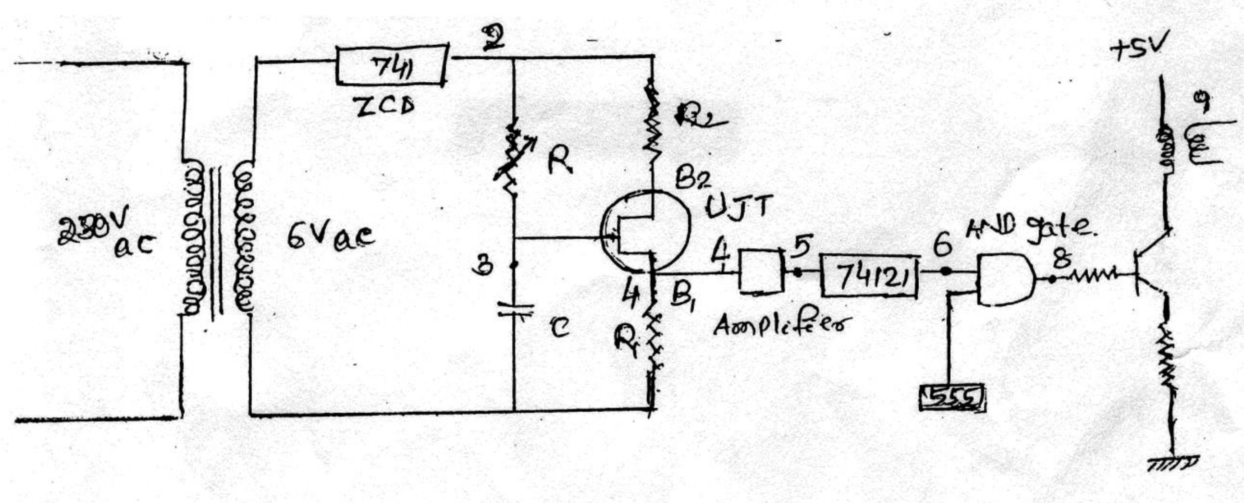
The amplifier output is of small width. So to get fixed pulse width it is fed to mono stable (74121).

This output is ANDed with high frequency timer (555) to get trains of pulses, by which thyristor will easily turn on, because sometime single gate pulse may not have sufficient strength to turn on the thyristor.

PROCEDURE:

Note: In practical circuit amplifier is not provided. So UJT output is directly fed to Mono stable.

Circuit Diagram of UJT triggering method



Tabulation for UJT triggering method.

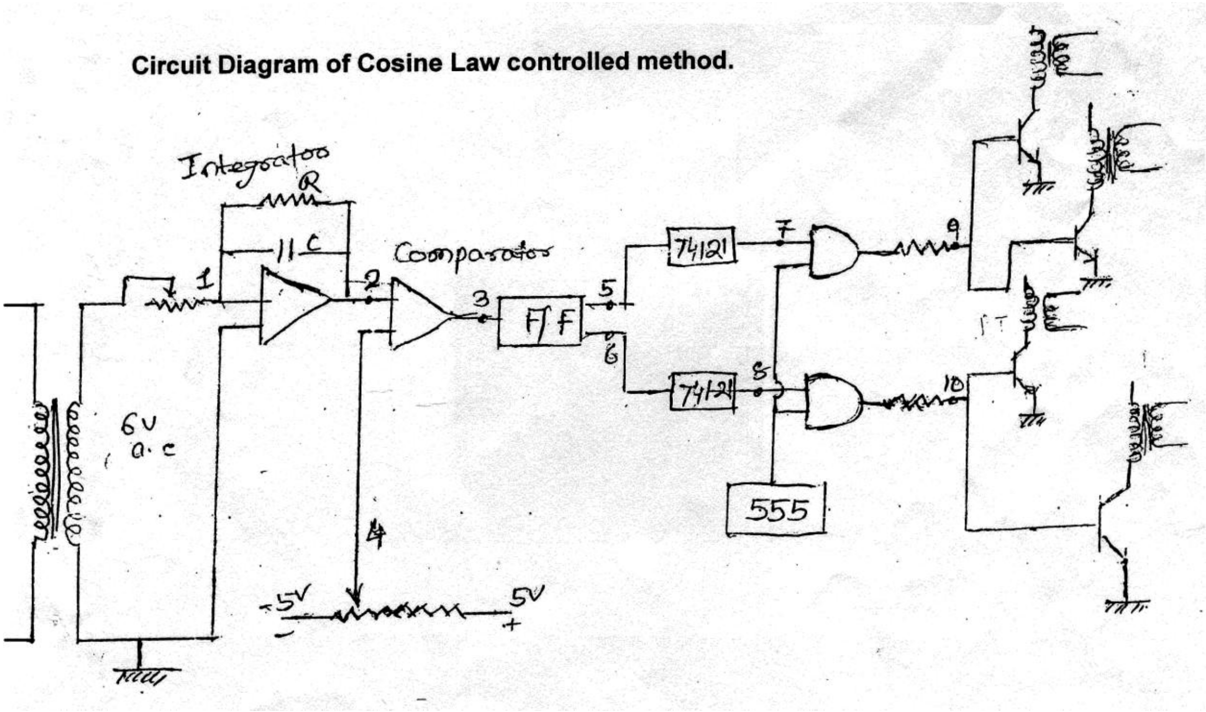
Sl.No	Waveforms	Amplitudes	Time periods (ms)	Frequency
1.				
2.				
3.				
4.				
5.				

(ii) <u>Cosine Law controlled method.</u>

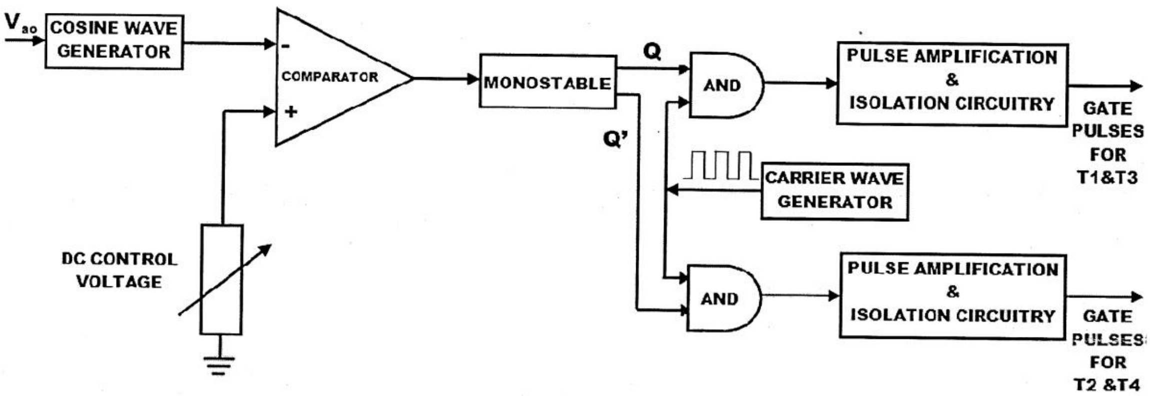
The output of step down transformer is integrated through an integrator circuit to aget a Cosine waveform. Then it is compared with fixed DC level to get a variable square wave. This output is splitted into two signals which are 180^0 out of phase by the help of flip flop (F/F). The two outputs of (F/F) are reduced to suitable pulse width by mono stable circuit. These are finally ended to get train of pulses for gate circuit of thyristors. The circuit can be used for both full wave and half wave converter.

OBJECTIVE:

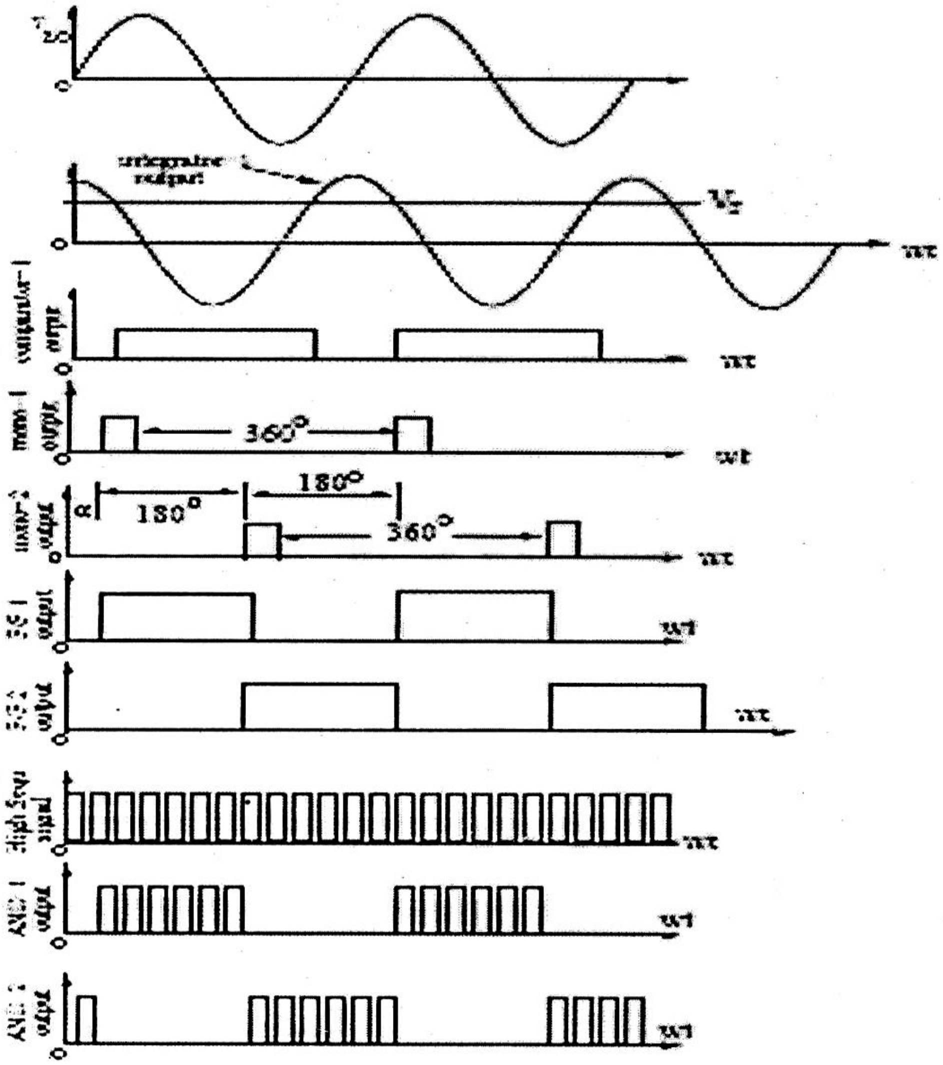
Observe and trace the waveforms at different knobs provided on circuit board & justify the nature of the waveform.



BLOCK DIAGRAM



WAVE FORM



Tabulation for Cosine Law triggering method.

Sl.No	Waveforms	Amplitudes	Time periods (ms)	Frequency
1.				
2.				
3.				
4.				
5.				

CONCLUSION:

DISCUSSION QUESTIONS:

1. Explain the working operation of Cosine law and UJT triggering circuits?
2. What are the different methods of triggering SCR?
3. Why gate triggering is preferred? What happens to constant triggering voltage is applied?
4. Why UJT triggering circuit is superior when compared to R and RC triggering circuit?
5. Why do we require turn on circuits for thyristors?
6. Why do we require turn off circuits for thyristors?
7. Explain why we require cosine law instead of sinusoidal law triggering?

Experiment 5

AIM OF THE EXPERIMENT

Study of Single phase full wave converters with R & R-L loads with and without freewheeling action.

APPARATUS REQUIRED:

Sl.No.	Name of the Items	Type	Range	Quantity
1.	SCR module with protection	25TTS12	25A,1200V	4nos.
2.	SCR Triggering Kit	--	--	--
3.	Isolation Transformer		230/115V	1
3.	Ammeter	MC	0-2.5A	1
4.	Voltmeter	MC	0-250V	1
5.	Rheostat	Toshniwal	220Ω2.8A,13Ω7.9A	2
6.	Inductor		120mH,4A	1
7.	CRO		30MHz.	1
8.	CRO Probe		1:1, 1:10	2
9.	Patch Chords & wires			Few

FORMULA USED:

FOR R-LOAD

1. Average DC output voltage V_{dc} is $$V_{dc} = \frac{V_m}{\pi}(1+\cos\alpha)$$

2. RMS output voltage is V_{rms} $$V_{rms} = \frac{V_m}{\sqrt{2\pi}}\left[\frac{1}{\pi}(\pi-\alpha+\sin 2\alpha)\right]^{½}$$

FOR RL – LOAD

3. Average DC output voltage V_{dc} is $$V_{dc} = \frac{V_m}{\pi}[\cos\alpha-\cos\beta]$$

4. RMS output voltage is V_{rms} $$V_{rms} = \frac{V_m^2}{2\pi}\left[\left(\beta-\alpha-\frac{\sin 2\beta}{2}+\frac{\sin 2\alpha}{2}\right)\right]^{½}$$

5. Rectification efficiency $$\%\eta = \frac{V_{dc}^2}{V_{rms}^2}$$

6. From factor $$FF = \frac{V_{rms}}{V_{dc}}$$

7. Peak inverse voltage $$PIV = V_m$$

8. Ripple factor $$RF = \sqrt{FF^2-1}$$

Where

V_m = maximum or peak voltage in volts $\sqrt{2V_i}$

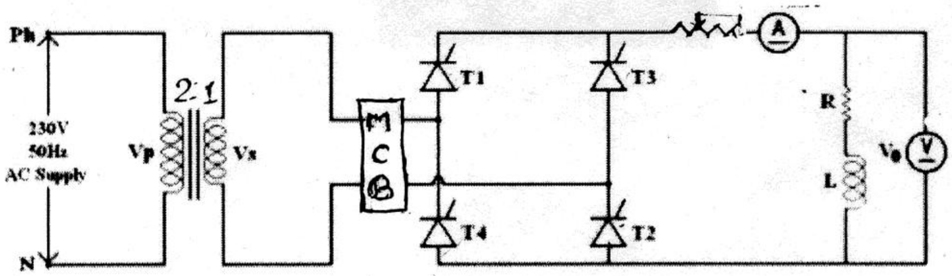
V_i = Supply voltage in volts

α = Firing angle

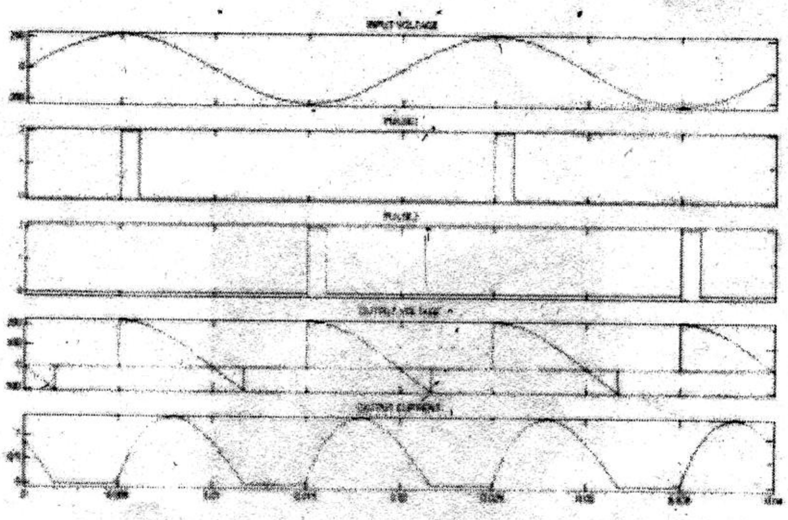
β = Extinction angle

γ = conduction angle = $\beta - \alpha$

Circuit Diagram for fully wave converters with R & R-L loads



Model graph for R-L load $\alpha=90^0$, R=220Ω, L= 120mH



PROCEDURE:

1. Connections are made as per the circuit diagram for R-Load using isolation transformer.
2. The gate cathode terminals of 2 SCR's are connected to respective points on the firing module.
3. Check all the connections and confirm connections are made correct before switching the equipments.
4. Keep the firing angle knob at 180^0(minimum position).
5. Switch on the firing unit.
6. Switch on the Power Circuit (MCB)
7. By varying potentiometer vary the firing angle of the converter in order to vary the output voltage step by step.
8. For each step note down the firing angle, output voltage and load current.
9. The output voltage is theoretically calculated for each step and readings are tabulated.
10. Keep the firing angle potentiometer at 180^0 (minimum position). Switch OFF the power circuit (MCB) & then firing circuit. Remove the connection.
11. Repeat the same procedure for RL load.

TABULATION

for R Load : ***Vs =*** ***R=***

Sl.No.	Firing angle α^0	Practical Vavg.(V)	Practical Iavg.(A)	Reading from CRO		% error in	
				V	**A**	**V**	**A**
1							
2							
3							
4							
5							

For R-L Load ***Vs =*** ***R=*** ***L=*** ***β=***

(With FD & without FD)

Sl.No.	Firing angle α^0	Practical Vavg.(V)	Practical Iavg.(A)	Reading from CRO		% error in	
				V	A	V	A
1.							
2.							
3.							

PRECAUTION:

Keep the firing angle always at 180^0 before turning ON or OFF the circuit.

CONCLUSION:

DISCUSSION QUESTIONS

1. What is inversion mode of operation?
2. When we connect a freewheeling diode in full converter what will be the output.
3. Why the inversion mode is not possible in semi converter?
4. What is β α μ and γ?
5. What are the application of phase control convertor in home appliances?

Experiment 6

AIM OF THE EXPERIMENT

Study of characteristics of three phase diode bridge rectifier with R and R-L loads.

APPARATUS REQUIRED:

Sl.No.	Name of the Items	Type	Range	Quantity
1.	Diode bridge module	S12HR25	25A,1200V	6 nos.
2.	3Φ Isolation transformer		400/130V	1
3.	3Φ Auto transformer		9 KVA, 0-400V	1
4.	Ammeter	MC	0-2.5A	1
5.	Voltmeter	MI & MC	0-150V	2
6.	Rheostat	Toshniwal	100Ω,5A,13Ω7.9A	2
7.	Inductor		120mH,4A	1
8.	Single way key			2nos.
9	Patch Chords & wires			Few

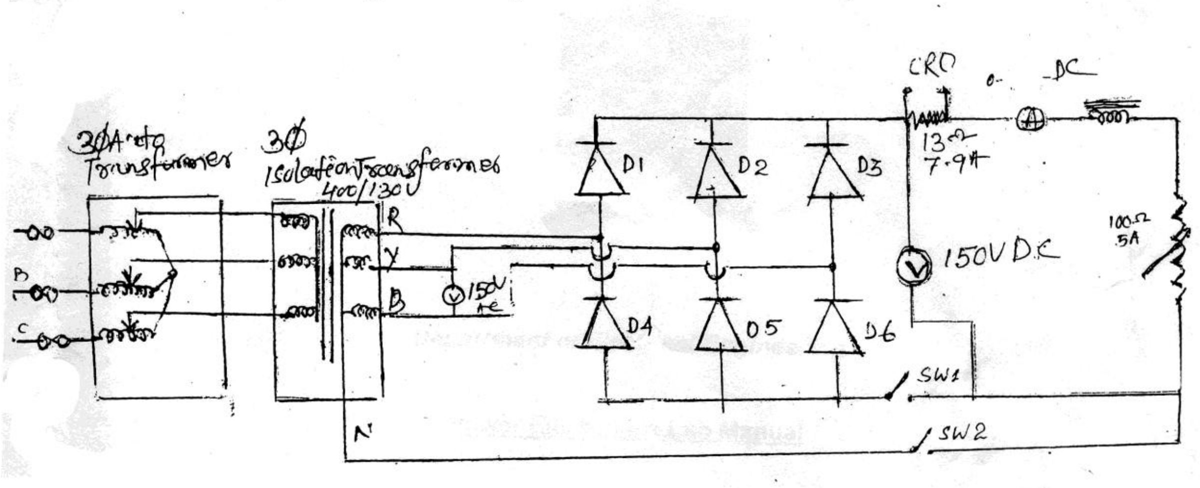
THEORY:

The diode connected to a phase which has the maximum instantaneous value would conduct at any time. The conduction of phase E_{AC} means that the current starts flowing from the phase A to C returns to the phase C through diode D1, load and diode D6. The conduction of phase E (A-B) means the current starts flowing from the phase A and returns to the phase B through D1, the load and D5. The current may starts flowing from phase A, but may return to either phase B or phase C. This depends upon which phase has max^{m}. – ve value.

PROCEDURE:

1. Various connections are made as per the circuit diagram for half wave and full wave converter.
2. Apply 3-Phase, 400V supply voltage by 3- phase variac and set to 160V L-L to 3-phase diode terminal through isolation transformer.
3. When switch SW_2 ON the +ve terminal of the bridge of the diodes B-phase connected to the loads in series and then neutral. In this case, the diode: D4, D5 and D6, does not function and half wave conversion occurs.
4. The voltage waveform returns through were observed across the loads both for R & R-L loads.
5. Repeat same procedure for full wave configuration when SW_1 is made ON. Make sure to keep SW_2 Open

Circuit Diagram of three phase Half/Full wave diode bridge rectifier.



TABULATION

Type of Load	Type of rectification	Input voltage	Load current	Load current	Voltage from CRO	Current from CRO	% error in voltage	% error in current
R-	Half Wave							
Load	Full Wave							
R-L	Half Wave							
Load	Full Wave							

CONCLUSION: