ANNAMALAI UNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

B.E (EEE)

V - SEMESTER

2020 - 2021

POWER ELECTRONICS AND DRIVES LAB

Name…………………………………………………………………

Reg. No……………………………………………………………….

Semester……………………………………………………………….

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

To develop the Department into a "Centre of Excellence" with a perspective to provide quality education and skill-based training with state-of-the-art technologies to the students, thereby enabling them to become achievers and contributors to the industry, society and nation together with a sense of commitment to the profession.

MISSION

M1: To impart quality education in tune with emerging technological developments in the field of Electrical and Electronics Engineering.

M2: To provide practical hands-on-training with a view to understand the theoretical concepts and latest technological developments.

M3: To produce employable and self-employable graduates.

M4: To nurture the personality traits among the students in different dimensions emphasizing the ethical values and to address the diversified societal needs of the Nation

M5: To create futuristic ambience with the state-of-the-art facilities for pursuing research.

CONTENTS

Ex. No.:
Date:

PERFOMANCE EVALUATION OF THREE PHASE HALF AND FULL CONTROLLED CONVERTER

AIM:

To study the operation and performance of the half and fully controlled converter with resistive load.

APPARATUS REQUIERD:

Three phase Semi and Full converter Power module and Control module.

CRO (isolated CRO).

Voltmeter (0 - 300V) MI – 1, (0 - 300V) MC – 1,

Ammeter (0 – 5A) MC – 1.

Patch Chords.

PRECAUTIONS:

The phase sequence synchronous of SCR firing circuit & SCR power circuit is checked.

The SCR firing and power circuit are switched off and the MCB is set to off position.

The SCR firing circuit module POT P_1 is kept at minimum position.

The SCR firing circuit for P_1 nearer the switch in working for module one is "INT" internal and "EXT" external mode. Therefore the switch is set in "INT" mode.

PROCEDURE:

1. The SCR firing circuit is switched ON, check the firing pulses and other waveforms at the test points.
2. For fully controlled converter, SCR terminals K_1, K_3 and K_5, A_2, A_4 and A_6 are connected.
3. For Half controlled converter, SCR terminals K_1, K_3 and K_5, Diode terminals A_2, A_4 and A_6 are connected.
4. The R-load is connected across the K_5 and A_6.
5. The voltmeter and CRO with attenuation probe is connected across the load.
6. Supply is switched ON and the voltmeter (Vo) readings for various load conditions are tabulated.
7. Output voltage waveform is traced.

FRONT PANEL VIEW OF POWER CIRCUIT
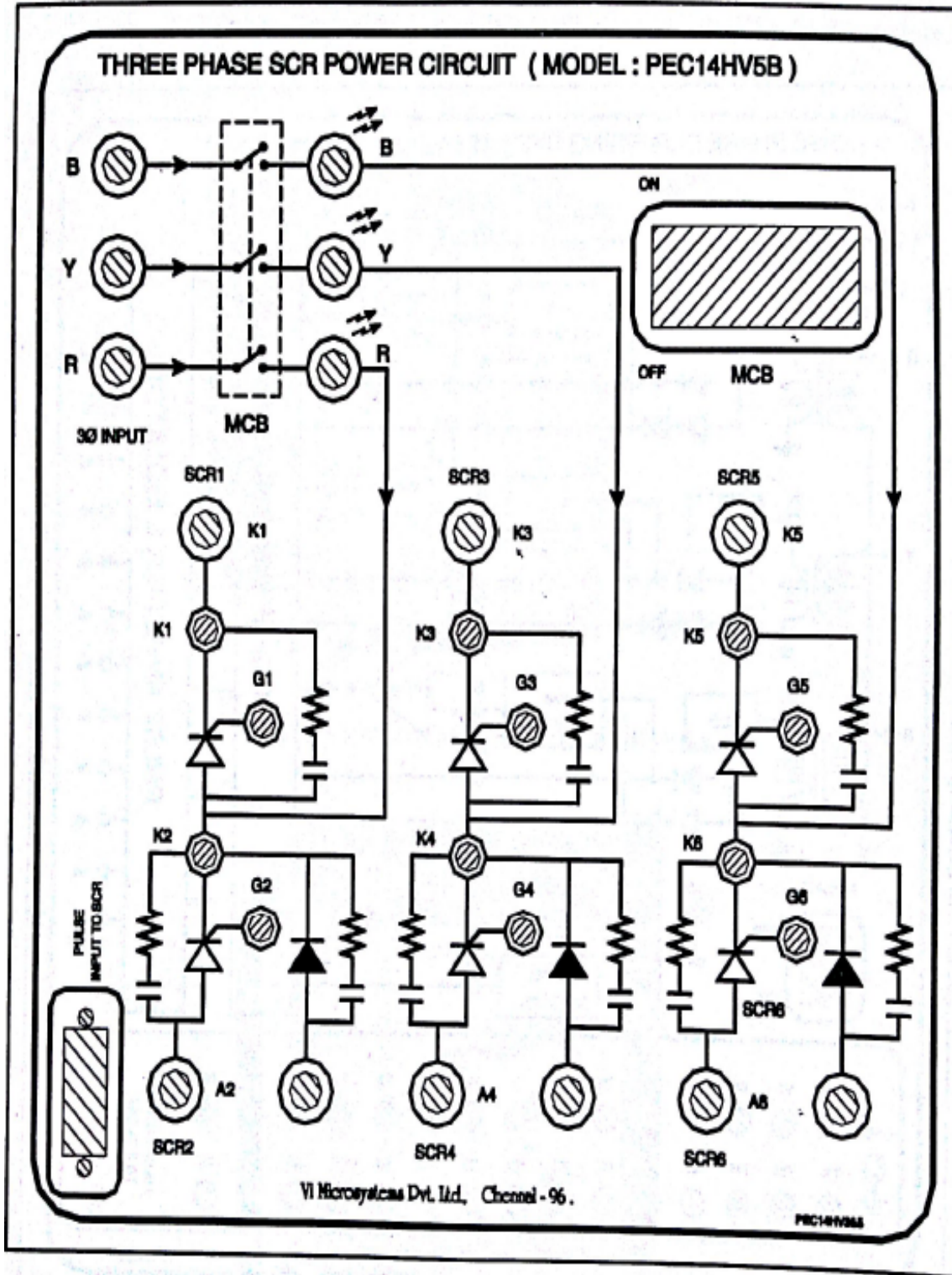
FORMULAE:

Three phase fully controlled converter

$$V_{dc} = \frac{3V_m}{\pi}(Cos\alpha)$$

Three phase half controlled converter

$$V_{dc} = \frac{3V_m}{2\pi}(1 + Cos\alpha)$$

Where,

V_{dc} - Average load voltage

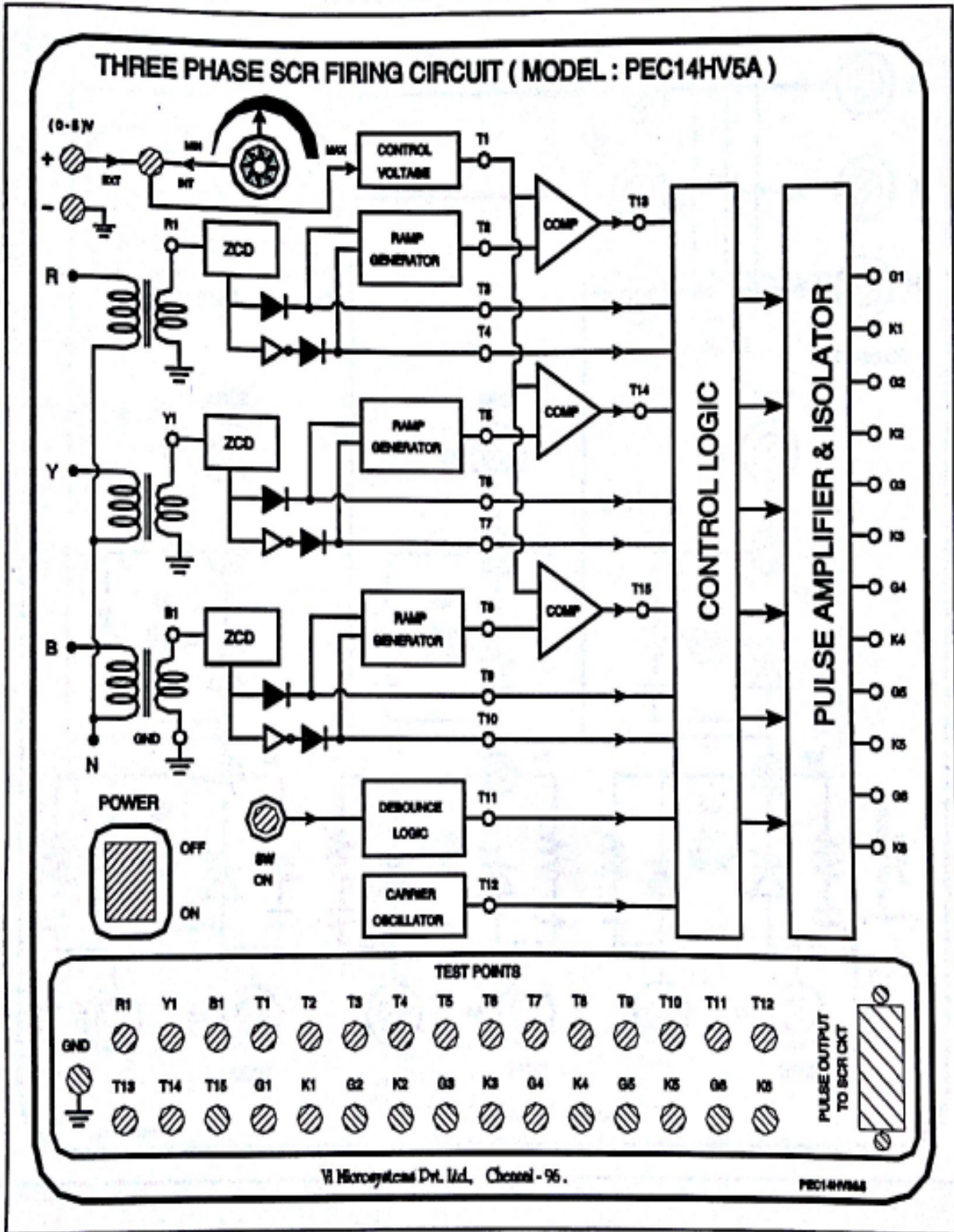α - Firing Angle

V_m - Peak voltage magnitude of AC wave

<u>Three phase fully controlled converter</u>

$$V_{dc} = \frac{3}{\pi}\int_{\frac{\pi}{3}+\alpha}^{\frac{2\pi}{3}+\alpha} V_{ml}Sin\omega t.d(\omega t)$$

$$= \frac{-3Vml}{\pi}(Cos\ \omega t)_{\frac{\pi}{3}+\alpha}^{\frac{2\pi}{3}+\alpha}$$

$$= \frac{-3Vml}{\pi}\left[Cos\left(\frac{2\pi}{3}+\alpha\right) - Cos\left(\frac{\pi}{3}+\alpha\right)\right]$$

We know that,

$$Cos\ C - Cos\ D = -2Sin\frac{C+D}{2}Sin\frac{C-D}{2}$$

$$V_{dc} = \frac{-3Vml}{\pi}\left[-2Sin\left(\frac{\pi+2\alpha}{2}\right)Sin\frac{\frac{\pi}{3}}{2}\right]$$

$$= \frac{-3Vml}{\pi}\left[-2Sin\left(\frac{\pi+2\alpha}{2}\right)Sin\frac{\pi}{6}\right]$$

$$= \frac{-3Vml}{\pi}\left[-2Sin\left(\frac{\pi}{2}+\ \alpha\right)\left(\frac{1}{2}\right)\right]$$

FRONT PANEL VIEW OF CONTROL CIRCUIT

THREE PHASE SCR FIRING CIRCUIT (MODEL : PEC14HV5A)

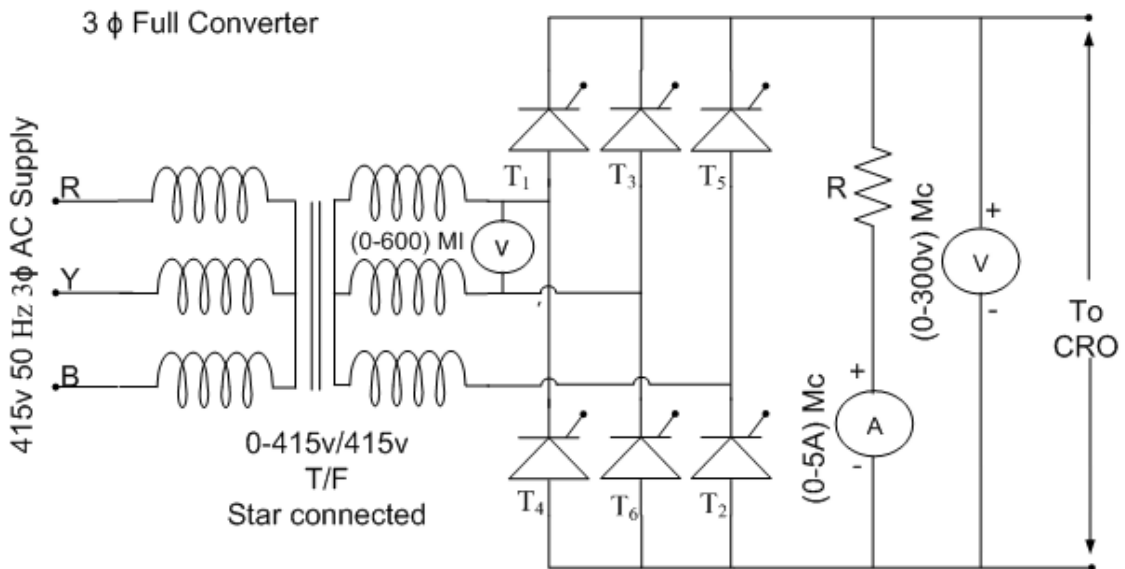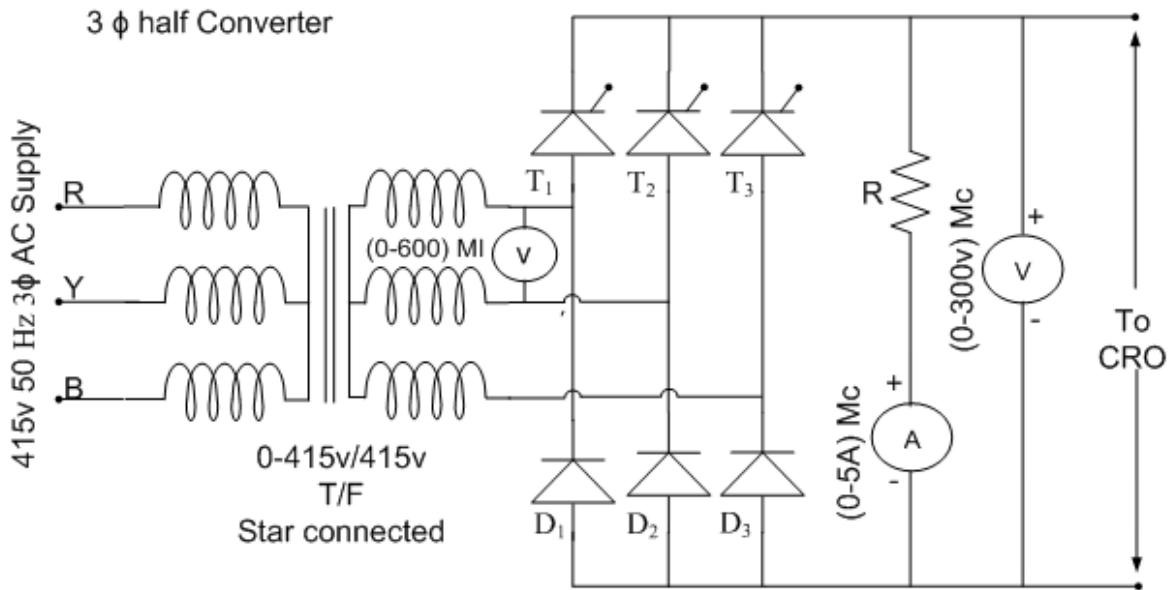We know that $Sin\left(\frac{\pi}{2}+\alpha\right)=Cos\alpha$

So, $\qquad V_{dc}=\dfrac{3Vm}{\pi}Cos\alpha$

Three phasehalf controlled converter

$$V_{dc}=\frac{3}{\pi}\int_{\alpha}^{\pi}(Vm\ Sin\ \omega t\ d\omega t)$$

$$=\frac{-3Vm}{2\pi}[Cos\omega t]_{\alpha}^{\pi}$$

$$=\frac{-3Vm}{2\pi}(Cos\ \pi-Cos\alpha)$$

$$V_{dc}=\frac{3Vm}{\pi}(1+Cos\ \alpha)$$

3 φ half Converter

3 φ Full Converter

TABULATION

Fully controlled converter

SI.NO	Vdc	Vrms	Idc	Vdc Calcutated

Half controlled converter

SI.NO	Vdc	Vrms	Idc	Vdc Calcutated

RESULT:

       The performance characteristics of the three phase semi and full converters are studied and the output waveforms are traced.

Ex. No.:
 Date:
<p align="center">**SPEED CONTROL OF DC SHUNT MOTOR USING SCR**</p>

AIM:
      To obtain the no load speed voltage characteristics of the given DC Shunt motor in the open loop mode

THEORY:
The Fig-1 shows the power circuit. Applying KVL around the loop,

$-V_t + I_a R_a + E_b = 0$

$V_t = E_b + I_a R_a$

$I_a R_a$ is very small when compared to V_t on No load, hence

$V_t \propto E_b$.....(i)

From the EMF equation of the dc motor,

$$E_b = \frac{\varphi ZNP}{60\ A}$$

i.e $E_b \propto N\varphi$ ....(ii)

Substituting (ii) in (i),

$V_t \propto N\varphi$

Since the field is separately excited, φ remains constant.
Therefore,

$V_t \propto N$

      Therefore by obtaining a dc voltage of variable amplitude from a dc voltage of fixed amplitude using the dc chopper and applying the same to the armature of dc shunt motor, the speed of the motor can be varied.

PRINCIPLE OF OPERATION:
1. The field winding of the motor is separately excited through a Full-wave Bridge Rectifier D_1, D_2, D_3 and D_4.
2. The armature of the motor is connected across a Half-Controlled Full wave Bridge circuit and hence experiences variable voltage depending upon the triggering pulse applied to the gates of SCR_1 and SCR_2.

FIELD FAILURE PROTECTION:

      In a dc shunt motor the speed is inversely proportional to flux. On other words it is inversely proportional to field current. If the field circuit is open, the field current becomes zero and hence the speed becomes uncontrollable. To avoid this, the circuit incorporates a field failure protection.

Block Diagram
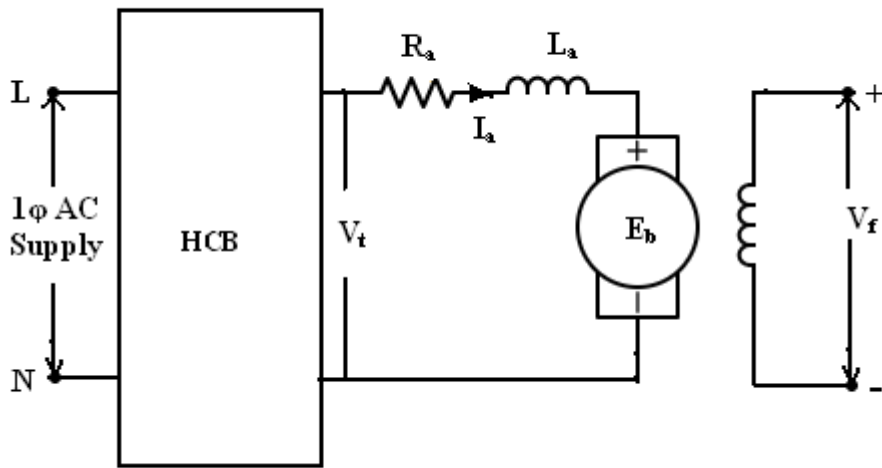
Practical Circuit Diagram for Speed Control of dc Shunt Motor
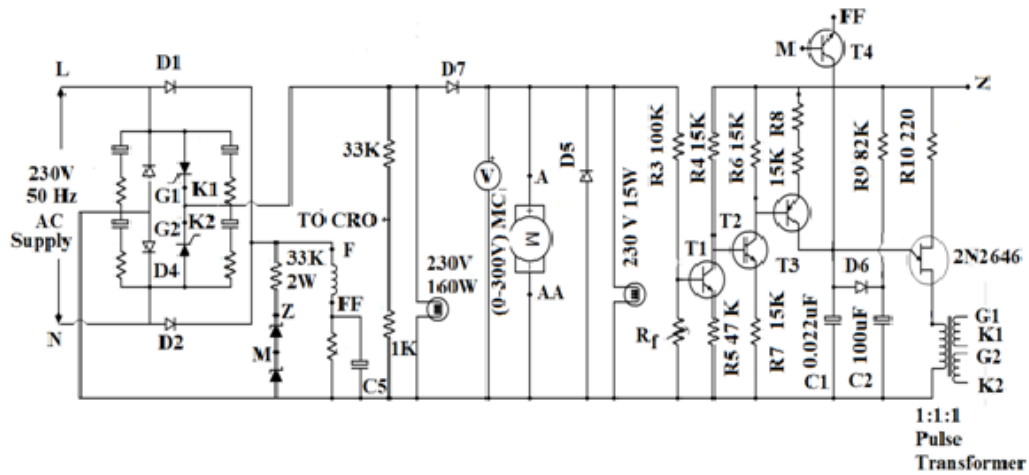
The transistor T_4 is used for this protection. The emitter is connected to the field terminal FF and the base is connected to the point M.

When the dc voltage is applied across the field, the resistor R_2 which is connected in series with the field winding drops about 6V. Only when sufficient field current is drawn, this drop approaches 6V. This voltage is greater than the potential at the point M and hence T_4 will remain in OFF state.

If the field current becomes zero the drop across the resistor R_2 becomes zero which turns ON T_4 and capacitor C_1 is discharged through T_4 and R_2. Therefore, the emitter voltage of UJT is also zero and hence no firing pulse will be applied to the SCRs.

CONTROL CIRCUIT:

When the supply is switched ON, T_2 will start conducting through R_5 ($R_5 < R_7$) and the hence voltage at the collector of T_2 goes low which helps T_3 to turn ON. The capacitor C_2 is charged through R_S, T_3 and D_6. C_1 charges simultaneously but at a slower rate. D_6 prevents charging of C_1 by C_2. When the voltage across C1 exceeds peak voltage the UJT gets triggered and the relaxation oscillator generates a pulse train across the pulse transformer secondary's. This fires SCR_1 and SCR_2 developing voltage across the motor armature "A-AA".
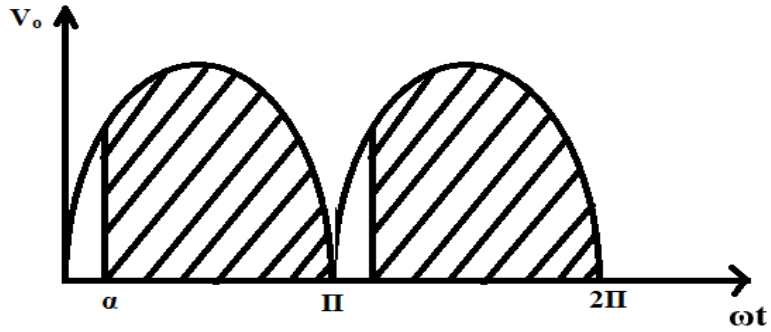
By varying the "Speed" control potentiometer the rate of charging of C_1 can be varied and hence the instant of firing (firing angle) can be varied. Thus speed of the motor can be controlled by using R_S.

The transistor T_1 is used for Armature Feedback Regulation.

SOFT START ACTION:

The soft start action is introduced by D_6-C_2-R_9, the capacitor C_1 is 0.022μF and C_2 is 100 μF. Initially when the circuit is turned ON the capacitor C_2 starts charging at a much faster rate compared to charging of C_1. The impedance offered by C_1 is greater than that of C_2. So even if the potentiometer R_S were fully anticlockwise (i.e. zero) the charging of C_1 is restricted by the charging rate of C_2. The SCR firing remains heavily reduced for the first few cycles, when the circuit is put ON, irrespective of the setting of R_S thus giving rise to 'soft-start'. After a few cycle C_2 charges to the full voltage through R_9 and gets effectively disconnected from the firing circuit due to the reverse biasing of D_6.

Model Graph

Formula Used:

$$V_{av} = \frac{1}{\pi} \int_{\alpha}^{\pi} V_m \, Sin\theta \, d\theta$$

$$= \frac{V_m}{\pi} [-cos\theta]_{\alpha}^{\pi}$$

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

$$V_{av} = \frac{V_m}{\pi} [1 + cos\alpha]$$

Sl. No	α (Degrees)	Calculated Voltage (Volts)	Voltmeter Reading (Volts)	Speed (RPM)

FUSE RATING:

      30% of the rated current = 30/100 x 2.3 = 1A.

APPARATUS REQUIRED:

1. E.T. Thyset Kit 13M
2. Digital Tachometer.
3. 230V, 100W Lamp & 230V, 15W Lamp.
4. CRO with unearthed terminals.

RATINGS/SPECIFICATIONS:

SCR- 106D

      I   : 4A

      PIV   : 400V

      IGT   : 200μA

      IH   : 3mA

MOTOR

      I   : 2.3A

      Speed: 1500 rpm

      Wdg : Shunt

      KW : 0.377

UJT 2N2646

      le : 20mA

      Vb2e : 30V max

      Vb2b1 : 35V max

      1b2 : 15mA

      : 0.56 to 0.78

ZENER - 20V

PRECAUTIONS:
1. The earth pin of the CRO must to be removed.
2. The variable potentiometer R_S is kept at maximum resistance position.
3. External connections are made in the location relevant to the circuit diagram.

PROCEDURE:
1. The points on the circuit plate designated by the same letter are internally connected.
2. The dotted line between two points indicates that external connection is necessary.
3. The motor field and armature connections are made at appropriate points.
4. Observing the precautions the supply is effected.
5. By gradually varying the variable potentiometer RS, the speed of the motor can be varied and for each variation the corresponding voltmeter and speed readings are noted and the waveforms are traced.

GRAPH:

A graph of speed verses voltage is drawn using the tabulated readings.

RESULT:

Thus the speed voltage characteristics of the given dc shunt motor is obtained.

Ex. No.:
Date:

DUTY CYCLE CONTROL OF IGBT BASED DC CHOPPER

AIM:

To study the operation of a single quadrant chopper with one switch.
To trace the PWM pulses and output voltage waveform for various values of duty cycles.

PRECAUTIONS:

1. Ensure all switches are in the OFF position while doing connection.
2. Ensure pulse release ON/ OFF switch is in OFF position, whenever power is switched ON to the chopper module.

APPARATUS REQUIRED:

IGBT trainer Module
Control Kit
 Inductor
 32V, 10W Lamp load
Voltmeter (0-75V)MC - 2 Nos
 CRO

PROCEDURE:

1. Using the chopper module, connect the circuit as shown in the figure. Use either the switch T_2 or T_4.
2. Referring the mimic diagram make the following connections with power OFF to both modules.
   - i. Connect V+1 to B21 using patch cords.
   - ii. Connect the load rheostat between B23 and V-1.
   - iii. Connect a DC voltmeter (0- 30V) across the load rheostat.(B23 and V-2).
   - iv. Connect the gating signal cable from the control module to the chopper module.
3. Connect the power cable to chopper module and chopper control module, connect the CRO to mains.

Panel Diagram
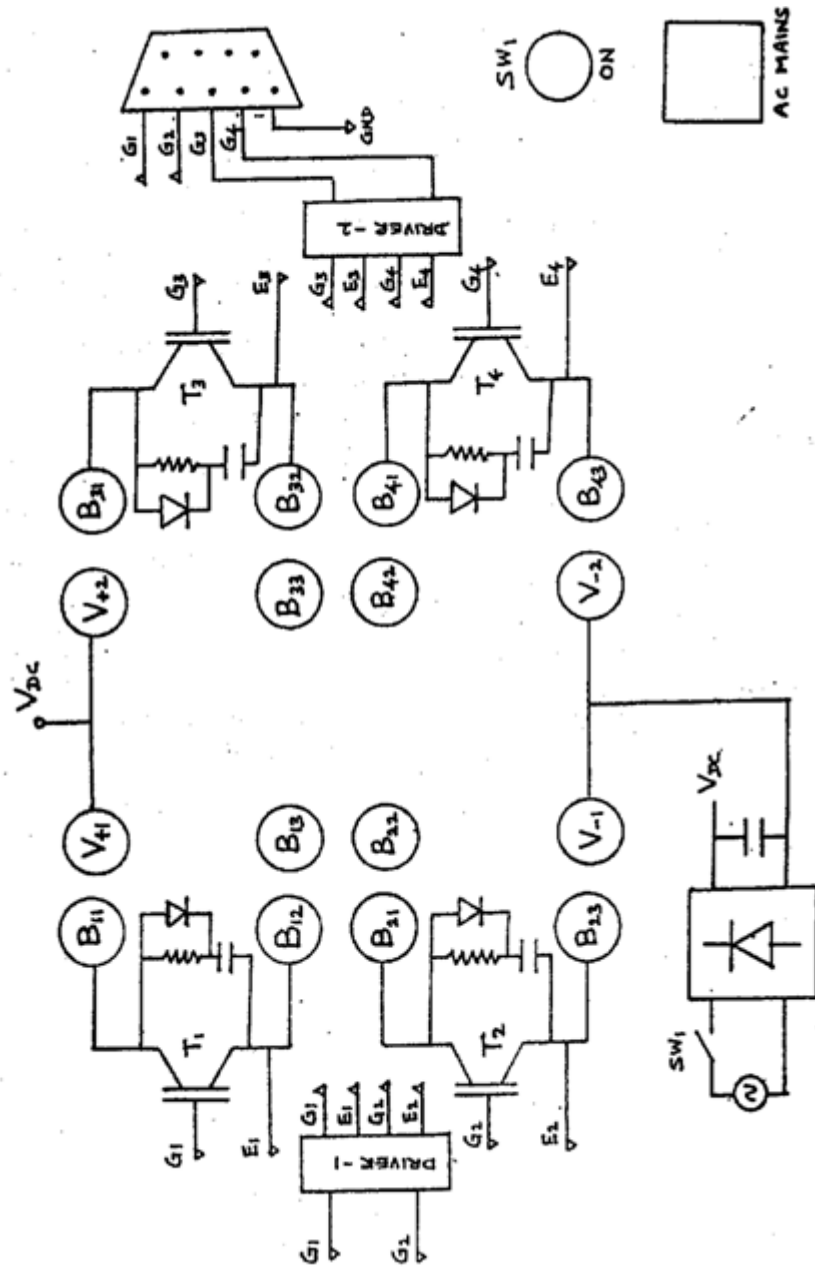
4. Switch ON power supply to CRO. Switch ON AC main to control module and adjust the carrier frequency to about2.2 KHZ. Keep the mode switch SW_3 in the control module at position 1 and pulse release ON/ OFF switch in OFF position.
5. Switch ON powers supply to the chopper module and switch ON SW_1.
6. Release the gating signal by switching on the switch SW2 in the chopper control module.
7. Observe the load voltage waveform through the CRO.
8. Vary the duty cycle ratio by means of pot P_2 and measure the output voltage. Measure the ON period T_{on} and the chopping period T using CRO. Calculate Vo using the formula $v_0 = Dv_{dc}$
9. Plot the graph between the output voltage $_{Vo}$ and the duty cycle ratio D.
10. Keep the duty cycle ratio around 50% and vary the chopper frequency from about 1 kHz to 2.2 kHz in steps. For each step, note down the output dc voltage and measure the frequency and T_{0n} through the CRO.
11. Plot V_o verses frequency characteristics. In this the chopper is operated at various switching frequencies.

THEORY:

INSULATED GATE BIPOLAR TRANSISTORS:

The IGBT has some of the advantages of the MOSFET, the BJT and the GTO combined. Similar to the MOSFET, the IGBT has a high impedance gate, which requires only a small amount of energy to switch the device. Like the BJT, the IGBT has a small on state voltage even in devices with a large blocking voltage ratings (for example, V_{on} is 2-3V in a 1000V device).

IGBTs have the turn on and turn off times on the order of 1 µs and are available in module ratings as large as 1700V and 1200A. Voltage ratings up to 2-3 kV are projected.

CHOPPER CIRCUIT USING IGBT:

INTRODUCTION:

In ac application, the transformer serves to convert electrical power efficiently from one voltage level to another. Static dc to dc converters called as choppers achieve a similar function in dc. The operation of ac transformer is based on an alternating magnetic field. But in Chopper, the voltage conversion is achieved by power semiconductors, which functions as static switches switching at high repetitive frequency. Choppers are widely used for traction motor control, in electric automobiles, trolley cars, marine hoists, fork lift trucks and mine haulers. They provide smooth acceleration control, high efficiency and fast dynamic response. Choppers are also used in dc voltage regulators. The circuit configuration of a chopper

SINGLE QUADRANT CHOPPER
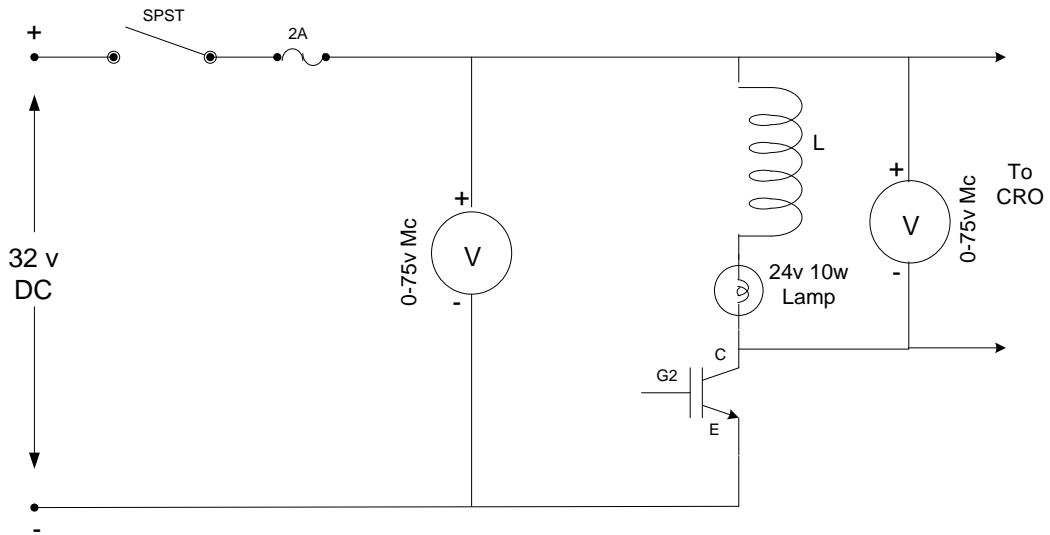
For Resistive Load

S.No	V_{supply} (Volts)	T_{on} (ms)	$T_{on} + T_{off}$ (ms)	V_{load} (Volts)	$V_{theoretical}$ (Volts)	% Duty Cycle

converter can be designed either to step down the input voltage level or to step up the input voltage to a higher level. Accordingly the chopper is called as step down or step up chopper.

STEP DOWN CHOPPER:

The switch SW is a semiconductor device. When a switch is ON for a time Ton, the input voltage Vs appears across the load. If the switch is OFF for a time Toff, the voltage across the load is zero. The waveforms of the output voltage and load current for resistive load are shown in figure.

Neglecting the voltage drop across the switch, the average output voltage V_o is given by

$$\text{Vo} = \frac{Ton}{T} \cdot Vs = f . Ton . Vs = D . Vs$$

where D = duty cycle ratio

T = chopping period

f = 1/T = chopping frequency

Theoretically the duty cycle ratio D can be varied from 0 to 1 by varying T_{on} and T_{off}. Thus output voltage V_o can be varied from 0 to V_s by controlling D and hence the power flow can be controlled.

When the chopping frequency f is kept constant and the ON time T_{on} is varied, the width of the pulse is varied and the chopper is known as constant frequency chopper. This type of control is known as Pulse Width Modulation (PWM) control.

IGBT MODULE:

The module consists of 4 IGBTs and is brought out to banana connectors mounted at the front panel. Various power converter configurations can be made by proper interconnection of the IGBT terminals at the front panel. An RCD snubber circuit is provided for each device to provide protection against dv/dt.

CIRCUIT DESCRIPTION:

The dc link voltage is obtained through a step down transformer and a full-wave diode rectifier. A mains power switch (with indicator) is provided to switch ON or OFF ac power (230V) to the input transformer. It will provide +15V DC to the gate drive IRF2110. A toggle switch SW_1 provided on the secondary side switch ON/OFF ac supply to the bridge rectifier. Once SW_1 is switched ON, V_{dc} (dc link voltage) will be available between the banana connectors V+1 (V+2) and V-1 (V-2).

For Resistive Inductive Load

S.No	V_{supply} (Volts)	T_{on} (ms)	$T_{on} + T_{off}$ (ms)	V_{load} (Volts)	$V_{theoretical}$ (Volts)	% Duty Cycle

Model Graph
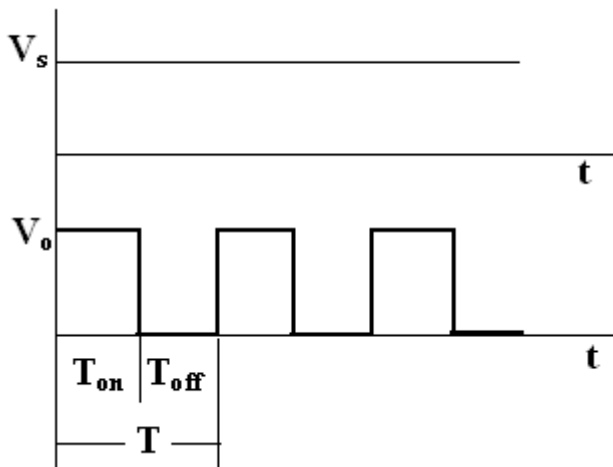
$$\text{Vo} = \frac{Ton}{T} \cdot Vs = f.Ton.Vs = D.Vs$$

The gating signals from the control module is to be connected at the 9 pin D connector through the signal cable provided. The gating signals are isolated from the control power supply by means of high speed opto couplers. The isolated gating signals are then applied IGBT drive IRF2110, two such drivers are used; one driver IC provides gating signals to the device one leg. Each IGBT can be used independently to study the switching characteristics or it may be inter connected with others depending on the required converter topology.

RESULT:

An experiment has been conducted in IGBT based single quadrant chopper circuit and the various waveforms traced.

Ex. No.:
Date:

PERFORMANCE EVALUATION OF SERIES RESONANT CONVERTER

AIM:

To study the operation and characteristics of a series resonant converter

To trace the PWM pulses, the resonant current and output voltage waveforms at two frequencies one above and one below the resonant frequency.

THEORY

TYPES OF RESONANT CONVERTERS:

1) Series Resonant Converter (SRC)

2) Parallel Resonant Converter (PRC)

3) Series and Parallel Resonant Converter (SPRC)

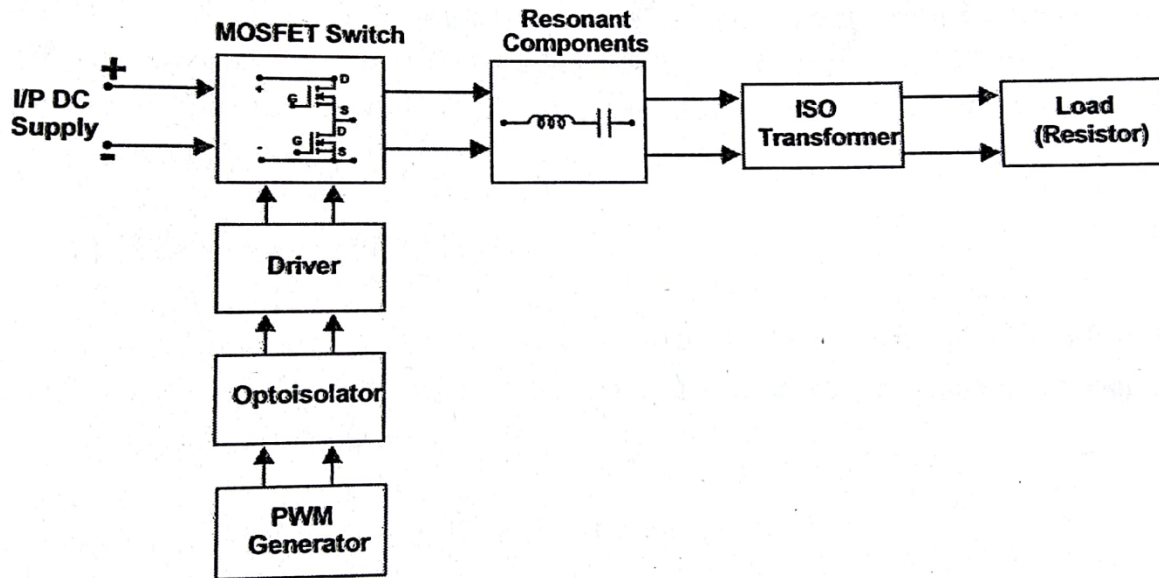**SERIES RESONANT CONVERTER:**

The circuit diagram of half bridge series resonant converter is shown in figure. The resonant inductor L_r and resonant capacitor C_r are in series. They form a series resonant tank. The resonant tank will then in series with the load. From this configuration, the resonant rank and the load act as a voltage divider. By changing the frequency of the input voltage V_a, the impedance of resonant tank will change. This impedance will divide the input voltage with load. Since it is a voltage divider, the dc gain of the SRC is always lower than 1. At resonant frequency, the impedance of series resonant tank will be very small; all the input voltage will drop on the load. The maximum gain happens at resonant frequency in the SRC.

BLOCK DIAGRAM OF SERIES RESONANT CONVERTER:

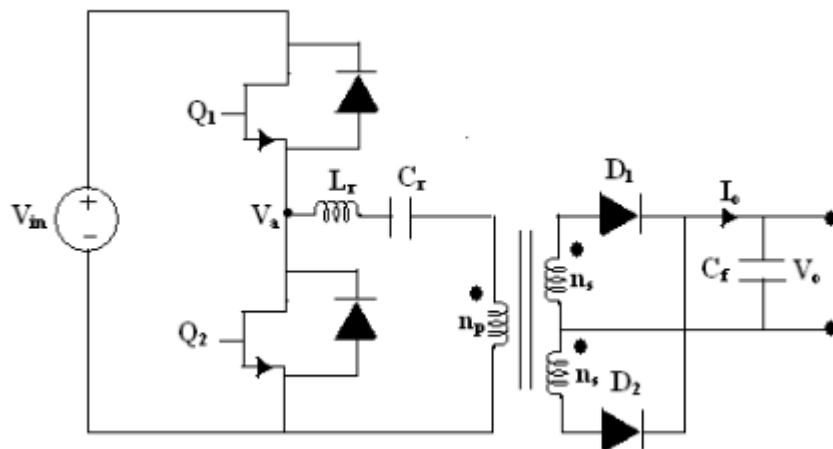It consist of

(i)   PWM generator
(ii)   Opto- isolator
(iii)   Driver
(iv)   MOSFET switch
(v)   Isolation transformer and resonant components

Block diagram of series resonant converter

Power Circuit of Series Resonant Converter

(i)   PWM generator (dsPIC 30F2010)

The PWM signal is generated from the dsPIC 30F2010. It is done by the comparation of the saw tooth waveform and referance voltage signal. The saw tooth wave generator,a comparator and other auxiliary circuits are intergrated on the chip .

(ii)   Opto-isolator (6N137)

The function of Opto- isolator is to isolate the control circuit from the power circuit. PWM signal from dsPIC 30F2010. It is not directly fed to the power circuit inorder to protect the PWM signal. It is essential to provide isolation circuit between the power and the control circuit.

(iii)   Driver (IR2110)

A MOSFET drive circuit is designed to connect the gate directly to a voltage bus with no invervening resistence other than the impedance of the driver circuit switch. The gate driver acts as a high power buffer stage between the PWM output of the controlled device and the gates of the primary power switching MOSFET.

(iv)   MOSFET switch (IRF250)

A MOSFET switch is used as a switching device in the boost converter circuit. The PWM signal from the driver IC is fed to the gate of the switch. The drain of the switch is connected to the primary of the isolation transformer.

(v)   Isolation transformer and resonant components

The isolation transformer is used to isolate the input and output grounds of the circuit. The series resonant circuit consist of an inductor, a capacitor and a resistor, with one more of these elements actually being part of the load. Usually atleast the resistor is part of the load.

APPARATUS REQUIRED

1. VPET- 315 module
2. Patch chords
3. Pulse patch chords
4. (0-30V) DC Power supply
5. CRO

HALF BRIDGE SERIES RESONANT CONVERTER:

For front end dc/dc application, a SRC is designed to meet the specifications with following parameters:

The operating region is on the right side of resonant frequency f_r. It is because of Zero Voltage Switching (ZVS) is preferred for this converter. When the switching frequency is lower

Characteristics of Series Resonant Converter

$V_{in} =$
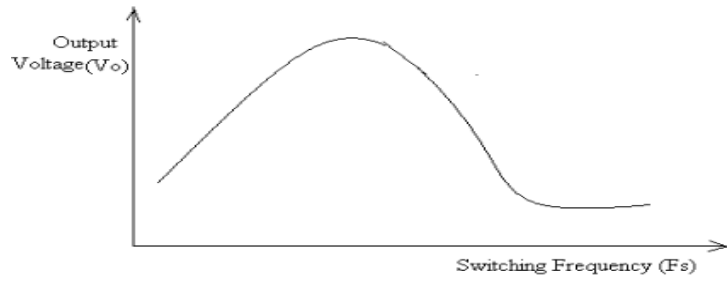
S.No.	Switching frequency (Hz)	Output voltage (V)

$V_{in} =$

S.No.	Switching frequency (Hz)	Output voltage (V)

than resonant frequency, the converter will work under Zero Current Switching (ZCS) condition. In fact, the rule is when the dc gain slope is positive, the converter will work under zero current switching condition. For Power MOSFET, zero voltage switching is preferred.

It can be seen from the operating region that at light load, the switching frequency need to increase to very high to keep output voltage regulated. It is a big problem for SRC. To regulate the output voltage at light load, some other control method has to be added.

ZERO CURRENT SWITCHING (ZCS):

When the series resonant inverters are operated below resonance, the zero current switching phenomenon can occur, in which the circuit causes the transistor current to go to zero before the transistor is turned off. There are two types of ZCS Resonant converters, L type and M type. Both of these circuit topologies use L and C as a series resonant circuit; in addition L also limits di/dt of the switching current.

ZERO CURRENT SWITCHING (ZVS):

When the series resonant converter is operated above resonance, the zero- voltage switching phenomenon can occur, in which the circuit causes the transistor voltage to become zero before the controller turns the transistor on. With a minor circuit modification, the transistor can also be caused to occur at zero voltage. This process can lead to significant reduction in switching losses of converters based on MOSFETs and diodes.

PRECAUTIONS:

1. Before switching on the power supply to the module the variable adjustment POT is kept in the minimum position.
2. The PWM signal connector and feedback voltage connector should be connected properly.
3. The output terminal should not be shorted.

CONNECTION PROCEDURE:

1. Connect the trainer module to the 230V, 50Hz AC supply using PC Power chord.
2. Connect PWM1 of PWM generator to PWM1 Input of series resonant converter circuit.
3. Connect PWM2 of PWM generator to PWM2 Input of series resonant converter circuit.
4. Connect (0-30V) DC regulated supply across P_1 and P_2 terminal of the trainer and set the Voltage value at 24V.

EXPERIMENTAL PROCEDURE:

1. Switch ON AC power supply.
2. Switch ON the power ON/OFF switch.
3. Initially keep frequency adjustment POT in minimum position.
4. View the PWM signal in the CRO at T_1 and T_3.
5. Switch ON the variable DC supply.
6. Check all the rest point waveform.
7. Now observe the switch voltage waveform across the test point T_{12} and T_{10} and current waveform across the test point T_{12} and T_{13}.
8. Similarly, note the switch voltage and current waveform for various switching frequency. (Below and above resonance frequency) and note down the corresponding load voltage.

RESULT:

Thus the operation and characteristic of series resonant converter has been studied. The PWM pulse, the resonant current and the output waveform has been traced.

PERFORMANCE EVALUATION OF SINGLE PHASE AC VOLTAGE CONTROLLER

AIM:

To study the operation of a single phase AC voltage controller

APPARATUS REQUIRED:

AC voltage controller [power kit and control kit]
CRO
Single phase 230V, 3.5Kw load rheostat.
Ammeter (0-5A) MI
Voltmeter (0-75V) MI
Wattmeter (150V, 5A, UPF)

THEORY:

The phase control rectifier using SCR's are used to obtain controlled AC voltage from the fixed AC input voltage. The output voltage is varied by controlling the firing angle of the SCR. The phase controlled rectifier is simple, less expensive. The SCR's in phase controlled circuit are turned ON by a gate triggering signal operated in synchronize with the AC main voltage. They are turned OFF due to natural (or) line commutation

SINGLE PHASE AC VOLTAGE CONTROLLER WITH R LOAD:

The figure shows a single phase voltage controller feeding power to a resistive load R. As stated before the two thyristors are connected in anti parallel. The waveform for source voltage V_s, gating pulse for T_1 and T_2 and load voltage V_0, are shown in the same figure.

PRECAUTION:

1. Firing angle controlled should be in maximum position.
2. Load should be in OFF position.

PROCEDURE:

1. The connections are made as per the circuit diagram.
2. After observing the precaution supply is effected for particular value of α, the load switch is ON.
3. The load is varied and corresponding readings are taken.
4. The procedure is repeated for the different values of α.

Single Phase Voltage Controller with Resistive Load
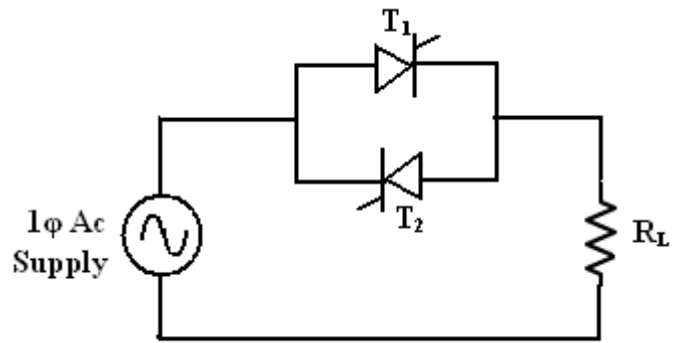
Model Graph

DERIVATION FOR OUTPUT VOLTAGE AND POWER FACTOR:

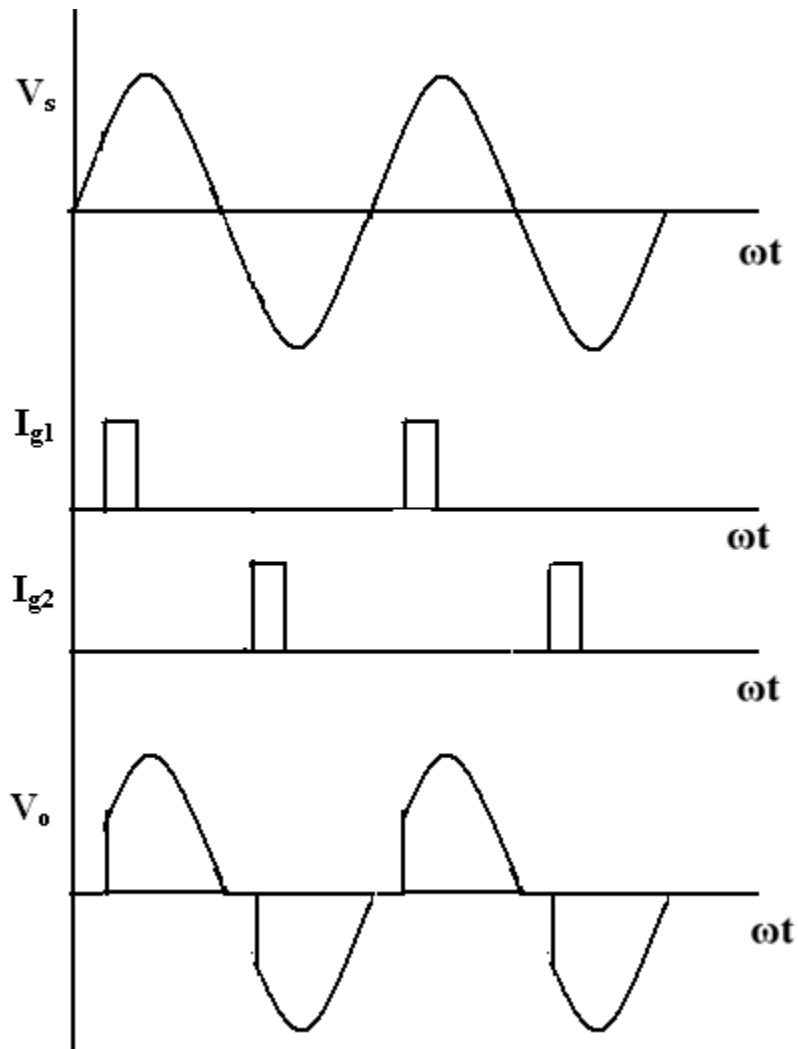$$V_{rms} = \left\{ \frac{1}{\pi} \left[\int_0^\alpha 0.\,d\omega t + \int_\alpha^\pi V_m^2 \, Sin^2 \omega t.\,d\omega t \right] \right\}^{\frac{1}{2}}$$

$$= \frac{V_m}{\sqrt{\pi}} \left[\int_\alpha^\pi \left(\frac{1 - cos2\omega t}{2} \right) d\omega t \right]^{\frac{1}{2}}$$

$$= \frac{V_m}{\sqrt{2}\sqrt{\pi}} \left[\left(\omega t - \frac{sin2\omega t}{2\omega t} \right)_\alpha^\pi \right]^{\frac{1}{2}}$$

$$= \frac{V_m}{\sqrt{2}\sqrt{\pi}} \left[\left\{ (\pi - \alpha) - \frac{sin2\pi}{2} + \frac{sin2\alpha}{2} \right\} \right]^{\frac{1}{2}}$$

$$= \frac{V_m}{\sqrt{2}\sqrt{\pi}} \left[\left\{ (\pi - \alpha) + \frac{sin2\alpha}{2} \right\} \right]^{\frac{1}{2}}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}\sqrt{\pi}} \left[\left\{ \beta + \frac{sin2\alpha}{2} \right\} \right]^{\frac{1}{2}}$$

Where $(\pi - \alpha) = \beta$

Real power desired to load $= \dfrac{V_{rms}^2}{R}$

Apparent power delivered to load $= V_m I_{or} = V_s \dfrac{V_{rms}}{R}$

Power Factor $= \dfrac{Real\ Power}{Apparent\ Power}$

$$= \frac{\frac{V_{rms}^2}{R}}{\frac{V_s V_{rms}}{R}}$$

$$= \frac{V_{rms}}{V_s}$$

$$\frac{\frac{V_m}{\sqrt{2}\sqrt{\pi}} \left[\left\{ \beta + \frac{sin2\alpha}{2} \right\} \right]^{\frac{1}{2}}}{V_s}$$

$$= \frac{\sqrt{2}V_s}{V_s \sqrt{2}\sqrt{\pi}} \left[\{ \beta + sin2\alpha/2 \} \right]^{\frac{1}{2}}$$

$$= \frac{1}{\sqrt{\pi}} \left[\{ \beta + sin2\alpha/2 \} \right]^{\frac{1}{2}}$$
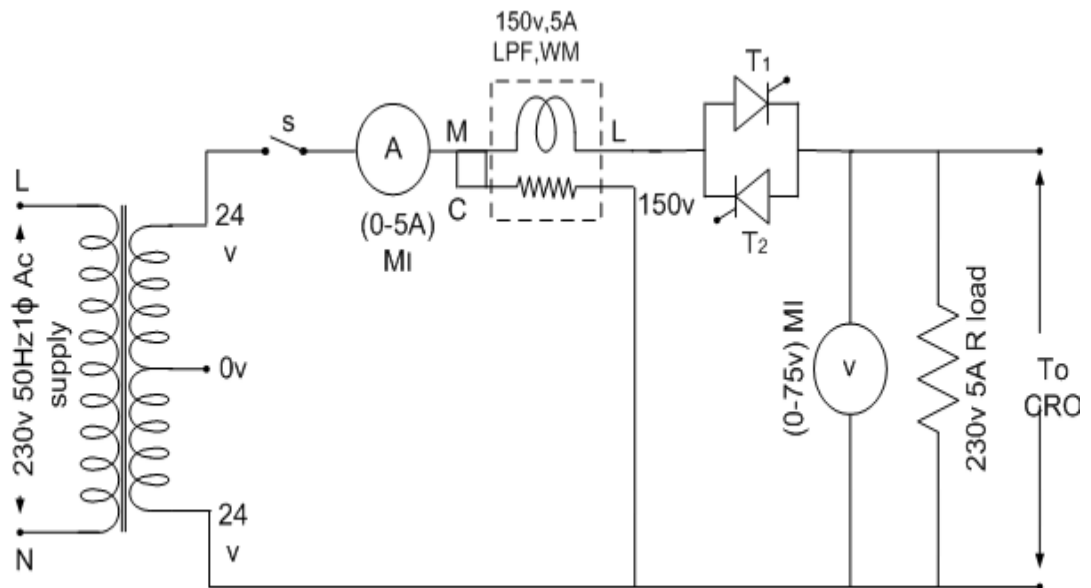
AC Voltage Controller with Resistive Load

FORMULA USED:

1. Theoretical voltage $= V_{rms} = \frac{V_m}{\sqrt{2}\sqrt{\pi}}\left[\left\{\beta + \frac{sin2\alpha}{2}\right\}\right]^{\frac{1}{2}}$

2. Practical power factor = Load Voltage / Terminal Voltage

3. Theoretical power factor $\quad = \frac{1}{\sqrt{\pi}}[\{\beta + sin2\alpha/2\}]^{\frac{1}{2}}$

SI. No	FIRING ANGLE (α)	TERMINAL VOLTAGE (volts)	WATTMETTER READINGS		IL (Amps)	LOAD VOLTAGE		POWER FACTOR	
			OBS	ACT		Practical	Theoretical	Practical	Theoretical

RESULT:

The performance of a single phase AC voltage controller with R load has been studied and the values tabulated.

Ex. No.:
Date:

FIRING ANGLE CONTROL OF SINGLE PHASE CYCLOCONVERTER

AIM:

To study the principle of operation of single phase Cyclo Converter

To trace the input and output waveforms when the output frequency is an integral submultiples of the input frequency.

THEORY:

Cyclo-Converter is a variable frequency variable voltage AC-AC converter. The output frequency is the sub-multiple or integral sub-multiple of the input frequency.

Let us consider, $f_o = \frac{1}{3} f_i$

In this 3 Cycles AC input corresponds to one cycle AC output and 6 cycles AC input corresponds to 2 cycles AC output.

One group of SCRs (1 & 1') that produces positive polarity load voltage are called the positive group SCR's, and the group of SCR's that produces the negative half cycle of the output are called negative group SCR's (2 & 2').

For simplicity in control circuit, both SCR's in a group are fired together but only the forward biased SCR of that group will conduct.

In the positive half cycle SCR_1 and SCR_1' are fired and we have positive load voltage since SCR_1 conducts (SCR_1' does not conduct since Q is -ve w.r.t O). Though SCR_2' is in a position to conduct, it is not fired since it will produce -ve polarity load voltage.

In the negative half cycle, SCR_1 and SCR_1' are fired we have +ve load voltage since SCR_1, conducts (SCR_1 does not conduct since P is -ve w.r.t O). Though SCR_2 is in a position to conduct, it is not fired since it will produce -ve polarity load voltage.

By changing the firing angle α the duration of conduction of each SCR (and thereby the magnitude) can be varied. Each conducting SCR goes OFF by natural commutation at the end of half cycle.

Cyclo Converter with Resistive Load
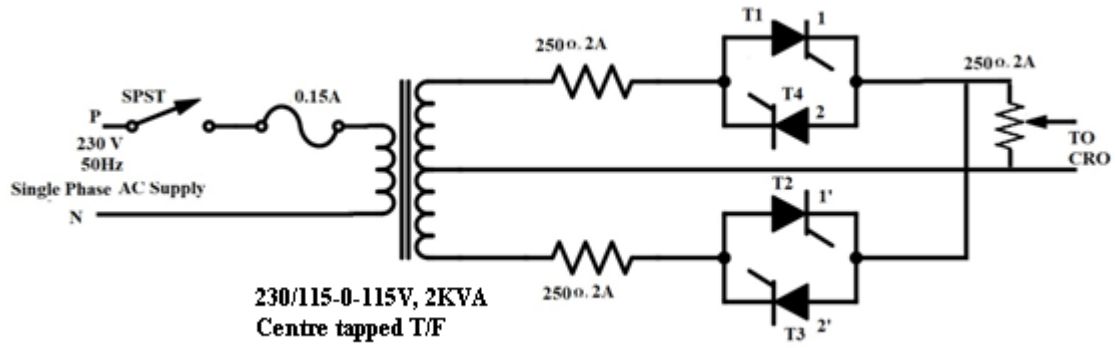
Model Graph

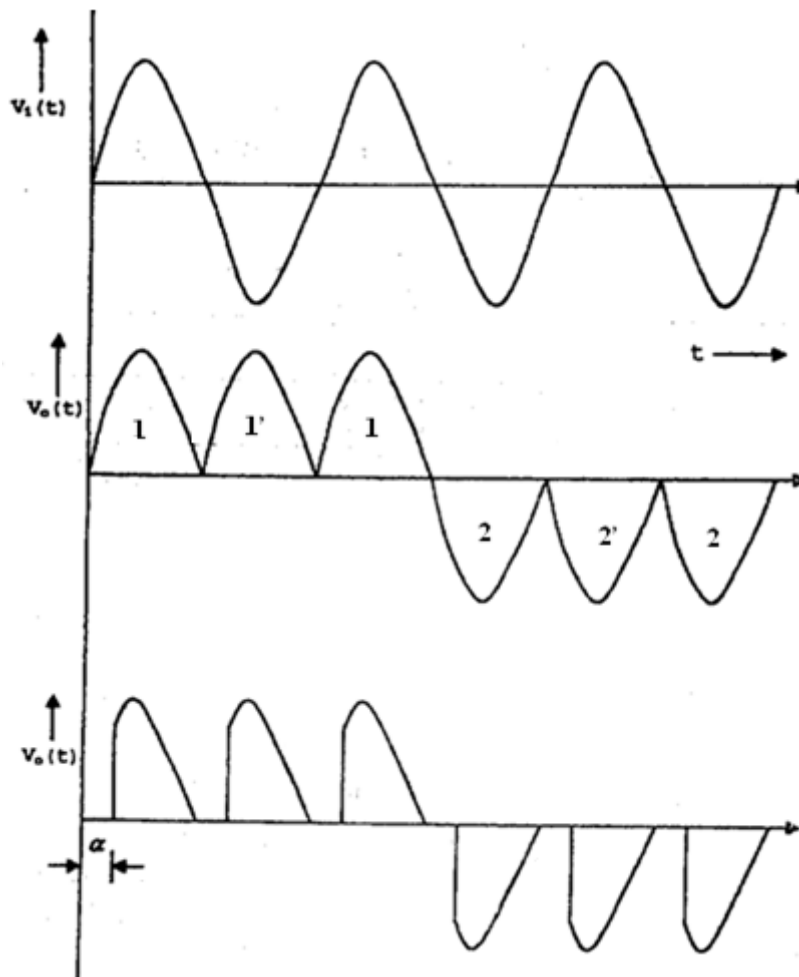At the end of each half period of the output (at the frequency desired) the firing pulses to the SCRS of the +Ve group will be stopped, and SCRs 2 & 2' will conduct when P is -Ve and SCR$_2$' will conduct when Q is -Ve.

Sl. No of half cycle	Polarity of half cycle	SCR 1	SCR 2	SCR 1'	SCR2'
1	Positive Half Cycle	FORWARD BIASED(✔)	REVERSE BIASED	REVERSE BIASED	FORWARD BIASED
2	Negative Half Cycle	REVERSE BIASED	FORWARD BIASED	FORWARD BIASED (✔)	REVERSE BIASED
3	Positive Half Cycle	FORWARD BIASED (✔)	REVERSE BIASED	REVERSE BIASED	FORWARD BIASED
4	Negative Half Cycle	REVERSE BIASED	FORWARD BIASED (✔)	FORWARD BIASED	REVERSE BIASED
5	Positive Half Cycle	FORWARD BIASED	REVERSE BIASED	REVERSE BIASED	FORWARD BIASED (✔)
6	Negative Half Cycle	REVERSE BIASED	FORWARD BIASED (✔)	FORWARD BIASED	REVERSE BIASED

The cycloconverter output voltage waveform with Resistive load for $f_o = 1/3 \, f_i$ may be improved by,

1. Having zero firing angle (no firing delay)

2. Connecting 1' and 2' to a higher tap on the secondary winding. Number of turns OP < Number of turns of OQ

For $f_o = 1/3 \, f_i$ the firing sequence is 11' 122' 2.

If $f_0 = 1/4 \, f_i$ the firing sequence will be 11' 11'2' 22' 2.

The output frequency control may be got by varying the firing sequence of SCR's.

S. No	No. of Cycles	Input Frequency (Hz) (from display)	Calculated Output Frequency (Hz)	Firing Angle (from display) (Degrees)	Calculated Firing Angle (Degrees)

APPARATUS REQUIRED:

1. Thyristor module TMC - 4 Nos.
2. Integrated Thyristor control kit.
3. Transformer 230V / (115V-0-115V), 2KVA centre tapped type
4. Load rheostat 250Ω, 2A - 3Nos.
5. Digital storage oscilloscope with unearthed terminals.

RATINGS / SPECIFICATIONS :

Thyristor Module TMC
VDRM : 1200V
ITAV : 30A
ITRMS : 50A
Fuse : GSG 1000/35

FUSE RATING CALCULATION:

Secondary current $I_2 = 115/500 = 0.23A$
Primary current $I_1 = I_2. V_2/V_1 = (0.23 \times 115) / 230 = 0.115A$
125% of primary current = $1.25 \times 0.115 = 0.144$ A ˜0.25 A

PRECAUTIONS:

1. The RESET key in the ITC kit should not be pressed.
2. The jockey of the load rheostat must be kept at minimum potential position.
3. An oscilloscope with unearthed pins must be used.

.

PROCEDURE:

1. The connections are given as per the circuit diagram.
2. The trigger outputs T_1, T_2, T_3 and T_4 are connected to the corresponding numbered thyristors in the power circuit.
3. Observing the precautions, the power supply is effected.
4. The SELECT key is pressed to select the single phase Cyclo converter.
5. The FIR/DTY key is pressed. The corresponding LED lits up, and the default value of the firing angle (180˚) is displayed. At $\alpha = 180$˚, the output zero. The firing angle is reduced by pressing DEC key.
6. When the DIV/FRQ key is pressed, the associated LED lits up and the display shows the default value of DIVISION 3n.
7. The RUN/STOP key is pressed to trigger the SCR1.

8. The trigger pulses to SCRs are removed by pressing RUN/STOP key.
9. The above may be repeated for
    1. Different values of firing angles (By pressing FIR/DTY key followed by DEC key)
    2. Different values of output frequency (By pressing DIV/FRQ key followed by INC key)
10. The triggering process is stopped and then the power supply is switched OFF.
11. The frequency using Time/sec scale in the CRO is calculated and the same is verified with the practical value shown by the display of the kit.

RESULT:

Thus the conversion of single phase AC voltage of particular frequency to a single phase AC voltage of a lower frequency is achieved with a cyclo converter and the relevant waveforms are traced.

MODULATION INDEX CONTROL OF SINGLE PHASE BRIDGE INVERTER

AIM:

To study the operation of single phase inverter using MOSFET with sinusoidal pulse width modulation

To study the modulation technique applied to the inverter in order to shape the output ac voltage to sine wave as close as possible.

To study the relationship between modulation index, dc voltage, output current and voltage.

APPARATUS REQUIRED:

Single phase MOSFET power inverter module
Inverter control module
CRO
Resistive or Lamp load
Digital multimeter

PRECAUTION:

1. Don't change the carrier frequency at the middle of the experiment.
2. Keep all switches in OFF condition both in power and control module.
3. Ensure the minimum position of the potentiometer provided for amplitude variation.
4. Block the gating signals by throwing the pulse release switch to OFF position.

PROCEDURE-1:

1. Ensure that the circuit breaker and pulse release ON/OFF toggle switch are in off position.
2. Connect the R-L load across the output terminals, Lo and No, provided in the front panel; include an ammeter to measure the current and voltmeter to measure the voltage.
3. Connect the ac input at the input terminals L and N provided in the front panel.
4. With the pulse release ON/OFF switch and circuit breaker in off condition, give the power to the inverter module. This will ensure the control power to all the control circuitry.
5. Set the amplitude of the reference sine wave to minimum value.

Panel diagram of Control Circuit
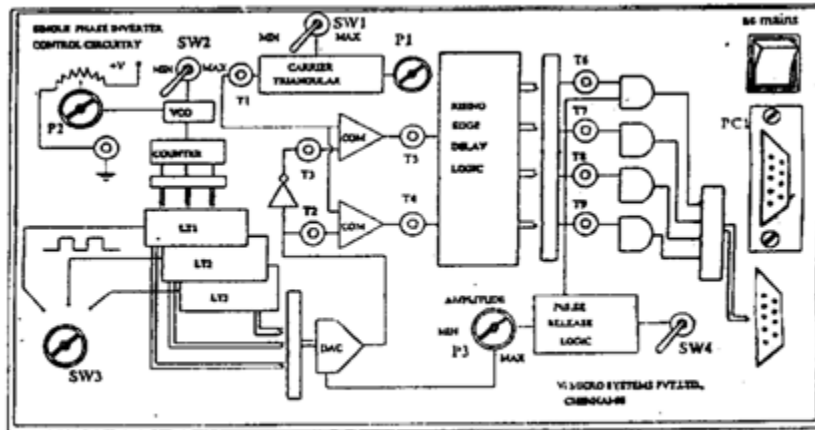
Single Phase Bridge Inverter
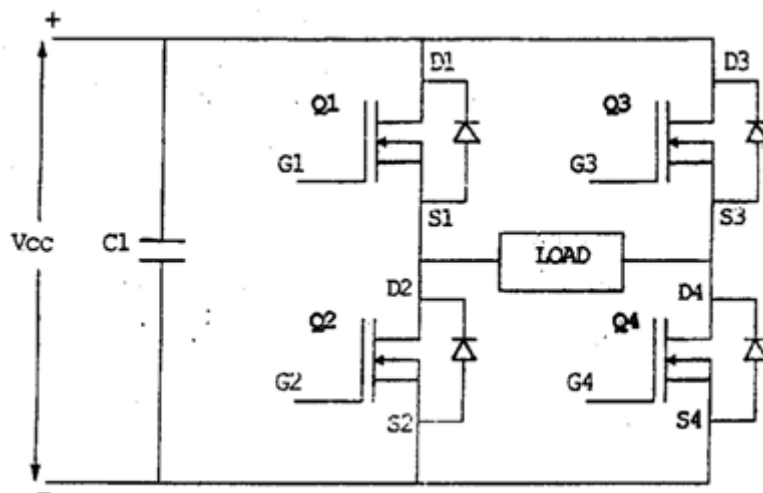
6. Keeping the pulse release ON/OFF switch in OFF position. Switch ON the power source to the bridge rectifier.
7. Release the gating signals to the inverter switches by turning on the pulse release ON/OFF switch.
8. Observe the triangular carrier and the reference sine waveforms on the CRO. Measure the amplitude and the frequency of the triangular carrier through CRO and note it down. Adjust the sine wave frequency to above 50 Hz.
9. Connect the CRO probes to observe the load voltage and current waveforms.
10. Observe the load voltages and load current waveforms. Sketch the waveforms on a graph sheet to scale for one cycle period of the inverter output frequency. Measure the amplitude of the voltage pulses.
11. Measure the output voltage either by using an analogue or a digital multimeter.
12. Calculate the modulation index m_a and the rms output voltage V_0.

$$m_a = \frac{V_{control}}{V_{tri}}$$

13. Increase the amplitude of the reference sine wave and noted down its value.
14. Repeat steps 8 to 13 for various amplitude of reference sine wave and tabulate the readings as given. Plot the characteristics of modulation index versus output voltage. It will be shown in figure.

THEORY:

CONTROL MODULE:

The module provides the gating signals required for a single phase bridge inverter. The gating signals are obtained with sine-triangular modulation. The frequency and the amplitude of the reference sine wave can be varied. The triangular corner frequency can be selected at 2.2khz or 4.2khz. Test points are provided in the front panel to study the operation of various stages of the control circuitry. The power supply required are +5v and ± 15v for the control circuitry is built in. The various stages involved in generating the gating signals for the bridge inverter is depicted in mimic diagram at the front panel.

CIRCUIT DESCRIPTION:

The ac power required to provide dc supply to control circuitry is switched ON/OFF through the mains power switch SW with indicator. 5v power supply is used for EPROM and DAC circuitries and 15v is used for other IC's and logical circuits.

The triangular carrier frequency can be selected either at 2.2khz or 4.2khz. By means of the toggle switch SW_1. If necessary, it can be varied to some extent using the control pot P_1.

Voltage waveform

Variation of V_0 with m_a
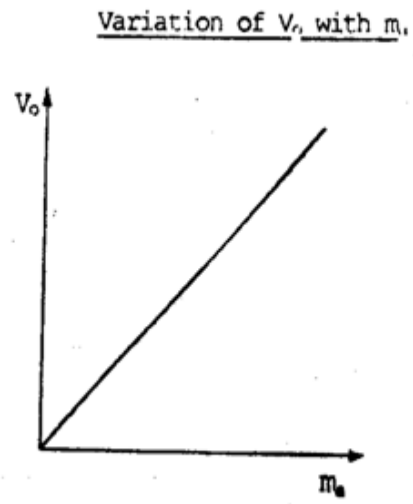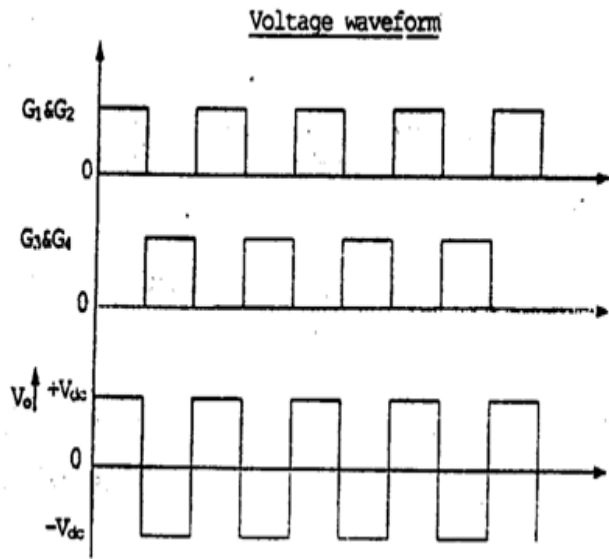
$Vs =$

Sl.No	V_{tri} (Volts)	V_{sinu} (Volts)	m_a	$V_{0\ measured}$ (Volts)	$V_{0\ cal}$ (Volts)

The reference sine wave frequency can be varied by varying VCO frequency. It can be selected between two levels minimum and maximum through the toggle switch SW_2. For each level the frequency can be varied by means of the control pot P_2. The amplitude of the sine wave is controlled by means of the control pot P_3.

The modulating wave can be either Sine (or) Trapezoidal (or) Rectangular. Only sine wave is provided other modulating waveforms can be provided as optional. It can be selected through the selector switch SW_3.

The gating signals generated by means of pulse width modulation are applied to logic circuits and are terminated at 9 Pin connector PCI. The gating signals ca be blocked or released by means of the switch SW_4. The gating pulses to the inverter from the control module are connected to the inverter module through the cable provided.

SINUSOIDAL PULSE WIDTH MODULATION:

The switching sequence for the inverter switches in this case, is obtained by comparing a sinusoidal control signals, of adjustable amplitude and frequency with a fixed frequency triangular carrier. The frequency of the triangular carrier wave determines the switching frequency (f_s) of the inverter switches. The frequency (f_i) of the sinusoidal control signal decides the fundamental frequency of the inverter output voltage, and is also called the modulating frequency. The inverter output voltage will contain voltage components at harmonic frequencies of f_i.

The amplitude modulation ratio m_a also called the modulation index is defined as
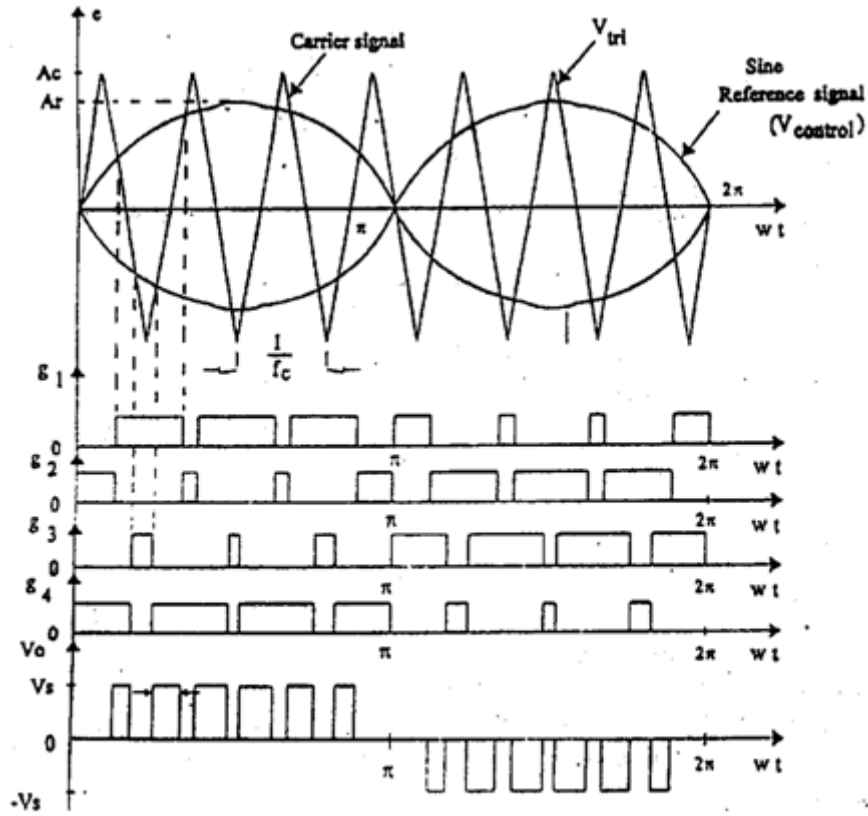
$$m_a = \frac{V_{control}}{V_{tri}}$$

Where, $V_{control}$ is the amplitude of the control signal
V_{tri} is amplitude of the triangular carrier, which is generally kept constant.

The frequency modulation ratio is defined as

$$m_f = \frac{f_s}{f_i}$$

Sinusoidal Pulse Width Modulation

The sinusoidal pulse width modulation can be programmed to have either bipolar voltage switching (or) unipolar voltage switching. The unipolar voltage switching has the advantage of efficiency doubling the switching frequency as compared to the bipolar voltage switching. This makes the, lowest harmonics in the output voltage at each switching are from 0 to Vs. whereas in case of bipolar voltage switching is from -Vs to +Vs and the magnitude of the voltage jumps to 2vs. For these reasons the unipolar voltage switching is mostly used.

DESCRIPTION OF THE POWER MODULE:

The dc to ac converters are known as inverters. The function of an inverter is to change a dc input voltage to a symmetrical ac output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency.

The output voltage waveform of the inverter is rectangular in nature. The frequency of the output voltage depends on the repetitive rate at which Q1 , Q2 and Q3, Q4 are switched.

The ideal output waveform required for most applications of inverter is a sinusoidal with variable amplitude and frequency. It is achieved by using Pulse-width-Modulation (PWM) control within the inverter. If the dc output is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of inverter, which is normally accomplished by pulse width modulation (PWM) control within the inverter. The inverter gain may be defined as the ratio of the ac output voltage to ac input voltage.

SINGLE PHASE BRIDGE INVERTER:

A single phase bridge inverter is shown in fig. It consists of four switching devices Q1, Q2, Q3 and Q4 switches. When the switches Q1 and Q2 are switched on simultaneously the input voltage Vdc appears across the load. If the switches Q3 and Q4 are turned on at the same time the voltage across the load is reversed and is —Vdc. The waveform of the output voltage is shown in fig.

RESULT:

Thus the operation of the single phase inverter using MOSFET with sinusoidal pulse width modulation has been studied and waveforms are traced.

Ex. No.:
Date:

LOAD TEST ON AC DRIVE UNIT

AIM:

To perform a load test on a PWM input fed three phase induction motor.

SPECIFICATION:

D.C GENERATION: INDUCTION MOTOR: SPWM INVERTER:

Capacity: 3.7 KW   Capacity: 3.7 KW   Type: KVR037 G%-S4
Speed: 1500 rpm   Speed: 1430 rpm   Input: 415 V, 50 Hz
Voltage : 220 V   Voltage : 415 V   Output : 0-415 V, 50 Hz
Current: 17A   Current: 7.6A   Current: 8.5A
                          Frequency: 50 Hz   Capacity: 3.7 KW

THEORY:

The basic principle of speed control methods employed in, power semiconductor controlled induction motor drives are:

1. Variable stator voltage control
2. Variable frequency control
3. Rotor resistance control
4. Slip power recovery scheme

The methods 1 & 2 are applicable to both squirrel-cage and wound rotor motors and methods 3 & 4 can be used only for wound-rotor motors.

1. STATOR VOLTAGE CONTROL

The stator voltage control is done by connecting two thyristors in antiparallel in each phase. By suitably controlling the firing angle of the thyristors, the voltage applies to the stator of the induction motor and hence its speed can be changed. By varying the firing angle from 0 to 180, the variac like function is obtained.

2. STATOR FREQUENCY CONTROL

The synchronous speed is directly proportional to the supply frequency. The synchronous speed and motor speed can be controlled above the normal full-load speed by changing the supply frequency. The starting and low speed torques increases largely and the corresponding currents are also reduced by a large amount. Thus the starting and low speed

Power Circuit Diagram
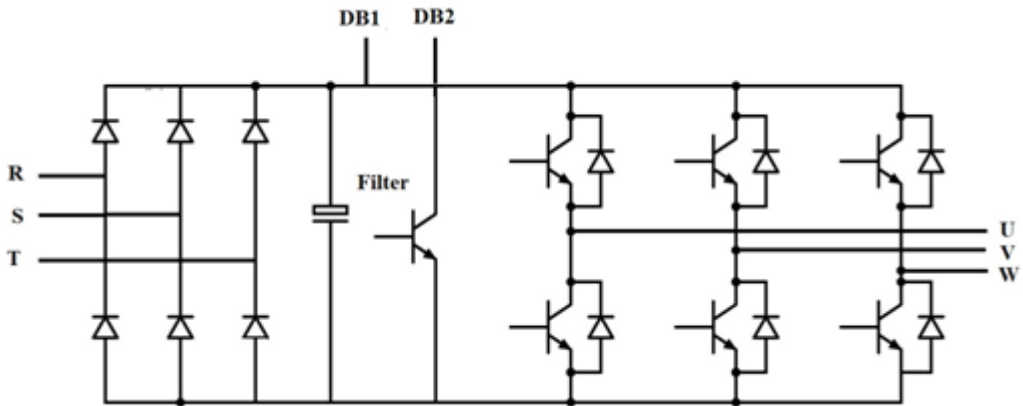
Practical Circuit Diagram
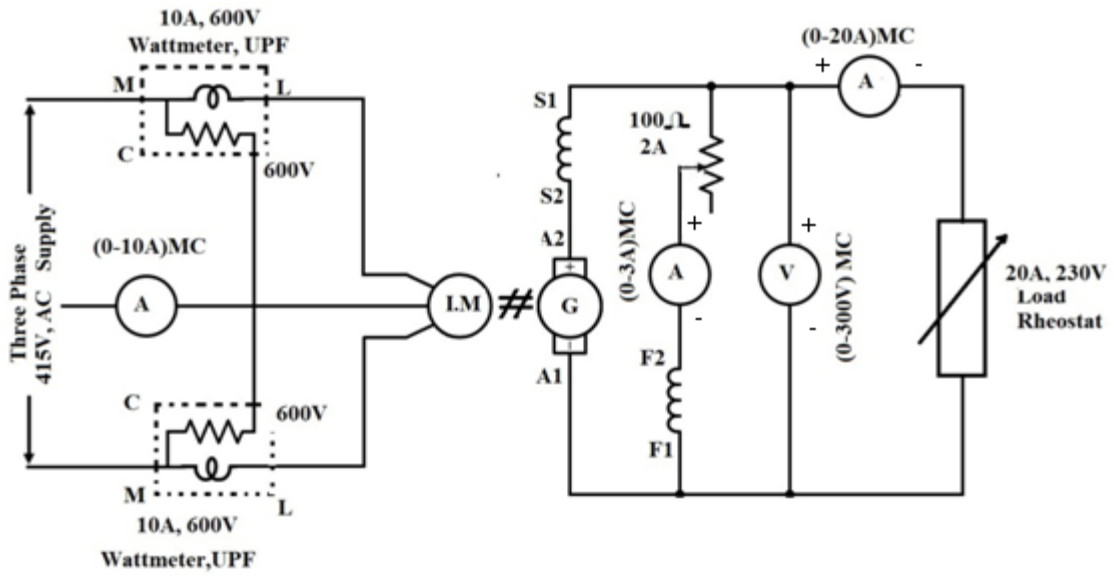
performances of a variable frequency drive is far superior compared to that with the fixed frequency operation.

3. STATOR V/F CONTROL

The voltage induced in the stator E is proportional to the product of the supply frequency and the air-gap flux. Any reduction in the supply frequency, without a change in the terminal voltage causes an increase in the air-gap flux. An increase in the flux beyond the rated value is undesirable from the consideration of saturation effects, a decrease in flux is also avoided to retain the torque capability of the motor. Therefore, the variable frequency control below the rated frequency is generally carried out by reducing the machine phase voltage 'V' along with the frequency F in such a manner that the flux is maintained constant.

The operation of the machine at a constant flux requires a closed loop control of flux-closed loop control becomes complicated because the measurement of the flux is always difficult. Hence flux is controlled indirectly by operating the machine as a constant V/F ratio for most of the frequency range.

POWER CIRCUIT

The inverter power circuit uses transistors. In order to provide a good control of the harmonic content at the fundamental frequency, it is necessary to obtain high switching frequency. For this reason we use power transistors as switching elements.

The aim of the power circuit is to convert the fixed voltage, fixed frequency ac to dc first and then, variable voltage, variable frequency ac. So speed control of ac motor is easy.

The three phase ac voltage is first changed to dc voltages using an uncontrolled bridge rectifier and filtered; dc is the input to the three phase bridge inverter consisting of power switching transistors.

The diode bridge is a naturally commutated uncontrolled rectifier. Each diode conducts for 120 degrees and commutates at the natural commutation angle. The rectifier capacitor filter is used as shown to reduce the ripples. The transistorized three phase bridge inverter operates in PWM mode. At any time three transistors will be conducting and each transistor conducts for 180 degrees in each cycle.

FORMULA USED:

1. TORQUE:

Assume $\eta = 80\%$

$$\text{Output} = \frac{2\pi NT}{60}$$

S.No	Vac (volts)	Iac (amps)	W1+W2 (Watts)		Vdc (volts)	Idc (amps)	Output (Watts)	PF	Actual Torque N-m	pu Torque N-m	% η	Actual H.P	p.u H.P
			Obs	Act									

$$\text{Power} = \frac{V_{dc}I_{dc}}{\eta}$$

$$\text{Torque} = \frac{\frac{V_{dc}I_{dc}}{\eta}}{\frac{2\pi NT}{60}}\text{Syn.Watts}$$

$$\text{Base Torque} = \frac{Output\ in\ watts}{\frac{2\pi NT}{60}}$$

$$\text{Per Unit Torque} = \frac{Actual\ Torque}{Base\ Torque}$$

2. BRAKE HORSE POWER:

$$\text{H.P} = \frac{\frac{V_{dc}I_{dc}}{\eta}}{746}$$

$$\text{Base H.P} = \frac{Output\ in\ Watts}{746}$$

$$\text{Per Unit H.P} = \frac{Actual\ H.P}{Base\ H.P}$$

PRECAUTIONS:

1. Generator field rheostat should be kept at maximum resistance position.
2. There should be no load at the time of starting.
3. The SPWM inverter should operated precautious

PROCEDURE:

1. Connections are given as per the circuit diagram.
2. The frequency can be set depending on the V/F pattern by referring the frequency code table. The V/F pattern is selected from the V/F pattern table. The frequency to be set in microcontroller can be chosen by matching the V/F pattern and frequency code in the frequency code table.
3. For various frequencies load is varied and the readings are tabulated.
4. The torque and H.P for various loads are calculated using the formulae.
5. The constant torque and constant H.P graphs are drawn with the help of the per unit frequency Vs per unit torque and per unit frequency Vs per unit H.P.

RESULT:

The motor when operated below rated frequency develops constant torque at reduced HP and motor when operated above rated frequency gets constant HP, whereas torque is decreased.

Ex. No.:
Date:

PERFORMANCE CHARACTERISTIC OF PMDC MOTOR

AIM:

To obtain speed Vs torque characteristic of PMDC Motor.

APPARATUS REQUIRED:

Controller unit   -   PMDC Motor
Ammeter (0-2A)mc   -   1no
Voltmeter (0-50V)mc -   1no

PROCEDURE:

1. Ensure power is OFF to motor control unit and pulse ON/OFF switch is in OFF position.
2.   Ensure that the speed feedback loop is open, so that the motor is operated on open loop.
3. Connect the motor to output of the power amplifier in the controller through (0-2A) ammeter. Connect a Voltmeter (0-30V) across the motor armature.
4. Set the controller to be proportional by connecting I controller input to ground.
5. Set the proportional gain K_p at minimum.
6. Switch ON power to the motor controller and Pulse Release. Switch to ON position.
7. Set Vref =1volt. Slowly increases the gain K_p by means of the proportional gain adjustment pot and find voltage at wheel motor just starts running.
8. Run the motor at 1500 rpm by suitably adjusting the V_{ref} and K_p . Note down the armature voltage (Va), armature current (Ia) and speed (N).
9. Apply load by moving the brake magnet close to the disc. Apply the load in steps (the current is increased by 0.25A).
10. Note the armature current, voltage and speed in each step and tabulate the readings.
11. Decrease the load and reduce the gain to minimum.
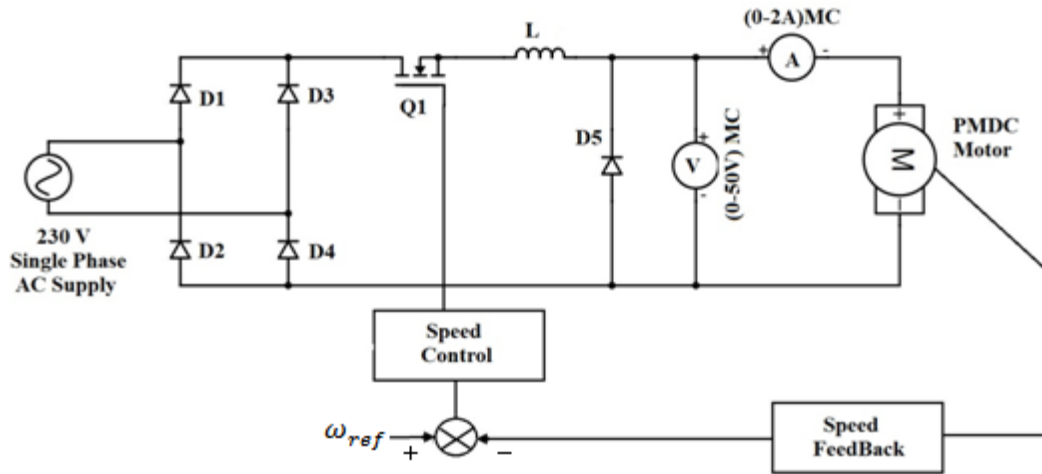12. Switch OFF the power supply.

FORMULA USED:

1. $E_b = V_a - I_a R_a$

2. $\omega = \frac{2\pi N}{60}$ rad/sec
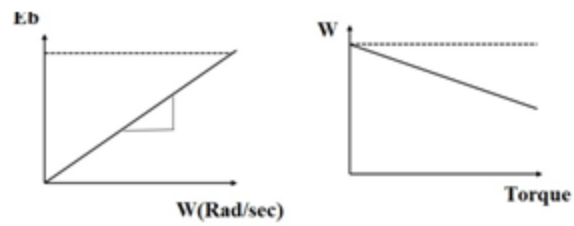
3. $E_b = \frac{\Delta E_b}{\Delta \omega}$

4. $T = K_b I_a$

Practical Circuit for Speed Control of dc Motor

Model Graph

Open Loop

$R_a = 0.9\Omega$

Sl. No	Armature voltage (Volts)	Armature current (amps)	Speed (N) (rpm)	$\omega = \frac{2\pi N}{60}$ rad/sec	$T = K_b I_a$ (N-m)	E_b (Volts)

Closed Loop

$R_a = 0.9\Omega$

Sl. No	Armature voltage (Volts)	Armature current (amps)	Speed (N) (rpm)	$\omega = \frac{2\pi N}{60}$ rad/sec	$T = K_b I_a$ (N-m)	E_b (Volts)

RESULT:

Thus both the open loop and closed loop speed Vs torque characteristics of PMDC motor is obtained.

Ex. No.:
Date:

PSIM OF POWER CONTROL CIRCUIT

AIM:

To study the principal of operation of single phase bridge rectifier and chopper.
To simulate the single phase bridge rectifier and chopper using PSIM software and obtain their input and output voltage waveforms.
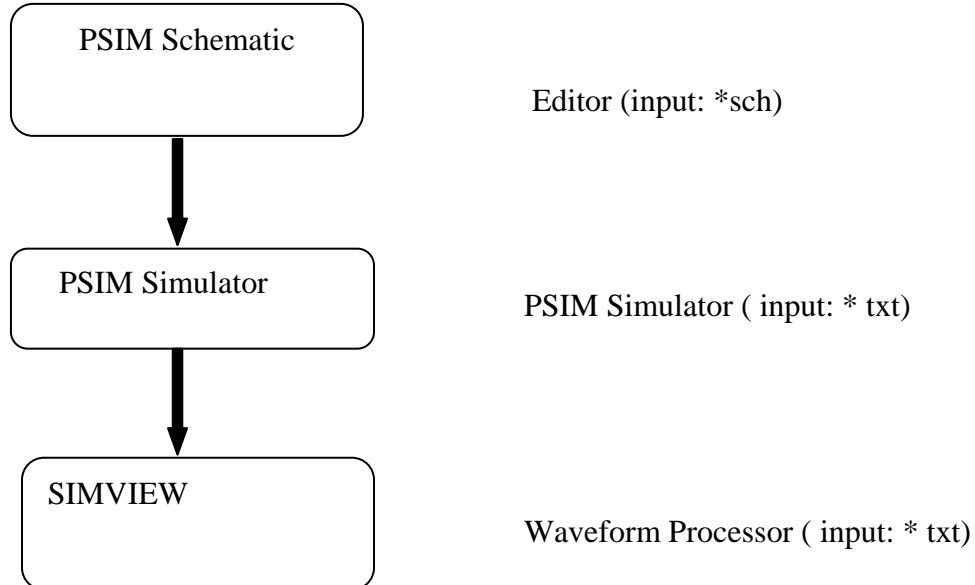
**APPARATUS REQUIRED:**

Personal computer with PSIM package.

PSIM:

PSIM is a simulation package specifically designed for power electronics and motor control with fast simulation and friendly user interface. PSIM provides a powerful simulation environment for Power Electronics, Analog and Digital Control and Motor Drive System Studies.

The simulation environment is illustrated as follows.

```
┌─────────────────────┐
│                     │
│   PSIM Schematic    │          Editor (input: *sch)
│                     │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│                     │
│   PSIM Simulator    │          PSIM Simulator ( input: * txt)
│                     │
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│                     │
│   SIMVIEW           │          Waveform Processor ( input: * txt)
│                     │
└─────────────────────┘
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Single Phase Bridge Rectifier Circuit and Model Graph
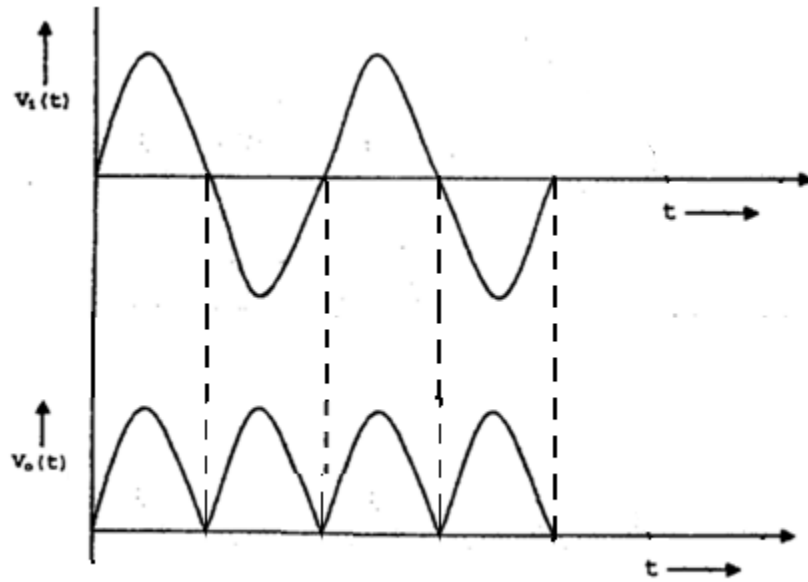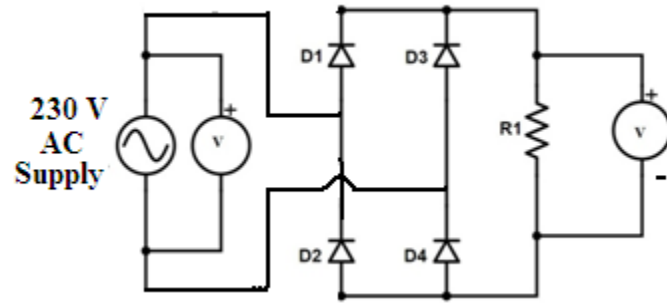
CREATING A CIRCUIT:

The following functions are in PSIM for circuit creation

      Get: To get an element from the element library. Click on the **Elements** menu. Choose the submenu and highlight the element to be selected. For example. to get a dc source.Click on **Element, Source** and **Voltage**. Then highlight **dc**.

      Place: Once an element is selected from the menu, the image of the element will appear on the screen and move with the mouse. Click the left button of the mouse to place the element.

      Rotate: Once an element is selected; select **Rotate** to rotate the element.

      Wire: To connect a wire between two nodes. Select **Wire**, An image of a pen will appear on the screen. To draw a wire, keep the left button of the mouse pressed and drag the mouse. A wire always starts from and ends at a grid intersection. For easy inspection, a floating node is displayed as a circle, and a junction node is displayed as a solid dot.

      Label If two or more nodes are connected to the same label, they are connected. It is equivalent as though they are connected by wire. Using labels reduce cross- wiring and improve the schematic layout. The text of a label can be moved. To select the text, left click on the label, then press the **Tab** key.

      Assign To assign the parameters of an element, double click on the element. A dialog box will appear. Specify the values and hit then < Return> key or click on **OK**.

EDITING A CIRCUIT

      The following functions are provided in the **Edit** menu and **view** menu for circuit editing.

      Select: To select an element, click on the element. A rectangle will appear around the element. To select a block of a circuit, keep the left button of a mouse pressed and drag the mouse until the rectangle covers the selected area.

      Copy: To copy an element or a block of the circuit, select the element or the region, and choose **Copy**. Then choose **Paste** place the element or circuit.

      Delete: To delete an element, a block of a circuit, or a wire, select the item, and choose **Cut**, or hit the < Delete> key. Note that if **Cut** is used, the last deleted item can be pasted back. This is equivalent to un-do.

      Move: To move an element or a circuit block, select the element/circuit block and drag the mouse while keeping the left button pressed

      Text: To place text on the screen, choose **Text**. Enter the text in the dialog box, and clock the left button of the mouse to place it.

      Disable: To disable an element or a part of a circuit. When the element or the circuit is disabled, it will be grayed out and will be treated as nonexistent as far as the simulation is concerned. This function is useful if an element or circuit needs to be excluded but not deleted from the circuit.

      Enable: To enable a previously disabled element or circuit.

Single Quadrant Chopper and Model Graph
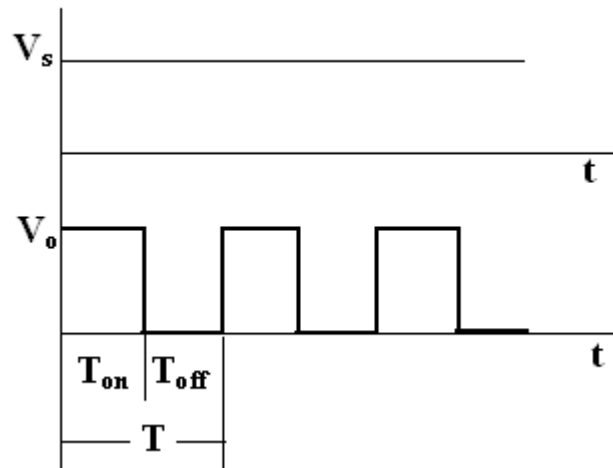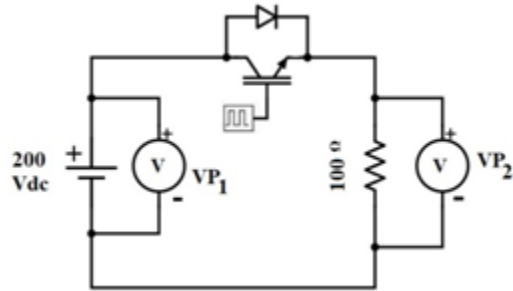
Zoom: Select **Zoom In** to zoom in the circuit, or **Zoom in Selected** to zoom in to a selected region. Choose **Zoom Out** to zoom out or **Fit to Page** to zoom out to fit the entire circuit to the screen.

Escape: Quit from any of the above editing modes by choosing **Escape**.

SIMULATING A CIRCUIT

To simulate the sample one- quadrant chopper circuit"chop.sch".

Start PSIM. Choose **Open** from the **File** menu to load the file "chop.sch".

From the **Simulate** menu, choose **Run PSIM** to start the simulation. The simulation results will be saved to File "chop. txt". Any warning messages occurred in the simulation will be saved to File "message. doc".

If the option **Auto- run SIMVIEW** is not selected in the **Options** menu, from the **Simulate** menu, choose **Run SIMVIEW** to start SIMVIEW.

If the option **Auto- run SIMVIEW** is selected, SIMVIEW will be launched automatically, select curves for display.

RESULT:

A single phase bridge rectifier and a chopper circuit is simulated using PSIM and the input/ output waveforms are obtained.