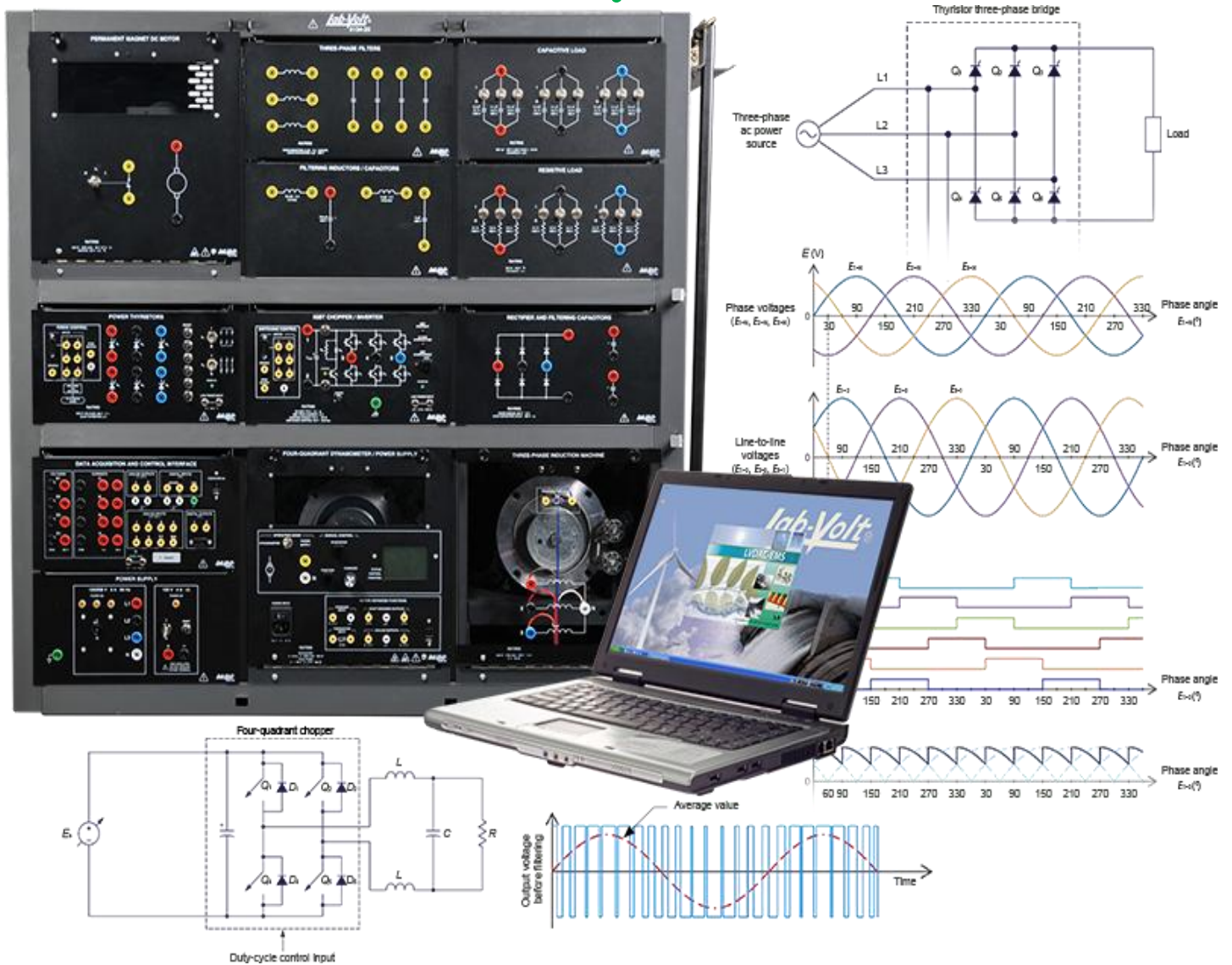# Department of Electrical and Electronics Engineering

POWER ELECTRONIC CONVERTERS

Laboratory Manual

Gokaraju Rangaraju Institute of Engineering & Technology

POWER ELECTRONIC CONVERTERS

Laboratory Manual

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HYDERABAD 500090.

Power Electronics Lab Record

CERTIFICATE

This is to certify that it is a Bonafide Record of practical workdone in the Power Electronics Laboratory in I sem of III Year during the year……………

Name:………………………………………………………...
Roll no:………………………………………………………....
Course: M.Tech. ………. Year……Semester…………
Branch: …………………………………………………...

SIGNATURE OF STAFF MEMBER

CONTENTS

LIST OF EXPERIMENTS

(Simulation Experiments)

COURSE OBJECTIVES & OUTCOMES

COURSE OBJECTIVES:

1. To provide the students hands on experience on power electronics switches.
2. To program different switching patterns in power electronics systems.
3. To study advanced power electronic converters.
4. To familiarize the operation of rectifier circuits.
5. To study the power electronics based resonant inverters.

COURSE OUTCOMES:

1. Define the basics of power electronics switches and Evaluate the V-I characteristics of SCR
2. Relate the operating characteristics of Thyristor controlled & IGBT controlled rectifiers
3. Analyze the operation of 3-ph bridge rectifiers
4. Apply the knowledge of triggering of IGBT & MOSFET for Chopper circuit
5. Extend the knowledge of control technique for Cyclo-converter and relate the operating characteristics of converters for different loads.

INDEX

SI.NO:	DATE	EXPERIMENT	SIGNATURE

SI.NO:	DATE	EXPERIMENT	SIGNATURE

STUDY EXPERIMENTS

EXPERIMENT-1

Study of Characteristics of SCR, MOSFET & IGBT

AIM: -

　　To plot the characteristics of SCR, MOSFET & IGBT

 APPARATUS: -

S.no	Description	Quantity
1	Characteristics Kit	1
2	Ammeter (0-500)mA	2
3	Voltmeter (0-50)V	2
4	RPS (0-30)V,2A	1

PROCEDURE:

To obtain Characteristics of SCR:

1.　The connections are made as per circuit diagram.
2.　Switch on the regulated power supply. Apply 10V across anode & cathode of SCR.
3.　Gradually increase the gate current till the SCR becomes ON. Note down V_{AK}, I_A.
4.　Now increase supply voltage gradually and I_A are noted for three or four readings.
5.　Steps 3 to 4 are repeated for another values of V_{AK} say 20V.
6.　Tabulate the readings in the table.
7.　Plot a graph of V_{AK} versus I_A.
8.　 To determine Holding current I_H :
　　i) Keep proper V_{AK} to trigger SCR by gate current. Trigger SCR by applying gate current .Keep sufficient load current by varying load resistance in fully clock wise direction.

　　ii) To open gate circuit, now reduce load current till SCR jump to blocking state.iii) the minimum current for which SCR suspend under ON condition is noted which is Holding current I $_H$.

9. Latching current is 1.5 to 2 times of holding current value
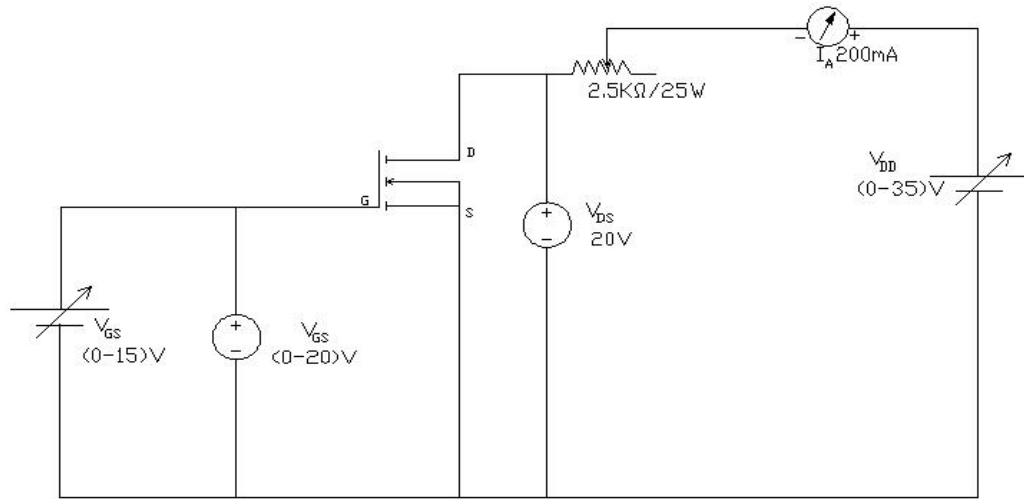
Circuit Diagram for obtaining the characteristics of MOSFET
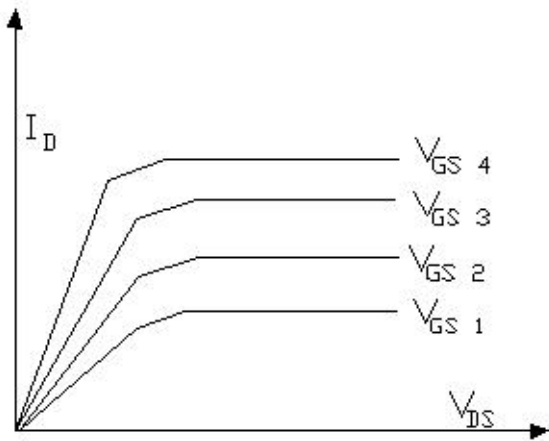
Output Characteristics for MOSFET
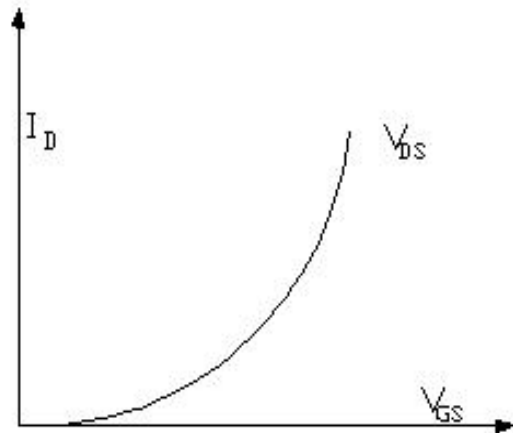
Transfer Characteristics for MOSFET

To obtain Characteristics of MOSFET :

Output Characteristics:

The connections are made as per circuit diagram
1. Switch on the equipment. Keep V_{DS} say 10V, vary V_{GS} note down the range of V_{GS} for which drain current is varying for constant V_{GS}.

2. Keep V_{GS} constant, (V_{GS} must be within the range determined by step 2).
3. Vary V_{DS} in steps, note down corresponding I_D.
4. Step 4 is repeated for different values of V_{GS}.
5. Tabulate the readings in the table.
6. Plot a graph of I_D against V_{DS} for different V_{GS}.

Transfer Characteristics:

The connections are made as per circuit diagram
1. Switch on the equipment. Keep V_{DS} say 10V, vary V_{GS} in steps ,note down the corresponding drain current I_D.
2. Tabulate the readings in the table.
3. Plot a graph of I_D against V_{GS}.

To obtain Characteristics of IGBT :

Output Characteristics:

1. Connections are made as per circuit diagram.(Use 20V Voltmeter for V_{GE} , 200V Voltmeter for V_{CE} , 200 ma Ammeter for IC 15V Power supply for base & 35V Power supply for collection circuit).
2. Switch on the equipment .Keep V_{CE} 10V, vary V_{GE} note down the range of V_{GE} for which collector current is varying for constant V_{CE}.
3. Keep V_{GE} constant,(V_{GE} must be with in the range determined by step 2).
4. Vary V_{CE} in steps, note down the corresponding I_C.
5. Adjust V_{GE} to constant while doing step 4.
6. Step 4 is repeated for different V_{GE}.
7. Tabulate the readings in the table.
8. Plot a graph of I_C against V_{CE} for different V_{GE}.

Transfer Characteristics:

1. Connections are made as per circuit diagram.(Use 20V Voltmeter for V_{GE} , 200V Voltmeter for V_{CE} , 200 ma Ammeter for IC 15V Power supply for base & 35V Power supply for collection circuit).
2. Switch on the equipment. Keep V_{CE} constant, vary V_{GE} in steps , note down corresponding I_C.
3. Adjust V_{CE} to constant while doing step 2.
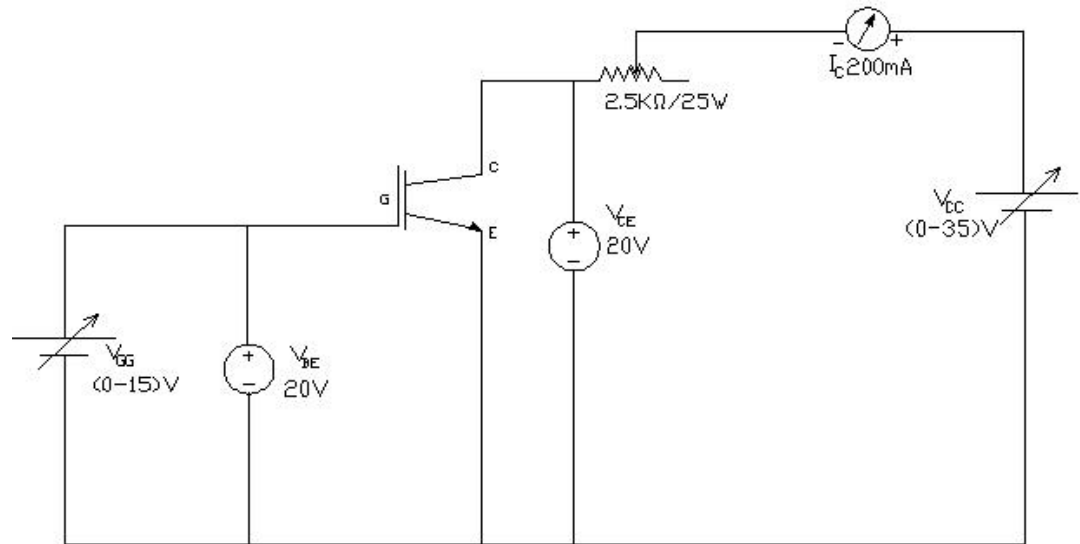4. Tabulate the readings in the table.
5. Plot a graph of I_C against V_{GE} for different V_{CE}

CIRCUIT DIAGRAM FOR IGBT:

Circuit Diagram for obtaining the characteristics of IGBT
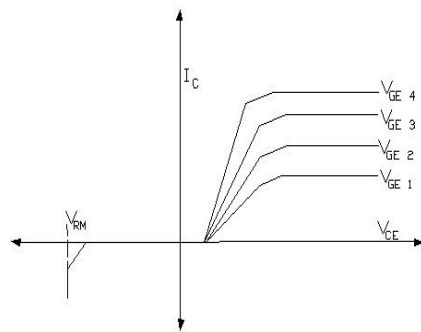
Output Characteristics for IGBT

Transfer Characteristics for IGBT

OBSERVATRIONS:

Static V-I Characteristics' of   SCR

$V_{G1} =$

S.No	$V_{AK}(V)$	$I_A(mA)$

Static V-I Characteristics of SCR

$V_{G2} =$

S.No	$V_{AK}(V)$	$I_A(mA)$
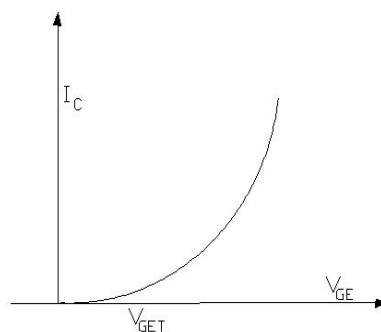
OUTPUT WAVE FORMS:

Output Characteristics of MOSFET

$V_{DS} =$ _____

Transfer Characteristics of MOSFET

$V_{GS} =$

S.No	V_{DS} (V)	I_D (mA)

S.No	V_{GS} (V)	I_D (mA)

Output Characteristics of IGBT

$V_{GE} =$_____

S.No	V_{CE} (V)	I_C (mA)

Transfer characteristics of IGBT

$V_{GE} =$

S.No	V_{GE} (V)	I_C (mA)
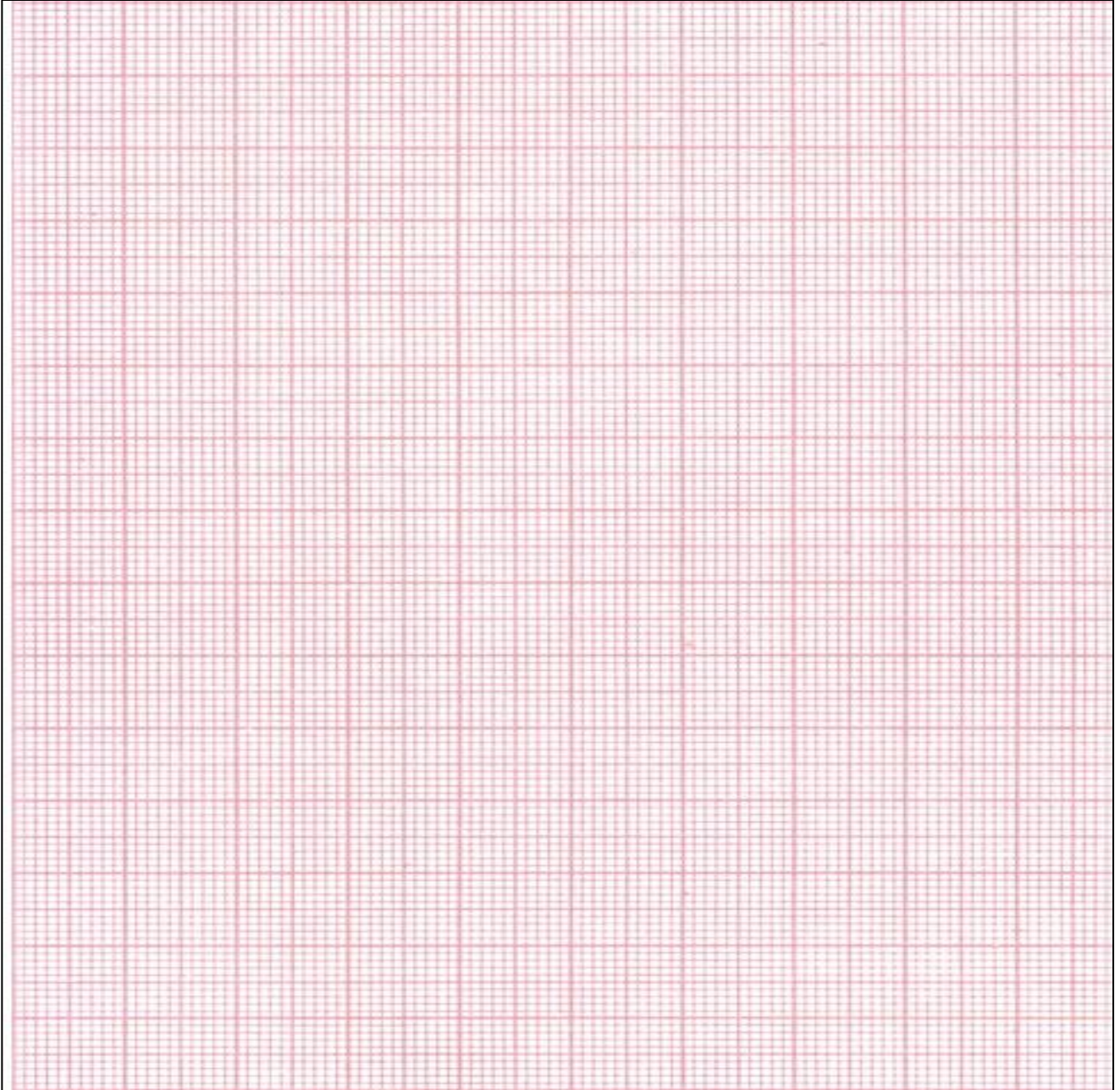
OUTPUT WAVEFORMS

Result:

Experiment No 2

Gate Firing Circuits for SCR's

AIM: -

To trigger an SCR by using R, RC & UJT triggering circuits and observe the output waveforms for different firing angles.

APPARATUS: -

| S.no	Description	Quantity
1	Triggering circuit Kit	1
2	Unearthed C.R.O	1
3	Connecting probes	1

PROCEDURE:

Resistance firing circuit:

(1) Apply 12V of AC input to the anode and cathode of SCR terminals from a step down transformer.
(2) Connect the anode, cathode & gate terminals of SCR to the corresponding A, K, G terminals in the R – Triggering circuit.
(3) Connect the load of 50Ω/2A between the load terminals.
(4) Observe the variations in the voltage across the load for different firing angles (by varying potentiometer) with the help of CRO, plot waveforms of firing signals & output voltage for firing angle 45^0, 90^0.

CIRCUIT DIAGRAM:

R- Triggering:
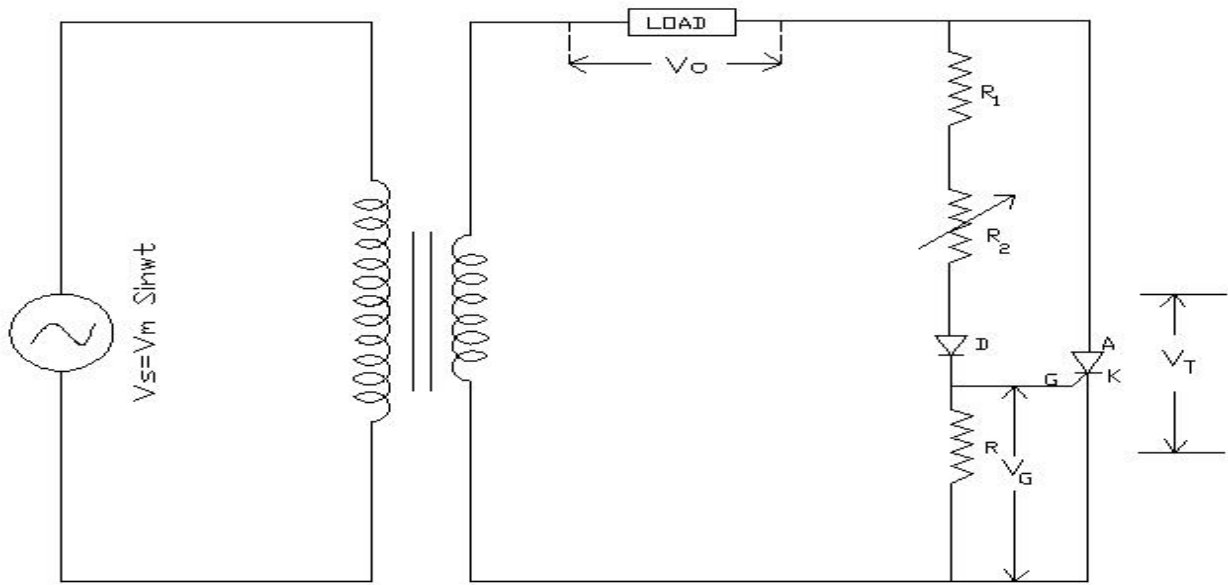
Step Down Transformer
230V / 12V

Circuit Diagram to obtain Resistance Triggering

MODEL GRAPHS:

RC firing circuits:

1. Apply 12V of AC input to the anode and cathode of SCR terminals from a step down transformer.
2. Connect the anode, cathode & gate terminals of SCR to the corresponding A, K, G terminals in the R – Triggering circuit.
3. Connect the load of 50Ω/2A between the load terminals.
4. Observe the variations in the voltage across the load for different firing angles (by varying potentiometer) with the help of CRO, plot waveforms of firing signals & output voltage for firing angle 45^0, 180^0.

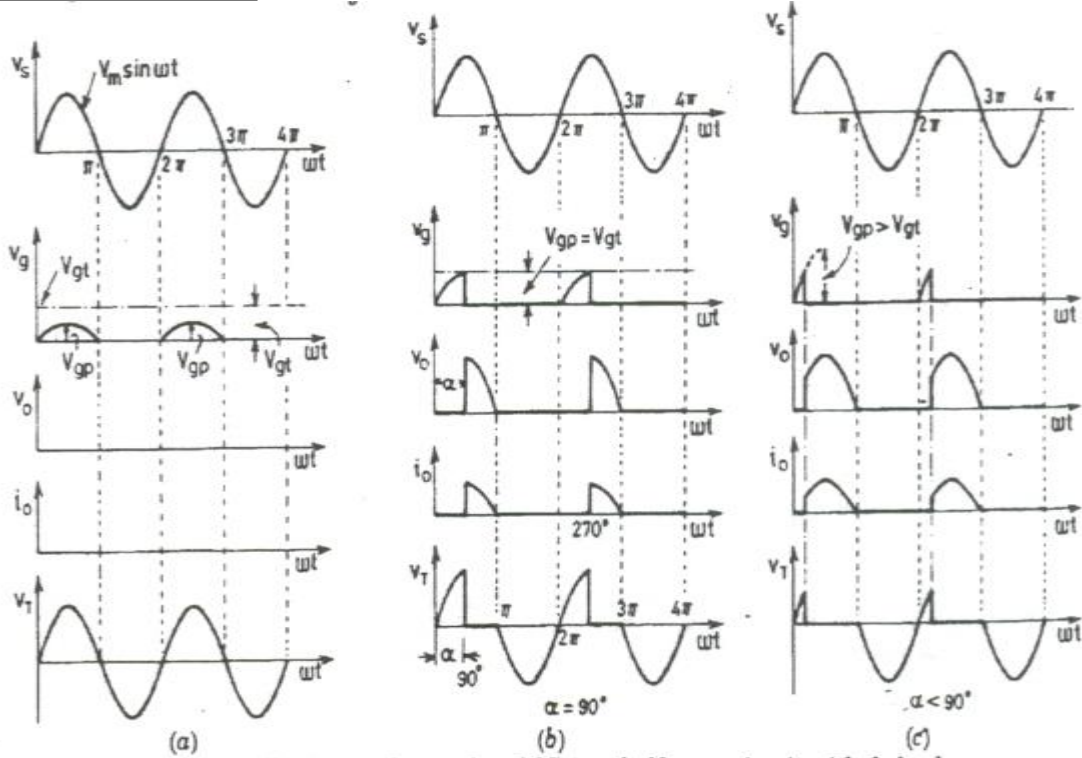Step Down Transformer
230V / 12V

Circuit Diagram to obtain RC Triggering

(a)

(b)

OUTPUT WAVE FORMS
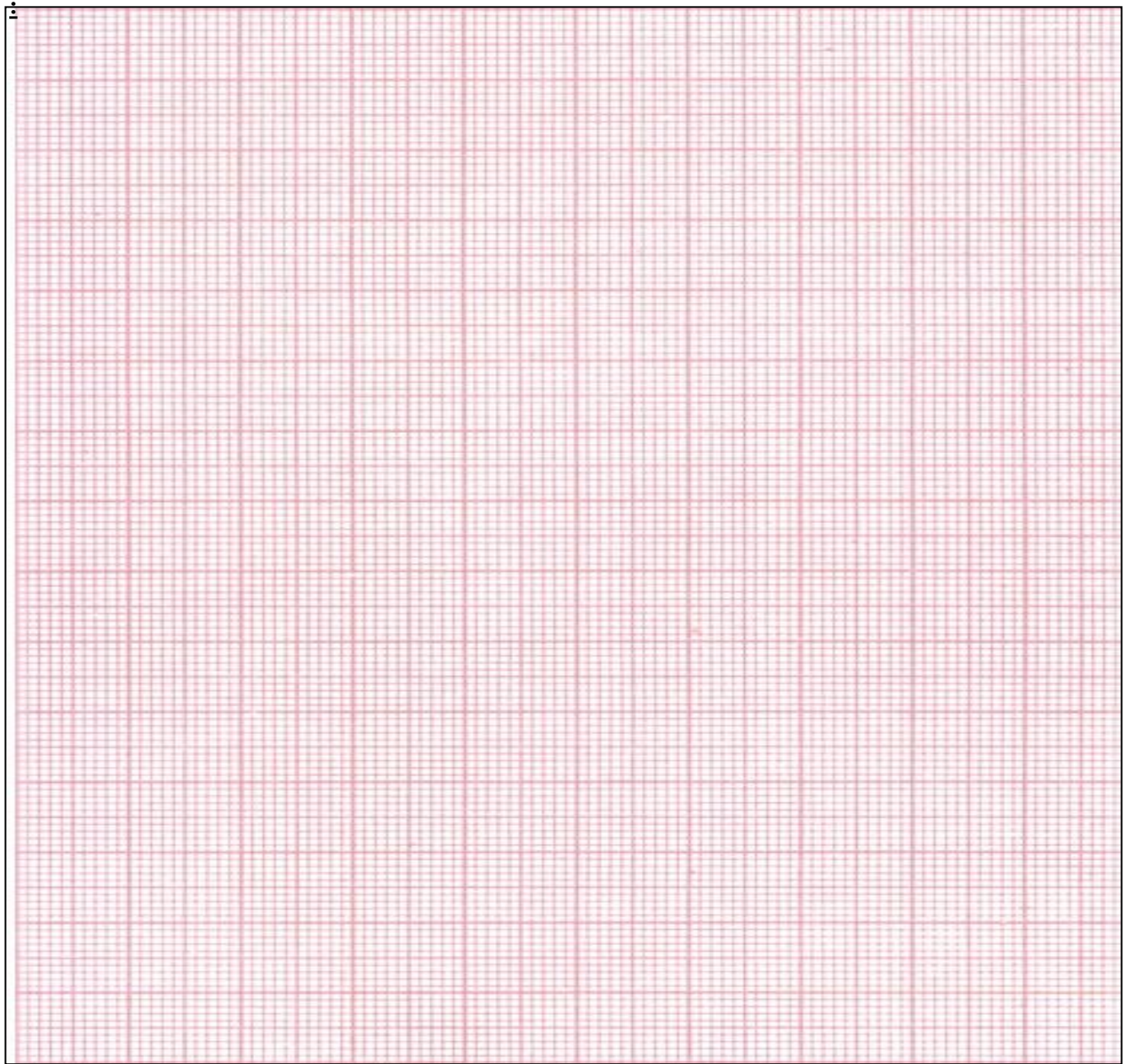
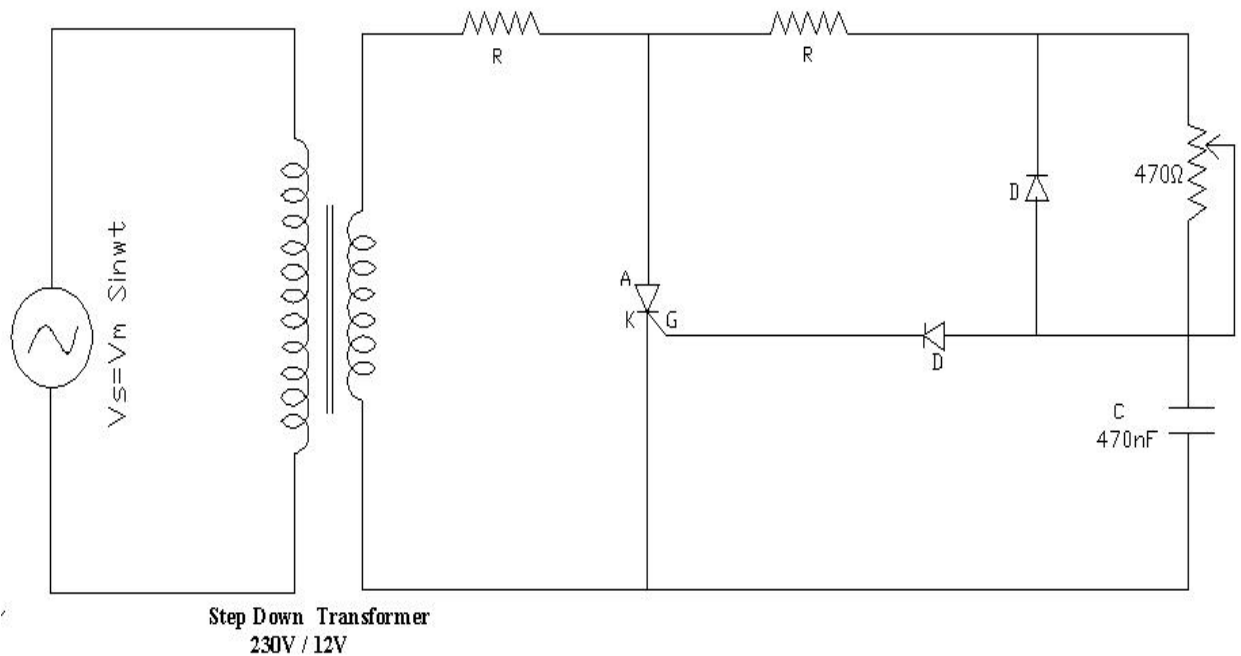**Result:**

UJT Firing Circuits
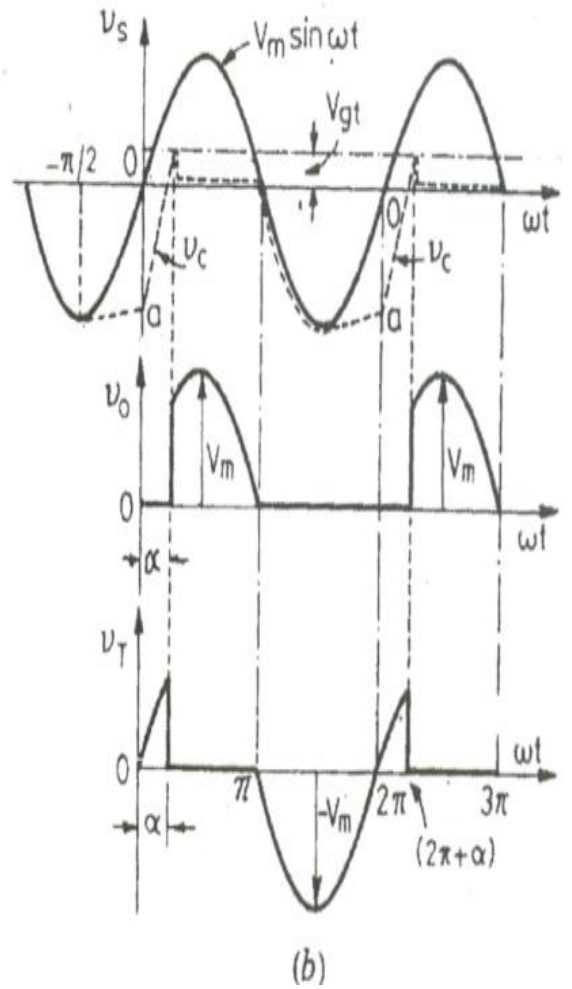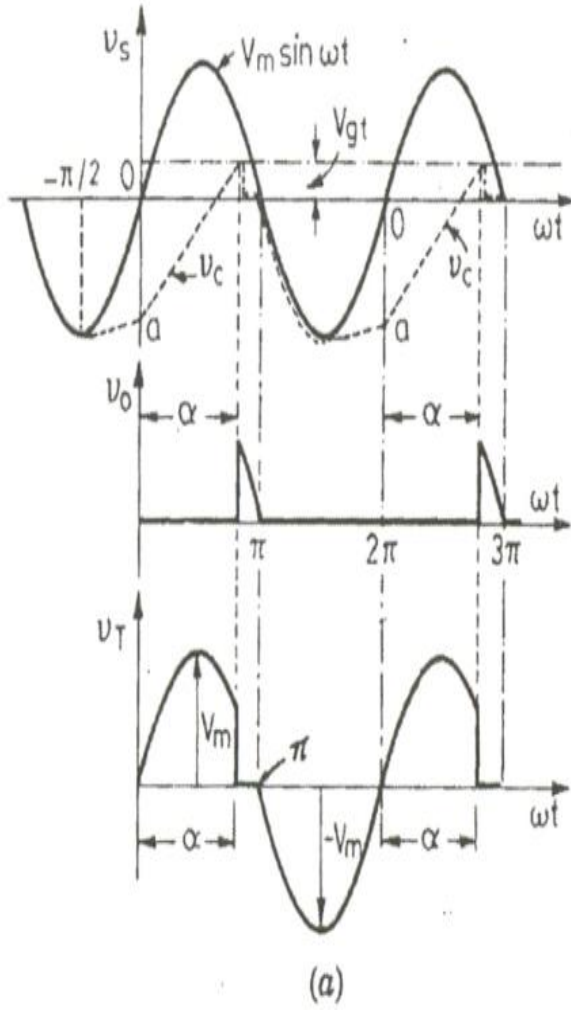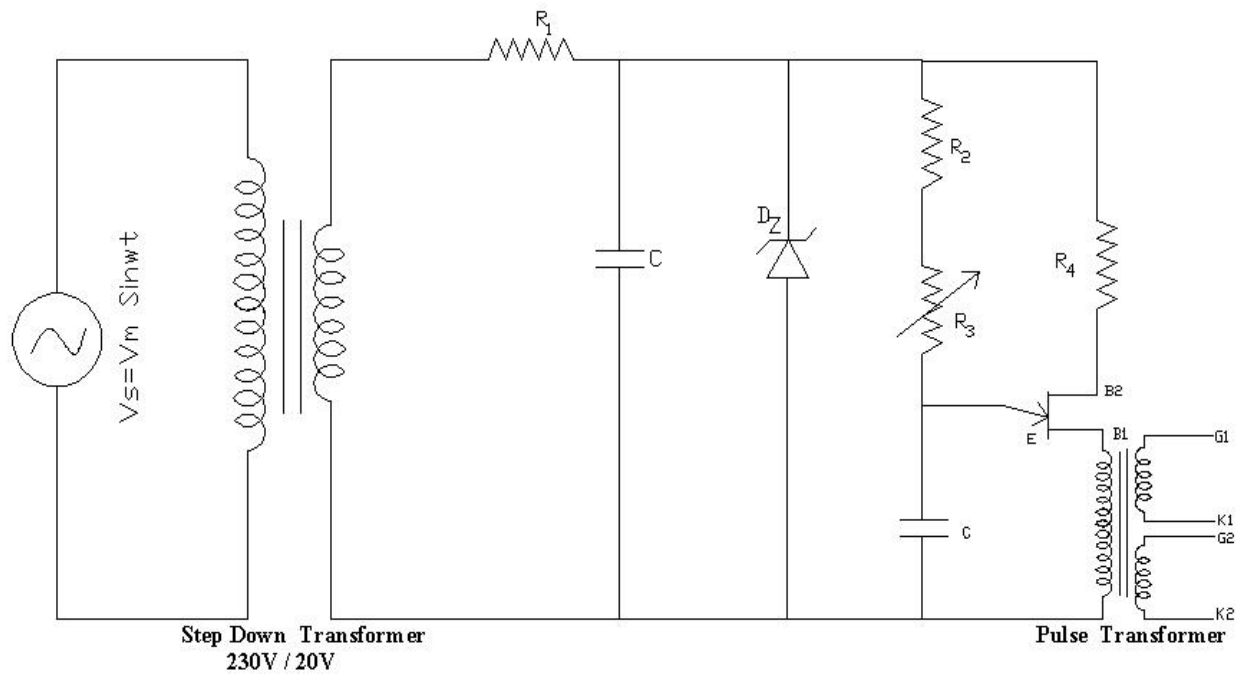

Circuit Diagram to obtain UJT Triggering

Model Graphs:
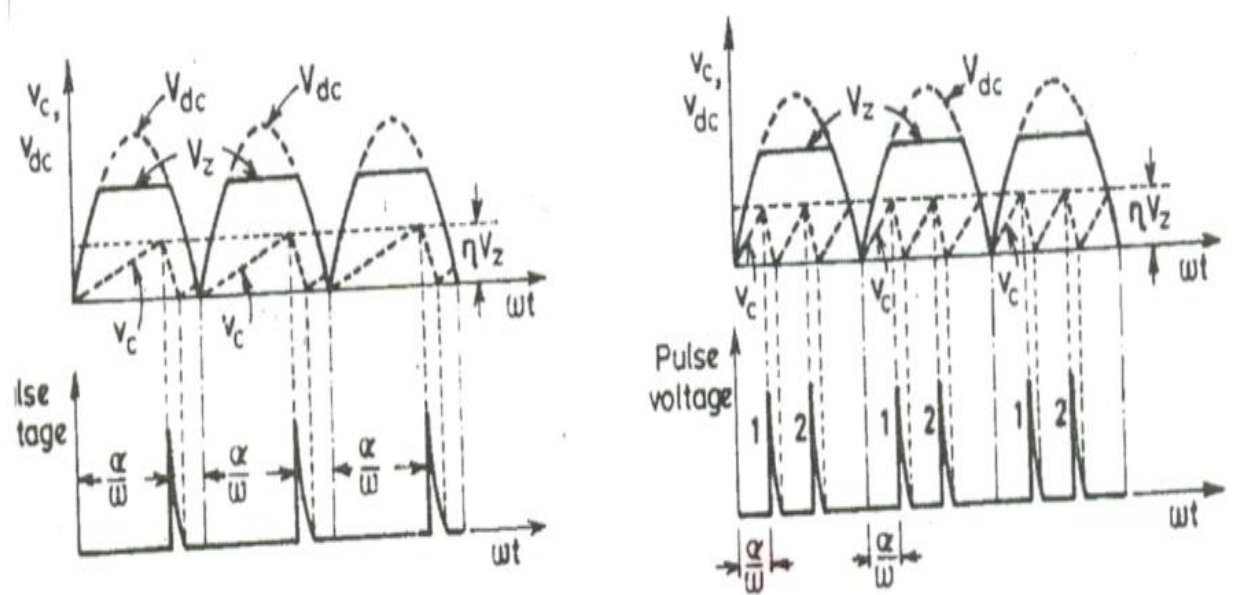
UJT firing circuit:

1. Apply 12V of AC input to the anode and cathode of SCR terminals from a step down transformer.
2. The rectified output is applied to the UJT terminals through the résistance as shown in the circuit diagram.
3. Connect the cathode & gate terminals of SCR to the corresponding K, G terminals in the UJT – Triggering circuit.
4. Connect the load of 50Ω/2A between the load terminals.
5. Switch ON the supply for UJT Triggering circuit.
6. Observe the variations in the voltage across the load for different firing angles (by varying potentiometer) with the help of CRO, plot waveforms of firing signals & output voltage for firing angle 45^0, 180^0.

PRECAUTIONS:

(1) Initially the potentiometer should be in minimum resistance position.
(2) Vary the Potentiometer gradually.
(3) Observe the output waveforms carefully on the CRO

Pulse Width Modulation techniques

PWM is a technique that is used to reduce the overall harmonic distortion (THD) in a load current. It uses a pulse wave in rectangular/square form that results in a variable average waveform value f(t), after its pulse width has been modulated. The time period for modulation is given by T. Therefore, waveform average value is given as

$$y = (1/T) \int_{0}^{T} f(t)dt$$
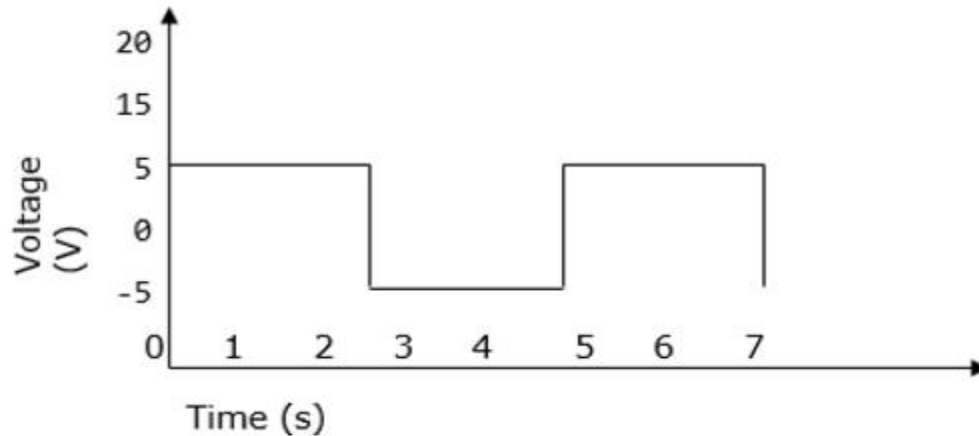
Sinusoidal Pulse Width Modulation

In a simple source voltage inverter, the switches can be turned ON and OFF as needed. During each cycle, the switch is turned on or off once. This results in a square waveform. However, if the switch is turned on for a number of times, a harmonic profile that is improved waveform is obtained.

The sinusoidal PWM waveform is obtained by comparing the desired modulated waveform with a triangular waveform of high frequency. Regardless of whether the voltage of the signal is smaller or larger than that of the carrier waveform, the resulting output voltage of the DC bus is either negative or positive.
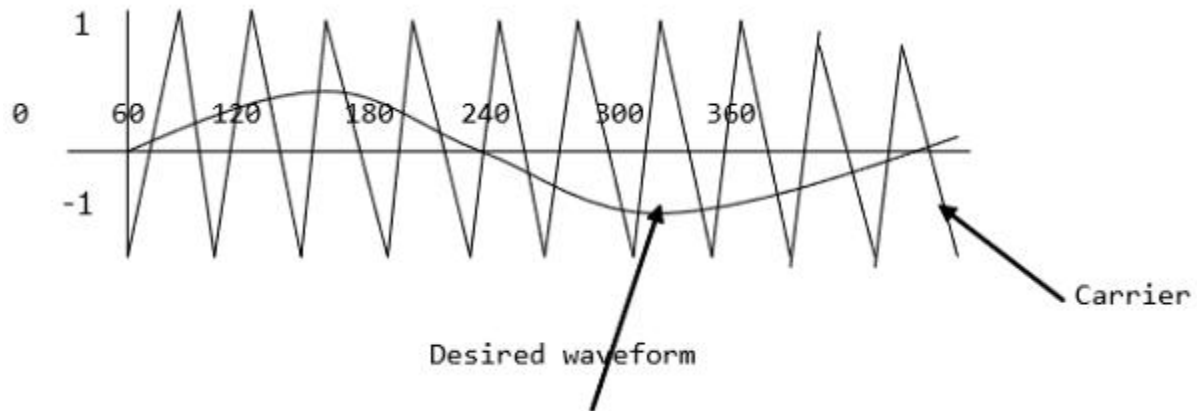
The sinusoidal amplitude is given as A_m and that of the carrier triangle is give as A_c. For sinusoidal PWM, the modulating index m is given by A_m/A_c.

Modified Sinusoidal Waveform PWM

A modified sinusoidal PWM waveform is used for power control and optimization of the power factor. The main concept is to shift current delayed on the grid to the voltage grid by modifying the PWM converter. Consequently, there is an improvement in the efficiency of power as well as optimization in power factor.

Input AC Voltage waveform

Modified AC voltage output
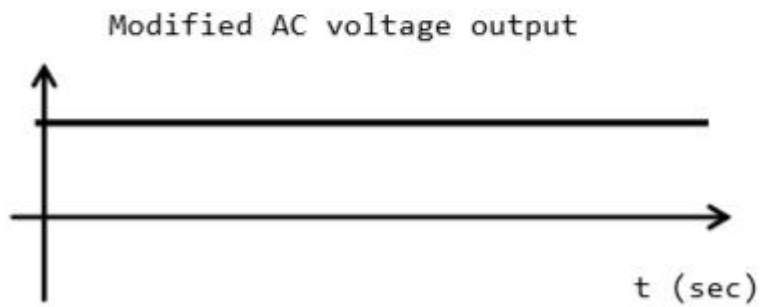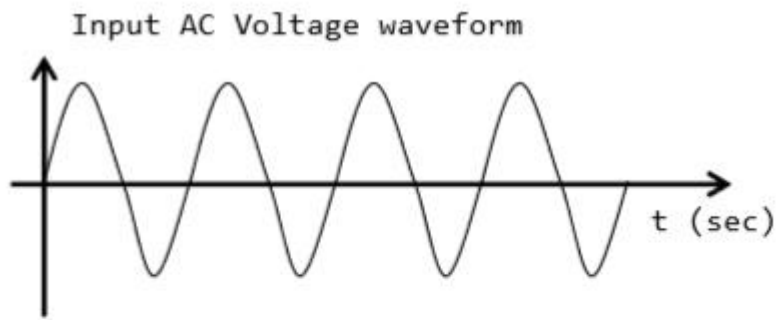
Multiple PWM

The multiple PWM has numerous outputs that are not the same in value but the time period over which they are produced is constant for all outputs. Inverters with PWM are able to operate at high voltage output.
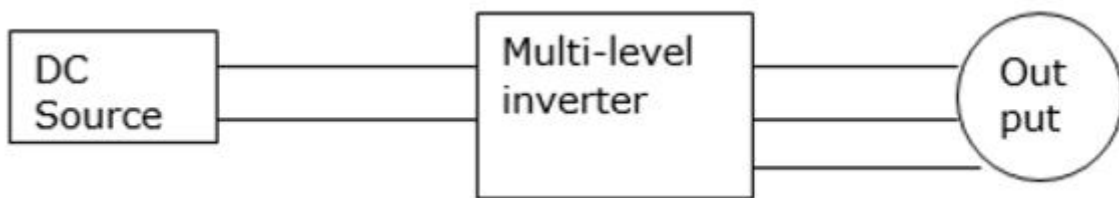
The waveform below is a sinusoidal wave produced by a multiple PWM

Voltage Output vs t (sec)
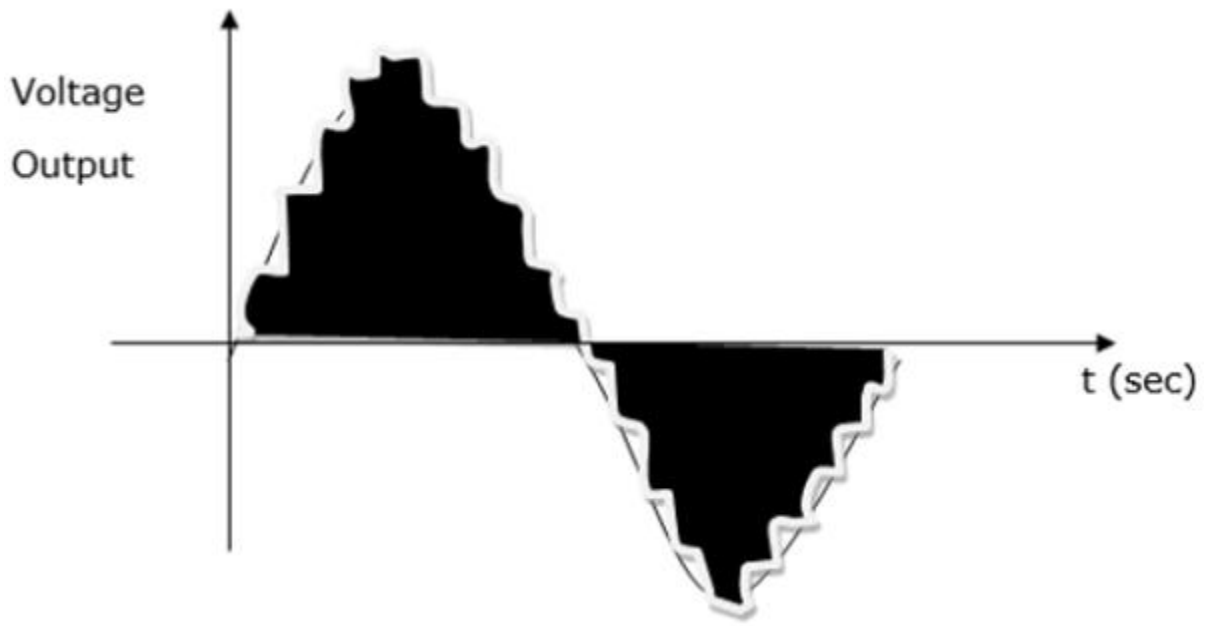
SIMULATION EXPERIMENTS
EXPERIMENT NO: 4
1-PHASE HALF WAVE CONTROLLED CONVERTER WITH R RL &RLE LOAD

AIM: To study the simulation of half wave controlled rectifier with R & RL-load using matlab - simulink.

SOFTWARE : MATLAB

CIRCUIT DIAGRAM:
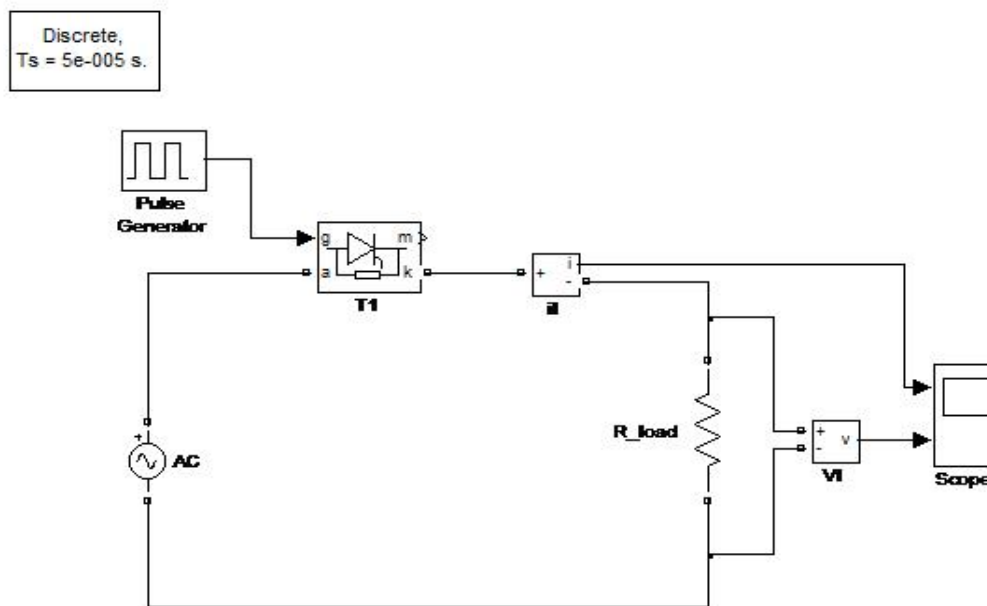
Half Wave Rectifier With R-Load
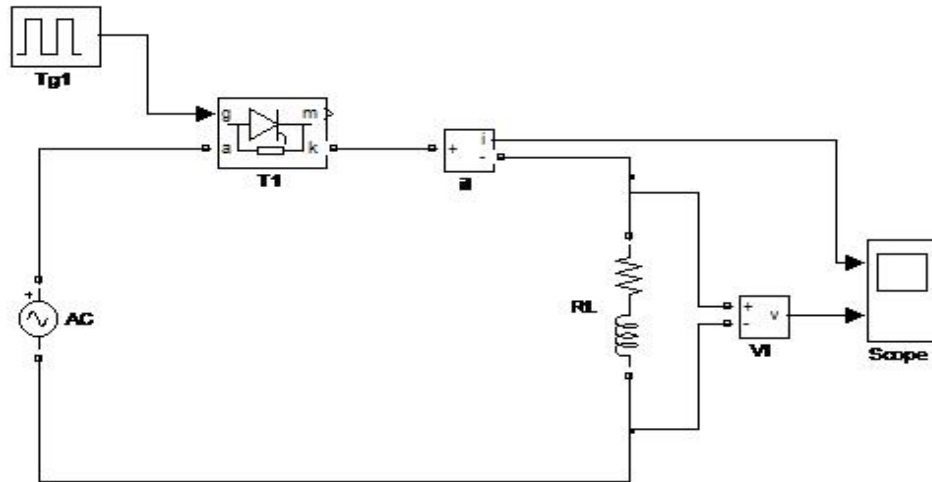
Half Wave Rectifier WithRL-Load
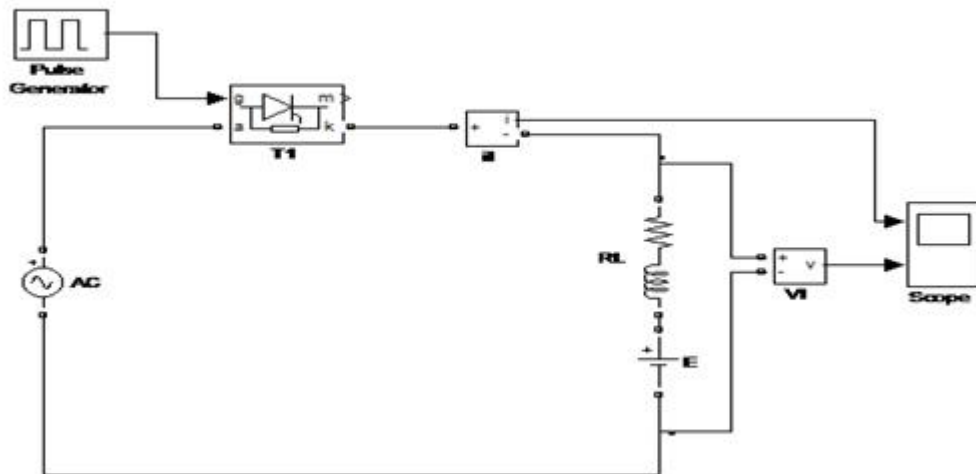
Half Wave Rectifier WithRLE-Load

THEORY:

A single phase half wave controlled converter only has one SCR is employed in the circuit. The performance of the controlled rectifier very much depends upon the type and parameters of the output (load) circuit.

The simulation circuit of the half wave converter is shown in fig (1) during the positive half-cycle of input voltage, the thyristor anode voltage is positive with respect to cathode and the thyristor is said to be forward biased. When thyristor T_1 is fired at wt=α, thyristor T_1 is conducts and input voltage appears the load. When the input voltage starts to be negative at wt=∏, the thyristor anode is negative with respect to cathode and thyristor is said to be reverse biased; and it is turned off. The time after the input voltage starts to go positive until the thyristor is fired is called the delay or firing angle α.

The simulation waveforms of input voltage, output voltage and load current are shown in fig. This converter is not used in industrial applications because its output has high ripple content and low ripple frequency.

Gating Sequence. The gating sequence for the thyristor is as follows:

1. Generate a pulse-signal at positive zero crossing of the supply voltage Vs.
2. Delay the pulse by desired angle α and apply it between the gate and cathode terminal terminals of T1 through a gate-isolating circuit.

Note: Both the output voltage and input current non-sinusoidal. The performance of the controlled rectifier can be measured by the distortion factor (DF), total harmonic distortion (THD), PF, transformer utilization factor (TUF), and harmonic factor.

PROCEDURE:

1. Connect the circuit as shown in the circuit diagram.

2. Give the firing pulses accordingly at a suitable firing angle from the firing circuit.

3. Observe the load voltage on the screen and note down the firing angle.

4. Draw the waveforms and calculate the Average and RMS value of output voltage.

CALCULATIONS:

MODEL WAVE FORMS:R- LOAD
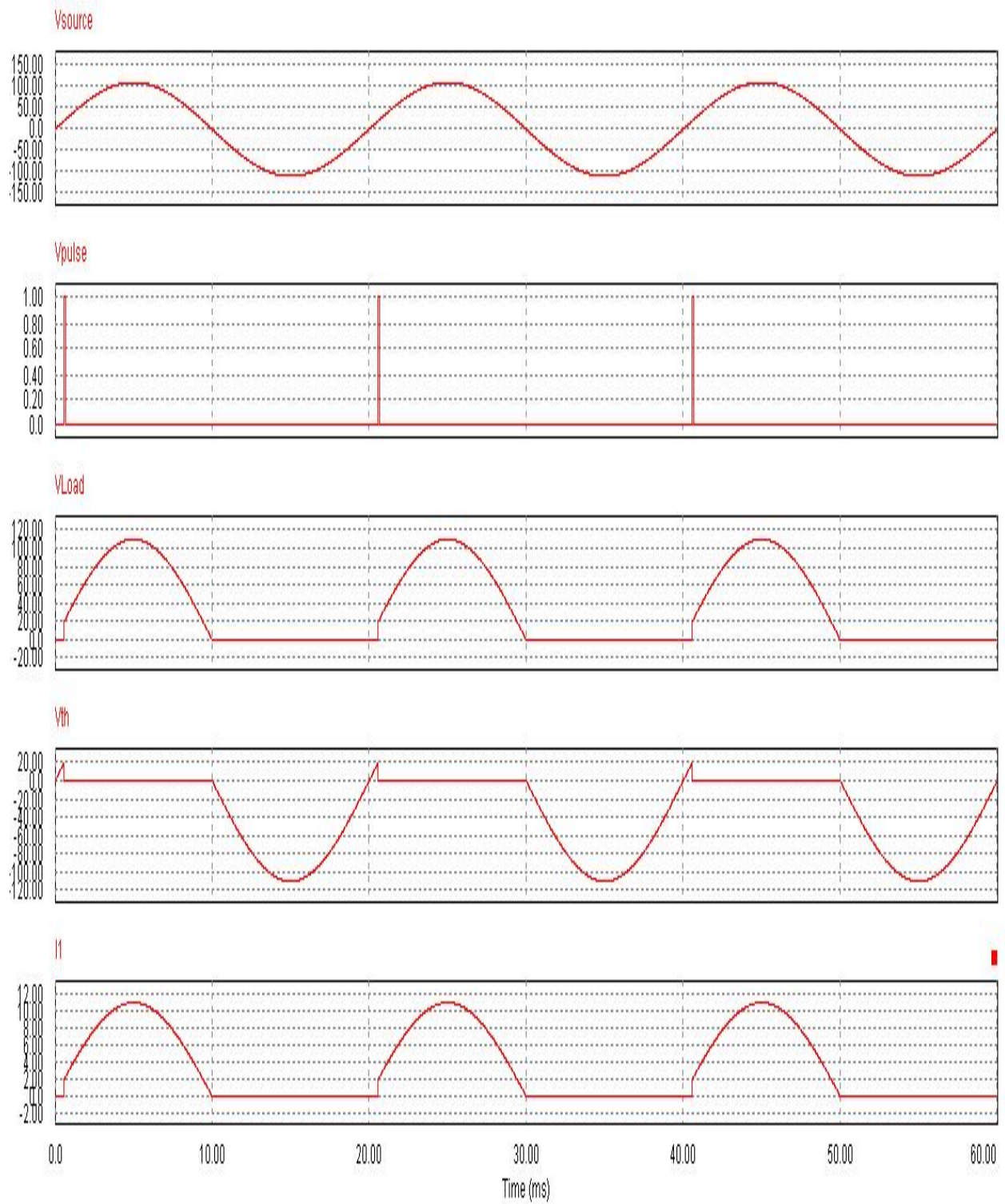
GRAPH SHEET:

MODEL WAVE FORMS:<u>RL- LOAD</u>

Vsource

Vpulse

VLoad

Vth

I1

Time (ms)
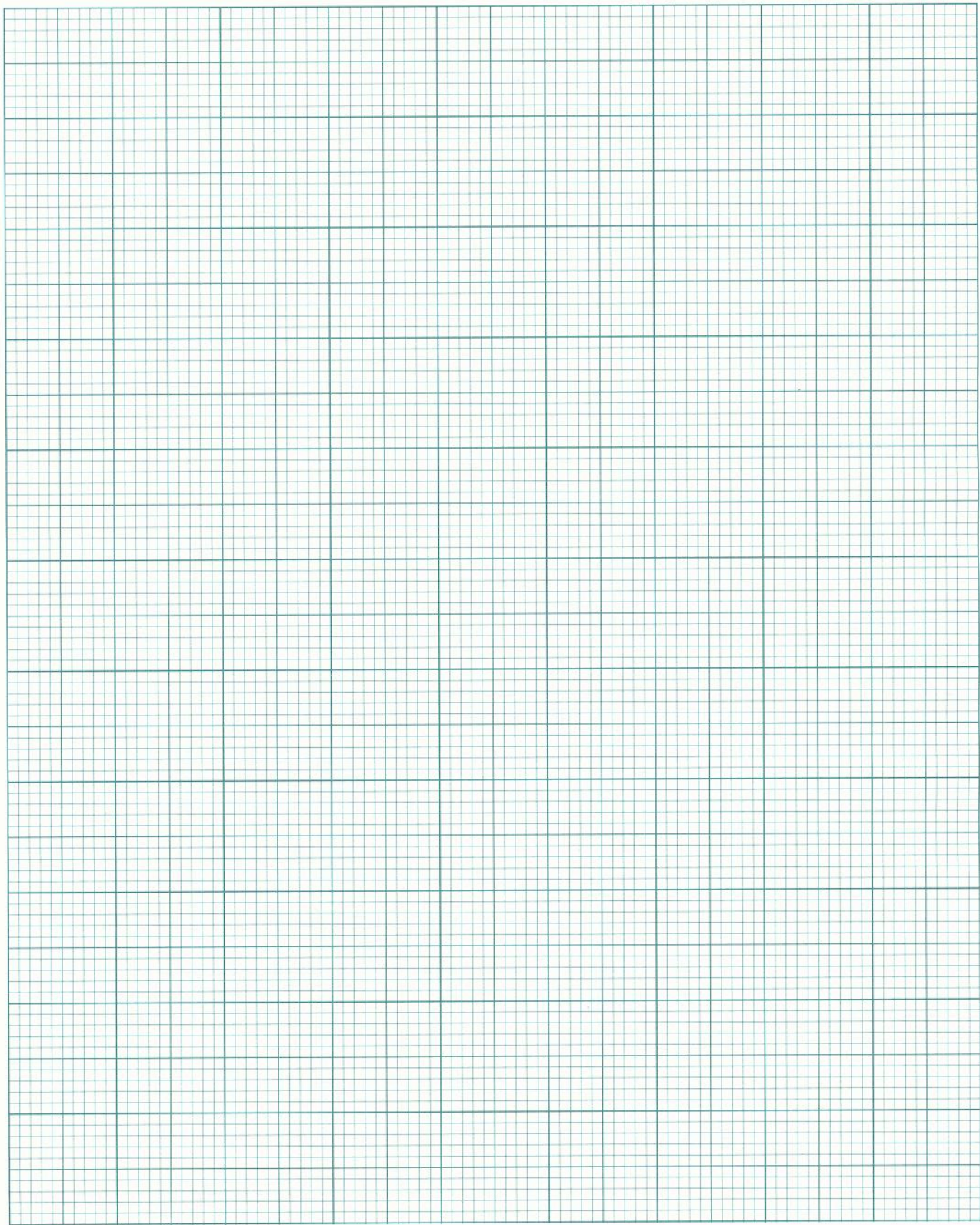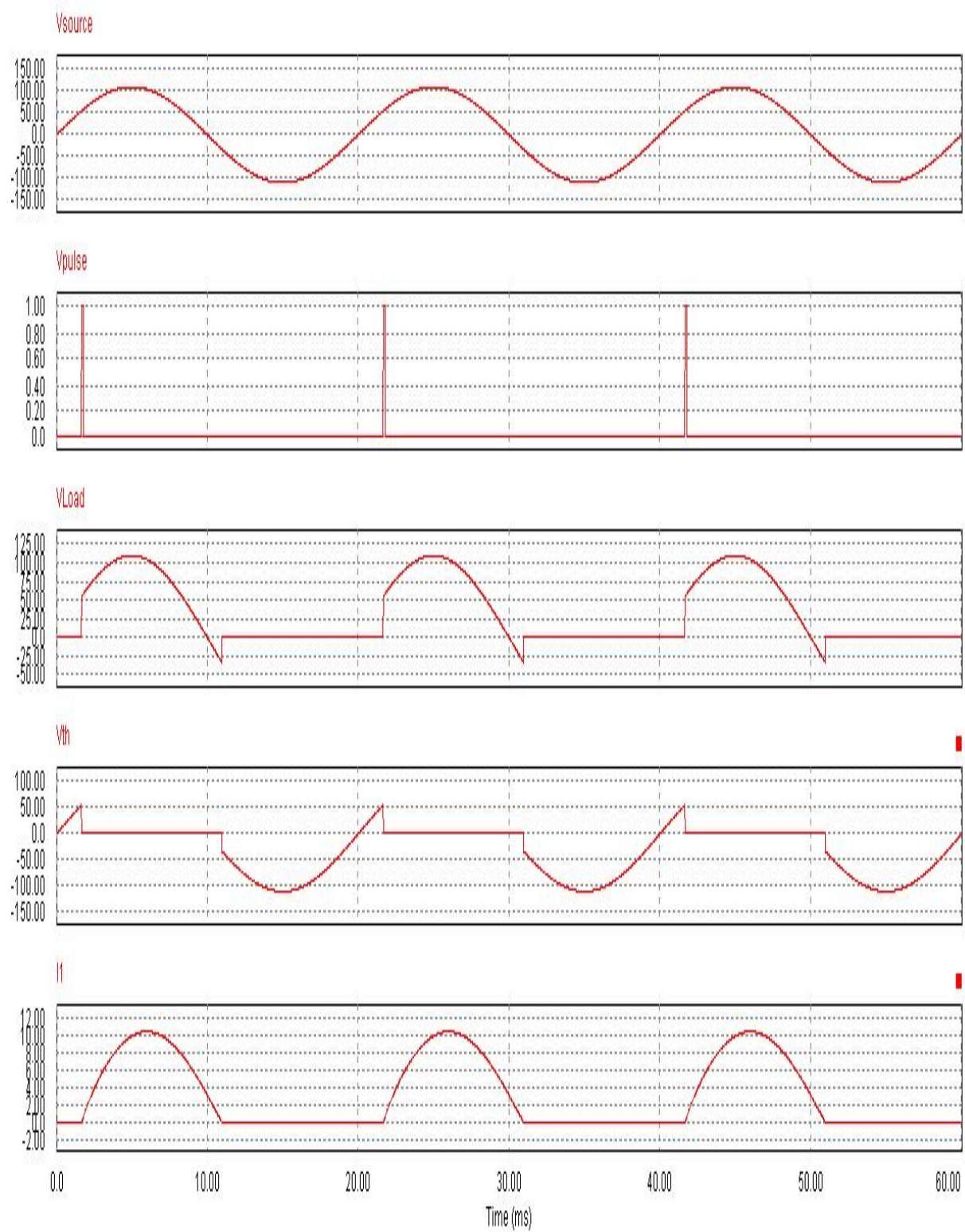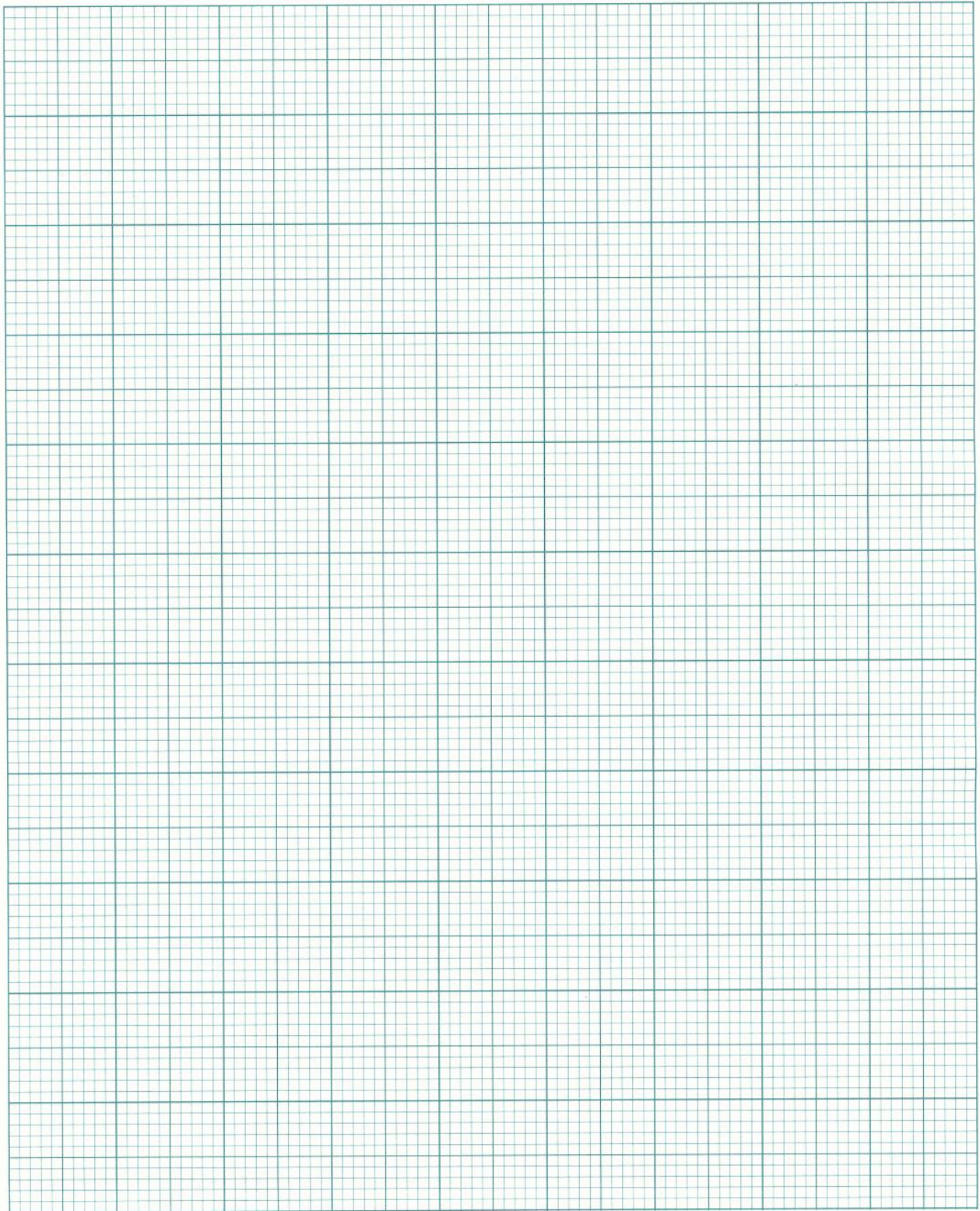
GRAPH SHEET:

MODEL GRAPH: <u>RLE- LOAD</u>
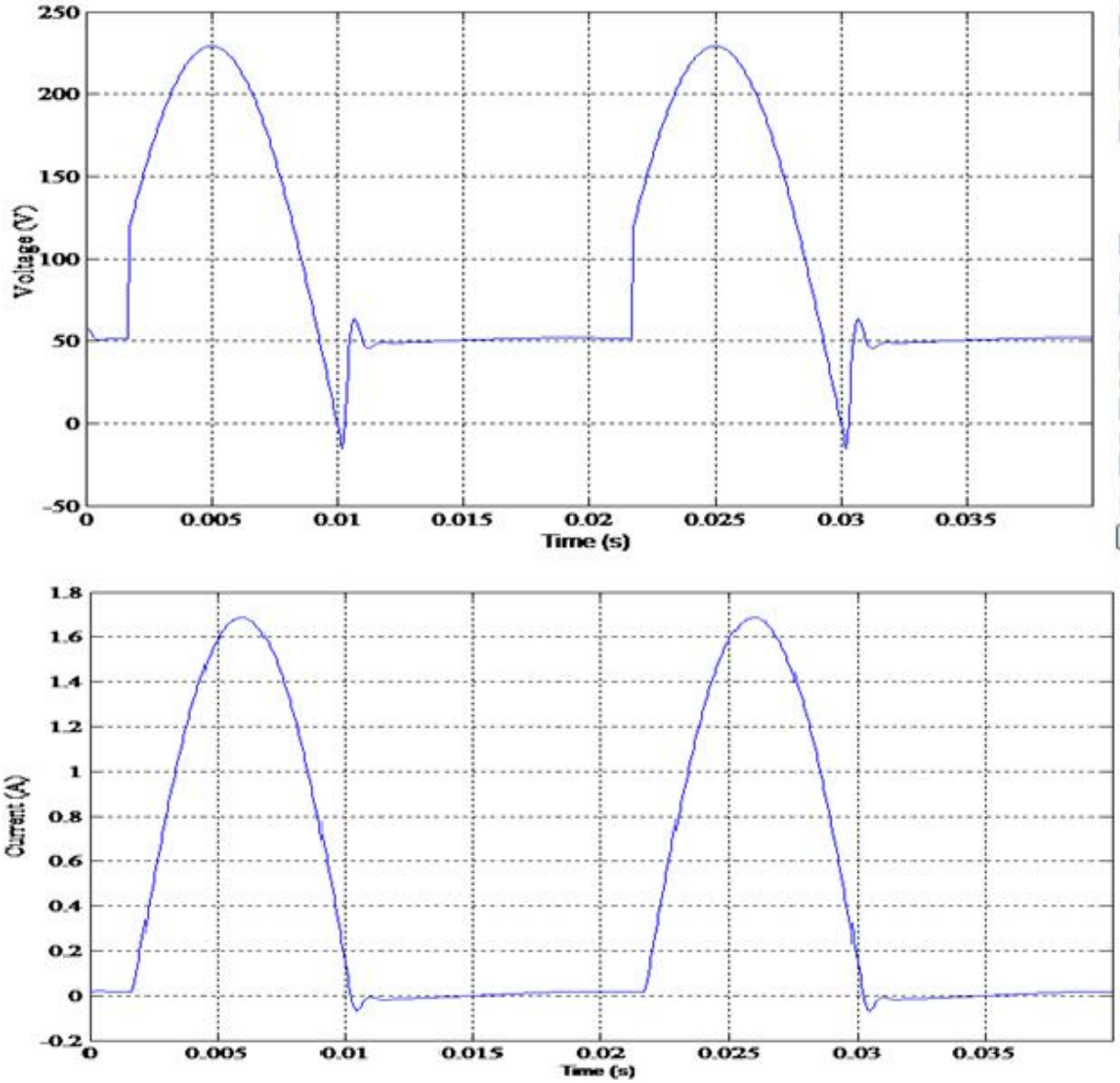
Half Wave Rectifier Output Voltage and Current at Load

GRAPH SHEET:
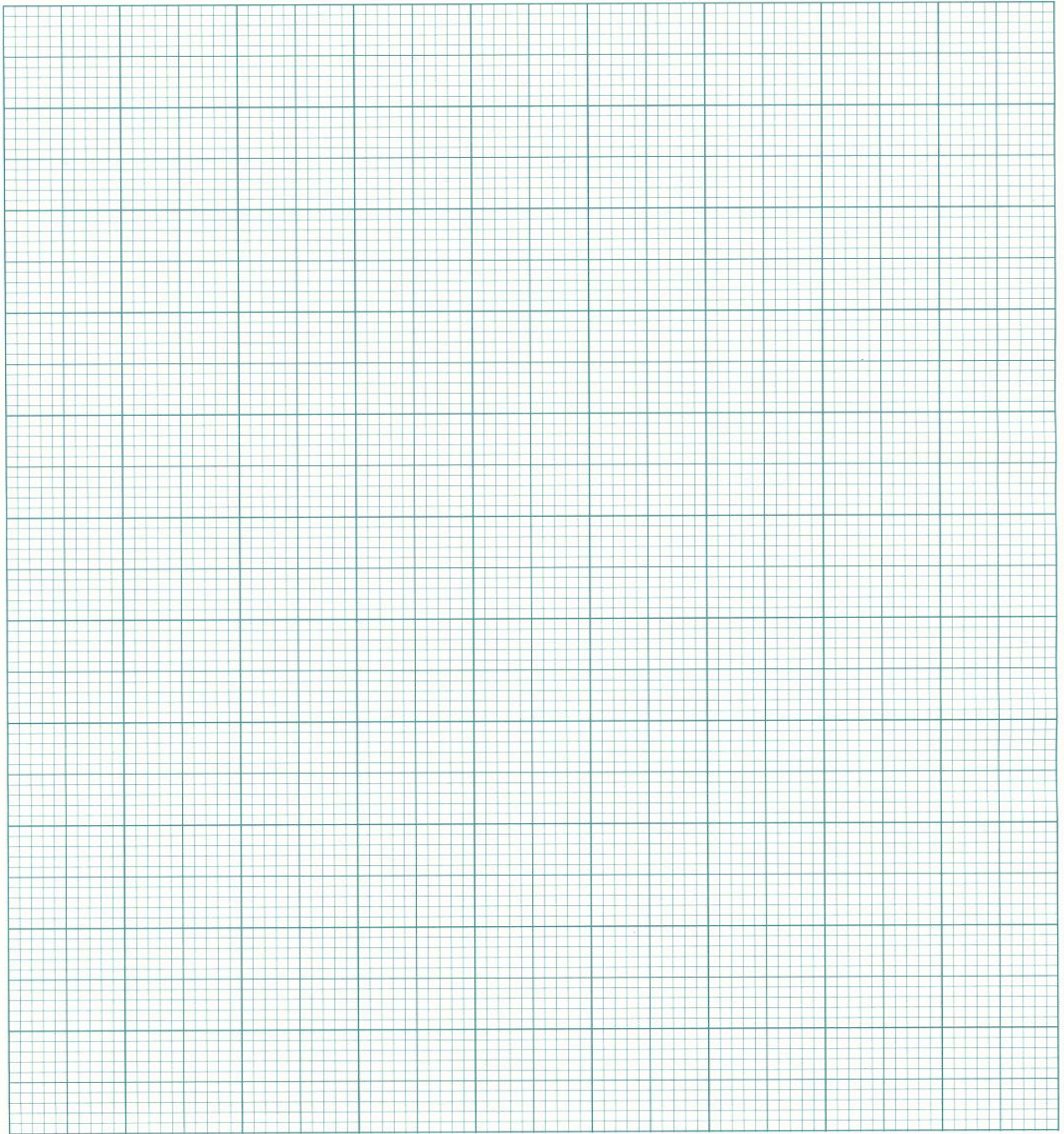
RESULT:

Experiment No 5

SINGLE PHASE HALF CONTROLLED BRIDGE

CONVERTER

AIM: To construct a single phase half controlled bridge rectifier and to observe the output wave forms with

1. R load

2. RL Load

3. RLE Load

SOFTWARE : MATLAB

CIRCUIT DIAGRAM:

1-PH HALF CONTROLLED BRIDGE CONVERTER CIRCUIT DIAGRAM

THEORY: The bridge rectifier with two thyristors and two diodes connected in a control switch this is called as half controlled bridge.

The two thyristors are t1,t2;the two diodes are d1,d2;the third diode connected across the freewheeling diode FD. after θ=0, T1 is forward biased only when source voltage is $V_m\sin\theta$ exceeds E. Thus, T1 is triggered at a firing angle delay α such that $V_m\sin\alpha > E$.

HALF CONTROLLED BRIDGE WITH R LOAD.

During positive half cycle SCR T1 and diode D1conducts. T1 conducts from α to π. During negative half cycle T1 is off T2 and D2conducts from π+α to 2π. Thus there is output across the load for both the half cycles.

For R load the average out voltage can be found from

$V_0 = 1/\pi \int_\alpha^\pi V_m\sin\theta d\theta$

$$= V_m/\pi(1+\cos\alpha)$$

SINGLE PHASE HALF CONTROLLED BRIDGE WITH MOTOR LOADS.

When the single phase semi converter is connected with R-L motor load a freewheeling diode must be connected across the load. During positive half cycle T1 is forward biased and T1 is fired at ωt=0 .The load is connected to the input supply through T1 and D1 during period α≤ωt≤π. During the period from π≤ωt≤(π+α).The input voltage in negative and freewheeling diode D1 is forward biased, DE conducts to provide the continuity of current in the inductive load. The load current is transferred from T1 and D1 to Df and thyristor T2 is forward biased, and the firing of T2 at ωt   will reverse bias D1.The diode D1 is turned off and the load connected to the supply through T2 and D2.

When the load is inductive and T1 is triggered. First it will conduct with D1 to pass current through load. When supply voltage is negative, load EMF will drive current through T1D2.This is an exponentially decreasing current. When the new negative half cycle begins T1 is in conduction and it keep on conducting with D1 as if triggered at ωt=0.In this case load may not receive the DC power. To ensure proper operation at the beginning of positive half cycle T2 has to be turned off and similarly T1 should be turned off when negative half cycle begins. This is achieved by the freewheeling diode.

` This conversion has better power factor due to freewheeling diode.

For RL load with freewheeling diode the average output voltage can be found from

$$=1/\pi$$

$$=/\pi) [-]$$

$$=/\pi) [1+]$$

SINGLE PHASE HALF CONTROLLED BRIDGE CONVERTER - CONNECTION

SINGLE PHASE HALF CONTROLLED BRIDGE CONVERTER - FROUNT VIEW

PROCEDURE:

Notes -

- Do not attempt to observe load voltage and input voltage simultaneously. If does so input voltage terminal directly connected to load terminals due to the no isolation of both channels of the CRO. While using dual channels on the CRO ensure that both the ground terminals must be connected to the same point.
- it is recommended to use low AC voltage when students are doing experiments to eliminate electric shock
- Do not apply high voltage to CRO.10:1 probe may be used while doing high voltage measurement or use power scope

Procedure for R loads

1. The connections are made as shown in the circuit of fully controlled rectifier with R load using isolation transformer
2. The gate cathode terminals of the 2 SCR's are connected to the respective points on the firing module.
3. Check all the connections and conform connections made are correct before switching on the equipments.
4. Keep the firing angle knob atdegree (minimum position).switch ON the firing unit.
5. Now switch ON the power circuit switch.
6. The firing angle is varied output waveform is seen on a CRO.
7. The firing angle is varied and DC output voltage and current through the load is noted.
8. Tabulate the practical values. (Refer given table).
9. Keep the firing angle knob at 180 degree (minimum position).Switch OFF the power circuit& then firing unit. Remove the patch cards.

Procedure for motor loads

1. The connections are made as shown in the circuit of half controlled rectifier
2. The gate cathode terminals of the 2 SCR's are connected to the respective points on the firing module.

Check all the connections and conform connections made are correct before simulating.

3. Now simulate the circuit.
4. **The** firing angle is varied and the variation of the output voltage is observed.

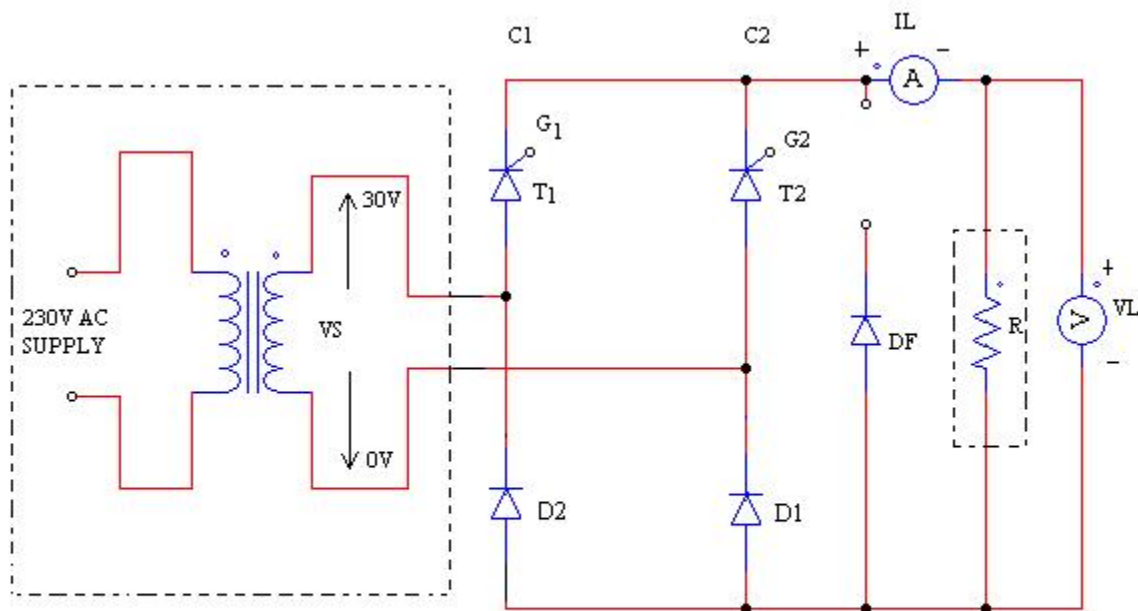## **OUTPUT WAVEFORMS**
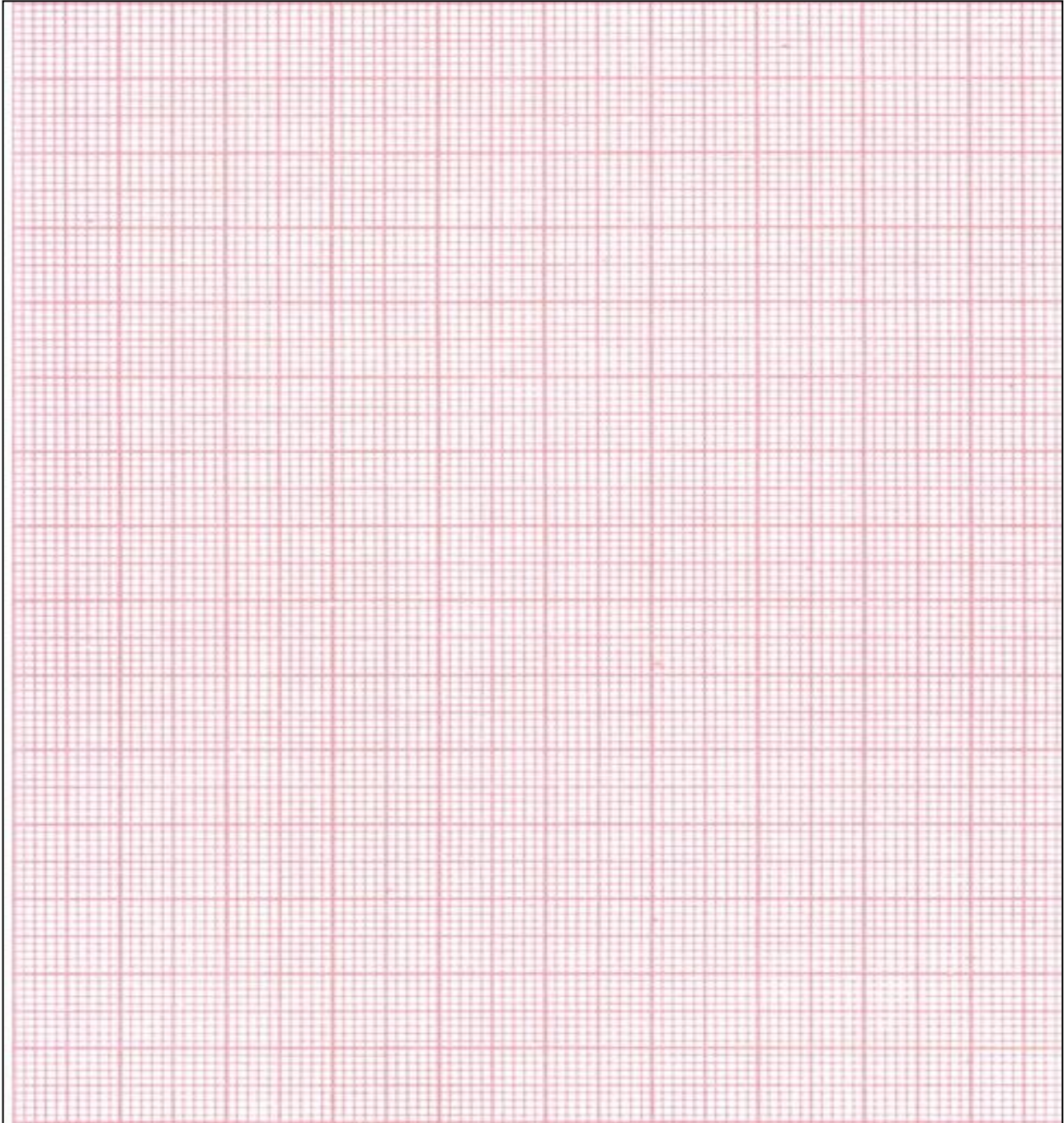
RESULT:

Experiment No: 6

Single Phase Fully Controlled Bridge Converter

AIM: To construct a single phase fully controlled full wave bridge rectifier and to observe the output wave forms with

1. R load
2. R-L load with freewheeling diode
3. R-L load without freewheeling diode

SOFTWARE : MATLAB

CIRCUIT DIAGRAM:

1-PH FULLY CONTROLLED CONVERTER CIRCUIT DIAGRAM

THEORY:

In the bridge rectifier the entire four rectifier is the capability of wide voltage variation between $+V_{dc\ (av)}$ to $-V_{dc\ (av)}$, maximum i.e. $2V_m/\pi$ volts. Such rectifiers find application in DC motor loads for both motoring and electrical braking of the motor.

FULL CONTROLLED BRIDGE CONVERTER WITH R LOAD:

During positive half cycle, SCR T1 and SCR T1[1] are triggered simultaneously through independent isolated gate pulses. The pair of SCR's conducts up to π. SCR T2 and SCR T2[1] are to be triggered in the next half cycle with another pair of isolated gate pulses. The triggering angle of the pairs of SCR's can be varied by varying the control voltages.

For R load, the average output voltage can be found from

$$V_{dc\,(av)} = (1/\pi)\alpha\int^\pi V_m sin\Theta d\theta$$

$$= (Vm/\pi)\,[-cos\Theta]_\alpha^\pi$$

$$V_{dc\,(av)} = (Vm/\pi)\,[1+cos\alpha]$$

FULLY CONTROLLED BRIDGE CONVERTER FOR R-L LOAD WITH FREE WHEELING DIODE:

When the single phase fully controlled bridge converter is connected with RL load with freewheeling diode during positive half cycle T_1 and T_1^1 are forward biased. When T_1 and T_1^1 fired at wt=α, the load is connected to the input supply through T_1 and T_1^1 during period $\alpha \leq wt \leq \pi$. During the period from $\pi \leq wt \leq (\pi+\alpha)$, the input voltage is negative and freewheeling diode D_F is forward biased, DF conducts to provide the continuity of current in the inductive load. The load current is transferred from T_1 and T_1^1 to $D_F$andthyristor are turned off at wt=π. During negative half cycle of input voltage, thyristor T_2 and T_2^1 are forward biased, and the firing of T2and T_2^1 at wt=$\pi+\alpha$ will reverse bias D_F. The diode is turned off and the load connected to the supply through T_2 and T_2^1.

This conversion has better power factor due to the freewheeling diode.

The average output voltage can be found from

$$V_{dc\,(av)} = (1/\pi)\,\alpha\int^\pi V_m Sin\Theta d\Theta$$

$$= (V_m/\pi)\,[-cos\Theta]_\alpha^\pi$$

$$V_{dc\,(av)} = (Vm/\pi)\,[1+cos\alpha]$$

FULLY CONTROLLED BRIDGE CONVERTER FOR R-L LOAD WITH OUT FREEWHEELING DIODE:

When the single phase fully controlled bridge converter is connected with R-L load, during the positive half cycle thyristor T_1 and T_1^1 are forward biased and these two thyristors are fired simultaneously at wt=α, the load is connected to the input supply through T_1 and T_1^1. Due to inductive load T_1 and T_1^1 will continue to conduct till wt=π+α, even though the input voltage is already negative. During negative half cycle of the input voltage, thyristor are forward biased, and firing of thyristors T_2 and T_2^1 at wt= π+α will apply the supply voltage across thyristors T_1 and T_1^1 as reverse blocking voltage. T_1 and T_1^1 will be turned off due to line or natural commutation and load current will be transferred from T_1 and T_1^1 to T_2 and $T_2^{1.}$

During the period from α to π, the input voltage Vs and input current is positive, and the power flows from the supply to the load. The converter is said to be operated in rectification mode. During period from π to π+α, the input voltage Vs is negative and the input current is positive, and there will be reverse from the load to the supply. The converter is said to be operated in inversion mode.

The average output voltage can be found from

$$V_{dc\,(av)} = (1/\pi)_\alpha\int^{\pi+\alpha}V_m Sin\Theta d\Theta$$

$$= (V_m/\pi)\,[-cos\Theta]_\alpha^{\pi+\alpha}$$

$$V_{dc\,(av)} = (2Vm/\pi)\,[1+cos\alpha]$$

NOTE:

In case of fully controlled bridge the triggering angle should not increase beyond α_{max} (approx. 150^0) to allow conducting SCR sufficient time to turn off. The maximum value of firing angle is obtained from the relation.

$$E = V_m \sin (\pi+\alpha)$$

There fore $\alpha = \pi - \sin^{-1}(E/V_m)$

Where E is the counter e.m.f. generated in the inductor.

SINGLE PHASE FULL ` CONTROLLED BRIDGE CONVERTER - FROUNT VIEW

SINGLE PHASE FULL ` CONTROLLED BRIDGE CONVERTER - CONNECTION

PROCEDURE:

1.Open MATLAB software

TABULAR COLUMN:

SI. NO.	Firing angle α in degrees	Load voltage In volts	Load current In Amp
1			
2			
3			
4			
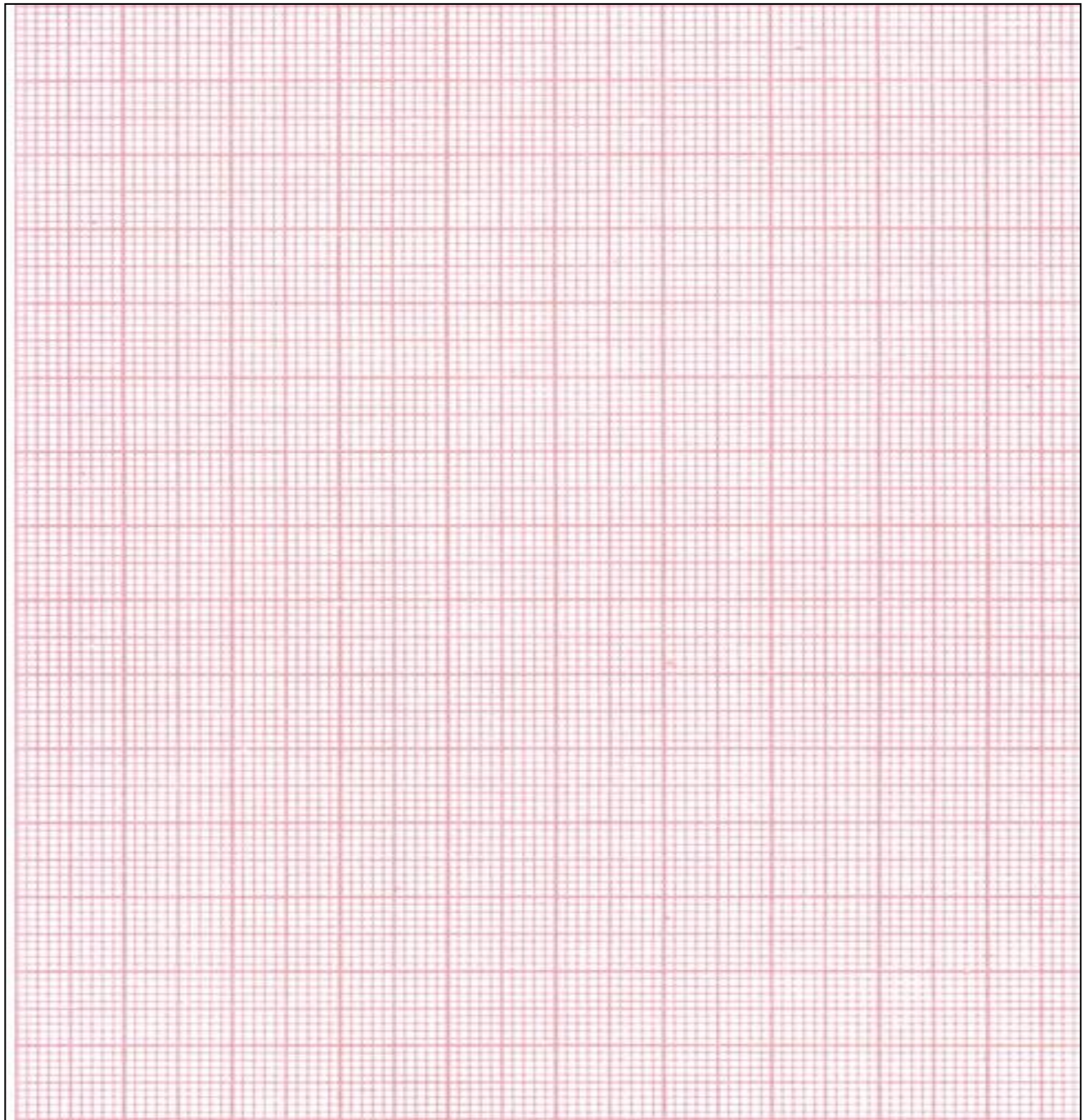
OUTPUT WAVEFORMS

Result:

Experiment No :7

THREE PHASE HALF CONTROLLED BRIDGE CONVERTER WITH R& RL LOADS

AIM: To obtain the output waveforms of three-phase full wave half-controlled bridge rectifier with R and RL load and with or without commutating or freewheeling Diode.

APPARATUS : MATLAB SOFTWARE

Circuit Diagram:
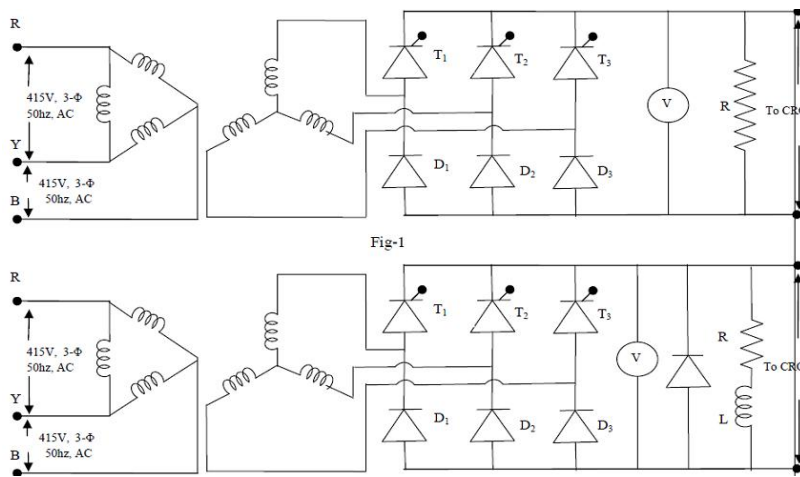
Fig-1

Procedure:

1. Make the connections as per the circuit diagram.

2. Verify the connections before simulating.

3. Set the value of resistance.

4. Connect the scope and simulate the circuit.

5. Observe output voltage waveform.

6. Note down readings of firing angle and output voltage.

7. Also calculate theoretical and practical values of output voltages and compare.

8. Repeat above steps for various firing angles.

9. For RL-load connect Inductance in series with resistance.

10. Repeat the above steps.

Model Graphs:
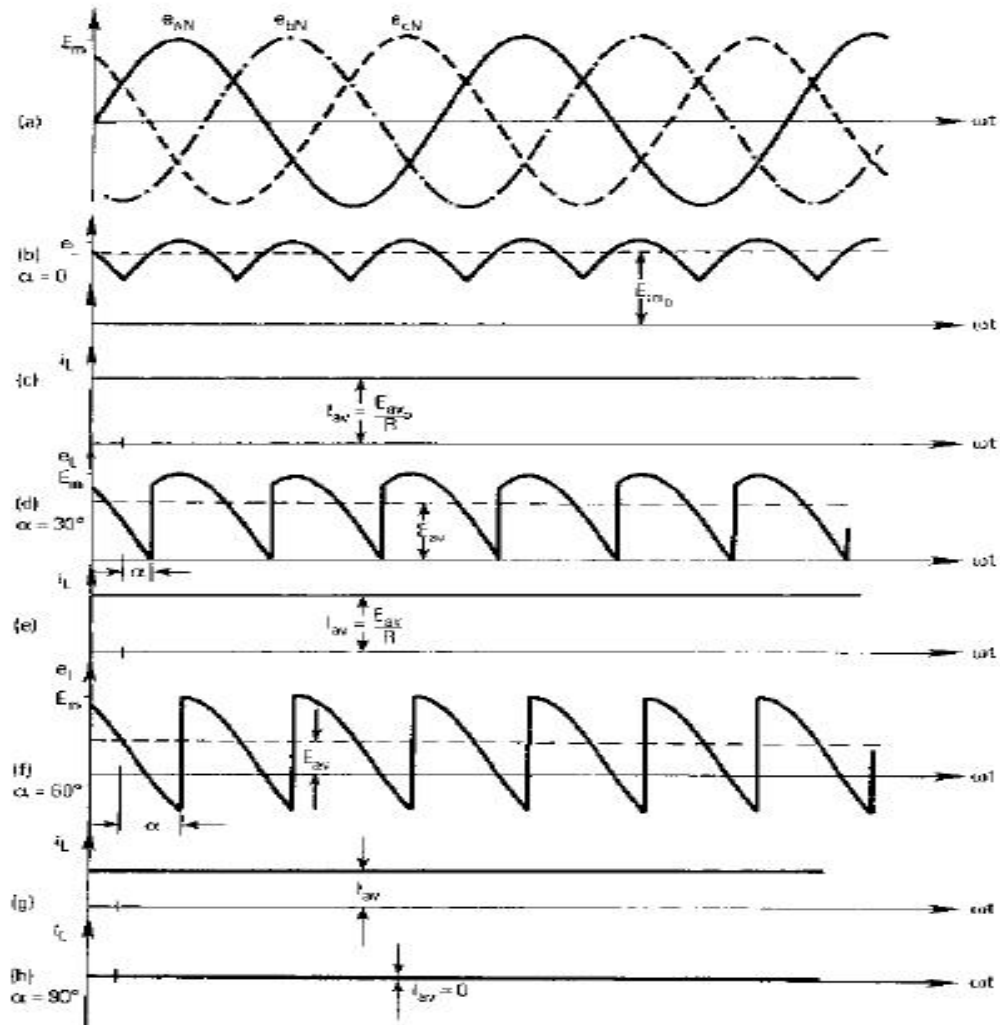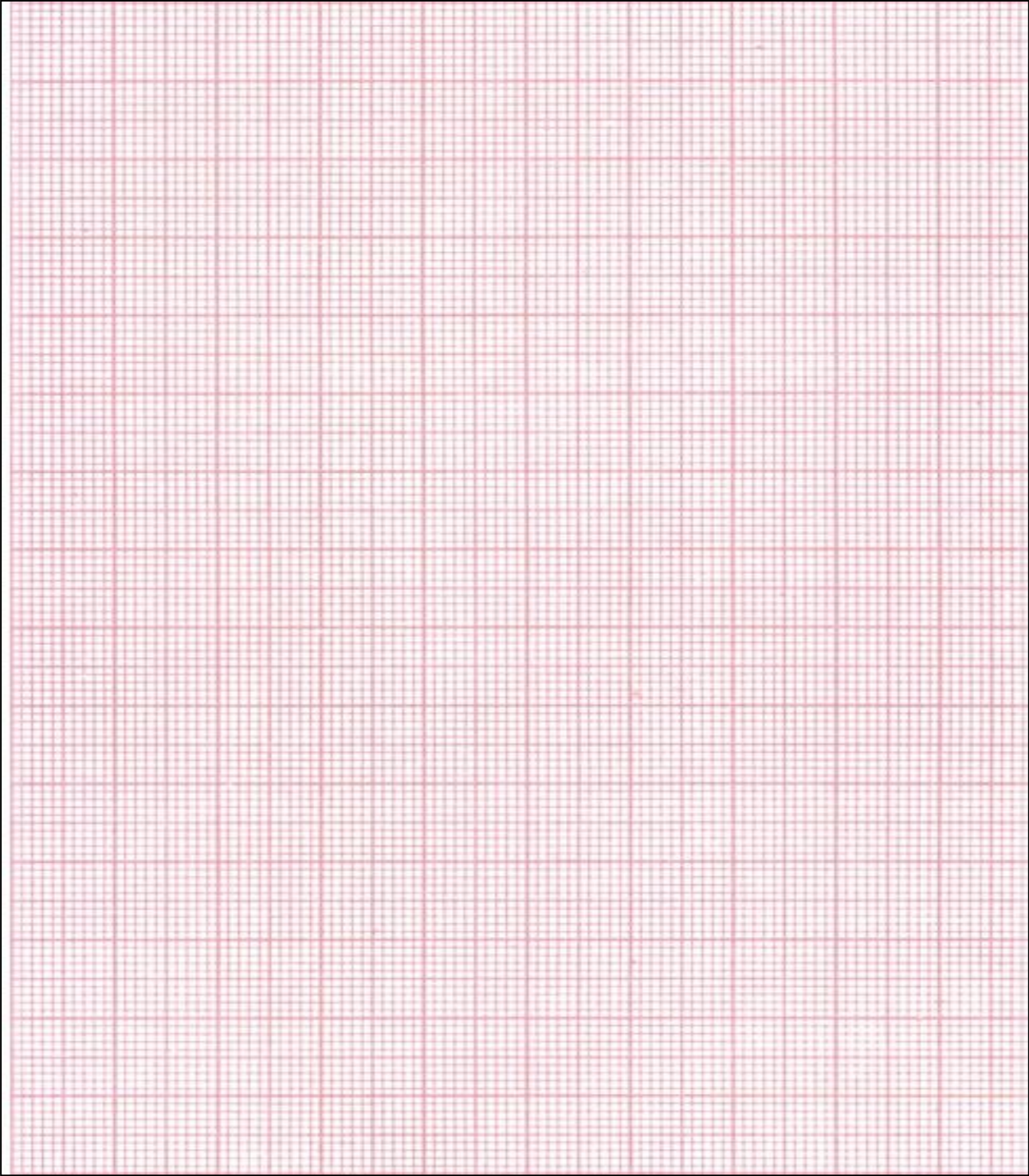
Output waveforms:

Result:

Experiment No: 8

Three Phase fully controlled converter with R,RL&RLE Loads

AIM: To obtain the output waveforms of three-phase full wave full-controlled bridge rectifier with R and RL load and RLE load with or without commutating or freewheeling Diode.
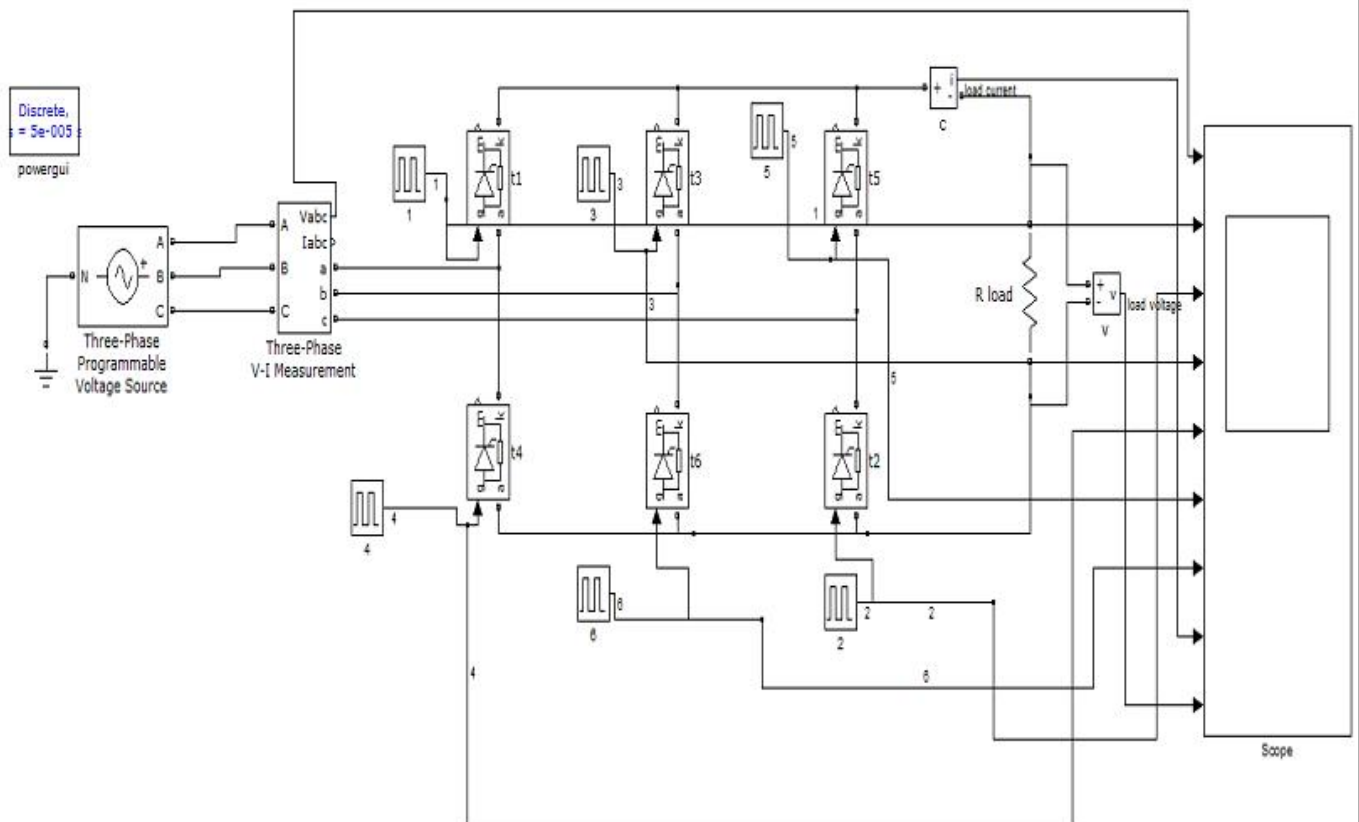
APPARATUS: - MATLAB

Citcuit Diagram:

Procedure:

1. Make the connections as per the circuit diagram.

2. Verify the connections before simulating.

3. Set the value of resistance .

4. Connect the scope and simulate the circuit.

5. Observe output voltage waveform.

6. Note down readings of firing angle and output voltage.

7. Also calculate theoretical and practical values of output voltages and compare.

8. Repeat above steps for various firing angles.

9. For RL-load connect Inductance in series with resistance.

10. Repeat the above steps.

ModelGraphs:
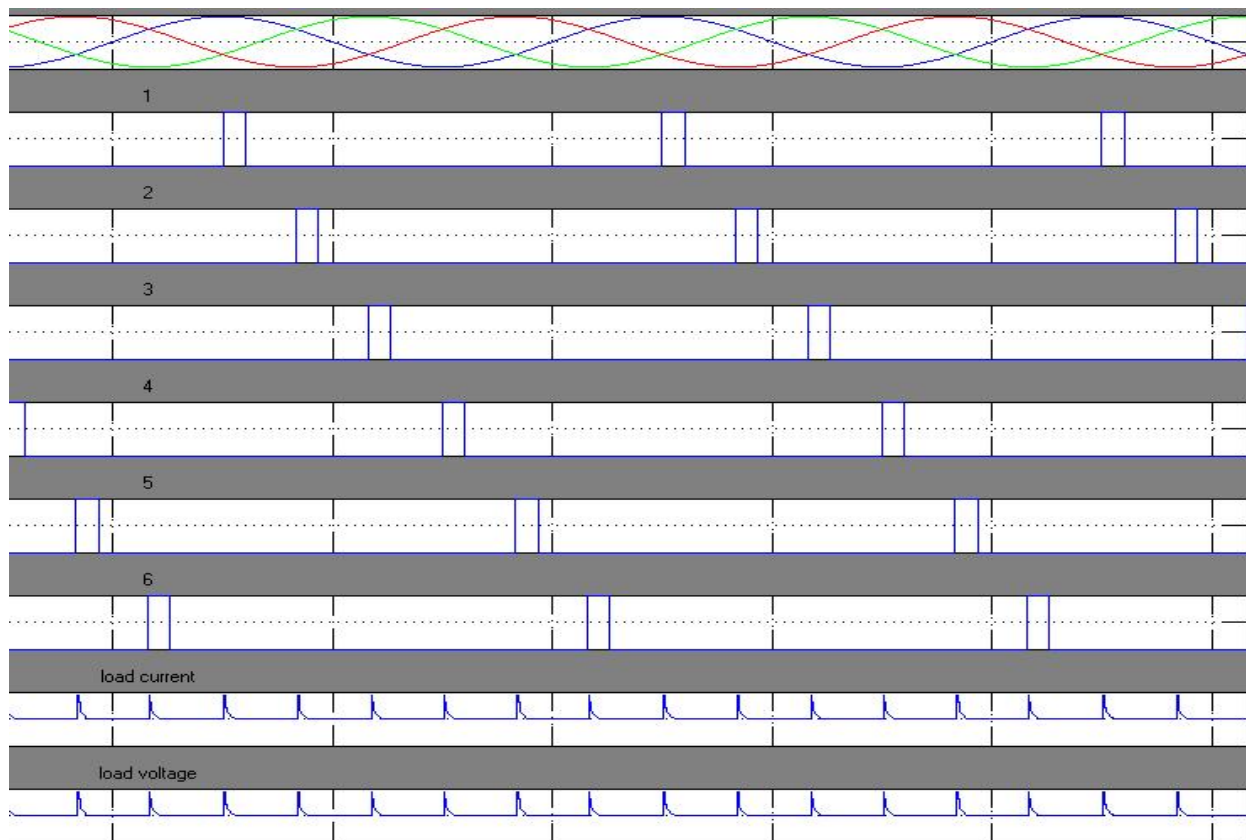
OUTPUT WAVE FORMS:
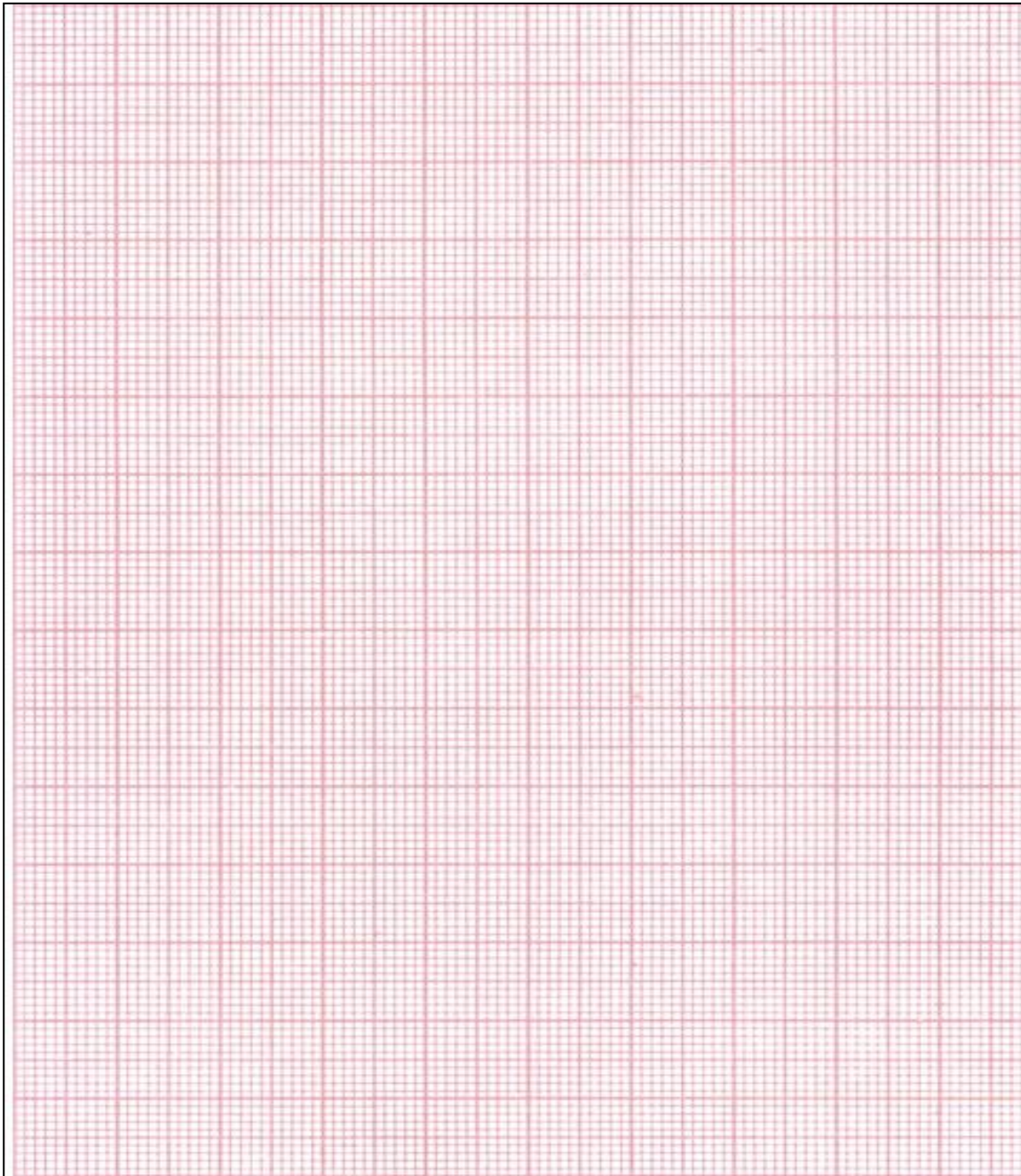
RESULT :

1-PHASE AC VOLTAGE CONTROLLER WITH
RL - LOAD

AIM: To study the performance of a single phase AC Voltage controller with RL-load.

APPARATUS : MATLAB
CIRCUIT DIAGRAM :
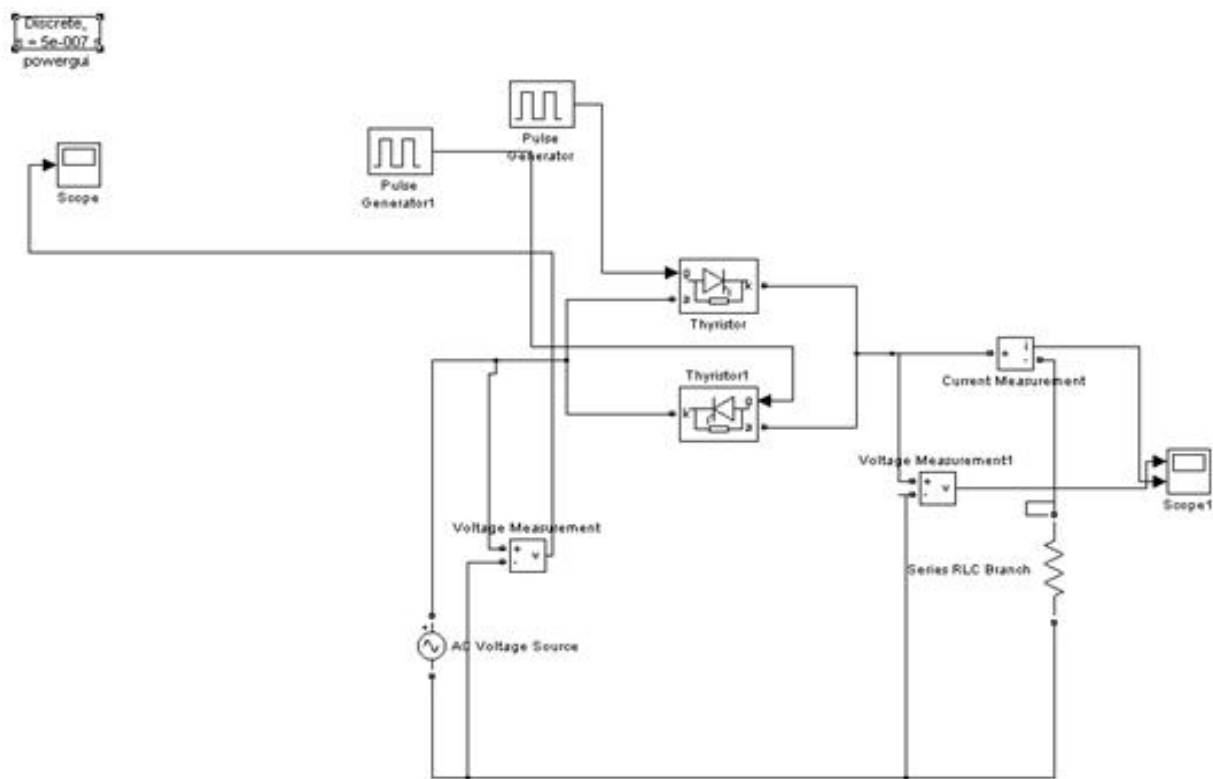
Single Phase AC Voltage Controller Using R Load
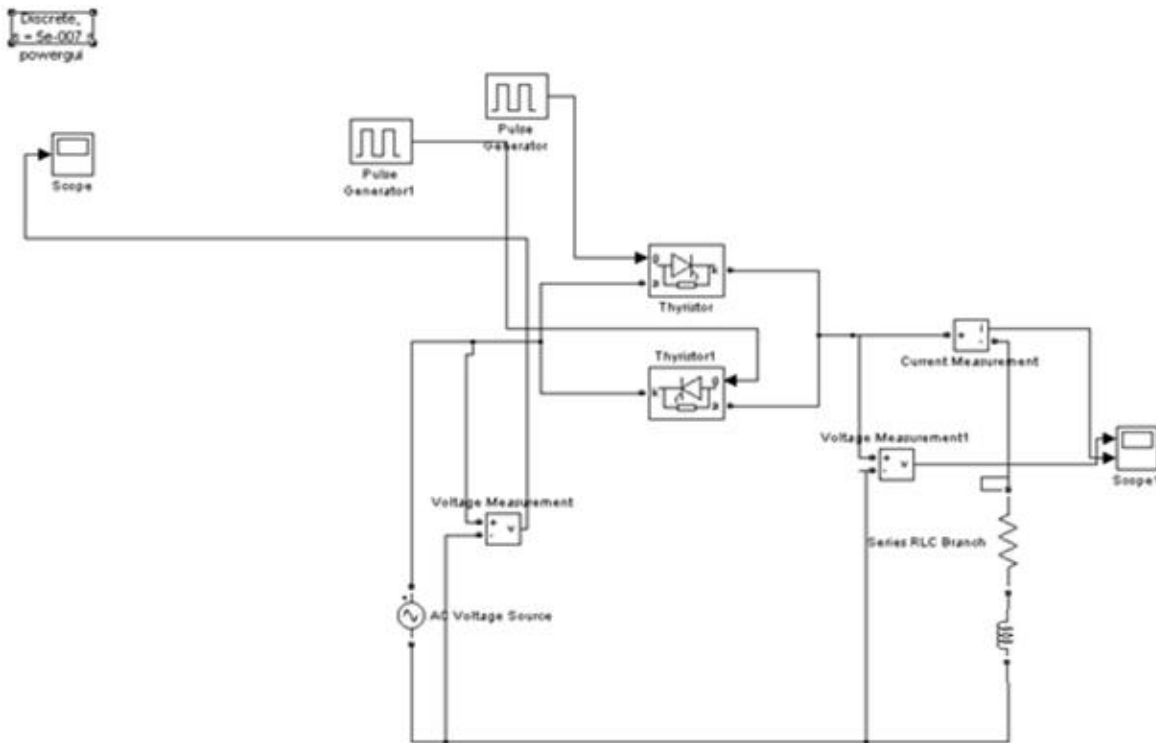
Single Phase AC Voltage Controller Using RL Load

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. Connect the circuit as shown in the circuit diagram.

2. Give the firing pulses accordingly at a suitable firing angle from the firing circuit.

3. Observe the load voltage on the screen and note down the firing angle.

4. Draw the waveforms and calculate the RMS value of output voltage.

CALCULATIONS:

MODEL WAVEFORMS:

R-LOAD
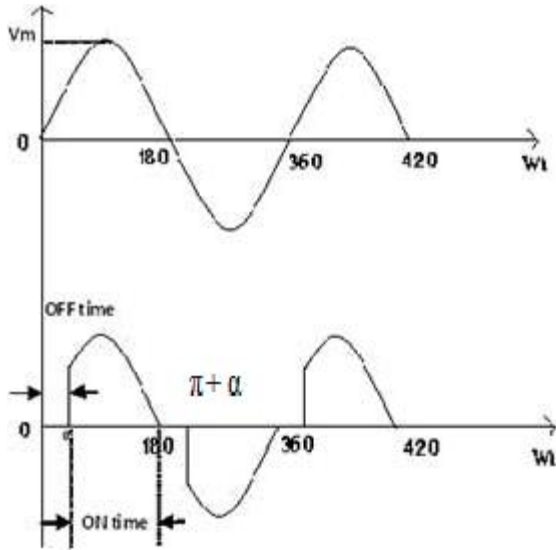
RL- LOAD
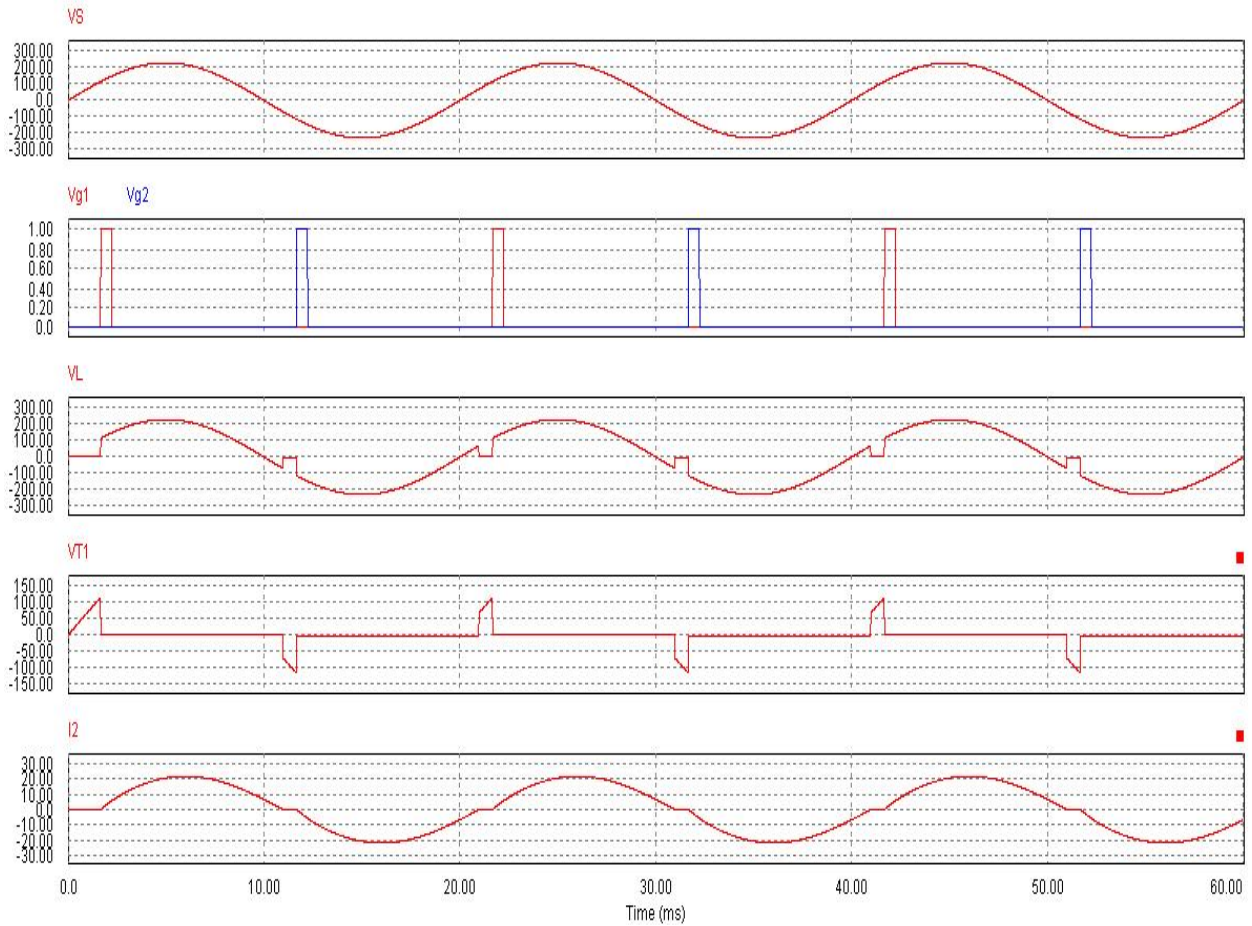
GRAPH SHEET:
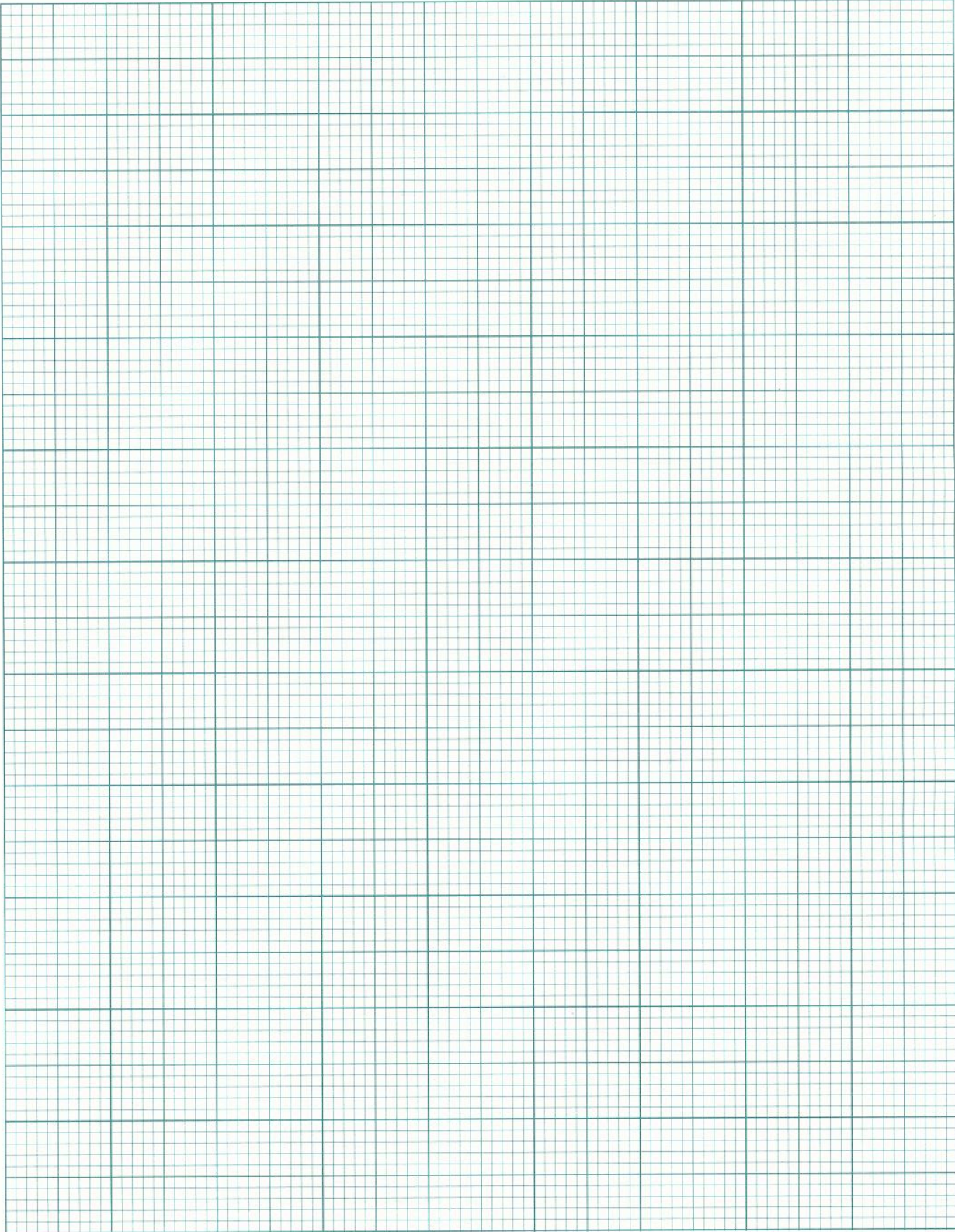
GRAPH SHEET:
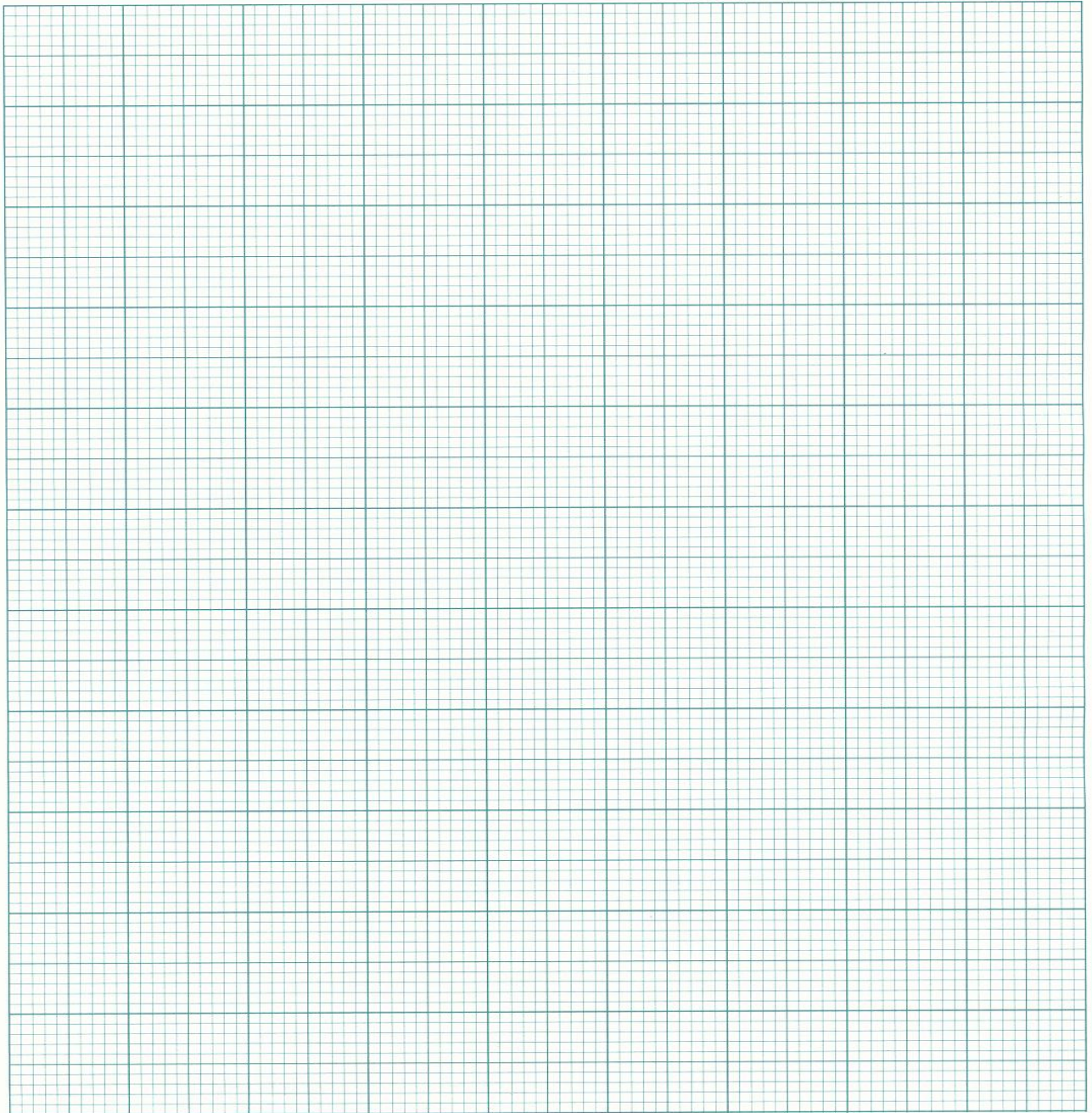
RESULT:

EXPERIMENT No 10

DC-DC BOOST CONVERTER AND DC-DC BUCK CONVERTER

Aim:

To study the operation of DC-DC Boost Converter,DC-DC Buck Converter and observe the output waveforms.

Apparatus required : MATLAB

Circuit Diagram:
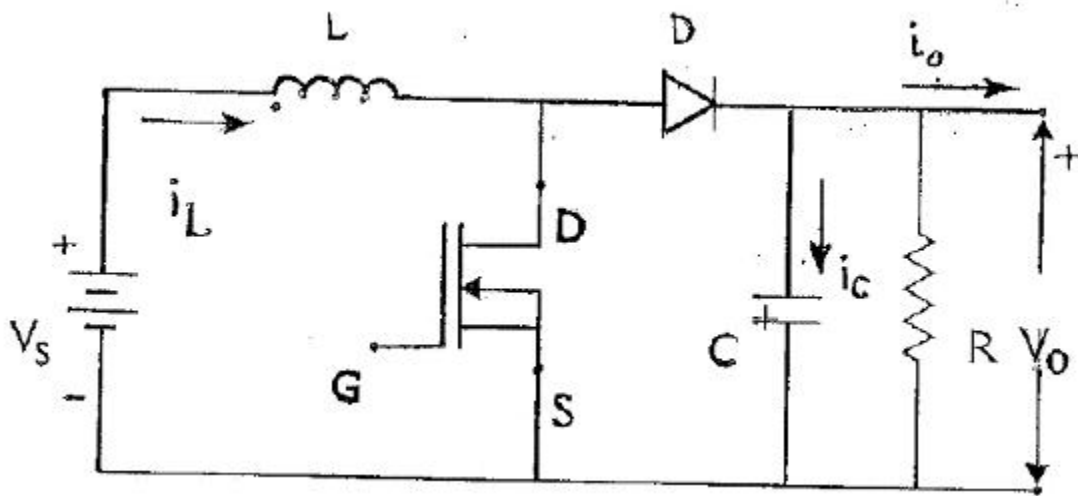
Boost Converter
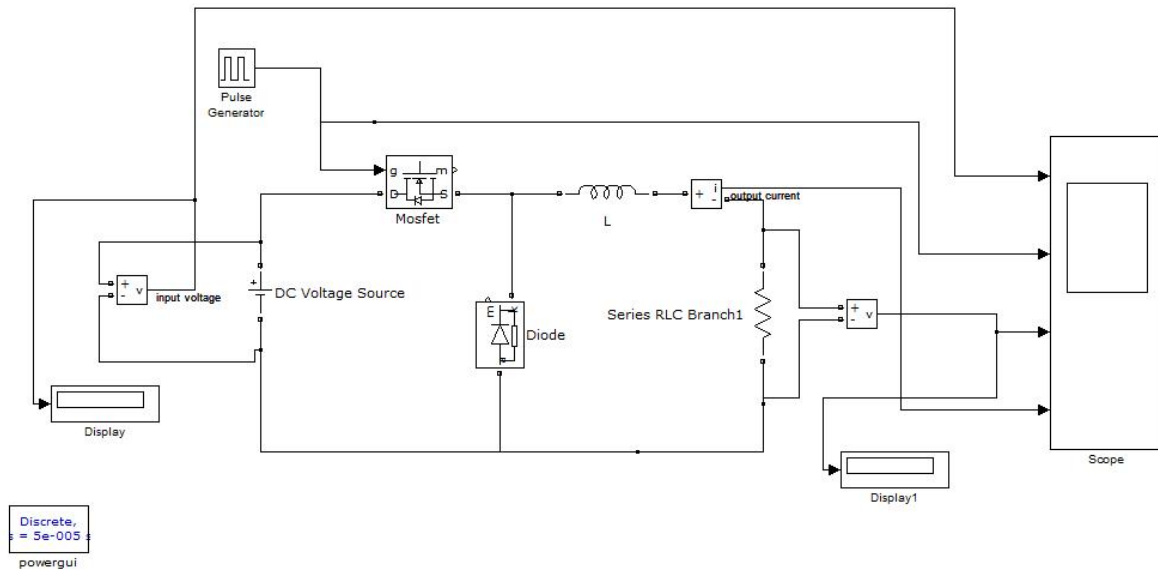
Buck Converter

Procedure:

1. Make the connections as per the circuit diagram.

2. Connect scope and voltmeter across the load.

3. Give the DC regulated power supply.

4. Simulate the circuit.

5. Observe the wave form on screen and note the voltage across the load

6. Note the corresponding reading of the voltmeter.

Model Graphs:
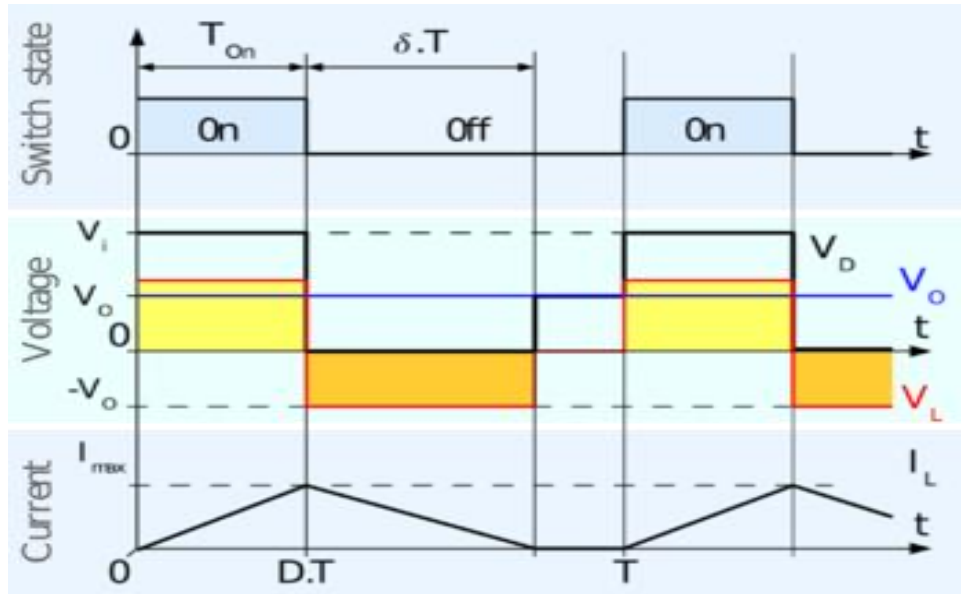
Boost Conveter
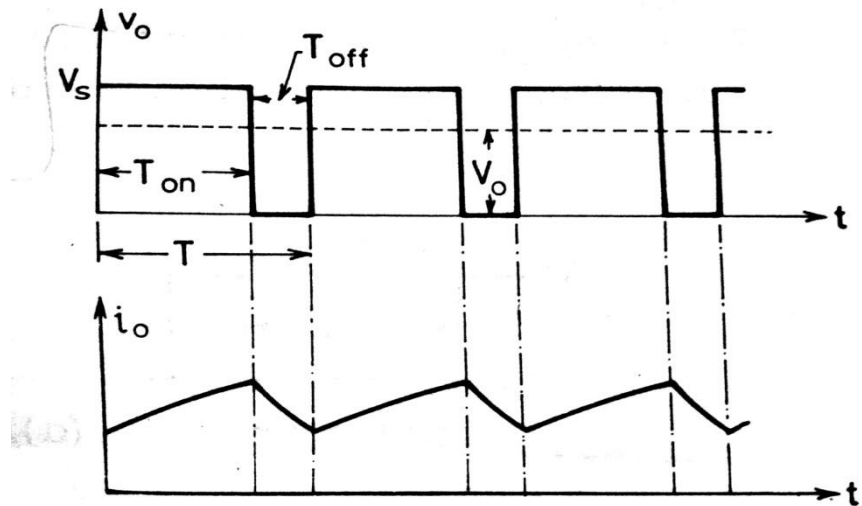
Buck converter

OBSERVATIONS:

Boost Converter:

S.No	Vin	Ton	Toff	D=Ton/T	Vo	Output calculated Vo=D*Vs

Buck Converter:

S.No	Vin	Ton	Toff	D=Ton/T	Vo	Output calculated Vo=(1-D)*Vs

OUTPUT WAVEFORMS:
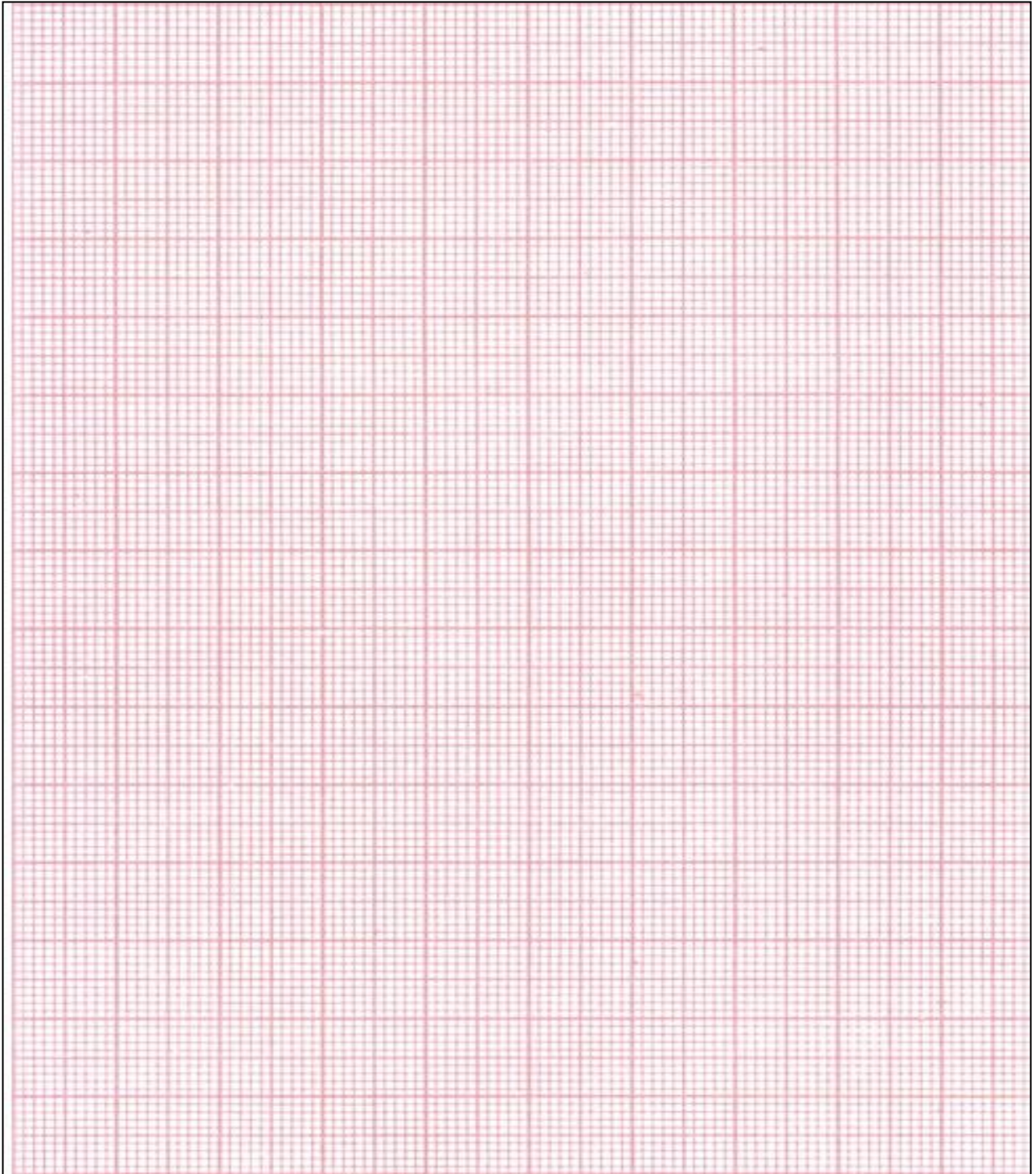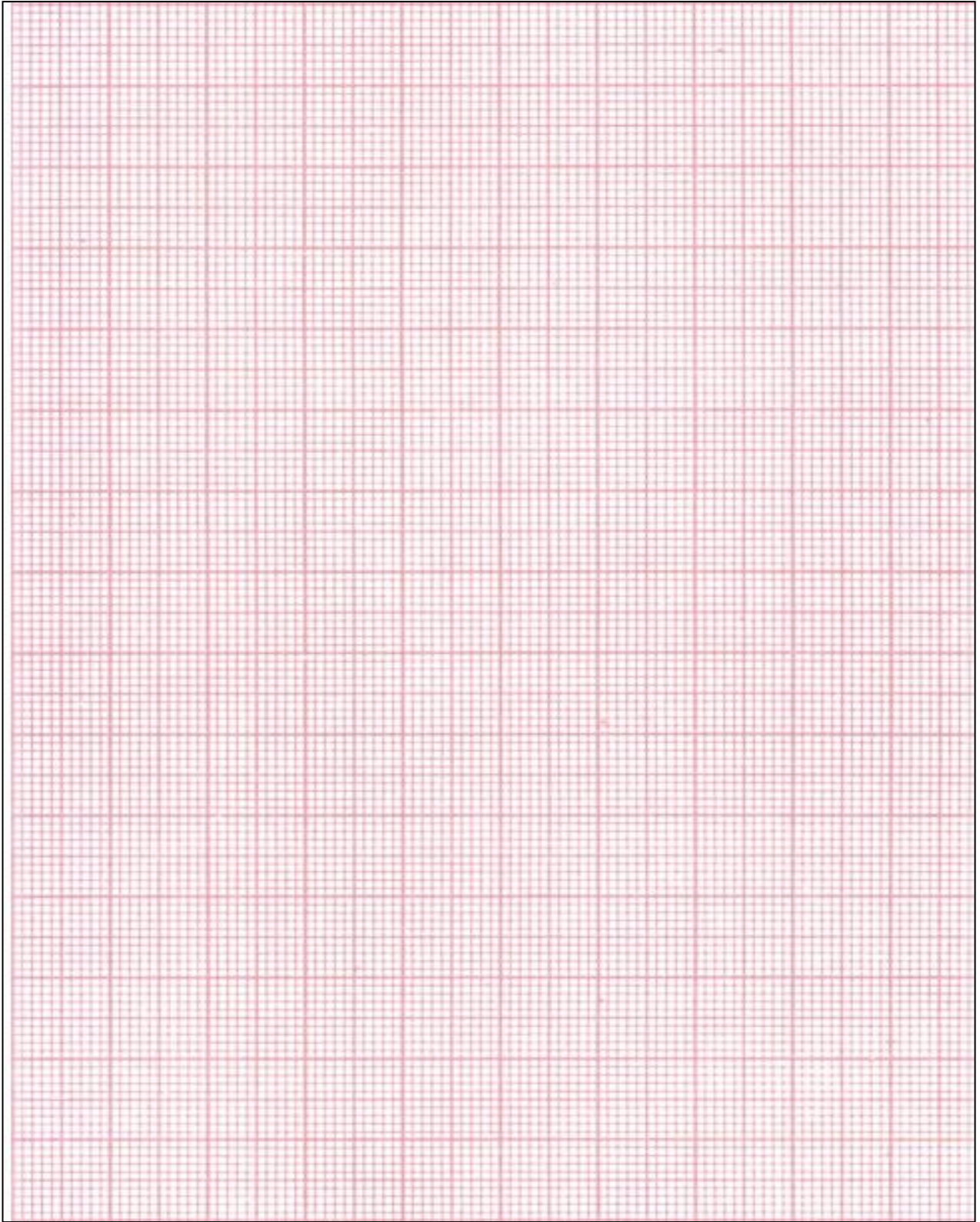
RESULT:

EXPERIMENT – 11

SINGLE PHASE   INVERTER

AIM: To study the performance of a single phase inverter with R & RL -load.

APPARATUS: MATLAB

CIRCUIT DIAGRAM:
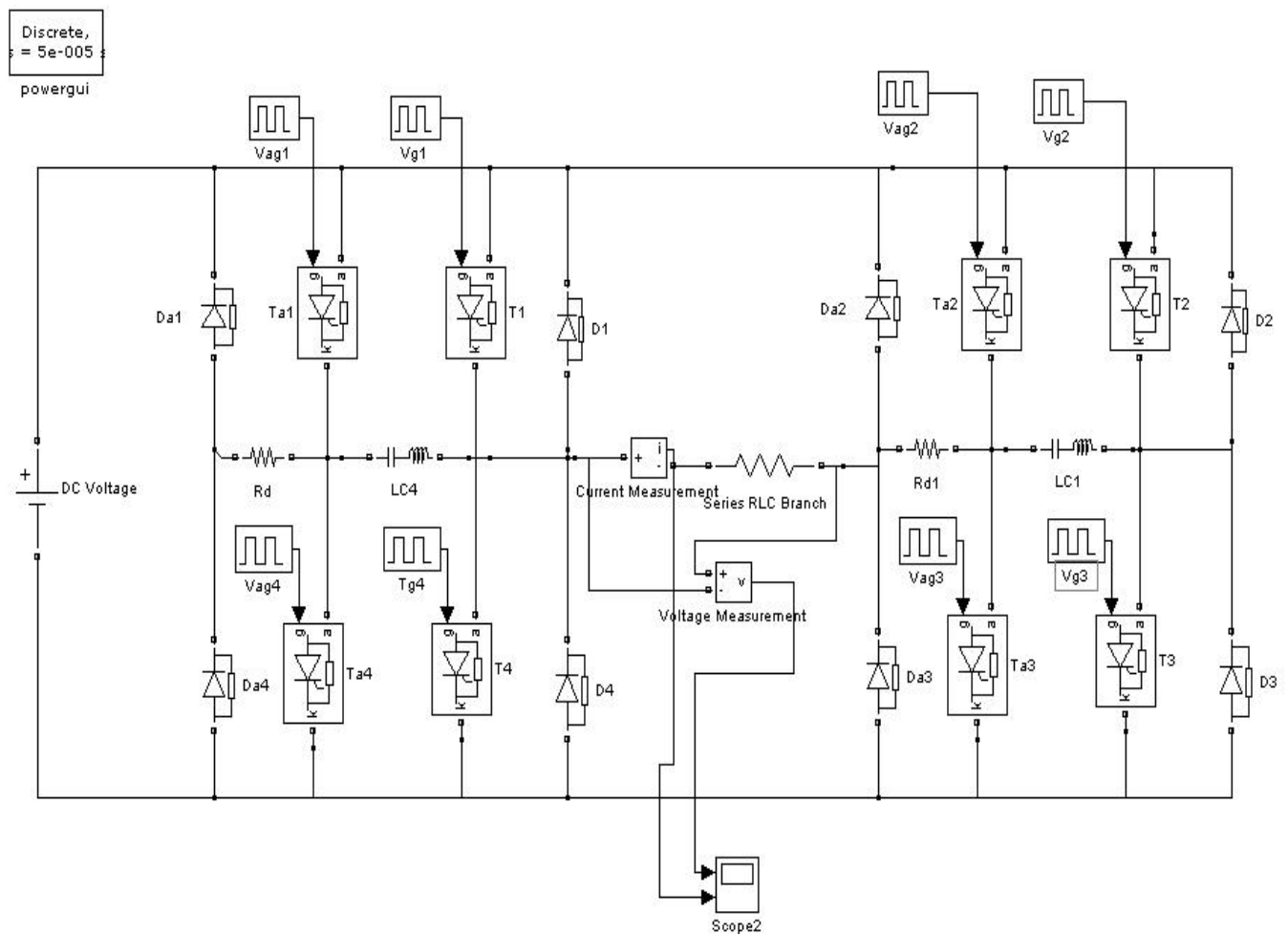
THEORY:

In the full bridge inverter thyristors SCR1, SCR2, SCR3 & SCR4 are connected connected in series with the source. During inverter operation it should be ensured

that two SCRs in the same branch such as SCR1 & SCR2 donot conduct simultaneously as this would lead to a direct short circuit of the source.

For a full bridge inverter thyristors SCR1 and SCR2 conduct for positive half cycle and SCR3 & SCR4 for conduct for negative half cycle.

When the thyristors are turned OFF the diodes D1, D2, D3, D4 acts as feedback diodes as they supply energy back to the source.

MODEL WAVEFORMS:

A Single-phase Bridge Inverter with Gating Signals and Output Voltage
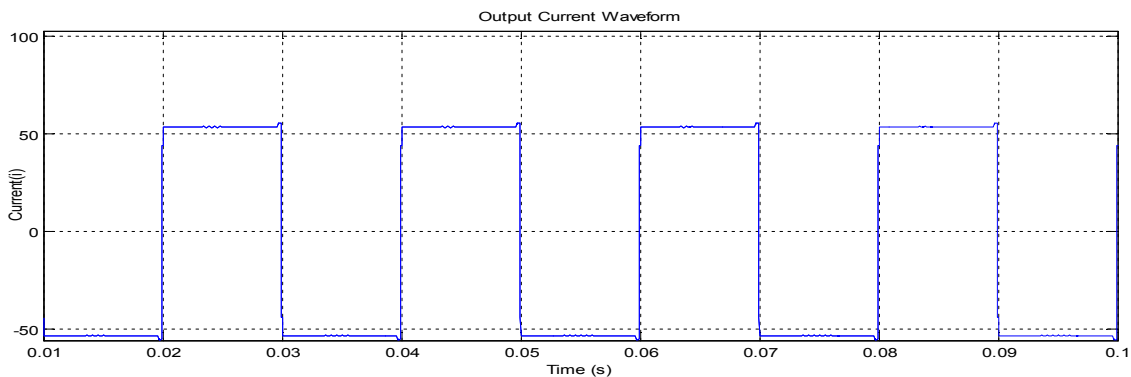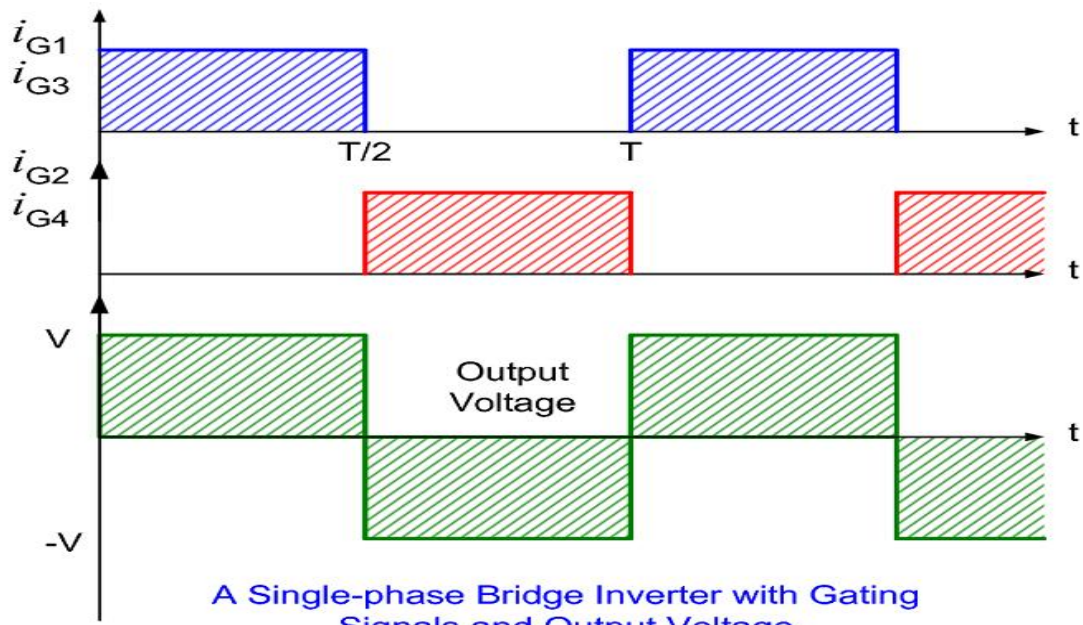
CALCULATIONS:

GRAPH SHEET:

RESULT:

Experiment No: 12

SINGLE PHASE CYCLO CONVERTER

AIM: To construct a single phase cycloconverter circuit and study its performance.

APPARATUS: MATLAB

CIRCUIT DIAGRAM:

THEORY:

A cycloconverter converts input power at one frequency to output power at a different frequency with one stage conversion. cycloconverter is used in speed control of high power AC drives ,induction heating etc.

The circuit shown is for obtaining single phase frequency divided output from a single phase AC input. One group of SCR's produces positive polarity load voltage and other group produces negative half cycle of the output. SCR's T_1 and T_3 of the positive group are gated together depending on the polarity of the input, only one of them will conduct, when upper AC terminal is positive with respect to O, SCR T_1 will conduct and when upper AC terminal is negative, SCR T_3 will conduct thus in both half cycles of input, the load voltage polarity will be positive by changing firing angle, the duration of conducting of each SCR (and there by the

magnitude of the output voltage) can be varied. For the sake of simplicity it is assumed that the load is positive. Then each SCR will have a conduction angle of $(\pi - \alpha)$ and turn off by natural commutation at the end of every half cycle of the input. At the end of each half period of the output, the firing pulses to the SCR's of the positive group will be stopped and SCR's T2 and T_4 of the negative group will be fired.

PROCEDURE:

SINGLE PHASE CYCLOCONVERTER

1. Make the connections as per the circuit diagram.

2. Connect scope and voltmeter across the load.

3. Give the AC   supply.

4.Simulate the circuit.

5. Observe the wave form on screen and note the voltage across the load

6. The firing angle is varied and AC output voltage across the load is noted.

7. Repeat the above procedure for divided by four frequency.

EXPERIMENTAL OBSERVATIONS:

Frequency divided by 2

Output waveforms
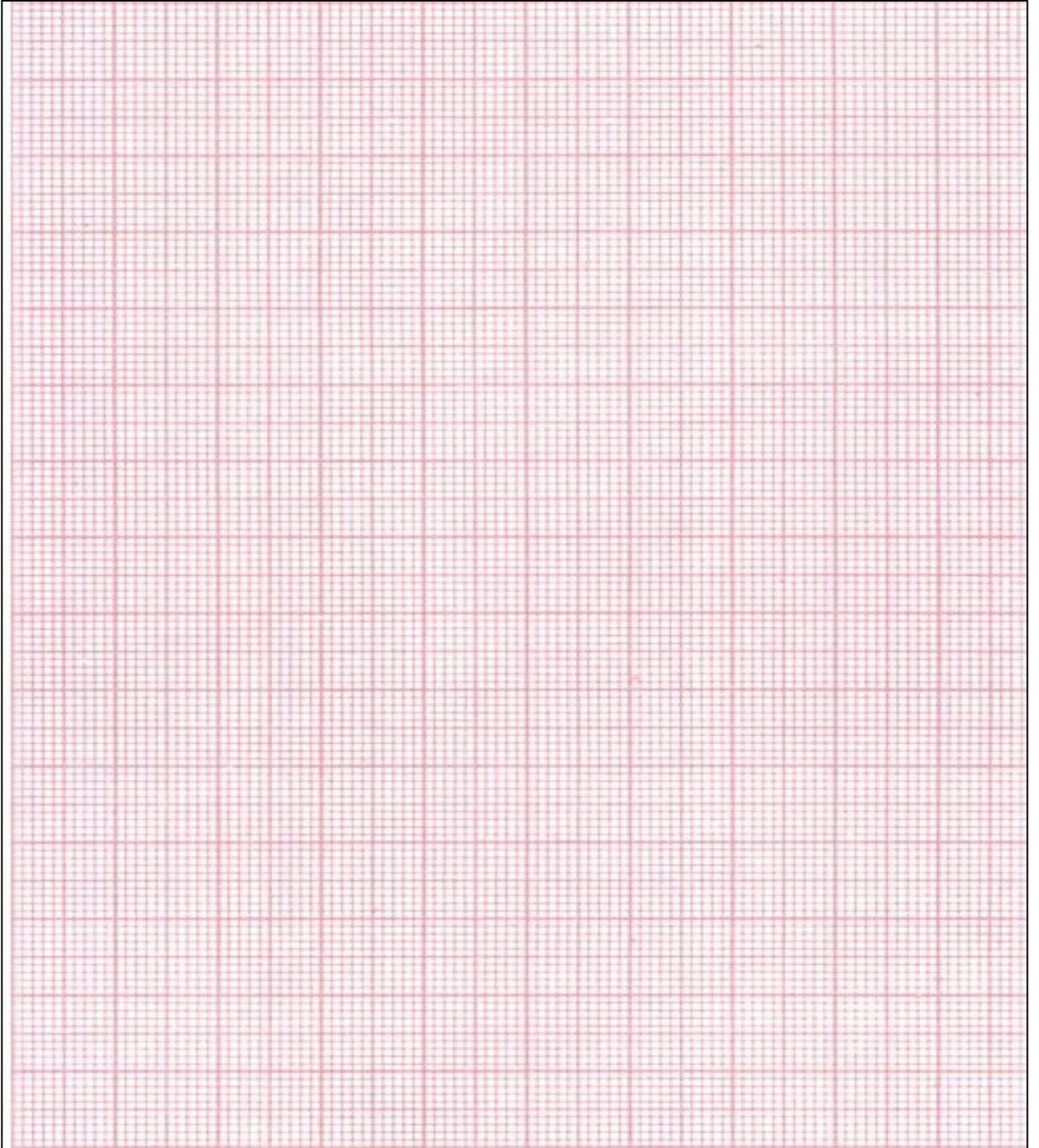
RESULT:

HARDWARE EXPERIMENTS
EXPERIMENT – 1

Single Phase Half controlled rectifier and fully controlled rectifier

SINGLE PHASE HALF CONTROLLED BRIDGE CONVERTER

AIM: To construct a single phase half controlled bridge rectifier and to observe the output wave forms with R load and Motor load

APPARATUS: Isolation transformer, controlled rectifier module, firing unit, rheostat 100ohm/2A, inductance 100mH or 250 mH/3A, patch cards etc.

CIRCUIT DIAGRAM:

1-PH HALF CONTROLLED BRIDGE CONVERTER
CIRCUIT DIAGRAM

THEORY: The bridge rectifier with two thyristors and two diodes connected in a control switch this is called as half controlled bridge.

The two thyristors are t1,t2;the two diodes are d1,d2;the third diode connected across the freewheeling diode FD. after θ=0, T1 is forward biased only when source voltage is $V_m\sin\theta$ exceeds E. Thus, T1 is triggered at a firing angle delay α such that $V_m\sin\alpha{>}E$.

HALF CONTROLLED BRIDGE WITH R LOAD.

During positive half cycle SCR T1 and diode D1conducts. T1 conducts from α to π. During negative half cycle T1 is off T2 and D2conducts from π+α to 2π. Thus there is output across the load for both the half cycles.

For R load the average out voltage can be found from

$V_0=1/\pi\int_\alpha^\pi V_m\sin\theta d\theta$

$$= V_m/\pi(1+\cos\alpha)$$

SINGLE PHASE HALF CONTROLLED BRIDGE WITH MOTOR LOADS.

When the single phase semi converter is connected with R-L motor load a freewheeling diode must be connected across the load. During positive half cycle T1 is forward biased and T1 is fired at ωt=0 .The load is connected to the input supply through T1 and D1 during period α≤ωt≤π. During the period from π≤ωt≤(π+α).The input voltage in negative and freewheeling diode D1 is forward biased, DE conducts to provide the continuity of current in the inductive load. The load current is transferred from T1 and D1 to Df and thyristor T2 is forward biased, and the firing of T2 at ωt   will reverse bias D1.The diode D1 is turned off and the load connected to the supply through T2 and D2.

When the load is inductive and T1 is triggered. First it will conduct with D1 to pass current through load. When supply voltage is negative, load EMF will drive current through T1D2.This is an exponentially decreasing current. When the new negative half cycle begins T1 is in conduction and it keep on conducting with D1 as if triggered at ωt=0.In this case load may not receive the DC power. To ensure

proper operation at the beginning of positive half cycle T2 has to be turned off and similarly T1 should be turned off when negative half cycle begins. This is achieved by the freewheeling diode.

`   This conversion has better power factor due to freewheeling diode.

For RL load with freewheeling diode the average output voltage can be found from

$$=1/\pi$$

$$=/\pi) [-]$$

$$=/\pi) [1+]$$

SINGLE PHASE HALF CONTROLLED BRIDGE CONVERTER - CONNECTION

SINGLE PHASE HALF CONTROLLED BRIDGE CONVERTER - FROUNT VIEW

PROCEDURE:

Notes –

- Do not attempt to observe load voltage and input voltage simultaneously. If does so input voltage terminal directly connected to load terminals due to the no isolation of both channels of the CRO. While using dual channels on the CRO ensure that both the ground terminals must be connected to the same point.
- it is recommended to use low AC voltage when students are doing experiments to eliminate electric shock
- Do not apply high voltage to CRO.10:1 probe may be used while doing high voltage measurement or use power scope

Procedure for R loads

10. The connections are made as shown in the circuit of fully controlled rectifier with R load using isolation transformer
11. The gate cathode terminals of the 2 SCR's are connected to the respective points on the firing module.
12. Check all the connections and conform connections made are correct before switching on the equipments.

13. Keep the firing angle knob atdegree (minimum position).switch ON the firing unit.
14. Now switch ON the power circuit switch.
15. The firing angle is varied output waveform is seen on a CRO.
16. The firing angle is varied and DC output voltage and current through the load is noted.
17. Tabulate the practical values. (Refer given table).
18. Keep the firing angle knob at 180 degree (minimum position).Switch OFF the power circuit& then firing unit. Remove the patch cards.

Procedure for motor loads

5. The connections are made as shown in the circuit of half controlled rectifier with motor load.
6. The gate cathode terminals of the 2 SCR's are connected to the respective points on the firing module.
7. Check all the connections and conform connections made are correct before switching on the equipments.
8. Keep the firing angle knob at degree (minimum position).switch ON the firing unit.
9. Now switch ON the power circuit switch.
10. The firing angle is varied and the variation of the motor speed is observed.
11. Tabulate the speed in rpm for different firing angles. (refer given table).
12. Keep the firing angle knob at degree (minimum position).Switch OFF the power circuit (MCB) &then firing unit. Remove the patch cards.

OBSERVATIONS

For R loads

SI.No	Firing angle α in degrees	Load voltage in volts	Load current in Amp
1			
2			
3			
4			
5			

For motor loads

SI.No	Firing angle α in degrees	Speed in rpm
1		
2		
3		
4		
5		

OUTPUT WAVEFORMS
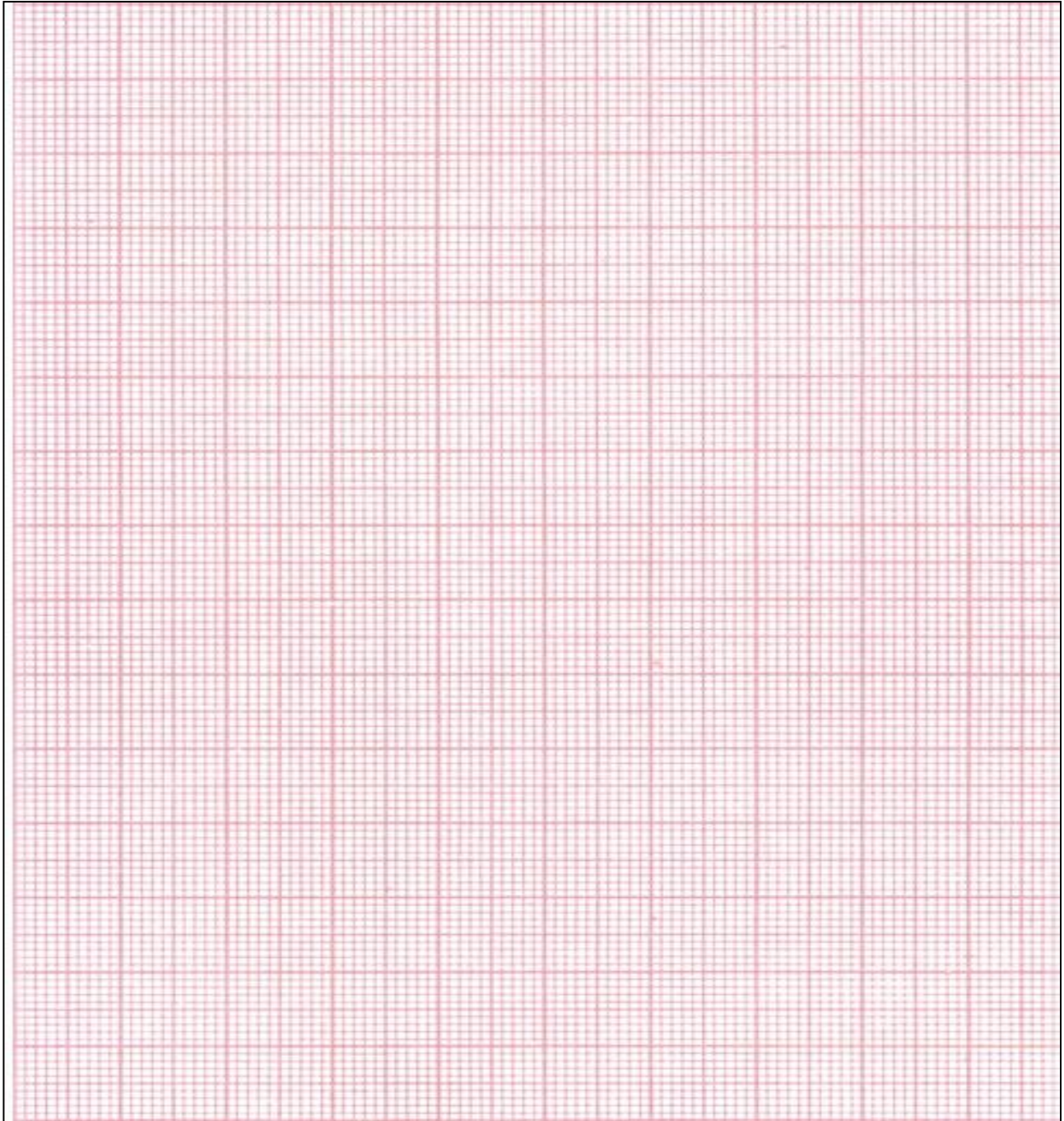
RESULT:

EXPERIMENT – 2

Single Phase Fully Controlled Bridge Converter

AIM: To construct a single phase fully controlled and half controlled full wave bridge rectifier and to observe the output wave forms with

4. R load
5. R-L load with freewheeling diode
6. R-L load without freewheeling diode

APPARATUS: Isolation transformer, controlled rectifier module, firing unit, rheostat 100 ohms/2A, inductance 100 mH or 250 mH/3A, patch cards etc.

CIRCUIT DIAGRAM:

1-PH FULLY CONTROLLED CONVERTER CIRCUIT DIAGRAM

THEORY:

In the bridge rectifier the entire four rectifier is the capability of wide voltage variation between $+V_{dc\,(av)}$ to $-V_{dc\,(av)}$, maximum i.e. $2Vm/\pi$ volts. Such rectifiers find application in DC motor loads for both motoring and electrical braking of the motor.

FULL CONTROLLED BRIDGE CONVERTER WITH R LOAD:

During positive half cycle, SCR T1 and SCR T1[1] are triggered simultaneously through independent isolated gate pulses. The pair of SCR's conducts up to π. SCR T2 and SCR T2[1] are to be triggered in the next half cycle with another pair of isolated gate pulses. The triggering angle of the pairs of SCR's can be varied by varying the control voltages.

For R load, the average output voltage can be found from

$$V_{dc\,(av)} = (1/\pi)\alpha\int^\pi V_m \sin\Theta d\Theta$$

$$= (Vm/\pi)\,[-\cos\Theta]_\alpha^\pi$$

$$V_{dc\,(av)} = (Vm/\pi)\,[1+\cos\alpha]$$

FULLY CONTROLLED BRIDGE CONVERTER FOR R-L LOAD WITH FREE WHEELING DIODE:

When the single phase fully controlled bridge converter is connected with RL load with freewheeling diode during positive half cycle T_1 and $T_1{}^1$ are forward biased. When T_1 and $T_1{}^1$ fired at wt=α, the load is connected to the input supply through T_1 and $T_1{}^1$ during period $\alpha \leq wt \leq \pi$. During the period from $\pi \leq wt \leq (\pi+\alpha)$, the input voltage is negative and freewheeling diode D_F is forward biased, DF conducts to provide the continuity of current in the inductive load. The load current is transferred from T_1 and $T_1{}^1$ to D_F and thyristor are turned off at wt=π. During negative half cycle of input voltage, thyristor T_2 and $T_2{}^1$ are forward biased, and the firing of T2 and $T_2{}^1$ at wt=$\pi+\alpha$ will reverse bias D_F. The diode is turned off and the load connected to the supply through T_2 and $T_2{}^1$.

This conversion has better power factor due to the freewheeling diode.

The average output voltage can be found from

$$V_{dc\,(av)} = (1/\pi)\,\alpha\int^\pi V_m \sin\Theta d\Theta$$

$$= (V_m/\pi)\,[-\cos\Theta]_\alpha^\pi$$

$$V_{dc\,(av)} = (Vm/\pi)\,[1+\cos\alpha]$$

FULLY CONTROLLED BRIDGE CONVERTER FOR R-L LOAD WITH OUT FREEWHEELING DIODE:

When the single phase fully controlled bridge converter is connected with R-L load, during the positive half cycle thyristor T_1 and $T_1{}^1$ are forward biased and these two thyristors are fired simultaneously at wt=α, the load is connected to the input supply through T_1 and $T_1{}^1$. Due to inductive load T_1 and $T_1{}^1$ will continue to conduct till wt=$\pi+\alpha$, even though the input voltage is already negative. During negative half cycle of the input voltage, thyristor are forward biased, and firing of thyristors T_2 and $T_2{}^1$ at wt= $\pi+\alpha$ will apply the supply voltage across thyristors T_1 and $T_1{}^1$ as reverse blocking voltage. T_1 and $T_1{}^1$ will be turned off due to line or natural commutation and load current will be transferred from T_1 and $T_1{}^1$ to T_2 and $T_2{}^1$.

During the period from α to π, the input voltage Vs and input current is positive, and the power flows from the supply to the load. The converter is said to be operated in rectification mode. During period from π to $\pi+\alpha$, the input voltage Vs is negative and the input current is positive, and there will be reverse from the load to the supply. The converter is said to be operated in inversion mode.

The average output voltage can be found from

$$V_{dc\,(av)} = (1/\pi)_\alpha\!\int^{\pi+\alpha} V_m Sin\Theta d\Theta$$

$$= (V_m/\pi)\,[-\cos\Theta]_\alpha{}^{\pi+\alpha}$$

$$V_{dc\,(av)} = (2Vm/\pi)\,[1+\cos\alpha]$$

NOTE:

In case of fully controlled bridge the triggering angle should not increase beyond α_{max} (approx. 150^0) to allow conducting SCR sufficient time to turn off. The maximum value of firing angle is obtained from the relation.

$$E = V_m \sin(\pi+\alpha)$$

There fore $\alpha=\pi-\sin^{-1}(E/V_m)$

Where E is the counter e.m.f. generated in the inductor.

SINGLE PHASE FULL CONTROLLED BRIDGE CONVERTER - FROUNT VIEW

SINGLE PHASE FULL 'CONTROLLED BRIDGE CONVERTER - CONNECTION

PROCEDURE:

Notes:

1. Do not attempt to observe load voltage and input voltage simultaneously, if does so input voltage terminal directly connected to load terminals due to the no isolation of both channels of the CRO.
2. It is recommended to use low AC voltage when students are doing experiments to eliminate electric shock.
3. Do not apply high voltage to CRO. 10:1 probe may be used while doing high voltage measurements or use power scope.

PROCEDURE FOR R LOADS:

1. The connections are made as shown in the circuit of fully controlled rectifier with R load using isolation transformer.
2. The gate cathode terminals of the 4 SCR's are connected to the respective points on the firing module.

3. Check all the connections and confirm connections made are correct before switching on the equipments.
4. Keep the firing angle knob at 180 degree (minimum position). Switch ON the firing unit.
5. Now switch ON the power circuit (MCB).
6. The firing angle is varied output wave form is seen on a CRO.
7. The firing angle is varied and DC output voltage and current through the load is noted.
8. The firing angle knob at 180 degree (minimum position), Switch OFF the power circuit (MCB) & then firing unit. Remove the patch cards.
9. Do the experiment for R-L & motor loads.

TABULAR COLUMN:

SI. NO.	Firing angle α in degrees	Load voltage In volts	Load current In Amp
1			
2			
3			
4			

OUTPUT WAVEFORMS
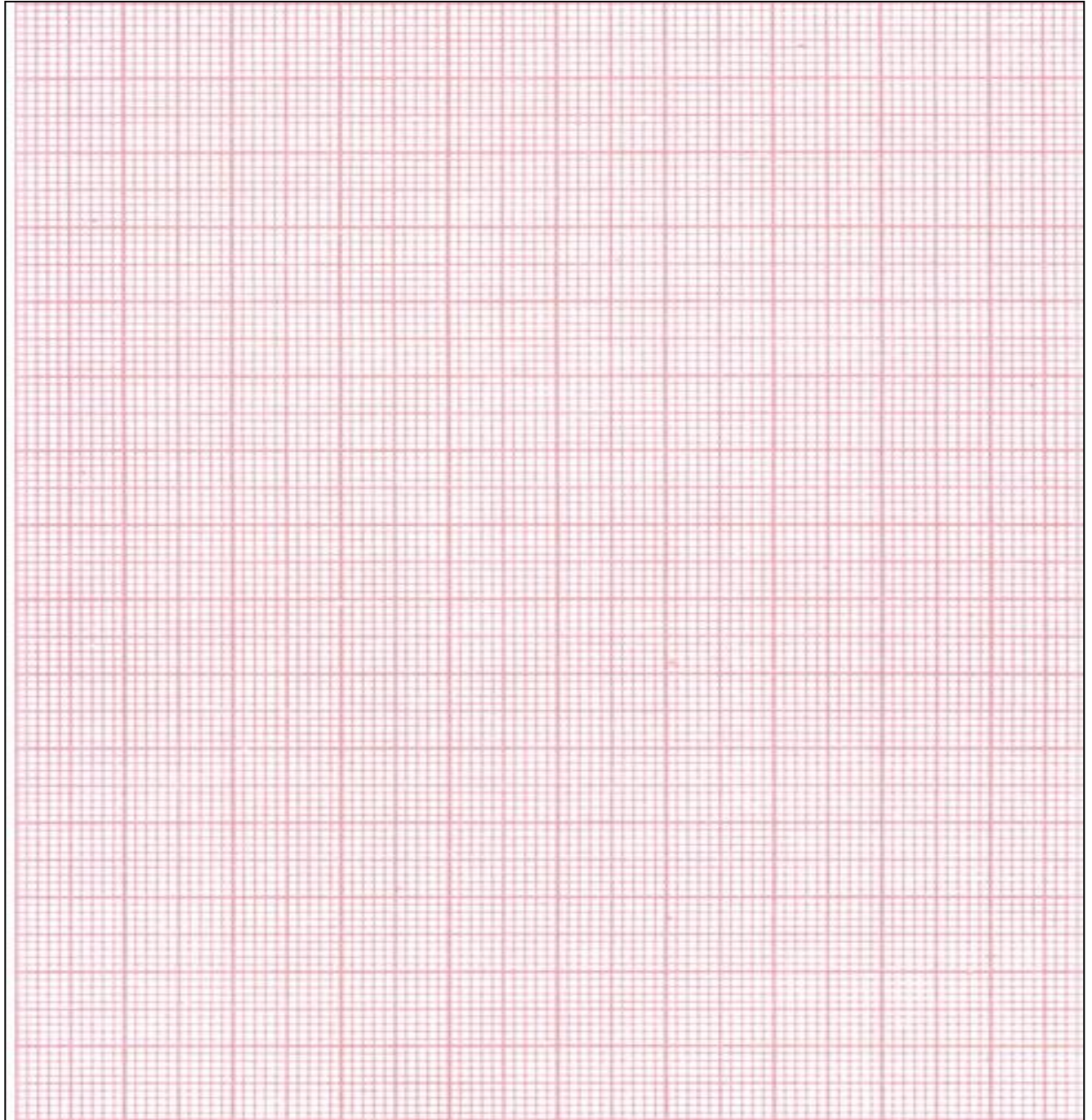
RESULT:

EXPERIMENT - 3

THYRISTORISED DRIVE FOR PMDC MOTOR WITH SPEED MEASUREMENTAND CLOSED LOOP CONTROL

AIM: To control the speed of the PMDC motor using thyristorised converter unit.

APPARATUS: Thyrisroised converter unit, CRO, patch cards, etc

CIRCUIT DIAGRAM:
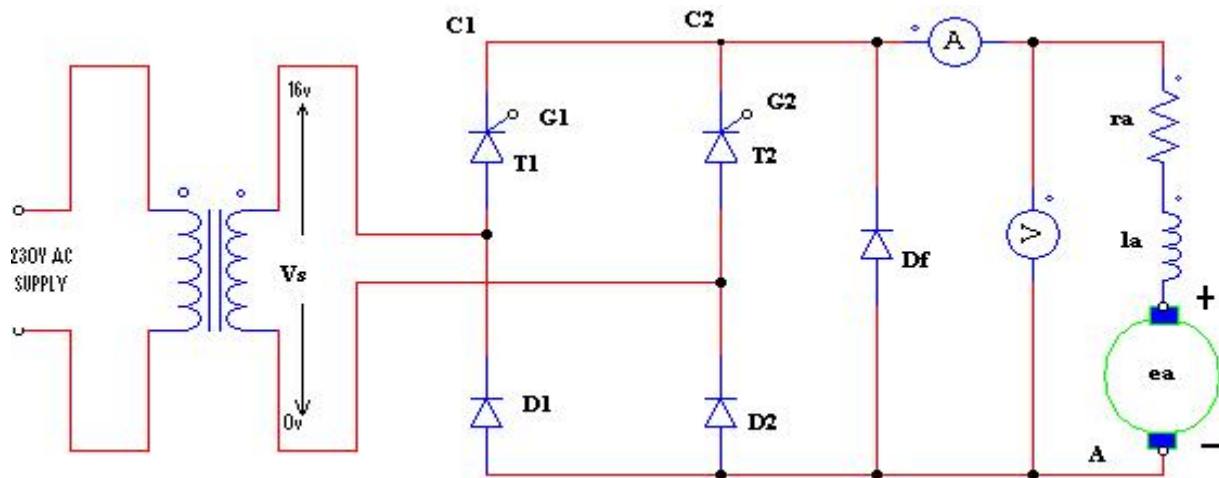
THEORY:

Rectifier converts AC supply to DC supply. with thyristor, variable DC supply 0 V to maximum can be obtained from a fixed AC source by triggering (turning ON) SCR i.e., by applying gate current to the SCR at any desired instant when the SCR is applied with positive voltage to anode. Unlike diode, SCR can block the forward voltage when gate current is not supplied. Hence converters using SCR's are termed as controlled rectifier. Normally for DC power requirement such as in DC drives single phase full wave controlled rectifier are used.

SINGLE PHASE HALF CONTROLLED BRIDGE WITH MOTOR LOADS.

When the single phase semi-converter is connected with R-L/motor load a freewheeling diode must be connected across the load. During positive half cycle T1 is forward biased & T1 is fired at $\omega t=\alpha$, the load is connected to the input

supply through T1 and D1 during period $\alpha \le \omega \le \pi$, During the period from $\pi \le \omega t \le (\pi+\alpha)$, the input voltage in negative and free wheeling diode Df is forward biased, Df conducts to provide the continuity of current in the inductive load. the load current is transferred from T1 and D1 to Df, and thyristor T1 and D1 are turned off at $\omega t=\pi$.During negative half cycle of input voltage, thyristor T2 is forward biased, and the firing of T2 at $\omega t=\pi+\alpha$ will reverse bias Df.The diode Df is turned off and the load connected to the supply through T2 and D2.

When the load is inductive and T1 is triggered, first it will conduct with D1 to pass current through load. When the supply voltage is negative load emf will drive current through T1D2.This is an exponentially decreasing current. When the new negative half cycle begins T1 is in conduction and it would keep on conducting with D1 as if triggered at $\omega t=0$.In this case load may not receive the D.C power. To ensure proper operation, at the beginning of positive half cycle T2 has turned off and similarly T1 should be turned off when negative half cycle begins. This is achieved by the free wheeling diode.

For R-L load with freewheeling diode the average output voltage can be found from

$Vdc\ (av) = (1/11)\ {}_\alpha\!\int Vmsin\theta d\theta$

$$= (V_{m}/\pi)\ [-cos\theta]_\alpha{}^\pi$$

$$Vdc\ (av) =(V_{m}/\pi)[1+cos\alpha]$$

PROCEDURE:

1. Connect motor terminals to power circuit & speed sensor to feedback terminals socket
2. Switch on the unit, Display shows –sda 85.
3. Now press GO 4B00 EXEC keys.
4. Display shows SPDC CO indicates that single phase DC motor control.
5. Press NEXT key.
6. Display shows rP indicates select rpm you would like to run motor.
7. Now enter rpm through keyboard
   Example for rpm 1000

Press keys 1, 0, 0, 0.

8. Switch on the power circuit.
9. Press key

Now motor starts rotating it reaches its set rpm within few seconds.

10. To increase RPM press NEXT key. Pressing next key repeatedly increases rpm by 10 every time however microprocessor will give the command to power circuit only when EXEC key is pressed.
11. To decrease RPM press PREV key. Pressing PREV key repeatedly decreases rpm by 10 every time however microprocessor will give command to power circuit only when EXEC key is pressed.
12. Note down motor voltage.
13. Now note down the firing angle using CRO.
14. Add the weight upto 250 grams in the interval of 50 grams. Study the performance of the motor for the closed loop.

TABULAR COLUMN:

RPM=

SI .No	Weight(grams)	Load voltage	Load current	Firing angle
1				
2				
3				

INTERFACING ADC WITH DRIVER CIRCUIT
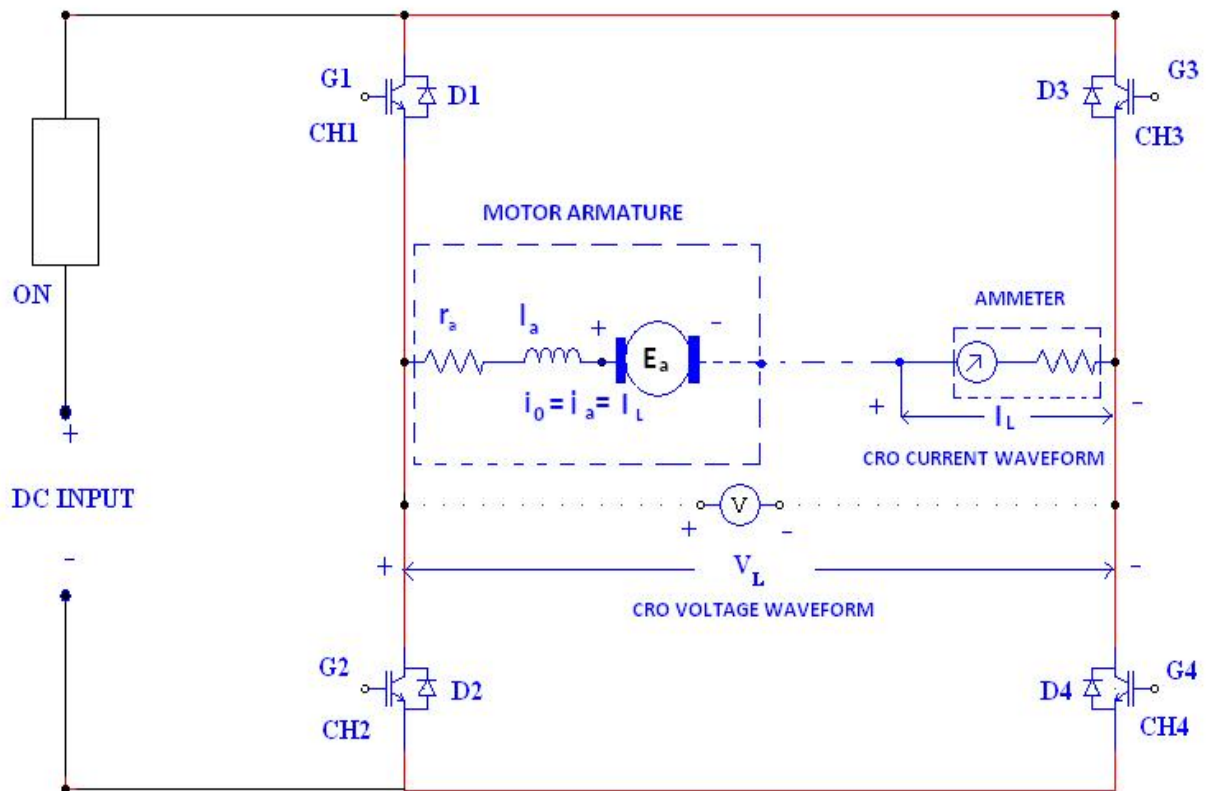
RESULT:

EXPERIMENT – 4

IGBT BASED 4 QUADRANT DRIVE FOR PMDC MOTOR WITH SPEED MEASUREMENT & CLOSED LOOP CONTROL

AIM: To construct chopper drive circuit and to control PMDC motor.

APPARATUS: four quadrant chopper circuit, DC power supply 30V/2A, CRO, patch cards, etc.

CIRCUIT DIAGRAM:

FOUR QUADRANT CHOPPER CIRCUIT DIAGRAM

THEORY:

Chopper converts fixed DC voltage to variable DC voltage through the use of semi conductor devices. The DC to DC converters have gained popularity in the modern industry. Some practical applications of DC to DC converters includes armature voltage control of DC voltages converting one DC voltage level to another level , and controlling DC power for wide verity 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 cam be made to work in forward motoring mode (I quadrant), forward regenerative braking mode (II quadrant) ,reverse motoring mode (III quadrant) and reverse regenerative braking mode(IV quadrant). The circuit shown offers four quadrant operation of a PMDC motor. its operation in the four quadrants can be explained as under.

Forward motoring mode (I quadrant): During this mode or first quadrant operation. Chopper CH2, CH3 are kept off, CH4 is kept on where as CH1 is operated. When CH1, CH4 are ON, motor voltage is positive and positive armature current rises. When CH1 is turned off, positive armature operation in first quadrant is obtained.

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, and Ra. When CH2 is turned OFF, diodes D1, D4 are turned on the motor acting as a generator returning energy to dc source. This results in forward regenerative-breaking mode in the second-quadrant.

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 ia is 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 Ea is opposite to that shown in fig.

Reverse Regenerative-breaking mode: 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 ia 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.

PROCEDURE:

1. Connect speed sensor to feedback socket.
2. Power circuit connections are made as shown in the circuit diagram.
3. Connect motor terminals respective points in the power circuit, ammeter and voltmeters as shown in the circuit diagram to observe the respective current and voltage waveforms.
4. Check the connections and conform the connections made are correct switching on power supply.
5. Switch on the four quadrant chopper unit, Display shows –sda 85.
6. Now press GO 4B00 EXEC keys. (the monitor program for closed loop control of DC motor using four quadrant chopper is stored from the memory location 4B00H)
7. Display shows 4Qd CH indicates four quadrant chopper.
8. Press NEXT key.
9. Display shows SEL CH indicates select chopper to start with 1st or 3rd quadrant chopper.
10. Press key 1 or 3 (if key 1 is pressed then chopper operates in 1st& 2nd quadrant-forward rotation. If key 3 is pressed then chopper operates in 3rd& 4th quadrant-reverse rotation).
11. Display shows rP indicates select rpm you would like to run motor.
12. Now enter rpm through keyboard

    Example for rpm 1000

    Press keys 1, 0, 0, 0.

13. Switch on the power supply keeping supply voltage at minimum then switch on the power circuit.
14. Press key EXEC from keyboard of the firing unit.
15. Slowly set the DC supply voltage to suitable value (15 V approximately)
    Now motor starts rotating slowly it reaches its set rpm within certain delay time.
16. Note down the motor voltage, motor current.
17. Observe the load voltage & load current waveforms using CRO.
18. Load the motor in steps of 50 grms. Study the performance of the motor for the closed loop by loading motor up to 250 grms.
19. Reduce the power supply voltage; switch off the power circuit and DC power supply.
20. Press RESET key to stop firing pulses, chopper unit mains & remove the connections.

TABULAR COLUMN:

FORWARD ROTATION

Set rpm =1000rpm

SL. NO.	Weight In KGs	Load Voltage	Load Current	Running speed In rpm
1.				
2.				
3.				

REVERSE ROTATION:

Set rpm = 1000rpm

SL. NO.	Weight In KGs	Load Voltage	Load Current	Running speed In rpm
1.				
2.				
3.				

Result:

EXPERIMENT- 5

THREE PHASE INPUT THYRISTORISED DRIVE FOR DC MOTOR WITH CLOSED LOOP CONTROL

AIM: To construct a three phase fully controlled full wave bridge rectifier and to control speed of the DC motor.

APPARATUS: 415 V input, 185V output or any suitable isolation transformer, controlled rectifier module, firing unit, DC shunt motor, patch cards etc.,

CIRCUIT DIAGRAM:
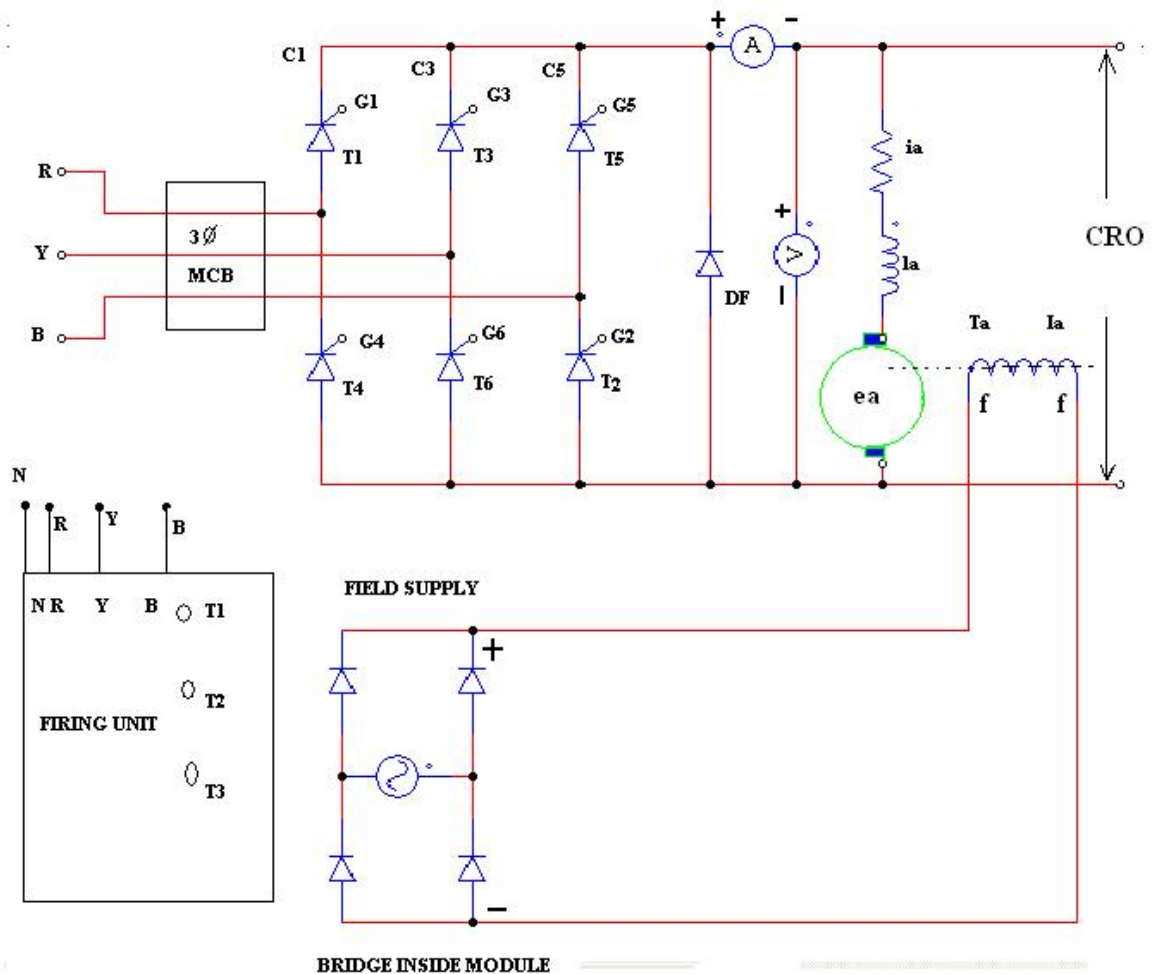
THEORY:

In the bridge rectifier all the three arms of SCR's are connected as control switches. This is called fully controlled bridge converter. Depending on the delay angle, the output current can be either continuous or discontinuous. In fully controlled rectifier the load voltage may be positive or negative for inductive loads. The power circuit & the control circuits are provided with the manual.

PROCEDURE:

1. Connect motor terminals (field & armature) to respective points in the power circuit & speed sensor to feedback socket.
2. Circuit connections are made as shown in the circuit diagram.
3. Connect 3 pin power cards from power unit (rectifier) to the mains supply.
4. Switch on the field supply of the motor.
5. Switch on the three phase power input.
6. Switch on the power circuit through MCB.
7. Keeping PID OFF now switch on the firing unit.
8. Set the rpm through the knob.
9. Switch on P, I, D switches, adjust the gains.
10. Load the motor up to 3 to 4A load. Note down the speed for different loads.
11. Switch off power circuit by MCB, switch off firing circuit, switch off field supply & remove the connections.

TABULAR COLUMN:

Set RPM =

SL. NO.	Load Current	Load Voltage	Running rpm
1.	0.5A		
2.	1A		
3.	2A		
4.	3A		

Note: Field supply must be switched on before applying voltage to armature.
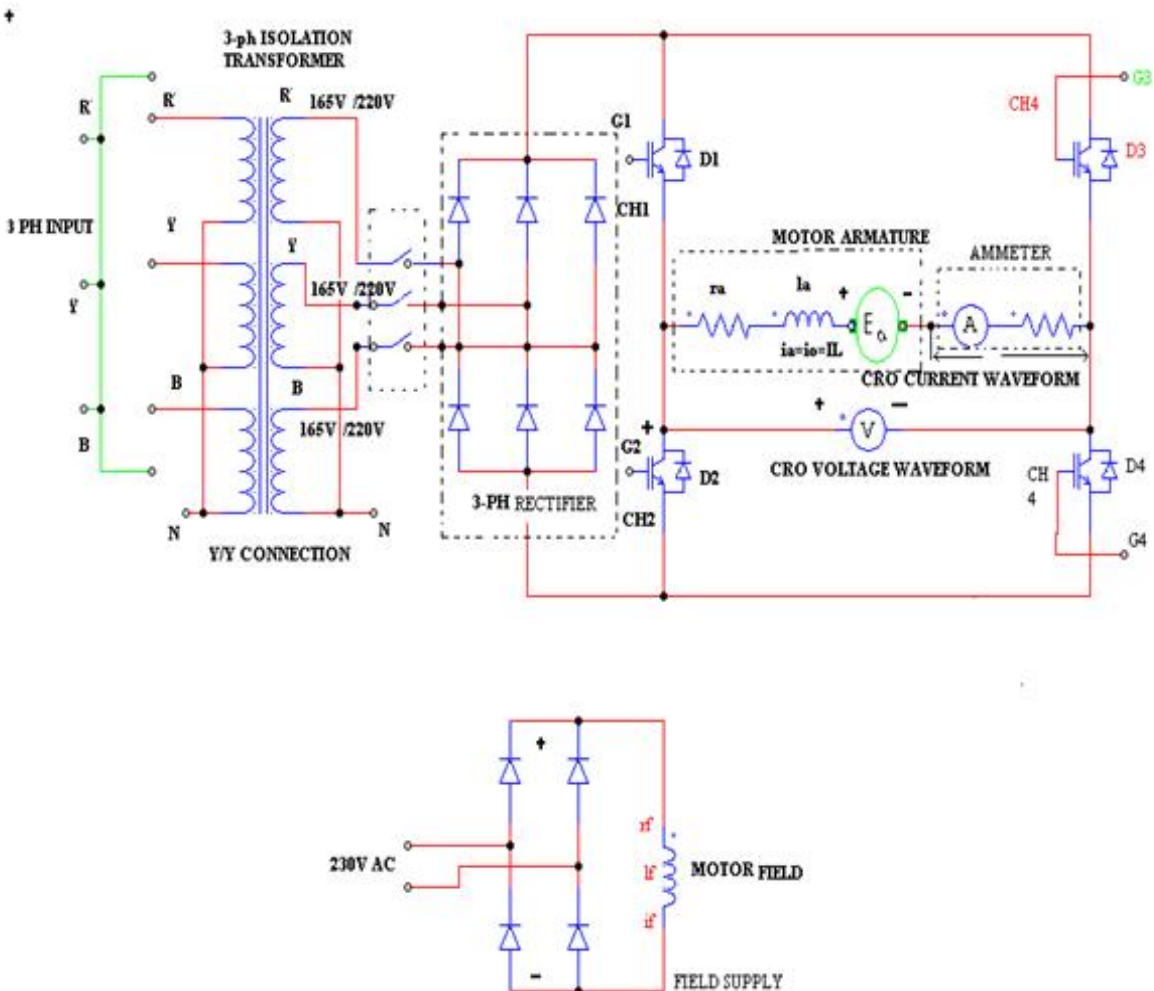
RESULT:

EXPERIMENT- 6

CLOSED LOOP OF DC MOTOR USING THREE PHASE FED FOUR QUADRANT CHOPPER DRIVE

AIM: To construct three phase fed closed loop chopper drive circuit and to control the speed of the separately-excited dc motor.

APPARATUS: Chopper power module, chopper firing unit, three phase isolation transformer, CRO, patch cards, etc.

CIRCUIT DIAGRAM:

THEORY:

This speed control unit is based on PID controller. This unit generates four triggering pulses. RPM can be set through knob provided on the unit. The unit is programmed to adjust its duty cycle. The unit generates four chopper triggering pulses CH1, CH2, CH3 & CH4. RPM can set through knob of the unit. Triggering pulses are generated to operate the chopper in all for quadrants. The unit programmed to adjust its firing pulse width keeping frequency constant.

The feedback sensor (proximity detector) attached to the shaft of the motor is magnetic sensor. The sensor output goes high whenever metal screw comes near the switch. The sensor output is connected to the voltage to frequency converts. The output voltage of the F/V converter is proportional to running rpm. Then the system compares the running RPM with the set RPM. If running speed is less than the set speed then the duty cycle is increased& if the running speeds more than the set speed then the duty is decreased. The system is keeps on comparing the set speed and running speed. In the forward rotation of the motor chopper drive is operated in 1 and 2 quadrant. In the reverse rotation of the motor chopper operates in the 3 and 4 quadrant.

During forward rotation of the motor the chopper operates in forward motoring (1quadrant) &forward regenerative breaking (2quadrant) mode. During reverse rotation of the motor the chopper operates in reverse motoring (3quadrant) &reverse regenerative breaking (4quadrant) mode.

chopper converts fixed DC voltage to variable DC voltage through the use of semiconductor devices. The DC to DC converters have gained popularity in the modern industry. Some practical applications of DC to DC converter include armature voltage control of DC motors converting one DC voltage level to another level, 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 (1quadrant), forward regenerative breaking mode (2quadrant), reverse motoring mode (3quadrant) and reverse regenerative breaking mode (4quadranet).the circuit shown offers four quadrant operation of a separately-excited dc motor. This circuit consists of 3 phase fed diode rectifier, four choppers,
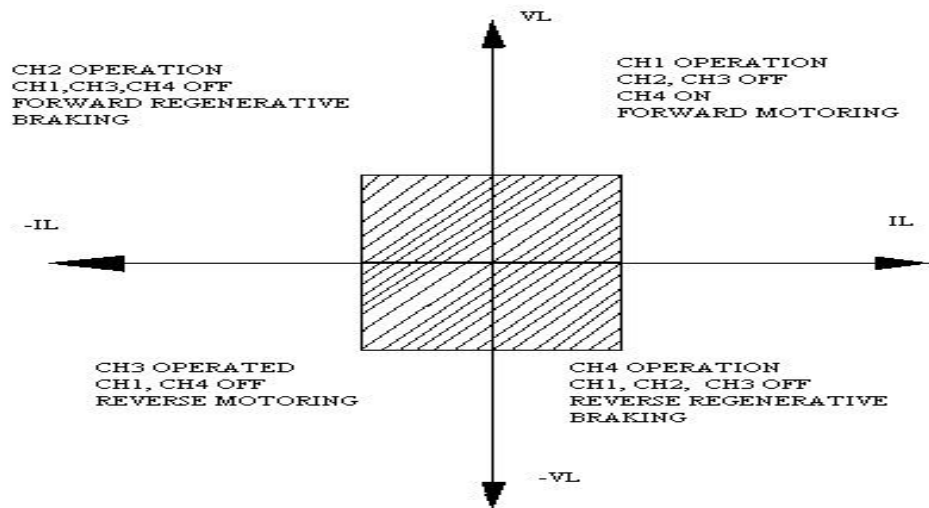
four diodes and a separately-excited dc motor. Its operation in the four quadrants can be explained as under.

Forward motoring mode (1quadrant): 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 1st quadrant is obtained.
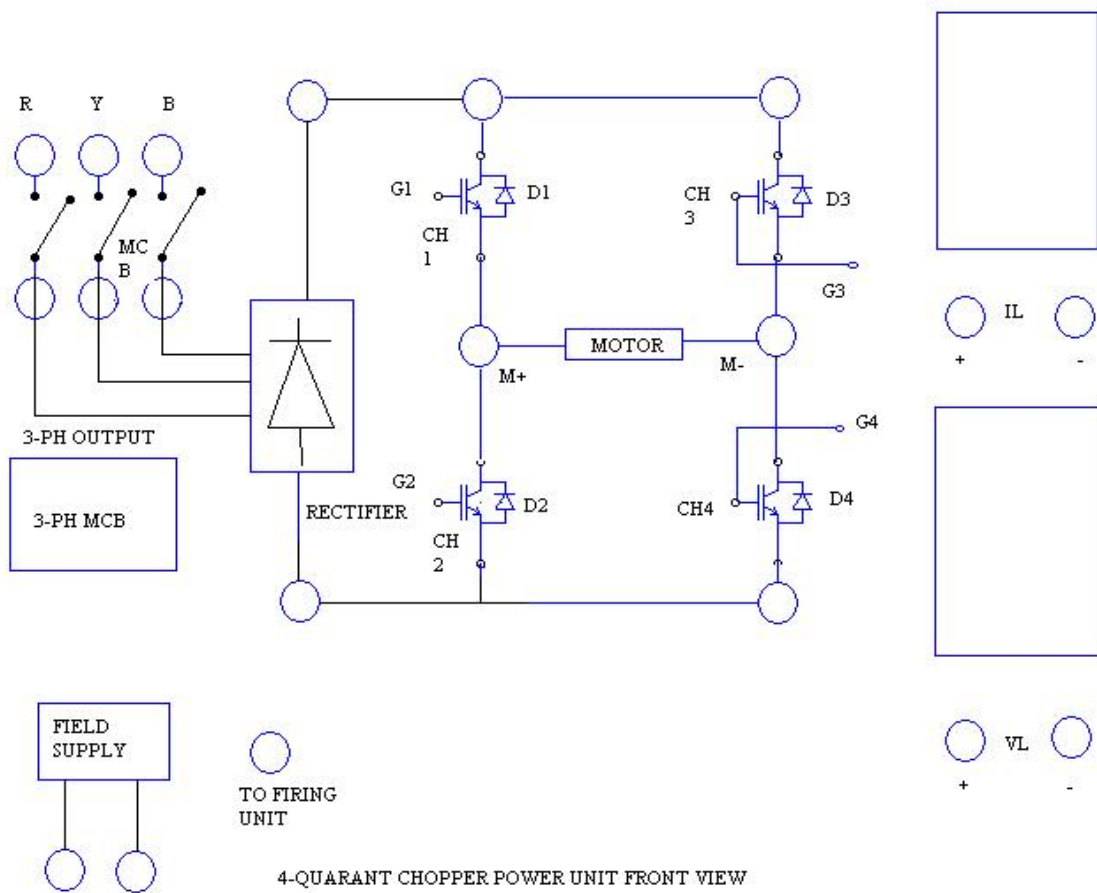
Forward regenerative breaking mode (II quadrant): a dc motor can work in the regenerative-breaking mode only if motor generated emf is made to exceed the dc source voltage. For obtaining this mode CH1, CH3 and CH4 are kept off whereas CH2 is operated. When CH2 is turned on, negative armature current 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.

Reverse motoring mode (III quadrant): This operating mode is opposite to forward motoring mode. Chopper CH1, CH4 are kept off, CH2 is kept on where as CH3 is operated. When CH3 and CH2 are on, armature gets connected to source voltage Vs so that both armature and voltage armature current Ia is negative. As armature current is reverse, motor torque reversed and consequently motoring mode In third quadrant is obtained. When CH3 is turned off, negative armature current free wheels through CH2 , D4, Ea, La, Ra, armature current decreases and thus sped controlling obtained in 3rd quadrant. Note that during this mode polarity of Ea is opposite to that shown in figure.

Reverse regenerative –braking mode: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 where as CH4 operator is operated. When CH4 is turn on, positive armature current Ia rises through CH4, D2 Ra, La, Ea. When CH4 is turn off, diodes D2, D3 begin to conduct and motor acting as generator return energy to dc source. The leads to reverse regenerative – braking operation of the DC separately exited motor in 4Th quadrant.
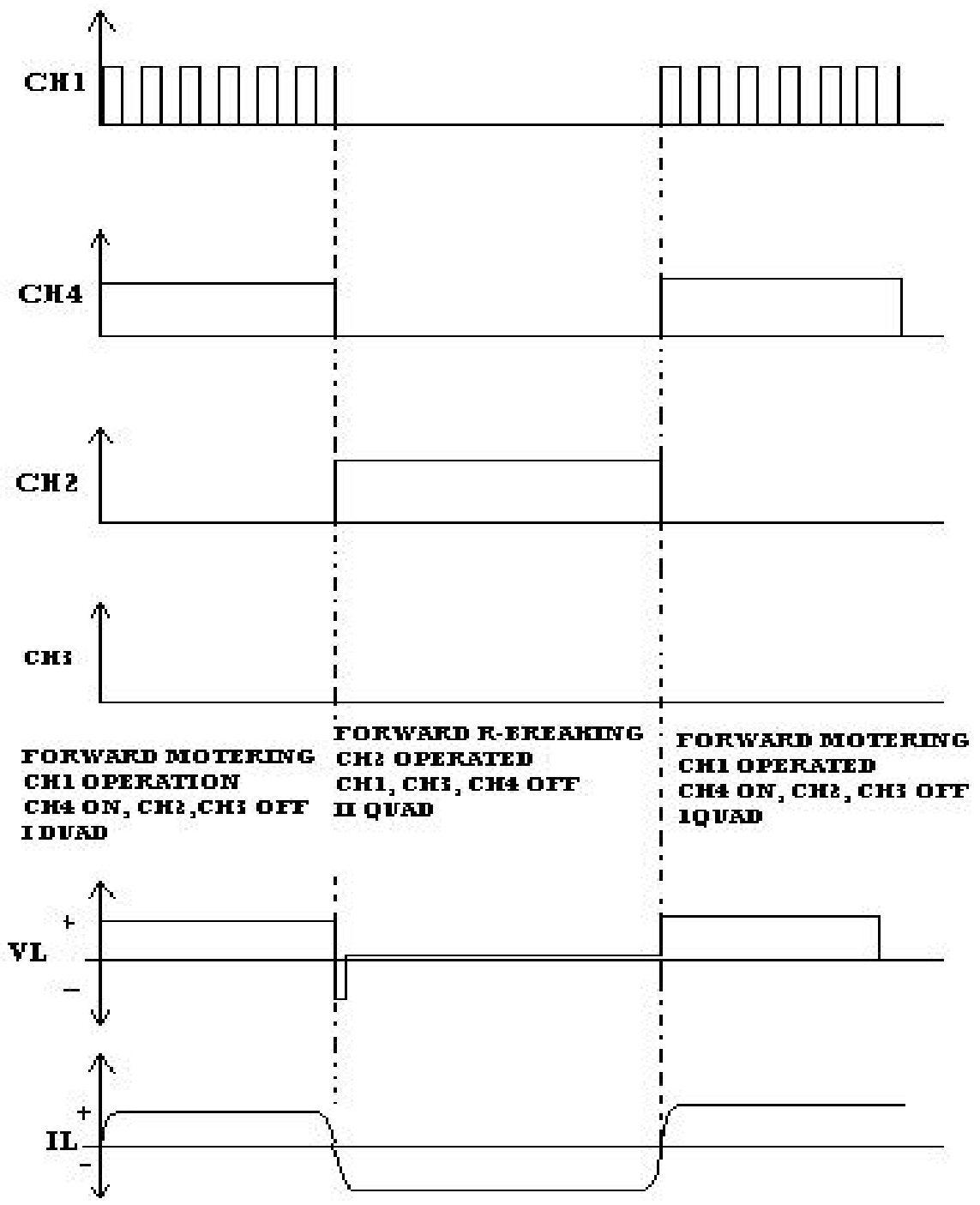
CH2 OPERATION
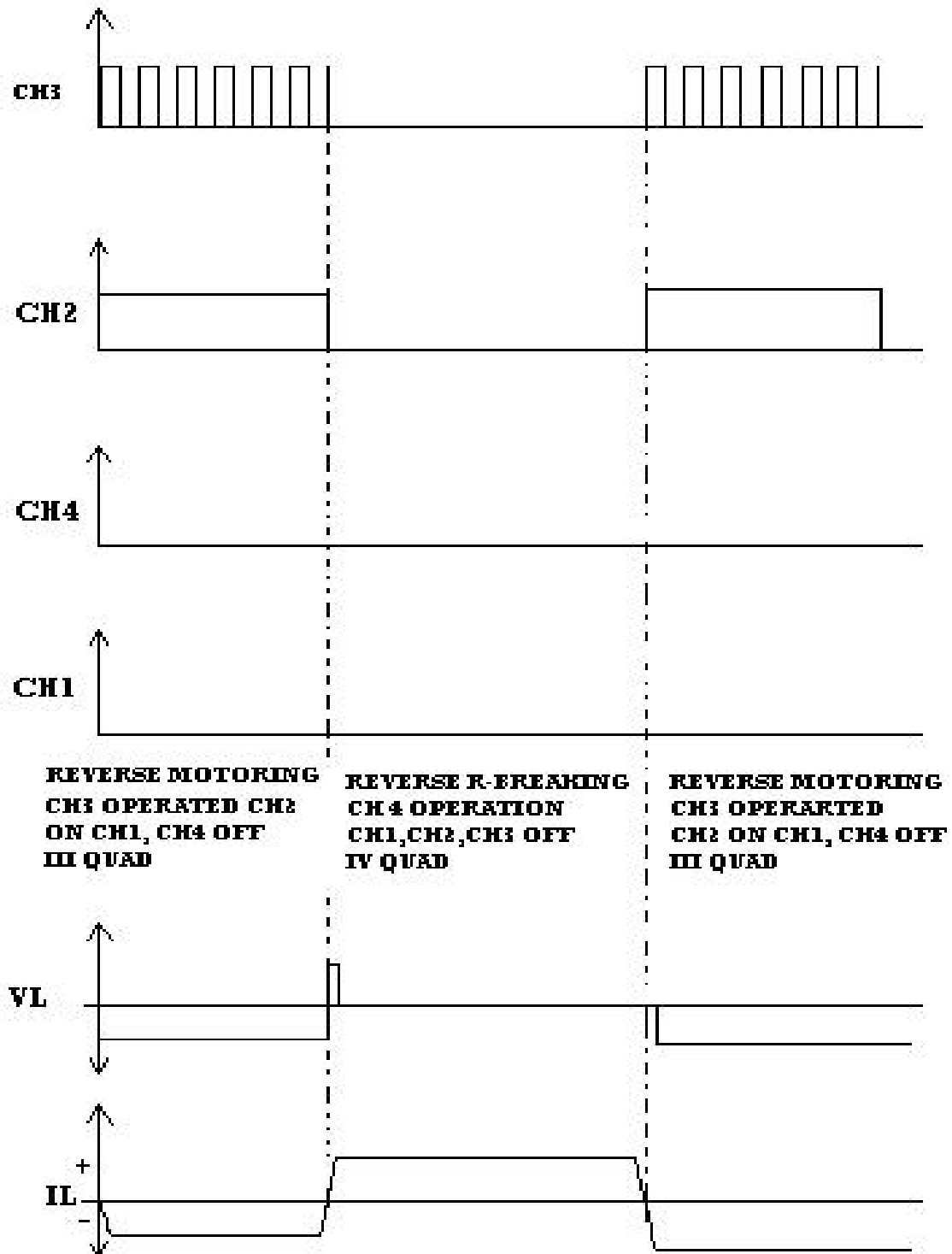CH1,CH3,CH4 OFF
FORWARD REGENERATIVE
BRAKING

CH1 OPERATION
CH2, CH3 OFF
CH4 ON
FORWARD MOTORING

-IL

IL

CH3 OPERATED
CH1, CH4 OFF
REVERSE MOTORING

CH4 OPERATION
CH1, CH2, CH3 OFF
REVERSE REGENERATIVE
BRAKING

VL

-VL

FOUR QUADRANT DIAGRAM

R   Y   B

MC
B

3-PH OUTPUT

3-PH MCB

RECTIFIER

G1   D1
CH
1

G2   D2
CH
2

M+   MOTOR   M-

CH
3   D3

G3

G4
CH4   D4

IL
+   -

VL
+   -

FIELD
SUPPLY

TO FIRING
UNIT

4-QUARANT CHOPPER POWER UNIT FRONT VIEW

WAVE FORMS FOR I AND II QUADRANT

CH1

CH4

CH2

CH3

FORWARD MOTERING
CH1 OPERATION
CH4 ON, CH2, CH3 OFF
I DUAD

FORWARD R-BRERKING
CH2 OPERATED
CH1, CH3, CH4 OFF
II QUAD

FORWARD MOTERING
CH1 OPERATED
CH4 ON, CH2, CH3 OFF
1QUAD

VL

+

−

IL

+

−

WAVE FORMS FOR III AND IV QUADRANT

CH3

CH2

CH4

CH1

| REVERSE MOTORING CH3 OPERATED CH2 ON CH1, CH4 OFF III QUAD | REVERSE R-BREAKING CH4 OPERATION CH1,CH2,CH3 OFF IV QUAD | REVERSE MOTORING CH3 OPERARTED CH2 ON CH1, CH4 OFF III QUAD |

VL

IL

PROCEDURE*:*

1. Connect motor terminals (field &armature) to respective points in the power circuit &speed sensor to feedback terminals socket.
2. Circuit connections are made as shown in the circuit diagram.
3. Connect 3 pin power cord from power unit (rectifier) to the mains supply.
4. Switch on the field supply of the motor.
5. Switch on the three phase power input.
6. Switch on the power circuit through MCB.
7. Keeping PID ON now switch on firing unit.
8. Set the rpm through the knob.
9. Switch ON P, I, D switches adjust the gains.
10. Load the motor
11. Switch off power circuit by MCB, switch off firing circuit, switch off field supply & remove the connections.

TABULAR COLUMN*:*

Sl. No	Load Current	Load Voltage	Running Rmp
1.			
2.			
3.			
4.			

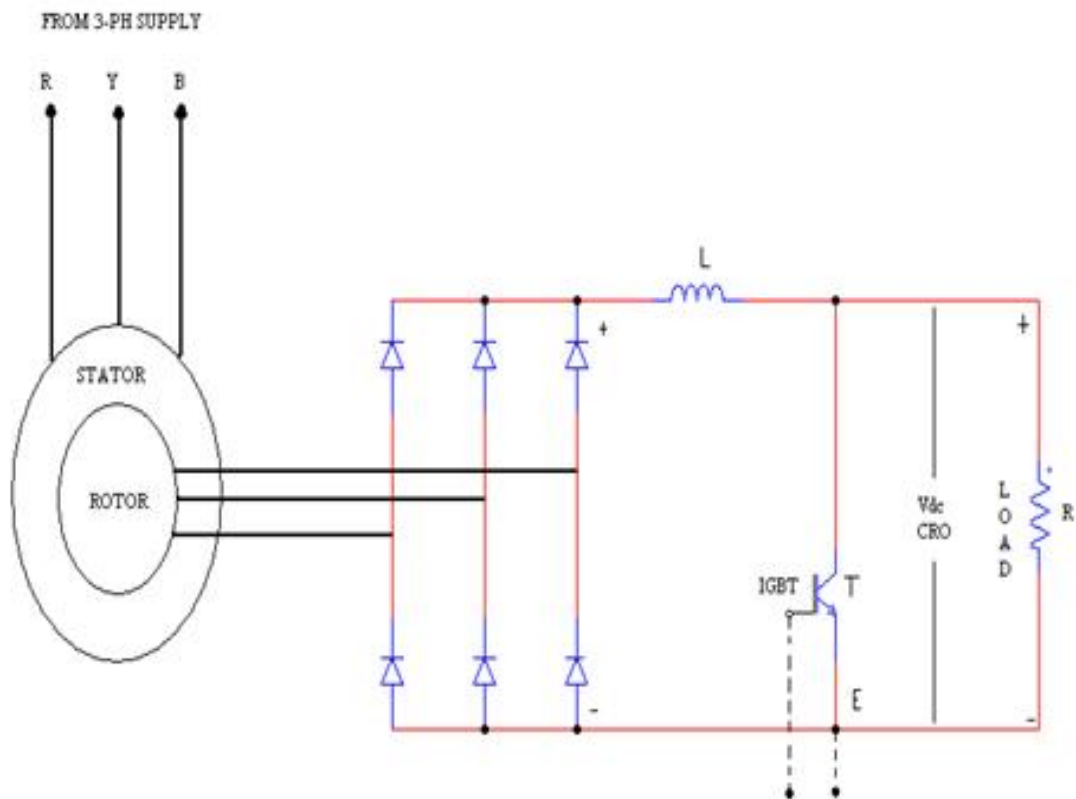**Note:** Field supply must be switched on before applying voltage to armature.

RESULT:

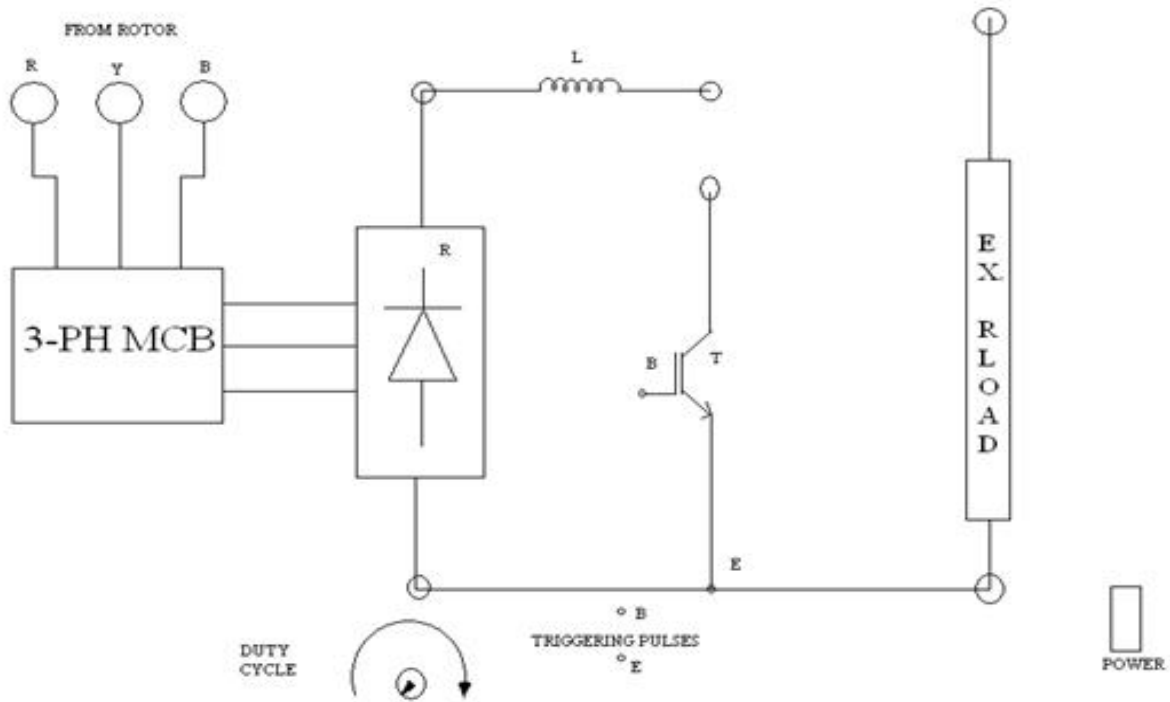## SPEED CONTROL OF THREE PHASE WOUND INDUCTION MOTOR

AIM: To control speed of three phase wound rotor induction motor

APPARATUS: Chopper module, rheostat 100 ohm/0.4A, CRO, Tachometer, three phase wound rotor induction motor, patch cards, etc

CIRCUIT DIAGRAM:

SPEED CONTROL OF 3-PH WOUND ROTOR INDUCTION MOTOR - CIRCUIT DIAGRAM

SPEED CONTROL OF THREE PHASE WOUND ROTOR INDUCTION MOTOR-FRONT VIEW

THEORY:

Three phase Diode Bridge rectifies rotor voltage to DC. Chopper converts fixed DC voltage to variable 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 another level, 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

Time ratio controller (TRC) or chopper is basically a semiconductor switch as shown in fig. Connected between the source and load. The switch is closed and opened periodically such that the load is connected to, and disconnected from, the supply alternatively. Thus the average voltage on the load is controlled by controlling the ratio of ON state interval to one cycle duration

The most important factor that governs the performance of the chopper is the duty ratio. The duty ratio can be controlled in many ways, such as by changing the on period duration by keeping frequency constant or by changing frequency

keepping on period constant. The third alternative method is to change both ON period and frequency. Changing the frequency of the chopper introduces different harmonics at different frequencies. At some frequency of operation the harmonic contents are larger than the tolerable limits. Therefore fixed frequency choppers with a variable on period technique are generally used.

Chopper 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 maximum duty cycle.

PROCEDURE:

1. Power circuit connections are made as shown in the circuit diagram. Connect three phase input to the three phase auto transformer. The output of the autotransformer terminals are connected to the respective R,Y,B stator terminals of three phase wound rotor induction motor. The rotor terminals of the three phase wound rotor induction motor is connected to the 3 phase input of respective R,Y,B terminals of three phase wound rotor induction motor control unit

2. Connect the rheostat load & CRO probe across the load. Adjust the rheostat at suitable value

3. Keeping duty cycle knob at minimum position switch on the chopper firing circuit,

4. Keeping auto transformer at minimum position switch on the three phase mains. Switch on the chopper power circuit using three phase MCB.

5. Check all the connections and confirm connections made are correct before switching on the equipments.

6. Increase the autotransformer voltage slowly for suitable value such that motor rotates

7. Vary duty cycle of the chopper firing circuit in steps and note down corresponding rpm.

8. The output waveforms are seen on a CRO

9. Plot a graph of duty cycle against speed.

TABULAR COLUMN:

SI.No	Duty cycle in%	Speed in RPM
1.	20	
2.	30	
3.	40	
4.	50	
5.	60	
6.	70	
7.	80	

RESULT:

Experiment No: 8
DC Jones Chopper with R& RL Loads

AIM: -

To study the operation of Jones Chopper and to observe the output waveforms.

APPARATUS: -

S.no	Description	Quantity
1	Jones Chopper Kit	1
2	Unearthed C.R.O	1
3	RPS (0-30)V,2A	1
4	Connecting probes	1
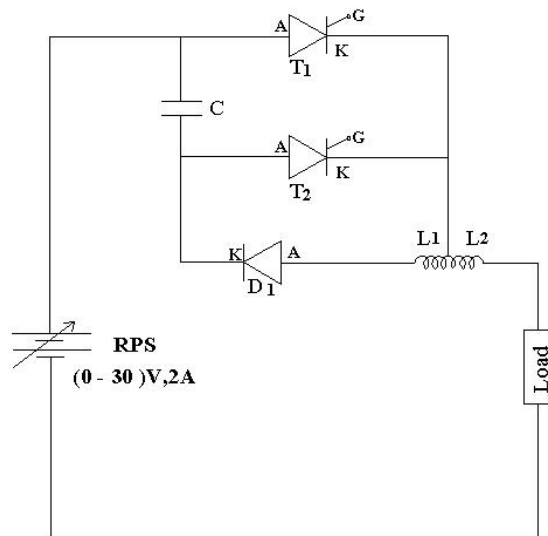
Citcuit Diagram:

PROCEDURE:

    1. Make the inter connections of the power circuit as shown in the circuit diagram.

    2. Connect the trigger pulses to the gate and cathode terminals of SCR's from G & K terminals of the firing circuit module.

    3. Before switching ON the supply ensure that switching sequence is followed.

    4. Connect CRO across the load.

1. Apply 10V DC input voltage by using 30V/2A RPS.
2. Switching on the toggle switch provided in the firing circuit module triggers Thyristors.
3. Keeping duty cycle knob constant and by varying the frequency knob of firing circuit module , observe and plot the voltage across load, current waveforms with the help of CRO.
4. Repeat step 7 by varying frequency knob constant and by varying duty cycle.
5. Repeat step 7 and step 8 for RL loads.

Model Waveforms:
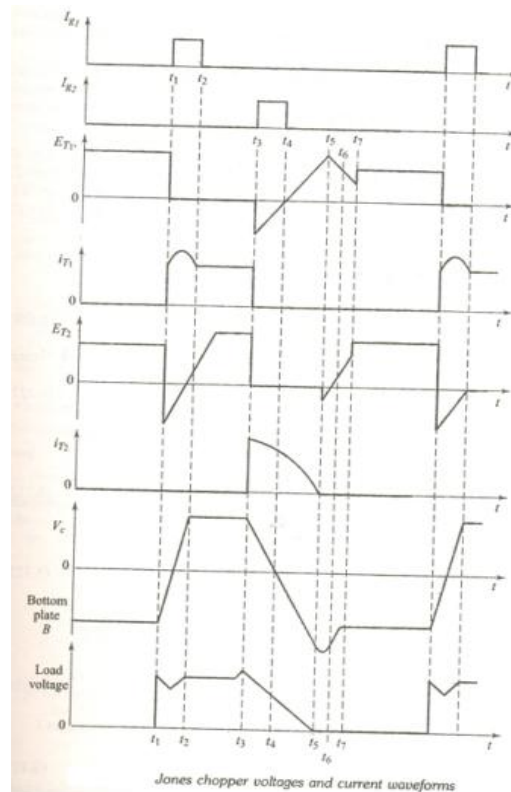
Jones chopper voltages and current waveforms

1. Identify the terminals of the SCR carefully before connecting the circuit
2. Use and unearthed CRO.
3. Before switching ON the supply see that the firing angle knob and the auto transformer are in minimum position.

OUTPUT WAVE FORMS:
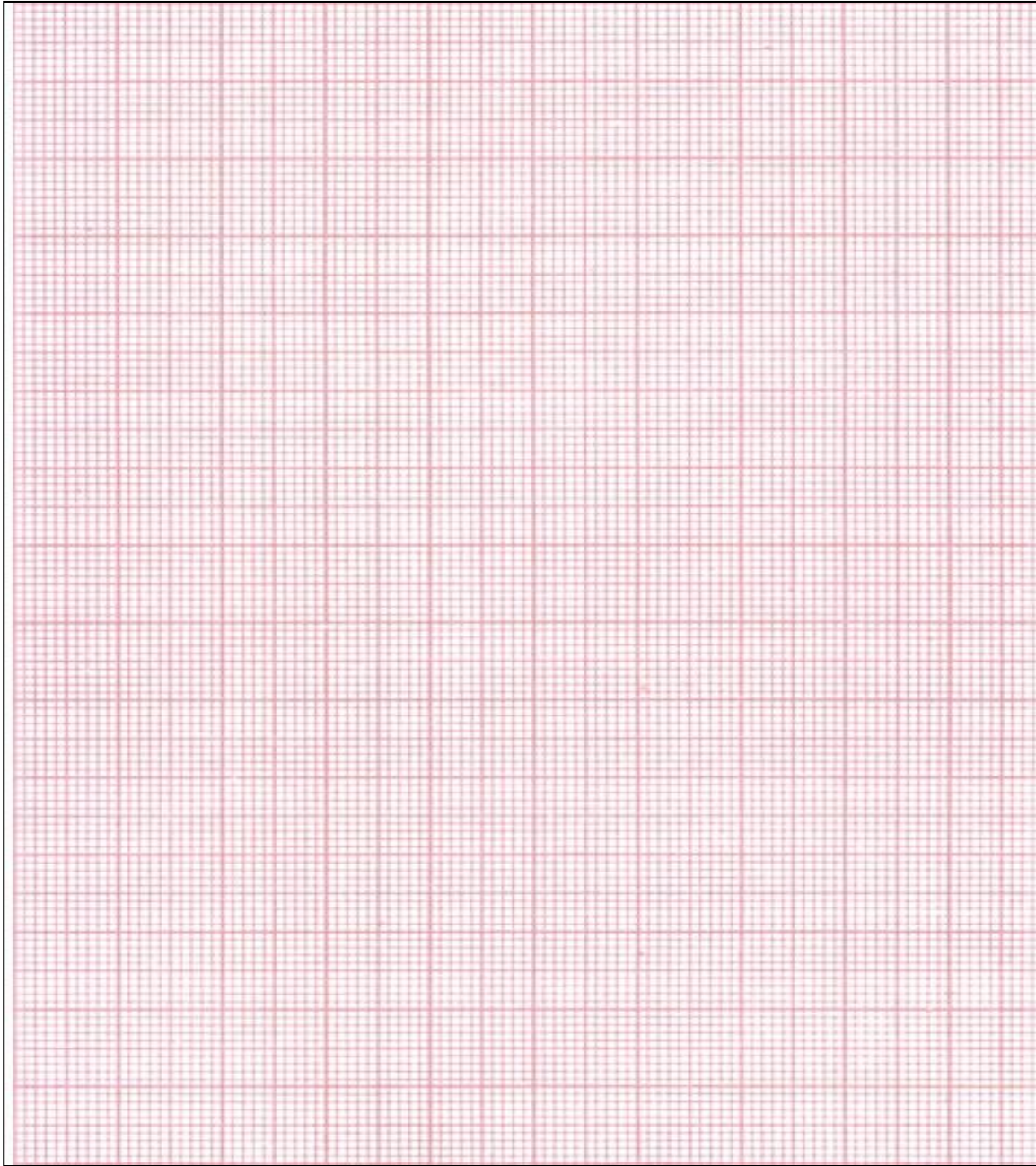
Result:

Experiment No 9

Single Phase Dual Converter with R & RL Loads

AIM:

To study the operation of a single phase dual converter in circulating and non – circulating current modes for various types of loads.

APPARATUS:

S.no	Description	Quantity
1	Dual Converter Kit	1
2	Unearthed C.R.O	1
3	Connecting probes	1
4	Loading resistor 50Ω/8A	1
5	Inductor with mid point 100 – 0 - mH	1
6	Inductor 25mH	1

PROCEDURE

DUAL CONVERTER WITH NON - CIRCULATING CURRENT MODE

(I) P – Converter is ON & N converter is OFF:
1) Make the connections as per the power circuit shown in the circuit diagram.
2) Connect the trigger pulses to the gate and cathode terminals of SCR's from G & K terminals of the firing circuit module.
3) Before switching on the supply ensure that switching sequence is followed.
4) Connect CRO across the load.
5) Apply 10V AC input voltage using isolation transformer.
6) Make P – Converter ON & OFF the N Converter in the firing angle circuit module.
7) Observe and plot the variation in the output voltage waveform across the load terminals with the help of CRO.
8) Repeat step 7 by varying firing angle pulses in sequence.

Circuit Diagram:
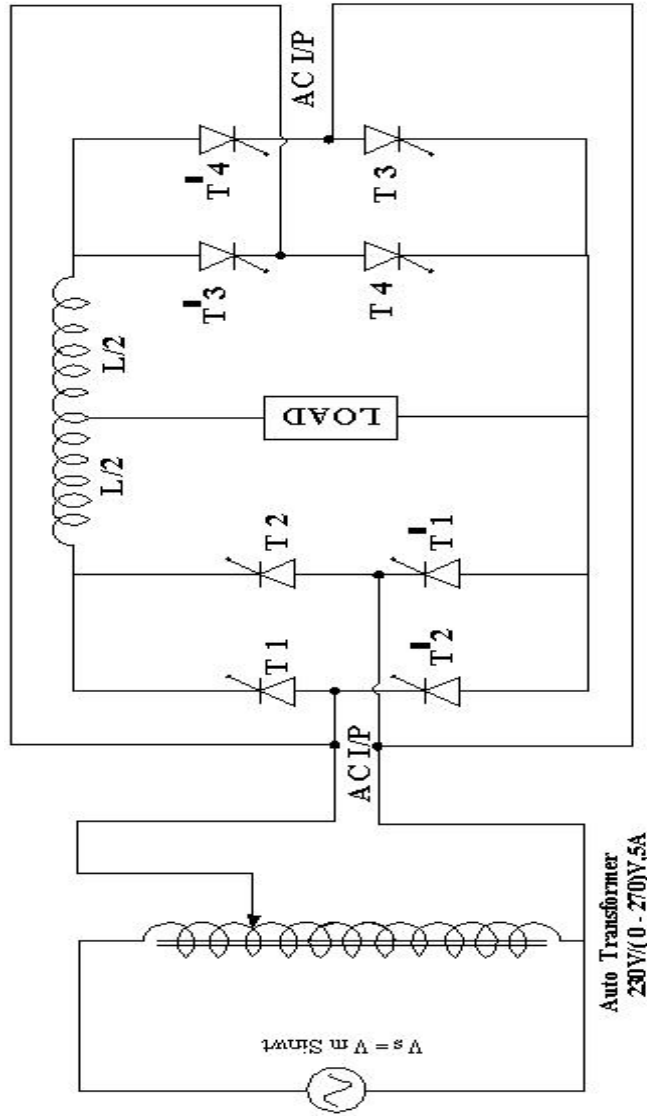
Circuit Diagram for Dual Converter with Circulating Current Mode

(II) N – Converter is ON & P converter is OFF:

1) Make the connections as per the power circuit shown in the circuit diagram.
2) Connect the trigger pulses to the gate and cathode terminals of SCR's from G & K terminals of the firing circuit module.
3) Before switching on the supply ensure that switching sequence is followed.
4) Connect CRO across the load.
5) Apply 10V AC input voltage using isolation transformer.
6) Make N – Converter ON & OFF the P Converter in the firing angle circuit module.
7) Observe and plot the variation in the output voltage waveform across the load terminals with the help of CRO.
8) Repeat step 7 by varying firing angle pulses in sequence.

DUAL CONVERTER WITH CIRCULATING CURRENT MODE

1) Make the connections as per the power circuit shown in the circuit diagram
2) Connect the trigger pulses to the gate and cathode terminals of SCR's from G & K terminals of the firing circuit module.
3) Before switching on the supply ensure that switching sequence is followed.
4) Connect CRO across the load.
5) Apply 10V AC input voltage using isolation transformer.
6) Make N – Converter ON & OFF the P Converter in the firing angle circuit module.
7) Observe and plot the variation in the output voltage waveform across the load terminals with the help of CRO.
8) Repeat step 7 by varying firing angle pulses in sequence.

PRECAUTUIONS:

1. Identify the terminals of the SCR carefully before connecting the circuit.
2. Use an unearthed CRO.
3. Before switching ON the supply see that the firing angle knob and auto transformer are in minimum position.
4. With outcentre tapped inductor between the two converters don't operate in circulating current mode.
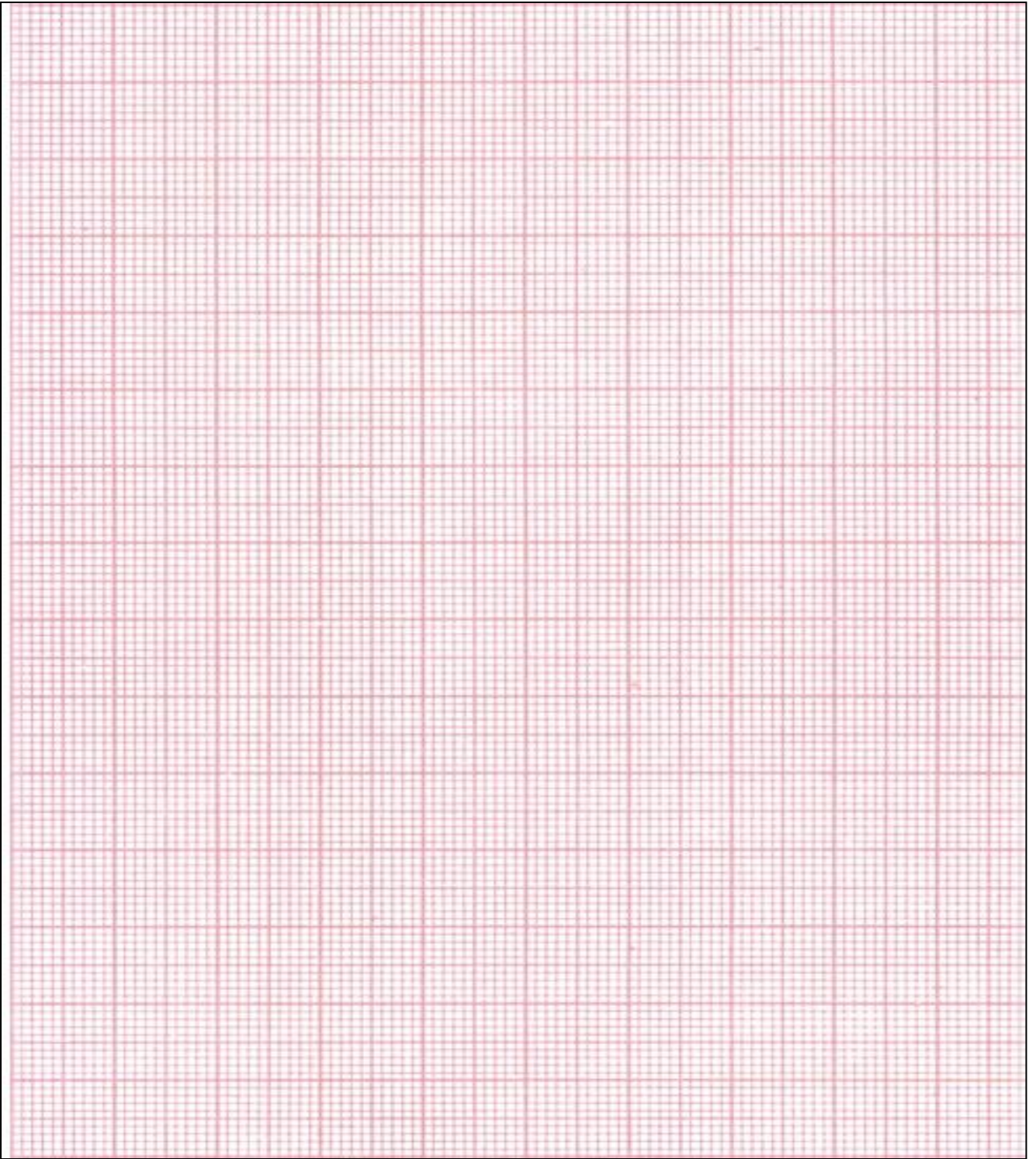
OBSERVATIONS:

Dual Converter with Non - Circulating Current Mode

SNo	Firing Angle	P – ON & N - OFF		N – ON & P - OFF	
		Vo (Theoretical)	Vo (Practical)	Vo (Theoretical)	Vo (Practical)

MODEL GRAPHS:
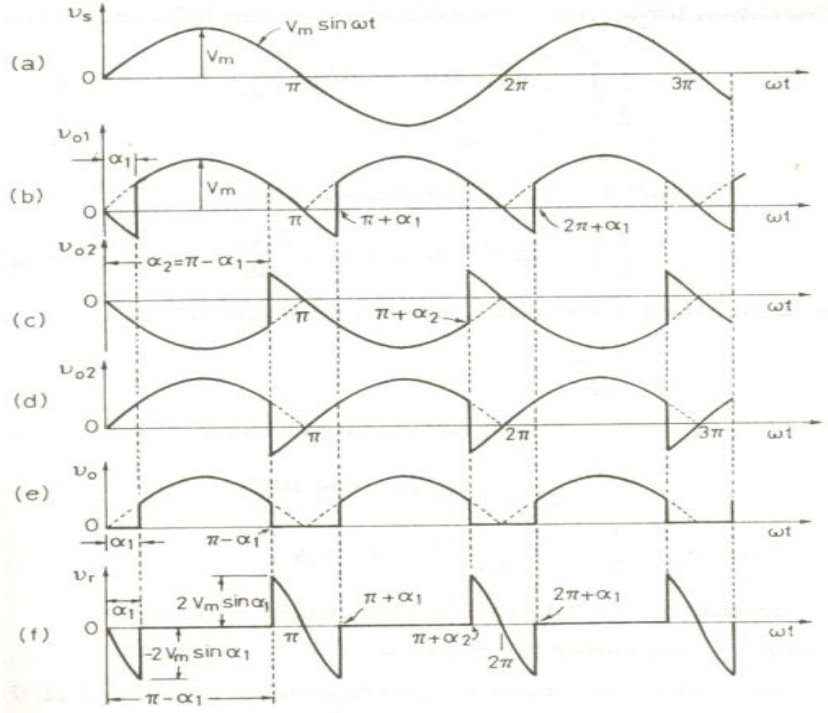
OUTPUT WAVE FORMS:

Result:

Experiment No 10
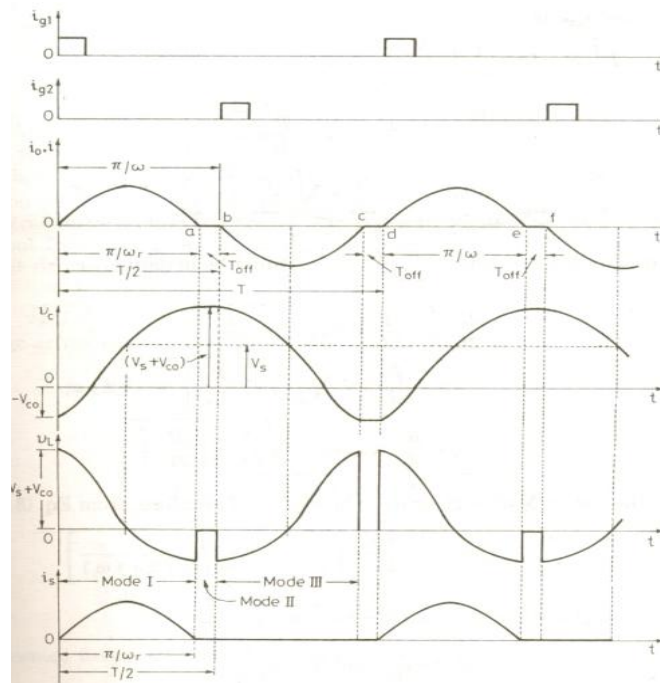
Single Phase Series Inverter with R & RL Loads.

AIM: -

To study the operation of a series inverter for various types of load and observe the output waveforms.

APPARATUS: -

S.no	Description	Quantity
1	Series inverter Kit	1
2	Unearthed C.R.O	1
3	Connecting probes	1

Circuit Diagram:
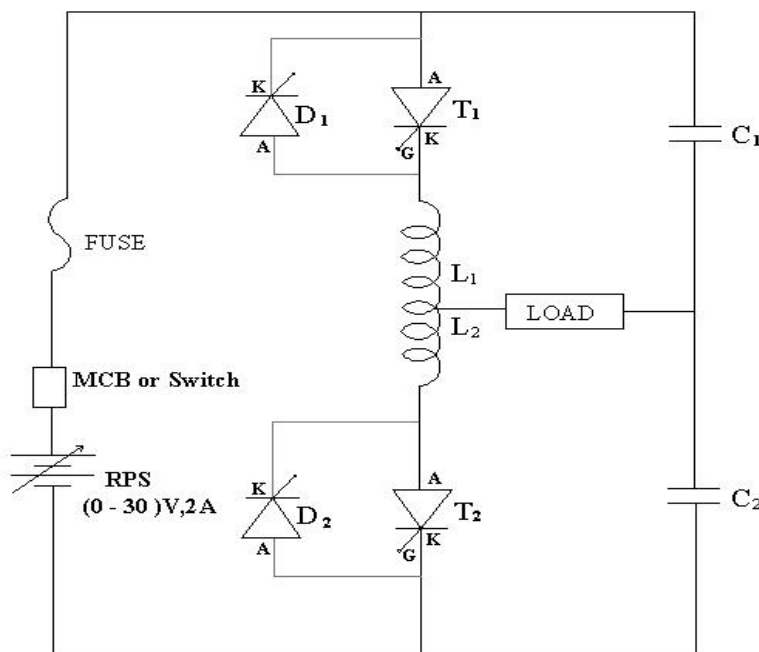
PROCEDURE:

1. Make the inter connections of the power circuit as shown in the circuit diagram.

2. Connect the trigger pulses to the gate and cathode terminals of SCR's from G & K   terminals of the firing circuit module.

3. Before switching ON the supply ensure that switching sequence is followed.

4. Connect CRO across the load.

5.Apply 10V DC input voltage by using 30V/2A RPS.

1. Thyristors are triggered by switching on the toggle switch provided in the firing circuit module.
2. Observe and plot the voltage waveforms across the load T 1 & T2 with the help of CRO.
3. Repeat step 7 by varying the firing angle in sequence of 30º.
4. Repeat step 7 and step 8 for RL loads (L = 25mH).

MODEL GRAPHS:

Voltage and Current waveforms for Series Inverter.

PRECAUTIONS:-

1. Identify the terminals of the SCR carefully before connecting the circuit

2. Use and unearthed CRO

3. Disconnect all the circuit before going for next experiment.

4. Before switching on the supply see that the firing angle knob & the auto transformer are in minimum position.
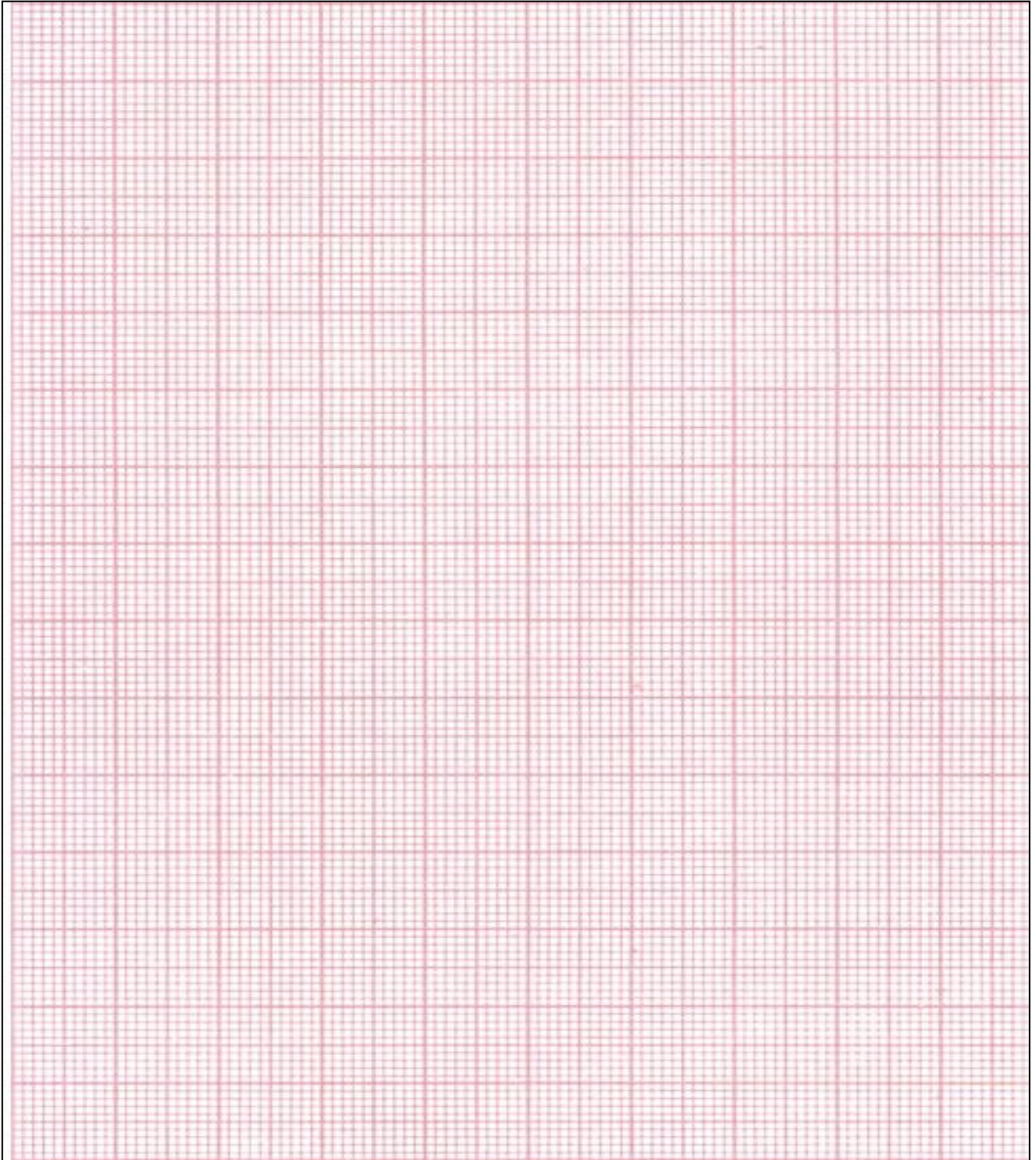
Output Waveforms:

Result:

EXPERIMENT NO: 11

SINGLE PHASE PARALLEL INVERTER WITH

R & RL LOADS

AIM:

To study the operation of a single-phase Parallel inverter and to observe the output waveforms.

APPARATUS: -

S.no	Description	Quantity
1	Parallel inverter Kit	1
2	Unearthed C.R.O	1
3	Connecting probes	1

PROCEDURE:

1. Make the inter connections of the power circuit as shown in the circuit diagram.

2. Connect the trigger pulses to the gate and cathode terminals of SCR's from G & K terminals of the firing circuit module.

3. Before switching ON the supply ensure that switching sequence is followed.

4. Connect CRO across the load.

5. Apply 10V DC input voltage by using 30V/2A RPS.

6. Switching on the toggle switch provided in the firing circuit module triggers Thyristors.

7. Observe and plot the voltage across load, current waveforms with the help of CRO.

8. Repeat step 7 by varying the firing angle in sequence of 30°.

Repeat step 7 and step 8 for RL loads.
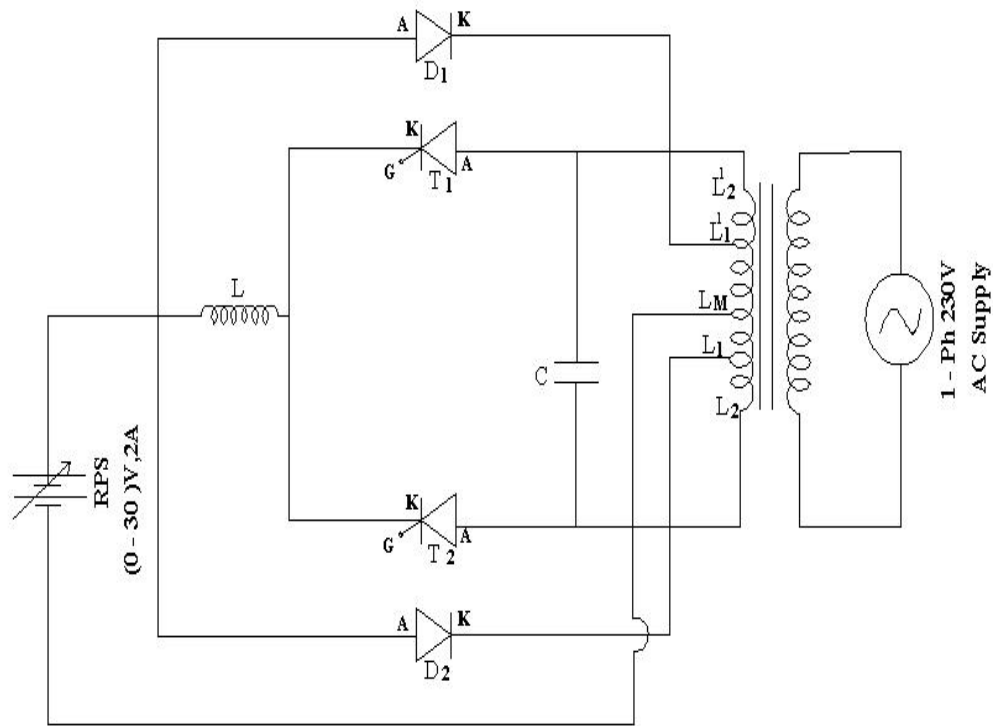
MODEL GRAPHS:
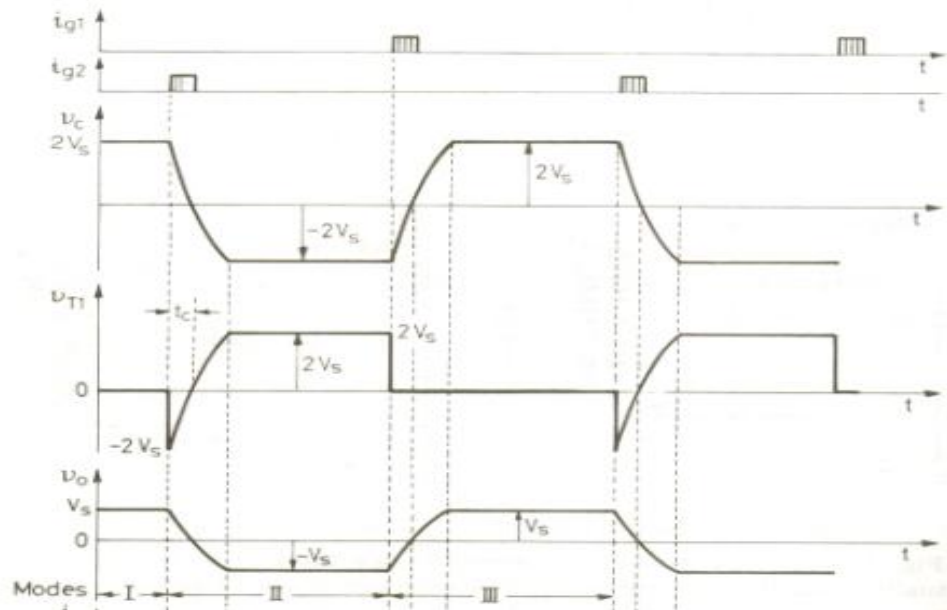
*Load voltage and current Waveforms*

Precautions: -

1. Identify the terminals of SCR carefully before connecting the circuit.

2. Use an unearthed CRO.

3. Before switching ON the supply see that the firing angle knob and the auto transformer are in minimum position.

4. When the inverter frequency increases above the resonant frequency commutation failure occurs. Switch OFF the DC supply and reduce the inverter frequency to continue the experiment.

Viva Questions:

1. What is the main difference between series inverter and parallel inverter?

2. what are the commutating elements in parallel inverter.

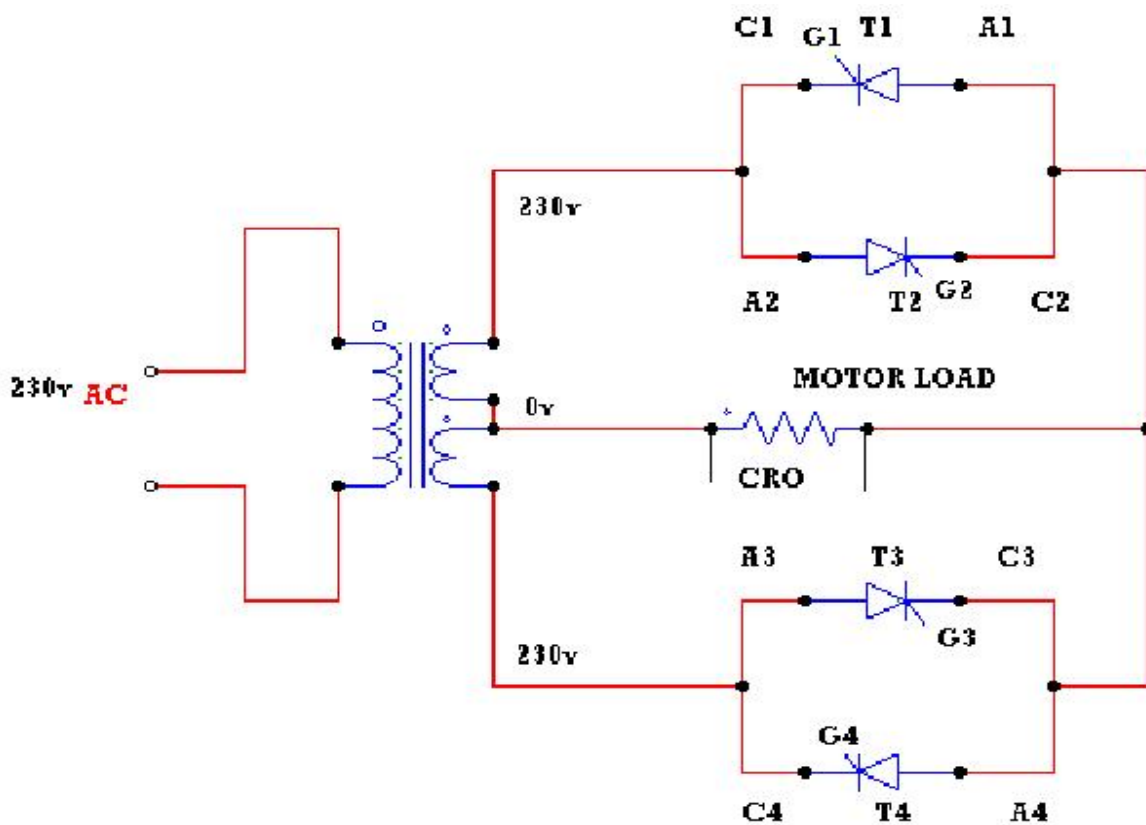### OUTPUT WAVE FORMS:
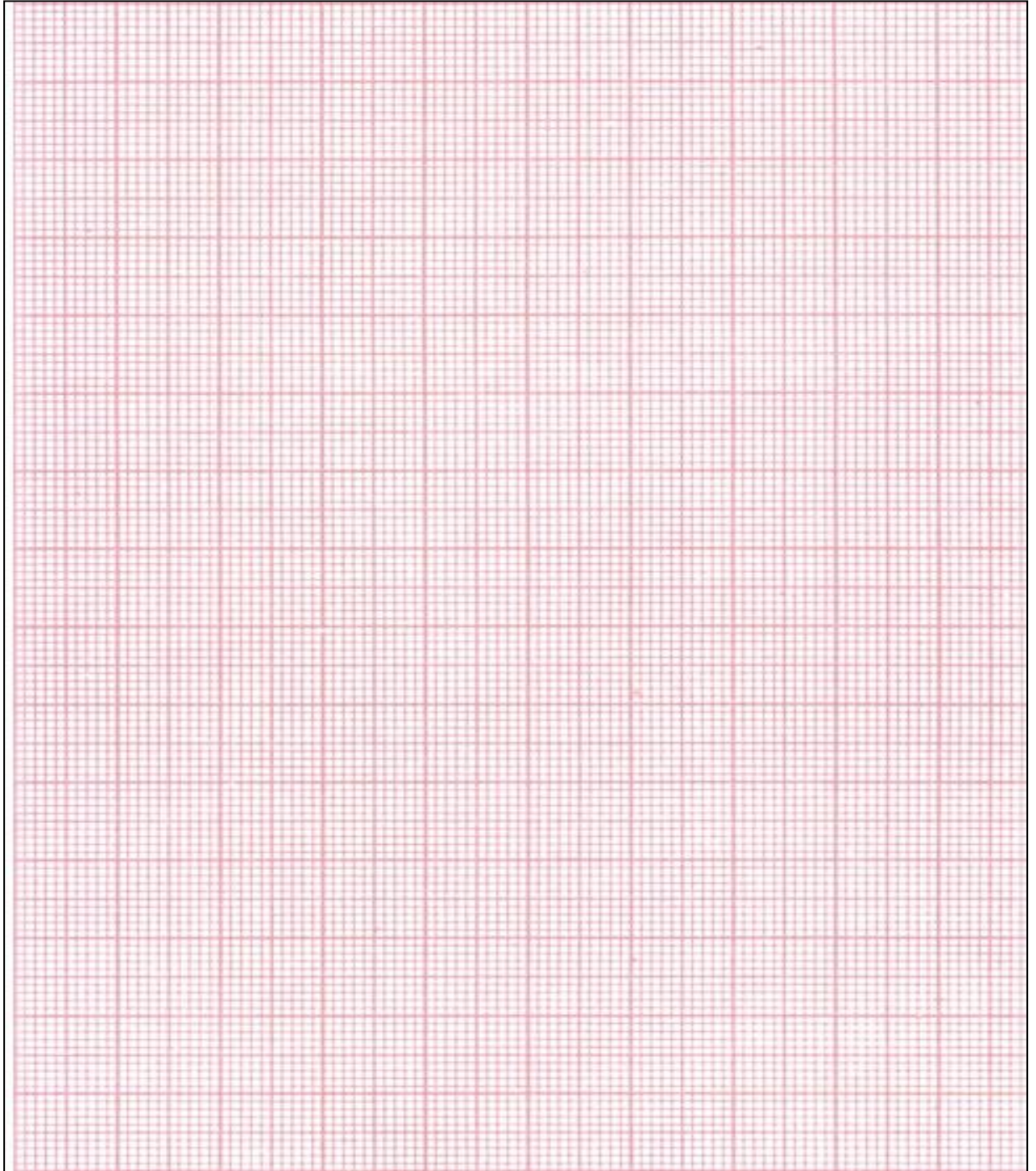
RESULT: -

Experiment No: 12

SINGLE PHASE CYCLO CONVERTER

AIM: To construct a single phase cycloconverter circuit and study its performance.

APPARATUS:

230V input 150V-0-15V output AC step down transformer (provided within the unit), cycloconverter power circuit with firing circuit, loading rheostat 100 ohms/2A. Digital multimeter, CRO,Path cards etc.

CIRCUIT DIAGRAM:

THEORY:

A cycloconverter converts input power at one frequency to output power at a different frequency with one stage conversion. cycloconverter is used in speed control of high power AC drives ,induction heating etc.

The circuit shown is for obtaining single phase frequency divided output from a single phase AC input. One group of SCR's produces positive polarity load voltage and other group produces negative half cycle of the output. SCR's T_1 and T_3 of the positive group are gated together depending on the polarity of the input, only one of them will conduct, when upper AC terminal is positive with respect to O, SCR T_1 will conduct and when upper AC terminal is negative, SCR T_3 will conduct thus in both half cycles of input, the load voltage polarity will be positive by changing firing angle, the duration of conducting of each SCR (and there by the magnitude of the output voltage) can be varied. For the sake of simplicity it is assumed that the load is positive. Then each SCR will have a conduction angle of $(\pi - \alpha)$ and turn off by natural commutation at the end of every half cycle of the input. At the end of each half period of the output, the firing pulses to the SCR's of the positive group will be stopped and SCR's T2 and T_4 of the negative group will be fired.

PROCEDURE:

SINGLE PHASE CYCLOCONVERTER

1. The connections are made as shown in the circuit of single phase cycloconverter with Motor Load with divided by 2 frequency.

2. The gate cathode terminals of the thyristors are connected to the respective points on the firing module.

3. Check all the connections and confirm connections made are correct before switching on the equipments.

4. Switch ON unit.

5. The output wave forms are seen on a CRO.

6. The firing angle is varied and AC output voltage across the load is noted.

7. A graph of V_{ac} verses load voltage is plotted.

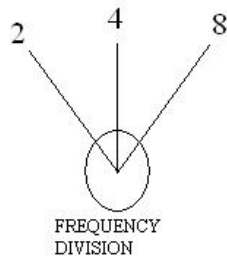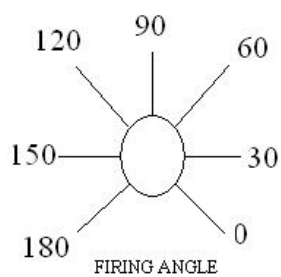8. Repeat the above procedure for divided by four frequency.

AC OUTPUT

V   O   V

MCB

V   O   V

AC INPUT

T1   C1

G1

G2

C2   T2

EX LOAD

T3   C3

G3

C4

C4   T4
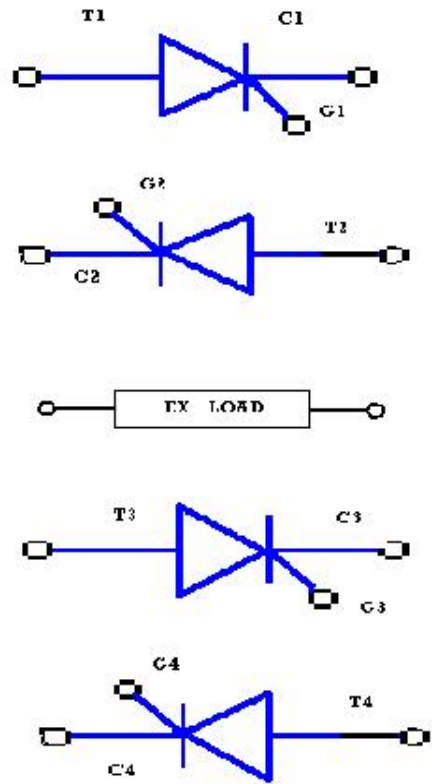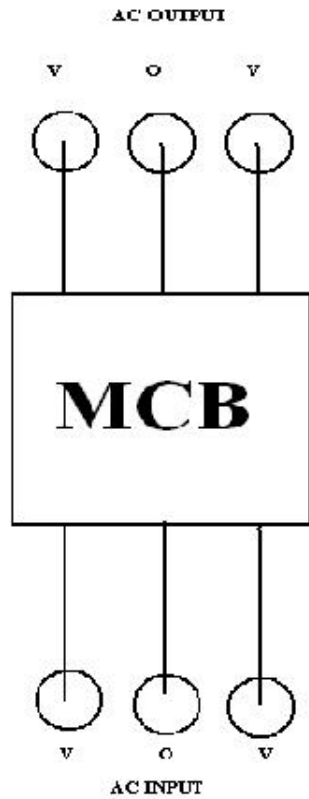
SINGLE PHASE CYCLOCONVERTER POWER UNIT – FRONT PANEL

TESTING POINT

SINGLE PHASE CYCLOCONVERTER
FIRING UNIT

GATE   CATHOD

POWER

T1

T2

120   90   60

150   30

180   0

FIRING ANGLE
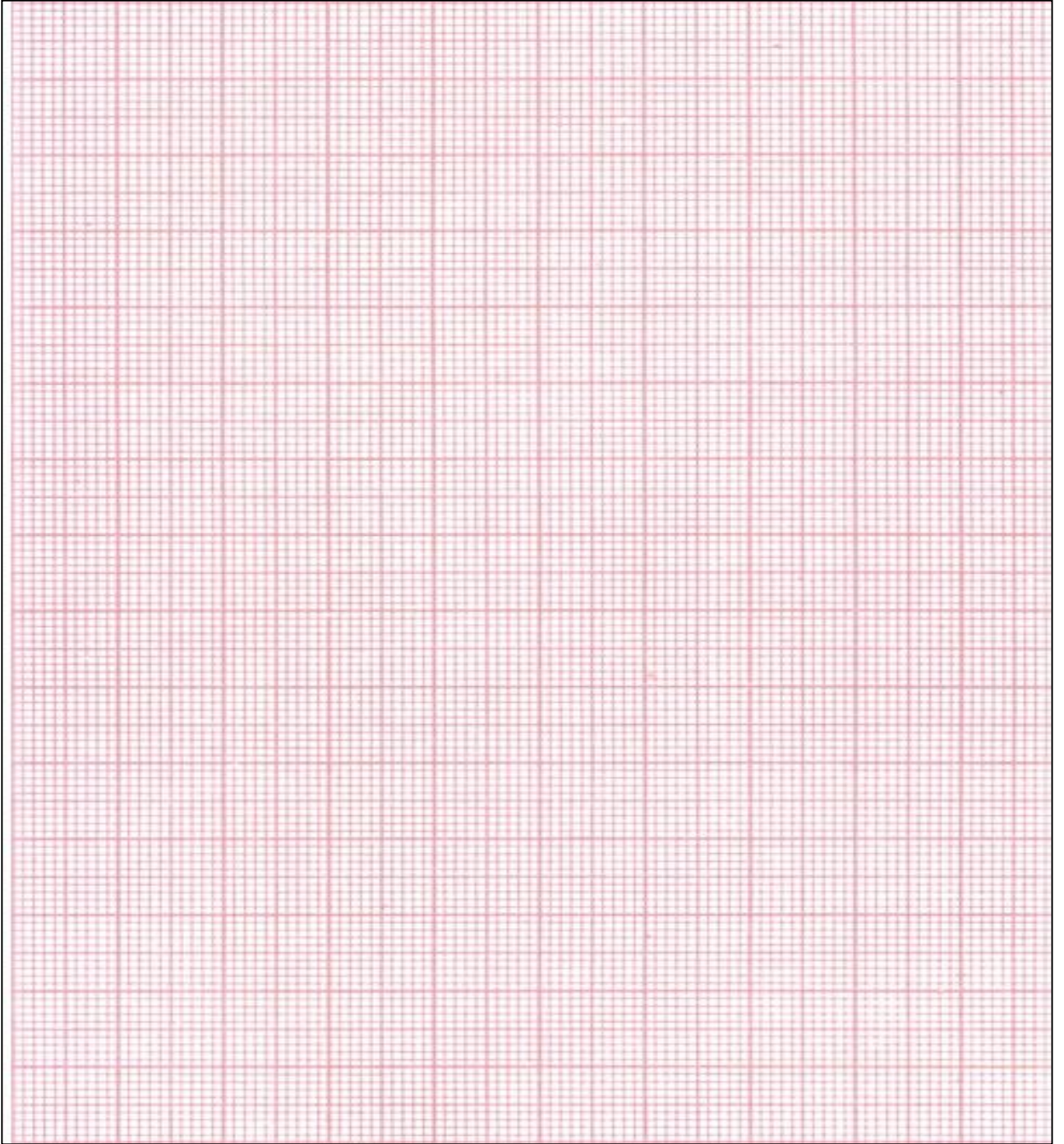
2   4   8

FREQUENCY
DIVISION

T3

T4

GND

SINGLE PHASE CYCLOCONVERTER 1ST UNIT - FRONT VIEW

EXPERIMENTAL OBSERVATIONS:

Frequency divided by 2

Sl.No	Firing angle α(in degrees)	Load voltage in volts using AC voltmeter in volts	RPM
1.	180º		
2.	150º		
3.	120º		
4.	90º		
5	60º		
6	30º		
7	0º		

Output waveforms

RESULT: