B.Tech.(VI Sem) **20EE60- POWER ELECTRONICS AND DRIVES LAB**

L	T	P	Cr.
0	0	3	1.5

Prerequisite: Power Electronics

Course Educational Objective: This course enables the student to provide practical exposure to converter circuits, hardware modules and Software tools to simulate various power electronic converters and drives.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Examine the characteristics of Power electronic devices **(Understand-L2)**

CO2: Analyze the performance of different power converters and drives using trainer kits. **(Apply-L3)**

CO3: Evaluate the performance of different power converters and drives using simulation tools **(Apply-L3)**

LIST OF EXPERIMENTS

1. Characteristics of SCR, IGBT & Power MOSFET.
2. Single phase AC voltage controller with R & RL Loads.
3. Single phase IGBT inverter with R and R-L Loads.
4. Single phase Cyclo converter with RL load.
5. Three phase fully controlled bridge converter fed dc motor drive.
6. Four quadrant operation of chopper fed dc drive.
7. Three phase Ac Voltage controller fed Induction motor drive.
8. Three phase slip ring Induction motor by Static Rotor Resistance Control.
9. Single phase fully controlled rectifier with R & RL loads using simulation tools.
10. Single phase inverter with PWM technique using simulation tools.

ADDITIONAL EXPERIMENTS

11. PWM control of Boost converter with R and R-L loads.
12. IGBT based three phase PWM Inverter with R load.
13. Single phase fully controlled bridge converter With R & RL Loads.

17/11/22

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Characteristics of SCR, IGBT & Power MOSFET

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

OBJECTIVE: To understand the operation of the SCR and to study the IGBT & Power MOSFET characteristics.

APPARATUS:

Sl.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1.	SCR, MOSFET & IGBT characteristic kit module	230V/5A	1 no
2.	Multi Meter	0-30V	2 no
3.	RPS , Dual Channel	0-30V	1 no

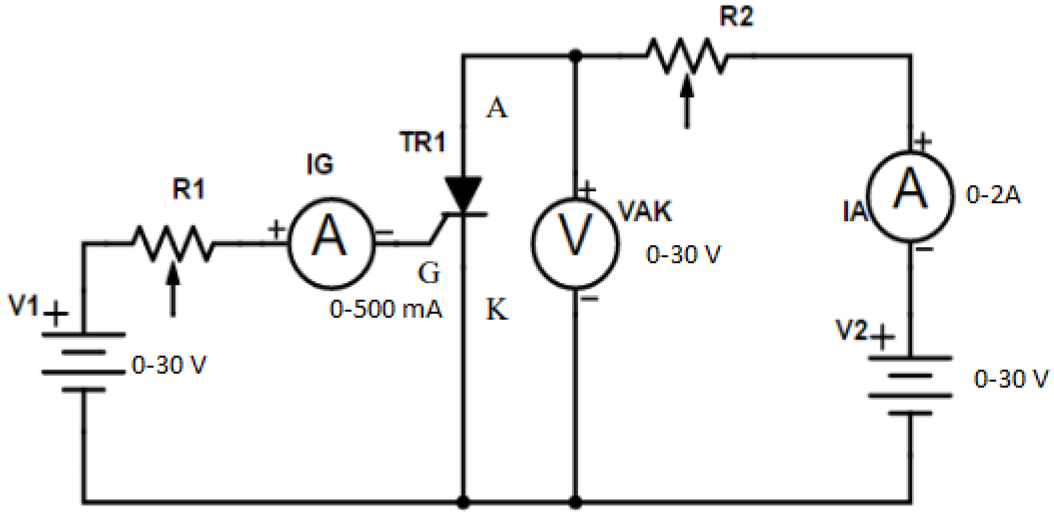
THEORY:

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).

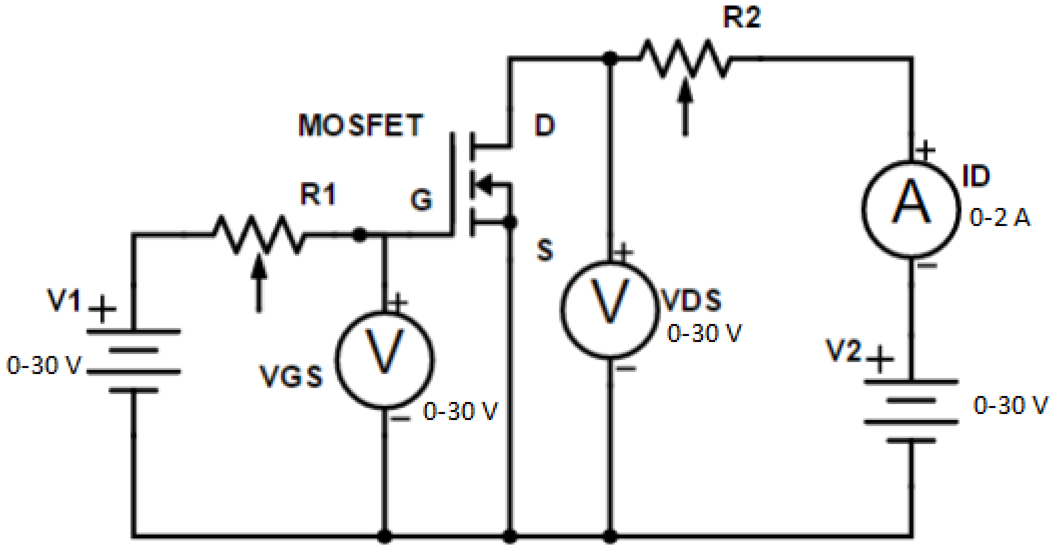
MOSFET: MOSFET is a three terminal semi conducting device. Its conductivity can be controlled by gate signal. The three terminals are gate (G), source (S) and drain (D). It can be operated as an amplifier or as a switch. Static output characteristic curve is drawn between drain current (I_D) and drain 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}).

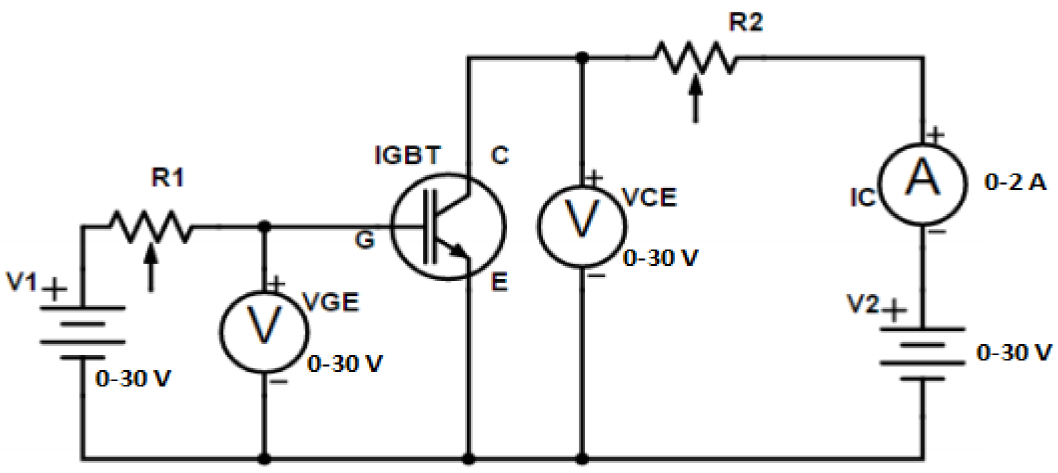
CIRCUIT DIAGRAMS:



SCR



MOSFET



IGBT

PROCEDURE:

For plotting SCR VI characteristics:

1. Connections are made as per the circuit diagram given in Fig.

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.

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.

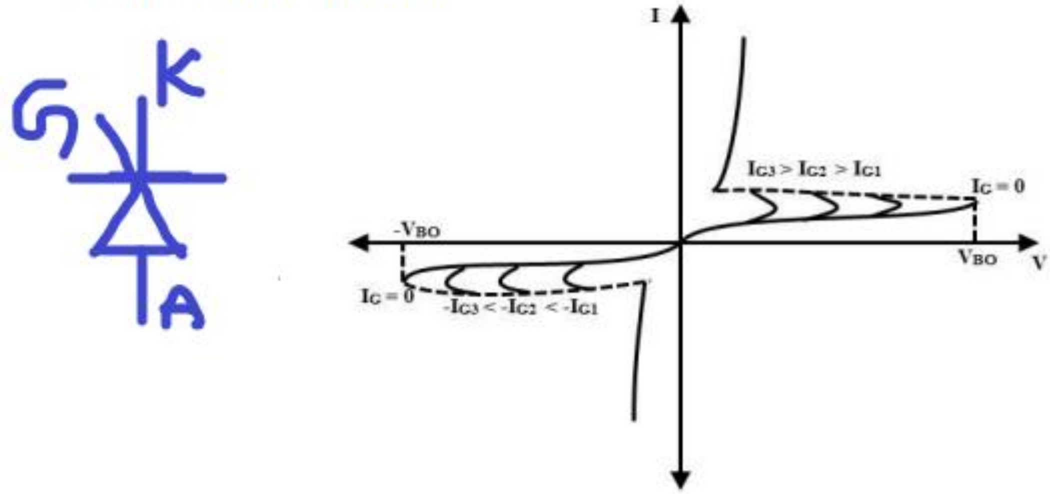
2. Set a finite gate source voltage (V_{GE1}) by varying R_1 and V_1.

3. By varying V_2 (or R_2), note down V_{CE} and I_C.

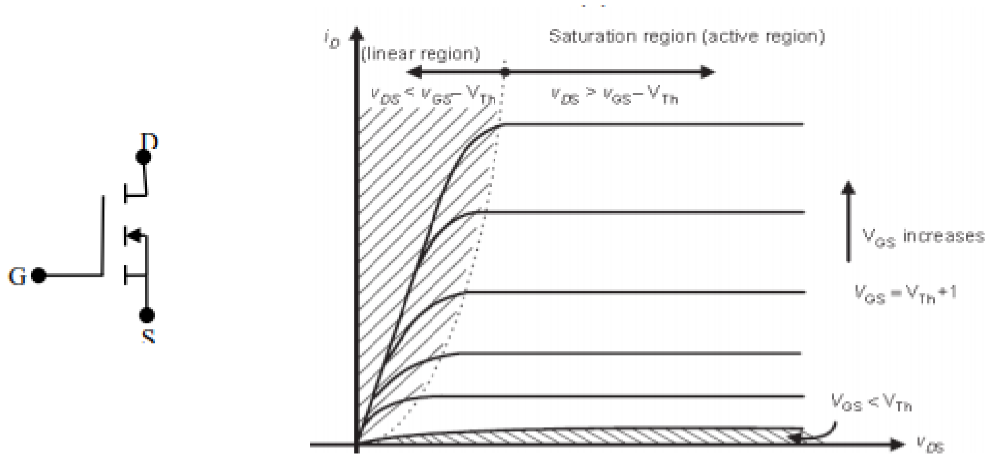
4. Repeat the steps 3 and 4 for second gate source voltage (V_{GE2}).

MODEL GRAPHS

V-I Characteristics of SCR

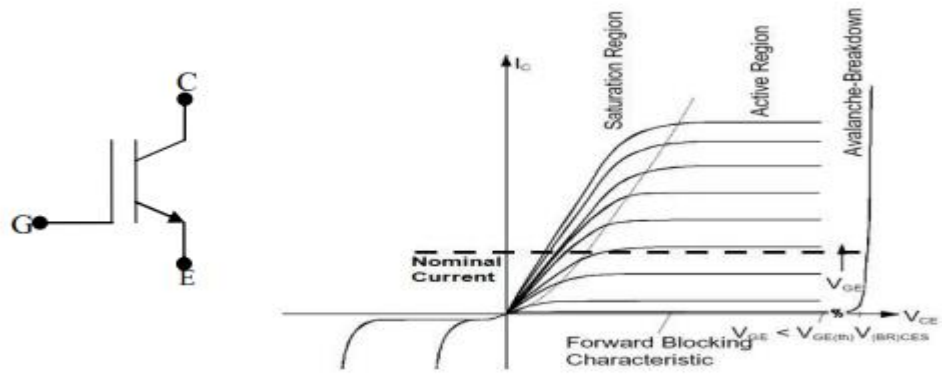


(a)



(b)

Transfer Characteristics



(c)

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

Observations of SCR

I_{G1}= µA		I_{G2}= µA	
V_{AK}(V)	I_A(mA)	V_{AK}(V)	I_A(mA)

Observations of Power MOSFET

Transfer Characteristics			
V_{GS1}= V		V_{GS2}= V	
V_{DS}(V)	I_D(mA)	V_{DS}(V)	I_D(mA)

Observations of IGBT

V_{GE}= V		V_{GE}= V	
V_{CE}(V)	I_C(mA)	V_{CE}(V)	I_C(mA)

RESULT: Thus the Characteristics of SCR, IGBT & Power MOSFET.

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?

2. SINGLE PHASE AC VOLTAGE CONTROLLER WITH R & RL LOADS

AIM: To analyze the Single phase AC Voltage Controller with R & RL loads.

OBJECTIVE: Study operating principle of Single phase AC Voltage Controller and analyze the output voltage of the converter.

APPARATUS:

SI.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1.	Thyristor trainer kit (Power Circuit)	12 Amps / 600V	1no
2.	SCR Triggering kit (Firing Circuit)	230V, 2A	1no
3.	Iolation Transformer	24 V-0-24 V @ 2Amps	1no
4.	CRO	30 M Hz	1no
5.	Resistive load	60 ohms/5A, 125 ohms/5A	1no
6.	Inductive load	100 mH	1no
7.	Multimeter	0-300 V	1no
8.	CRO probes, Connecting wires	For required	1 no

THEORY:

The AC regulators are used to obtain a variable AC output voltage from a fixed AC source. A single phase AC regulator is shown in the figure. It consists of two SCRs connected in anti-parallel. Instead of two SCRs connected in anti parallel, a TRIAC may also be used. The operation of the circuit is explained with reference to RL load. During positive half-cycle SCR-1 is triggered into conduction at a firing angle. The current raises slowly due to the load inductance. The current continues to flow even after the supply voltage reverses polarity because of the stored energy in the inductor. As long as SCR-1conducts, conduction drop across it will reverse bias SCR-2.Hence SCR-2 will not turn on even if gating signal is applied. SCR-2 can be triggered into conduction during negative half cycle after SCR-1 turns off.

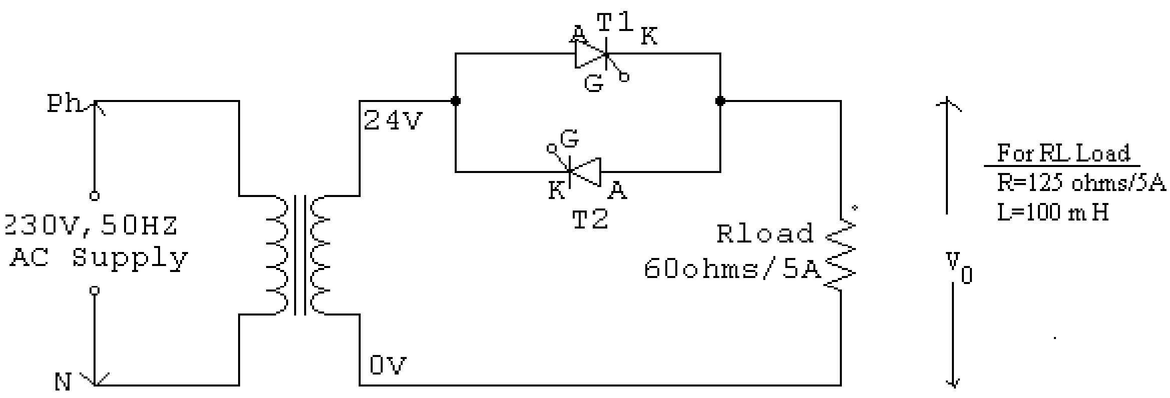
PROCEDURE:

1. Connections are made as per the circuit diagram.
2. The main supply is switched ON and triggering circuit is switched ON.
3. Firing pulses are applied for the respective SCR's from the firing circuit.
4. Wave forms across the load are observed in CRO, values are noted down and tabulated for different firing angles.

INSTRUCTIONS:

1. Check all the SCR's for good conduction before making the connections.
2. Check the firing circuit trigger outputs and its relative magnitude.
3. Make fresh connections before you make a new experiment.
4. Preferably work at low voltages (20-30 V) for every new connection after careful verification it can be raised to maximum ratings.
5. Keep all knobs at min. position before you switch ON the supply.

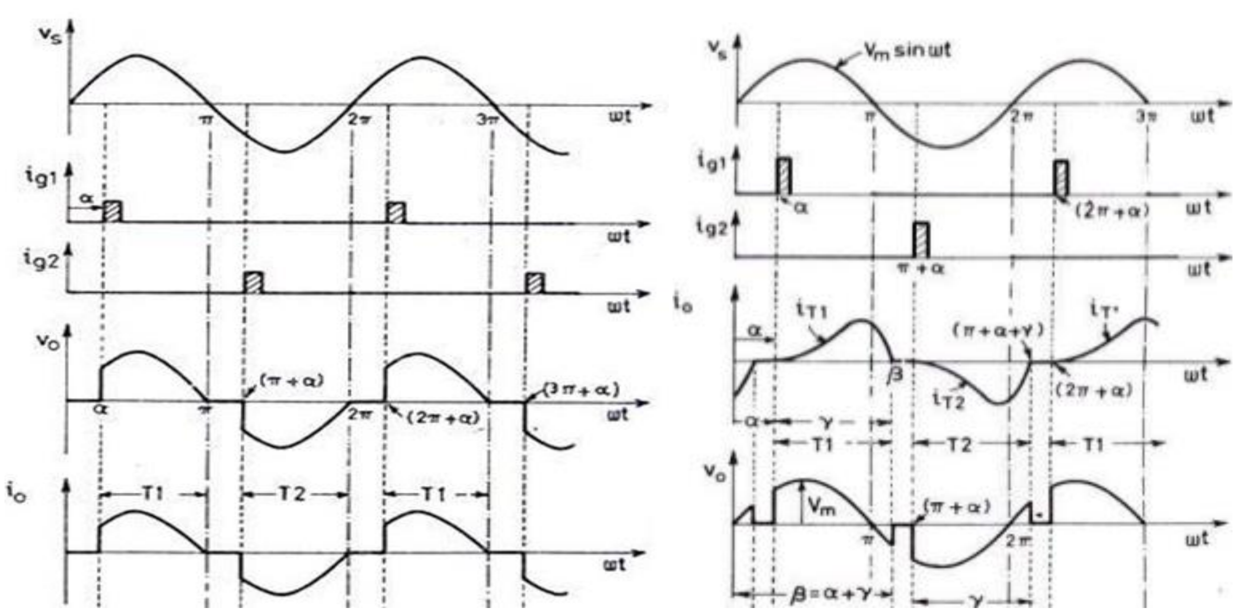
CIRCUIT DIAGRAM:



SINGLE PHASE AC VOLTAGE CONTROLLER

Waveforms:

R Load **RL Load**



OBSERVATIONS:

AC Voltage Controller using R Load $V_m = 24V$

R – Load		
Triggering angle ά (deg)	Output voltage V_0 (V) (Measured)	Output voltage V_0 (V) (Calculated)
0 30 60 90 120 150 180		

AC Voltage Controller using RL Load $V_m = 24V$

RL – Load		
Triggering angle ά (deg)	Output voltage V_0 (V) (Measured)	Output voltage V_0 (V) (Calculated)
0 30 60 90 120 150 180		

theoretical caliculations :

$$V_{a.c} = V_{rms} = \sqrt{\frac{1}{T}\left[\int_{\alpha}^{\pi} V^2{}_m Sin^2\omega t.d\omega t + \int_{\pi+\alpha}^{2\pi} V^2{}_m Sin^2\omega t.d\omega t\right]}$$

$$= V_m\left[\frac{\pi-\alpha}{2\pi} + \frac{Sin2\alpha}{4\pi}\right]^{1/2}$$

PRECAUTION: Initially input voltage is low and firing angle 180^0. Slowly increase the voltage to the rated voltage and angle to 0^0.

RESULT: The output voltage at various firing angles is noted with R load and RL load. The relevant waveforms are observed.

(Viva voce questions)

1. What happens if the two thyristers applied from the same gate source ?
2. What is meant by Line commutation ?
3. How the thyristers get commutated ?
4. What is the expression for rms voltage of the output wave form ?
5. What is the difference between Transformer & AC voltage controller ?
6. What are the applications of a AC Voltage controller?

3.SINGLE PHASE IGBT INVERTER WITH R & RL LOADS

AIM: To analyze Single phase IGBT based PWM inverter with R & RL loads.

OBJECTIVE: To study the operation of a single-phase IGBT based PWM inverter and to observe the output waveforms.

Apparatus:

SI.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1	DC Power supply	0-30V	1 no
2.	IGBT based PWM inverter modules	0-30 V, 5A	1 no
3.	CRO	30 MHz	1 no
4.	Resistive load	125 ohms/2A	1 no
5.	Inductive load	100 mH	1 no
6.	Multimeter	0-300V	1 no
7	CRO probes, Connecting wires	For requirement	1 no

THEORY: A device that converts DC power into AC power at output voltage and frequency is called an inverter. Some industrial applications of inverter are for adjustable AC drives, inductive heating, stand by aircraft supplies, UPS, HVDC transmission lines etc.

Schematic diagram of a single phase inverter is given in the fig. The current can be supplied to the load by proper gating the IGBTs. Only two IGBTs will be on at one time. Load voltage is PWM signal.

The power circuit is IGBT based full bridge inverter shown in fig. When T_1, T_2 conduct, load voltage is +Vs and when T_3, T_4 conducts load voltage is -Vs .The frequency of the output voltage can be controlled by varying the time period. For inductive loads diode connected anti parallel with thyristors will allow the current to flow when the main thyristors are turned off. These diodes are called feedback diodes. The modulation technique used is sinusoidal PWM technique. The modulation index can be varied by the parameter setting through the key board. The AC load voltage is controlled by controlling modulation index. Modulation index is the ratio of maximum amplitude of sine wave to maximum amplitude of triangular wave. When modulation index is set keeping amplitude of triangular wave constant, the amplitude of sine wave is varied. This will happen in the internal circuit. The speed of motor can also be varied by varying the frequency of inverter circuit.

Procedure:

1. Circuit connections are made as shown in circuit diagram.
2. Connect the required load.
3. Check all connections and conform connections made are correct before switching on the equipment.
4. Keep the DC voltage knob at minimum position.
5. Switch on firing circuit switch.
6. Switch on the MCB.
7. Set frequency and modulation index at suitable value. Press RUN key.
8. Adjust DC voltage input to 30V slowly.
9. Observe the load voltage waveforms using CRO.
10. Record the frequency of the inverter circuit &the variation in the input AC voltage with reference to the modulation index.
11. Reduce the DC voltage to minimum position.
12. Press STOP key.
13. Set new modulation index. Press RUN key.
14. Tabulate the readings in the table.
15. Slowly reduce the DC voltage to zero. Switch OFF the switches when the voltage is completely reduced.
16. Remove the connections.
17. Do the experiment for R-L load.

CIRCUIT DIAGRAM:

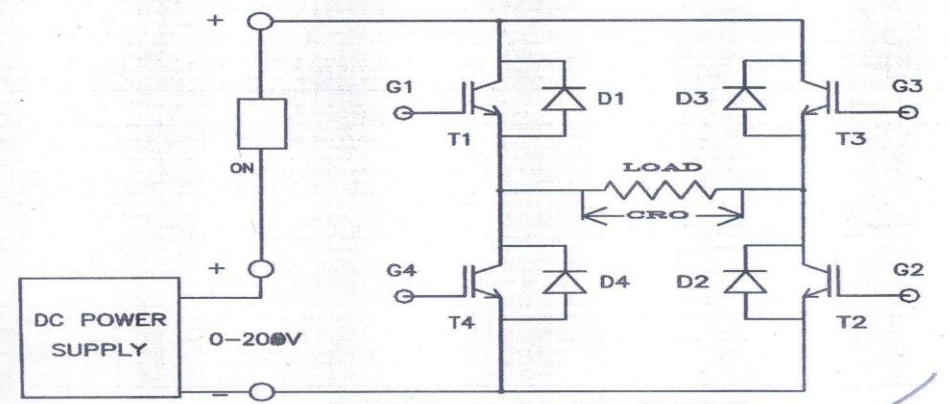


FIG SINGLE PHASE PWM INVERTER

WAVEFORMS:

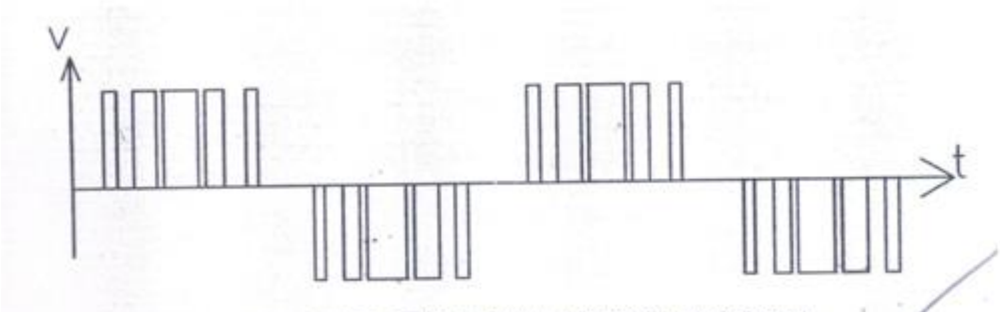


FIG SINGLE PHASE PWM INVERTER WAVEFORM

OBSERVATIONS:

Frequency = Hz
Input DC Voltage = 15 V
$V0 = MI * V_{dc}$
MI=_______

S.NO	Modulation Index(%)	Measured output Voltage(V_0)	Calculated output Voltage(V_0)
1.			
2.			
3.			
4.			
5.			
6.			

Result: Thus the output waveform for IGBT inverter (PWM) was obtained

Viva Voce Questions

1. Why IGBT is very popular.

2. IGBT is called voltage controlled device. Why?

3. What is meant by inverter.

4. What are the applications of an inverter.

5. Why thyristors are not preferred for inverters.

6. What is meant a series inverter.

7. What are the applications of IGBT inverter.

8.What are the important criteria that should be considered when selecting switches?

9. What is the symbol for IGBT.

10.What are advantages of IGBT over SCR.

4. SINGLE PHASE CYCLO CONVERTER WITH RL LOAD

AIM: To analyze the Single Phase Cyclo Converter with RL loads.

OBJECTIVE: To study the module and waveforms of a 1- Φ center tapped cycloconverter with RL load.

APPARATUS:

SI.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1.	Thyristor trainer kit (Power Circuit)	12 Amps / 600V	1no
2.	SCR Triggering kit (Firing Circuit)	230V, 2A	1no
3.	1Φ center tap transformer	230V / 20V-0-20V	1no
4.	CRO	30 M Hz	1no
5.	Resistive load	60 ohms/5A, 125 ohms/5A	1no
6.	Inductive load	100 mH	1no
7.	Multimeter	0-300 V	1no
8.	CRO probes, Connecting wires	For required	1 no

THEORY: Cyclo converter is a direct frequency changer that converts ac power at one frequency to AC power at other frequency by AC – AC conversion with out any intermediate conversion link.

The output is limited to a value that is only a fraction of the source frequency. As a result the applications of cyclo converters are low speed ac motor drives range up to 15000 KW with frequencies from 0 to 20 Hz.

If SCR 1 & SCR 2 pair is triggered continuously for N half cycles followed by SCR3 & SCR 4 pair for next N half cycles then the frequency of the output voltage would be fin/N. If ά P is the delay angle of positive converter (T_1, T_2), the delay angle of negative converter (T_3, T_4) is (π-ά). Hence the average output voltage of the positive converter is equal and apposite to that of a negative converter.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Firing pulses are applied for the respective SCR's from the firing circuit.
3. The main supply is switched ON and triggering circuit is sitched ON
4. Wave forms across the load are observed in CRO values are noted down and tabulated

For different frequencies $f_s/2$, $f_s/3$, $f_s/4$,etc.,

5. The out put wave forms are plotted on the graph sheet.

INSTRUCTIONS:

1. Check all the SCR's for good conduction before making the connections.
2. Check the firing circuit triggers outputs and its relative phase sequence.
3. Make fresh connections before you make a new experiment.
4. Preferably work at low voltages (20-30 V) for every new connection after careful verification it can be raised to maximum ratings (this is to reduce damages due to wrong connections and high starting current problems).
5. Do not make Gate & Cathode measurements when the power circuit ON.

CIRCUIT DIAGRAM:

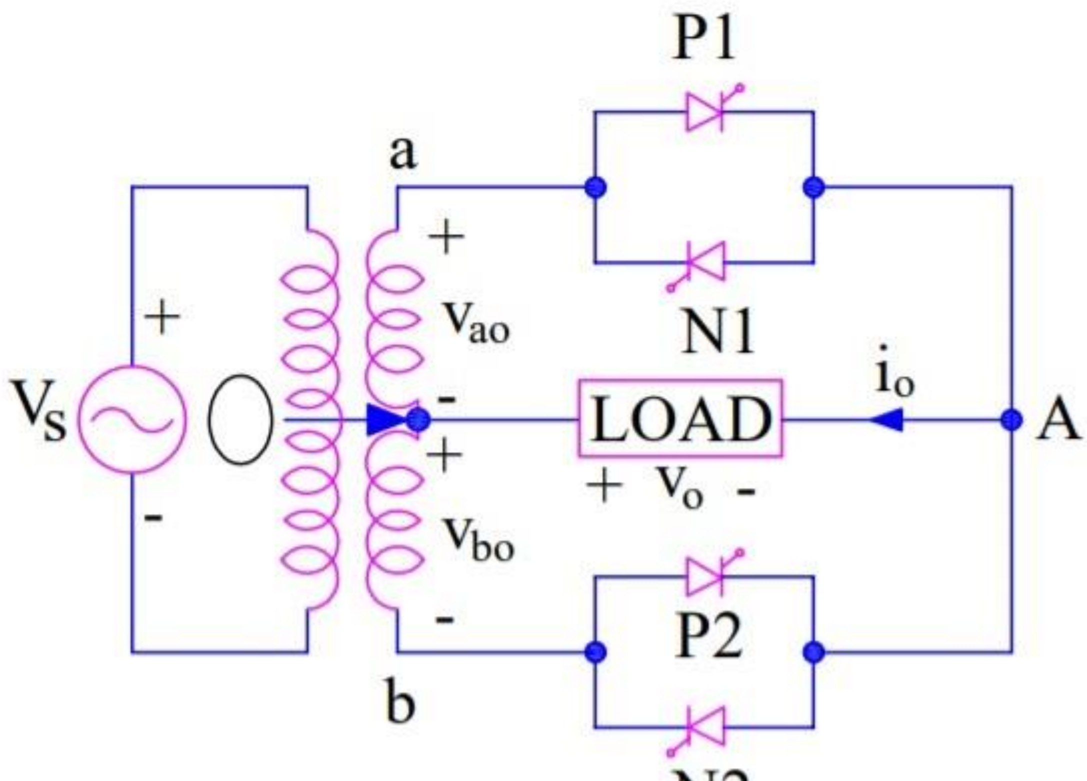
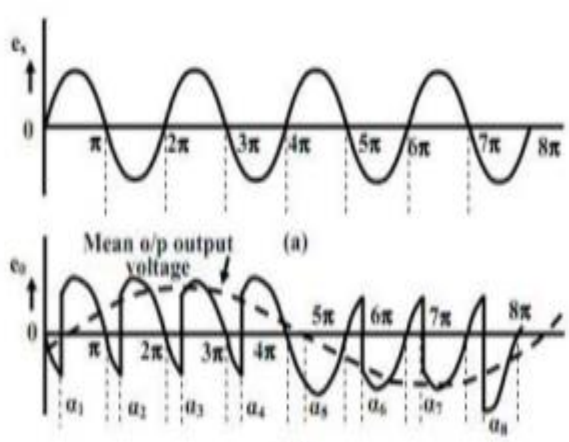


Fig. - 1

1Φ Cyclo converter

WAVEFORMS:

RL Load



TABULAR COLUMN

S.NO	Input Voltage(V)	Frequency division	Firing angle	Output voltage V_0(V)

THEORETICAL CALCULATIONS:

We know that source frequency (fs)=50 Hz, i.e.,Ts= 20 mSec. ; [f =1/T]

fo= fs /2 =25 Hz, i.e.To=2 Ts = 40 mS ;

fo= fs /3 =16.66 Hz, i.e.To=3 Ts = 60 mS ;

RESULT: The performance of Single phase Cyclo converter for RL -load are studied and out put wave forms for different frequencies are drawn on the graph sheet.

Viva-Voce Questions

1. What is Step down & Step up Cyclo converter ?
2. What is meant by natural & Forced commutation ?
3 What is meant by Positive & negative converter groups in Cycloconverter?
4 Differentiate step-down cycloconverter and step-up cycloconverter
5. List the advantages & disadvantages of Cycloconverters.
6. What are the applications of a Cyclo Converter?
7. What is the importance of Center tap Transformer.

5. THREE PHASE FULLY CONTROLLED BRIDGE CONVERTER FED DC MOTOR DRIVE

AIM : Control speed of dc motor using 3-phase full controlled bridge converter.

OBJECTIVE: To study the control speed of dc motor using 3-phase full controlled bridge converter

APPARATUS:

SI.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1	Supply Voltage	415V/50Hz	1 no
2.	Three phase fully controlled Bridge converter power module	200V/5A	1 no
3.	Three phase converter firing unit	230V/2A	1 no
4.	CRO	50 MHz	1 no
6.	Resistive load	230 ohms/2 A	1 no
7.	Multimeter	0-300V	1 no
8.	CRO probes, Connecting Wires	For required	10:1 probe

THEORY: In the bridge rectifier all the six arms of SCR's are connected as control switches. This advantage of fully controlled rectifier is the capability of wide voltage variation between V_{dc} min to V_{dc} max voltage such a rectifier and application in DC motor loads for both motoring and electrical braking of the motor.

The figure shows the circuit diagram of three phase bridge controlled rectifier. It consist of upper group (T1,T3,T5) and lower group (T2,T4,T5) of thyristors .Thyristor T1 is forward biased ad can be triggered for conduction only when Va is greater than both Vb and Vc. From figure this condition occurs at $wt=30^0$. Hence T1 can be triggered only at $wt=30^0$.If firing angle is α, then T1 starts conduction at wt=30 + α and conducts for 120^0 where it get commutated by turning on of next thyristor ie, T3.Similarly triggering instant for T3 and T5 are determined when considering Vb and Vc respectively. For lower group T4,T6 and T2, negative voltages,ie,-Va,-Vb and -Vc respectively are considered. Thus the forward bias instant and triggering instants are obtained as:

Thyristor	Forward Bias instant(degree)	Triggering instant(degree)	Conduction period (degree)
T1	30	30+α	30+α to 150+α
T2	90	90+α	90+α to 210+α
T3	150	150+α	150+α to 270+α
T4	210	210+α	210+α to 330+α
T5	270	270+α	270+α to 390+α
T6	330	330+α	330+α to 450 +α

Average Value of output voltage is given by

$V_{avg} = \frac{3\sqrt{3}}{\pi} V_m \cos\alpha$ where V_m is the maximum value of phase to neutral voltage

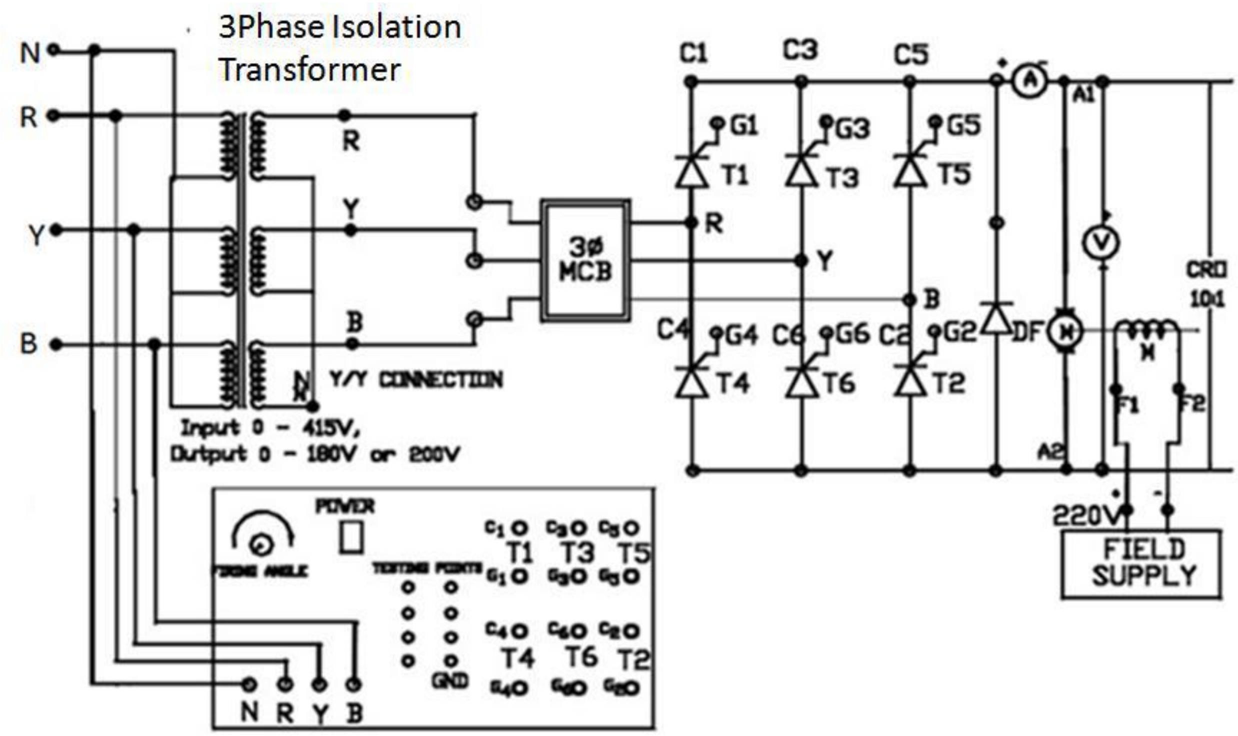
Average Value of output current is given by

$I_{avg} = \frac{3\sqrt{3}}{\pi R} V_m \cos\alpha$ where R is the load resistance

PROCEDURE:

1. The connections are made as shown in circuit diagram
2. Connect input terminals N,R,Y&B of isolation transformer to respective terminals N,R,Y,B of firing circuit.
3. Connect output terminals R,Y&B of isolation transformer to respective terminals R,Y&B of power module.
4. Connect input terminals N,R,Y,B of isolation transformer to respective terminals N,R,Y,B of firing circuit.
5. Connect CRO across the load. Use 10:1 CRO probe.
6. The gate cathode terminals of the three SCR's are connected to respective points of the firing unit.
7. Check all connections and conform connections made are correct before switching ON the instrument.
8. Keep the firing angle knob to min position. Switch ON the phase supply, power unit as well as firing unit.
9. Vary firing angle gradually. The output waveforms are see on a CRO.
10. Trace the load voltage waveform for any one firing angle.

CIRCUIT DIAGRAM:



OBSERVATIONS:

Input peak voltage:

	Practical		
S.NO	Firing angle	Average Load Voltage V_{dc} (V)	Speed(rpm)
1.	0^0		
2.	30^0		
3.	60^0		
4.	90^0		

RESULT: Analyzed the three phase fully controlled bridge converter fed dc drive for various firing angles with R load.

VIVA – VOCE QUESITIONS

1 What is the difference between open loop and closed loop control?

2 What is mean by 3phase isolating transformer?

3 What are the types of transformers?

4 What is the difference between DC Motor and DC Generator?

5 What is mean by 3phase MCB?

6.What is the advantage of Thyristorised control unit?

7.What is advantage of 3phase isolating transformer?

8.What is the torque equation of DC Motor?

9.What is the difference between field and armature windings?

10.What is the differences between separately and self excited dc motors?

6.CONTROL OF DC MOTOR USING FOUR QUADRANT CHOPPER DRIVE

AIM: Analyze speed control of a dc motor by using four quadrant chopper drive.

OBJECTIVE: To control speed of a dc motor by using four quadrant chopper drive.

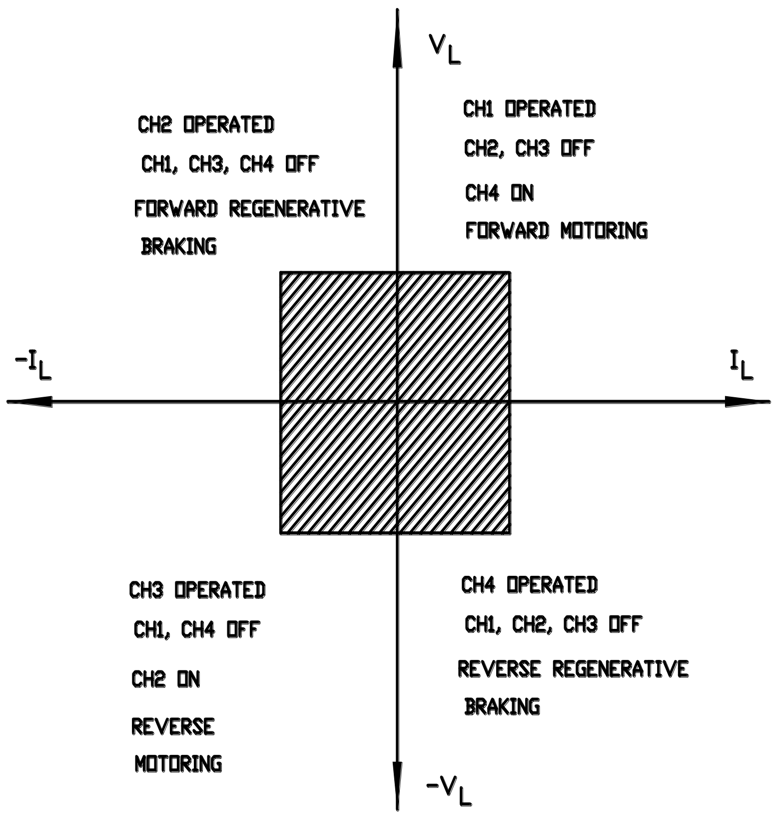
APPARATUS:

S.NO.	NAME OF THE EQUIPMENT	TYPE	RANGE	QUANTITY
1	IGBTs: V_{CES} I_C V_{GE}	GP30B120KD-E with diodes	. 1200 V 25 A 15 V	4 No
2	Single phase diode rectifier V_{RRM} I_{TAV}	-	800 V 10 A	1 No.
3	DC Motor	–	½ HP	1 NO
4	CRO/power scope	digital	-	1 NO
5	Tachometer	digital	-	1 NO
6	Multimeter	digital	-	1 NO
7	Patch chords	-	-	-

THEORY:

Chopper converts fixed DC voltage to variable DC voltage through the use of semiconductor devices. The DC to DC converters have gained popularity in modern industry. Some practical applications of DC to DC converter include armature voltage control of DC motors converting one DC voltage level to pulse width modulated voltage, and controlling DC power for wide variety of industrial processes. The time ratio controller (TRC) is a form of control for DC to DC conversion.

In four quadrant dc chopper drives, a motor can be made to work in forward-motoring mode (first quadrant), forward regenerative breaking mode (second quadrant), reverse motoring mode (third quadrant) and reverse regenerative breaking mode (fourth quadrant). The circuit shown offers four quadrant operation of a separately-excited dc motor. This circuit consists of a DC Power Supply, four choppers, four diodes and a dc motor. This circuit consists of a DC Power Supply, four choppers, four diodes and a dc motor. Its operation in the four quadrants can be explained as under.



1.Forward motoring mode (I quadrant): During this mode or first-quadrant operation, chopper CH2, CH3 are kept off, CH4 is kept on whereas CH1 is operated. When CH1, CH4 are on, motor voltage is positive and positive armature current rises. When CH1 is turned off, positive armature current free-wheels and decreases as it flows through CH4, D2. In this manner controlled operation in first quadrant is obtained.

2.Forward regenerative breaking mode (II quadrant): A dc motor can work in the regenerative-breaking mode only if motor generated emf is made to exceed the dc source voltage. For obtaining this mode CH1, CH3 and CH4 are kept off whereas CH2 is operated. When CH2 is turned on, negative armature current rises through CH2, D4, Ea, La, ra. When CH2 is turned off, diodes D1, D4 are turned on and the motor acting as a generator returning energy to dc source. This results in forward regenerative-breaking mode in the second-quadrant.

3.Reverse motoring mode (III quadrant): This operating mode is opposite to forward motoring mode. Chopper CH1, CH4 are kept off, CH2 is kept on whereas CH3 is operated. When CH3 and CH2 are on, armature gets connected to source voltage Vs so that both armature voltage and armature current i_a are negative. As armature current is reversed, motor torque reversed and consequently motoring mode in third quadrant is obtained. When CH3 is turned off, negative armature current freewheels through CH2, D4, Ea, La, ra; armature current decreases and thus speed control is obtained in third quadrant. Note that during this mode polarity of E_a is opposite to that shown in circuit diagram.

4.Reverse Regenerative-braking mode (IV quadrant): As in forward braking mode, reverse regenerative-braking mode is feasible only if motor generated emf is made to exceed the source voltage. For this operating mode, CH1, CH2 and CH3 are kept off whereas CH4 is operated. When CH4 is turned on, positive armature current i_a rises through CH4, D2, ra, La, Ea. When CH4 is turned off, diodes D2, D3 begin to conduct and motor acting as generator returns energy to dc source. This leads to reverse regenerative-braking operation of the dc separately excited motor in fourth quadrant.

AC is converted into DC by diode rectifier. The chopper is programmed in such a way that the duty cycle is restricted from 10% to maximum of 90%.

PROCEDURE:

I. To study operation of the chopper in all quadrant

In all quadrant operation the chopper continue to operate I quadrant, II quadrant, III quadrant, IV quadrant then again to I quadrant sequentially in a time interval. The chopper may be brought to set quadrant operation by throwing toggle switch to NORMAL position. However the chopper comes to set quad operation only when IV quadrant is completed.

1. Keep the toggle switch to ALL QUAD position.
2. Without connecting motor, keeping power supply voltage minimum do the following observations by switching on triggering circuit by power switch.
3. Observe the operation of choppers by connecting CRO across the testing points.

4. During forward motoring (I quadrant) CH1 is operated (on/off), CH4 is on and CH2, CH3 are off.
5. During forward breaking (II quadrant) CH2 is operated, CH1, CH2, CH3 are all off.
6. During reverse motoring (III quadrant) CH2 is on, CH3 is operating and CH1, CH4 are off.
7. During reverse breaking (IV quadrant) CH4 is operated, CH1, CH2 & CH3 are all off.
8. Now switch off the triggering circuit.
9. Connect motor terminals to respective points in the power circuit as shown in the circuit diagram. Field of the motor to field terminals of the unit. Armature to the respective terminals in the circuit.
10. Voltmeter and ammeter are connected internally as shown in the circuit.
11. Triggering pulses are connected internally to respective IGBTs.
12. Connect the power scope to monitor current and voltage waveforms (if provided) otherwise use CRO. Use 10:1 probe to monitor voltage waveform.
13. Connect three pin power plug from the four quadrant chopper power unit to the single phase three pin power mains.
14. Check the connections and conform the connections made are correct before switching on mains supply.
15. Switch on the field supply to the motor first**.**
16. Switch on the single phase power supply to the four quadrant chopper triggering circuit.
17. DC power supply voltage must be increased now from 0 up to suitable value (say 100-150V) by switching on MCB.
18. Observe the wave forms of current and voltages on all the four quadrants. (To observe current expand CRO knob)
19. During forward motoring current and voltages are positive.
20. During forward breaking voltage is positive and current is negative till all the energy stored in the inductor is reduced to zero. Once the energy stored in the inductor reduced to zero then both voltage and currents are zero.
21. During reverse motoring both current and voltage are all negative.

22. During reverse breaking voltage is negative and current is positive till all the energy stored in the inductor is reduced to zero. Once the energy stored in the inductor reduced to zero then both voltage and currents are zero.
23. Reduce DC voltage switch to minimum. Wait till all the power supply voltage is discharged through the motor.
24. Switch OFF MCB, Switch off triggering circuit power switch.
25. Switch OFF field supply to the motor at the end.
26. Remove the connections.

II .To study operation of the chopper in forward & reverse motoring:

1. Keep the toggle switch to NORMAL position.
2. Power circuit connections are made as shown in the circuit diagram.
3. Connect motor terminals to respective points in the power circuit as shown in the circuit diagram. Field of the motor to field terminals of the unit. Armature to the respective terminals in the circuit.
4. Voltmeter and ammeter are connected internally as shown in the circuit.
5. Triggering pulses are connected internally to respective IGBTs.
6. Connect the power scope to monitor current and voltage waveforms (if provided) otherwise use CRO. Use 10:1 probe to monitor voltage waveform.
7. Check the connections and conform the connections made are correct before switching on mains supply**.**
8. Connect three pin power plug from the four quadrant chopper power unit to the single phase three pin power mains.
9. Switch on the field supply to the motor.
10. Switch on the single phase power supply to the four quadrant chopper triggering circuit.
11. Keeping power supply voltage knob to minimum position set frequency, duty cycle, directions of the motor.
12. Enter RUN key.
13. DC power supply voltage must be increased now from 0 up to suitable value (say 100-150V) by switching on MCB.
14. When RUN key is pressed the chopper is gone for wait mode, during this mode the chopper duty cycle is adjusted to less than 10% for a time interval. After that the

chopper goes to RUN mode, during RUN the chopper duty cycle is adjusted to the set value.

15. Observe the speed of the motor in rpm.
16. Now reduce the supply voltage to minimum value.
17. Enter STOP key.
18. When STOP key is pressed the chopper is gone for wait mode, during this mode the chopper duty cycle is adjusted to less than 10% for a time interval. After that the chopper goes to SET mode, during SET the chopper frequency, duty cycle, chopper directions (Fw & Rw) can be set.
19. Do the experiment for different duty cycles.
20. Observe the load voltage & load current waveforms using power scope/CRO.
21. Reduce the DC supply voltage to minimum value.
22. Switch OFF power supply using MCB.
23. Switch OFF firing circuit & field supply to the motor at the end.
24. Remove the connections.

MIMIC DIAGARAM:

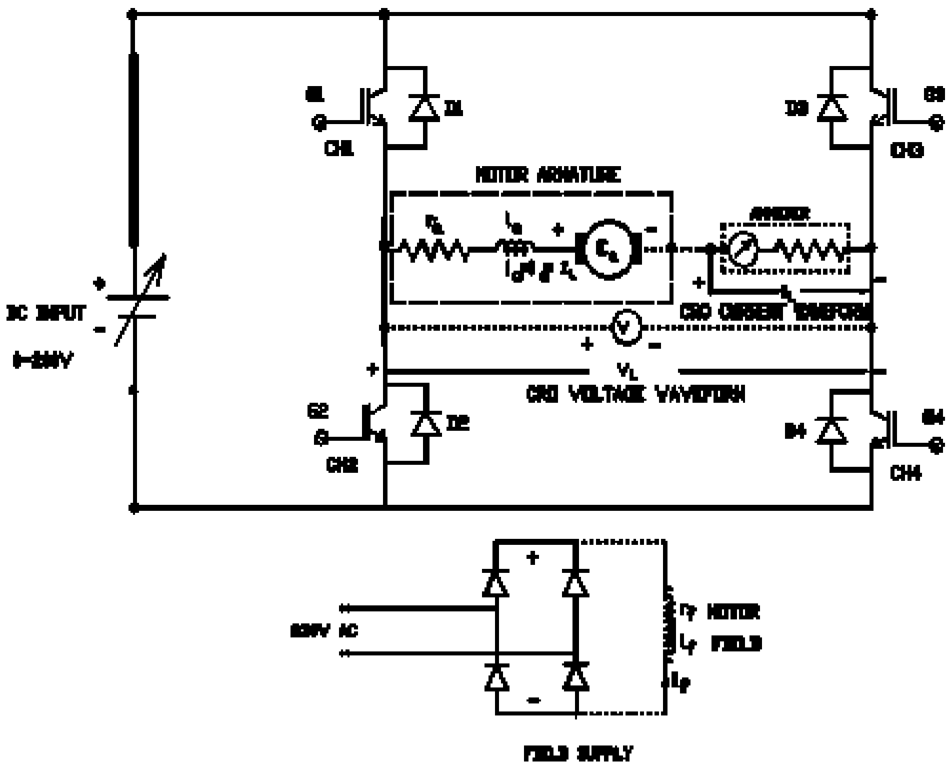


Fig: Four Quadrant chopper circuit diagaram

WAVE FORMS:

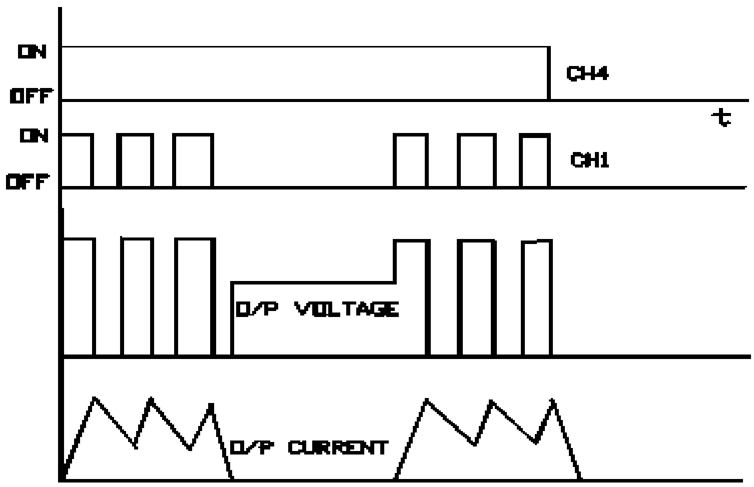


Fig: Wave forms during forward motoring

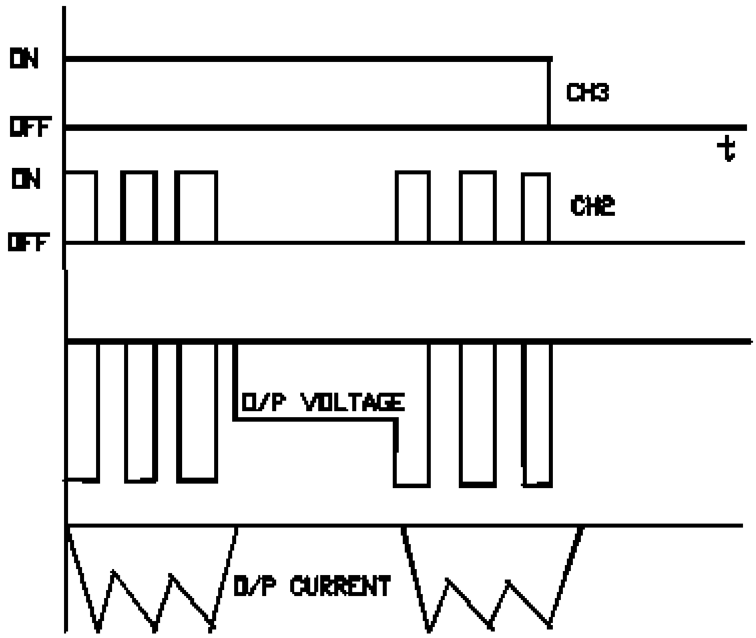


Fig: Wave forms during reverse motoring

TABULAR COLUMN:

Forward Rotation (Q1): During this mode, chopper is operating in I quadrant I & V are positive.

S. No .	**Duty Cycle**	**Speed in rpm**

Reverse Rotation (Q3): During this mode, chopper is operating in III quadrant I & V are negative.

S. No .	**Duty Cycle**	**Speed in rpm**

RESULT: Analyzed the four-quadrant chopper with dc motor

VIVA – VOCE QUESITIONS

1.What are choppers?

2. What are the applications of dc choppers?

3. On what basis choppers are classified in quadrant configurations?

4. What is different control strategies found in choppers?

5. Explain the principle of operation of a chopper?

7. THREE PHASE AC VOLTAGE CONTROLLER FED INDUCTION MOTOR DRIVE

AIM: Analyze speed control of three phase induction motor using three phase ac voltage controller

OBJECTIVE: To control the speed of three phase induction motor using three phase ac voltage controller

APPARATUS:

S.NO.	NAME OF THE EQUIPMENT	TYPE	RANGE	QUANTITY
1	Three phase ac voltage controller module	-	430V/2A	1
2	Three phase ac voltage controller firing unit	-	-	1
3	Isolation transformer	-	415V	1
4	Induction motor	-	1HP	1
5	CRO / Power scope	digital	-	1
6	Tachometer	digital	-	1
7	multimeter	digital	-	-
8	Patch chords	-	-	-

THEORY: AC voltage controller converts fixed AC supply to variable AC supply. With thyristor, variable AC supply 0V to maximum can be obtained from a fixed AC source by triggering (turning ON) thyristor i.e. by applying gate current to the thyristor at any desired instant when the thyristor is applied with positive voltage to anode. Unlike diode, thyristor can block the forward voltage when gate current is not supplied.

The circuit diagram of a three phase full-wave controller is shown in figure with a Y connected resistive load. The firing sequence of thyristor is T_1, T_2, T_3, T_4, T_5, T_6.

LOAD VOLTAGES:

For $0 \leq \alpha \leq 60^0$:

Immediately before the firing of T_1, two thyristors conduct. Once T1 is fired, three thyristors conduct. A thyristor turns off when its current attempts to reverse. The condition alternate between two and three conducting thyristors.

For $60^0 \leq \alpha \leq 90^0$:

Only two thyristors conduct at any time.

For $90^0 \leq \alpha \leq 150^0$:

Although two thyristors conduct at any time, there are period when no thyristors are on.

For $\alpha \geq 150^0$:

There is no period for two conducting thyristors and the output voltage become zero at $\alpha = 150^0$.

CIRCUIT DIAGRAM:

MIMIC DIAGRAM:

PROCEDURE FOR MOTOR LOAD:

1. The connections are made as shown in the circuit of three phase AC voltage controller with Motor load using Isolation transformer.
2. Connect input terminals N, R, Y & B of isolation transformer to respective terminals N, R, Y & B of firing unit.
3. Connect output terminals R, Y & B of isolation transformer (star connected) to respective terminals R, Y & B of power module.
4. The gate cathode terminals of the firing circuit are connected to respective gate cathodes of 6 SCR's of power circuit.
5. Check all the connections and conform connections made are correct before switching on the instrument.
6. Keep firing angle knob at minimum position.
7. Switch on three phase supply, power unit using MCB as well as firing unit.

8. The firing angle is varied output wave form is seen on CRO using 10:1 probe.
9. The speed of the motor is noted for different firing angle.
10. Tabulate values in the table. (refer given table).
11. A graph of speed verses firing angle is plotted.

WAVE FORMS:

Three phase ac voltage controller line to line voltage waveforms

Firing angle=180^0 Firing angle=120^0

Firing angle=90^0 Firing angle=75^0

Firing angle=60^0 Firing angle=30^0

Three phase ac voltage controller line to neutral voltage waveforms

Firing angle=180^0

Firing angle=135^0

Firing angle=90^0

Firing angle=75^0

Firing angle=45^0

Firing angle=30^0

Formulae used:

For star connected R load

Vo is the rms output phase voltage

OBSERVATIONS:

For motor load

S.No.	Firing angle in degrees	Speed in rpm	Output voltage(V)
1			
2			
3			
4			
5			

RESULT:

Controlled the speed of three phase induction motor using three phase ac voltage controller.

VIVA – VOCE QUESITIONS

1. What is the ac voltage controller?

2. What is the advantage with 3phase ac voltage controller with induction motor load?

3. What are the disadvantages with 3 phase ac voltage controller with induction motor load?

4. What are the applications for three phase ac voltage controller?

5. What are the different control methods for induction motor?

6. What is the range of delay angle in light loads?

7. What is the equivalent circuit of 3phase induction motor?

8. Draw the speed-torque characteristics of induction motor.

8.SPEED CONTROL OF THREE PHASE SLIP RING INDUCTION MOTOR BY STATIC ROTOR RESISTANCE CONTROL

AIM: Analyze the speed control of three phase slip ring induction motor by using static rotor resistance control.

OBJECTIVE: To understand the speed control of three phase slip ring induction motor by using static rotor resistance control.

APPARATUS:

S.No.	Name of the equipment	Type	Range	Quantity
1.	Chopper module	-	-	1
2.	Autotransformer 3-phase	12.21KVA	-	1
3.	Resistive load	-	100Ω/2A	1
4.	Inductive load	-	100mH	1
5.	Voltmeter	Digital	-	1
6.	Ammeter	Digital	-	1
7.	Tachometer	Digital	-	1
8.	Patch chords	-	-	-

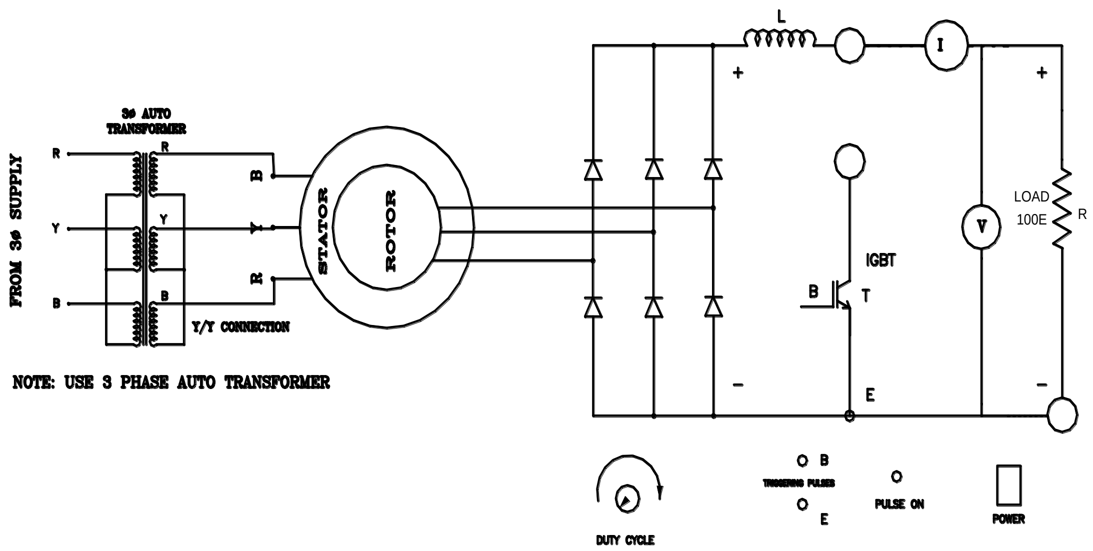
THEORY:

The slip-ring induction motor has a wound rotor carrying a three-phase winding similar to that of the stator. The ends of the winding are taken to slip-rings. If the slip ring external connections are open-circuited, no current can flow, and the voltage at the slip-ring when stationary will be given by the stator voltage times the turn ratio. If the shaft is rotated, then the voltage at the slip-rings is reduced in proportional to slip, as is its frequency. If resistors are connected to the slip-ring the current can flow. As we vary the resistance the speed of the motor is controlled.

Rotor resistance control method is more convenient. The rotor circuit with the chopper functions as a resistance modulator. The inductance in series helps to maintain the rotor current. The minimum speed of the motor occurs at high resistance at rotor. Chopper Power module consists of a three phase diode rectifier, inductor and IGBT. In addition, protections are provided for short circuits and fast fuses for IGBT protections. The devices are mounted on heat sinks and protected by fast fuses. A well designed snubber circuit is provided for dv/dt protection All the terminals of the power module are brought out to front panel through BTI-15 terminals for connection purposes. Chopper firing circuit is buildin generates firing pulse to trigger IGBT power circuit. Firing circuit duty cycle can be controlled from 10 % to 90 %. It is operated on fixed frequency variable duty cycle chopper.

MIMIC DIAGRAM:

I. By varying Rheostat connected to rotor circuit.



PROCEDURE:

1. Power circuit connections are made as shown in the circuit diagram. Connect three phase input to the three phase autotransformer. The output of the autotransformer terminals are connected to the respective R, Y, B stator terminals (top) of three phase wound rotor induction motor. The rotor terminals (bottom) of the three phase wound rotor induction motor is connected to the 3phase input of respective R, Y, B terminals of three phase wound rotor induction motor control power circuit consists of diode rectifier & a load resistance.
2. Connect the rheostat of 100Ω/2A load.
3. Ammeter and voltmeter are connected.
4. **Check all the connections and confirm connections made are correct before switching on the equipments.**

5. **Keep rheostat at minimum resistance (short or at 10Ω approximately)**
6. Keep pulse release at off position.
7. Keeping auto transformer at minimum position switch on the rectifier circuit to rotor using three phase MCB.
8. Switch on three phase Mains supply to auto transformer.
9. Increase the autotransformer voltage slowly for suitable value such that motor rotates.
10. Note down voltage V and current I in the meters.
11. Calculate resistance R = V/I
12. Do experiment for different rotor resistance values by varying rheostat and note down corresponding rpm.

TABULAR COLUMN:

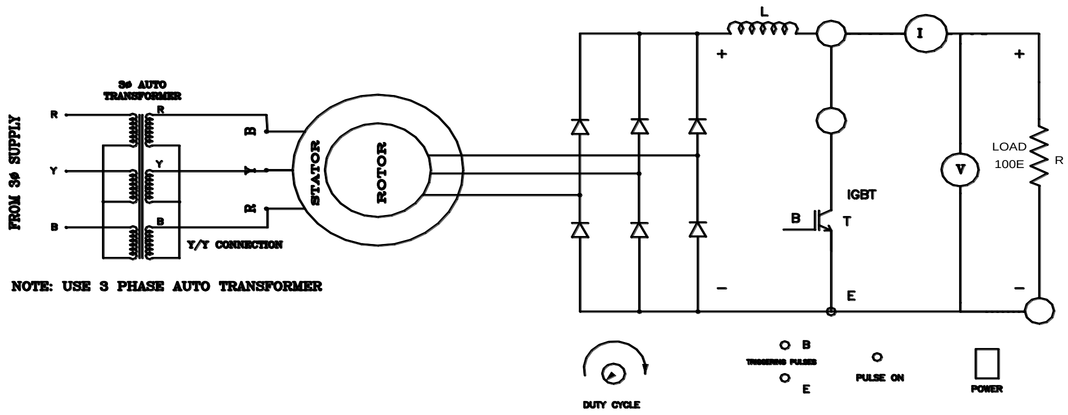
FOR R LOAD:

S. No.	Voltmeter readings V	Ammeter readings I	Rotor resistance R=V/I	Speed in RPM
1.				
2.				
3.				
4.				

FOR RL-LOAD:

S. No.	Voltmeter readings V	Ammeter readings I	Rotor resistance R=V/I	Speed in RPM
1.				
2.				
3.				
4.				

II By varying duty cycle of chopper connected to rotor circuit.



PROCEDURE:

1. Power circuit connections are made as shown in the circuit diagram. Connect three phase input to the three phase autotransformer. The output of the autotransformer terminals are connected to the respective R, Y, B stator terminals (top) of three phase wound rotor induction motor. The rotor terminals (bottom) of the three phase wound rotor induction motor is connected to the 3phase input of respective R, Y, B terminals of three phase wound rotor induction motor control power circuit consists of diode rectifier, IGBT chopper & a load resistance.
2. Connect the rheostat of 100Ω/2A load.
3. Ammeter and voltmeter are connected internally.
4. Check all the connections and confirm connections made are correct before switching on the equipments**.**
5. Keep rheostat at minimum resistance (0 Ω) initially.
6. Keep pulse release at off position.
7. Keeping auto transformer at minimum position switch on the rectifier circuit to rotor using three phase MCB.
8. Switch on three phase Mains supply to auto transformer.
9. Increase the autotransformer voltage slowly for suitable value such that motor rotates.
10. Now keep rheostat at 50 Ω approximately.
11. Now switch on the control circuit & pulse release key by keeping duty cycle at minimum position.

12. Vary the duty cycle of the chopper in steps record the speed of the motor.

TABULAR COLUMN:

FOR R LOAD:

S. No.	Duty cycle	Speed in RPM
1.		
2.		
3.		
4.		
5.		

FOR RL-LOAD:

S. No.	Duty cycle	Speed in RPM
1.		
2.		
3.		
4.		
5.		

RESULT: Observed speed control of three phase slip ring induction motor by using static rotor resistance control.

VIVA VOCE:

1. Classify induction motors based on rotor construction.

2. What is squirrel cage induction motor?

3. What is the advantage of slipring over squirrel cage induction motor?

4. What are the applications of induction motor?

5. What are the different speed control methods of induction motor.

6. What is rotor resistance contol?

9. SINGLE PHASE FULLY CONTROLLED RECTIFIER WITH R & RL LOADS USING SIMULATION TOOLS

AIM: To simulate single phase ac to dc converter with R & RL loads using matlab/simulink.

OBJECTIVE: To obtain the out put voltage waveforms of single phase fully controlled rectifier with R & RL loads using MATLAB/simulink.

APPARATUS:

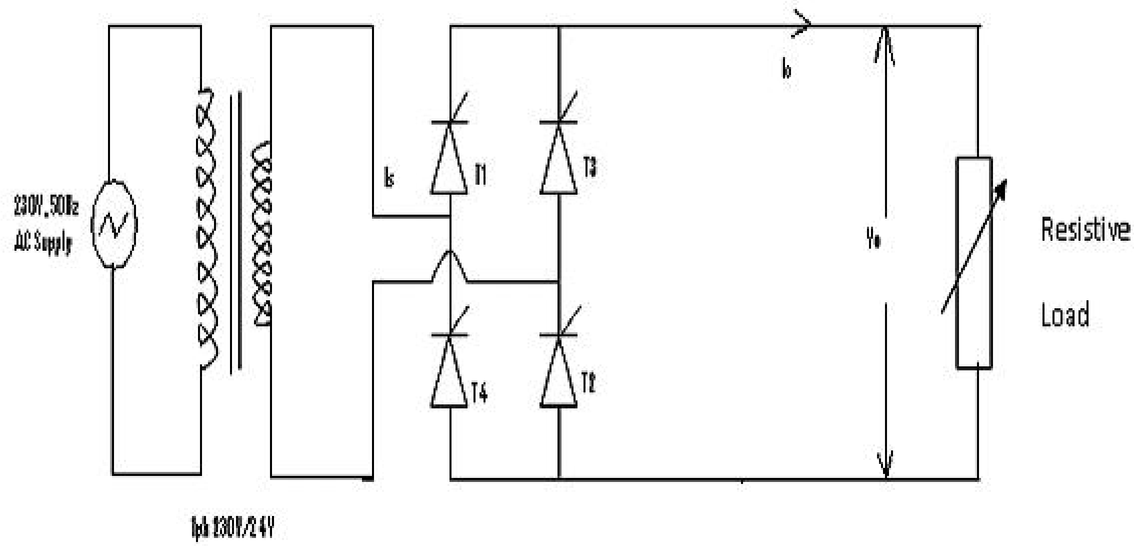
Sl.No.	**NAME OF THE COMPONENTS**	**RANGE**	**QUANTITY**
1	Computer	4 GB RAM, 500 HDD, 2.8 MHZ	1 no
2.	Matlab/Simulink software	2016 version	1 no

THEORY: The phase controlled rectifiers using SCRs are used to obtain controlled dc output voltages from the fixed ac mains input voltage. The circuit diagram of a fully controlled converter is shown in Figure. The output voltage is varied by controlling the firing angle of SCRs. The single phase fully controlled converter consists of four SCRs. During positive half cycle, SCR1 and SCR 2 are forward biased. Current flows through the load when SCR1 and SCR2 is triggered into conduction. During negative half cycle, SCR3 and SCR4 are forward biased. If the load is resistive, the load voltage and load current are similar.

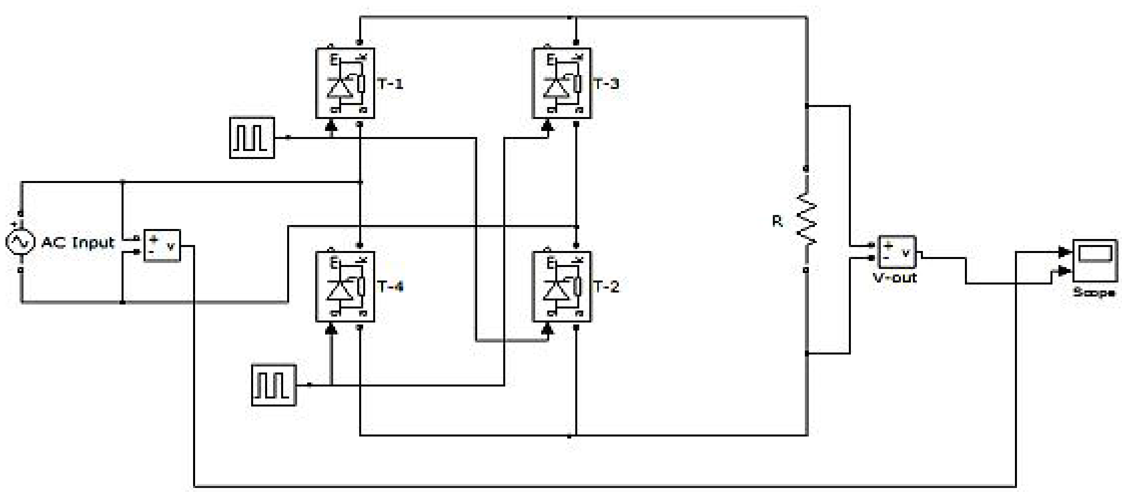
PROCEDURE:

1. In MATLAB software open a new model in File->New->model.
2. Start SIMULINK library browser by clicking the symbol in toolbar .
3. And Open the libraries that contain the blocks you will need . These usually will include the sources, sinks, math and continuous function block and possibly other.
4. Drag the needed blocks from the library folders to that new untitled Simulink Window. You must give it a name using the Save As menu command under the File menu heading. The assigned filename is automatically appended with an .mdl Extension.
5. Arrange these blocks in orderly way corresponding by Matlab Model Shown Below.
6. Interconnect the blocks by dragging the cursor from the output of one block to the Input of another block.
7. Double click on any block having parameters that must be established and set these parameters.
8. It is necessary to specify a stop time for the simulation; this is done by clicking on the simulation parameters entry on the simulation-> parameters entry on the Simulation toolbar.
9. Now we are ready to simulate our block diagram. Press start icon to start the Simulation. after simulation is done, double click the scope block to display the Output. Click the auto scale icon in the display window to scale the axis as per Variable range.
10. Finally Save the Output

CIRCUIT DIAGRAM:



MATLAB MODEL



OUTPUT WAVEFORMS:

Set AC Input Parameter

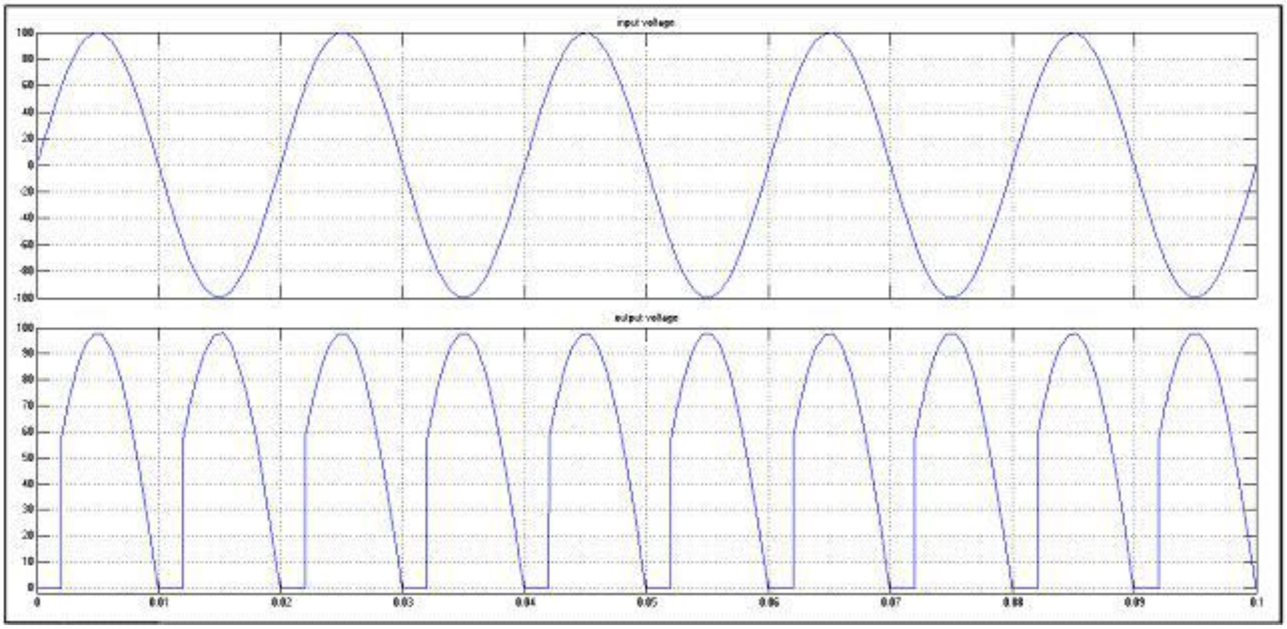
(Peak amplitude =100 V, Phase=0 deg and Frequency=50 Hz)

Set Pulse generator Parameter

(First pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.002 sec)

(Second pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.012 sec)

WAVEFORMS: (For R load)



RESULT: Thus the simulation of single phase Full converter model is done and the output is verified using MATLAB Simulink

Viva-Voce Questions

1. What will happen if the firing angle is greater than 90 degrees?
2. What are the performance parameters of rectifier?
3. What is the difference between half wave and full wave rectifier?
4. If firing angle is greater than 90 degrees, the inverter circuit formed is called as?
5. What is DC output voltage of single phase full wave controller?

10. SINGLE PHASE INVERTER WITH PWM TECHNIQUE USING SIMULATION TOOLS

AIM: To simulate single phase inverter with PWM technique using MATLAB.

OBJECTIVE: Understand the operation of single phase inverter with PWM technique using MATLAB.

APPARATUS:

SI.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1	COMPUTER	4 GB RAM, 500 HDD, 2.8 MHZ	1 no
2.	MATLAB/SIMULINK SOFTWARE	2016 version	1 no

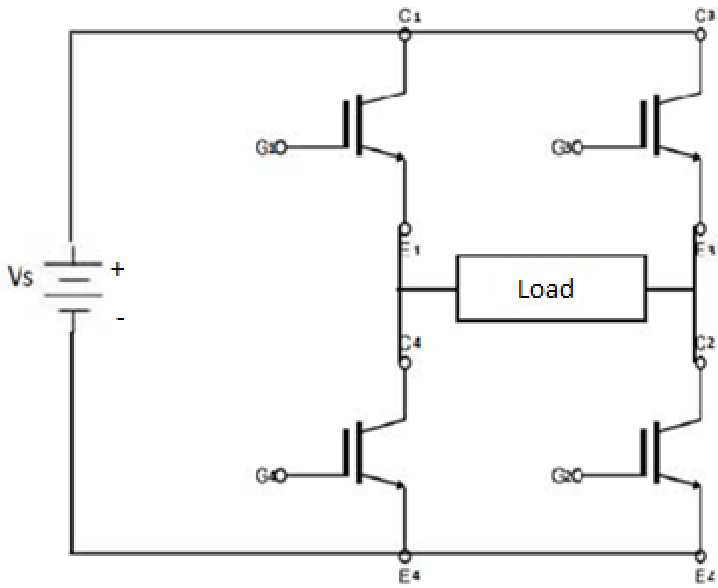
THEORY:

A device that converts DC power in to AC power at output voltage and frequency is called an inverter. Some industrial applications of inverters are for adjustable speed AC drives, inductive heating, stand by aircraft supplies, UPS, HVDC, transmission lines etc.

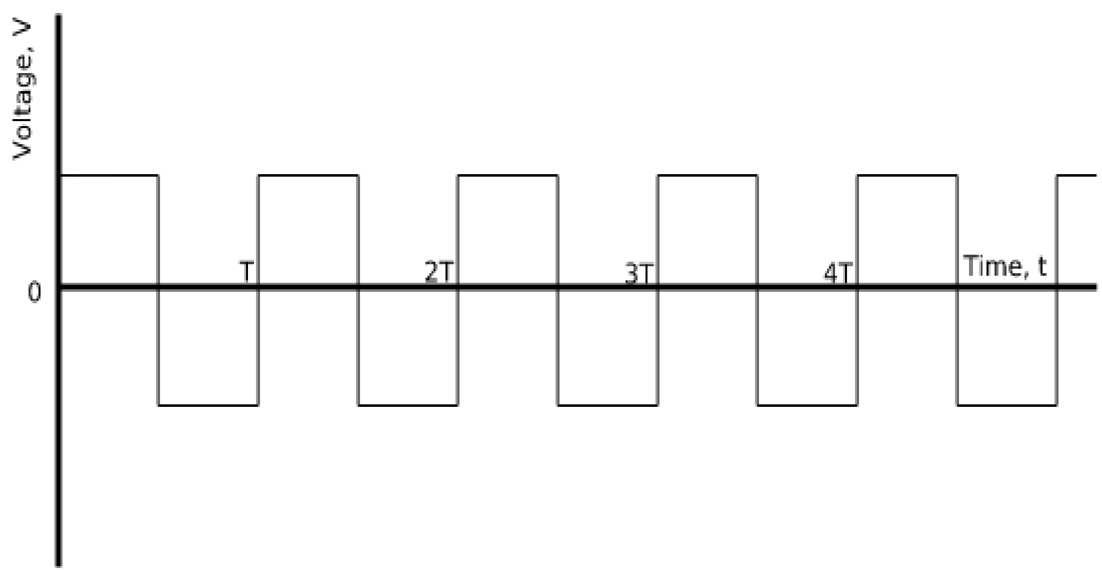
Schematic diagram of a single phase inverter is given in figure. The current can be supplied to the load by proper gating the IGBTs. Only two IGBTs will be on at any one time. Load voltage is PWM signal.

The power circuit is IGBT based full bridge inverter shown in figure. When T1, T2 conduct, load voltage is $+V_S$ and when T3, T4 conduct load voltage is $-V_S$. The frequency of the output voltage can be controlled by varying the time period. For inductive loads the diodes connected in antiparallel with thyristors will allow the current to flow when the main thyristors are turned off. These diodes are called feedback diodes. The modulation technique used is sinusoidal pulse width modulation technique. The modulation index can be varied by the parameter setting through keyboard. The AC load voltage is controlled by controlling modulation index. Modulation index is the ratio of maximum amplitude of sine wave to maximum amplitude of triangular wave. When modulation index is set keeping amplitude of triangular wave constant the amplitude of sine wave is varied. This will happen in the internal circuit.

CIRCUIT DIAGRAM:



OUTPUT WAVEFORM:



PROCEDURE:

1. In MATLAB software open a new model in File->New->model.

2. Start SIMULINK library browser by clicking the symbol in toolbar .

3. And Open the libraries that contain the blocks you will need . These usually will include the sources, sinks, math and continuous function block and possibly other.

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5. Arrange these blocks in orderly way corresponding by Matlab Model Shown Below.

6. Interconnect the blocks by dragging the cursor from the output of one block to the Input of another block.

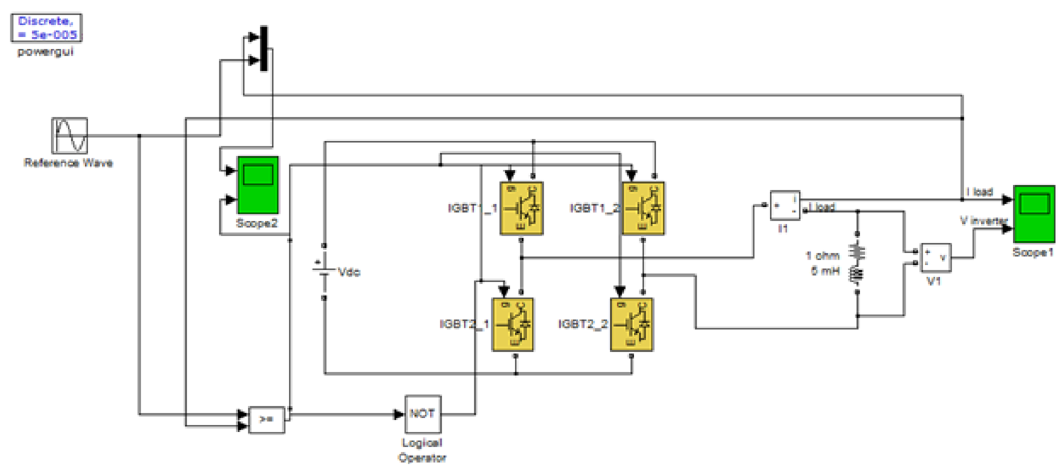
7. Double click on any block having parameters that must be established and set these parameters.

8. It is necessary to specify a stop time for the simulation; this is done by clicking on the simulation parameters entry on the simulation-> parameters entry on the Simulation toolbar.

9. Now we are ready to simulate our block diagram. Press start icon to start the Simulation. after simulation is done, double click the scope block to display the Output. Click the auto scale icon in the display window to scale the axis as per Variable range.

10. Finally Save the Output

MATLAB MODEL:



Result: Simulated the single phase inverter with PWM technique using MATLAB.

VIVA-VOCE QUESTIONS

1. What is meant by inverter?
2. What are the applications of an inverter?
3. What is THD?
4. What type of commutation preferable for inverter?
5. Draw the characteristics of SCR
6. What is modulation index?
7. What are different PWM techniques?
8. What is current control technique?
9. What is meant by H-bridge?
10. Expression for output voltage of inverter.

11.PWM CONTROL OF BOOST CONVERTER WITH R & RL LOADS

AIM: To study pwm control of boost converter with R & RL loads

Objective: To study the output voltage and output current waveforms of a boost converter, under CCM.

APPARATUS:

SI.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1.	Boost converter trainer kit	12 Amps / 600V	1no
2.	CRO	30 M Hz	1no
3.	Resistive load	60 ohms/5A, 125 ohms/5A	1no
4.	Inductive load	100 mH	1no
5.	Multimeter	0-300 V	1no
6.	CRO probes, Connecting wires	For required	1 no

THEORY:

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure.

(a) When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

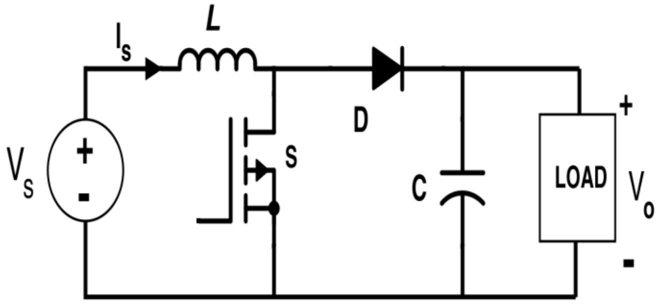
(b) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

PROCEDURE:

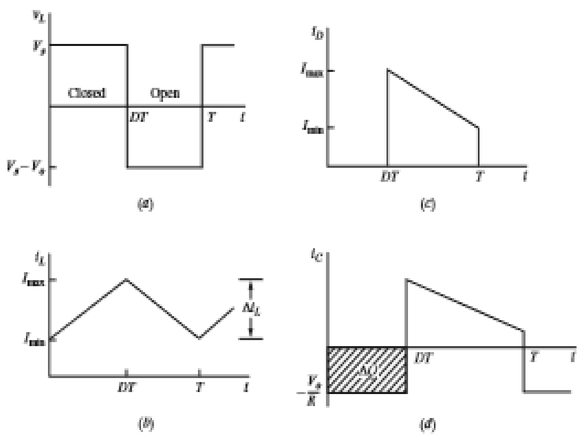
1. Connections are made as per the circuit diagram.
2. Switch on the DC input supply.
3. Give the gate pulses from the firing circuit.
4. Observe the waveforms across the load (R & RL) in the circuit for different firing angles.

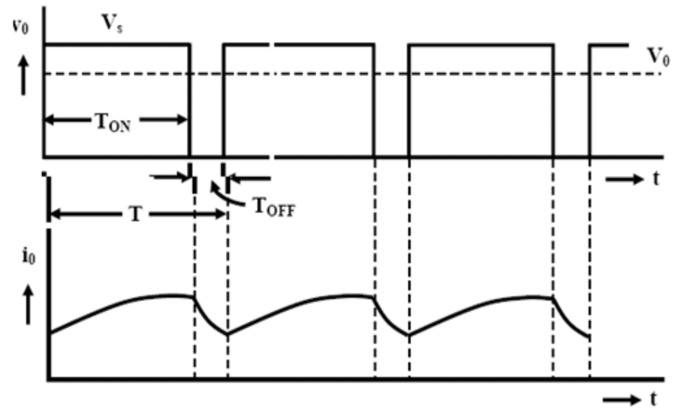
CIRCUIT DIAGRAM:



Waveforms:

R Load **RL Load**





OBSERVATIONS:

Set voltage for boost operation = 5V

S.No	Input Voltage(V)	T_{ON}	T_{OFF}	D=T_{ON}/T	Output voltage measured(V_o)	Output voltage calculated(V_o)
1.	3					
2.						
3.						

Model Calculations:
T=TON+TOFF
D=T_{ON}/T

Vo=$\frac{D}{1-D} V_s$ (calculated)

Precautions:
Check the circuit connections as per the schematics.
Confirm the connected input and output terminals correctly to source and load as shown in Fig.

RESULT: Analyzed pwm control of boost converter with R & RL loads.

(Viva voce questions)

1. Define boost converter.
2. Define is PWM.
3. What is the effect having more duty cycle and less duty cycle.
4. Explain working principle of boost converter.
5. What are the advantages of boost converter.
6. Give applications of boost converter.
7. Draw the boost topology.
8. Define duty cycle.
9. What is the range of duty cycle.
10. What is meant by pwm control in boost converter.

12. IGBT BASED THREE PHASE PWM INVERTER WITH R LOAD

AIM: Analyze the performance of three phase IGBT based pwm inverter.

OBJECTIVE: To study the performance of three phase IGBT based pwm inverter.

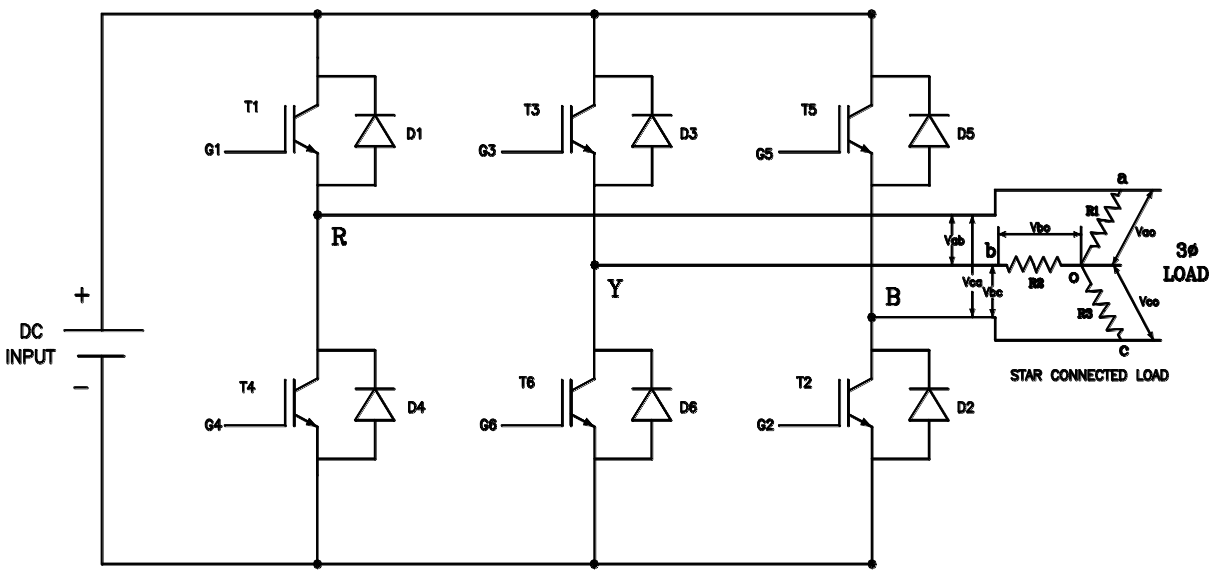
APPARATUS:

S.No	Name of the equipment	Type	Range	Quantity
1	Three phase inverter module	-	220V/2A	1
2	Regulated power supply		(0-30V)/(0-2A)	1
3	R-load	-	100Ω/2A	3
4	CRO/power scope	digital	-	1
5	Multimeter	digital	-	1
6	Patch chords	-	-	-

THEORY: Schematic diagram of a three phase inverter is given in the fig. The current can be supplied to the load by proper gating the IGBTs. Only two IGBTs will be on at any one time. Load voltage is PWM signal.

The AC waveform produced by a single phase inverter is poor version of the sine wave and is not suitable for most industrial applications 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 120^0 mode each device conducts for 120^0. The devices of same arm operate in complementary manner, i.e. T_1, T_4; T_3, T_6, and T_5, T_2, are turned on with a time interval the inverter arms are operated at 120^0 phase difference, i.e., the upper group of IGBTs T_1, T_3, T_5 conduct at an interval of 120^0. This means that if T_1 is triggered at $\omega t = 0$, then at $\omega t = 120^0$ T_3 must be triggered and at $\omega t = 240$, T_5. The same is true for lower group of thyristors. Thus, a period of one cycle has six steps and in each step, three IGBTs are in conducting state.

CIRCUIT DIAGRAM:



PROCEDURE:

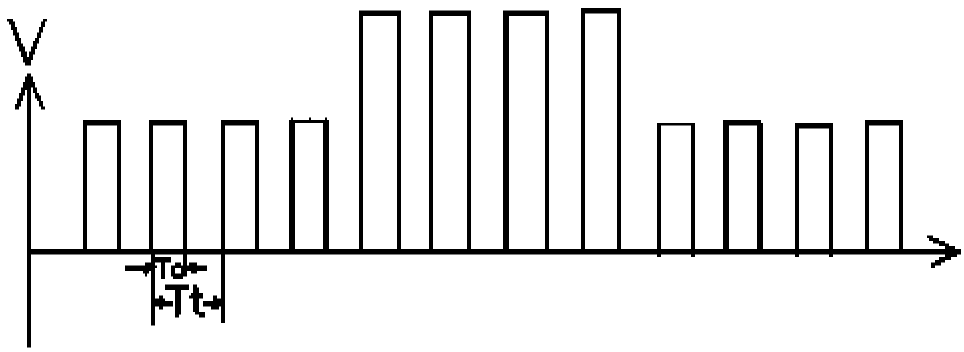
1. Circuit connections are made as shown in the circuit diagram.
2. Connect three phase R load.
3. Check all the connections and confirm connections made are correct before switching on the equipments.
4. Switch on Power switch.
5. Keep the DC Voltage, Frequency knob at minimum position.
6. Switch on the MCB.
7. Adjusting input DC voltage to 30V or suitable value.
8. Observe the load voltage wave forms using CRO/power scope.
9. Vary the modulation index & observe the wave forms on CRO.

10. Record the frequency of the inverter circuit & the variation in AC voltage with reference to the modulation index.
11. Set new modulation index.Tabulate the readings in the table.
12. Slowly reduce the DC voltage to zero. Switch off all the switches when the voltage is completely reduced.

Note:

Experiment may be conducted for different frequency keeping modulation index constant. In this procedure AC load voltage is found to be almost constant.

WAVEFORMS:



Three phase PWM inverter output

Modulation index=To/Tt

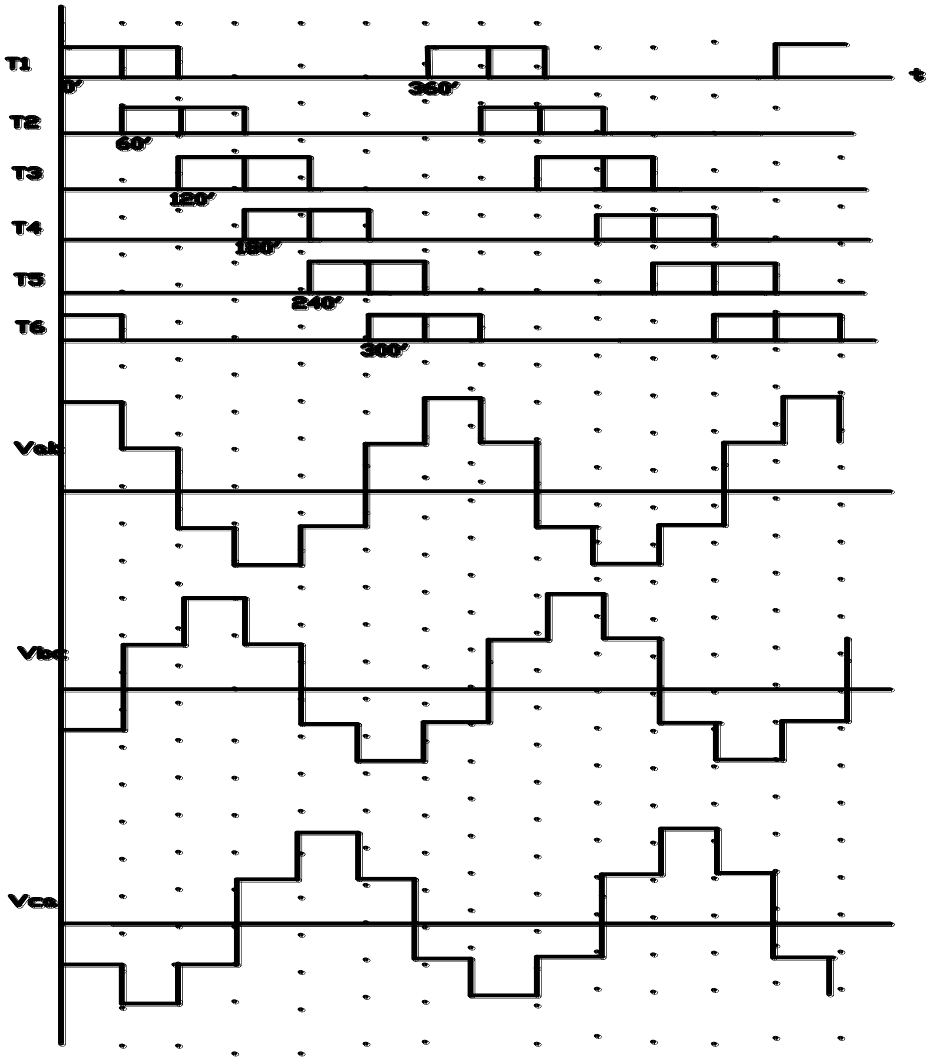


Fig: Voltage waveform for 120' mode six step 3 phase

Formulae used:

$$v_{ao} = \sum_{n=1,3,5..\infty} \frac{2E_{dc}}{n\Pi} \sin(n\omega t)$$

.......phase voltage

$$v_{ab} = \sum_{n=1,3,5..\infty} \frac{2E_{dc}}{n\Pi} \left[\sin\ n\omega t - \sin\ n(\omega t - \frac{2\Pi}{3} \right]$$

.........line voltage

OBSERVATIONS:

Frequency = Hz.
Input DC Voltage = V

S.No.	Modulation index	Load voltage(Vac)
1		
2		
3		
4		
5		

RESULT: The performance of 3-ø IGBT PWM Inverter with star connected load are studied and out put wave forms are drawn on the graph sheet.

VIVA-VOCE QUESTIONS

1. What is PWM ?
2. What are the various methods of PWM ?
3. What is the difference between SPWM and other PWM techniques ?
4. What is modulation index ?

5.By what means IGBT can be controlled?

6.What are the terminals of IGBT?

7.IGBT can be constructed by?.

8.What are the advantages of IGBT's over SCR?

9.What are the output voltage waveforms of phase and line voltages in 120 degree and 180 degree conduction modes?

13.SINGLE PHASE FULLY CONTROLLED BRIDGE CONVERTER WITH R & RL LOADS

AIM: To analyze the operation of Single Phase Fully Controlled Bridge Converter with R & RL load.

OBJECTIVE: To convert AC supply to variable DC supply by changing the firing angles of thyristers and
To observe the input and output waveforms by using CRO & calculate voltage and currents for different firing angles.

APPARATUS:

Sl.No.	NAME OF THE COMPONENTS	RANGE	QUANTITY
1.	Thyristor trainer kit (Power Circuit)	12 – 16 A, rms/1200 V	1 no
2.	SCR Triggering kit (Firing Circuit)	230V, 2A	1 no
3.	Isolation Transformer	230/0-24V, 2A	1 no
4.	CRO	30 MHz	1 no
5.	Resistive load	125 ohms/5A	1 no
6.	Inductive load	100 mH	1 no
7.	Multimeter	0-300V	1 no
8.	CRO probes, Connecting wires	For required	1 no

THEORY: This power circuit consists of four SCR’s connected as fully controlled bridge converter. A free wheeling diode is provided to observe the effect of free wheeling diode on inductive loads. Each device in the unit is mounted on an appropriate heat sink and is protected by snubber circuit. Short circuit protection is achieved using glass fuses. A circuit breaker is provided in series with the i/p supply for over load protection and to switch ON/OFF the supply to the power circuit.

When the circuit operation is considered two SCR’s conduct during + ve half cycle of the input and produces the load voltage and turns off at the end of + ve half cycle. The another two SCR’s conduct during – ve half cycle of the input which also gives out the load voltage and turns off at the end of a cycle. It is the circuit operation when R load is connected.

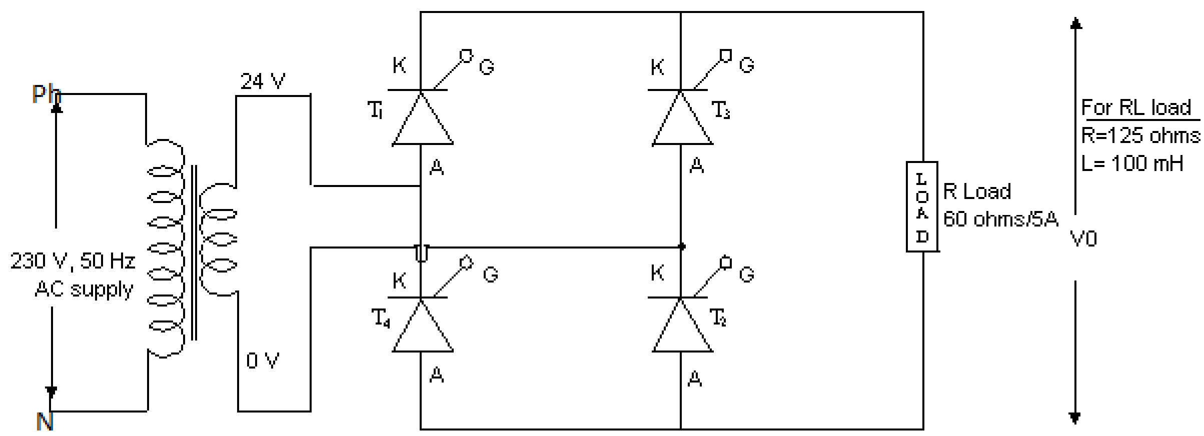
PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Firing pulses are applied for the respective SCR’s from the firing circuit.
3. The main supply is switched ON and triggering circuit is sitched ON
4. Wave forms across the load are observed in CRO values are noted down and tabulated for different firing angles.
5. Repeat the step 4 for different firing angles and different loads.
6. Similarly RL-load steps of the above are repeated.

INSTRUCTIONS:

1. Check all the SCR's for good conduction before making the connections.
2. Check the firing circuit triggers outputs and its relative phase sequence.
3. Make fresh connections before you make a new experiment.
4. Preferably work at low voltages (20-30 V) for every new connection after careful verification it can be raised to maximum ratings (this is to reduce damage due to wrong connections and high starting current problems).
5. Do not make Gate & Cathode measurements when the power circuit ON.

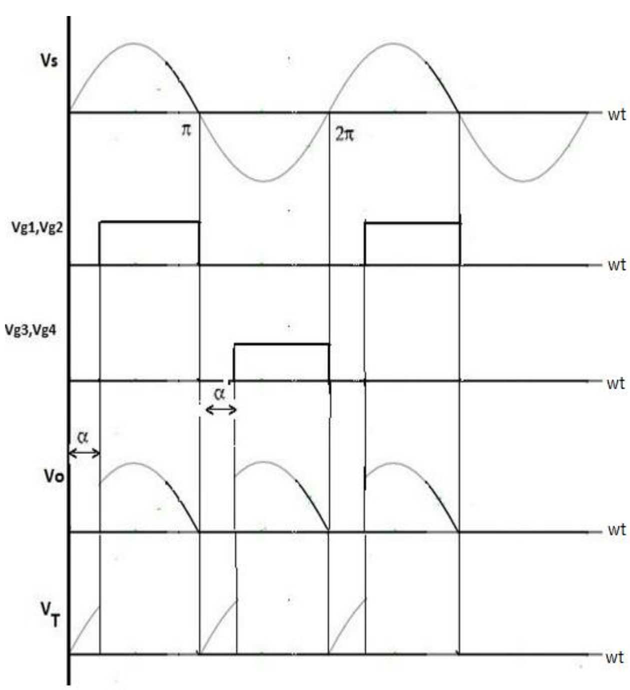
CIRCUIT DIAGRAM:



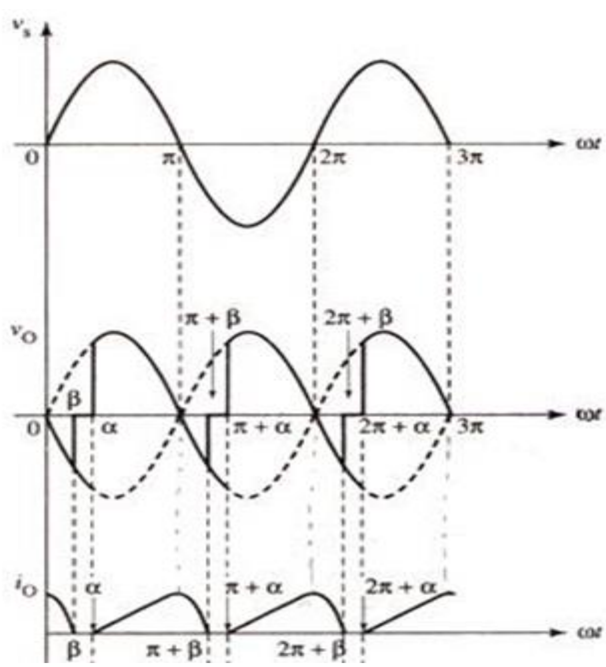
<u>1Φ fully controlled bridge converter</u>

Waveforms:

R Load



RL Load



OBSERVATIONS:

Fully Controlled Bridge Rectifier Using R Load $V_m = 24V$

R – Load		
Triggering angle ά (deg)	Output voltage V_0 (V) (Measured)	Output voltage V_0 (V) (Calculated)
0 30 60 90 120 150 180		

Fully Controlled Bridge Rectifier Using RL Load $V_m = 24V$

RL – Load		
Triggering angle ά (deg)	Output voltage V_0 (V) (Measured)	Output voltage V_0 (V) (Calculated)
0 30 60 90 120 150 180		

THEORETICAL CALICULATIONS :

$$V_{d.c} = V_{avg} = \frac{1}{T}\int_{\alpha}^{\pi} V_m Sin\,\omega t.d\omega t \quad \text{for R-Load}$$

$$= \frac{V_m}{\pi}(1 + Cos\alpha)$$

$$V_{d.c} = V_{avg} = \frac{1}{T}\int_{\alpha}^{\pi+\alpha} V_m Sin\,\omega t.d\omega t \quad \text{for RL-Load}$$

$$= \frac{2V_m}{\pi} Cos\alpha$$

RESULT: The performance of Single phase Fully controlled bridge converter of R & RL-load are studied and out put wave forms for different firing angles are drawn on the graph sheet.

Viva-Voce Questions

1. How many quadrants does a Full controlled rectifier works ?
2. What is meant by Line commutation ?
3. How the thyristers get commutated ?
4. When a full controlled rectifier work as inverter ?
5. What is the change observed in wave forms for R-load & RL-load