University of Global Village (UGV), Barishal

Dept. of Electrical and Electronic Engineering (EEE)

Lab Manual

Power Electronics Lab

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Course Title:	Power Electronics	Total Class Hour	37
Course Code:	EEE 320	Total Practice Hour	37
Supervised by	Noor Md Shahriar	Total Hour	85

Course Rationale

The Power Electronics Laboratory course aims to bridge theoretical knowledge and practical applications, enabling students to design, simulate, and analyze power electronic circuits and systems. The experiments provide hands-on experience with key devices like SCRs, MOSFETs, IGBTs, and various converters and inverters. By engaging in circuit design, testing, and troubleshooting, students develop a deeper understanding of power electronic components, their characteristics, and their integration into real-world systems. This course equips learners with the essential skills to tackle modern challenges in renewable energy, motor drives, and industrial power systems, aligning with industry requirements and fostering innovation.

Course Objectives

- To **understand** the characteristics and operation of power electronic devices such as SCRs, MOSFETs, and IGBTs.
- To **design, simulate,** and **implement** various power converter and inverter circuits for diverse applications.
- To **analyze** the performance of power electronic circuits under different load conditions (R, RL).
- To **explore** advanced commutation and control techniques for power devices.
- To **develop** problem-solving and troubleshooting skills relevant to modern power electronic systems.

Course Learning Outcome

CLO1	**Understand Power Devices**: Identify and explain the characteristics and operations of SCR, MOSFET, and IGBT.
CLO2	**Analyze Converter Systems**: Design and test half-controlled, fully-controlled, and dual converters for R and RL loads.
CLO3	**Evaluate Voltage and Frequency Control**: Implement and analyze AC voltage controllers, cycloconverters, and commutation circuits.
CLO4	**Develop and Test Inverter Circuits**: Construct series and parallel inverters and evaluate their performance with different load types.
CLO5	**Integrate and Troubleshoot Systems**: Apply learned concepts to design, integrate, and troubleshoot power electronic systems in real-world scenarios.

Course Outline

Sl. No.	Topic & Details	Class Hours	CLO Mapping
1	Introduction to Power Semiconductor Devices: Characteristics and operation of SCR, MOSFET, and IGBT; Understanding gate firing circuits for SCR	3	CLO1
2	Single-phase Half-controlled Converter with R and RL load	3	CLO1, CLO2
3	Single-phase Fully Controlled Bridge Converter with R and RL loads	3	CLO1,

			CLO2
4	Single-phase AC Voltage Controller with R and RL loads	3	CLO2
5	Single-phase Cyclo-converter with R and RL loads	3	CLO2, CLO3
6	Single-phase Dual Converter with R load	3	CLO2, CLO3
7	Three-phase Fully Controlled Bridge Converter with RL load	3	CLO3
8	Forced Commutation Circuits: Class A, Class B, Class C, Class D, and Class E	3	CLO3, CLO4
9	Single-phase Series Inverter with R and RL loads	3	CLO4
10	Single-phase Parallel Inverter with R and RL loads	3	CLO4, CLO5
11	Practical Applications and Troubleshooting: Implementation of circuits and real-world applications	3	CLO5

Course Schedule

Week	Experiment Title	Teaching-Learning Strategy	Assessment Strategy	CLO Mapping
1	**Characteristics of SCR, MOSFET, and IGBT:** Study and analyze the characteristics of power semiconductor devices.	Interactive demonstration and hands-on practice.	Observation, viva, and documentation.	**CLO 1**
2	**Gate Firing Circuits for SCRs:** Design and test different types of gate firing circuits for SCRs.	Circuit design explanation and supervised implementation.	Circuit performance evaluation and viva.	**CLO 1, CLO 3**
3	**Single-Phase Half-Controlled Converter with R & RL Load:** Implement and analyze the converter's behavior for resistive and inductive loads.	Simulation and lab-based implementation.	Lab report and viva.	**CLO 2**
4	**Single-Phase Fully Controlled Bridge Converter:** Study the bridge converter operation with R & RL loads.	Problem-solving and experiment setup walkthrough.	Observation and report analysis.	**CLO 2**
5	**Single-Phase AC Voltage Controller with R & RL Loads:** Understand the operation and characteristics of an AC voltage controller.	Step-by-step experimental setup and supervision.	Circuit testing and functional understanding.	**CLO 2, CLO 3**
6	**Single-Phase Cycloconverter with R & RL Loads:** Analyze frequency conversion using cycloconverters.	Guided hands-on setup and troubleshooting assistance.	Performance assessment and report.	**CLO 3**
7	**Single-Phase Dual Converter with R Load:** Study the operation and control of dual converters.	Instructor-led explanation and experiment execution.	Result analysis and viva.	**CLO 2, CLO 4**
8	**Single-Phase Diode Bridge Rectifier with R Load and Capacitance Filter:** Implement and study the effect of filters on rectifier output.	Discussion of concepts followed by practical demonstration.	Efficiency calculation and written evaluation.	**CLO 2, CLO 5**
9	**Three-Phase Fully Controlled Bridge Converter:** Operate and analyze three-	Team-based problem-solving and execution.	Observation, teamwork	**CLO 2**

	phase bridge converters with RL loads.		evaluation, and report.	
10	**Forced Commutation Circuits:** Study and implement Class A to E commutation circuits.	Instructor-guided circuit setup and testing.	Commutation analysis and report.	**CLO 3, CLO 4**
11	**Single-Phase Series Inverter with R & RL Loads:** Design and evaluate a series inverter for different loads.	Explanation of inverter concepts with practical application.	Lab observations and viva voce.	**CLO 4**
12	**Single-Phase Parallel Inverter with R & RL Loads:** Implement and study the parallel inverter's performance for different loads.	Comparative analysis of inverters during experimentation.	Written report and viva questions.	**CLO 4**
13	**Experiment Design and Application Discussion:** Review and apply knowledge to an integrated system.	Brainstorming and design sessions.	Group participation and presentation.	**CLO 5**
14	**Capstone Project Initiation:** Start working on a comprehensive project integrating various concepts.	Project supervision and periodic review sessions.	Progress presentation and instructor feedback.	**CLO 5**
15	**Capstone Project Development:** Develop and refine the project with instructor guidance.	Troubleshooting and optimization sessions.	Peer review and instructor observations.	**CLO 5**
16	**Capstone Project Completion:** Finalize and test the project for complete functionality.	Final testing and debugging support.	Final project evaluation and report submission.	**CLO 5**
17	**Capstone Project Presentation and Evaluation:** Present the completed project with a demonstration.	Showcase and Q&A session with instructors and peers.	Final presentation scoring and comprehensive viva.	**CLO 1–5**

Assessment Pattern

- **Continuous Assessment**

Bloom's Category	Marks
Imitation	12
Manipulation	8
Precision	6
Articulation	2
Naturalization	2

- **Semester End Examination: (SEE):**

<table>
<tr><th>Bloom's Category
Marks (out of 30)</th><th>Tests (20)</th><th>Quiz (10)</th><th>External Participation in Curricular/Co-Curricular Activities (20)</th></tr>
<tr><td>Imitation</td><td>06</td><td>06</td><td rowspan="5">Bloom's Affective Domain: (Attitude or will)
• Attendance: 10
• Viva-Voca: 5
• Report Submission: 5</td></tr>
<tr><td>Manipulation</td><td>04</td><td>04</td></tr>
<tr><td>Precision</td><td>06</td><td></td></tr>
<tr><td>Articulation</td><td>02</td><td></td></tr>
<tr><td>Naturalization</td><td>02</td><td></td></tr>
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References

1. Rashid, M. H. "Power Electronics: Circuits, Devices, and Applications" (4th Edition). Pearson Education.
2. Mohan, N., Undeland, T. M., & Robbins, W. P. "Power Electronics: Converters, Applications, and Design" (3rd Edition). Wiley.
3. Singh, M. D., & Khanchandani, K. B. "Power Electronics" (2nd Edition). Tata McGraw-Hill Education.
4. Lander, C. W. "Power Electronics" (3rd Edition). McGraw-Hill.
5. Erickson, R. W., & Maksimovic, D. "Fundamentals of Power Electronics" (2nd Edition). Springer.
6. IEEE Xplore Digital Library: Articles and technical papers on Power Electronics applications and devices.
7. Manufacturer Datasheets for Power Devices (SCR, MOSFET, IGBT, etc.).
8. Lab manuals and application notes from companies like Texas Instruments, STMicroelectronics, and Infineon Technologies.

Experiment no: 01

Experiment Title: STUDY OF CHARACTERISTICS OF SCR, MOSFET AND IGBT

AIM: To plot the V-I characteristics of SCR, MOSFET and IGBT.

APPARATUS:

S.NO.	COMPONENTS	RANGE
1	SCR, MOSFET & IGBT characteristic kit module	
2	CRO with probes	20MHz
3	Multi Meter	
4	Ammeter	(0-1A, MC)
5	RPS , Dual Channel	0-30 V

THEORY:

SCR:

The full form of SCR is "Silicon Controlled Rectifier". It is a three terminal semi conducting device. The three terminals are anode (A), cathode (K) and gate (G). SCR is used as static switches in relay control, motor control, phase control, heater control, battery chargers, inverter, and regulated power supplies. SCR characteristic is drawn between anode to cathode voltage (V_{AK}) vs. anode current (I_A) for different values of gate current (I_G).

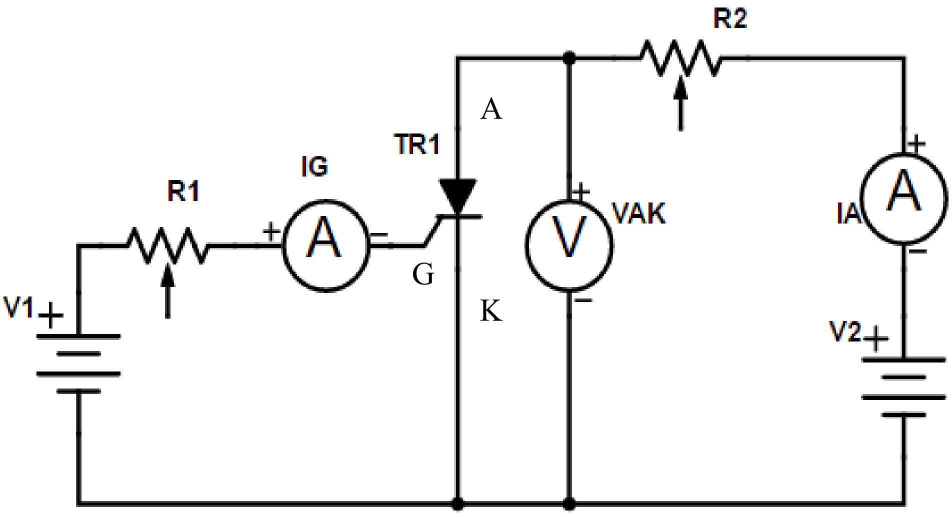
MOSFET:

MOSFET is a three terminal semi conducting device. Its conductivity can be controlled by gate signal. The three terminals are gate (G), source (S) and drain (D). It can be operated as an amplifier or as a switch. Static output characteristic curve is drawn between drain current (I_D) and drain to source voltage (V_{DS}) for the given value of gate to source voltage (V_{GS}). Transfer characteristic is drawn between drain current (I_D) vs. gate to source voltage (V_{GS}).

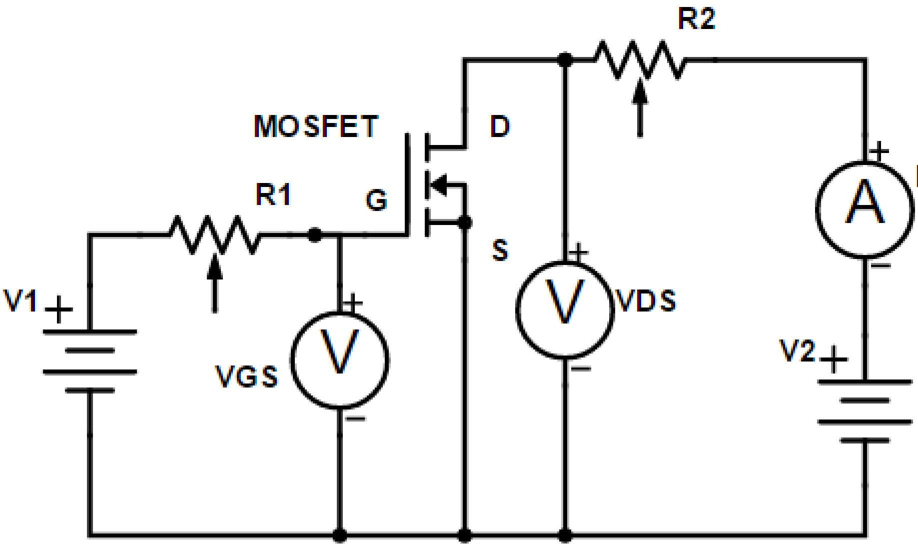
IGBT:

IGBT is a three terminal semi-conductor device. The device is turned ON by applying positive voltage greater than threshold between gate and emitter. The three terminals are base (B) or gate (G), collector (C) & emitter (E). It can be operated as an amplifier or as a switch. Static output characteristic curve is drawn between collector current (I_C) and collector to emitter voltage (V_{CE}) for a given value of base/gate to emitter voltage (V_{GE}).

CONNECTION DIAGRAM



(a)



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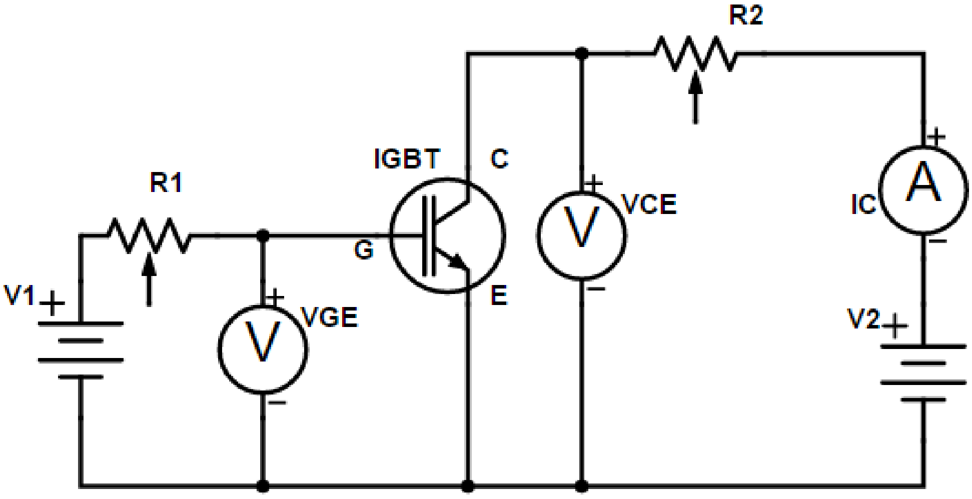


(c)

Fig.1.1. Connection diagram to plot V-I characteristics of (a) SCR, (b) MOSFET and (c) IGBT

PROCEDURE:

For plotting SCR characteristic curves:

1. Connections are made as per the circuit diagram given in Fig. 1.1 (a).
2. Set R_1 and R_2 to mid positions and V_1 and V_2 to minimum.
3. Set a finite gate current (I_{G1}) by varying R_1 and V_1.
4. Slowly vary V_2 (or R_2) and note down V_{AK} and I_A.
5. Repeat the steps 3 and 4 for second gate current (I_{G2})
6. Reverse the anode voltage polarity to find the reverse characteristics.

For finding holding current of SCR:

1. Ensure SCR is at ON state
2. Remove the gate voltage and start reducing V_{AK} ; simultaneously verify the state of SCR. If SCR is turned off, note the current (I_A) just before it comes to zero.

For finding latching current of SCR:

1. Ensure that the SCR is in the state of conduction.
2. Start reducing anode voltage (V_{AK}) slowly; simultaneously check the state of SCR by switching off gate supply. If SCR switches off just by removing gate terminal, and switches on by connecting gate supply, then the corresponding anode current (I_A) is the latching current for the SCR.

For plotting MOSFET static (Drain) characteristic curves:

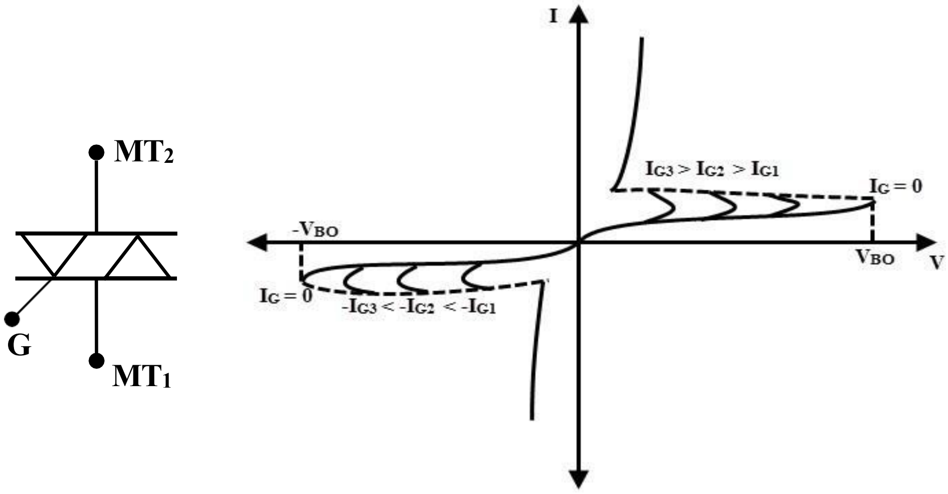
1. Connect the circuit as given in Fig. 1.1 (b).
2. Set a finite gate source voltage (V_{GS1}) by varying R_1 and V_1.
3. By varying V_2 (or R_2), note down V_{DS} and I_D.
4. Repeat the steps 3 and 4 for second gate source voltage (V_{GS2})

For plotting IGBT static (Collector) characteristic curves:

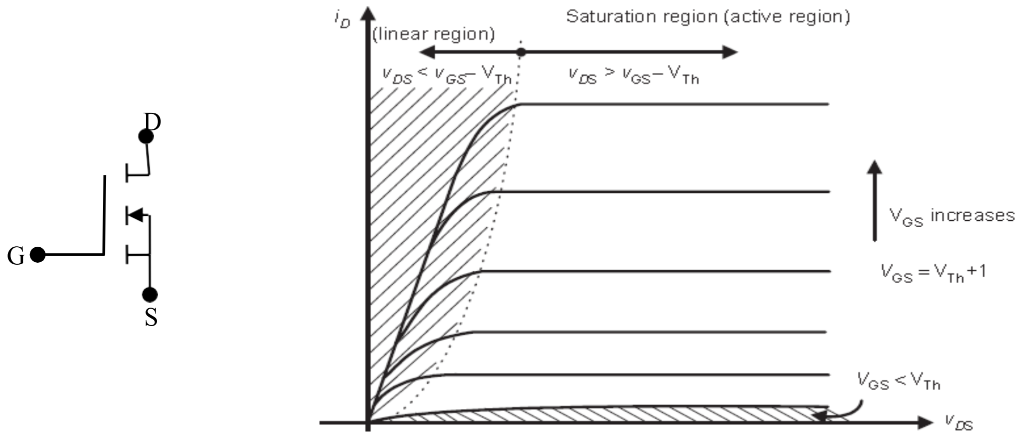
1. Connect the circuit as given in Fig. 1.1 (c).
2. Set a finite gate source voltage (V_{GE1}) by varying R_1 and V_1.
3. By varying V_2 (or R_2), note down V_{CE} and I_C.
4. Repeat the steps 3 and 4 for second gate source voltage (V_{GE2})

MODEL GRAPHS

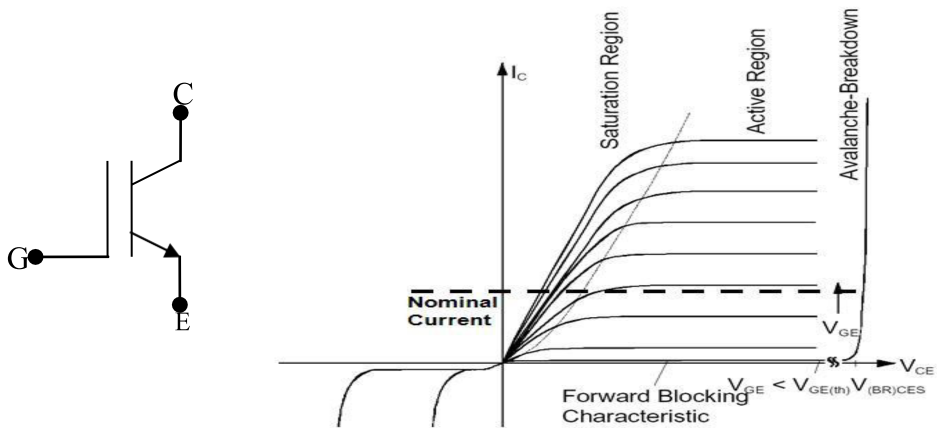
V-I Characteristics of SCR



(a)



(b)



(c)

Fig.1.2. V-I characteristics of (a) SCR (b) MOSFET (c) IGBT

TABULAR FORM:

Observations of SCR

I_{G1}		I_{G1}	
V_{AK}	I_A	V_{AK}	I_A

Observations of MOSFET

V_{GS1}		V_{GS2}	
V_{DS}	I_D	V_{DS}	I_D

Observations of IGBT

V_{GE1}		V_{GE2}	
V_{CE}	I_C	V_{CE}	I_C

RESULTS:

Viva questions:

1. What is semi controlled device?
2. What is fully controlled device?
3. What is uncontrolled device?
4. What are the devices used for high frequency applications?
5. What are the different methods of turning on an SCR?
6. Why is dv/dt technique not used in SCR?
7. What are applications of SCR, MOSFET and IGBT?
8. Which parameter defines the transfer characteristics in MOSFET and IGBT?
9. Write the procedure to plot the transfer characteristics of MOSFET and IGBT using the experimental setup?
10. What are the merits and demerits of SCR, MOSFET and IGBT?
11. What is rating of SCR, MOSFET and IGBT?

Experiment no: 02

Experiment Title: Study Of Gate Firing Circuits

AIM: To observe the output voltage waveforms of half controlled rectifier using resistance (R), resistance-capacitance (RC) and UJT gate firing Circuits of SCR.

APPARATUS:

S.NO.	COMPONENTS	RANGE
1	R, RC & UJT firing circuit module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	MultiMeter	
5	Ammeter	(0-1A, MC)
6	RPS , Dual Channel	0-30 V
7	Transformer	230/0-30V

THEORY:

In power electronic applications SCR is used as switching device to control power flow from source to load. SCR is a semi controlled device and has three modes of operation forward blocking, forward conduction and reverse blocking mode. In order to bring SCR to ON state, a minimum gate current (latching current) is required. This experiment shows simple method of obtaining gate current for triggering the SCR using R, RC and UJT to control SCR.

R-Triggering:

It includes few fixed resistor, variable resistor, diode, SCR (Silicon Controlled Rectifier), Load resistor. The circuit diagram of R-triggering is given in Fig. 2.1 (a). This figure shows a very simple variable resistance half-wave circuit. It provides phase retard from essential zero (SCR full "on") to 90 electrical degrees of the anode voltage wave (SCR half "on"). Diode D1 blocks reverse gate voltage on the negative half-cycle of anode supply voltage.

RC-Triggering:

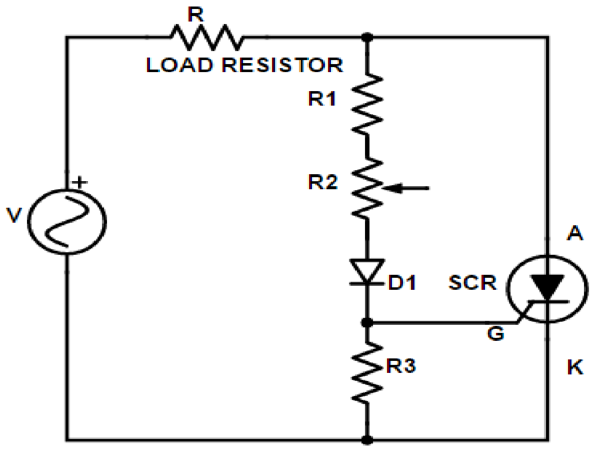
It includes variable resistor, two diodes, SCR (Silicon Controlled Rectifier), Capacitor, Load resistor. The circuit diagram is shown in Fig. 2.1 (b). On the positive half-cycle of SCR anode voltage the capacitor charges to the trigger point of the SCR in a time determined by the RC time constant and the rising anode voltage. The top plate of the capacitor charges to the peak of the negative voltage cycle through diode D2 on the negative half-cycle, resetting it for the next charging cycle.

UJT Triggering

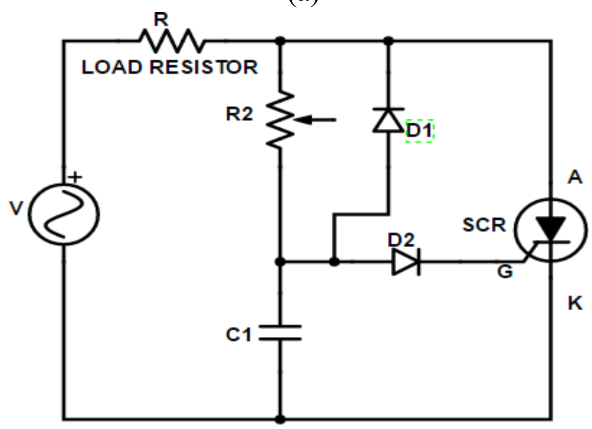
A unijunction transistor (UJT) is an electronic semiconductor device that has only one junction. The **UJT** has three terminals: an emitter (E) and two bases (B1 and B2). The base is formed by lightly doped n-type bar of silicon. The emitter is of p-type and it is heavily doped. Initially the capacitor charges through R whose voltage is applied to the emitter of UJT. When the capacitor voltage reaches peak point voltage of UJT. The UJT will switch to on condition. Now the capacitor discharges through the output resistance. Thus the pulse is generated in the circuit.

RC firing circuit and UJT firing circuit controls firing angle of SCR from 0-180 deg.

CIRCUIT DIAGRAM:



(a)



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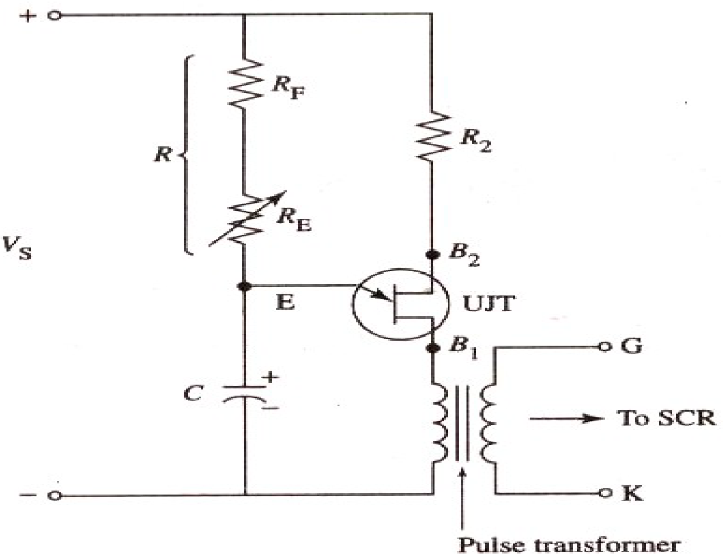


(c)

Fig. 2.1 Connection diagram of (a) R (b) RC and (c) UJT-firing circuit

PROCEDURE:

R-Triggering

1. All connections are to be made as per the circuit diagram given in Fig. 2.1. (a).
2. Keep all resistances in max position.
3. Connect the Oscilloscope across the load.
4. Turn on power supply.
5. Vary the firing angle and observe the output voltage and gating pulse waveforms on the CRO.
6. Draw the corresponding waveforms.

RC-Triggering

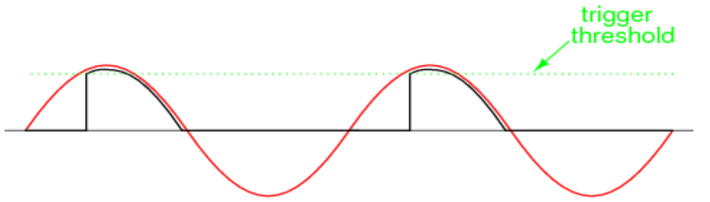
1. All connections are to be made as per the circuit diagram given in Fig. 2.1. (b).
2. Keep all resistances in max position.
3. Connect the Oscilloscope across the load.
4. Turn on power supply to the module.
5. Vary the firing angle (0^0 - 180^0) and observe the waveforms on the CRO
6. Draw the corresponding waveforms.

UJT-Triggering

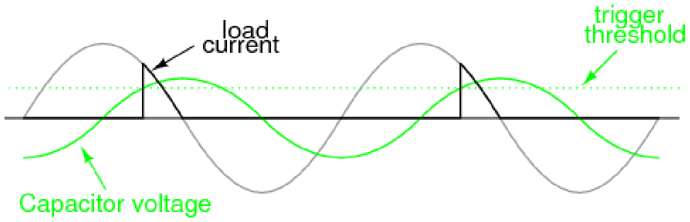
1. All connections are to be made as per the circuit diagram given in Fig. 2.1. (c).
2. Keep all resistances in max position.
3. Connect the Oscilloscope across the load.
4. Turn on power supply to the module.
5. Vary the firing angle (0^0 - 180^0) and observe the waveforms on the CRO
6. Draw the corresponding waveforms.

MODEL GRAPHS:

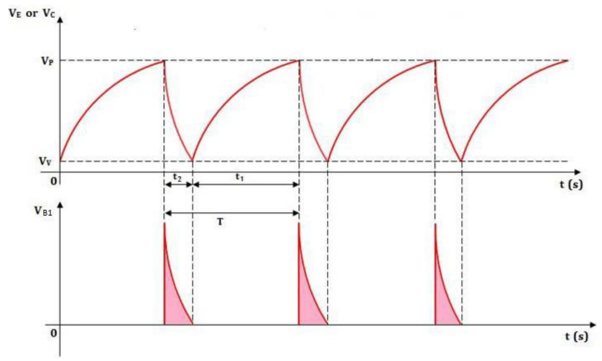
R-Triggering



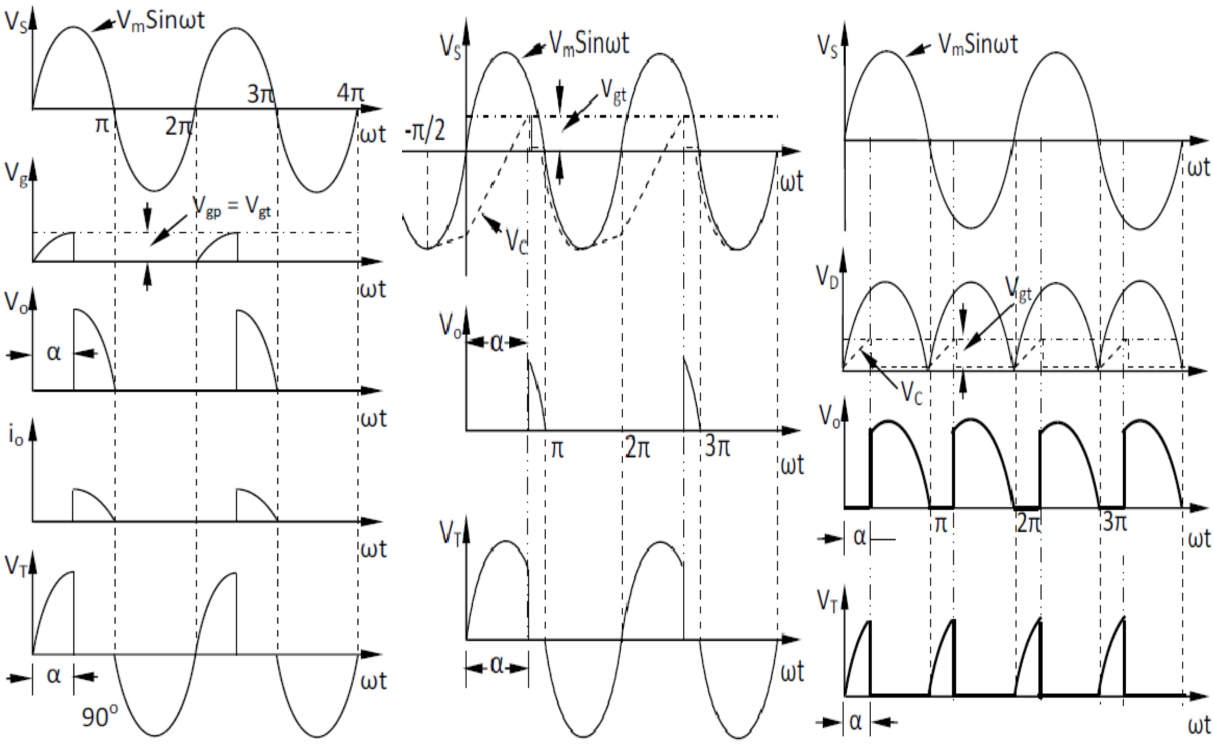
RC Triggering



UJT Triggering



Output voltage waveform:



(a) (b) (c)

Fig. 2.2.Output voltage waveforms of (a) R (α=90) (b) RC (α>90) and (c) UJT (α>90) triggering.

TABULAR FORM:

R-Firing Circuit:

S. No.	α , Firing Angle	Theoretical V	Practical V	I_L in A

RC-Firing Circuit:

S. No.	α , Firing Angle	Theoretical V	Practical V	I_L in A

UJT-Firing Circuit Load:

S. No.	α, Firing Angle	Theoretical V	Practical V	I_L in A

RESULT:

Viva questions:

1. Differentiate R, RC and UJT firing schemes?
2. State relative advantages& disadvantages of R, RC& UJT firing schemes?
3. Explain the operation of R, RC and UJT firing schemes?
4. Draw few other firing circuits for SCR triggering?
5. Collect hardware components list for implementing R, RC& UJT firing circuits?

Experiment no: 03

Experiment Title: Single Phase Half Controlled Converter With R & Rl Loads

AIM: To plot and observe the output waveform of single phase half controlled bridge rectifier with R and RL Loads.

APPARATUS:

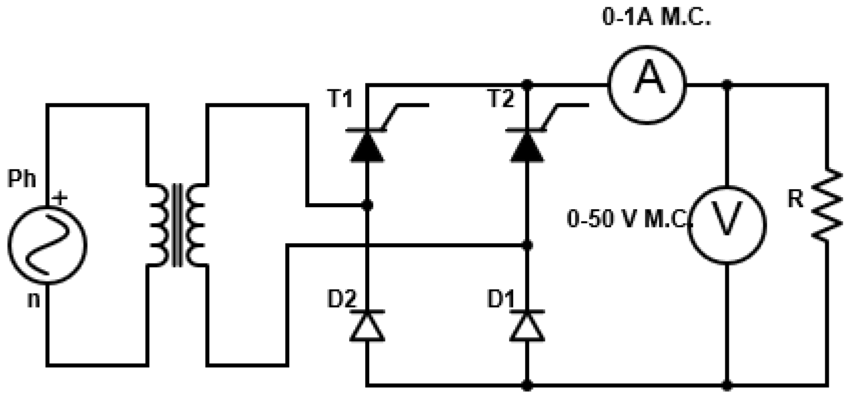
S.NO.	COMPONENTS	RANGE
1	Half Controlled Converter Module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	Inductive load	100mH
5	RPS , Dual Channel	0-30 V
6	Transformer	230/0-30V

THEORY:

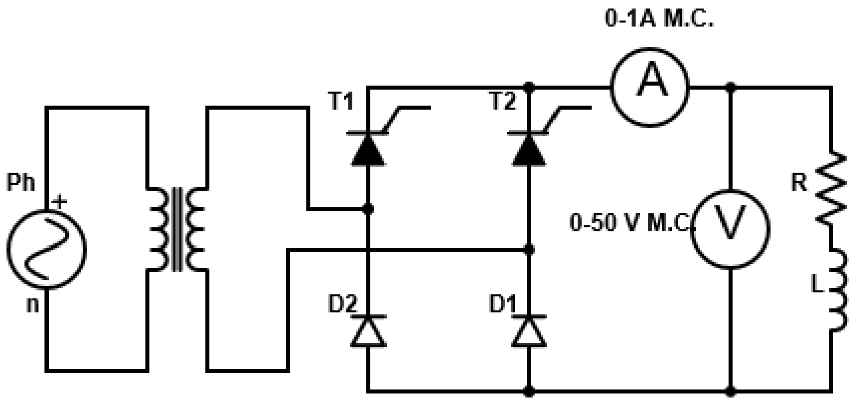
Rectification is a process of converting an alternating current or voltage into a direct current or voltage. Rectifier circuits are classified into three classes:
1. Uncontrolled
2. Fully Controlled
3. Half Controlled.

A half/semi controlled converter is given in Fig.3.1. It has two thyristors and two diodes. Thyristors need to be triggered by firing circuits; diodes conduct depends on the polarity of the input supply. Due to presence of diodes, freewheeling operation takes place without allowing the bridge output voltage to become negative. In a semi-controlled rectifier, control is affected only for positive output voltage, and no control is possible when its output voltage tends to become negative. When source, V_{in} is positive, SCR T_1 can be triggered at a firing angle called α and then current flows out of the source through SCR T_1 first, then through the load and returns via diode D_1. SCR T_1 and diode D_1 conduct during $\alpha<\omega t<\pi$. When $\pi<\omega t< 2\pi$, V_{in} is negative and SCR T_2 is normally triggered at $\omega t = \pi + \alpha$. During $\pi<\omega t< (\pi + \alpha)$, diode D_2 tends to get forward-biased and it starts conducting along with SCR T_1 and hence the bridge output voltage is clamped at zero. During $(\pi + \alpha)<\omega t< 2\pi$, the devices in conduction are SCR T_2 and diode D_2. SCR T_2 and diode D_1 would conduct during $0 <\omega t<\alpha$.

CIRCUIT DIAGRAM:



(a)



(b)

Fig. 3.1 Single phase half controlled rectifier with (a) R-load and (b) RL load

PROCEDURE:

With R-load:

1. Connect the circuit with R-load as shown in the circuit diagram.
2. Switch on the main supply.
3. Vary the firing angle, observe the load voltage waveform on CRO and note down the firing angle and sketch the output voltage.

With RL-load:

1. Connect the circuit with R-L load as per the circuit diagram.
2. Switch on the main supply.
3. Vary the firing angle, observe the load voltage waveform on CRO and note down the firing angle and sketch the output voltage.

TABULAR FORM:

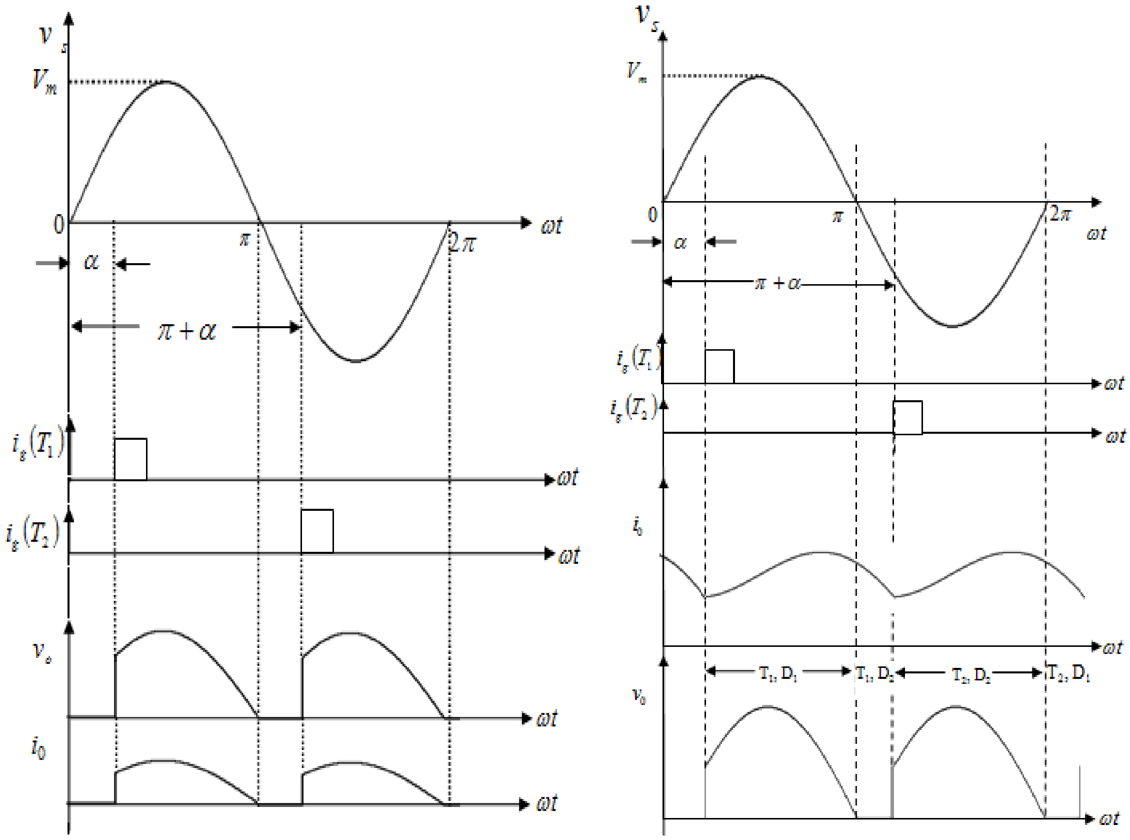
R-Load:

S. No.	α, Firing Angle	Theoretical V	Practical V	I_L in A

RL-Load:

S. No.	α, Firing Angle	Theoretical V	Practical V	I_L in A

MODEL GRAPH:



(a) (b)

Fig. 3.2 Waveforms of semiconverter with (a) R-load and (b) RL load.

RESULT:

Viva questions:

1. Differentiate RMS and DC value of output voltage?
2. What is rectifier?
3. What is semi controlled rectifier?
4. Draw the waveforms of semiconverter with RL-load operated under discontinuous mode.
5. What is the function of zero crossing detector (ZCD) circuit?
6. Realize ZCD circuit using OP-AMP?

Experiment no: 04

Experiment Title: Single Phase Fully Controlled Bridge Rectifier With R & Rl Loads

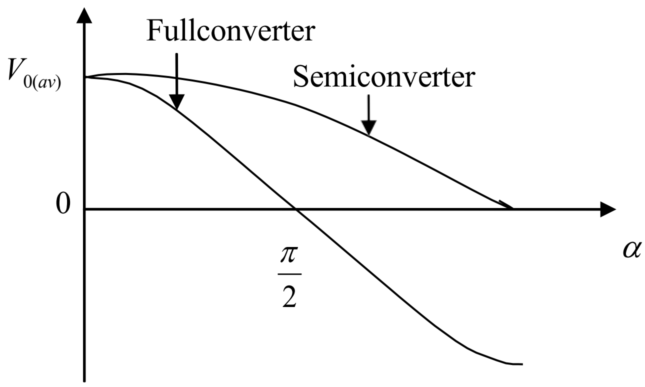
AIM: To obtain controlled output waveforms of a single phase fully controlled bridge rectifier with R and RL Loads.

APPARATUS:

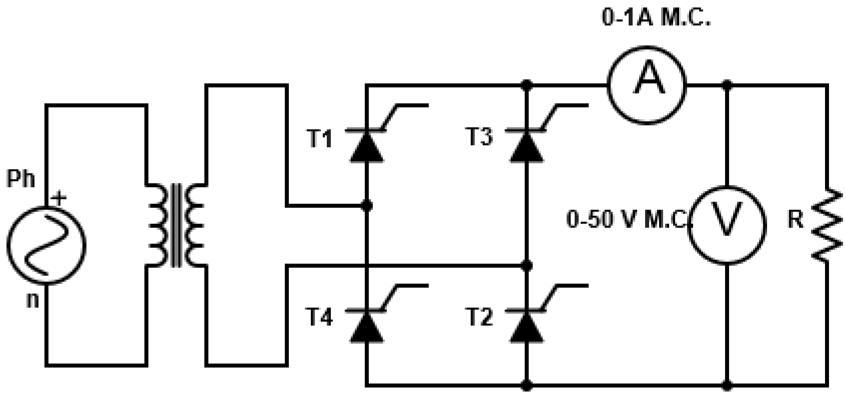
S.NO.	COMPONENTS	RANGE
1	Single Phase Fully Controlled Bridge Rectifier module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	Inductive load	100mH
5	Multi Meter	
6	Ammeter	(0-1A, MC)
7	RPS , Dual Channel	0-30 V
8	Transformer	230/0-30V

THEORY:

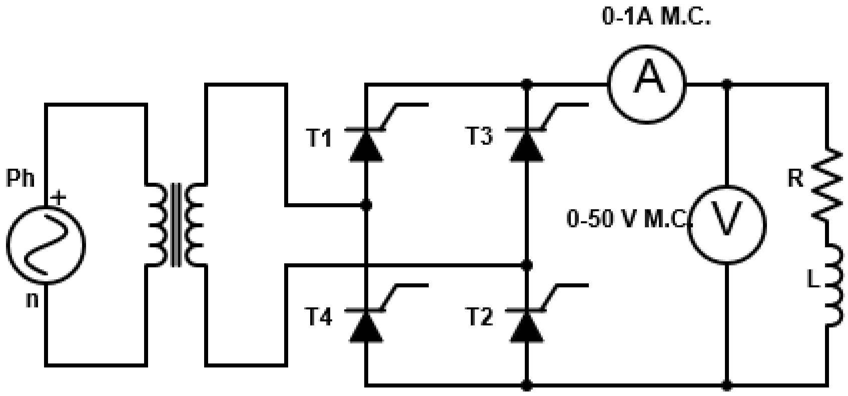
The full controlled rectifier has four thyristors; two thyristors, one from top and the other from bottom will conduct at any point of time. During positive half cycles of input voltage, thyristors T_1 and T_3 are triggered at $\omega t=\alpha$; similarly, T_2 and T_4 are triggered at $\omega t = \pi + \alpha$. Unlike semiconverters, the output voltage contain negative portion too; thus average output voltage can be either positive or negative which depends on firing angle show in below figure. Hence, full converter can be employed for motoring as well as for regenerative braking applications.



CIRCUIT CONNECTIONS:



(a)



(b)

Fig. 4.1. Power circuit of full converter with (a) R load and (b) R-L load.

PROCEDURE:

WITH R-LOAD:

1. Connect the circuit with R-load as shown in the circuit diagram.
2. Connect the firing circuit to the semiconductor devices appropriately.
2. Check the pulses from the firing circuit and switch on the power supply.
3. Vary the firing angle; observe the output and SCR waveforms on CRO and plot observed waveforms on graph.
4. Tabulate output voltage and output current and compare theoretical and practical values.

WITH RL-LOAD:

1. Connect the circuit with R-L load as per the circuit diagram.
2. Repeat the steps 1 to 4 for R-L load.

TABULAR FORM:

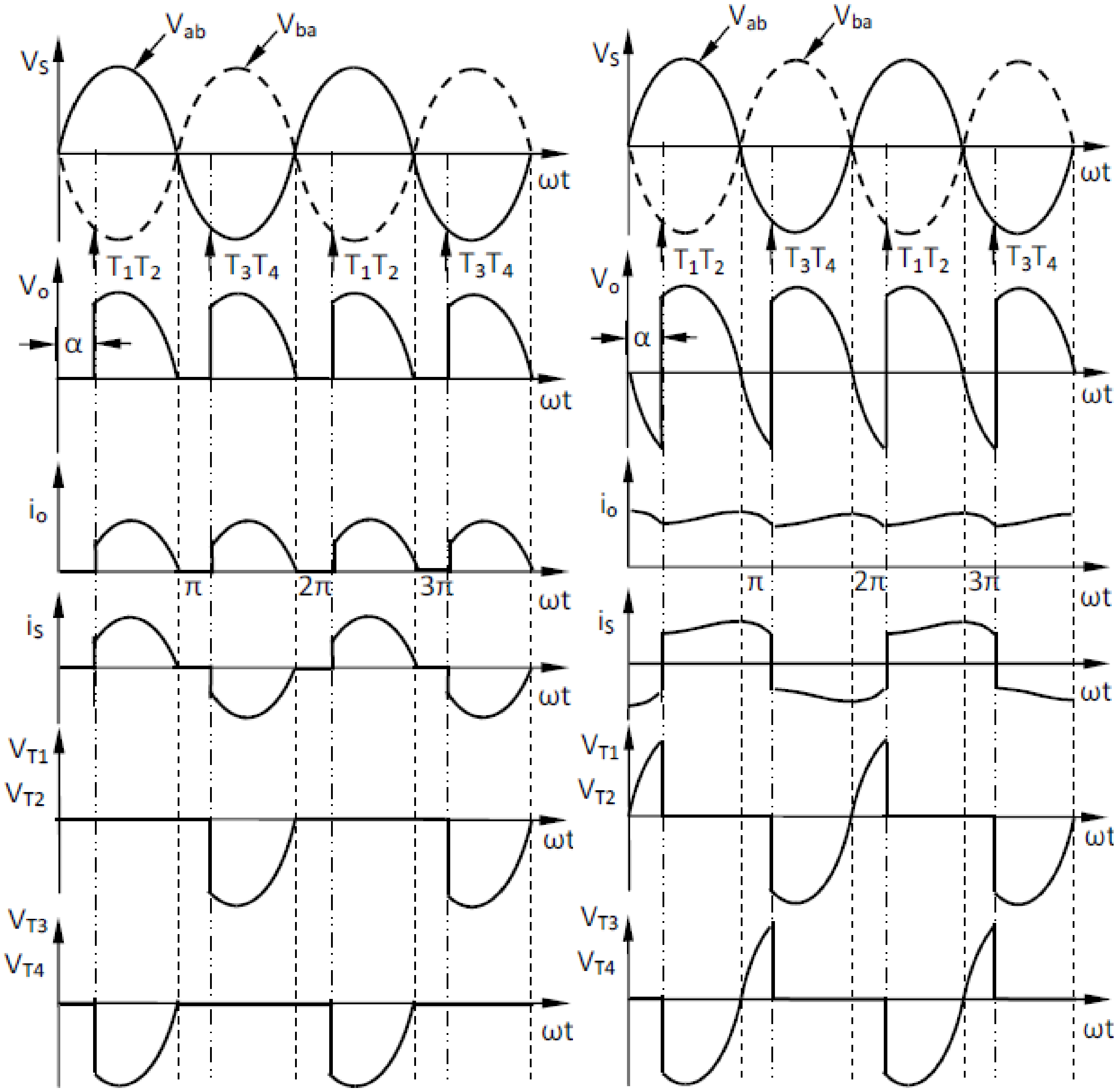
R-Load:

S. No.	α, Firing Angle	Theoretical V	Practical V	I_L in A

RL-Load:

S. No.	α, Firing Angle	Theoretical V	Practical V	I_L in A

MODEL GRAPH:



(a) (b)

Fig. 4.2 Output and SCR voltage wave forms of full bridge converter for (a) R and (b) RL loads.

RESULTS:

Viva questions:

1. Explain the operation of full bridge converter operation in discontinuous and continuous mode?
2. Compare half controlled converter and full controlled rectifier?
3. Derive the relations for load current (assuming R-L load) and output voltage equations for (a) half controlled and (b) full controlled rectifiers.
4. Collect the components list to fabricate half and full controlled rectifiers.

Experiment no: 05

Experiment Title: Single Phase Ac Voltage Controllers With R & R-L Loads

AIM: To plot and observe various voltage & current wave forms AC Voltage Controller with R & R-L loads.

APPARATUS:

S.NO.	COMPONENTS	RANGE
1	AC voltage controller module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	Inductive load	100mH
5	Multi Meter	
6	Ammeter	(0-1A, MC)
7	RPS , Dual Channel	0-30 V
8	Transformer	230/0-30V

THEORY:

AC voltage controllers are thyristor-based devices, which convert fixed alternating voltage directly to variable alternating voltage without change in the frequency. In AC voltage controllers, two SCR's are connected in anti parallel. Applications of AC voltage controllers are domestic and industrial heating, transformer tap changing, lightening controls, speed control of single phase and three phase AC drives.

R-load

AC voltage controller or phase angle controller for R load is given in Fig. 5.1 (a). During positive half cycle, T_1 is triggered at α, making v_o same as v_s. At $\omega t=\pi$, both v_o and i_o go to zero and T_1 is turned OFF. Similarly, T_2 is fired at $\pi+\alpha$ and is naturally commutated at 2π. The output r.m.s. voltage which is a function of input voltage and firing angle can be derived from the output voltage wave shape and is given below:

$$V_{0rms} = \frac{V_m}{\sqrt{2\pi}}\left[\pi-\alpha+\frac{\sin 2\alpha}{2}\right]^{\frac{1}{2}}$$

R-L load

If the load is in inductive in nature, the load current has both transient and steady state components.

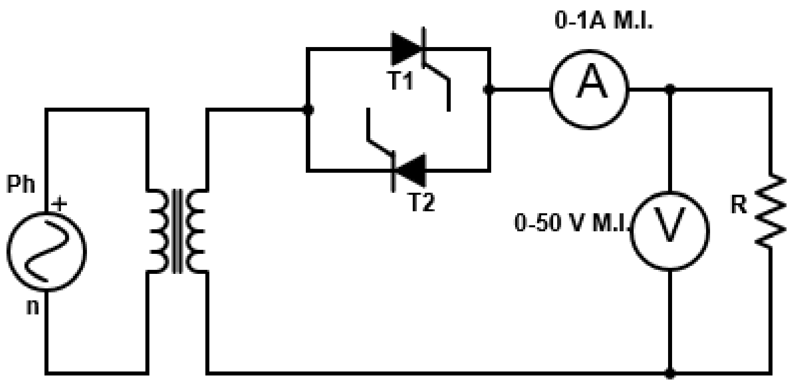
$$i = -\frac{V_m}{2}\sin(\alpha-\phi)e^{-\frac{R}{L}\left(t-\frac{\alpha}{\omega}\right)}+\frac{V_m}{2}\sin(\alpha-\phi)$$

Where,

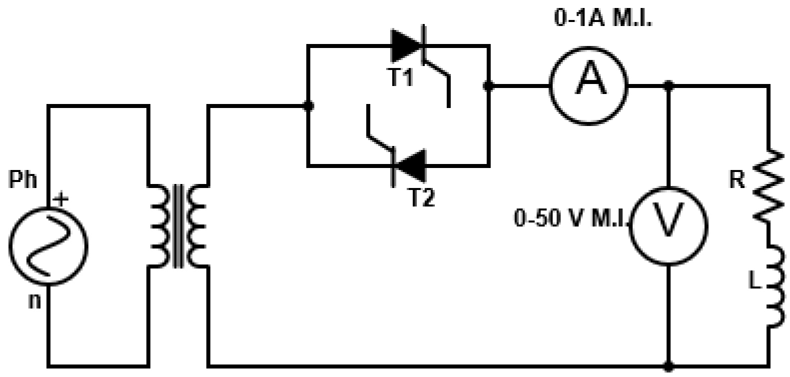
ϕ is the load power factor angle and is given by $\tan^{-1}\left(\frac{\omega L}{R}\right)$

β is the angle at which $i_0(t)$ falls to zero.

CIRCUIT DIAGRAM:



(a)



(b)

Fig. 5.1 Circuit diagram of AC voltage controller with (a) R and (b) R-L load.

PROCEDURE:

With R load:

1. All connections are to be made as per the circuit diagram given in Fig. 5.1 (a)
2. Keep all resistances in max position.
3. Connect the oscilloscope across the load.
4. Turn on power supply to the module.
5. Vary the firing angle and observe the output and SCR waveforms on the CRO
6. Draw the corresponding waveforms for different values of firing angle.
7. Measure the load current and voltage and compare with the theoretical values.

With R-L load:

1. Repeat above procedure for R-L load.

TABULAR FORM:

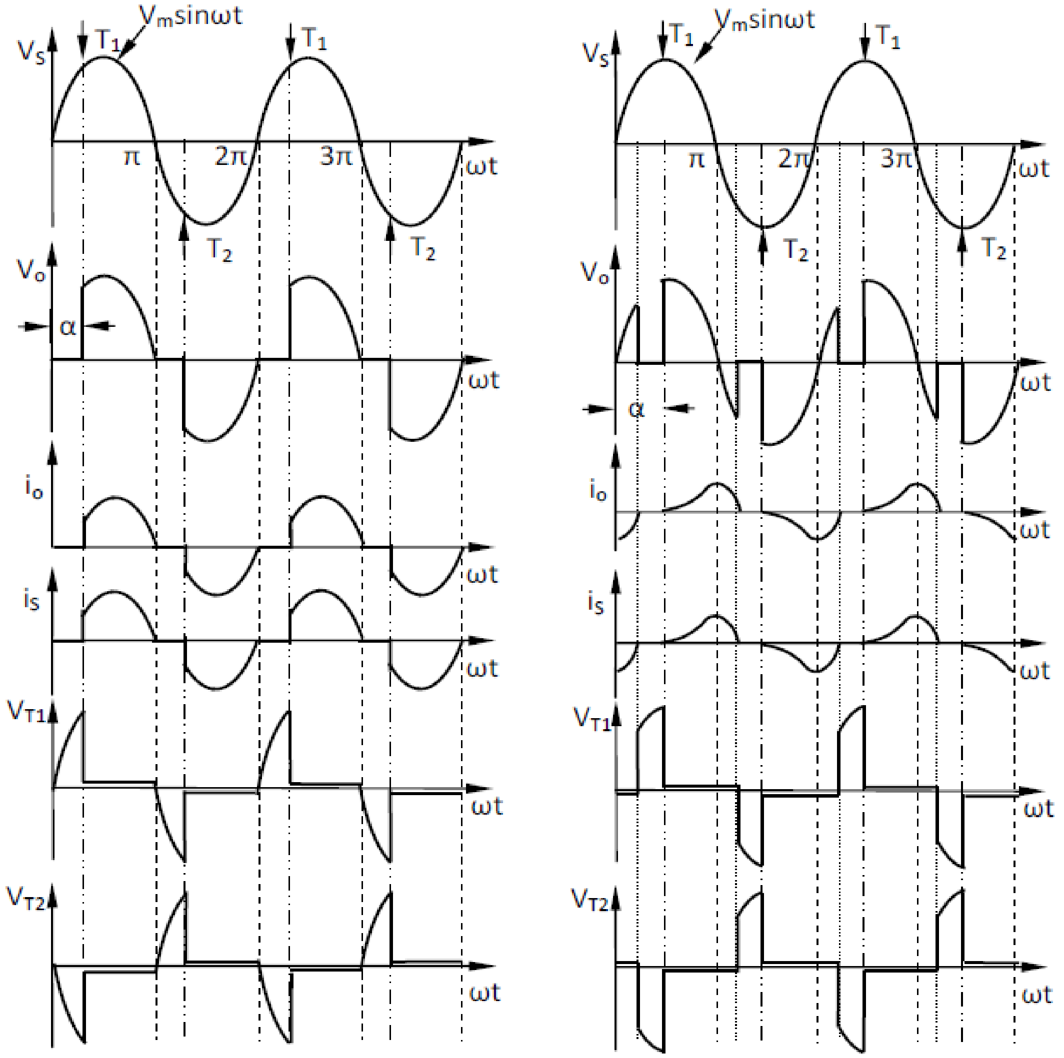
R-Load:

S. No.	α, Firing Angle	Theoretical V	Practical V	I_L in A

RL-Load:

S. No.	α, Firing Angle	Theoretical V	Practical V	I_L in A

MODEL GRAPH:



(a) (b)

Fig. 5.2 Output and SCR voltage wave forms of ac-ac converter for (a) R and (b) RL loads

RESULTS:

Viva questions:

1. Explain the procedure to evaluate extinction angle, β for the given R-L load for ac-ac converter?
2. List out various applications of AC voltage controllers?

Experiment no: 06

Experiment Title: Cyclo-Converter

AIM: To obtain the output waveforms of a single-phase cyclo-converter.

APPARATUS:

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S.NO.	COMPONENTS	RANGE
1	Single phase Cycloconverter module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	Inductive load	100mH
5	Multi Meter	
6	Ammeter	(0-1A, MC)
7	Transformer	230/0-30V

THEORY:

A device that converts input power at one frequency to the output power at another frequency with one stage is known as cyclo-converter; basically there are two types:

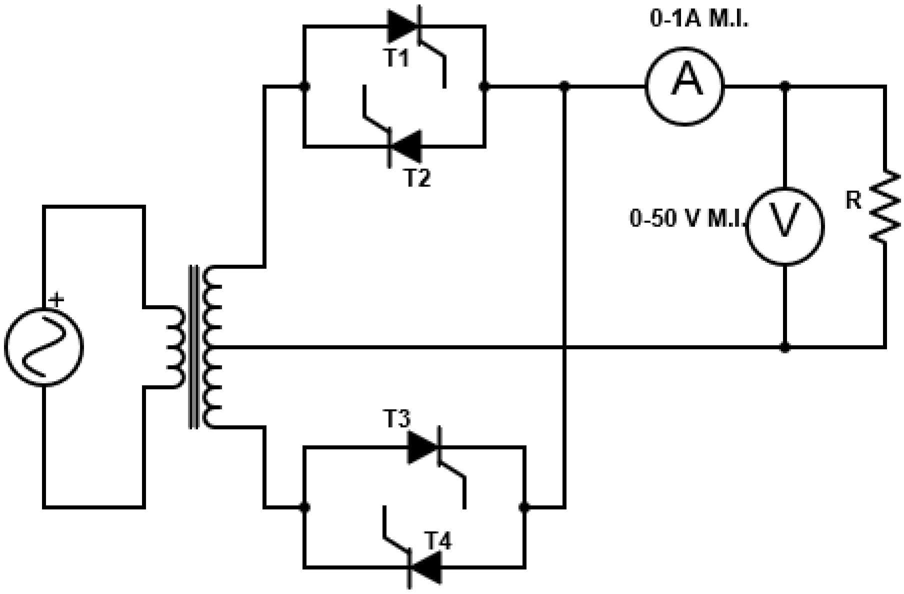
1. Step- down
2. Step up cyclo-converter

In step down cyclo-converter, the output frequency f_0 is lower than the supply frequency f_s. i.e. $f_o<f_s$. In step up $f_o>f_s$. A cyclo-converter is controlled through the timing of its firing pulse so that it produces an alternating output voltage at lowest frequency. The majority of cyclo-converters are naturally commutated and the maximum output frequency is limited to a value that is only a fraction of the source frequency ($f_s/2$).

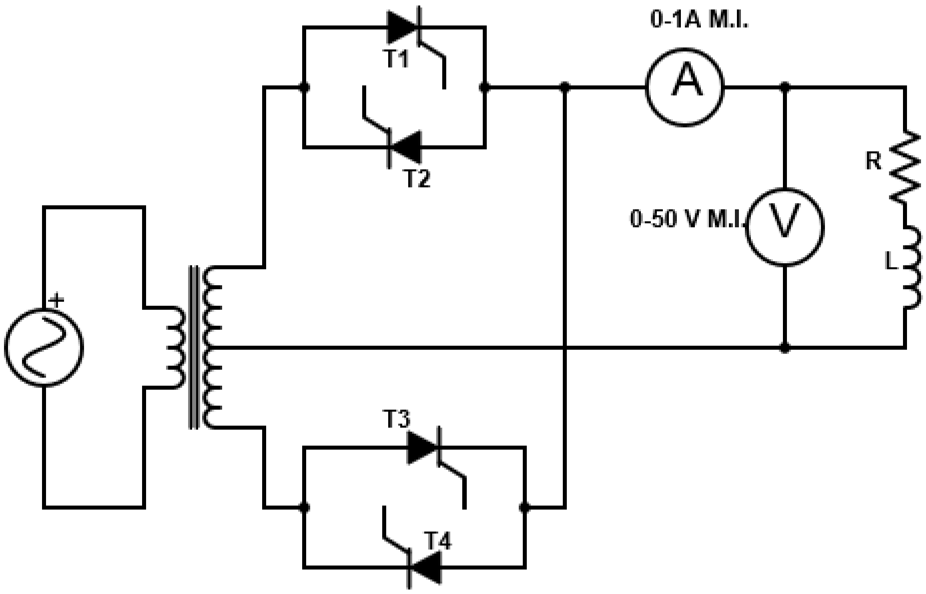
The applications of cyclo-converters are given below:

1. Speed control of high-power ac drives
2. Induction heating
3. Static VAR. generation
4. For converting variable speed alternator voltage convert into constant frequency output voltage for use as power supply in aircraft or shipboards.

CIRCUIT DIAGRAM:



(a)



(b)

Fig. 6.1 Cycloconverter circuit with (a) R laod and (b) R-L load.

PROCEDURE:

1. All connections are made as per the circuit diagram given in Fig. 6.1.
2. Check all firing circuit triggering outputs and its relative phase sequence.
3. Switch on the power supply to the kit and release firing pulses to the corresponding SCR switches.
4. If the output is zero after all proper connections, switch OFF the MCB, switch OFF the AC supply to the isolation transformer and just inter change the AC input connections in the power circuit. This is to make the firing circuit and power circuit to synchronize.
5. Change the frequency division only when the trigger output pulse switch at off position
6. Observe and plot output voltages across load at different frequencies.
7. Repeat for R-L load

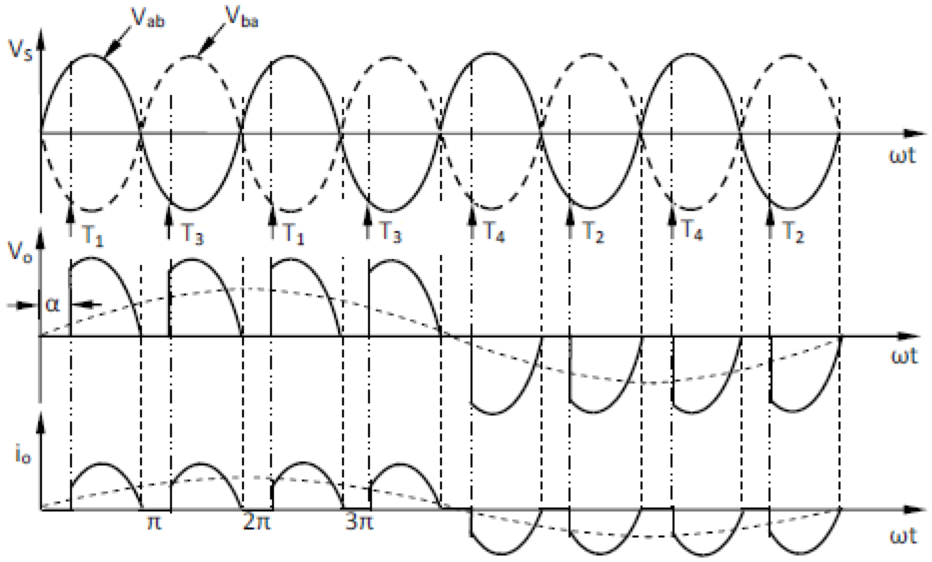
TABULAR FORM:
R load

S.No.	$f_s/2$			$f_s/3$			$f_s/4$		
	Firing angle, α	Output voltage, V_o	Output current, I_o	Firing angle, α	Output voltage, V_o	Output current, I_o	Firing angle, α	Output voltage, V_o	Output current, I_o

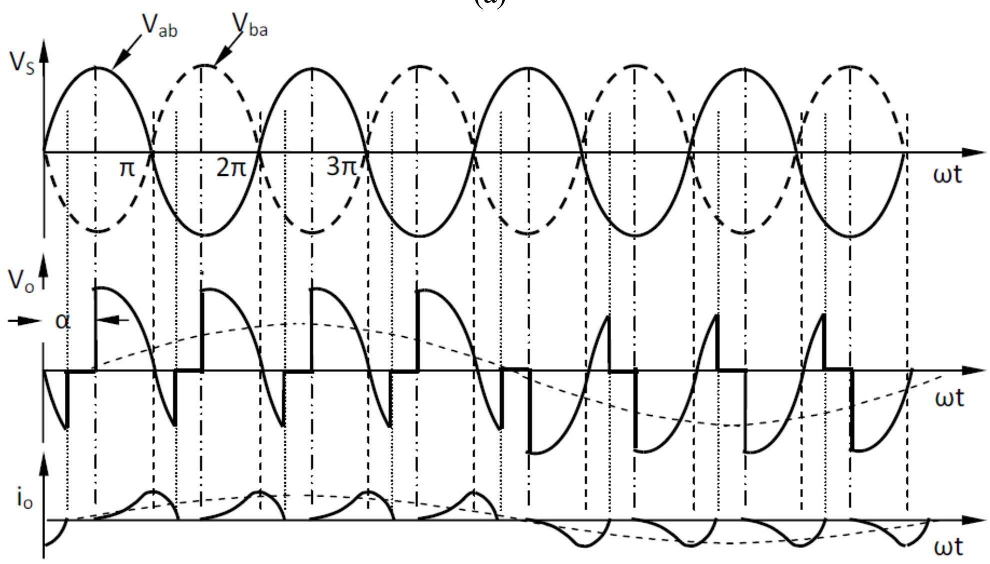
R-L load

S.No.	$f_s/2$			$f_s/3$			$f_s/4$		
	Firing angle, α	Output voltage, V_o	Output current, I_o	Firing angle, α	Output voltage, V_o	Output current, I_o	Firing angle, α	Output voltage, V_o	Output current, I_o

MODEL GRAPH:



(a)



(b)

Fig. Cycloconverter waveforms for (a) R and (b) R-L loads

RESULTS:

Viva Questions:

1. Explain operation of cyclo-converter?
2. Derive the output voltage equation for cyclo-converter?
3. Differentiate cyclo-converter and ac-ac converter?

Experiment no: 07

Experiment Title: Single Phase Dual Converter

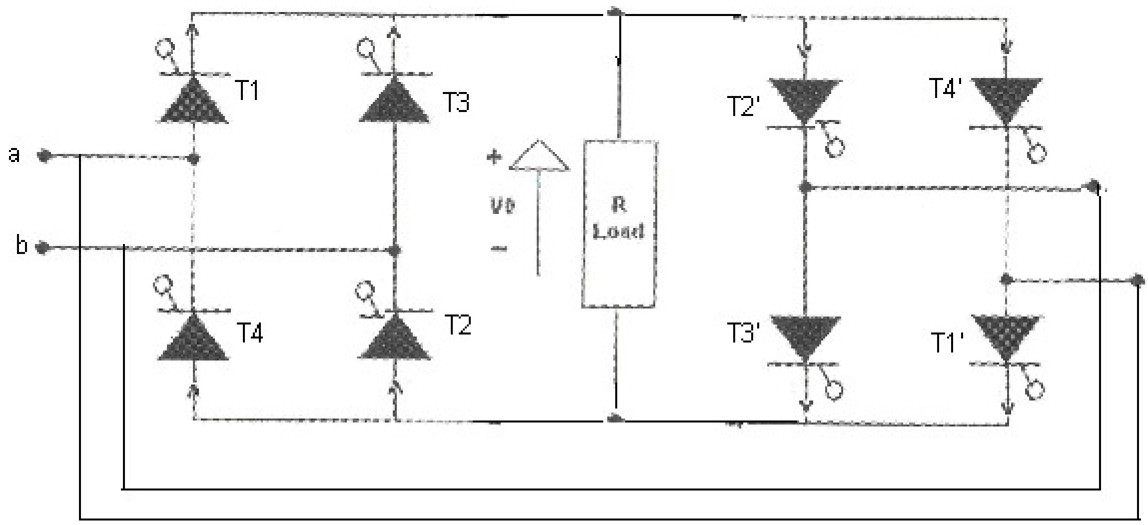
AIM: To study the dual converter with R & L load.

APPARATUS REQUIRED:

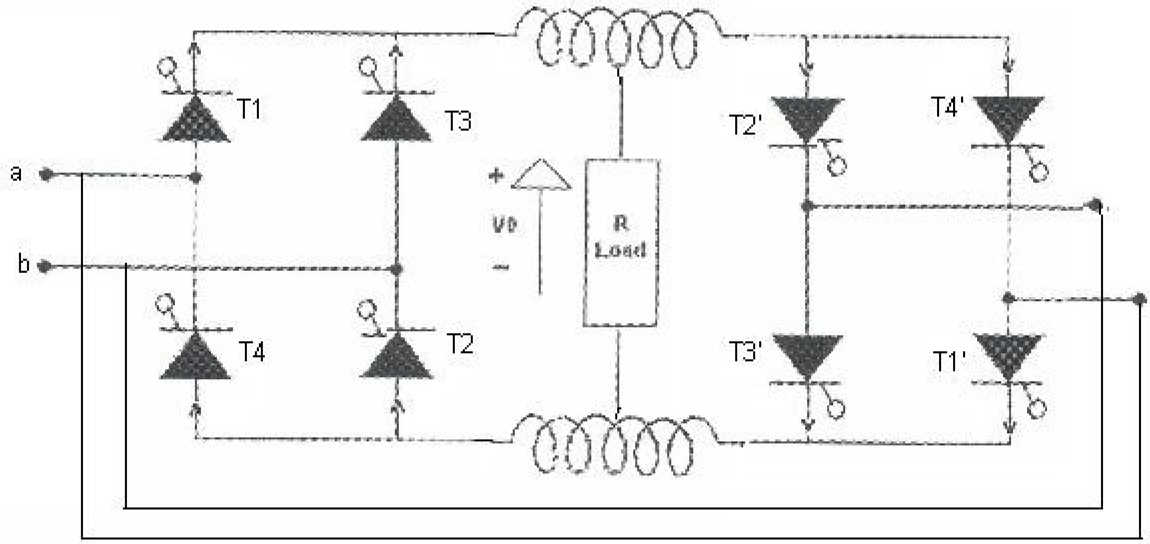
S.No.	Name of the equipment	Range	Qty
01	Single phase dual converter.(power circuit & firing circuit.)	-	01
02	Patch chords & Probes	-	Adequate
03	CRO	-	01
04	Isolation transformer(With tappings)	-	01
05	R load	0-200 ohm / 5A	01
06	L load(center tapped)	300-0-300mH/5A	01

CIRCUIT DIAGRAM:

NON- CIRCULATING CURRENT MODE:



CIRCULATING CURRENT MODE:



PROCEDURE:

NON- CIRCULATING CURRENT MODE:

1. Make all connections as per the non circulatory circuit diagram.
2. Connect R-load across load terminals.
3. Connect the input AC supply to the power circuit through an Isolating Transformer(take input voltage 30V)
4. Select the NCC mode in firing circuit.
5. Give the firing pulses and keep P-converter in ON position and also put on the MCB switch.
6. By varying the firing angle observe related out put waveforms in the CRO.Tabulate all the readings.
7. Repeat all above procedure for RL-load.

CIRCULATING CURRENT MODE:

1. Make all connections as per the circulatory circuit diagram.
2. Connect R-load across load terminals.
3. Connect the input AC supply to the power circuit through an Isolating Transformer(take input voltage 30V)
4. Select the CC mode in firing circuit.
5. Give the firing pulses and keep P-converter in ON position and also put on the MCB switch.
6. By varying the firing angle observe related out put waveforms in the CRO.Tabulate all the readings.
7. Repeat all above procedure for RL-load.

TABULAR COLUMN:

S.No.	Input Voltage (V_{in})	Firing angle in Degrees	Output voltage (V_0)		Output Current (I_0)	
			Theoretical	Practical	Theoretical	Practical

MODULE CALCULATIONS:

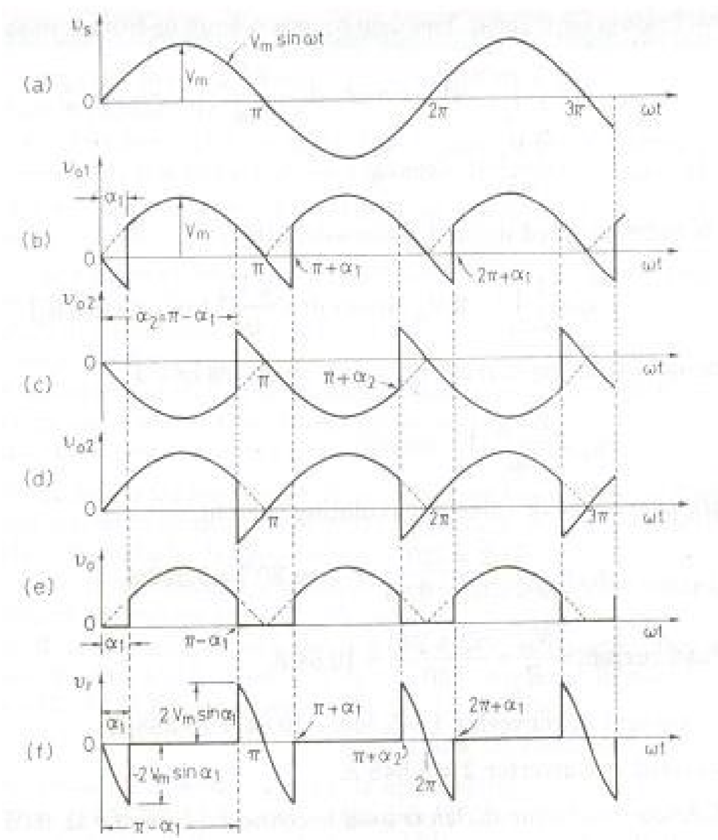
V_0 = $(2\sqrt{2}V / \pi) * (\cos\alpha_1)$

I_0 = $(2\sqrt{2}V / \pi Z) * (\cos\alpha_1)$

α = Firing Angle

V = RMS Value across transformer output

MODEL GRAPH:



RESULT: The single phase dual converter with R & RL load is studied.

Experiment no: 08

Experiment Title: single Phase Diode Bridge Rectifier With R Load And Capacitance Filter.

AIM: To observe and plot the various waveforms of full-wave bridge rectifier circuit with R load and using a capacitor filter.

APPARATUS:

S.NO.	COMPONENTS	RANGE
1	Single phase step down transformer	6-0-6
2	PN diode	IN4007 – 2 No.
3	Resistors	1k,10k,100k
4	Capacitors	47µf,10µf, 100µf
5	Bread board	I No.

Theory:

The circuit diagram of diode bridge rectifier circuit is given in Fig. 8.1. During the positive half cycle of the input voltage, the load current flows from the positive input terminal to the negative through D_1, R_L and D_4. During this time, the positive input terminal is applied to the cathode of D_2 and D_3, so it is reversed biased. These two diodes are forward biased during negative half cycle; D_1 and D_4 are reverse biased. And finally both half cycles are rectified and the output is unidirectional voltage. In order to convert unidirectional to ripple free/reduced ripple DC voltage filters are used. The size of the filter depends on load current, line frequency, ripple factor. In other words, the ripple content depends on the load current and capacitor values. Hence, in this experiment ripple contents are measured for different load resistor and filter capacitor values.

CIRCUIT DIAGRAM:

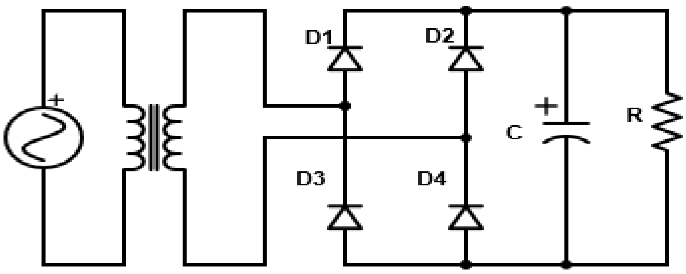


Fig. 8.1 Diode bridge rectifier

PROCEDURE:

Without filter:

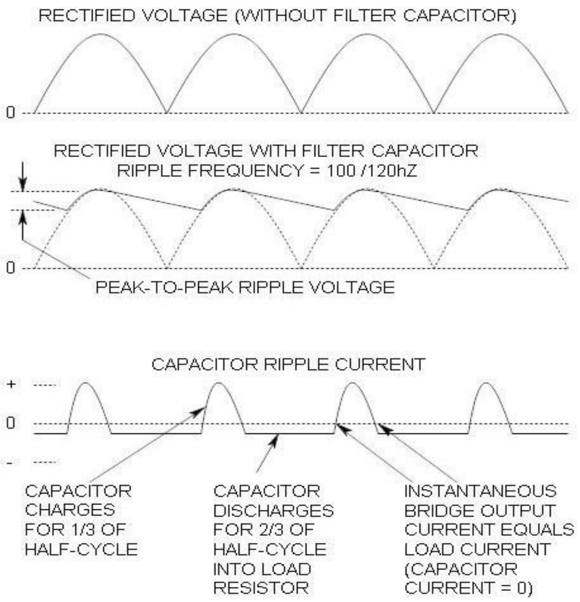
1. Connect the circuit as per the circuit given in Fig. 8.1 without capacitor.
2. Connect CRO across the load
3. Switch the CRO in DC mode and observe the waveform. Note down the shift.
4. Calculate $V_{DC} = \frac{2V_m}{\pi}$, V_{RMS} and the ripple factor (RF) = $\sqrt{\left(\frac{V_{RMS}}{V_{DC}}\right)^2 - 1}$

5. Find the voltage regulation by measuring the output voltage with load and without load.

With filter:

1. Connect the circuit as per the circuit given in Fig. 8.1
2. Connect CRO across the load
3. Switch the CRO in DC mode and observe the waveform. Note down the shift.
4. Calculate $V_{DC} = V_m\left[1-\frac{T}{2RC}\right]$, V_{RMS} and peak to peak ripple voltage $V_{R(PP)}=\frac{V_mT}{RC}$
5. Find the voltage regulation by measuring the output voltage with load and without load.
6. Draw the instantaneous output voltage using
   $V_0=V_me^{-t/RC}$ (During capacitor discharging)
   $V_0=|V_m\sin(\omega t)|$ (During capacitor charging)

MODEL GRAPH:



TABULAR FORM:

Circuit	R	C	V_{DC}	V_{RMS}	$V_{R(PP)}$	RF
Without filter		-				
With filter						

RESULTS:

Viva Questions:

1. Derive the voltage and current expressions of the capacitor?

2. Explain the procedure to derive r.m.s. voltage, DC voltage and ripple factor of full bridge rectifier with C filter?

Experiment no: 09

Experiment Title: Three Phase Fully Controlled Bridge Converter With, Rl Load

AIM: To study a three phase fully controlled full wave bridge rectifier for RL load

APPARATUS: 430V input 200V output star connected isolation transformer, controlled rectifier module,, firing unit, rheostat 230 Ohm//2 A, connecting wire etc.

THEORY:

In fully controlled bridge rectifier, six SCR's are connected as control switches. The advantage of fully controlled bridge rectifier is the capability of wide voltage. The firing angle is measured with respect to crossing points of phase voltages. For example, in order to set firing angle X^0, after zero crossing point of phase R, give a delay of time (= $((30^0+X^0)/360)*T$). This converter can be used for motoring and regenerative braking applications. For $\alpha > 90$ degrees, if the motor back emf is reversed either using contactors or field current reversing, it is possible to make the average output voltage of the converter negative (regenerative braking).

CIRCUIT DIAGRAM:

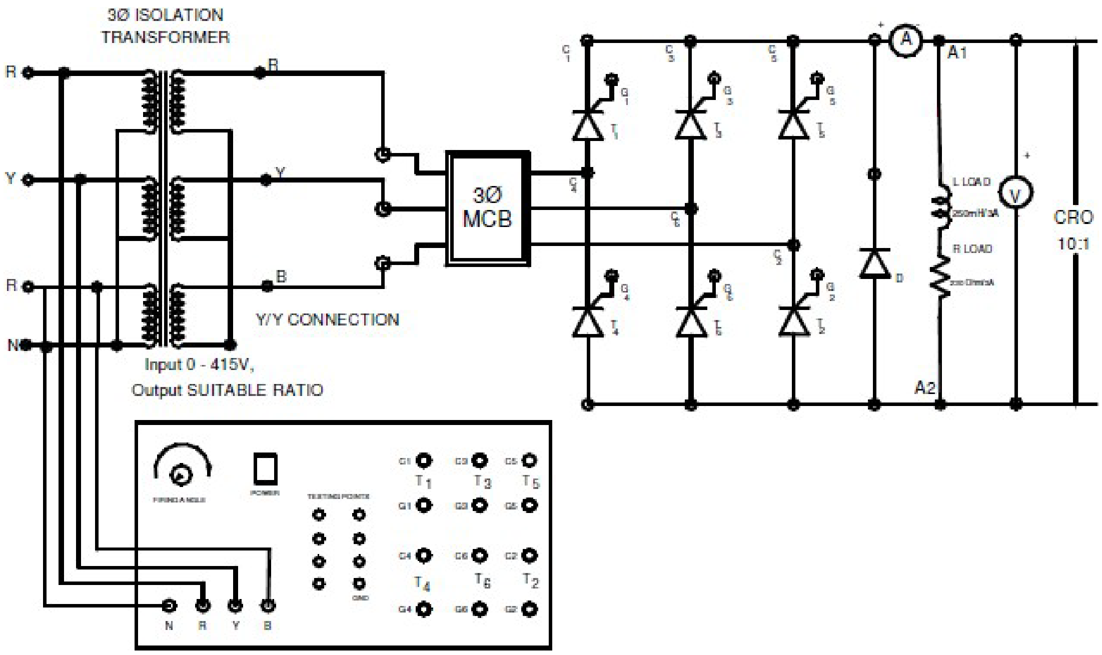


Fig. 9.1 Three phase fully controlled bridge converter with RL load

PROCEDURE:

1. Connections are made as per the circuit diagram given above with R load.
2. Connect CRO across the load
3. Gate cathode terminals of the three arms of the bridges are connected to the respective points on the firing unit.
4. Keep the firing angle knob at its minimum position. Switch on three phase supply, power unit as well as firing unit.
5. Vary firing angle gradually and observe the change in output voltage on CRO and tabulate the r.m.s. value against the firing angles.
6. Plot the output voltage waveforms for different firing angles.
7. Bring the firing angle knob to minimum and switch of the circuits.
8. Repeat the experiment for RL load.

NOTE:

1. Do not conduct the experiment without three phase isolation transformer. If you try to conduct experiment without isolation transformer the instrument may be damaged due to short circuit exists between single phase & three phase supply while making measurement using CRO.

2. Do not attempt to observe load voltage and input voltage simultaneously, if does so input voltage terminal directly connected to load terminals due to the non isolation of both channels of the CRO. Conduct experiment for lesser AC voltages using resistive load.

3. It is advised to use power scope for the isolation purposes.

TABULAR FORM:

S. No.	R Load		RL Load	
	Firing angle	Output voltage	Firing angle	Output voltage

MODEL GRAPH:

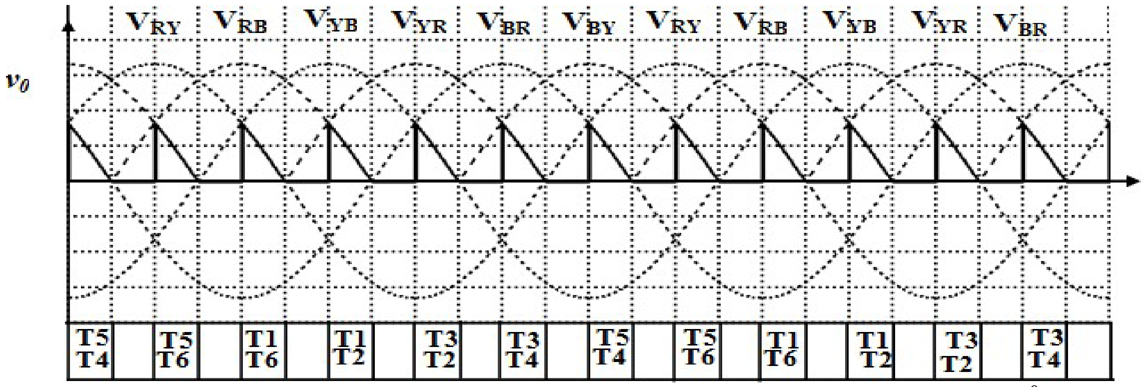
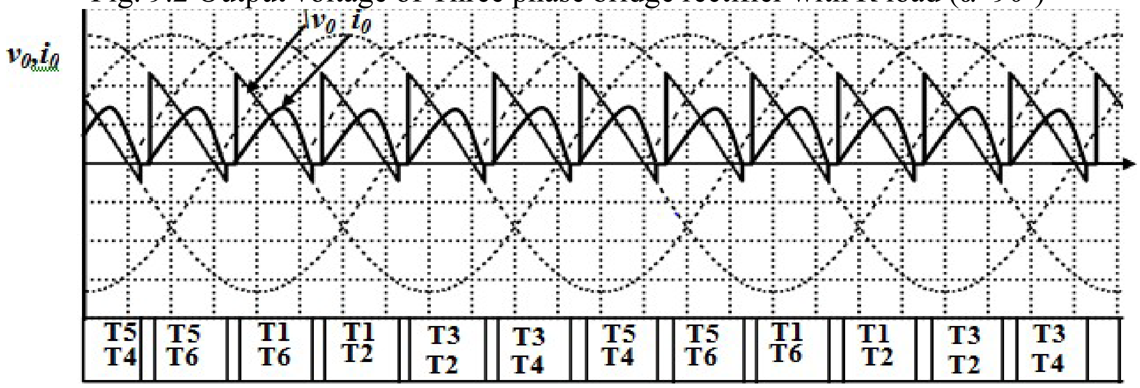
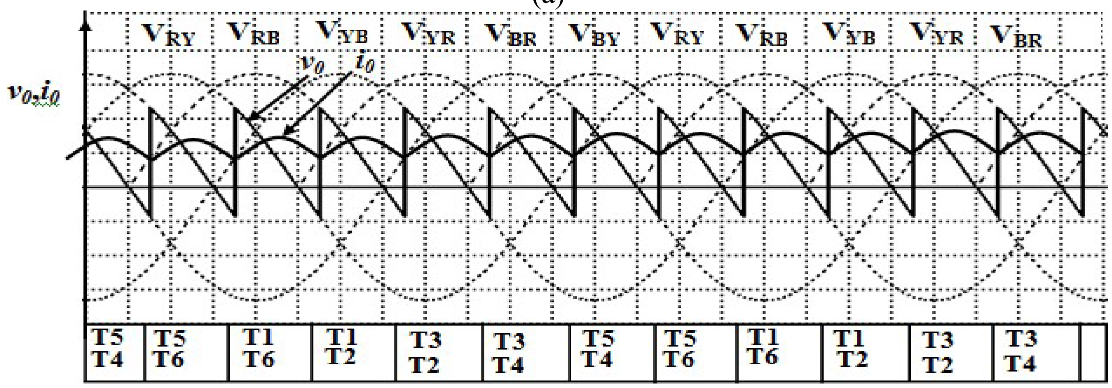


Fig. 9.2 Output voltage of Three phase bridge rectifier with R load ($\alpha=90^0$)



(a)



(b)

Fig. 9.2 Output voltage of Three phase bridge rectifier with RL load (a) $\alpha=75^0$ Discontinuous mode (b) $\alpha=75^0$ continuous mode

RESULT:

Viva Questions:

1. Derive the average output voltage expression for R and RL loads?
2. Compare three phase full controlled bridge converter with semi-controlled converter?
3. Through vector diagram and show that in three phase supply, line voltage leads phase voltage by 30^0?

Experiment no: 10

Experiment Title: Study Of Forced Commutation Circuits

AIM: To observe the operation of different commutation circuits.

APPARATUS:

S.NO.	COMPONENTS	RANGE
1	Forced Commutation study Module	
2	Rheostat	50Ω/1A,360Ω/1.2A
3	Loading Inductor	
4	CRO	100mH
5	Connecting Wires	

Theory:

SCR is semi-controlled devices, if the input is DC supply, the commutation circuits are mandatory to turn OFF the thyristor. There are three methods of switching the device off or commutating the thyristor.

i) The anode current can be reduced below the holding current value.

ii) By reversing the anode voltage the conducting thyristor is commutated.

iii) In low current Gate Turn-Off (GTO) thyristor the holding current value is increased by supplying the gate with negative current.

Commutation circuits are classified into

(a) Class-A commutation
(b) Class-B commutation
(c) Class-C commutation
(d) Class-D commutation
(e) Class-E commutation

Last three circuits has extra controlled device to commutate the SCR when it is turned ONN.

CIRCUIT DIAGRAM:

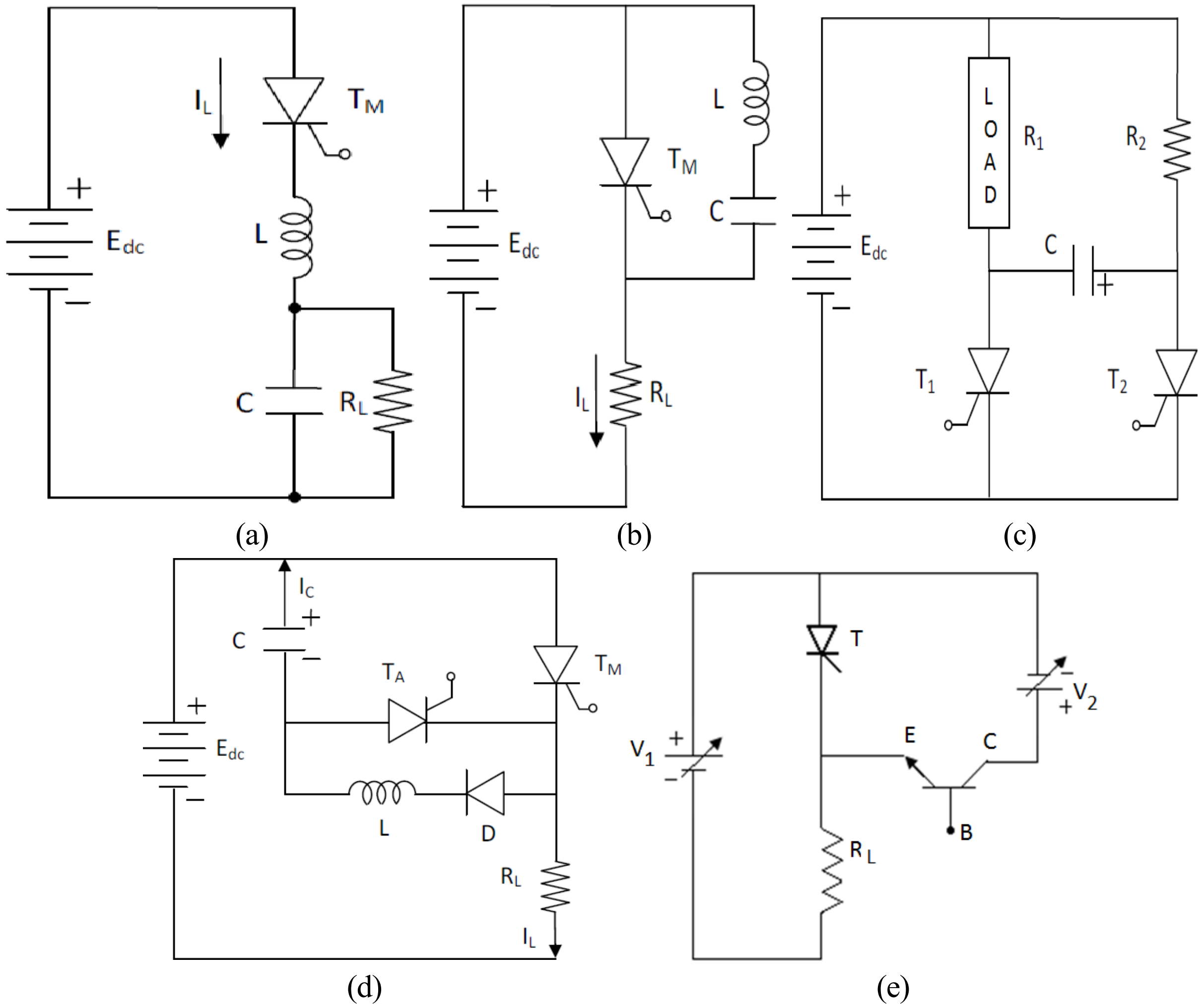


Fig. 10.1 Commutation circuits: (a) class-A, (b) class-B, (c) class-C, (d) class-D and (e) class-E

PROCEDURE:

Class-A:

1. Connections are made as per the circuit diagram given in Fig. 10. 1 (a).
2. Connect trigger output to gate and cathode of SCR.
3. Switch ON the supply to power circuit and observe the voltage waveforms across load, thyristor and capacitor by varying the frequency potentiometer.
4. Repeat the above procedure for different values of R, L & C.
5. Plot the output waveforms.

Class-B:

1. Connections are made as per the circuit diagram given in Fig. 10. 1 (b).
2. Repeat step 2-step 5 as given in Class-A.

Class-C:

1. Connections are made as per the circuit diagram given in Fig. 10. 1 (c).
2. Connect T_1 and T_2 gate pulse from the firing circuit to gate and cathode of thyristors T_1 and T_2 and observe the waveforms across R_1 and R_2.
3. Draw the output wave forms on the graph sheet.

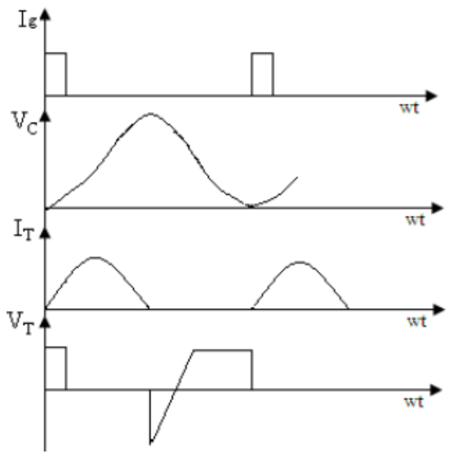
Class-D:

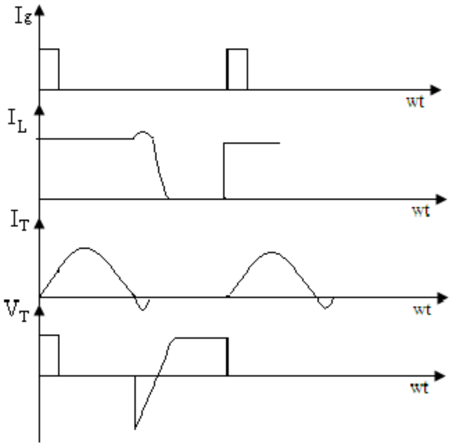
1. Connections are made as per the circuit diagram given in Fig. 10.1 (d).
2. Connect T1 and T2 gate pulse from firing circuit to corresponding SCR in power circuit.
3. Initially keep trigger circuit at OFF position and charge the capacitor. This can be observed by connecting CRO to the capacitor.
4. Now trigger circuit is kept ON position and note down the voltage waveform at different duty cycles.
5. Sketch the output wave forms.

Class-E:

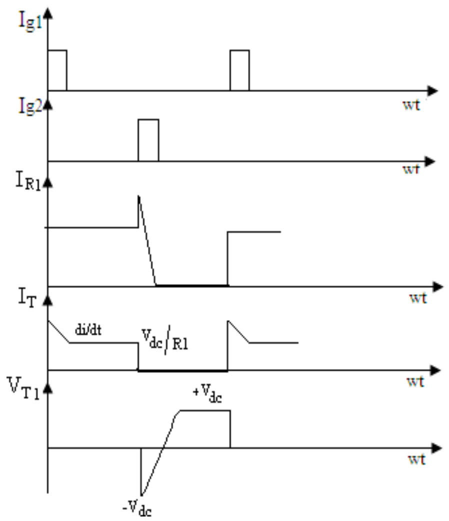
1. Connections are made as per the circuit diagram given in Fig. 10. 1 (a).
2. Connect trigger output to gate and cathode of SCR.
3. Switch ON the supply to power circuit and observe the voltage waveforms across load, thyristor and capacitor by varying the frequency potentiometer.
4. Plot the output waveforms.

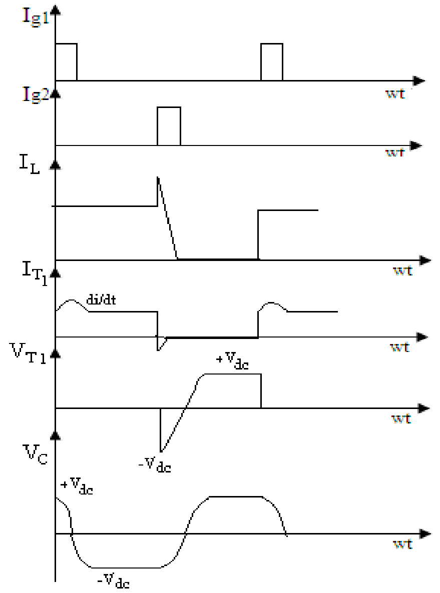
MODEL GRAPHS:



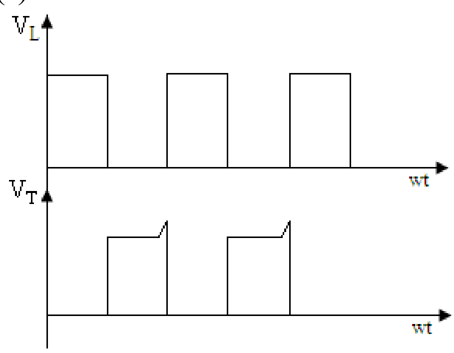


(a) (b)





(c) (d)



(e)

Fig. 10.2 voltage and current waveforms of (a) class-A, (b) class-B, (c) class-C, (d) class-D and (e) class-E commutation circuits

RESULTS:

Viva Questions

1. Explain the operation each commutation circuit using waveforms?

Experiment no: 11

Experiment Title: SINGLE PHASE SERIES INVERTER

AIM: To study the operation of Single Phase Series Inverter and to obtain variable AC from DC input.

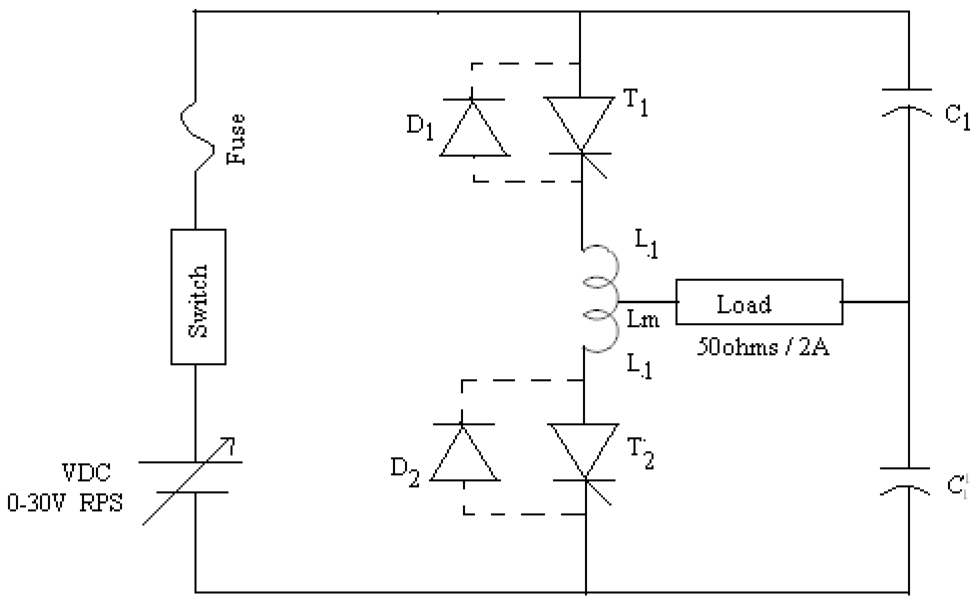
APPARATUS REQUIRED:

S.NO.	COMPONENTS	RANGE
1	Single Phase Series Inverter module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	Inductive load	100mH
5	Multi Meter	
6	Ammeter	(0-1A, MC)
7	RPS , Dual Channel	0-30 V
8	Transformer	230/0-30V

THEORY:

This circuit which converts DC power into AC power is called inverter. If the thyristors commutation circuit of the inverter is in series with the load, then the inverter is called series inverter. In this circuit, it is possible to turn-on-thyristor T_1 before the current through thyristor T_2 has become zero and vice-versa. Moreover, the modified series inverter given in below figure can be operated beyond the resonance frequency (f_r) of the circuit. The inverter's resonance frequency depends on the values of L, R and C in the circuit.

CIRCUIT DIAGRAM:



Modified Series Inverter

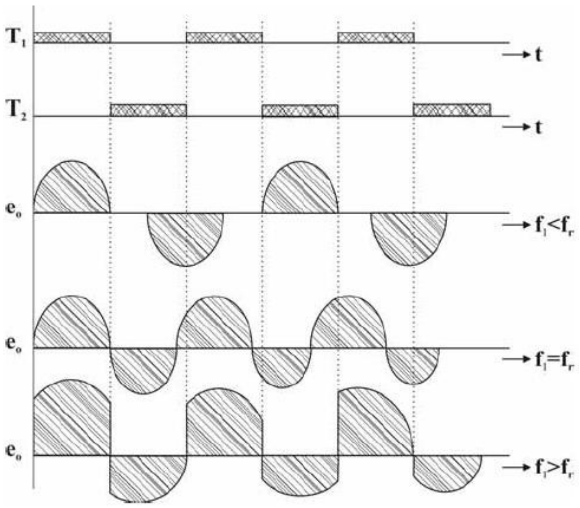
PROCEDURE:

1. Switch on the power supply to the firing circuit check that Trigger pulses by varying the frequency.
2. Connections are made as shown in the circuit diagram.
3. Now connect trigger outputs from the firing circuits to gate and cathode of SCRs T_1 and T_2.
4. Connect DC input from a 30v/2A regulated power supply and switch on the input DC supply.
5. Now apply trigger pulses to SCRs and observe voltage waveform across the load.
6. Measure V_{rms} and frequency of output voltage waveform.

TABULAR FORM:

S. No.	Amplitude (Volts)	T_{ON} (mS)	T_{OFF} (mS)

MODEL GRAPH:



RESULT:

VIVA QUESTIONS:

1. What is the dead zone of an inverter?
2. Up to what maximum voltage will the capacitor charge during circuit operation?
3. What is the amount of power delivered by capacitor?
4. What is the purpose of coupled inductors in half bridge resonant inverters?
5. Types of resonant pulse inverters?

Experiment no: 12

Experiment Title: Single Phase Parallel Inverter

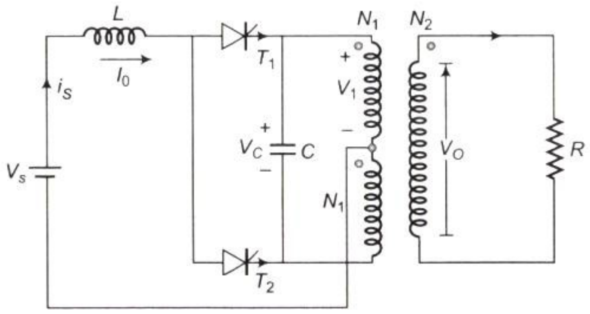
AIM: To study and obtain the AC output voltage waveform of single-phase parallel inverter with R & RL loads.

APPARATUS:

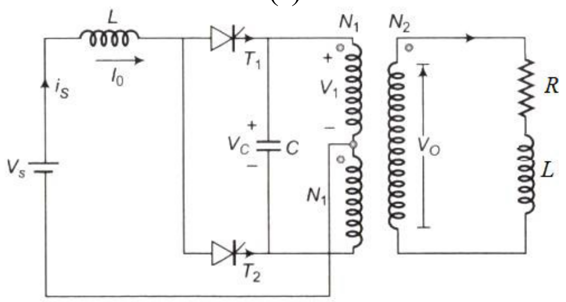
S.NO.	COMPONENTS	RANGE
1	Single Phase Parallel Inverter module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	Inductive load	100mH
5	Multi Meter	
6	Ammeter	(0-1A, MC)
7	RPS , Dual Channel	0-30 V
8	Transformer	230/0-30V

THEORY:

Power electronic converter that converts dc power into ac power at desired output voltage and frequency is called an inverter. When T_1 is turned on capacitor is charged to twice the supply voltage as shown in figure. When T_2 is turned on capacitor starts discharging, applies reverse voltage across T_2 and turns off T_2. And it charges capacitor to reverse polarity and to twice the supply voltage. This voltage is used to turn off T_1 when T_2 is fired.



(a)



(b)

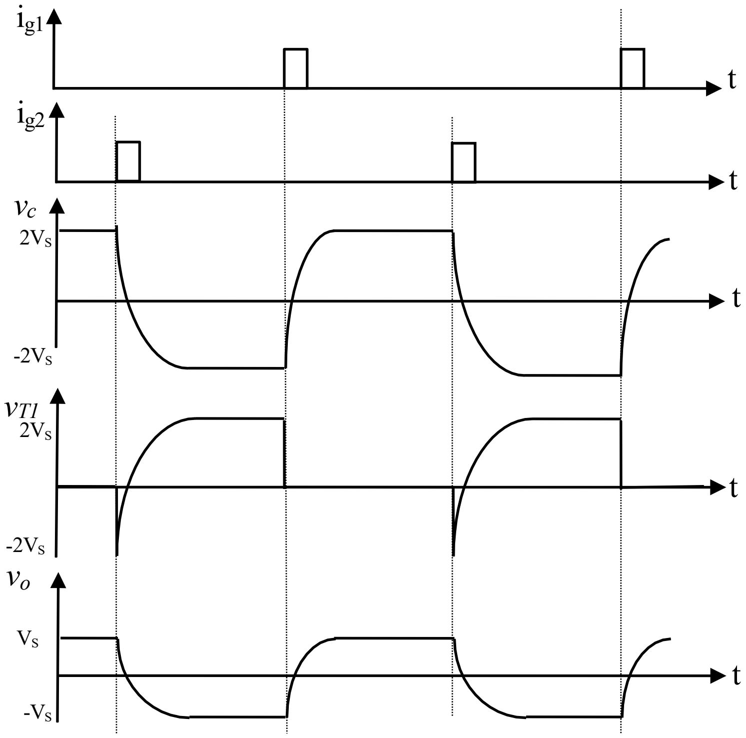
Parallel inverter with (a) R and (b) R-L loads

PROCEDURE:

1. Connect the DC supply across DC input terminals and turn ON.
2. The trigger circuit now by providing the trigger pulses.
3. Observe & draw the different waveforms.
4. Repeat the same procedure with RL loads.

MODEL GRAPHS:

R-load:



RESULT:

Viva questions:

1. Explain the operation of parallel inverter?
2. Differentiate switch mode inverter and line frequency inverter?
3. What are operating frequencies of switch mode inverter and line frequency inverter?

Experiment no: 13

Experiment Title: Single Phase Bridge Inverter

AIM: To obtain the output waveforms of single phase bridge inverter.

APPARATUS:

S.NO.	COMPONENTS	RANGE
1	Single Phase Bridge Inverter Module	
2	CRO with probes	20MHz
3	Resistive load	500Ω, 1KΩ
4	Inductive load	100mH
5	Multi Meter	
6	Ammeter	(0-1A, MC)
7	RPS , Dual Channel	0-30 V
8	Transformer	230/0-30V

THEORY:

Rectifier fed voltage source inverter is given in Fig. 7.1. First AC supply is converter to DC through rectifier and filter circuit and is connected to the inverter input. The inverter has four IGBT's; each leg has two IGBT's. For a full bridge inverter, when $IGBT_1$ and $IGBT_4$ conducts, the load voltage is V_{DC} and when $IGBT_2$ and $IGBT_3$ conduct, the load voltage is $-V_{DC}$. Frequency of the output voltage can be controlled by varying the periodic time.

During the inverter operation, it should be ensured that two IGBT's in the same leg such do not conduct simultaneously as this would lead to a direct short circuit of the source.

The voltage source inverter topologies are the most widely used because they naturally behave as voltage sources as required by many industrial applications, such as adjustable speed drives (ASDs), which are the most popular application of inverters. Static power converters, specifically inverters, are constructed from power switches and the ac output waveforms are therefore made up of discrete values. This leads to the generation of waveforms that feature fast transitions rather than smooth ones.

CIRCUIT DIAGRAM

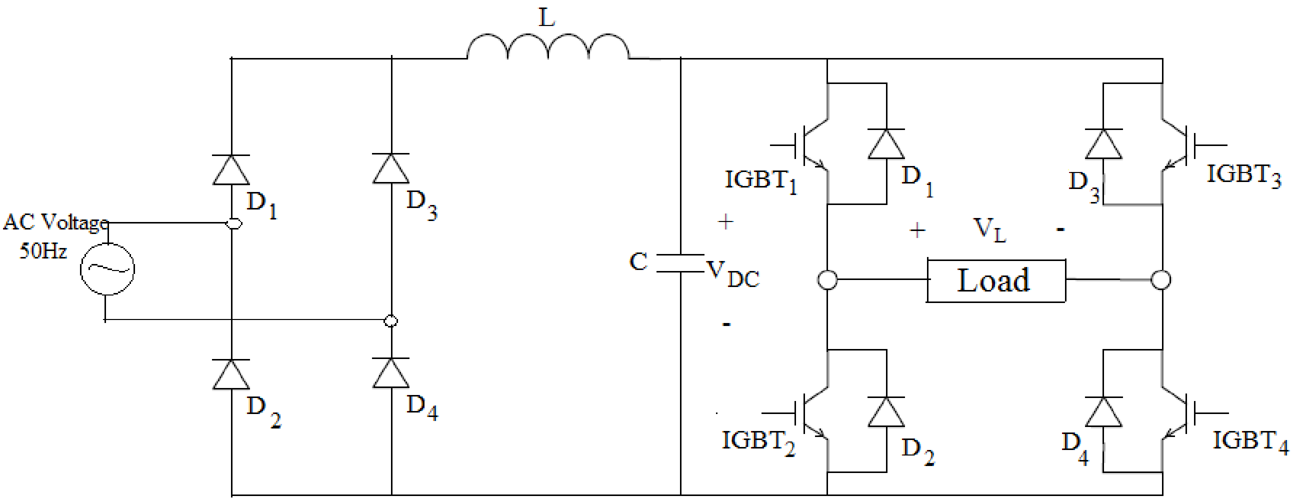


Fig. 7.1 Single phase bridge inverter

PROCEDURE:

1. All connections are to be made as per the circuit diagram.
2. Connect the required load and connect CRO across the load.
3. Check all the connections before switching on the equipment.
4. Keep the DC voltage at minimum value.
5. Switch on the firing circuit followed by MCB.
6. Set the frequency and modulation index at suitable value
7. Adjust the DC voltage at 30V and observe the output waveforms.
8. Record the frequency of the inverter circuit and vary modulation index.
9. Reduce the DC voltage to the minimum value and press stop key.
10. Slowly reduce DC voltage to zero, switch off all the switches.

TABULAR FORM:

S. No.	Modulation Index in %	Load Voltage(V)	Time in seconds	Frequency f=1/T

MODEL GRAPH:

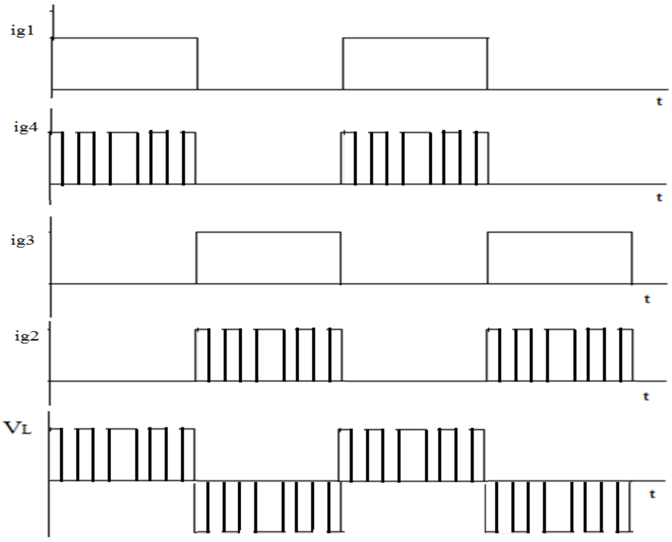


Fig. 7.2 Inverter output voltage

RESULT:

Viva Questions:

1. Draw phase and line voltage waveforms of three phase voltage source inverter operating in 120^0 and 180^0 mode?
2. Find the Fourier coefficients for the square wave inverter?