2023

EDITION ONE

POWER ELECTRONICS

LAB MANUAL

Department of Electrical Engineering

Government College of engineering, Keonjhar

GYANAM ANANTAM

ज्ञानम् अनन्तम्

GOVERNMENT COLLEGE OF ENGINEERING, KEONJHAR

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CONTENTS

DO’S AND DON’TS IN THE LAB

DO’S: -

1. Proper dress has to be maintained while entering the lab.
2. All students should come to the lab with necessary tools.
3. Students should carry observation notes and record completed in all aspects.
4. Correct specifications of the equipments have to be mentioned in the circuit diagram.
5. Students should be aware of operating the equipments.
6. Students should be at their concerned experiment table; unnecessary moment is restricted.
7. Students should follow the indent procedure to receive and deposit the equipment from the Lab Store Room.
8. After completing the connections students should verify the circuits by the Lab Instructor.
9. The reading must be shown to the Lecturer In-Charge for verification.
10. Students must ensure that all switches are turned OFF position, all the connections are removed.
11. All patch cords and stools should be placed at their original positions.

DON’Ts: -

1. Don’t come late to the lab.

2. Don’t enter into the lab with gold rings, bracelets and bangles.

3. Don’t make or remove the connections while the supply is ON.

4. Don’t switch ON the supply without verification by the Staff Member.

5. Don’t switch OFF the machine with load.

6. Don’t leave the lab without the permission of the Lecturer In-Charge/Lab Instructor.

EXPERIMENT: – 1(a)

AIM OF THE EXPERIMENT

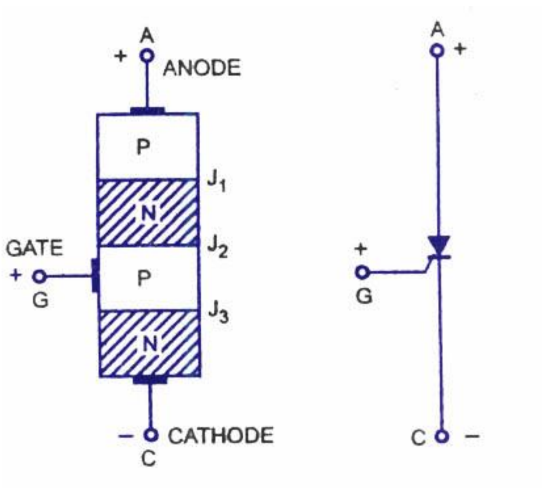
To study and plot V-I characteristics of SCR.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	SCR Trainer		
2	Mains supply		
3	DC power supply		
4	Voltmeter		
5	Ammeter		
6	Patch cords		

THEORY

A thyristor is a four-layer semiconductor device of PNPN structure with three PN junctions. It has three terminal anode, cathode and gate. When the anode voltage is made positive with respect to cathode, the junctions J_1 and J are forward biased. The junctions J_2 is reversed biased and, only a small leakage current flows from anode to cathode. The thyristor is then said to be in the OFF mode. If a Anode to Cathode voltage is increased to a sufficiently large value, the reversed biased junction J_2 will break. This is known as avalanche breakdown and the corresponding voltage is called forward breakdown voltage VBO. Since junctions J1 and J_3 are already forward biased, there will be free movement of carriers across all three junctions, resulting in a large forward anode current. The device will then be in a conducting state or on state. The voltage drop would be due to the ohmic drop in the four layers and it is small, typically, 1V. In the on state, the anode current is limited by an external impedance or resistance.



(a) (b)

Fig 1.1: (a)Schematic Diagram (b)Symbolic Representation of SCR

MODEL GRAPH

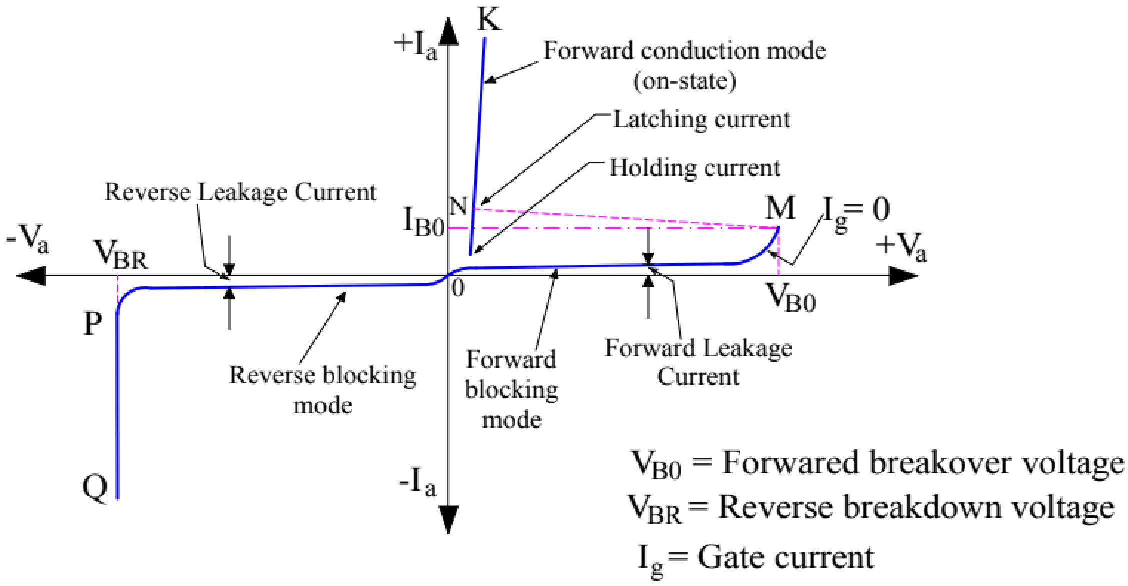


Fig 1.2: V-I characteristics of SCR

CIRCUIT DIAGRAM

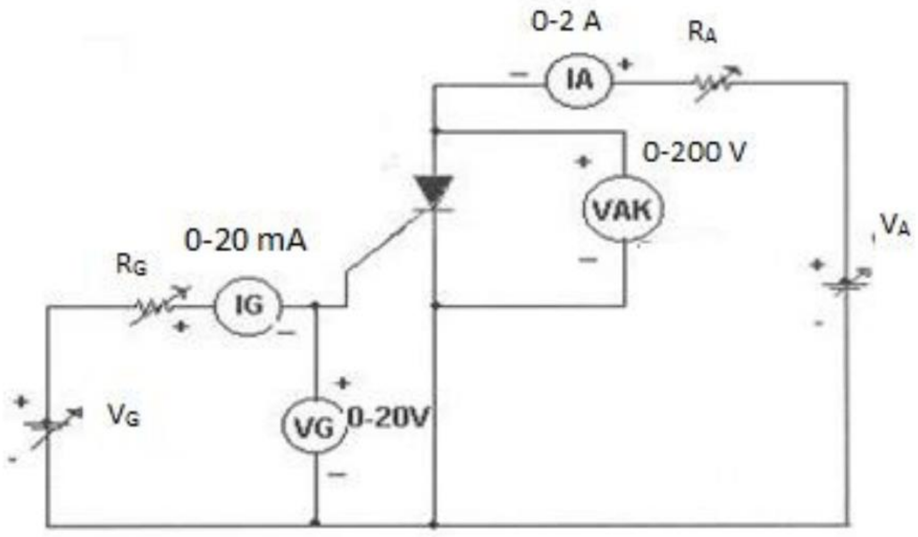


Fig 1.3: Circuit diagram of SCR

PROCEDURE

1. Make all connections as per the circuit diagram.
2. Initially keep VG & VA at minimum position and R1 & R2 maximum position.
3. Adjust Gate current Ig to some constant by varying the VG or RG.
4. Now slowly vary VA and observe Anode to Cathode voltage VAK and Anode current IA.
5. Tabulate the readings of Anode to Cathode voltage VAK and Anode current IA.
6. Repeat the above procedure for different Gate current Ig.

OBSERVATION TABLE

SL. No.	Anode voltage (V_{AK} in volt)	Anode current (I_A in mA)

CONCLUSION

QUESTIONS

1. What is latching current in SCR?
2. What is holding current in SCR?
3. What is forward break over voltage?
4. What is reverse breakdown voltage?
5. What is avalanche breakdown?

EXPERIMENT: – 1(b)

AIM OF THE EXPERIMENT
To study and plot V~I characteristics of TRIAC

APPARATUS REQUIRED

Sl No.	Name of Apparatus	Specification	Quantity
1	TRIAC Trainer		
2	Mains supply		
3	DC power supply		
4	Voltmeter		
5	Ammeter		
6	Patch cords		

THEORY

The TRIAC is a three terminal, four-layer semiconductor device for controlling current. It gains its name from the term triode for Alternating Current. Its three terminals are MT_1, MT_2 and the gate (G). TRIAC is the most widely used member of the thyristor family. It is basically a combination of two SCRs connected in antiparallel configuration within the same chip. Unlike SCRs, it is a bidirectional device, and can be triggered either by positive or negative gate signal. Because of its bidirectional conduction property, TRIAC is widely used in the field of Power electronics for control purposes. TRIAC BT_{136} is the most widely used in the fan regulator. Like and SCR, a TRIAC also starts conducting only when the break over voltage is reached. Earlier to that the leakage current which is very small in magnitude, flows through the device and therefore it remains in the OFF state. The first quadrant characteristic is just like an SCR, but in the third quadrant characteristics of a TRIAC is identical to its first quadrant, except that, as the polarities of the main terminals change, the direction of current changes. MT_2 is positive with respect to MT_1 in the first quadrant and if is negative it is negative in the quadrant. The device when starts conducting allows very heavy amount of current to flow through it. This high inrush of current must be limited by using external resistance, or it may otherwise damage the device. The gate is the control terminal of the device. By applying proper signal at the gate, the firing angle of the device can be changed thus, the phase control process can be achieved. Its main limitation as comparison to SCRs is, its low power handling capacity.

MODEL GRAPH

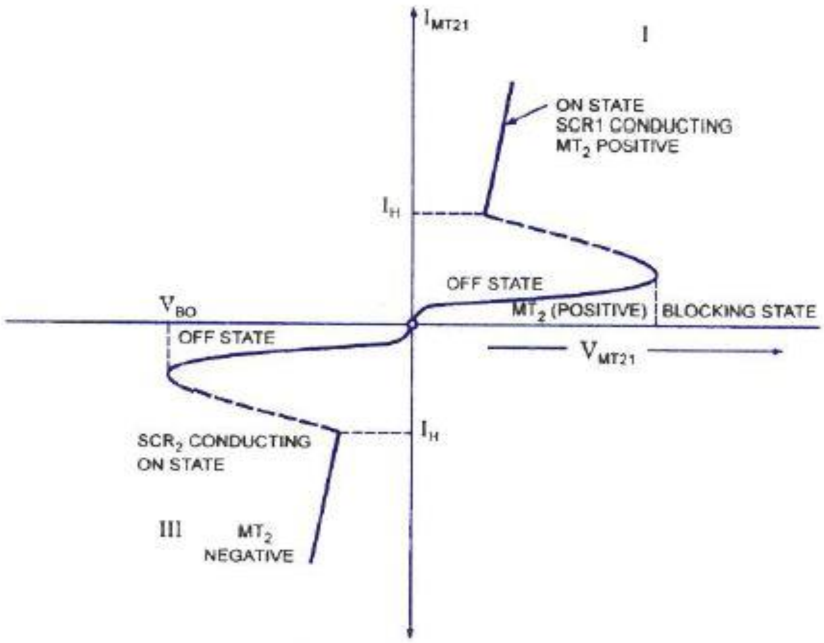


Fig 1.5: V-I characteristics of TRIAC

CIRCUIT DIAGRAM

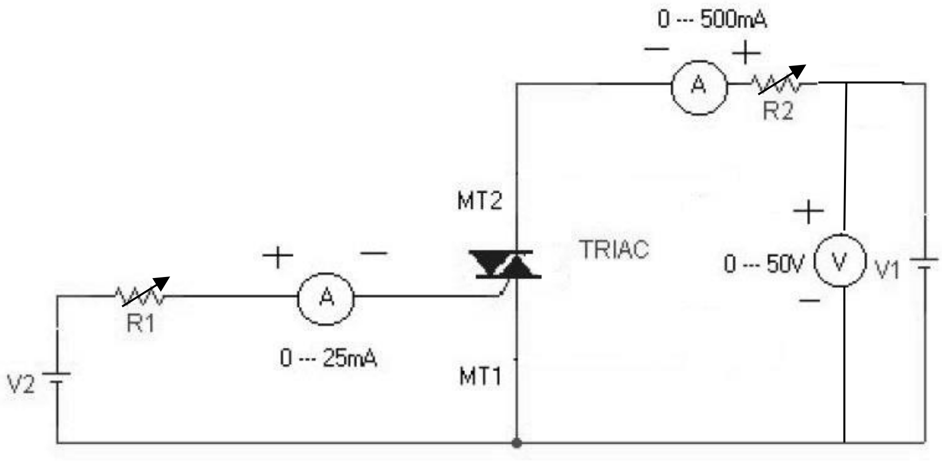


Fig 1.6: Circuit diagram of TRIAC

PROCEDURE

1) Connect the circuit as shown in circuit diagram.

2) Make the connections for positive biasing mode.

3) Keep the IG constant and note down the voltmeter and ammeter reading.

4) Now make the connections in negative biasing mode.

5) Keep IG constant and note down the voltmeter and ammeter reading.

6) Plot the graph for both the characteristics.

OBSERVATION TABLE

For +ve biasing

V_a in volts	I_a in amps

For -ve biasing

V_a in volts	I_a in amps

CONCLUSION

QUESTIONS

1) What are the applications of TRIAC?

2) Name the three terminals in TRIAC.

3) By what manner TRIAC is different from SCR.

4) Why TRIAC is known to be bi-directional devices?

5) Is TRIAC have a capability to work in rectifier mode?

EXPERIMENT: – 1(c)

AIM OF THE EXPERIMENT

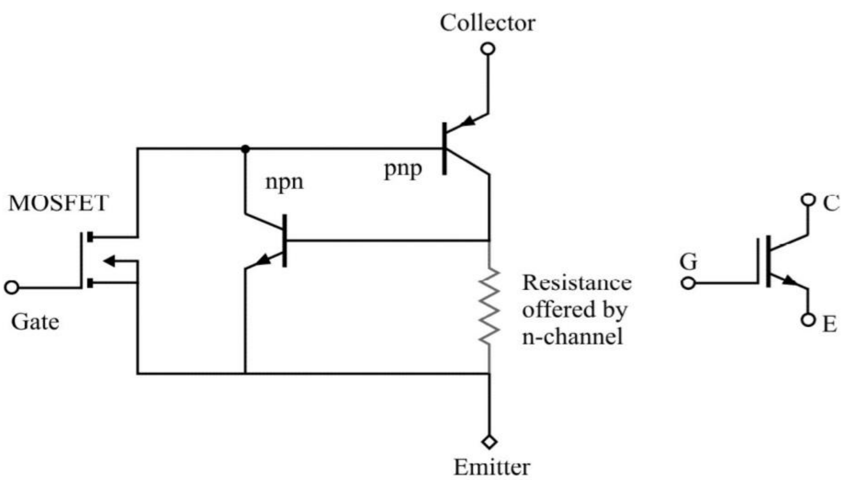
To study and plot V~I characteristics of IGBT.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	IGBT Trainer kit		
2	Mains supply		
3	Voltmeter		
4	Ammeter		
5	Patch cords		

THEORY

The insulated gate bipolar transistor (IGBT) combines the positive attributes of BJTs and MOSFETs. BJTs have lower conduction losses in the 'On'-state, especially in devices with larger blocking voltages, but have longer switching times, especially at turn- 'Off' while MOSFETs can be turned on and off much faster, but their on-state conduction losses are larger, especially in devices rated for higher blocking voltages. Hence, IGBTs have lower on-state voltage drop with high blocking voltage capabilities in addition to fast switching speeds and has become the most favoured power device in Industrial application. The performance of an IGBT is closer to that of a BJT rather than a MOSFET. The circuit symbol of an IGBT is shown in the below figure. When the gate is positive with respect to the emitter and this voltage is beyond the threshold value, a n channel is induced in the p-region of a MOSFET. These charge carriers forward bias the base-emitter junction of the p-n-p transistor and holes are injected into the n-type drift region.



(a) (b)

Fig 1.7: (a)Equivalent Circuit (b)Circuit Symbol of IGBT

MODEL GRAPH

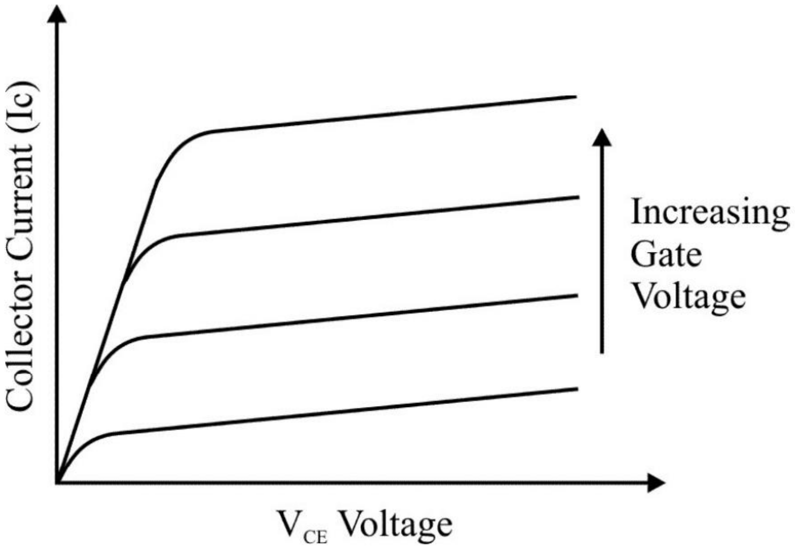


Fig 1.8: VI characteristics of IGBT

CIRCUIT DIAGRAM

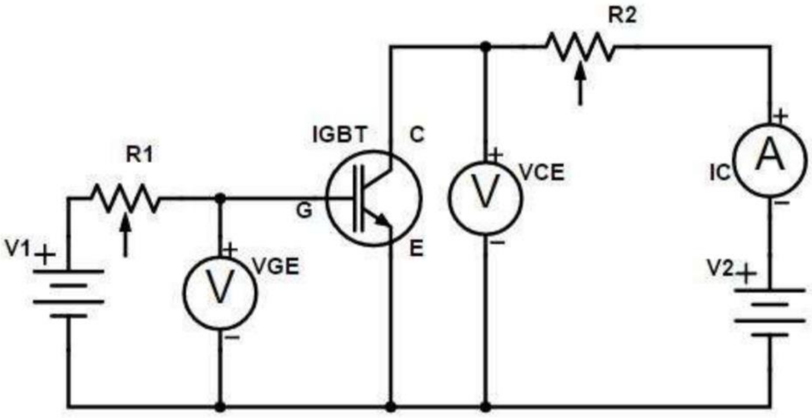


Fig 1.8: Circuit diagram of IGBT

PROCEDURE

1. Connect the circuit as given in circuit diagram.
2. Set a finite gate source voltage (V_{GE1}) by varying R_1 and V_1.
3. By varying V_2(orR_2), note down V_{CE} and I_C.
4. Repeat the steps 3 and 4 for second gate source voltage (V_{CE2}).

OBSERVATION TABLE

SL.No.	V_{GE1}		V_{GE2}	
	V_{CE}	I_C	V_{CE}	I_C

CONCLUSION

QUESTIONS

1. What is IGBT? What is the difference between an IGBT and SCR?
2. In what way IGBT is more advantageous than BJT and MOSFET?
3. Draw the symbol of IGBT.
4. Draw the equivalent circuit of IGBT.
5. What are on state conduction losses? How is it low in IGBT?

EXPERIMENT: – 1(d)

AIM OF THE EXPERIMENT
To study and plot V~I characteristics of MOSFET

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	MOSFET Trainer kit		
2	Mains supply		
3	Voltmeter		
4	Ammeter		
5	Patch cords		

THEORY
A MOSFET (Metal Oxide Semiconductor Field Effect Transistor) has three terminals called drain, source and gate. MOSFET is a voltage-controlled device. It has very high input impedance and works at high switching frequency. These devices can be classified into two types (depending on whether they possess a channel in their default state or not):

1. Enhancement type
2. Depletion type

MODEL GRAPH

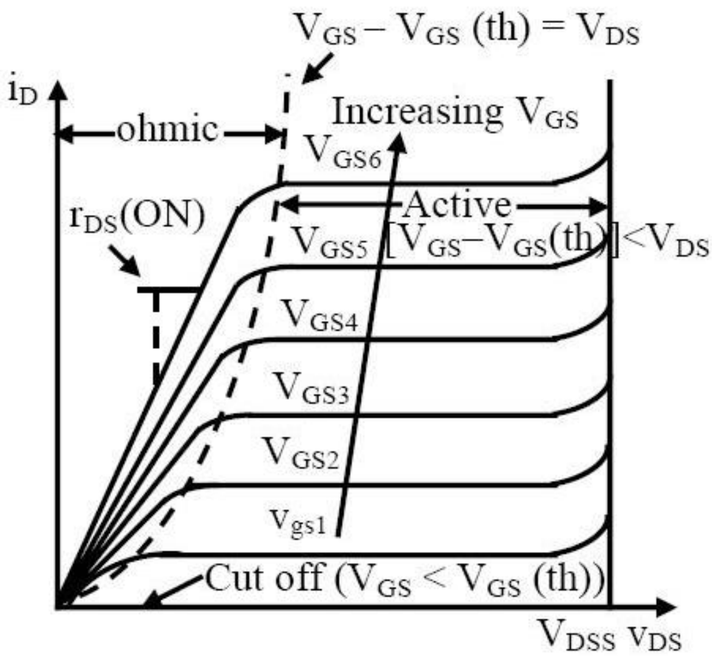


Fig 1.9: V-I characteristics of MOSFET

CIRCUIT DIAGRAM

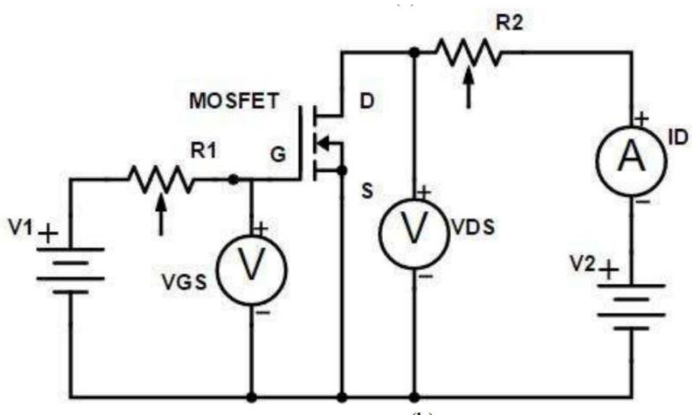


Fig 1.10: Circuit diagram of MOSFET

PROCEDURE

1) Keep V_{DS} say 5 V & vary V_{GS} in steps & note down corresponding value of drain current.
2) When keeping V_{GS} at V_{GS} & vary V_{DS} in steps to note corresponding value of drain current.
3) Then repeat for different values of constant V_{GS} & constant V_{DS}.
4) Plot the drain characteristics V_{DS}, V_S, I_D for constant value of V_{GS} & plot the graph for transfer characteristics where V_{GS}, V_S, I_D is plotted keeping V_{DS} constant.

OBSERVATION TABLE

CONCLUSION

SL. No	Voltage (V_{DS} in volt)	Current (I_D in mA)

QUESTIONS

1) Explain transfer characteristics of power MOSFET?

2) Explain enhancement type MOSFET?

3) What are the main constructional differences between a MOSFET and a BJT?

EXPERIMENT: – 2

AIM OF THE EXPERIMENT

To study the cosine-controlled triggering circuit

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	Cosine Trainer Kit		
2	Mains supply		
3	DC power supply		
4	Multimeter		
5	Ammeter		
6	DSO		
7	Patch cords		

THEORY

The synchronizing transformer steps down the supply voltage to an appropriate level. The input to this transformer is taken from the same source from which converter circuit is energized.The output voltage V_1 of synchronizing transformer is integrated to get cosine-wave V_2. The d.c. control voltage Ec varies from maximum positive Ecm to maximum negative Ecm so that firing angle can be varied from zero to 180°.The cosine wave V_2 is compared in comparators 1 and 2 with Ec and −Ec. When Ec is high as compared toV_2, output voltage v3 is available from comparator 1. Same is true for comparator 2. So, the comparators 1 and 2 give output pulses V_3 and V_4 respectively as shown in Fig. It is seen from this figure that firing angle is governed by the intersection of V_2 and Ee. When Ec is maximum, firing angle is zero. Thus, firing angle α in terms of V_{2m} and Ec can be expressed as

$$V_{2m}\cos\alpha = Ec$$

OR

$$\alpha = cos-^{1}\left(\frac{Ec}{V2m}\right) \text{-----(1)}$$

where V_{2m} = maximum value of cosine signal V_2

The signals V_3, V_4 obtained from comparators are fed to clock-pulse generators 1,2 to get clock pulses V_5, V_6 as shown in Fig. These signals V_5, V_6 energies a JK flip flop to generate output signals Vi and V_j. The signal V_j is amplified through the circuit and is then employed to turn on the SCRs in the positive half cycle. Signal V_j, after amplification. is used to trigger SCRs in the negative half cycle.

For a single-phase full converter, average output voltage is given by

$$V_o = \frac{2Vm}{\pi} cos\alpha \text{-----(2)}$$

Substituting the value of α from Eq. 1 in Eq. 2, we get,

$$V_o = \frac{2V_m}{\pi}\cos\left[cos^{-1}\frac{E_c}{V_{2m}}\right]$$

$$= \frac{2V_m}{\pi}.\frac{1}{V_{2m}}.E_c$$

$$V_o = kE_c$$

This shows that cosine firing scheme provides a linear transfer characteristic between the average output voltage V_o and the control voltage Ee. This scheme, on account of its linear transfer characteristic, improves the closed-loop response of the converter system.

MODEL GRAPH

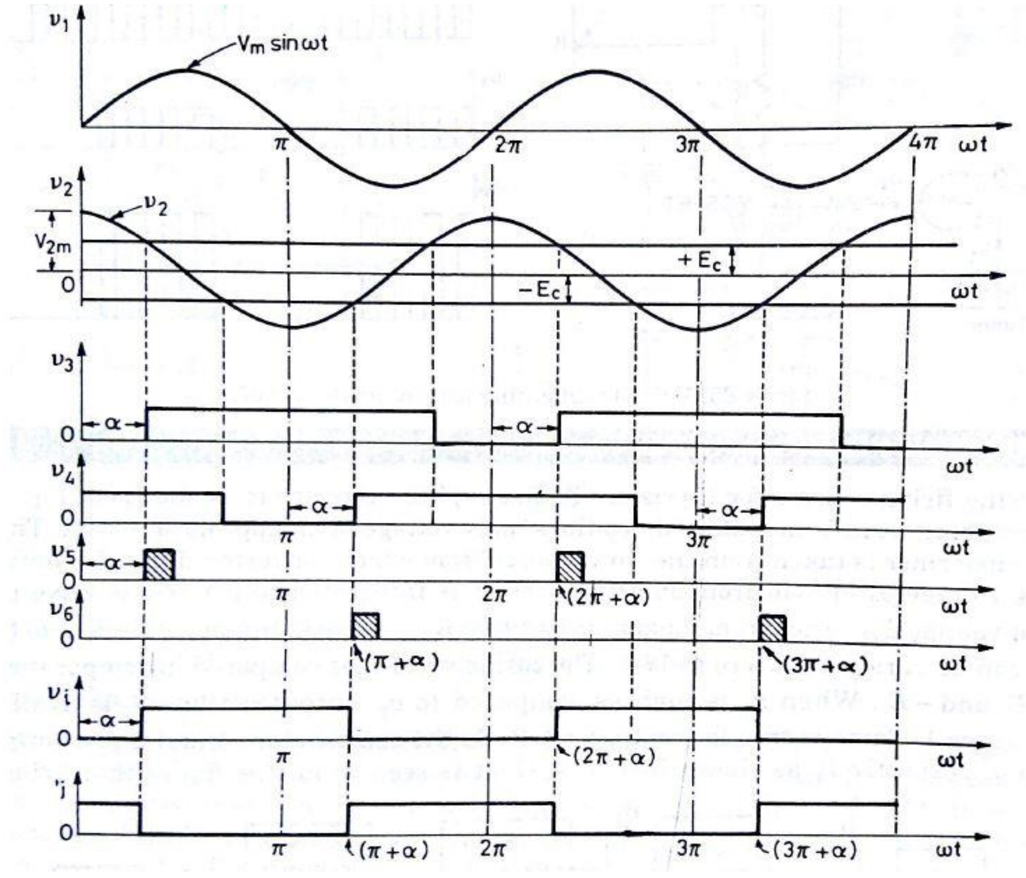


Fig 2.1: Waveform of cosine firing scheme

CIRCUIT DIAGRAM

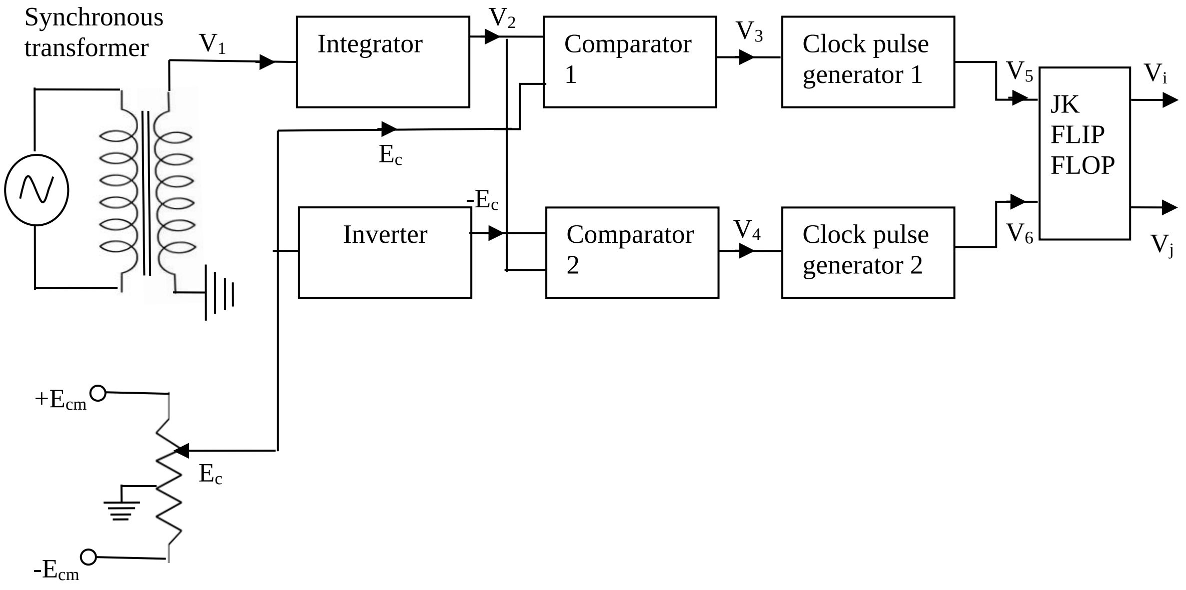


Fig.2.2: Circuit diagram for cosine firing scheme

PROCEDURE

1**)** Connect terminals of UJT triggering circuit to the gate cathode terminals of SCR.

2) Give a 24V ac supply.

3) Observe the waveforms and plot it for one particular firing angle by adjusting the potentiometer and observe the range over which firing angle is controllable.

4) Observe that capacitor voltage is set at every half cycle.

OBSERVATION TABLE

Resistor value	Capacitor voltage	Comparator Output voltage	Time period

CONCLUSION

QUESTIONS

1) Explain how synchronization of the triggering circuit with the supply voltage across SCR is achieved?
2) How can the capacitor charging be controlled?
3) What is ramp control or open loop control?

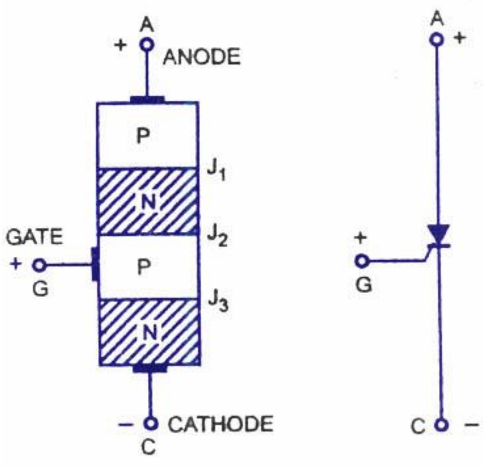
EXPERIMENT: – 3

AIM OF THE EXPERIMENT
To measure the latching and holding current of SCR.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	SCR Trainer		
2	Mains supply		
3	DC power supply		
4	Voltmeter		
5	Ammeter		
6	Patch cords		

THEORY
A thyristor is a four-layer semiconductor device of PNPN structure with three PN junctions. It has three terminal anode, cathode and gate. When the anode voltage is made positive with respect to cathode, the junctions J_1 and J_3 are forward biased. The junctions J_2 is reversed biased and, only a small leakage current flows from anode to cathode. The thyristor is then said to be in the OFF mode. If a Anode to Cathode voltage is increased to a sufficiently large value, the reversed biased junction J_2 will break. This is known as **avalanche breakdown** and the corresponding voltage is called **forward breakdown voltage** V_{BO}. Since junctions J_1 and J_3 are already forward biased, there will be free movement of carriers across all three junctions, resulting in a large forward anode current. The device will then be in a conducting state or on state. The voltage drop would be due to the ohmic drop in the four layers and it is small, typically, 1V. In the on state, the anode current is limited by an external impedance or resistance.



(a) (b)

Fig 3.1: (a)Schematic Diagram (b)Symbolic Representation of SCR

MODEL GRAPH

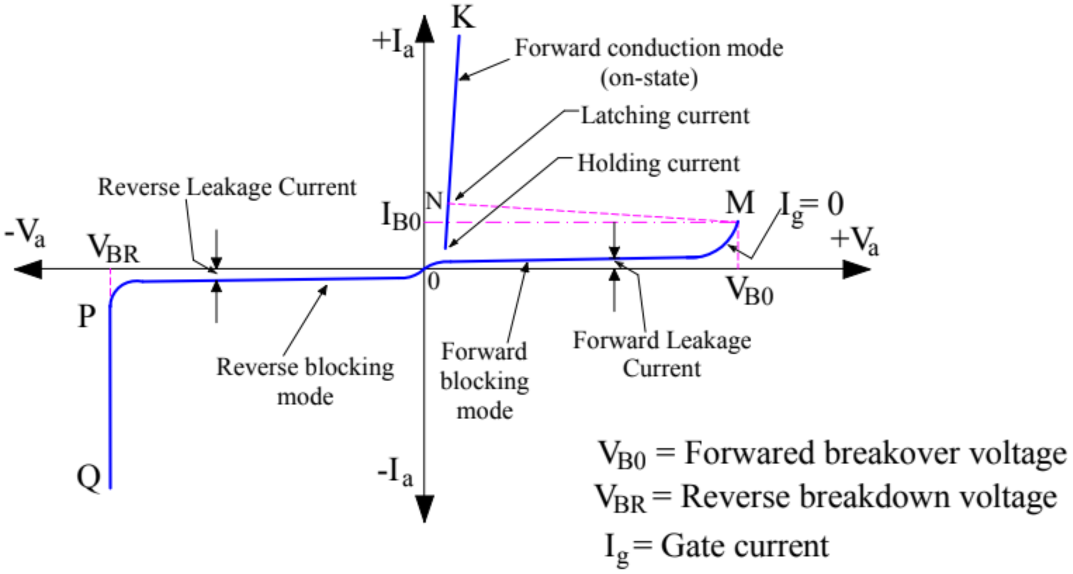


Fig 3.2: V-I characteristics of SCR

CIRCUIT DIAGRAM

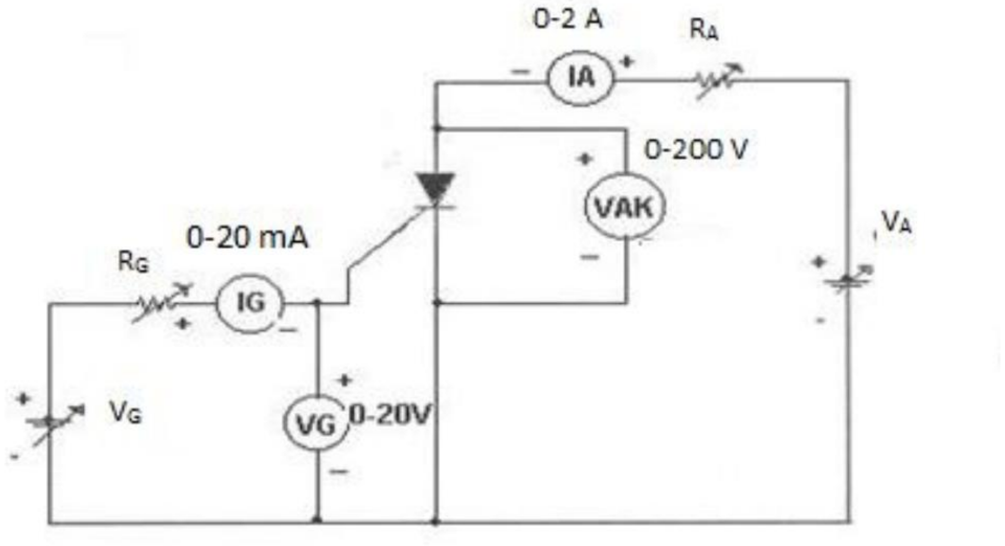


Fig 3.3: Circuit diagram of SCR

PROCEDURE

To find latching current:
1. Keep R_2 at middle position.
2. Apply 20V to the Anode to cathode by varyingV_2.
3. Rise the V_g voltage by varying V_G till the device turns ON indicated by sudden rise in I_A. At what current SCR trigger it is the minimum gate current required to turn ON the SCR.
4. Now set R_A at maximum position, then SCR turns OFF, if it is not turned off reduce V_A up to turn off the device and put the gate voltage.
5. Now decrease the R_A slowly, to increase the Anode current gradually in steps.
6. At each and every step, put OFF and ON the gate, voltage switches V_G. If the Anode current is greater than the latching current of the device, the device says ON even after switch OFF S1, otherwise device goes to blocking mode as soon as the gate switch is put OFF.
7. If $I_A > I_L$ then, the device remains in ON state and note that anode current as latching current. 8. Take small steps to get accurate latching current value.

To find holding current:
1. Now increase load current from latching current level by varying R_A & V_A.
2. Switch OFF the gate voltage switch S_1 permanently (now the device is in ON state).
3. Now increase load resistance(R_2), so that anode current reducing, at some anode current the device goes to turn off. Note that anode current as holding current.
4. Take small steps to get accurate holding current value.
5. Observe that $I_H < I_L$.

OBSERVATION

Latching current = ________________
Holding current = ________________

CONCLUSION

QUESTIONS

1. What is a Thyristor? Draw the structure of an SCR?
2. What are the different methods of turning on an SCR?
3. Differentiate between holding and latching currents.
4. What are applications of SCR?

EXPERIMENT: – 4(a)

AIM OF THE EXPERIMENT

To study the single-phase half wave-controlled rectifier with R and R-L load.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	1-phase controlled rectifier trainer kit		
2	Gate triggering circuit		
3	DSO		
4	1-ph Variac		
5	Multi-meter		
6	R and R-L load		
7	Connecting wires		

THEORY;

We know that thyristor is a unidirectional device, allowing the flow of current only in one direction. When the thyristor is forward-biased i.e., anode terminal is positive with respect to the cathode terminal, and the gate terminal is not triggered, there will be no conduction due to the reverse biasing of the inner junction of SCR. Hence, the entire supply voltage appears across the SCR. The magnitude of the conduction current depends upon the instant when it is triggered i.e., firing angle 'α', and the load resistance R. Since the circuit does not contain any energy storing elements, the load current will be in phase with voltage and becomes zero instantaneously with the voltage at zero crossing (at $\omega t = \pi$ rad/sec). The load current and voltage are zero from 0 to α. When SCR is triggered by giving gate signal at α. The entire supply voltage except for drop across SCR will be applied across the load (from $\omega t = \alpha$ to $\omega t = \pi$). At $\omega t = \pi$, the phase reversal takes place and the negative half-cycle of the input supply will start. Due to the negative half-cycle, the SCR will be reverse biased and will be turned OFF at $\omega t = \pi$. From $\omega t = \pi$ to $\omega t = 2\pi$, the load current and voltage will be zero. Again, when the positive half cycle starts i.e., from $\omega t = 2\pi$, SCR will be forward biased but it will not be switched ON until it is triggered i.e., until $\omega t = (2\pi + \alpha)$

MODEL GRAPH

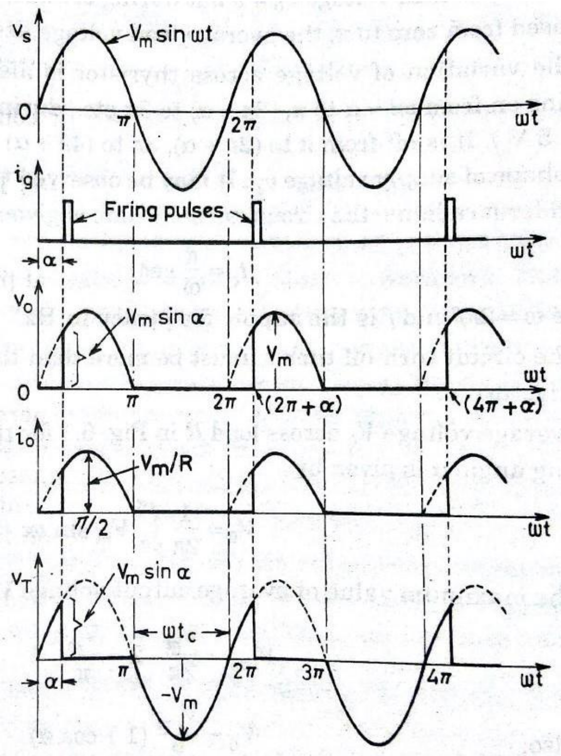


Fig 1: For R load

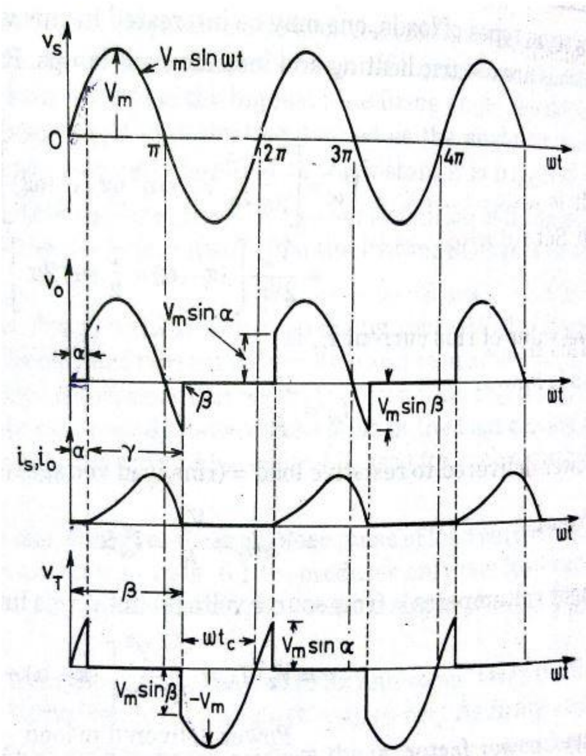
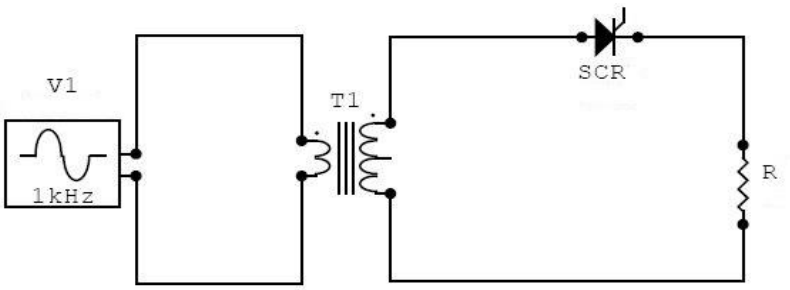
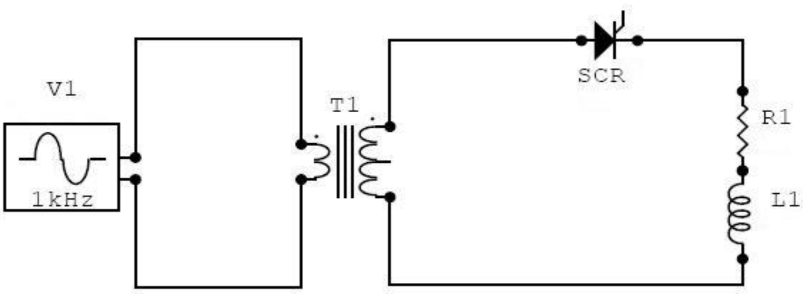


Fig 2: For RL load

CIRCUIT DIAGRAM



Half wave controlled rectifier with resistive load.



Half wave controlled rectifier with RL load.

Fig 3: Circuit diagram for half wave converter

PROCEDURE

1.Make the connections as per the circuit diagram.

2. Connect CRO and voltmeter across the load.

3. Keep the potentiometer at the minimum position.

4. Switch on the step-down ac source.

5. Check the gate pulses and observe the wave form on CRO and note the triggering angle ‘α’ and note the corresponding reading of the voltmeter and tabulate the readings.

OBSERVATION TABLE

SL No.	I/P Voltage (Volts)	Firing angle in degree	O/P Voltage (Volts)	O/P Current (Amperes)	Theoretical Calculations			
					RMS Voltage (Volts)	Average Voltage (Volts)	Form Factor	Ripple Factor

CONCLUSION

QUESTIONS

1. What is extinction angle?

2. What are the advantages of adding freewheeling diode in half wave circuit with RL load?

3. What are the disadvantages of half controlled converter circuit?

4. How to calculate the input power factor of half wave-controlled circuit.

EXPERIMENT: – 4(b)

AIM OF THE EXPERIMENT

To study the single-phase half wave semi-controlled rectifier with R and R-L load.

APPARATUS REQUIRED

Sl No.	Name of Apparatus	Specification	Quantity
1	1-phase SCR controlled trainer kit		
2	Gate triggering circuit		
3	DSO		
4	1-ph Variac		
5	Multi-meter		
6	R, R-L, Lamp Load		
7	Connecting wires		

THEORY;

The bridge circuit of the circuit of the semi converter has two diodes (D_1, D_2) and two SCRs (T_1, T_2). Pair of a diode and SCR (D_2, T_1) is connected in the parallel with another pair of a diode and SCR (D_1, T_2). And finally, the bridge circuit has a parallel connection with the RL circuit. Thus, this bridge circuit is the main circuit of the semi converter.

A free-wheeling diode (FD) has its connection in parallel with the load and bridge circuit. The freewheeling diode freewheels the energy stored in the inductor and, thus limits the overvoltage.

MODEL GRAPH

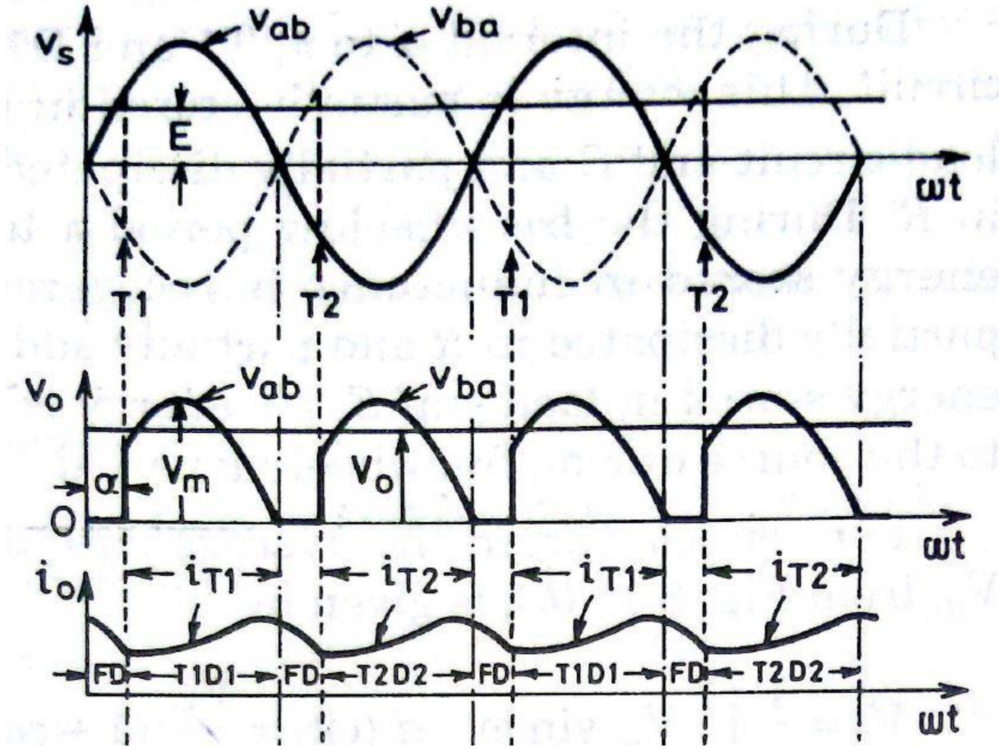


Fig 4: For RL Load

CIRCUIT DIAGRAM

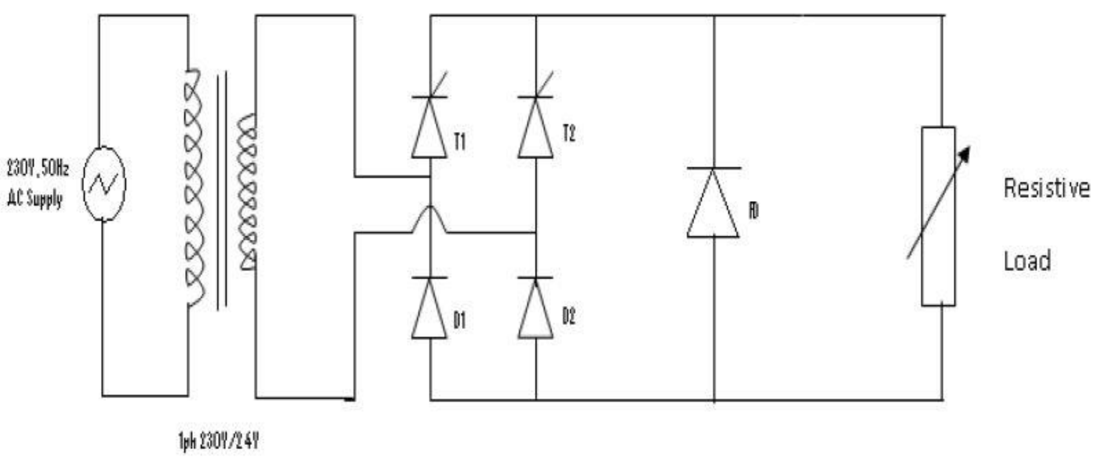


Fig 5: Circuit diagram for semi-controlled converter

PROCEDURE

1. Make the connections as per the circuit diagram.
2. Connect CRO and voltmeter across the load.
3. Keep the potentiometer at the minimum position.
4. Switch on the step-down ac source.
5. Check the gate pulses and observe the wave form on CRO and note the triggering angle ‘α’ and note the corresponding reading of the voltmeter and tabulate it.

OBSERVATION TABLE

SL No.	I/P Voltage (Volts)	Firing angle in degree	O/P Voltage (Volts)	O/P Current (Amperes)	Theoretical Calculations			
					RMS Voltage (Volts)	Average Voltage (Volts)	Form Factor	Ripple Factor

CONCLUSION

QUESTIONS

1. What is conduction angle?
2. What are the effects of adding freewheeling diode in this circuit?
3. What are the effects of removing the freewheeling diode in single phase semi converter?
4. Why is the power factor of semi converters better than that of full converters?
5. What is the inversion mode of converters?

EXPERIMENT: – 5(a)

AIM OF THE EXPERIMENT

To study single-phase full wave-controlled rectifier circuits (Bridge type) with R and R-L load.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	SCR trainer kit		
2	Gate triggering circuit		
3	DSO		
4	1-ph Variac		
5	Multi-meter		
6	Ammeter		
7	Connecting wires		

THEORY

A fully controlled converter uses thyristors only and there is a wider control over the leave of dc output voltage. With pure resistive load, it is single quadrant converter. Here, both the output voltage and output current are positive. With the RL-load it becomes a two-quadrant converter. Here, output voltage is either positive or negative but output current is always positive. This type of full wave rectifier circuit consists of four SCRs.

During the positive half cycle, SCRs T_1 and T_2 are forward biased. At $\omega t=\alpha$, SCRs T_1 and T_3 are triggered, then the current flows through the L – T_1-R load -T_3-N. At $\omega t=\pi$, supply voltage falls to zero and the current also goes to zero. Hence SCRs T_1 and T_3 turned off.

During negative half cycle (π to 2π). SCRs T_3 and T_4 Forward biased. At $\omega t=\pi+\alpha$, SCRs T_2 and T4 are triggered, then current flows through the path N-T_2 -R load -T_4-L. At $\omega t=2\pi$, supply voltage and current go to zero, SCRs T_2 and T_4 are turned off.

MODEL GRAPH

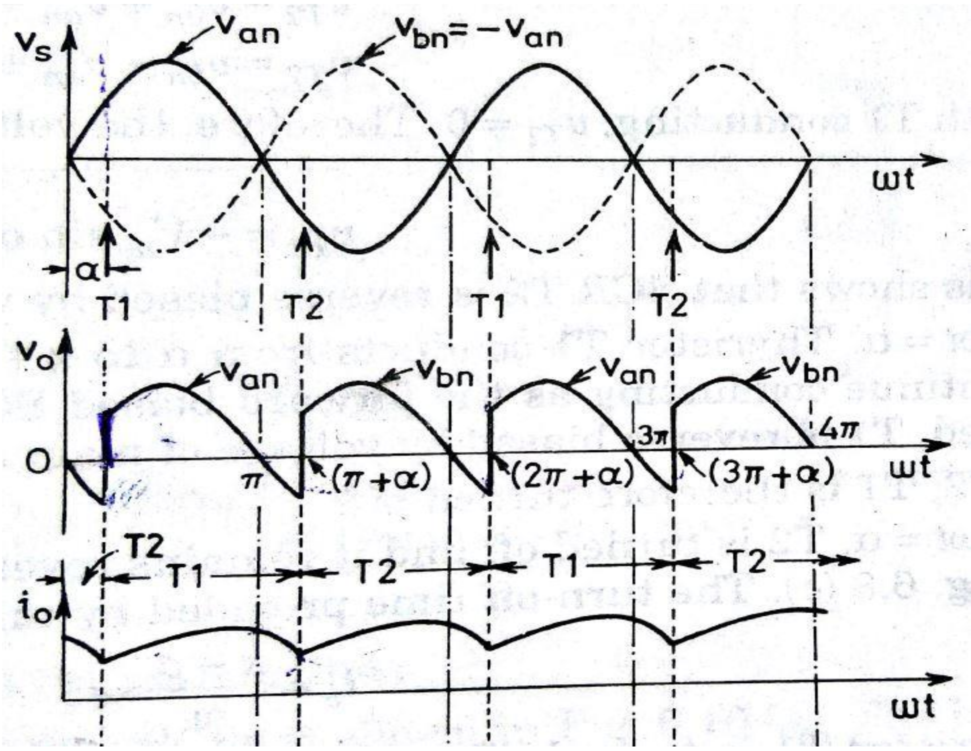


Fig 1: For RL load

CIRCUIT DIAGRAM

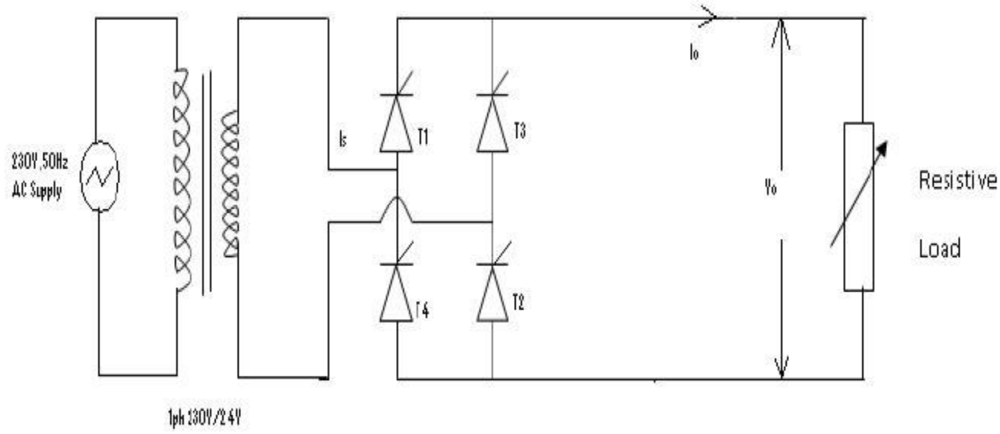


Fig 2: Circuit diagram for full wave bridge type converter

PROCEDURE

1. Make the connections as per the circuit diagram.

2. Connect CRO and voltmeter across the load.

3. Keep the potentiometer at the minimum position.

4. Switch on the step-down ac source.

5. Check the gate pulses and observe the wave form on CRO and note the triggering angle 'α' and note the corresponding reading of the voltmeter.

6. Draw the waveforms observed on CRO and tabulate the readings.

OBSERVATION TABLE

SL No.	I/P Voltage (Volts)	Firing angle in degree	O/P Voltage (Volts)	O/P Current (Amperes)	Theoretical Calculations			
					RMS Voltage (Volts)	Average Voltage (Volts)	Form Factor	Ripple Factor

CONCLUSION

QUESTIONS

1. If firing angle is greater than 90 degrees, the inverter circuit formed is called as?
2. What is displacement factor?
3. What is Dc output voltage of single-phase full wave controller?
4. What are the effects of source inductance on the output voltage of a rectifier?
5. What is commutation angle of a rectifier?
6. What are the advantages of three phase rectifier over a single-phase rectifier?

EXPERIMENT: – 5(b)

AIM OF THE EXPERIMENT

To study single-phase full wave-controlled rectifier circuits (mid-point type) with R and R-L load.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	Mid-point type SCR trainer kit		
2	Gate triggering circuit		
3	DSO		
4	1-ph Variac		
5	Multi-meter		
6	Connecting wires		

THEORY

When the single phase fully controlled converter is connected with R-L load.

During the positive half cycle. Thyristor T_1 and T_1' are forward biased and when these two thyristors are fixed simultaneously at ωt=α, the load is connected to the input supply, through T1 and T1'. Due to the inductive load T_1 and T_1' will continue to conduct till (ωt=π+α) even through the input voltage is already negative half cycle of the input voltage thyristor T2 and T2' at (ωt=π+α) will apply to the supply voltage across thyristor T_1 and T_1' as reverse blocking voltage T_1 and T_1' will be turned off due to linear or natural commutation.

During the period (π+α) the input voltage Vs and input current is positive and the power flows from the supply to load. The converter is said to be operated in rectification made. During period from π to π+α the input voltage Vs is negative and the input current is positive, and there will be reverse power from the load to supply. The converter is said to be operated in inversion mode. The average output voltage can be found from Vdc = {2Vm/π} cosα

Note: In case of fully controlled bridge the triggering angle should not increase beyond αmax (approx. 160°) to allow conducting SCR sufficient time to turnoff. The maximum value of firing is obtained from the relation.

E=Vm sin(π+α)

where $\alpha = \pi \sin^{-1}\frac{E}{Vm}$ and E is counter emf generated in the inductor Io=Vo/RL for continuous and constant current.

MODEL GRAPH

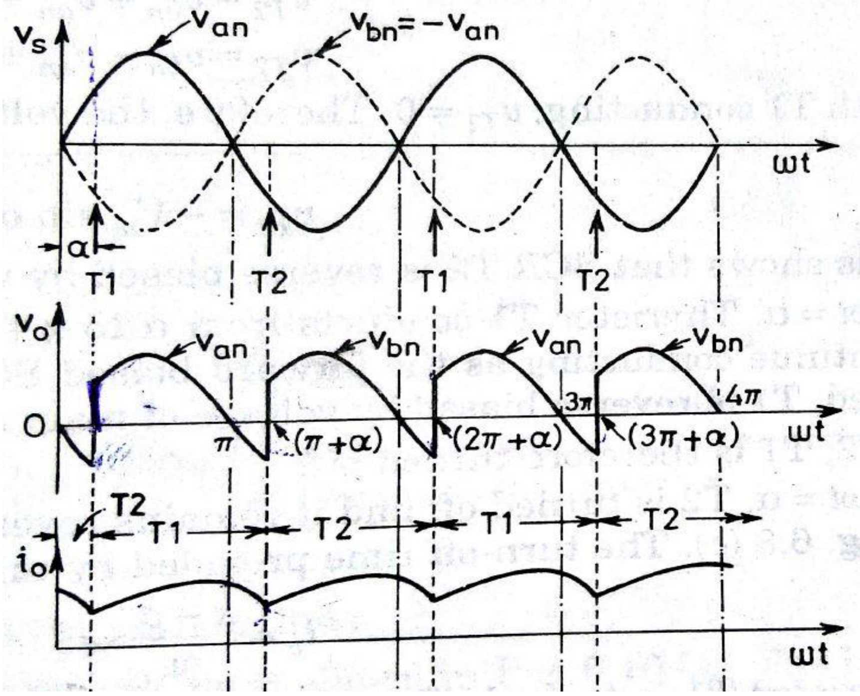
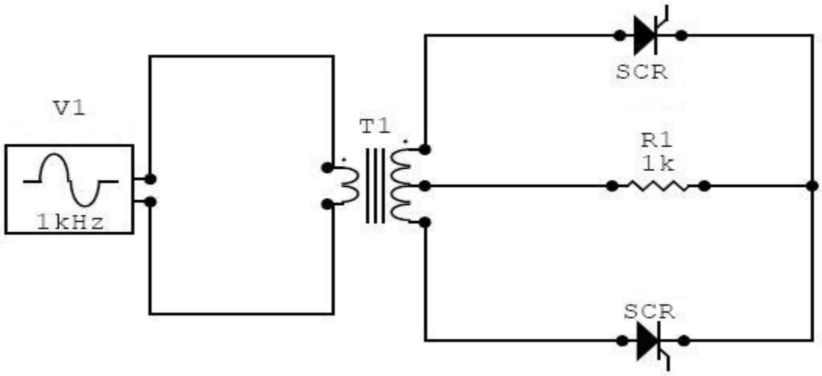


Fig 3: For RL load

CIRCUIT DIAGRAM



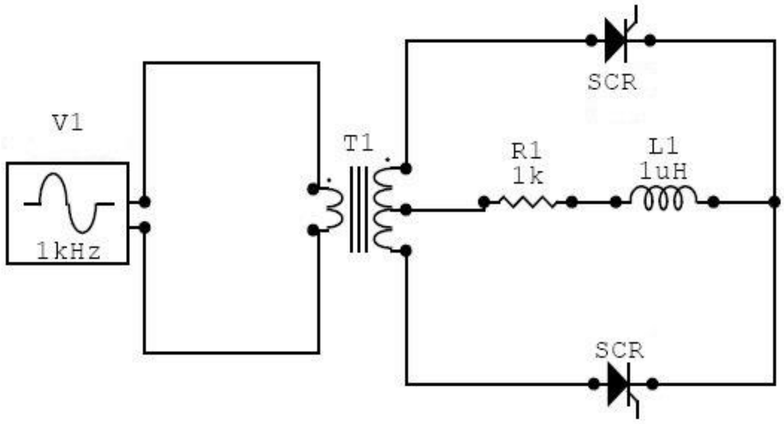


Fig 4: Circuit diagram for full wave midpoint type converter

PROCEDURE

1. Make the connections as per the circuit diagram.

2. Connect CRO and voltmeter across the load.

3. Keep the potentiometer at the minimum position.

4. Switch on the step-down ac source.

5. Check the gate pulses and observe the wave form on CRO and note the triggering angle ‘α’ and note the corresponding reading of the voltmeter.

6. Draw the waveforms observed on CRO and tabulate the readings.

OBSERVATION TABLE

SL No.	I/P Voltage (Volts)	Firing angle in degree	O/P Voltage (Volts)	O/P Current (Amperes)	Theoretical Calculations			
					RMS Voltage (Volts)	Average Voltage (Volts)	Form Factor	Ripple Factor

CONCLUSION

QUESTIONS

1. What is line commutation?
2. What are the disadvantages of midpoint configuration?
3. What is the effect of commutation failure in mid-point type full wave converter?
4. Differentiate midpoint type and bridge type full wave converter.
5. How to calculate the circuit turn off time.

EXPERIMENT: – 6

AIM OF THE EXPERIMENT

To study Three Phase Semi-controlled & Fully Controlled Rectifier circuit with R and R-L load.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
01	3-phase Power modulator Kit		
02	DSO		
03	Ammeter/Voltmeter		
04	3-phase Variac		
05	Multi-meter		
06	Type of Loads (R/R-L load)		
07	Patch Chord/ Connecting leads		

THEORY

Three phase converters are extensively used in industrial application up to 120kw level.

A full converters circuit, the thyristor is fired at an interval of π/3. The frequency of output ripple voltage is 6fs and the filtering requirement is less than that of three phase semi and half wave converters.

At ωt=π/6+α, thyristor T_4 is already conducting and thyristor T_1 is turned on during the interval (π/6+α) ≤ ωt ≤ (π/2+α), thyristor T_1 is turned on and the line-to-line voltage, Vab=(Van-Vbn) appears across the load.

At ωt=T_4 is turned off due to natural commutation. During the internal (π/2+α) ≤ ωt ≤ (π/2+α), thyristor $T_1$and T_6 conduct and the line-to-line voltage Vac appears the load. If the thyristor is numbered as shown in firing sequence is (1,6), (6,3), (3,2), (2,5), (5,4), and (4,1).

Formula Used

Semi-controlled Converter

$$Vdc = \frac{3\sqrt{3}\ \ Vm}{2\pi}(1+\cos\alpha)$$

Fully Controlled Converter

$$Vdc = \frac{3\sqrt{3}\ \ Vm}{\pi}\cos\alpha$$

CIRCUIT DIAGRAM

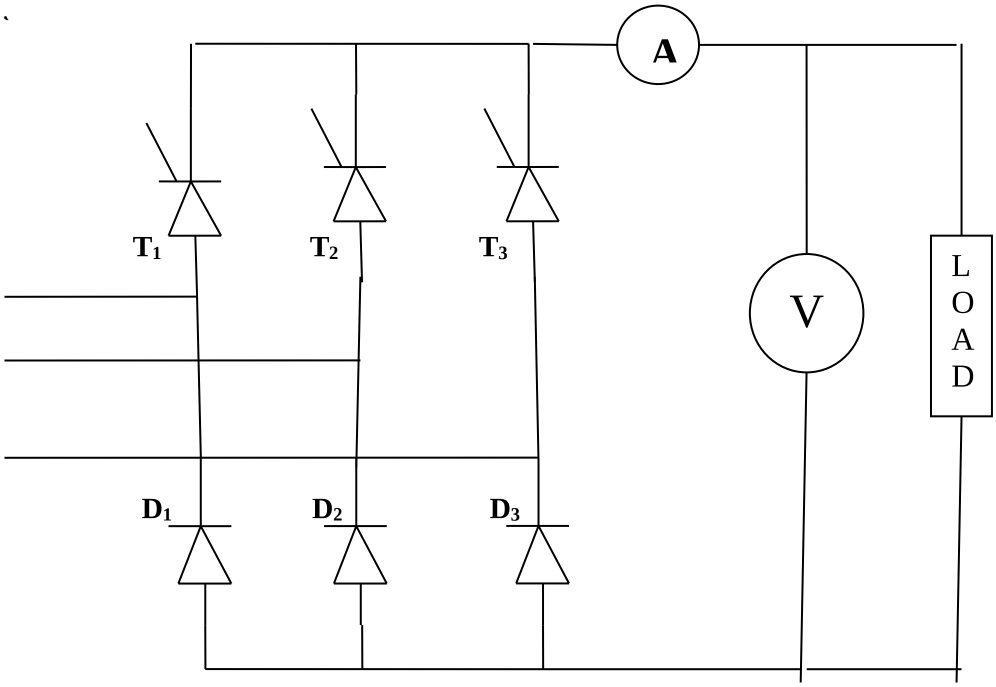


Fig : Three-phase semi-controlled Rectifier with R, R-L Load

3Phase, 440 V

50Hz ac supply

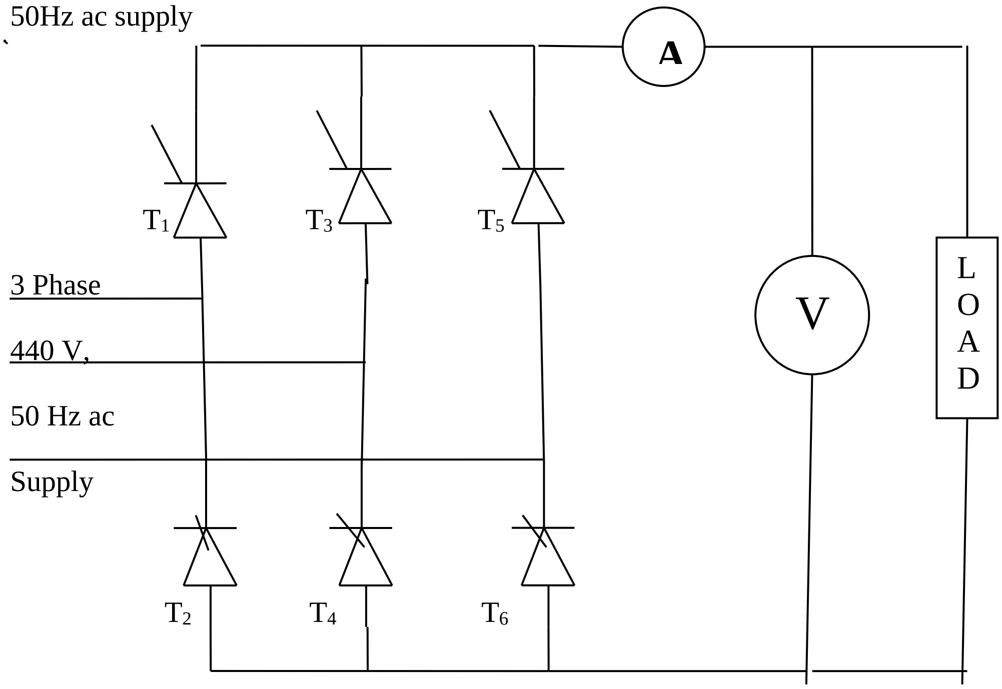
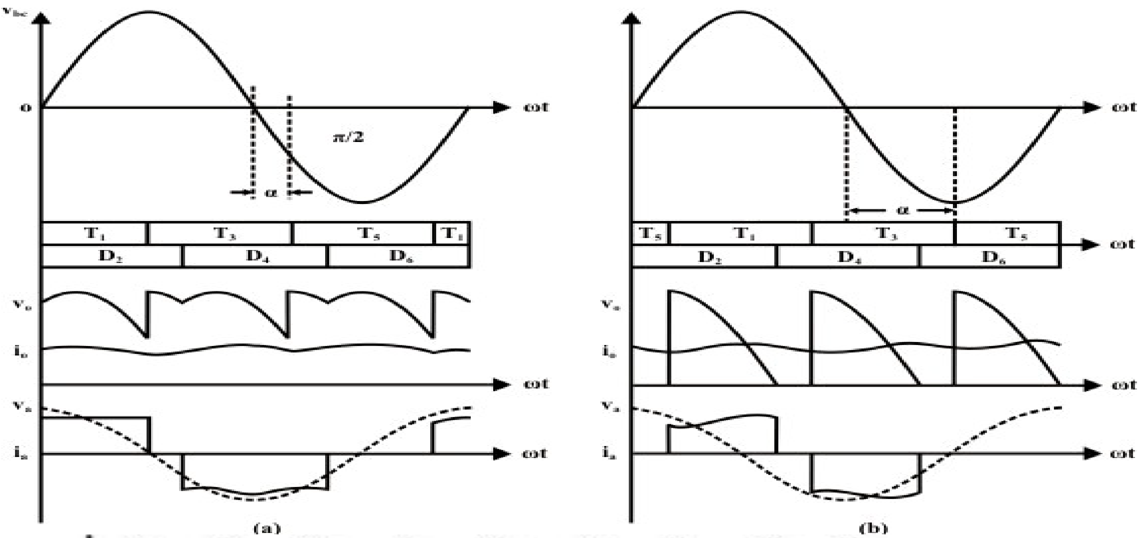


Fig 2: Three-Phase Fully Controlled Converter with R, R-L Load

Output Voltage Waveforms:

Fig : Output Waveforms of Semi-Controlled Converter (a) $\alpha = 30$ and (b) $\alpha = 90$



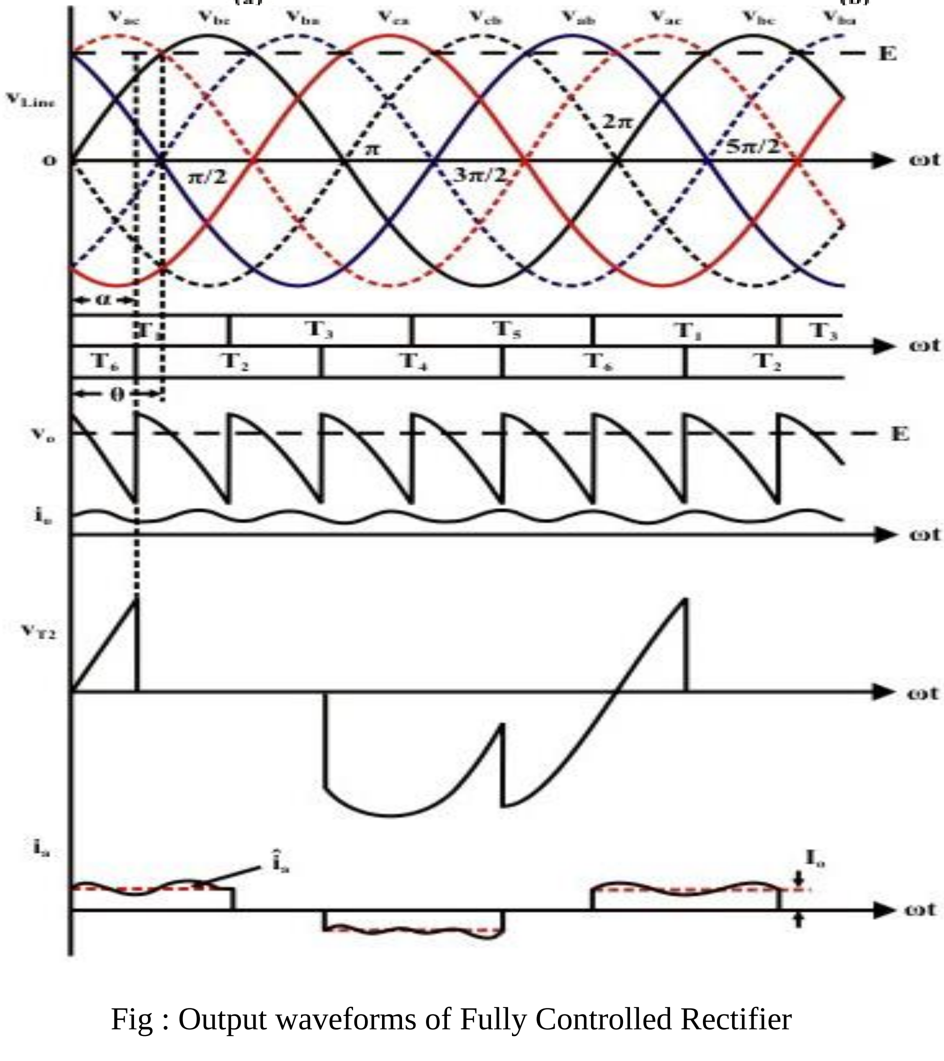


Fig : Output waveforms of Fully Controlled Rectifier

PROCEDURE

1. Connect the circuit as per circuit diagram.
2. Vary the firing angle of the Thyristor Pairs to obtain different values of Voltage & current.
3. Record the output voltage & current.
4. Trace the waveform displayed in the DSO.
5. Repeat step 2 to 4 for R-L Load.
6. Calculate the Performance Parameters.

OBSERVATION TABLE FOR SEMI-CONTROLLED CONVERTER

S No	V_{dc} practical (V)	I_{dc} Practical (A)	Firing Angle (degree)	Vdc Theoretical (V)	Idc Theoretical (A)	Vrms	Input Power Factor	TUF	Ƞ (%)

OBSERVATION TABLE FOR FULLY CONTROLLED CONVERTER

SL No	V_{dc} practical (V)	I_{dc} Practical (A)	Firing Angle (degree)	Vdc Theoretical (V)	Idc Theoretical (A)	Vrms (v)	Input Power Factor	TUF	Ƞ (%)

CONCLUSION:

QUESTIONS:

1. Why is the power factor of semi-converters better than full converters?
2. What are the drawbacks of semi-controlled converter over fully controlled converter?
3. What is the inversion mode of converter?
4. What are the advantages of 3-phase full wave converter over 3-phase semi-controlled converter?

EXPERIMENT: – 7

AIM OF THE EXPERIMENT
To study Buck Converter & Boost Converter.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
01	Chopper Power modulator Kit		
02	DSO		
03	Ammeter		
04	Voltmeter		
05	Type of Loads		
06	Patch Chords		

THEORY
Switches shown below in the circuit diagrams are power electronics switches. For low voltage and low power applications power BJTs are used, for medium power applications power MOSFETs & power IGBTs are used and for high voltage and high-power applications power IGCTs are used.
Formula Used for Buck Converter

$$V_0 = \frac{Ton}{T}\ Vs$$

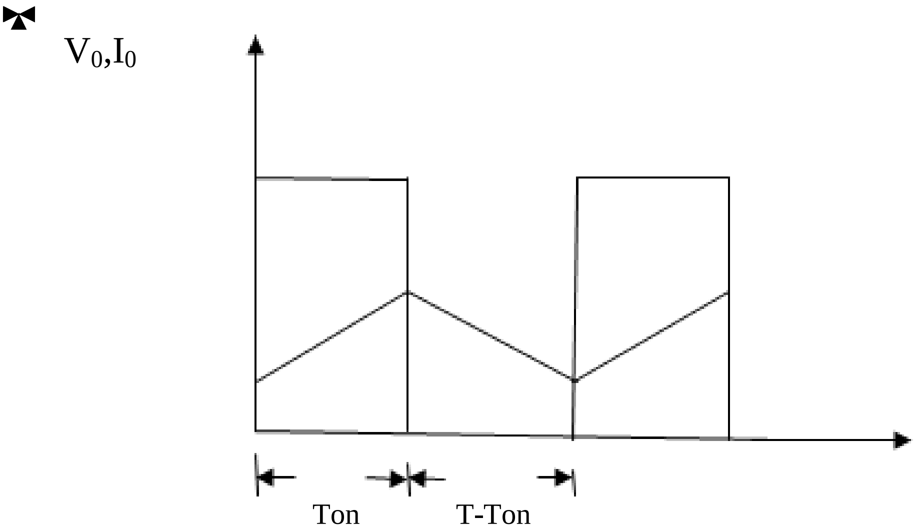


Fig: Output Voltage & Current waveform of Buck converter

Formula Used for Boost Converter

$$V_\circ = \frac{1}{1-\alpha}\ V_s$$

Where,

$$\alpha = Duty\ Cycle = \frac{T_{on}}{T}$$

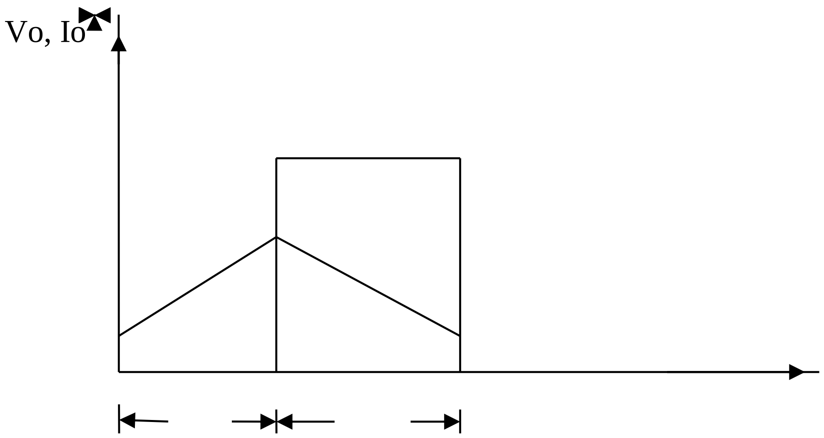


Fig: Output Voltage & Current Waveform of Boost Converter

CIRCUIT DIAGRAM

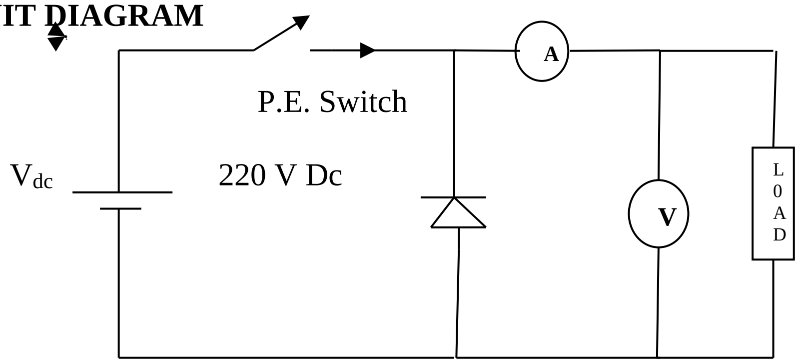


Fig : Buck Converter

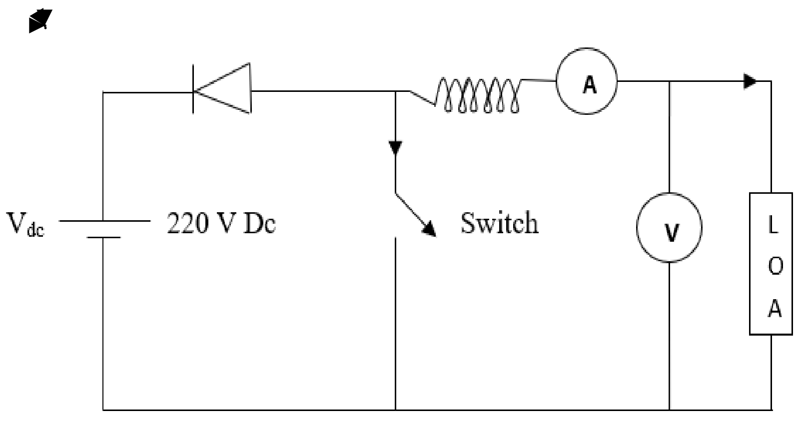


Fig: Boost Converter

PROCEDURE

1.Connect the circuit as per circuit diagram.
2.In case of buck converter during $0 \leq t \leq$ Ton, PE switch is closed and o/p voltage is obtained but during interval $T_{on} \leq t \leq T$, switch is opened and o/p voltage is zero.
3.In case of boost converter during $0 \leq t \leq$ Ton, PE switch is closed and o/p voltage is zero but during interval $T_{on} \leq t \leq T$, switch is opened and o/p voltage is obtained.
4.Vary the duty cycle of the power semiconductor device to obtain different values of Voltage & current.
5.Trace the waveform displayed in the DSO.
6.Repeat steps 2 to 4 for R-L Load.
7.Calculate the Performance Parameters.

OBSERVATION TABLE FOR BUCK CONVERTER

Sl. No	V_{dc} practical (V)	I_{dc} Practical (A)	Duty Cycle (Sec)	Vdc Theoretical (V)	Idc Theoretical (A)	Vrms (V)	Input Power Factor	η (%)

OBSERVATION TABLE FOR BOOST CONVERTER

Sl. No	V_{dc} practical (V)	I_{dc} Practical (A)	Duty Cycle (Sec)	Vdc Theoretical (V)	Idc Theoretical (A)	Vrms (V)	Input Power Factor	η (%)

CONCLUSION:

QUESTIONS:

1. What is the principle of operation of a step-down chopper?
2. What is the principle of operation of step-up chopper?
3. What is the frequency modulation of a converter?
4. Why step chopper is also known as fly-back converter?
5. What is the effect of load inductance on ripple load current?

EXPERIMENT: – 8

AIM OF THE EXPERIMENT

To study of single Phase PWM Voltage Source Inverter.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
01	Power modulator Kit		
02	DSO		
03	Ammeter/Voltmeter		
04	Load		
05	Connecting Leads		

THEORY

The system consists of two independent circuits illustrating single-phase PWM voltage-sourced inverters. The Half-Bridge Converter block and the Full-Bridge converter block are modeling simplified model of an IGBT/Diode pair where the forward voltages of the forced-commutated device and diode are ignored. The converters are controlled in open loop with the PWM Generator blocks. The two circuits use the same DC voltage (Vdc = 400V), carrier frequency (1620 Hz) and modulation index (m = 0.8). In order to allow further signal processing, signals displayed on the Scope block are stored in a variable named Scope Data For FFT, in structure with time format.

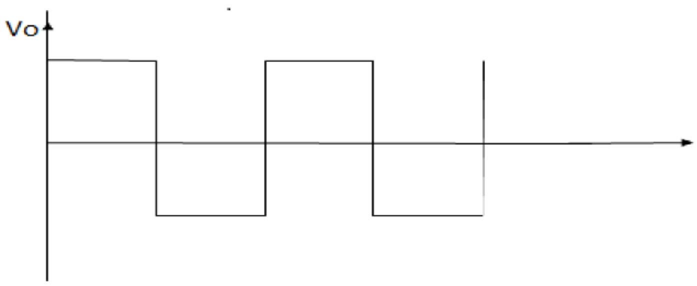


Fig : Output voltage waveform of single Phase Full Bridge Inverter

Note: Switches shown in the circuit diagrams are power electronics switches. For low voltage and low power applications power BJTs are used, for medium power applications power MOSFETs & power IGBTs are used and for high voltage and high-power applications power IGCTs are used.

CIRCUIT DIAGRAM

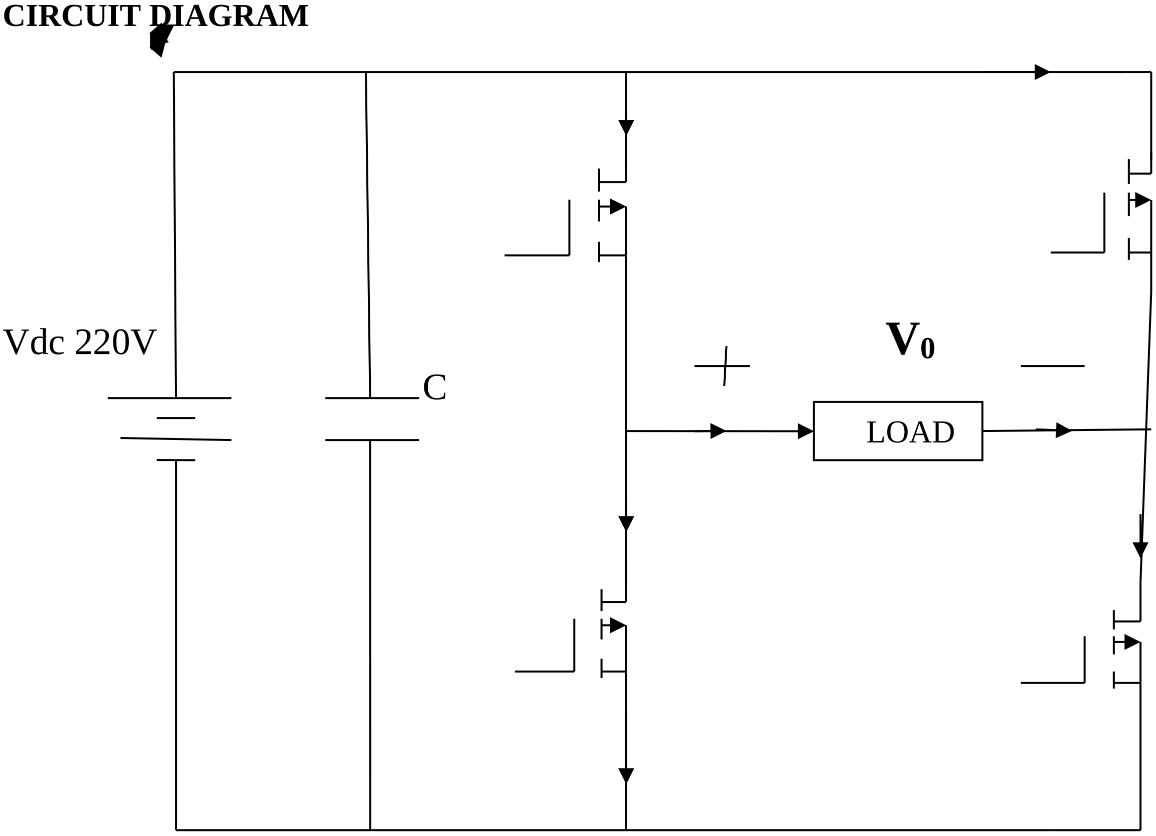


Fig: Single Phase PWM VSI Inverter

PROCEDURE

1.Connect the circuit as per circuit diagram.

2. Vary the firing angle of the power semiconductor devices pairs to obtain different values of Voltage & current.

3.Record the output voltage & current.

4.Trace the waveform displayed in the DSO.

5.Repeat step 2 to 4 for R-L Load.

6.Calculate the performance parameters.

OBSERVATION TABLE

SL. No	V_{dc} practical (V)	I_{dc} Practical (A)	Vdc Theoretical (V)	Idc Theoretical (A)	Input Power Factor	TUF	η (%)

CONCLUSION:

QUESTIONS:

1. What is an inverter?
2. What is the principle of operation of an inverter?
3. What is the function of voltage balancing capacitor?
4. What is the purpose of feedback diodes in an inverter?
5. What are the differences between half-bridge and full-bridge inverter?
6. What is modulation index?

EXPERIMENT: – 9

AIM OF THE EXPERIMENT

To study of three phase Voltage Source Inverter with Pulse Width Modulation control**.**

APPARATUS REQUIRED

Sl No.	Name of Apparatus	Specification	Quantity
01	3-Phase VSI Power modulator Kit		
02	DSO		
03	Multi-meter		
04	Ammeter/Voltmeter		
05	Load		
06	Connecting Leads		

THEORY

The AC waveform produced by a single-phase inverter poor version of the sine wave and is not suitable for most industrial applications. However, complex inverters which are multiple switching devices are capable of generating ac voltage that are extremely close to a sine wave. For example, a three-phase inverter consists of six switching devices such as IGBTs, connected in a bridge configuration, which converts the dc supply into a three-phase ac voltage.

The switching devices can be triggered by applying the gate signals in 120° made each device conducts for 120°.The devices on the same arm operates in complementary manner,i.e.,T_1,T_4;T_3,T_6;T_5,T_2 are turned ON within a time interval the inverted arms are operated at 120° phase difference, i.e. ,the upper group of IGBTs T_1,T_3,T_5 conducts at an interval of 120°.If T_1 is triggered at $\omega t = 0$,then T3 $\omega t = 120°$ and for T_5 $\omega t = 240°$.The same is true for lower group of IGBTs.

The frequency of the output voltage can be controlled by varying the duty cycle and the frequency (V/F) for inductive loads the diodes connected in anti-parallel with devices. These diodes are called feedback diodes.

The duty cycle and frequency can be varied by the parameter setting through keyboard. The AC load voltage is controlled by controlling duty cycle and frequency. This will happen in the internal circuit.

A keyboard is provided to set the frequency and the duty cycle. The various parameters can be displayed by the liquid crystal display.

Vo

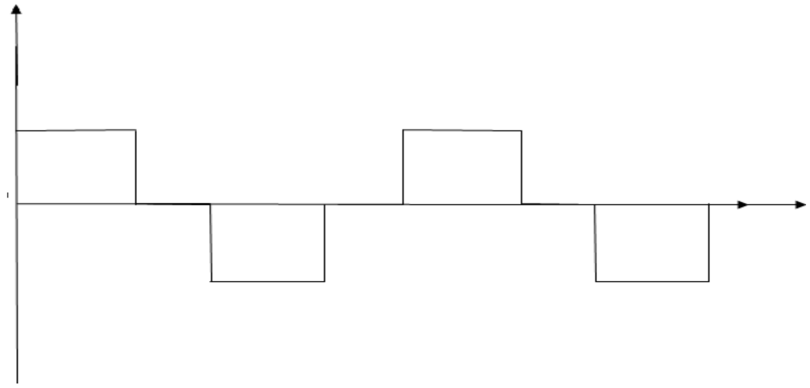


Fig: Output Voltage Waveform of 3 Phase Full Bridge VSI

Note: Switches shown in the circuit diagrams are power electronics switches. For low voltage and low power applications power BJTs are used, for medium power applications power MOSFETs & power IGBTs are used and for high voltage and high-power applications power IGCTs are used.

CIRCUIT DIAGRAM

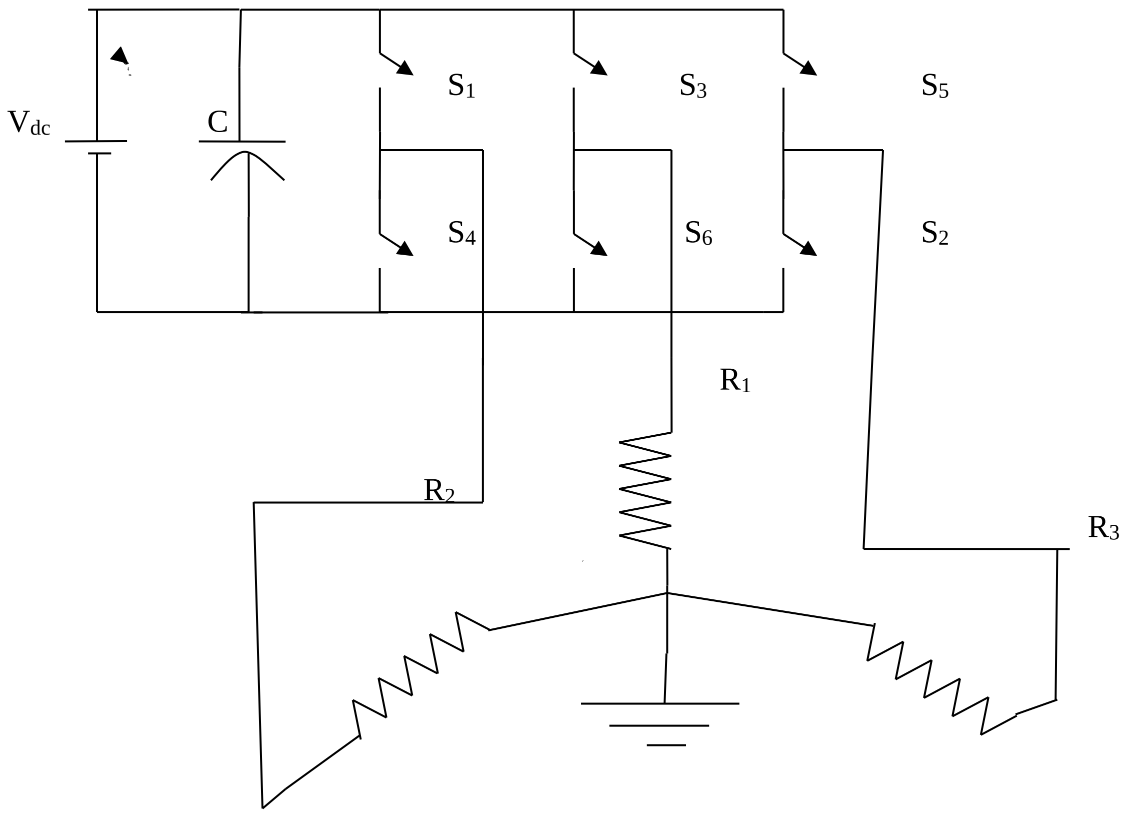


Fig : Three Phase PWM VSI

PROCEDURE

1.Connect the circuit as per circuit diagram.

2.Vary the firing angle of the Thyristor Pairs to obtain different values of Voltage & current.

3.Record the output voltage & current.

4.Trace the waveform displayed in the DSO.

5.Repeat step 2 to 4 for R-L Load.

6.Calculate the performance parameter.

OBSERVATION TABLE

Sl. No	V_{dc} practical(V)	I_{dc} Practical(A)	Vdc Theoretical(V)	I_{dc} Theoretical(A)	Input Power Factor	TUF	η (%)

CONCLUSION:

QUESTIONS:

1.What are the advantages of three- phase VSI over single phase full bridge inverter?

2.What are different conduction schemes of 3-phase Voltage Source Inverter?

3.Explain briefly 180° conduction scheme.

4.What are the different modulation schemes?

5.What are the advantages of multiple pulse width modulation scheme over sinusoidal pulse width modulation scheme?

6.What is space vector pulse width modulation scheme?

EXPERIMENT: – 10

AIM OF THE EXPERIMENT

To study of the fly back converter and forward converter.

APPARATUS REQUIRED

Sl. No.	Name of Apparatus	Specification	Quantity
1	MOSFET based Forward & Flyback Converter kit		
2	DC Regulated Power supply- 0-30V/2A (single)		
3	Rheostat-100 ohms/2Amps.		
4	CRO		
5	Patch cords		

THEORY

Fly Back Converter:

A chopper using MOSFET is shown in fig. The chopper is connected in parallel with the load. When the chopper CH is on, current builds up in the primary of transformer. When the MOSFET is off, as the inductor/transformer secondary current cannot die down instantaneously, this current forced to flow through the diode and load for a time Toff As current tends to decrease, polarity of the emf induced in L_2 is reversed. As a result, voltage across the load, given by Ve- Vs+12 (didt), exceeds the source voltage Vs. In this manner, the circuit acts as fly back converter and the energy stored in E2 is released to the load.

Forward Converter:

Forward converter is similar to fly back converter. The transformer core is reset by reset winding, as shown in fig. 1, where the energy stored in the transformer core is returned to the supply and the efficiency is increased. The dot on the secondary winding of the transformer is se arranged that the output diode D_2 is forward biased when the voltage across the primary is positive, that is when MOSFET is on. Thus, energy is not stored in the primary inductance as it was for the fly back. Forward converter operated in continuous mode. In discontinuous mode the forward converter is more difficult to control.

CIRCUIT DIAGRAM

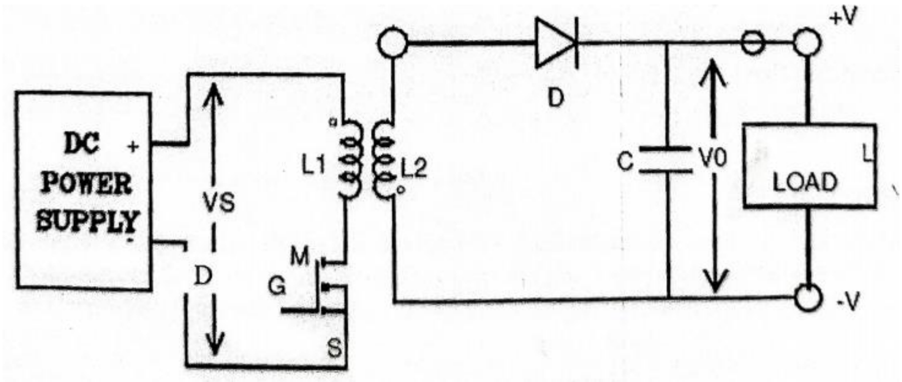


Fig: Fly Back Converter

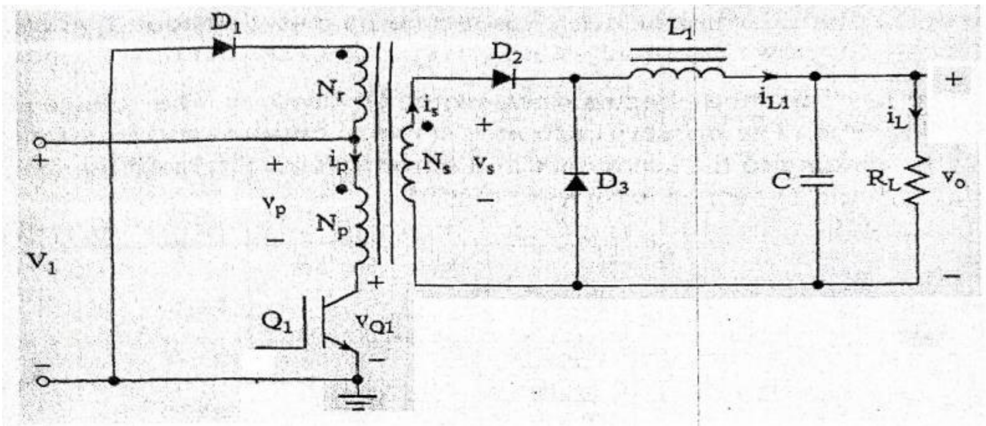


Fig: Forward Converter

PROCEDURE

For flyback Converter:

1) Switch ON the mains to the control circuit and observe the driver output by varying the frequency and duty cycle using INC and DEC keys.
2) The connect the driver Output to Gate the Source of POWER MOSFET.
3) Make the back converter circuit as shown in figure.
4) Connect 100 Ohms/2Amps Rheostat load at the load point.
5) Check all the connection and confirm connection made are correct before switching on the equipment.
6) Connect DC input from Regulated power supply (0-30V/2A) to the input terminal. Switch on the DC power supply adjust DC voltage to20-30V.
7) Switch ON the input switch in series with the DC input.
8) Apply the driver output pulses to the POWER MOSFET And observe the wave from at different points like across Load, across capacitor and across device with R- Load. And

observe the effect of changing in Ton and Toff periods of the Power MOSFET (At particular frequency) by varying the Duty cycle.

9) Vary the duty cycle of flyback converter as shown in the table and not down corresponding load voltage for different duty cycle.
10) Change the frequency and repeat the experiment.
11) Tabulated the reading.
12) Bring the driver outputs to STOP by change RUN/STOP key to STOP.
13) Switch off DC supply in the power circuit and switch off the mains supply to the unit.

For Forward Converter:

1) Switch ON the mains to the control circuit and observe the driver output by varying the frequency and duty cycle using INC and DEC keys.
2) The connect the driver Output to Gate the Source of POWER MOSFET.
3) Make the Forward converter circuit as shown in figure.
4) Connect 100 Ohms/2Amps Rheostat load at the load point.
5) Check all the connection and confirm connection made are correct before switching on the equipment.
6) Connect DC input from Regulated power supply (0-30V/2A) to the input terminal. Switch on the DC power supply adjust DC voltage to20-30V.
7) Switch ON the input switch in series with the DC input.
8) Apply the driver output pulses to the POWER MOSFET And observe the wave from at different points like across Load, across capacitor and across device with R- Load. And observe the effect of changing in Ton and Toff periods of the Power MOSFET (At particular frequency) by varying the Duty cycle.
9) Vary the duty cycle of forward converters as shown in the table and not down corresponding load voltage for different duty cycle.
10) Change the frequency and repeat the experiment.
11) Tabulated the reading.
12) Bring the driver outputs to STOP by change RUN/STOP key to STOP.
13) Switch off DC supply in the power circuit and switch off the mains supply to the unit.

OBSERVATION TABLE:

For flyback Converter:

SL. NO.	Vdc IN	Duty Cycle (%)	Load Voltage (VL)

For forward Converter:

SL. NO.	Vdc IN	Duty Cycle (%)	Load Voltage (VL)

CONCLUSION

QUESTIONS:

1. What is forward converter used for?
2. What is duty ratio of forward converter?
3. What is major problem of flyback converter?
4. What are the different types of flyback converter?