POWER ELECTRONICS

&

SIMULATION LABORATORY

M A N U A L

DEPARTMENT OF ELECTRICAL AND ELETRONICS ENGINEERING

BALAJI INSTITUTE OF TECHNOLOGY AND SCIENCE

Narsampet, Warangal.

Vision and Mission of EEE Department

Vision:

To nurture excellence in the field of Electrical & Electronics Engineering by imparting core values to the learners and to mould the institution into a centre of academic excellence and advanced research.

Mission:

M1: To impart students with high technical knowledge to make globally adept to the new Technologies

M2: To create, disseminate and integrate knowledge of engineering, science and technology that expands the electrical engineering knowledge base towards research

M3: To provide the students with a platform for developing new products and systems that can help industry and society as a whole.

Program Outcomes

PO1	**Engineering knowledge:** Apply the knowledge of basic sciences and fundamental engineering concepts in solving engineering problems.
PO 2	**Problem analysis:** Identify and define engineering problems, conduct experiments and investigate to analyze and interpret data to arrive at substantial conclusions.
PO 3	**Design/development of solutions:** Propose an appropriate solution for engineering problems complying with functional constraints such as economic, environmental, societal, ethical, safety and sustainability.
PO 4	**Conduct investigations of complex problems:** Perform investigations, design and conduct experiments, analyze and interpret the results to provide valid conclusions.
PO 5	**Modern tool usage:** Select/ develop and apply appropriate techniques and IT tools for the design and analysis of the systems.
PO 6	**The engineer and society:** Give reasoning and assess societal, health, legal and cultural issues with competency in professional engineering practice.
PO 7	**Environment and sustainability:** Demonstrate professional skills and contextual reasoning to assess environmental/ societal issues for sustainable development.
PO 8	**Ethics:** An ability to apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO 9	**Individual and team work:** Function effectively as an individual and as a member or leader in diverse teams and in multi-disciplinary situations.
PO 10	**Communication:** An ability to communicate effectively.
PO 11	**Project management and finance:** Demonstrate apply engineering and management principles in their own / team projects in multi-disciplinary environment.
PO 12	**Life-long learning:** An ability to do the needs of current technological trends at electrical industry by bridging the gap between academic and industry.

Program Specific Outcomes

PSO1	Apply fundamental knowledge to identify, analyze diverse problems associated with electrical and electronic circuits, power electronics drives and power systems.

PSO2	Understand the current technological developments in Electrical & Electronics Engineering and develop the innovative products/software to cater to the needs of society & Industry.

Program Educational Objectives

PEO1	To prepare students with solid foundation in Mathematics, Sciences and Basic Engineering to cover multi-disciplinary subjects enabling them to comprehend, analyze Electrical & Electronics Engineering problems and develop solutions.
PEO2	To design and develop an electrical system component or process to meet the needs of society and industry with in realistic constraints.
PEO3	To prepare students with technical competence to use advance techniques, skills and modern engineering tools that allow them to work effectively as electrical and electronics engineer.

ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Exp .No	Name of the Experiment	Program Outcomes Attained	Program Specific Outcomes Attained

1	Study of characteristics of SCR, MOSFET &IGBT	PO1, PO2, PO3	PSO1
2	Gate firing circuits for SCRs	PO1, PO3	PSO1
3	Single phase half controlled converter with R and RL loads	PO1, PO2, PO3	PSO1
4	Forced commutation circuits (class A, class B, class C, class D)	PO1, PO3	PSO1
5	Single phase fully controlled bridge converter with R and RL loads	PO1, PO2, PO3	PSO1
6	Single phase series inverter with R and RL loads	PO1, PO3	PSO1
7	Single phase parallel inverter with R and RL loads	PO1, PO3	PSO1
8	Single phase AC voltage controller with R and RL loads	PO1, PO2, PO3	PSO1
9	Single phase dual converter with R and RL loads	PO1, PO2, PO3	PSO1
10	Single phase Cycloconverter with R and RL loads	PO1, PO2, PO3	PSO1
11	Three phase half converter with R and RL loads	PO1,PO2, PO3	PSO1
12	Operation of step down chopper using MOSFET	PO1, PO3	PSO1
13	Simulation of three phase full converter and PWM inverter with R and RL loads by using MATLAB.	PO1, PO2, PO3	PSO2
14	Simulation of boost, buck, buck boost converter with R and RL loads by using MATLAB.	PO1, PO3	PSO2

# <u>POWER ELECTRONICS AND SIMULATION LAB</u>

<u>LIST OF EXPERIMENTS</u>

1. Study of SCR, MOSFET & IGBT characteristics
2. Single phase AC voltage controller with R and RL load

3. Single phase fully controlled bridge converter with R and RL Load

4. Forced commutation circuits
5. DC Jones chopper with R and RL load
6. Single Phase parallel inverter with R and RL load
7. Single phase half controlled rectifier with R load
8. Single phase series inverter with R and RL load
9. Single phase cycloconverter
10. Gate firing circuits for SCR

PSPICE EXPERIMENTS:

1. Simulation of single phase full rectifier and AC voltage   Controller
2. Simulation of single phase inverter with PWM control
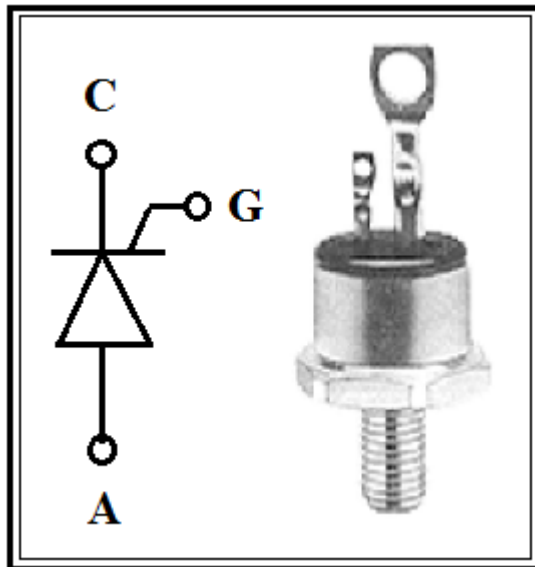
Prepared by

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Asst. Professor
EEE Department

Verified by

Head of the department

SAFETY WARNING

Before using this laboratory, read, understand and follow the Safety Precautions mentioned inside this manual.

This is an educational laboratory where high-voltage terminals and large current-carrying components and circuits are exposed for ease of measurements. Therefore, regardless of thevoltage and current levels, these should be treated as high voltages and high currents, and thesafety precautions mentioned in the manual must be followed.

SAFETY PRECAUTIONS

1. Why is safety important?

Attention and adherence to safety considerations is even more important in a power electronic laboratory than is required in any other undergraduate electrical engineering laboratories. Power electronic circuits can involve voltages of several hundred volts and currents of several tens of amperes. By comparison the voltages in many teaching laboratories rarely exceed 20V and the currents hardly ever exceed a few hundred milliamps.

In order to minimize the potential hazards, we will use dc power supplies that never exceed voltages above 40-50V and will have maximum current ratings of 5A or less. However in

spite of this precaution, power electronics circuits on which the student will work may involve substantially larger voltages (up to hundreds of volts) due to the presence of large inductances in

the circuits and the rapid switching on and off of amperes of current in the inductances. For example a boost converter can have an output voltage that can theoretically go to infinite values if it is operating without load. Moreover the currents in portions of some converter circuits may be many times larger than the currents supplied by the dc supplies powering the converter circuits. A simple buck converter is an example of a power electronics circuit in which the output

current may be much larger than the input dc supply current

2. Potential problems presented by Power Electronic circuits

• Electrical shock may take a life.

• Exploding components (especially electrolytic capacitors) and arcing circuits can cause

    blindness and severe burns.

• Burning components and arcing can lead to fire.

3. Safety precautions to minimize these hazards

3.1 General Precautions

• Be calm and relaxed, while working in Lab.

• When working with voltages over 40V or with currents over 10A, there must be at least two

    people in the lab at all times.

• Keep the work area neat and clean.

• No paper lying on table or nearby circuits.

• Always wear safety glasses when working with other than signal-level power.

• Use rubber door mats to insulate yourself from ground, when working in the Lab.

• Be sure about the locations of fire extinguishers and first aid kits in lab.

• A switch should be included in each supply circuit so that when opened, these switches will de-

    energize the entire setup. Place these switches so that you can reach them quickly in case of

    emergency, and without reaching across hot or high voltage components.

3.2 Precautions to be taken when preparing a circuit

• Use only isolated power sources (either isolated power supplies or AC power through isolation

    power transformers). This helps in using a grounded oscilloscope. This reduces the possibility

    of risk of completing a circuit through your body. This also reduces the possibility of

    destroying the test equipment.

3.3 Precautions to be taken before powering the circuit

• Check for all the connections of the circuit and scope connections before powering the circuit, to avoid shorting or any ground looping, that may lead to electrical shocks or damage of equipment.

• Check any connections for shorting two different voltage levels.

• Check if you have connected load at the output. **This is very important in Choppers and converters based on them.**

• Double check your wiring and circuit connections. It is a good idea to use a point-to-point wiring diagram to review when making these checks.

3.4 Precautions while switching ON the circuit

• Apply low voltages or low power to check proper functionality of circuits.

• Once functionality is proven, increase voltages or power, stopping at frequent levels to check for proper functioning of circuit or for any components is hot or for any electrical noise that can affect the circuit's operation.

3.5 Precautions while switching on or shutting down the circuit

• Reduce the voltage or power slowly till it comes to zero.

• Switch of all the power supplies and remove the power supply connections.

• Let the load be connected at the output for some time, so that it helps to discharge capacitor or inductor if any, completely.

3.6 Precautions while modifying the circuit

• Switch on the circuit as per the steps in section 3.5.

• Modify the connections as per your requirement.

• Again check the circuit as per steps in section 3.3, and switch ON as per steps in section 3.4.

3.7 Other Precautions

• No loose wires or metal pieces should be lying on table or near the circuit, to cause shorts and sparking.

• Avoid using long wires, that may get in your way while making adjustments or changing leads.

• Keep high voltage parts and connections out of the way from accidental touching and from any contacts to test equipment or any parts, connected to other voltage levels.

• When working with inductive circuits, reduce voltages or currents to near zero before switching

open the circuits.

- BE AWARE of bracelets, rings, metal watch bands, and loose necklace (if you are wearing any of them), they conduct electricity and can cause burns. Do not wear them near an energized circuit.

- Learn CPR and keep up to date. You can save a life.

- When working with energized circuits (while operating switches, adjusting controls, adjusting test equipment), use only one hand while keeping the rest of your body away from conducting surfaces.

GUIDELINES FOR LABORATORY NOTEBOOK

The laboratory notebook is a record of all work pertaining to the experiment. This record should be sufficiently complete so that you or anyone else of similar technical back ground can duplicate the experiment and data by simply following your laboratory note book. Record everything directly into the notebook during the experiment. Do not use scratch paper for recording data. Do not trust your memory to fill in the details at a later time. Organization in your note book is important. Descriptive headings should be used to separate and identify the various parts of the experiment. Record the data in chronological order. A neat, organized and complete record of an experiment is just as important as the experimental work.

1. **Heading:** The experiment identification (number) should beat the top of each page. Your name and date should beat the top of the first page of each day's experimental work.
2. **Objective:** A brief but complete statement of what you intend to find out or verify in the experiment should be at the beginning of each experiment
3. **Diagram:** A circuit diagram should be drawn and labeled so that the actual experiment circuitry could be easily duplicated at any time in the future. Be especially careful to record all circuit changes made during the experiment.
4. **Equipment List:** List those items of equipment which have a direct effect on the accuracy of the data. It may be necessary later to locate specific items of equipment for rechecks if discrepancies develop in the results.
5. **Procedure:** In general, lengthy explanations of procedures are unnecessary. Be brief. Short commentaries alongside the corresponding data may be used. Keep in mind the fact that the experiment must be reproducible from the information given in your notebook.

6. **Data:** Think carefully about what data is required and prepare suitable data tables. Record the instrument readings directly. Do not use calculated results in place of direct data; however, calculated results may be recorded in the same table with the direct data. Data tables should be clearly identified and each data column labeled and headed by the proper units of measure.

7. **Calculations:** Not always necessary but equations and sample calculations are often given to illustrate the treatment of the experimental data in obtaining the results.

8. **Graphs:** Graphs are used to present large amounts of results. Theoretical and experimental results should be on the same graph or arrange in the same table in a way for easy correlation of these results.

9. **Results:** The results should be presented in a form which makes the interpretation easy. Large amounts of numerical results are generally presented in graphical form. Tables are generally used for small amounts laboratory.

10. **Conclusion:** This is your interpretation of the results of the experiment as an engineer. Be brief and specific. Give reasons for important discrepancies.

STUDY OF SCR, TRIAC, DIAC, MOSFET AND IGBT CHARACTERISTICS

SCR, TRIAC, DIAC, MOSFET AND IGBT CHARACTERISTICS STUDY UNIT - CSU

Aim: to study the characteristics of various semiconductor devices namely SCR, IGBT, MOSFET.

Apparatus:

Sl. no	Equipment	Range	quantity
1	SCR, MOSFET, IGBT unit	----	1 no.
2	Ammeter, Voltmeter		
3	Connecting wires		required

Specifications:

1. MAINS   : Power ON/OFF switch to the unit with builtin indicator.

2. VI   : Potentiometer to vary the load voltage

3. ON   : Switch for VI.

4. FUSE   : 600 mA glass fuse for VI

5. + & -   : Positive and Negative points of power supply VI.

6. SCR   : TYN 616

7. TRIAC   : BT 136

8. DIAC   : DB – 3 – 32 Volts breakdown voltage.

9. MOSFET   : IRF 740.

10. IGBT   : IRGBC20S.

11. V2   : Potentiometer to vary the Gate voltage.

12. ON   : Switch for V2.

13. FUSE   : 250 mA Glass fuse.

14. + & -   : Positive and Negative points of power supply V2.

15. R1   : Load potentiometer – 2.5Kohms/25 watts is series with 68 ohm
Resistor.

16. R2   : Gate potentiometer – 10 K ohms/3 watts in series with 250 ohm
Resistor.

FRONT PANEL DETAILS

SCR, TRIAC, DIAC, MOSFET AND IGBT CHARACTERISTICS STUDY UNIT – CSU
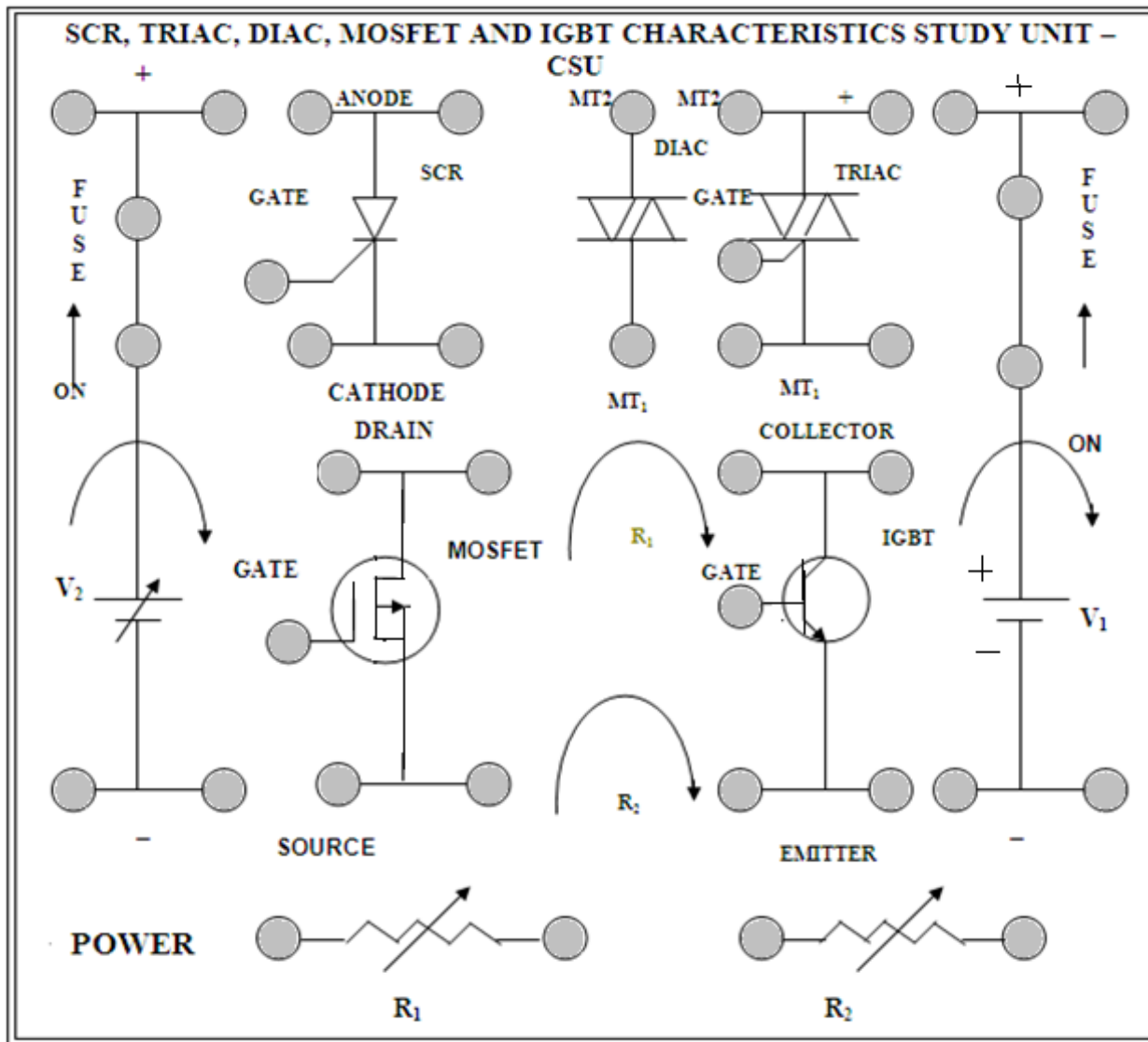
CHARACTERISTICS OF SCR

Circuit Diagram:
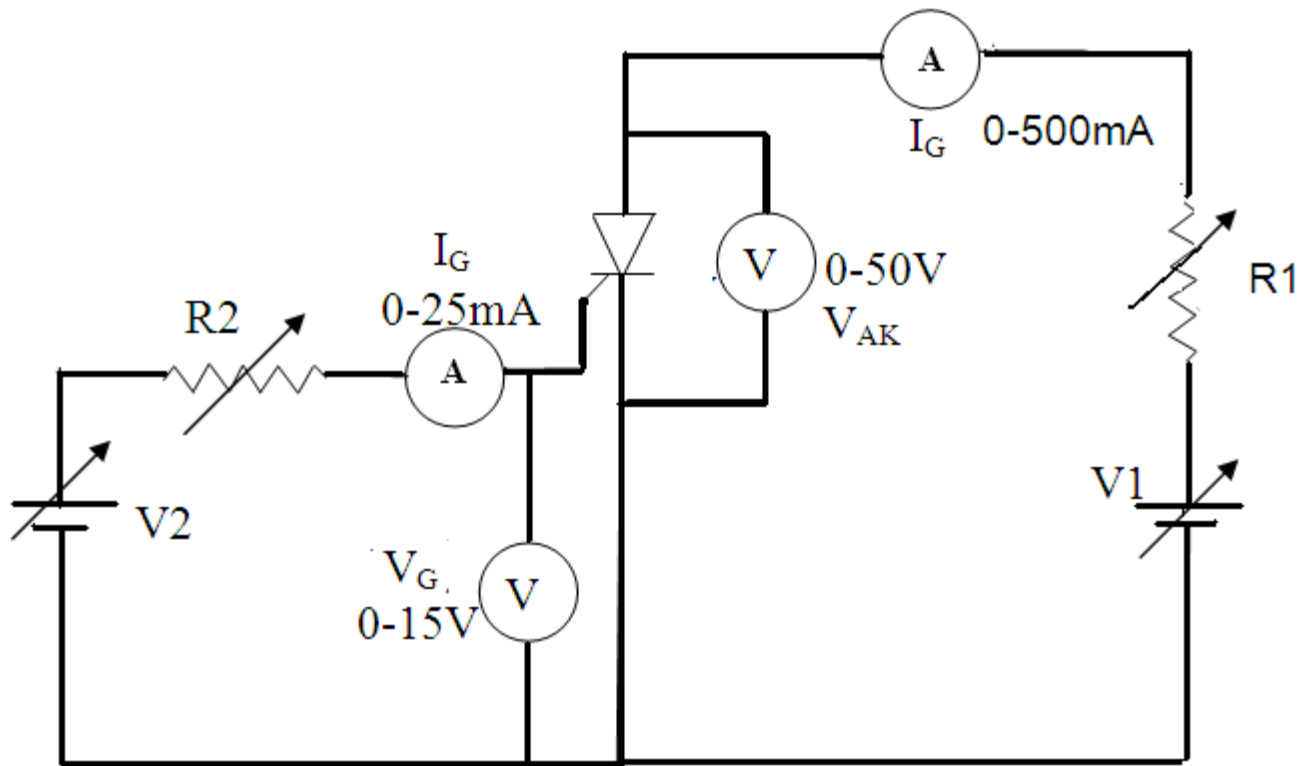
Procedure:

V – I Characteristics:

1. Make the connections as given in the circuit diagram including meters.
2. Now switch ON the mains supply to the unit and initially keep V_1 & V_2 at minimum.
3. Set load potentiometer R_1 in the minimum position
4. Adjust $I_G - I_{G1}$ say 5 mA by varying V2 or gate current potentiometer R_2.
5. Slowly vary V_1 and note down V_{AK} and I_L readings for every 5 Volts and entered the readings in the tabular column.
6. Further vary V_1 till Triac conducts, this can be noticed by sudden drop of V_{AK} and rise of I_L readings note down this readings and tabulated.
7. Vary V1 Further and note down IL and V AK readings. Draw the graph of VAK V/s IL. Repeat the same for IG=IG2 /IG3 and draw the graph

2. To find V_G/I_G :

1. Set V_2 to zero adjust V_{AK} to $V_1 - 10$Volts.

2. Connect voltmeter between V_{GK} points slowly increase V_2 till SCR conducts.

3. Note down the corresponding I_G & V_{AK} values. Repeat the procedure 2-3 times to accurately get the V_G and I_G values.

Table:

$I_G = I_{G1} = $ mA	
V_{AK}	I_A

$I_G = I_{G2} = $ mA	
V_{AK}	I_A

3. To find latching current:

1. Apply about 20 V between Anode and Cathode by varying V1.
2. Keep the load potentiometer R1 at minimum position.
3. The device must be in the OFF state with gate open.
4. Gradually increase Gate voltage - V2 till the device turns ON.
5. This is the minimum gate current (Igmin) required to turn ON the device.
6. Adjust the gate voltage to a slightly higher .
7. Set the load potentiometer at the maximum resistance position.
8. The device should comes to OFF state, otherwise decrease V1 till the device comes to OFF state.
9. The gate voltage should be kept constant in this experiment.
10. By varying R1, gradually increase load current IA in steps.
11. Open and close the Gate voltage V2 switch after each step.
12. If the anode current is greater the latching current of the device, the device stays on even after the gate switch is opened. Otherwise the device goes into blocking mode as soon as the gate switch is opened.

13. Note the latching current. Obtain the more accurate value of the latching current by taking small steps of IA near the latching current value.

4. To find Holding current:

1. Increase the load current from the latching current level by load pot R1 or V1.
2. Open the gate switch permanently. The Thyristor must be fully ON.

3. Now start reducing the load current gradually by adjusting R1. If the SCR does not turns OFF even after the R1 at maximum position, then reduce V1.
4. Observe when the device goes to Blocking mode. The load current through the device at this instant, is the holding current of the device.
5. Repeat the steps again to accurately get the Ih. Normally Ih < Il.

Model graph:
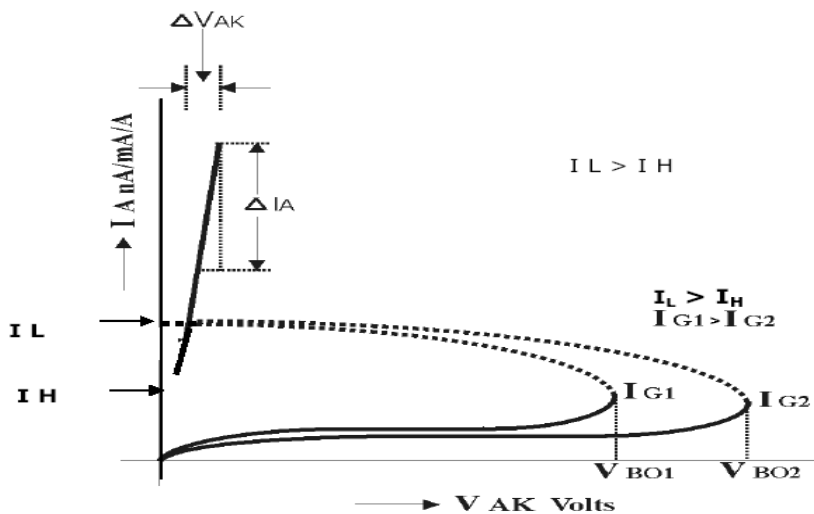
Characteristics of TRIAC

Circuit diagram:
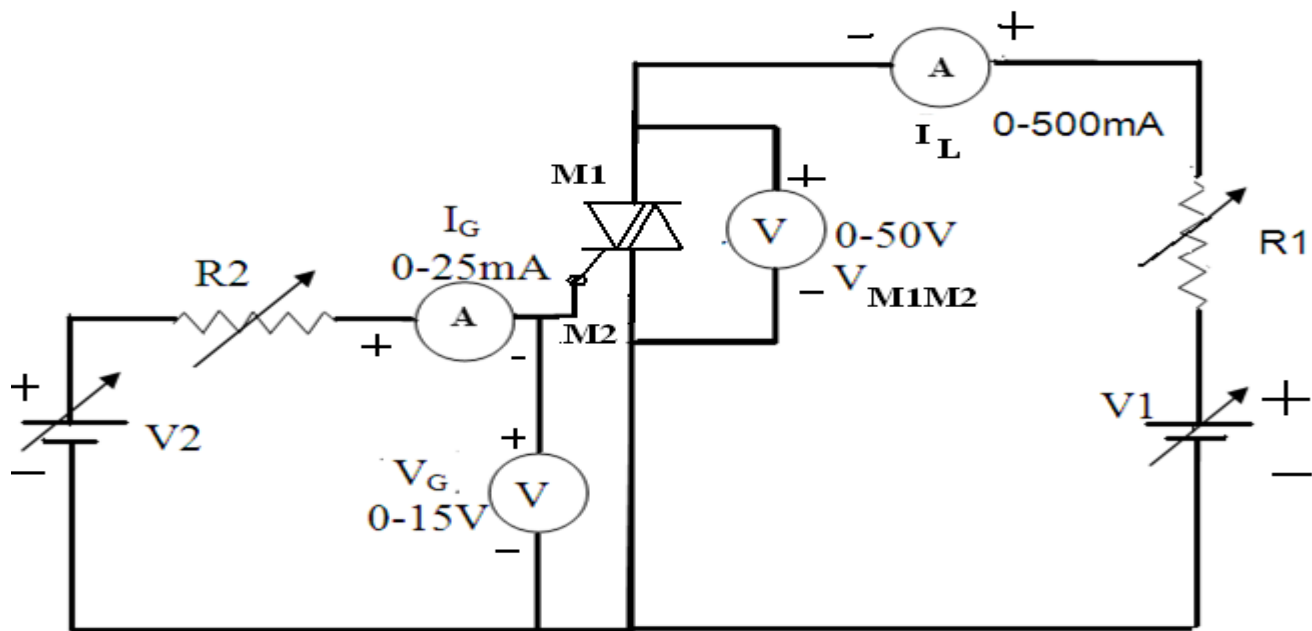
Procedure:

1. V – I Characteristics:

1. Make the connections as given in the circuit diagram including meters.

2. Now switch ON the mains supply to the unit and initially keep V1 &V2 at minimum.

3. Set load potentiometer R1 in the minimum position.

4. Adjust IG –IG1 say 10 mA by varying V2 or gate current potentiometer R2.

5. Slowly vary V1 and note down V T2 T1 and IL readings for every 5 Volts and entered the readings in the tabular column.

6. Further vary V1 till Triac conducts, this can be noticed by sudden drop of V T2 T1 and rise of IL readings note down this readings and tabulated.

7. Vary V1 Further and note down IL and V T2 T1 readings. Draw the graph of VT2 T1 V/s IL. Repeat the same for IG=IG2 /IG3 and draw the graph.

2. To find VG/IG :

1. Set V2 to zero adjust V T2 T1 to V1 – 10Volts.

2. Connect voltmeter between VG T1 points slowly increase V2 till TRIAC conducts.

3. Note down the corresponding IG & VG values. Repeat the procedure 2-3 times to accurately get the VG and IG values.

Table:

$I_G = I_{G1} = $ mA	
V_{M1M2}	I_L

$I_G = I_{G2} = $ mA	
$V_{M2\,M1}$	I_L

3. To find latching current:

1. Apply about 20 V between MT2 and MT1 by varying V1.

2. Keep the load potentiometer R1 at minimum position. The device must be in the OFF state with gate open.

3. Gradually increase Gate voltage - V2 till the device turns ON. This is the minimum gate current (Igmin) required to turn ON the device.

4. Adjust the gate voltage to a slightly higher . Set the load potentiometer at the maximum resistance position.

5. The device should comes to OFF state, otherwise decrease V1 till the device comes to OFF state.

6. The gate voltage should be kept constant in this experiment. By varying R1, gradually increase load current IA in steps.

7. Open and close the Gate voltage V2 switch after each step.

8. If the anode current is greater the latching current of the device, the device stays on even after the gate switch is opened.

9. Otherwise the device goes into blocking mode as soon as the gate switch is opened.

10. Note the latching current. Obtain the more accurate value of the latching current by taking small steps of IA near the latching current value.

11. Increase the load current from the latching current level by load pot R1 or V1.

12. Open the gate switch permanently. The Triac must be fully ON. Now start reducing the load current gradually by adjusting R1. If the Triac does not turns OFF even after the R1 at maximum position, then reduce V1.

13. Observe when the device goes to Blocking mode. The load current through the device at this instant, is the holding current of the device. Repeat the steps again to accurately get the Ih. Normally Ih < IL.

Model graph:
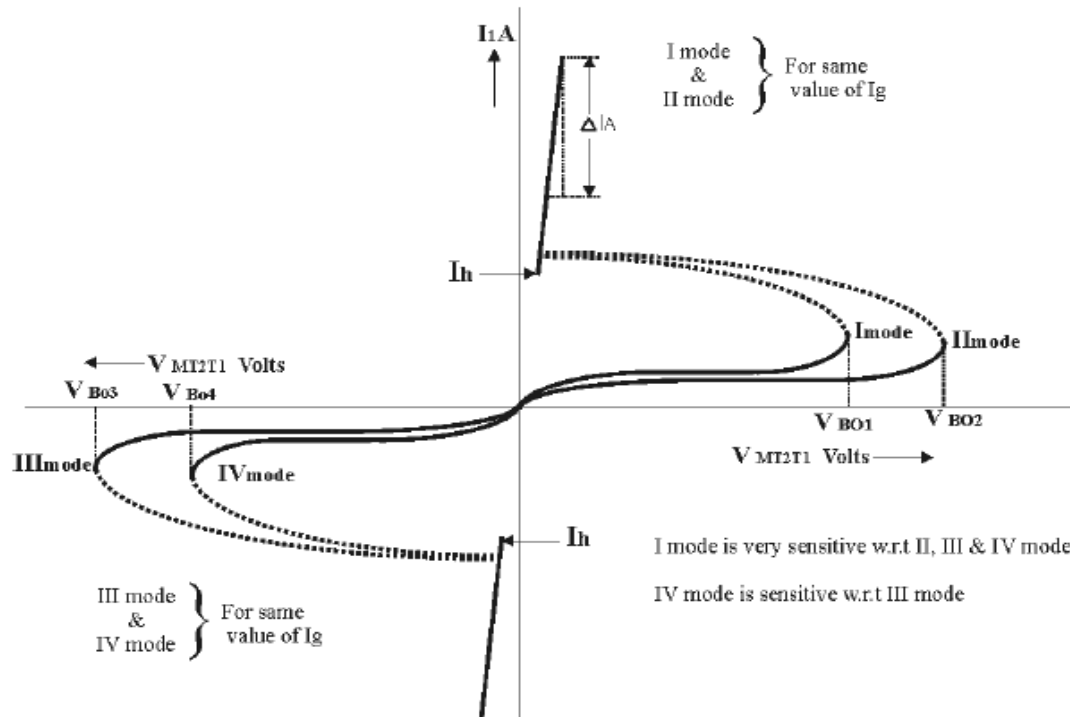
Characteristics of MOSFET

Circuit diagram:
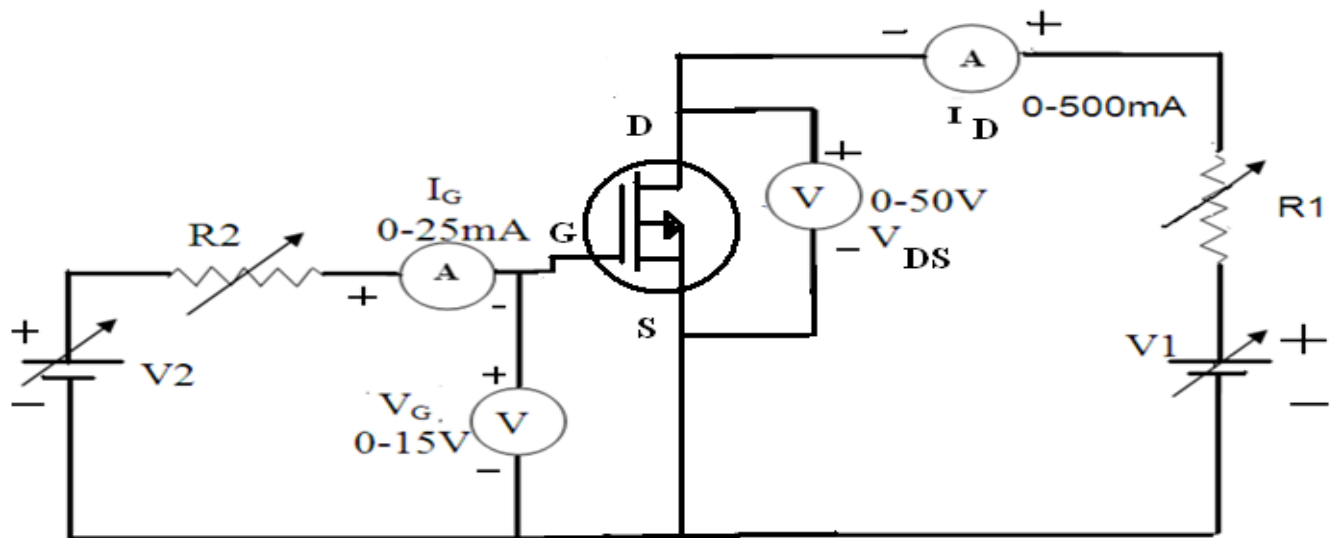
Procedure:

Trans Conductance Characteristics:-

1. Make the connections as shown in the circuit diagram with meters.
2. Initially keep V1 and V2 zero. Set V1= VDS1= say 10V.Slowly vary V2(VGS) and note down ID and VGS readings for every 0.5 Volts. and enter in the tabular column.

3. The minimum gate voltage VGS which is required for conduction to start in the MOSFE is called Threshold Voltage VGS(Th).

4.   If VGS is less than VGS (Th) only very small leakage current flows from Drain to Source.

5. If VGS is greater than VGS(Th), the Drain current depends on magnitude of the Gate Voltage. VGS varies from 2 to 5Volts.
6. Repeat the same for different values of VDS and draw the graph of I D V/S VGS.

Tabular column:

V1 = V$_{DS1}$ = 10 Volts.		V1 = V$_{DS2}$ = 30 Volts	
V$_{GS}$ Volts	I$_D$ ma	V$_{GS}$ Volts	I$_D$ ma

Drain characteristics:

1. Initially set V2 to VGS1= 3.5 Volts.
2. Slowly vary V1 and note down ID and VDS. For a Particular value of VGS1 there is a pinch off voltage (Vp) between drain and source as Shown in figure.
3. If VDS is lower than Vp, the device works in the constant resistance region and ID is directly proportional to VDS. If VDS is more than Vp, constant ID flows from the device and this operating region is called constant current region.
4. Repeat the above for different values of VGS and note down ID V/S VDS.
5. Draw the graph of I D V/S VDS for different values of VGS.

Tabular column:

V2 = V$_{GS}$ = 3.5 Volts		V2 = V$_{GS}$=3.8 Volts	
V$_{DS}$ Volts	I$_D$ ma	V$_{DS}$ Volts	I$_D$ ma

Model Graphs:

transconductance characteristics

Drain characteristics

$V_{GS} = 3.6V$

$V_{GS} = 3.55V$
$V_{GS} = 3.5V$
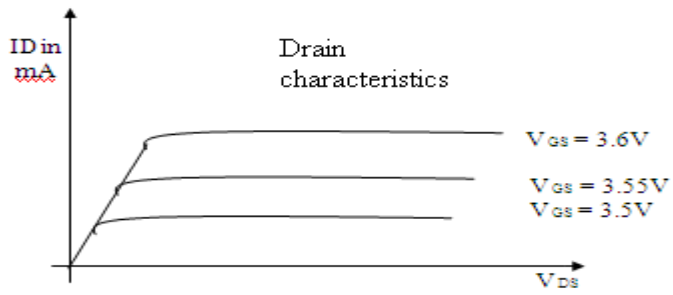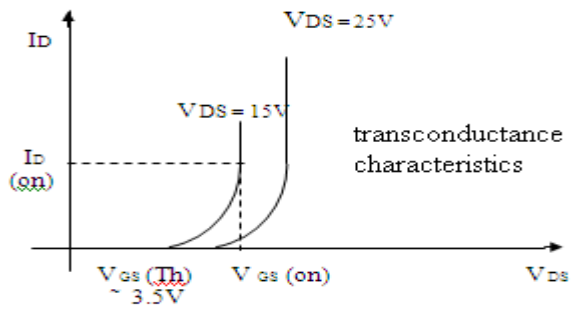
Characteristics of IGBT

Circuit diagram:
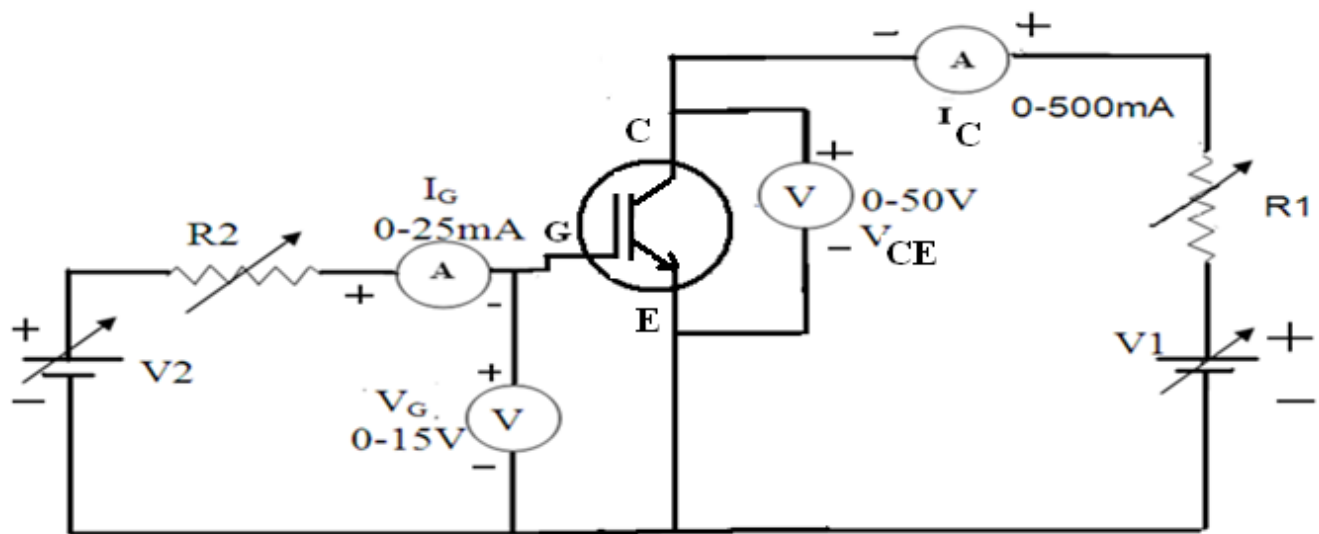
Procedure:

Transfer Characteristics :-

1. Make the connections as shown in the circuit diagram with meters.
2. Initially keep V1 and V2 zero. Set V1= VCE1= say 10V.Slowly vary V2 (VGE) and note

   down IC and VGE readings for every 0.5 Volts. and enter in the tabular column.
3. The minimum gate voltage VGE which is required for conduction to start in the IGBT

   is called Threshold Voltage VGE(Th).
4. If VGE is less than VGE (Th) only very small leakage current flows from Collector to Emitter.
5. If VGE is greater than VGE(Th), the Collector current depends on magnitude of the Gate

   Voltage. VGE varies from 5 to 6Volts.
6. Repeat the same for different values of Vc and draw the graph of Ic V/S VGE.

Table:

V1= VCE1 = 10 Volts.		V1 = VCE2 = 30 Volts	
V GE Volts	ID ma	VGE Volts	ID ma

Collector   Characteristics :-

1. Initially set V2 to VGE1= 5 Volts. Slowly vary V1 and note down IC and VGE.
2. For a Particular value of VGE1 there is a pinch off voltage (Vp) between Collector and Emitter as Shown in figure.
3. If VGE is lower than Vp, the device works in the constant resistance region and IC is directly proportional to VGE.
4. If VGE is more than Vp, constant IC flows from the device and this operating region is called constant current region.
5. Repeat the above for different values of VGE and note down IC V/S VGE
6. Draw the graph of I C V/S VGE for different values of VGE.

Table:

V1= VCE1 = 10 Volts.		V1 = VCE2 = 30 Volts	
V GE Volts	ID ma	VGE Volts	ID ma

Model graph:

Transfer characteristics: $V_{CE} = 25V$, $V_{CE} = 15V$, with I_C, $I_C(on)$, $V_{CE}(Th) \sim 5V$, $V_{CE}(on)$, V_{CE} axes.

Collector characteristics: I_C in mA vs V_{CE} for $V_{GE} = 5.25V$, $V_{GE} = 5.2V$, $V_{GE} = 5.15V$, $V_{GE} = 5.1V$.
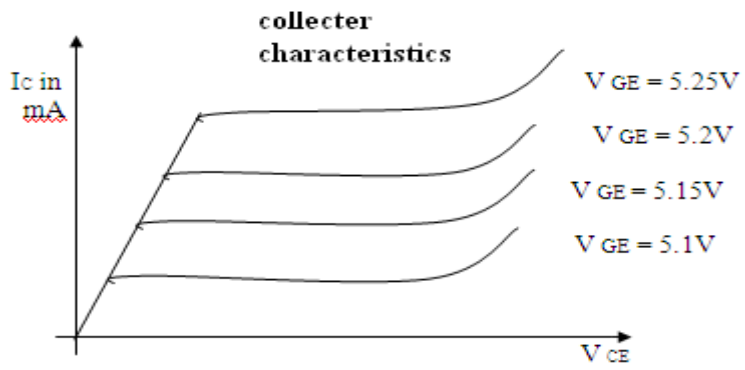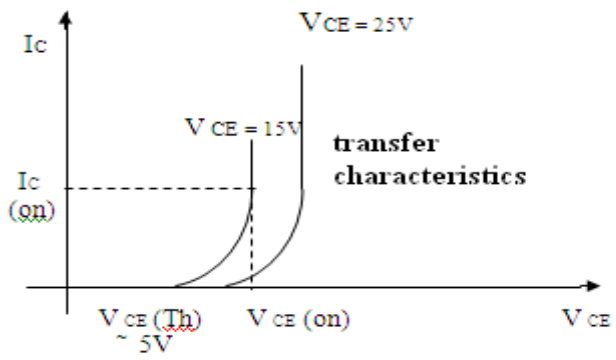
SERIES INVERTER

AIM:

To study the module

To obtain variable AC from DC ripple input and

To obtain the waveforms of a 1-Φ series inverter power circuit with R and RL loads

Apparatus

Sl. no	Equipment	range	quantity
1	1-Φ series inverter firing circuit and power circuit units		1 no
2	DC power supply -30V/2A (Single)		
3	Loading rheostat	50Ω, 2A	1 no
4	Loading Inductor:	50mH	1 no
5	20MHz dual trace oscilloscope with 1:10BNC probes (CRO)		1 no
6	Meters		
7	Connecting wires		required

Specifications:

1. Input: 230V, 1- Φ AC supply.

2. Load: R and RL

3. Thyristers: 12A, 600V type TYN 616

4. Diodes: 4A, 200V type BYW 51-200

5. Capacitors (C1 & C1') :6.8uF, 100V

6. Capacitors (C2 & C2') 10uF, 100V

7. Inductor: 10mh-5mH-0-5mH, 2A

8. MCB   : two pole 230V/ 16A

9. Fuses :16 A Glasstube

Circuit diagram:
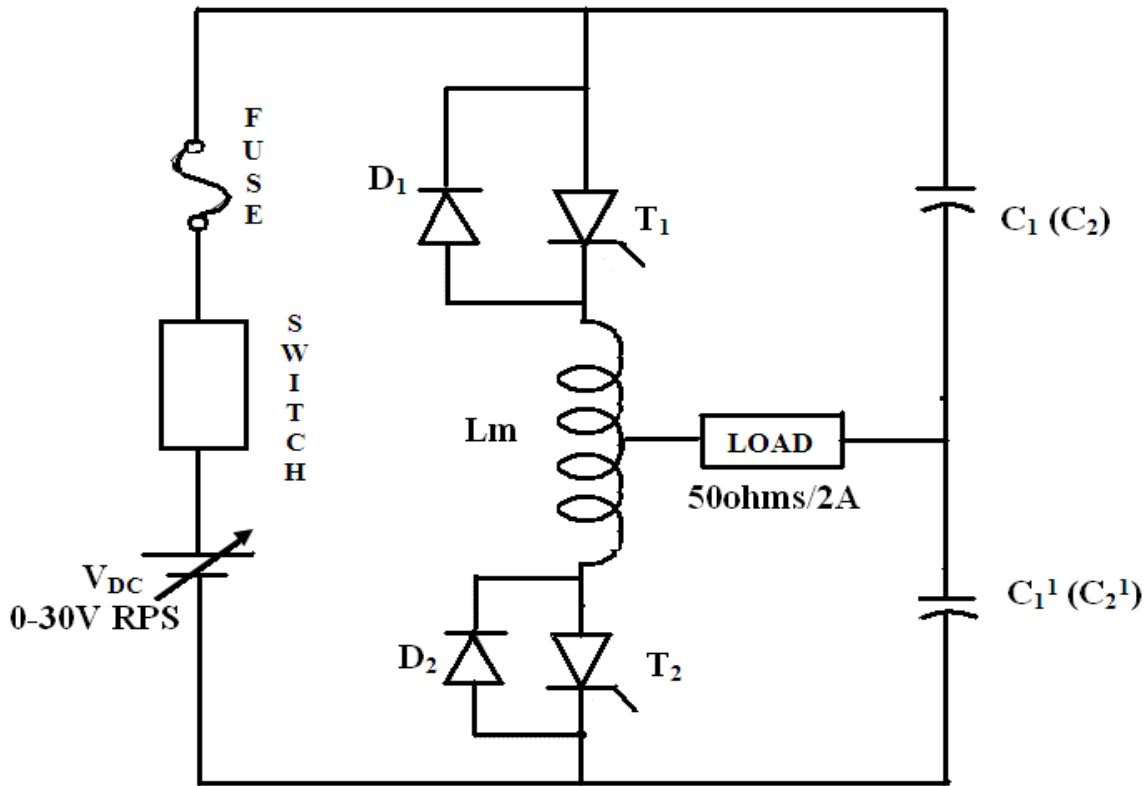
Procedure:

1. Switch ON the mains supply to the firing circuit. Observe the trigger outputs in the firing circuit. Make sure the firing pulses are proper before connecting to the power circuit.

2. Make the connections as per the circuit diagram.

3. Connect the firing pulses from the firing circuit to the respective SCRs in the power circuit.

4. Connect the DC input from the 30V/2A regulated power supply.

5. Switch ON the DC supply and now switch On the trigger pulses by operating ON/OFF switch in the firing circuit.

6. Observe the voltage waveform waveform across load using oscilloscope.

7. Vary the frequency and observe the waveforms. If the inverter frequency increases above the resonant frequency of the power circuit, commutation process will fail. Then switch OFF the DC supply and trigger pulses, reduce the inverter frequency and try again. If it fails again, check the fuses in series with the device and try again.

8. Repeat the same for different values of L, C and Load.

9. Observe the voltage waveforms in the graph at different frequencies.

10. And also observe the waveforms with and without fly wheel diodes. The output waveform is entirely depending on load.

11. To switch OFF the inverter, switch OFF the input first and then trigger pulses.

Resonant frequency:

$$fr = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

L=

C=

R=

Model waveforms
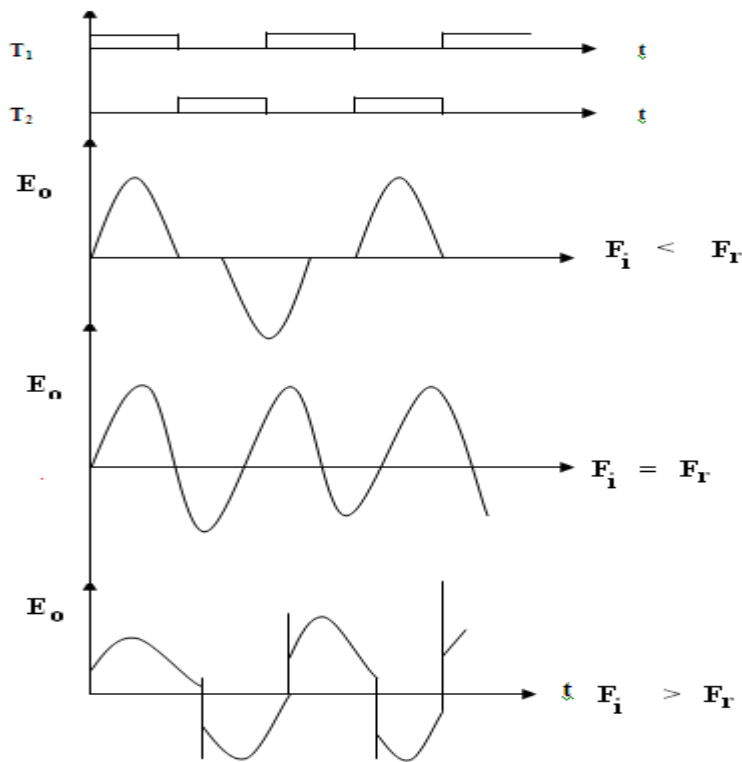
Waveforms at various conditions of the Inverter

Precautions:

1. Make sure all the connections links are tightly fixed

2. Ensure all the controlling knobs in fully counterclockwise position before starting experiment.

3. Handle everything with care

4. Make sure the firing pulses are proper before connecting to the power circuit.

5. Make sure to connect firing pulses from the firing circuit to their respective SCR's in the power circuit.

6. Ensure to switch OFF the supply first and then trigger pulses.

Result: The characteristics, waveforms are observed.

JONES CHOPPER

JONES CHOPPER

AIM:

1. To study the module
2. To obtain variable AC from DC ripple input and
3. To obtain the waveforms of a 1-Φ series inverter power circuit with R and RL loads

Apparatus:

Sl. no	Equipment	range	quantity

1	chopper firing circuit and power circuit units		1 no.
2	DC power supply -30V/2A (Single)		1 no.
3	Loading rheostat:	50Ω, 2A	1 no
4	Loading Inductor:	50mH	1 no
5	20MHz dual trace oscilloscope with 1:10BNC probes (CRO)		1 no
6	Meters		
7	Connecting wires		required

SPECIFICATIONS:

30V @ 2 Amps.

FRONT PANEL DETAILS:

1. VDC IN   :   Terminal to connect DC input 10V to 30V DC

2. ON   :   ON/OFF switch for the input DC supply to the power circuit

3. FUSE   :   In series with the DC input for short circuit protection – 2Amps

4. T1 & T2   :   SCR's – TYN 616-10A/600V

5. D1 & D2   :   Diodes – BYQ 28- 200.4A/200V

6. C   :   Commutation Capacitor – 6.8□F / 100V.

7. L1 –LM- L2   :   Commutation Inductor 500-0-500 Micro henry / 2Amps

FRONT PANEL VIEW:
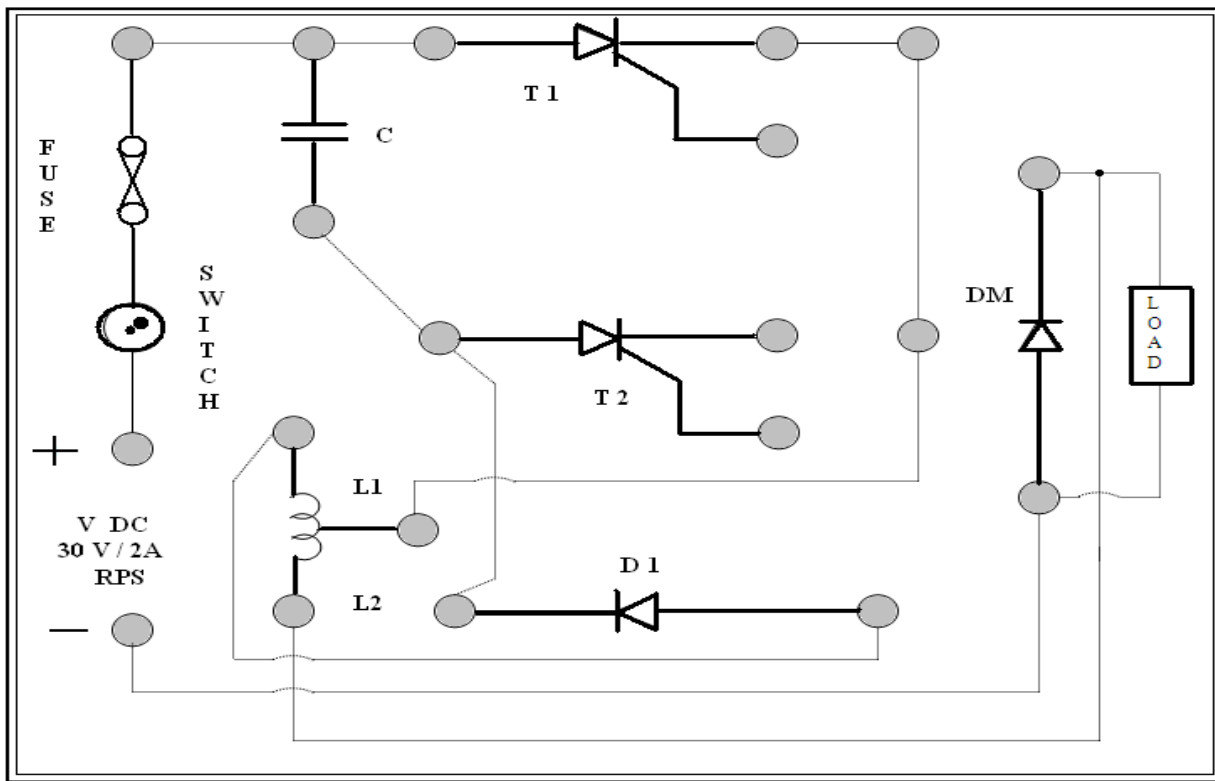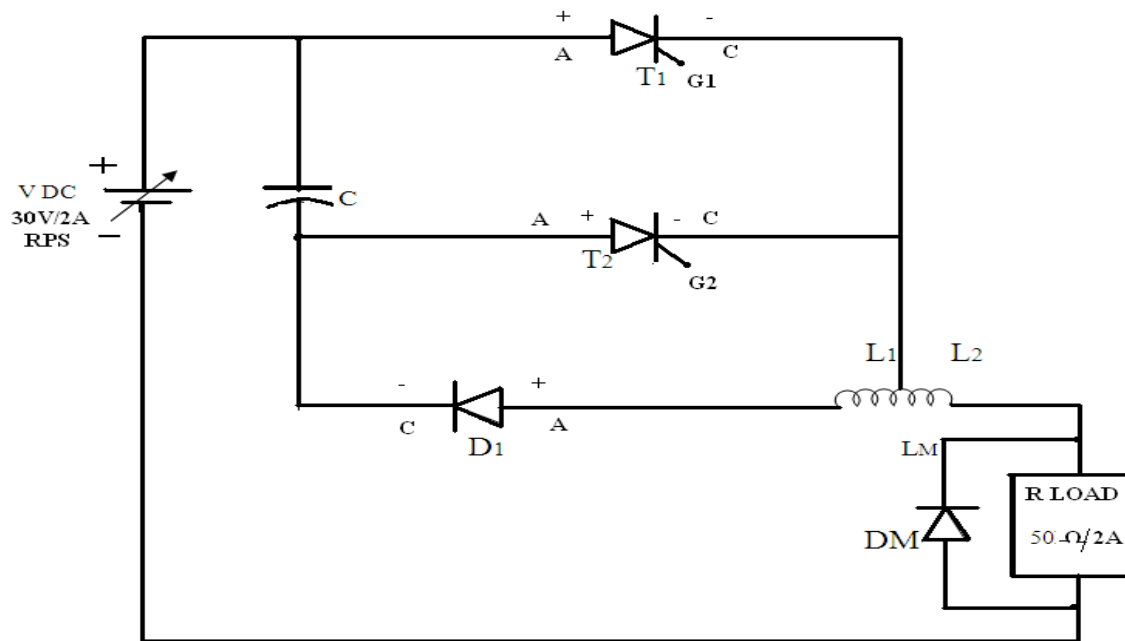
Circuit Diagram:

Procedure:

1. Make the connections as per the circuit diagram.

2. Switch ON the mains supply to the firing circuit. Observe the trigger outputs in the firing circuit. Make sure the firng pulses are proper before connecting to the power circuit..

3. Connect the firing pulses from the firing circuit to the respective SCRs in the power circuit.

4. Connect the DC input from the 30V/2A regulated power supply.

5. Switch ON the the Dc supply, set to 15 V and switch ON the trigger pulses by operating ON/OFF switch in the firng circuit.

6. Observe the voltage waveform waveform across load using oscilloscope.

7. Vary the frequency (duty cycle) and observe the voltage waveforms across the load with and without freewheeling diode.

8. Observe the voltage waveforms in the graph at different frequencies.

9. Draw the waveforms in the graph at different frequencies.

10. To switch OFF the inverter, switch OFF the input first and then trigger pulses.

11. Since the parallel inverter works on forced commutation, there is a chance of commutation failure. If the commutation fails, switch OFF the DC supply and then trigger outputs. Check the connections and try again.

Table:

Sl no.	Vin	Ton	Toff	Duty cycle	Vo	Io

Precautions:

1. Make sure all the connections links are tightly fixed

2. Ensure all the controlling knobs in fully counterclockwise position before starting experiment.

3. Handle everything with care

4. Make sure the firing pulses are proper before connecting to the power circuit.

5. Make sure to connect firng pulses from the firing circuit to their respective SCR's in the power circuit.

6. Ensure to switch OFF the supply first and then trigger pulses.

Model waveforms:

Result:

PARALLEL INVERTER

PARALLEL INVERTER

Aim: To study the module

To obtain variable AC from DC ripple input and

To obtain the waveforms of a 1-Φ series inverter power circuit with R and RL loads

Apparatus:

Sl. no	Equipment	range	quantity
1	1 –phase parallel inverter firing circuit and power circuit units		1 no.
2	DC power supply -30V/2A (Single)		1 no.
3	Loading rheostat:	50Ω, 2A	1 no
4	Loading Inductor:	50mH	1 no
5	20MHz dual trace oscilloscope with 1:10BNC probes (CRO)		1 no
6	Meters		

7	Connecting wires		required

Specifications:

1. Frequency : Potentiometer to vary the inverter frequency from 75 Hz to

to 200 Hz approximately.

2. ON/OFF : Switch for trigger outputs.

3. T1 & T2 : Trigger outputs.

4. Power : Mains switch for firing circuit.

5. Vdc in : Terminals for DC input

6. ON : Switch for DC input.

7. Tp & Tn : SCR's 10A/600V

8. Dp & Dn : Diodes 10A/600V

9. L : Inductance – 300mH / 2 A

10. C : 6.8 μF / 100V

11. Load : Terminals to connect load.

12. O : Transformer center tap point which should be connected to

positive of DC supply after fuse.

13. Fuse : 2A Glass fuse.

14. Output Transformer : - Primary - 30V-25V-0-25V-30V.

Secondary – 0-30V/2Amps.

Front panel view:
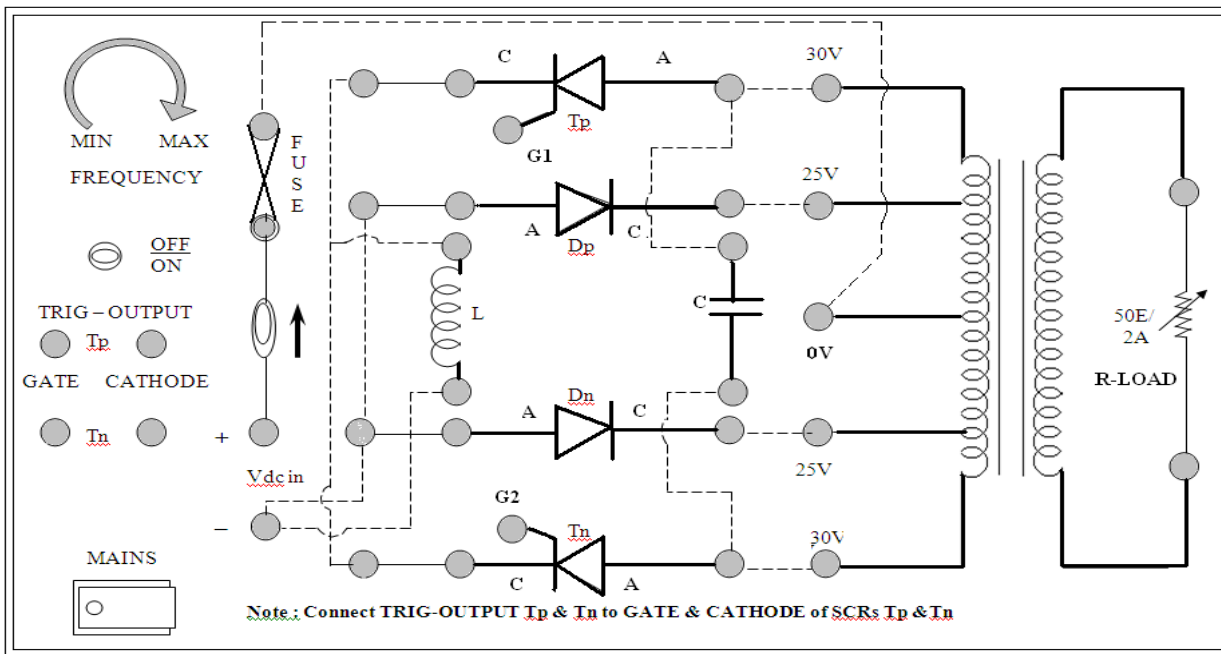
Circuit Diagram:
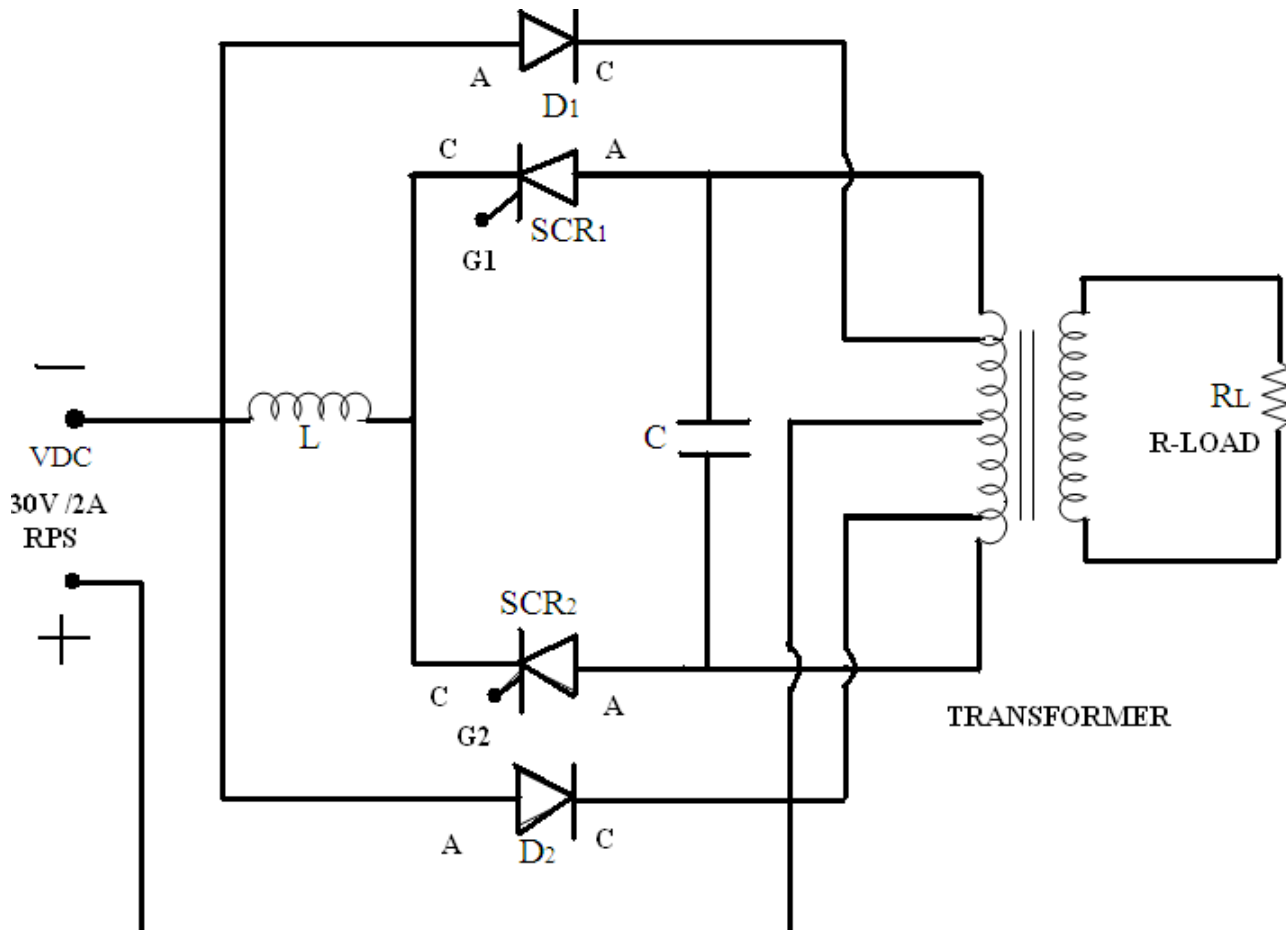
Procedure:

1) Switch on the firing circuit. Observe the trigger outputs TP and TN by varying frequency potentiometer and by operating ON/OFF switch.

2) Then connect input DC supply to the power circuit.

3) Connect trigger outputs to Gate and Cathode of SCR TP & TN.

4) Make the interconnections as shown in circuit diagram.

5) Connect load between load terminals.

6) Connect freewheeling diode in the circuit.

7) To begin with set input voltage to 15V. Apply trigger pulses to SCR and

   observe voltage waveforms across load.

8) Output voltage is square wave only. Then remove freewheeling diode connections

   and observe the waveforms.

9) Then vary the load, vary the frequency and observe waveforms. To switch OFF the inverter switch OFF DC input supply only. Switch OFF the trigger pulses will lead to short circuit.

10) Since the parallel inverter works on forced commutation, there is a chance of commutation failure.

11) **If the commutation fails, there is a dead short circuit in the input DC supply, which will leads to the blown off the input fuse.** Please check the fuse if the commutation fails. Preferably connect the input DC supply from the 30V/2A regulated DC power supply unit which has over current tripping facility thereby protect the DC supply unit

12) If the commutation fails, switch off the DC supply first and then trigger Outputs. Check the connections again.

Precautions:

1. Make sure all the connections links are tightly fixed

2. Ensure all the controlling knobs in fully counterclockwise position before starting experiment.

3. Handle everything with care

4. Make sure the firing pulses are proper before connecting to the power circuit.

5. Make sure to connect firng pulses from the firing circuit to their respective SCR's in the power circuit.

6. Ensure to switch OFF the supply first and then trigger pulses.

MODEL WAVEFORMS:

TRIGGER OUTPUTS
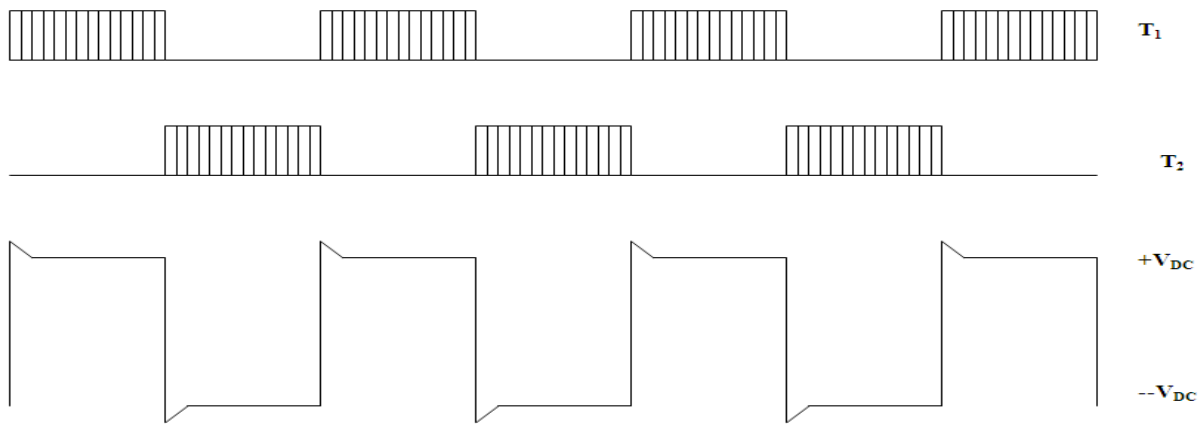
OUTPUT

Result: the characteristics and waveforms are studied.

Result:

SINGLE PHASE AC VOLTAGE CONTROLLER WITH R AND RL LOAD

SINGLE PHASE AC VOLTAGE CONTROLLER WITH R AND RL LOAD

Aim: To study the module and waveforms of a 1- Φ AC voltage controller with R and RL loads.

Apparatus:

Sl. no	Equipment	range	quantity
1	1-Φ AC voltage controller		
2	DC power supply -30V/2A (Single)		
3	Loading rheostat:	50Ω, 2A	1 no
4	Loading Inductor:	50mH	1 no
5	20MHz dual trace oscilloscope with 1:10BNC probes (CRO)		
6	Meters		
7	Connecting wires		required

Specifications:

1 .   Input   0-230V 1 – phase AC supply.

2.   Load   R and RL.

3.   Thyristors   12A, 600V.

4.   Triacs   10A, 600V.

5.   MCB   Two pole 230V/16A.

6.   Fuses   16A   HRC.

Circuit Diagram::

USING SCRS: -
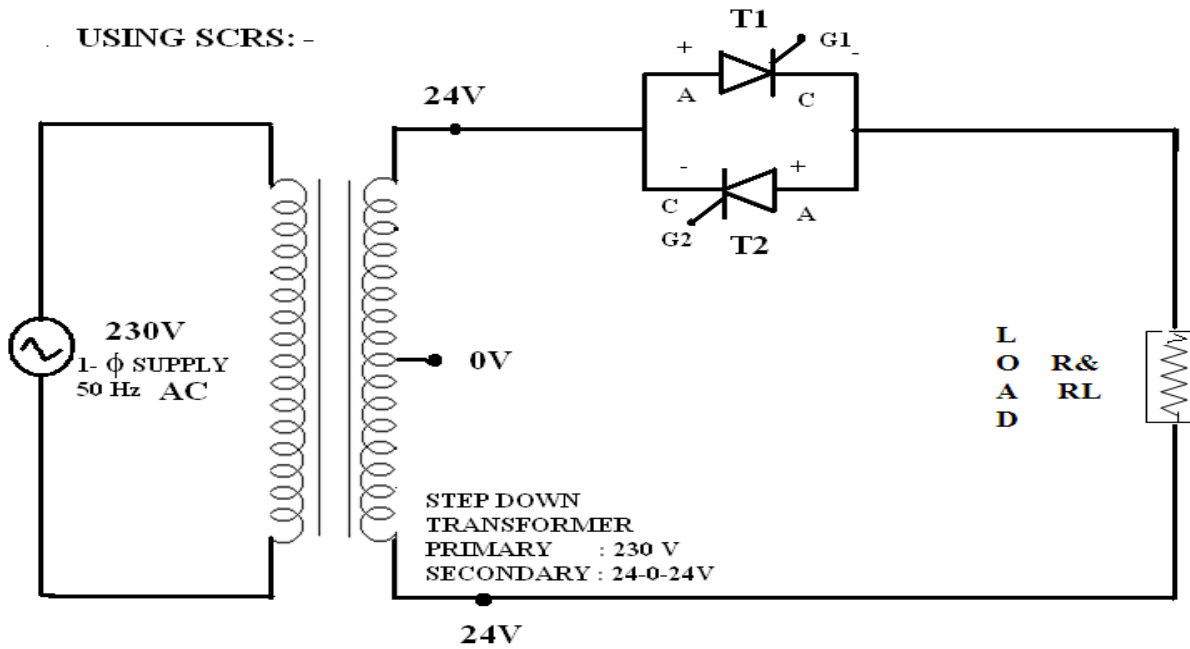
USING TRIAC
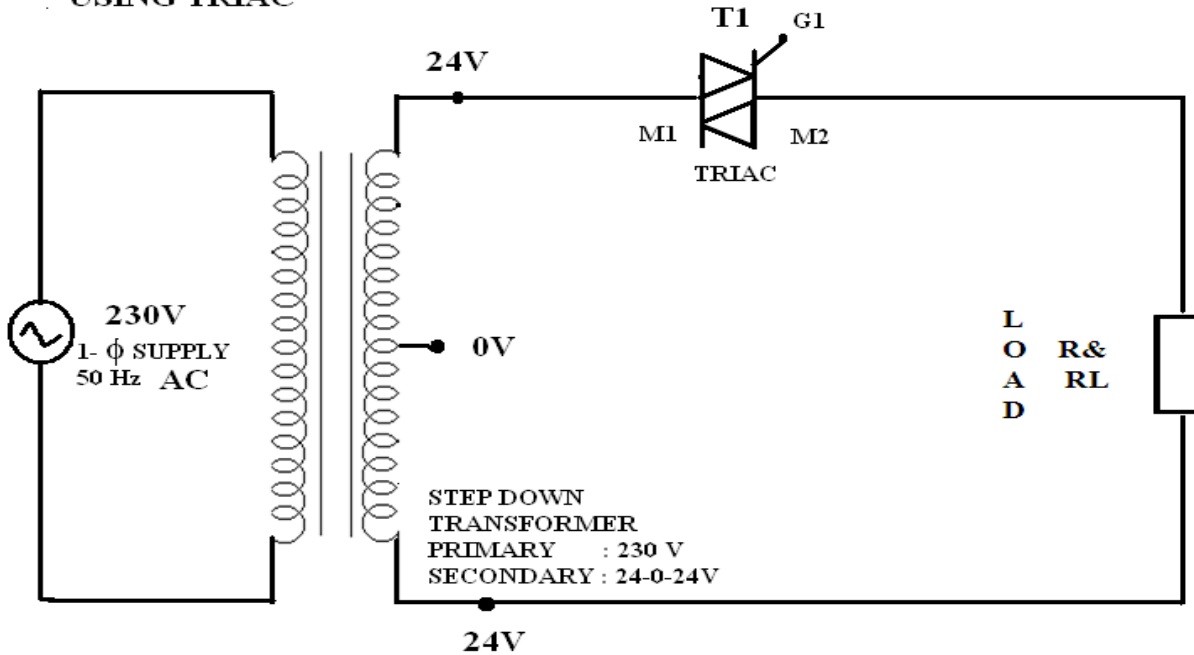
Procedure:

1. Switch ON the mains supply to the firing circuit. Observe the trigger outputs by varying firing angle potentiometer and by operating ON/OFF and SCR/TRIAC selector switch. Make sure the firing pulses are proper before connecting to the power circuit.

2. Make the connections as per the circuit diagram.

3. Connect firing pulses from the firing circuit to the corresponding SCRs/ TRIAC in the power circuit.

4. Switch ON the step down transformer supply (MCB) and now switch ON the trigger pulses by operating ON / OFF switch in the firing circuit.

5. Observe the output voltage waveforms across load using oscilloscope.

6. Note down the input voltage, firing angle and output voltage readings in the tabular column.

7. Draw the waveforms in the graph at 0, 45, 90, 135 and 180 Deg. Firing angles.

   NOTE: - If there is no output even after all the proper connections, switch OFF the
           Supply and just interchange the connections at step down transformer
           terminals. This is to make the power circuit and firing to synchronize.

Precautions:

1. Make sure all the connections links are tightly fixed

2. Ensure all the controlling knobs in fully counterclockwise position before starting experiment.

3. Handle everything with care

4. Make sure the firing pulses are proper before connecting to the power circuit.

5. Make sure to connect firng pulses from the firing circuit to their respective SCR's in the power circuit.

6. Ensure to switch OFF the supply first and then trigger pulses.

Table:

Sl no	Input voltage	Firng angle	output voltage

Model waveforms:
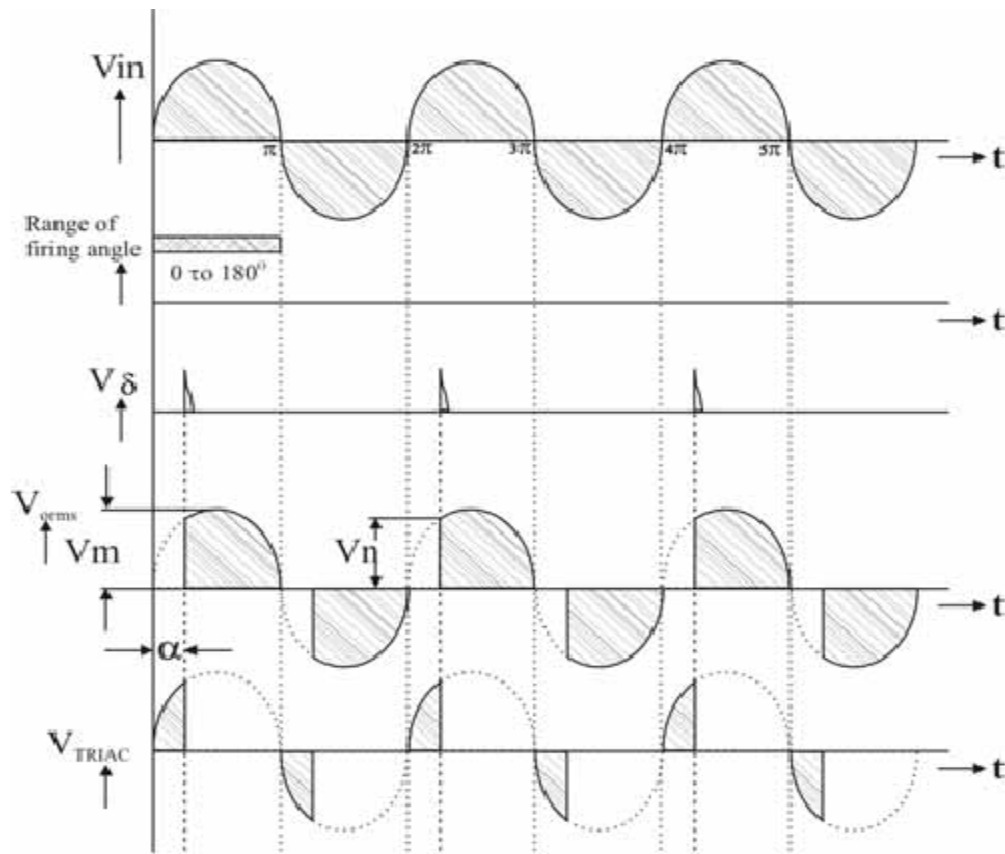
Where α = firing angle

Result:

SINGLE PHASE FULLY CONTROLLED BRIDGE CONVERTER WITH R AND RL LOAD

SINGLE PHASE FULLY CONTROLLED BRIDGE CONVERTER WITH R AND RL LOAD

Aim: To study the module and waveforms of a 1- Φ Full Bridge Converter with R, RL and RLE Loads.
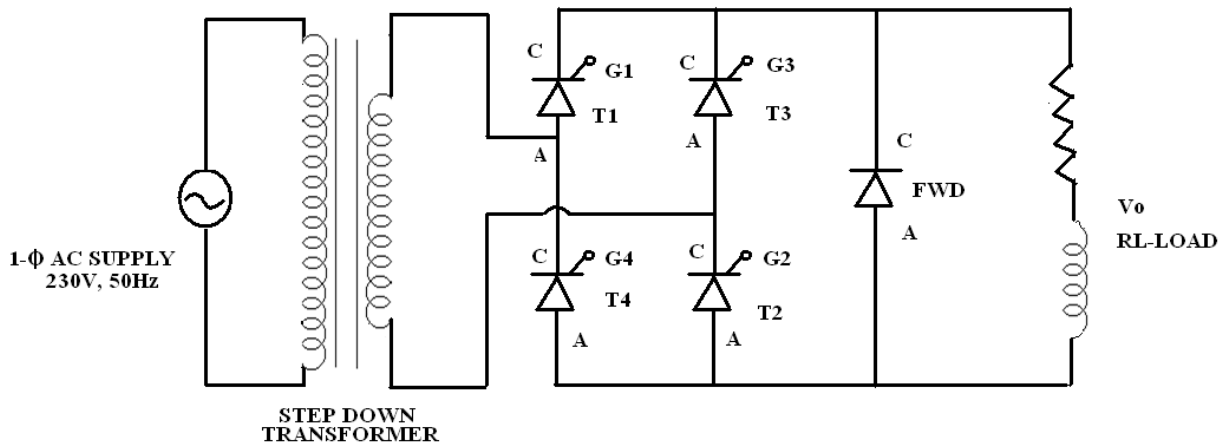
Apparatus:

Sl no	equipment	Range	type	quantity
1	1- Φ full bridge converter firing circuit and power circuit units.			
2	1- Φ Isolation transformer 230V/230V.			
3	Loading Rheostat :50 Ohms, 2A.			
4	Loading Inductor 50 mH.			
5	20 MHz dual trace oscilloscope with 1: 10 BNC pobes.			

6	Single phase converter firing circuit			
7	Connecting wires			

Specifications:

Input Voltage	:	15V to 230 V AC.
Load current	:	5 Amps maximum..
Fuses	:	6 amps fast blow glass fuses.
Field supply	:	2 Amps / 220V + 10 %
MCB	:	two pole 6 amps / 230V.
T1, T1^1, T2, T2^1,	:	SCR - 25 TTS 12 - 25 A rms / 1200Volts
DM	:	Freewheelingdiode - SPR16PB - 16A/1200V

Circuit diagram:

Procedure:

1. Switch ON the Mains Supply to the Firing circuit.
2. Observe all the test points by varying the firing angle using potentiometer and trigger o/Ps ON/OFF switch.

3. Then observe the trigger o/p s and phase sequence.
4. Make sure that all the trigger o/p s are proper before connecting to the power circuit.
5. The trigger o/p pulse width varies as we vary the firing angle.
6. Next make the connections in the power circuit.
7. Connect 30V tapping of the transformer secondary to the power circuit.
8. Connect the R-load between load points.
9. Connect firing pulses from the firing circuit to the respective SCR's in the power circuit.
10. Switch ON the MCB, switch ON the trigger o/ps and note down the voltage wave forms across load and devices.
11. Draw the waveforms across load and device for different firing angle.
12. Repeat the same for different input voltage up to maximum voltage as provided in the isolation transformer.
13. Repeat the same for R-L load with and without freewheeling diode and note down the waveform.

NOTE: - If the output is zero after all proper connections, switch off the MCB. Switch off the AC supply to the Isolation transformer. And just interchange the AC input connections in the power circuit. This is to make the firing circuit and the power circuit to synchronize.

TABULAR COLUMN

R-L LOAD WITH OUT FREE WHEELING DIODE

SL NO	Input Voltage- Vin	Firing angle	Output voltage	Output Current	Calculated o/p Voltage (Volts) Vo

R-L LOAD WITH FREE WHEELING DIODE

SL NO	Input Voltage- Vin	Firing angle	Output voltage	Output Current	Calculated o/p Voltage (Volts) Vo

Precautions:

1. Check all the SCRs for performance before making the connections.

2. Check the firing circuit trigger outputs and its relative phase sequence.

3. Make fresh connections before you make a new experiments.

4. Preferably work at low voltages (20 – 30V) for every new connections after careful verification it can be raised to the maximum ratings. (This is to reduce damages due to wrong connections and high starting current problems)

5. The thyristor has a very low thermal inertia as compared to machine and by any over load or short circuit the SCR will immediately get damaged. Therefore do not switch ON the supply until the instructor has checked the connections.

6. While observing the wave forms of two parameters on the oscilloscope, either differential input oscilloscope should be used or special differential probes should be used with normal oscilloscope. On normal oscilloscope observation of wave forms can be done with respect to single common point only. Ground connections of other probe must be avoided. It will lead to short circuit if ground connections of both the probes are used since they are internally shorted. In no case should oscilloscope input ground point be disconnected. This is a dangerous practice. Use 10:1 oscilloscope probe to see the wave forms at high voltages.

7. Do not make Gate & Cathode measurements when the power circuit is on.

8. Make sure all the connecting links are tightly fixed.

9. Ensure all the controlling knobs in fully counterclockwise position before starting experiment.

10. Handle everything with care.

11. Make sure the firing pulses are proper before connecting to the power circuit.

12. If the output is zero even after all power connections, switch OFF the MCB and just interchange AC input connections to the power circuit. This is to make the firing circuit and power circuit to synchronize.

Result:

SINGLE PHASE HALF CONTROLLED BRIDGE CONVERTER WITH R AND RL LOAD

SINGLE PHASE HALF CONTROLLED BRIDGE CONVERTER WITH R AND RL LOAD

Aim: To study the module and waveforms of a 1- Φ half Bridge Converter with R, RL and RLE

Loads.

Apparatus:

Sl no	equipment	Range	type	quantity
1	1- Φ full bridge converter firing circuit and power circuit units.			
2	1- Φ Isolation transformer 230V/230V.			
3	Loading Rheostat :50 Ohms, 2A.			
4	Loading Inductor 50 mH.			
5	20 MHz dual trace oscilloscope with 1: 10 BNC pobes.			
6	Single phase converter firing circuit			
7	Connecting wires			

Specifications:

Input   Voltage   : 15V to 230 V AC.

Load current   : 5 Amps maximum..

Fuses   : 6 amps fast blow glass fuses.

Field supply   : 2 Amps / 220V + 10 %

MCB   : two pole 6 amps / 230V.

T1, T1^1, T2, T2^1,   : SCR - 25 TTS 12 - 25 A rms / 1200Volts

DM   :   Freewheeling   diode   -   SPR   16PB   -   16   A   /   1200V

Circuit:

STEP DOWN TRANSFORMER

1-φ AC SUPPLY 230V, 50Hz

Procedure:

1. Switch ON the Mains Supply to the Firing circuit.
2. Observe all the test points by varying the firing angle using potentiometer and trigger O/Ps ON/OFF switch.
3. Then observe the trigger o/p s and phase sequence.
4. Make sure that all the trigger o/p s are proper before connecting to the power circuit.
5. The trigger o/p pulse width varies as we vary the firing angle.
6. Next make the connections in the power circuit.
7. Connect 30V tapping of the transformer secondary to the power circuit.
8. Connect the R-load between load points.
9. Connect firing pulses from the firing circuit to the respective SCR's in the power circuit.
10. Switch ON the MCB, switch ON the trigger o/ps and note down the voltage wave forms across load and devices.
11. Draw the waveforms across load and device for different firing angle.
12. Repeat the same for different input voltage up to maximum voltage as provided in the isolation transformer.
13. Repeat the same for R-L load with and without freewheeling diode and note down the waveform.

NOTE: - If the output is zero after all proper connections, switch off the MCB. Switch off the AC supply to the Isolation transformer. And just interchange the AC input connections in the power circuit. This is to make the firing circuit and the power circuit to synchronize.

TABULAR COLUMN

R-L LOAD WITH OUT FREE WHEELING DIODE

Sl no	Input Voltage-Vin	Firing angle	Output voltage	Output Current	Calculated o/p Voltage (Volts) Vo $Vm/\pi/(1+COS\alpha)$

R-L LOAD WITH FREE WHEELING DIODE

Sl no.	Input Voltage-Vin	Firing angle	Output voltage	Output Current	Calculated o/p Voltage $Vm/\pi/(1+COS\alpha)$

Precautions:

1. Check all the SCRs for performance before making the connections.
2. Check the firing circuit trigger outputs and its relative phase sequence.
3. Make fresh connections before you make a new experiments.
4. Preferably work at low voltages (20 – 30V) for every new connections after careful verification it can be raised to the maximum ratings. (This is to reduce damages due to wrong connections and high starting current problems)
5. The thyristor has a very low thermal inertia as compared to machine and by any over load or short circuit the SCR will immediately get damaged. Therefore do not switch ON the supply until the instructor has checked the connections.
6. While observing the wave forms of two parameters on the oscilloscope, either differential input oscilloscope should be used or special differential probes should be used with normal oscilloscope. On normal oscilloscope observation of wave forms can be done with respect to single common point only. Ground connections of other probe must be avoided. It will lead to short circuit if ground connections of both the probes are used since they are internally shorted. In no case should

oscilloscope input ground point be disconnected. This is a dangerous practice. Use 10:1 oscilloscope probe to see the wave forms at high voltages.

7. Do not make Gate & Cathode measurements when the power circuit is on.

8. Make sure all the connecting links are tightly fixed.

9. Ensure all the controlling knobs in fully counterclockwise position before starting experiment.

10. Handle everything with care.

11. Make sure the firing pulses are proper before connecting to the power circuit.

12. If the output is zero even after all power connections, switch OFF the MCB and just interchange AC input connections to the power circuit. This is to make the firing circuit and power circuit to synchronize.

Modeol waveforms:

Results:

FORCED

COMMUTATION

CIRCUITS

FORCED COMMUTATION CIRCUITS

Aim: To study the various commutation circuits

Apparautus:

Sl no	equipment	Range	type	quantity
1	1- Φ forced commutation units.			
2				
3	Loading Rheostat :50 Ohms, 2A.			
4	Loading Inductor 50 mH.			
5	20 MHz dual trace oscilloscope with 1: 10 BNC pobes.			
6				
7	Connecting wires			

Specifications:

1. POWER	:	Power ON/OFF switch to the unit with builtin indicator.
2. FREQUENCY	:	Potentiometer to vary the frequency of commutation from 50 Hz to 250Hz approximately.
3. DUTY CYCLE	:	Potentiometer to vary the duty cycle from 10% to 90% approximately.
4. TRIG.OUTPUT		
ON/OFF	:	ON/OFF Switch for mains pulse T1.
5. GATE / CAT	:	Positive and Negative points of trigger outputs to connect to Gate and Cathode of SCRs.
6. T1	:	Trigger output for SCR T1 – 200 us pulse.
7. T2	:	Trigger output for SCR T2 – 200 us pulse.
8. V dc IN	:	24V @ 2A unregulated DC supply is available at this terminals for DC source for the commutation power ckt
9. ON	:	ON/OFF switch for DC supply.
10. FUSE	:	2 Amps glass fuse DC power supply protection.
11. +	:	DC Power supply point after switch and fuse.
12. D	:	Free wheeling diode – BYQ 28 – 200.

13. T1 & T2   :   SCRs – TYN 616.

14. Tr   :   Transistor – TIP 122.

15. Commutation   :

   Inductance   – L1   :   250 mH.

                  - L2   :   500 mH

                  - L3   :   1 mH.

16. Commutation

   Capacitanc e   – C1   :   6.8 mF / 100V

                  - C2   :   10.0 mF / 100V

Procedure:

1) Switch On the mains supply to unit and observe the trigger outputs by varying frequency and duty cycle potentiometer and make sure that the pulse output are proper before connecting to the power circuit. Check the DC power supply between the DC Input points.

2)Check all the devices. Check the resistance between the Gate and Cathode of SCRs.

3) Check the resistance between anode and cathode. Check the diode and its polarity. Check the transistor and its polarity. Check the fuse in series with the DC input.

4) Make sure that all the components are good and firing pulse are correct before you start any commutation experiments.

CLASS A COMMUTATION CIRCUIT

The current reversing property of the LC load will force the device commutation. LC and R values are choosen such that the circuit is underdamped.

Since the commutation elements carry load current on a continuous basis. These ratings are generally high. For low frequency operation large value of L & C is required, make the cost of the commutation circuit prohibitive. This commutation is commonly employed in series inverters operating at frequencies above 400 Hz.

PROCEDURE: -
1. Make the interconnections in the power circuit as shown in the circuit diagram.
2. Connect trigger output T1 to gate and cathode of SCR T1.
3. Switch on the DC supply to the power circuit and observe the voltage waveform across load by varying the frequency Potentiometer.
4. Duty cycle potentiometer is of no use in this experiment.
5. Repeat the same for different values of L, C and R.

Circuit diagram:
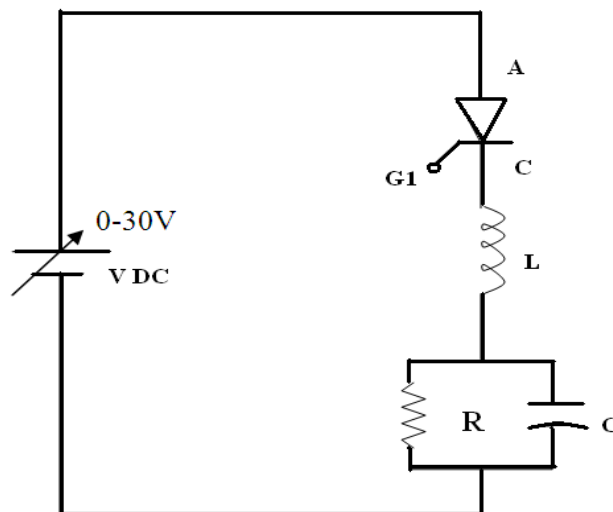
Model waveforms

CLASS - A
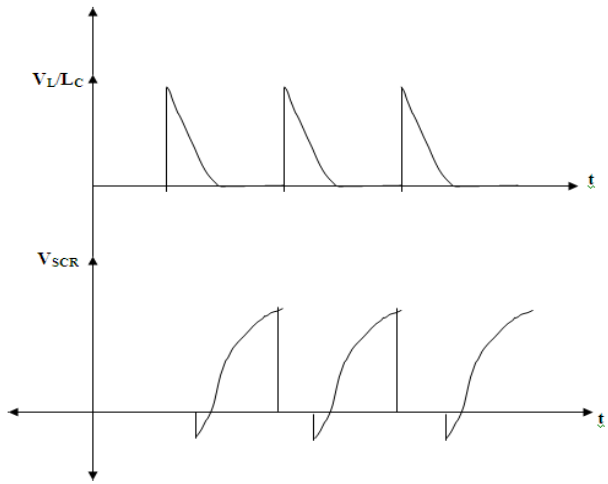
CLASS –B COMMUTATION CIRCUIT

In this type of commutation reverse voltage is applied to the thyristor by the over swinging of an

Under damped LC circuit connected across the Thyristor. Capacitor charges up to the supply voltage before the trigger pulse are applied to the gate. When the thyristor is triggered, two currents flow, a load current through the external circuit and a pulse of current through LC circuit and thyristor in opposite direction. This resonant current tends to turn – off the thyristor.

Circuit diagram
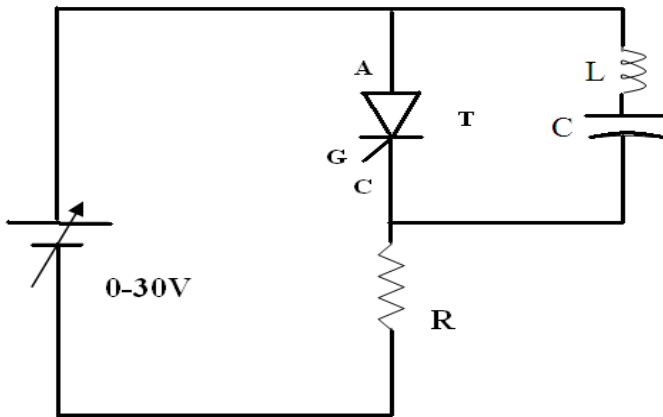
PROCEDURE:

1. Make the interconnections as shown in the circuit diagram, connect trigger output T1 to Gate and cathode of SCR T1.
2. Switch on the DC supply to the power circuit and observe the voltage wave forms across load by varying the frequency, potentiometer. Duty cycle potentiometer is of no use in this experiment
3. Repeat the same for different values of L, C and R.

MODEL WAVEFORMS:
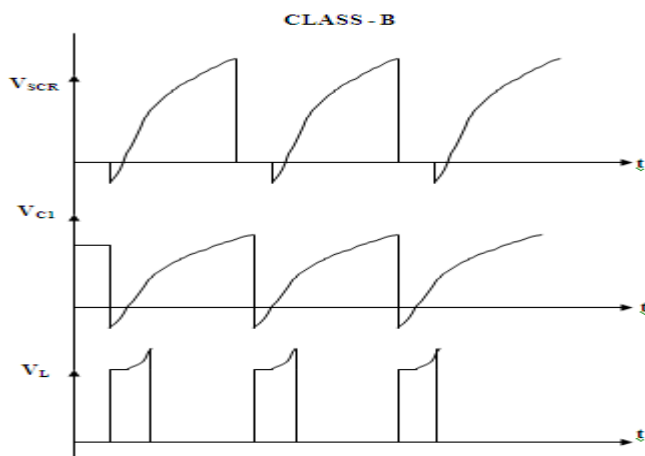
CLASS – C (Complimentary) Commutation: -

This commutation is used to transfer current between two loads. The firing of one thyristor

Commutates the other one. Both the thyristors are conducting the load current. However in

Some cases (Choppers) the thyristor used for turn-off may carry very small amount of

Current required for charging. In such case thyristor is called auxiliary Thyristor.

Circuit diagram:
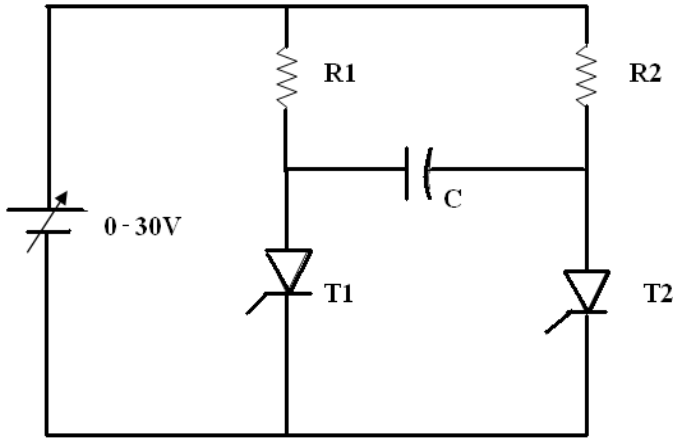
Procedure:

1) Make the interconnections as shown in the circuit diagram. Connect T1 and T2 from   firing Circuit to Gate amd Cathode of Thyristor T1 and T2.

2) Observe the wave forms across R1, R2, C by varying frequency and also duty cycle potentiometer. Repeat the same for

3) Different values of C and R in this circuit L is of no use.

Model Waveforms:
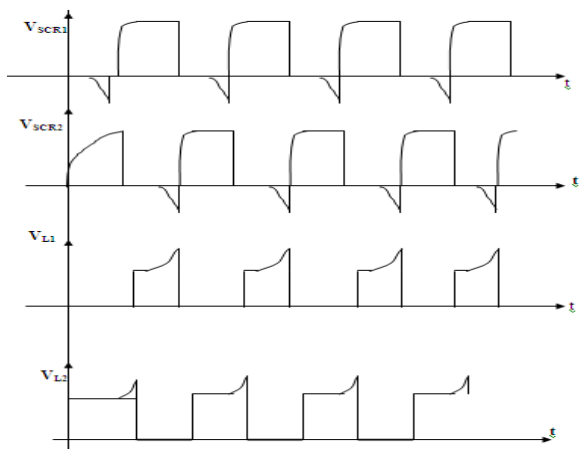
AUXILIARY SCR COMMUTATION (CLASS – D) MODULE

This type of commutation is popular due to the design flexibility. There are many choppers and
Inverters under this class. T2 must be triggered first in order to charge up capacitor 'C' is charged, T2 is
commutated off owing to lack of current. When T1 is triggered, current flows in two paths, load current
through R_L and Commutating current through 'C' T1, L and D1. The charge on the capacitor is reversed and
held with The hold – off diode D1. At any desired instant T2 may be triggered when then Places 'C' across
T1 via   T2 and T1 is turned off.

Circuit diagram:
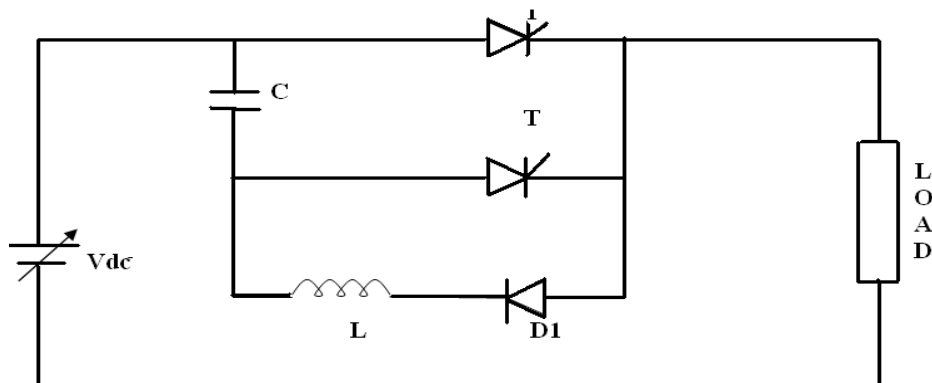
Procedure:

1. Make the connections as given in the circuit diagram.
2. Connect T1 and T2 gate pulsefrom the firing circuit to the corresponding SCRs in the power
   circuit.Initially keep the Trigger ON/OFFat OFF position to initially charge the capacitor, this can be
   observed by connecting CRO across the Capacitor.

3. Now Switch ON the trigger O/P switch and observe the Voltage wave forms across the load, T1, T2
   and Capacitor.
4. Note down the voltage waveforms Across the load, T1, T2 and capacitor.

5. Note down the voltage waveforms at different frequency of chopping and also at different duty cycle.
Repeat the experiment for different values of load resistance, commutation inductance and capacitance.
Compare the results with the theoretical results.

Model waveforms:
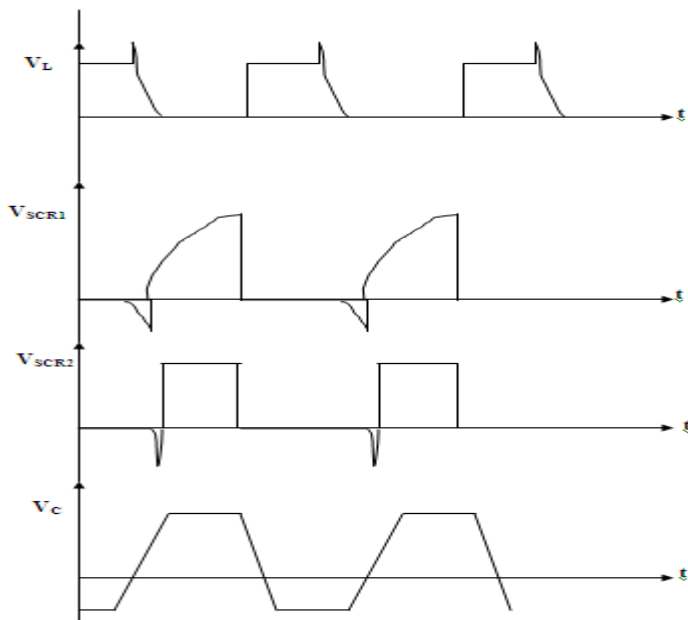
CLASS E – COMMUTATION-WITH AN EXTERNAL SOURCE OF PULSE FOR COMMUTATION

In class E turn off reverse voltage is applied to the load carrying thyristor from an external
Source across or in series with the conducting thyristor. The turn off time of the thyristor is
Smaller than the width of the pulse. The conducting period of the thyristor is from the instant
Of application of triggering pulse till the external turnoff voltage is applied. When TH is
Triggered, load current flows. This connects the negative auxiliary voltage to the thyrsitor to
Turn it off.

Circuit diagram:
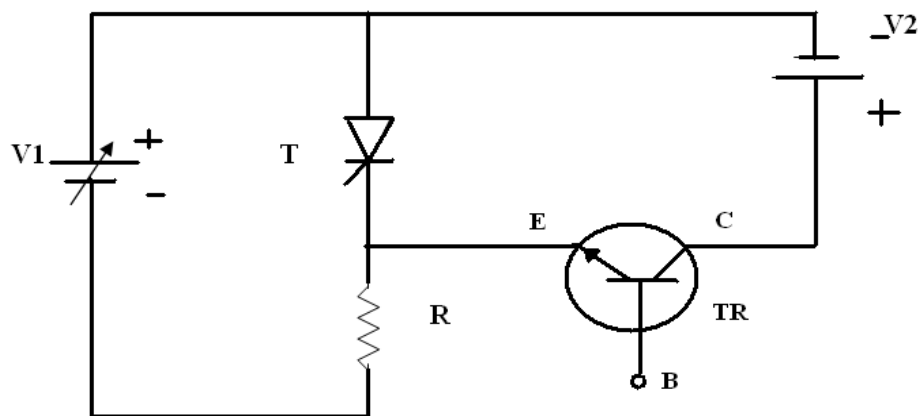
PROCEDURE:-

1) Make the connections as shown in the circuit diagram. Connect V2 supply from an external DC power supply unit.

2) Connect the trigger output T1 from the firing circuit to the SCR.

3) Connect T2 to the Transistor base and emitter points. Switch on the DC supply and external DC supply.

4) Switch on the trigger output and observe and note down the waveforms across the load.

5) Repeat the same by varying frequency and duty cycle.

Model waveforms:

CLASS - E
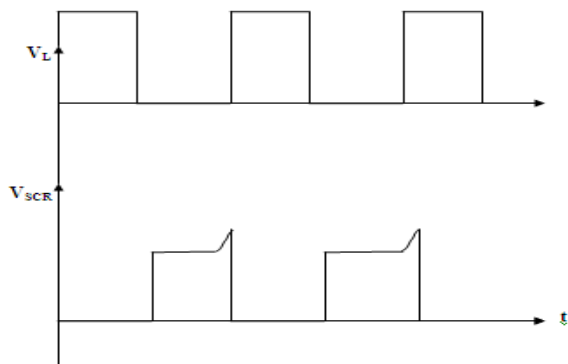
GATE TRIGGERING CIRCUITS

GATE TRIGGERING CIRCUITS

Aim: To study the gate trigger circuits and waveforms.

Apparatus:

Sl no	equipment	Range	type	quantity
1	1- Φ gate triggering unit..			
2	20 MHz dual trace oscilloscope with 1: 10 BNC pobes.			
3	Loading Rheostat :50 Ohms, 2A.			
4	Loading Inductor 50 mH.			
5	Connecting wires			
6				
7				

Specifications for R and RC triggering circuits.

1. **POWER**   **:** Mains switch for the circuit with built in indicator.

2. **AC**   : 20Volts / 1A AC supply.

3. **RC**   **:** Control potentiometer – 5 K ohms.

4. **D1 & D2**   **:** Diodes IN 5402.

5. **C**   **:** Capacitor 4.7 □f / 1000V for R – C triggering.

6. **T**   **:** SCR – TYN 612 12Amps / 600V

7. **R$_G$**   **:** Gate current limiting resistor.

8. **LOAD**   **:** Terminals to connect load.

R – TRIGGERING CIRCUIT
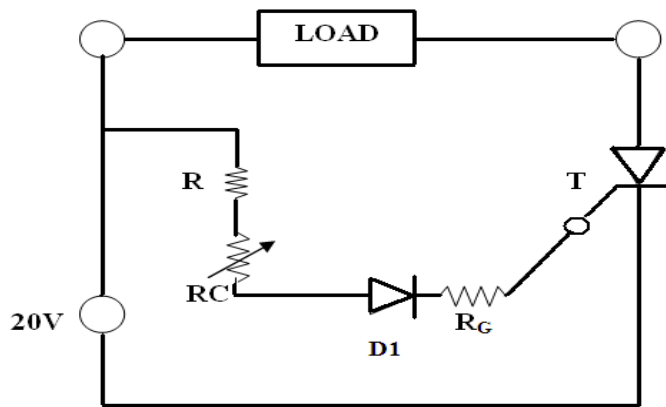
Circuit diagram:

Procedure:

1. Make the connections as given in the circuit diagram.
2. Connect a Rheostat of 100 ohms between the load points.
3. Vary the control pot and observe the voltage waveforms across load, SCR and at different points of the circuit.

Note: We can vary the firing angle from 0^0 to 90^0 only in R triggering.   In this triggering the synchronized firing angle can be obtained easily and economically in the positive half cycle of the supply. But there is a draw back that the firing angle can be controlled at the most at 90^0.   Because the gate current is in phase with the applied voltage.   A resistor is connected in series with the control pot, so that the gate current does not cross the maximum possible value Igmax.

R – C TRIGGERING CIRCUIT
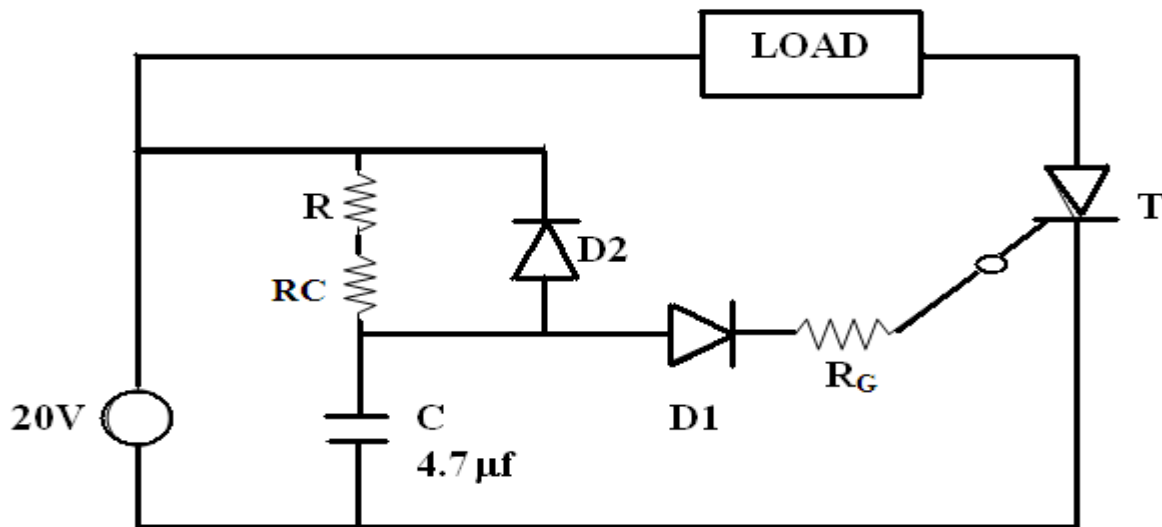
Circuit diagram:

Procedure:

1.   Make the connections as given in the circuit diagram.

2.   Connect a Rheostat of 100 ohms between the load points.

3.   Vary the control pot and observe the voltage across load, SCR and at different points of the circuit.

UJT TRIGGERING CIRCUIT:

Specifications:

1. MAINS   :   AC Supply ON/OFF switch to the unit with builtin indicator.

2. AC   :   20V / 1A AC supply for UJT relaxation oscillator and SCR

firing from a step down transformer.

3. CF	:	Filtering capacitor – 100mF/35V to study relaxation oscillator using UJT. In this exptt. Short Cf terminal to diode Bridge O/p to get filtered rectified DC and the UJT relaxation oscillator works in asynchronous mode.
4. DZ	:	Zener diode – 15V/1Watt. To limit the supply to UJT.
5. RC	:	Potentiometer to vary the firing angle in synchronous mode and to vary the frequency of oscillator in asynchronous mode.
6. UJT	:	2N 2646.
7. B1, B2, E	:	Basel, Base2 and emitter points of UJT.
8. T1 & T1	:	Pulse Transformer isolated pulse O/ps to trigger SCR.
9. SCR	:	TYN 612 – 12A/600V.
		A – Anode K – cathode & G – Gate points.

UJT FRONT PANEL:

UJT FIRING CIRCUIT
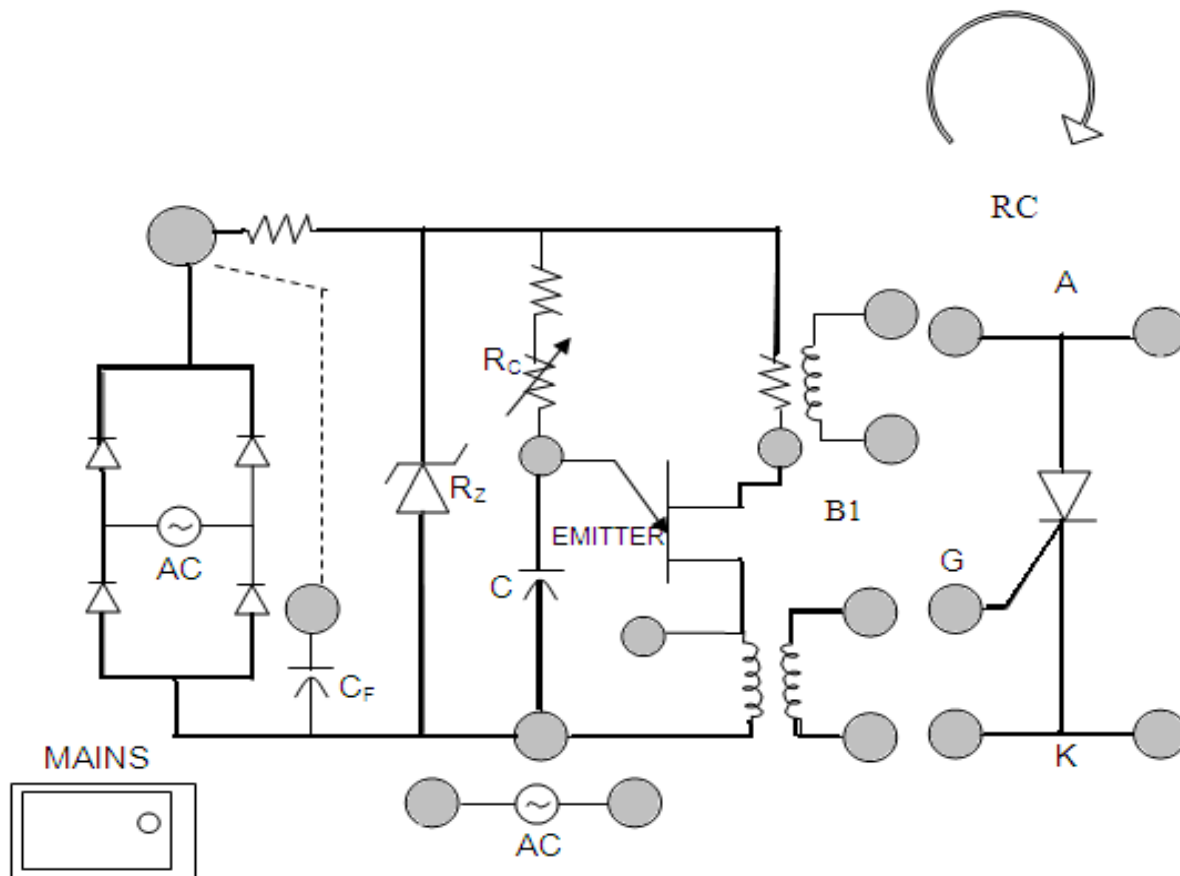
Procedure:

1. Switch ON the mains supply, observe and note down the wave forms at the different points in the circuit and also the trigger outputs – T1 & T1'.

2. Now make the connections as given the circuit diagram using AC source, UJT relaxation Oscillator, SCR and a suitable load (50 Ohms/2A)

3.)Now switch ON the mains supply, observe and note down the output waveforms across load and SCR.

4. Draw the wave forms at different firing angle – 120, 90 & 60.

5. In the UJT firing Circuit the firing angle can be varied from 150* – 30* approximately. We cannot vary exactly from 0*- 180* as we vary in single phase converter firing circuit

Circuit diagram:

UJT FIRING CIRCUIT
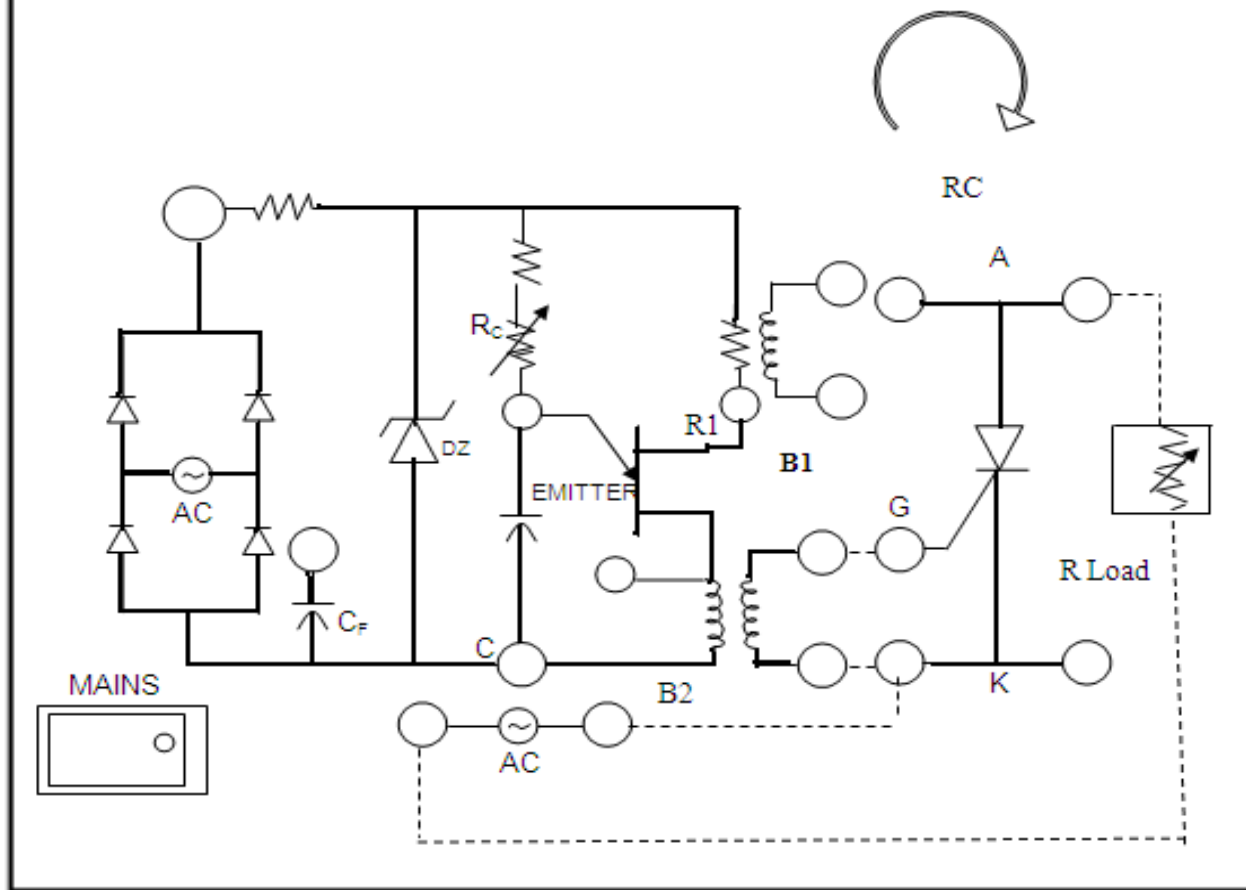
Connection Diagram for firing of SCR using UJT

Model waveforms:

Result:.

1-Φ CYCLO CONVERTER

.

1- Φ CYCLO CONVERTER

AIM:

To study the module and waveforms of a 1- Φ center tapped cycloconverter with R and RL loads.

APPARATUS:

Sl no	Name of the Equipment	Range	type	quantity
1	1- Φ Cyclo converter firing circuit and power circuit			
2	20 MHz dual trace oscilloscope with 1: 10 BNC pobes.			
3	Loading Rheostat :50 Ohms, 2A.			
4	Loading Inductor 50 mH.			
5	Connecting wires			
6				
7				

SPECIFICATIONS:

1. **Power**   :   Power ON/OFF switch to the unit with built in Indicator.

2. **OFF / ON**   :   Switch for trigger outputs with soft start and soft stop feature.

3. **Frequency Division:**   Division of line frequency (50 Hz) by 1,2,3,4,5,6,7,8,9 & 10

  using thumbwheel switch. Frequency division is 10 when thumb

  wheel switch is at 0.

4. **Firing angle**   :   Potentiometer to vary the firing angle from 180* to 0*.

5. **Test Points**   :   1 to 9 with respect to ground (GND) to study the firing circuit.

6. **Trigger o/p s**   **:** G – Gate   K – Cathode.

   T1, T2, T3 & T4   : 25 TTS 12 – thyristors.

Front panel view:
Single Phase Cycloconverter

From Center Tap Transformer
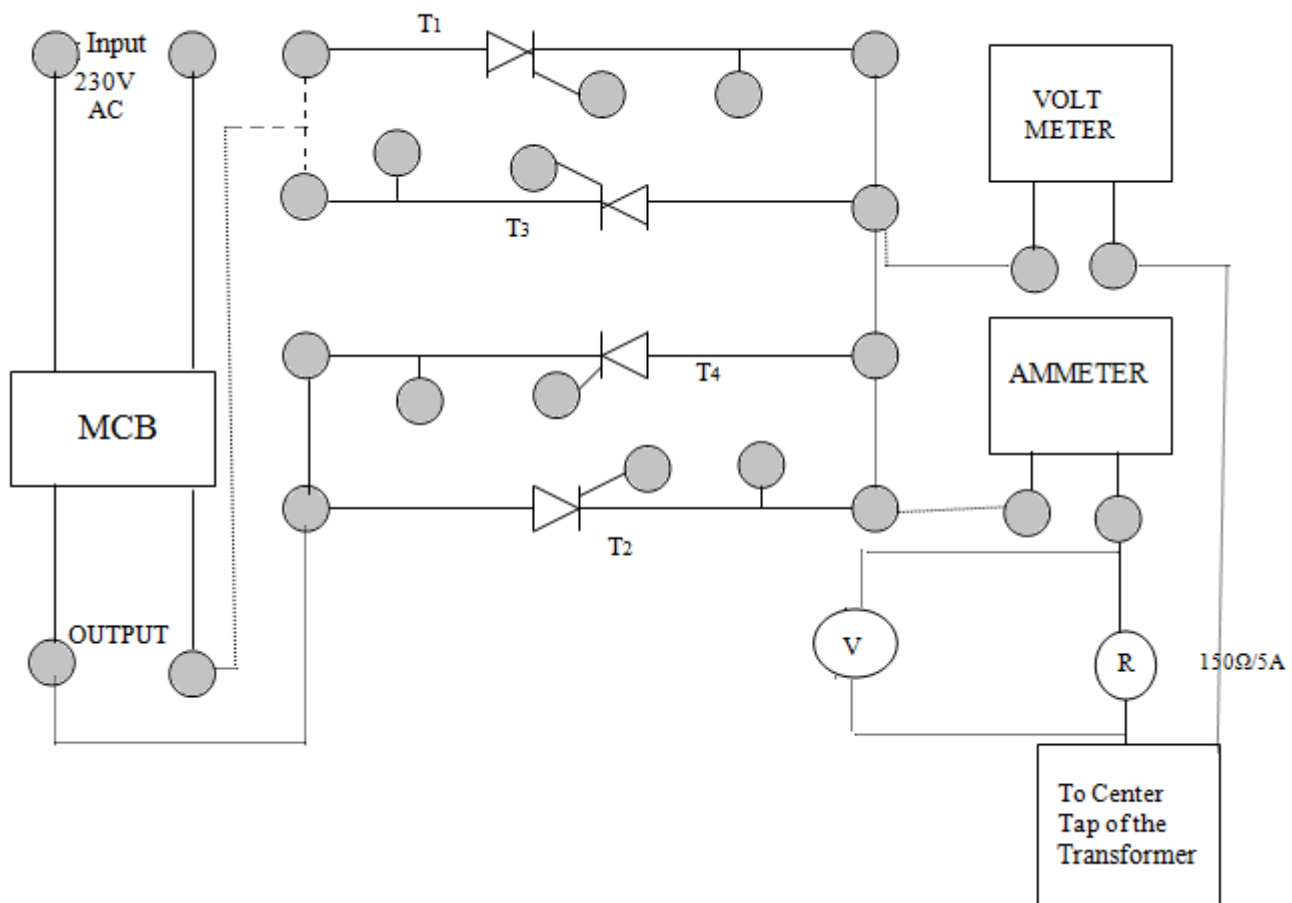
Circuit Diagram:
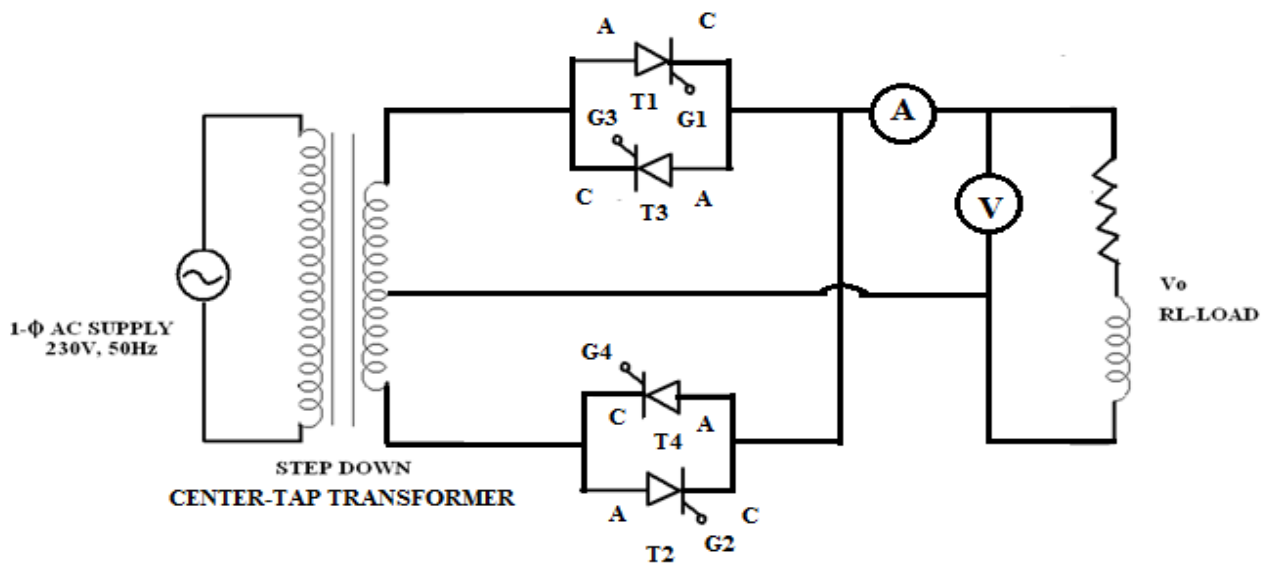
Procedure:
1. Switch ON the mains supply to the firing circuit. Observe test points and trigger outputs by changing frequency division and by varying the firing angle. Make sure that the firing pulses are proper before connecting to the power circuit.
2. Next make the power circuit connections as given in the circuit. Include Voltmeter and Ammeter in power circuit.

3. Connect the firing pulses from the firing circuit to the respective SCR's in the power circuit. Connect Rheostat - 150 ohms / 5A at the output. Initially connect input supply of 30V-0-30V from the center tap transformer.
4. Connect the firing pulses from the firing circuit to the respective SCR's in the power circuit. Connect Rheostat - 150 ohms / 5A at the output. Initially connect input supply of 30V-0-30V from the center tap transformer.
5. Switch ON the MCB, switch ON trigger pulses. Set the frequency division to 2. Vary the firing angle and observe the waveforms. Note down the readings in the tabular column
6. After you get the correct output at low voltage, increase the input voltage to 230V-0-230V in steps and note down the readings in the tabular column.

NOTE: The circuit works as 1– phase AC voltage controller when the frequency division is at 1. It works as cyclo converter from 2-10 division.

TABULAR COLUMN

Sl.No	Vin Volts.	Frequency Division	Firing Angle	Vo Volts.	IO Amps

Precautions:

1. Make sure all the connections links are tightly fixed.
2. Ensure all the controlling knobs in fully counterclockwise position before starting the experiment.
3. Handle everything with care.
4. Change the frequency division only when the trigger pulse switch is in OFF position.
5. Make sure that firing pulses are proper connecting to the power circuit.
6. If the output is zero even after all proper connections, switch OFF the MCB and interchange AC input connections to the power circuit. This is to make the firing circuit and power circuit to synchronize.
7. Change the frequency division only when the trigger pulse switch at OFF position.

Model waveforms:
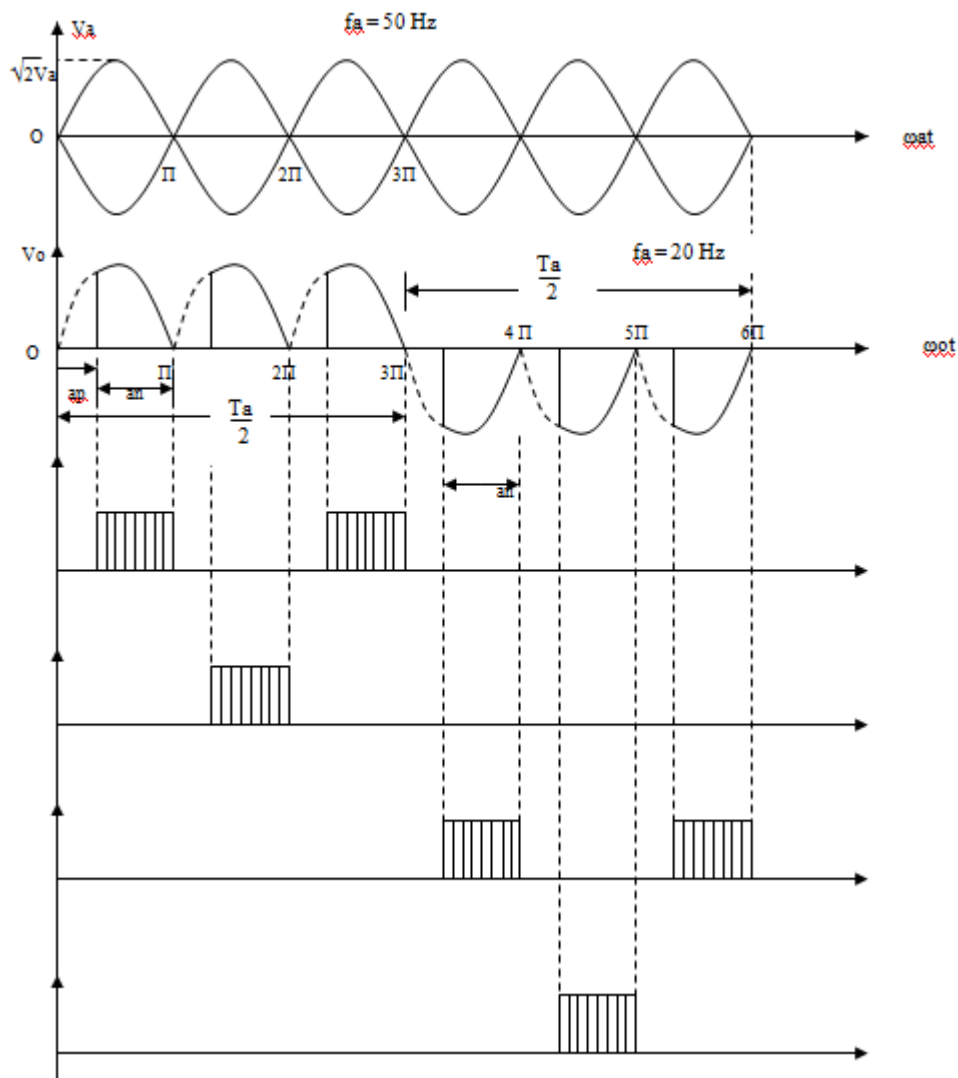
RESULT:

EXPERIMENT -

SINGLE PHASE DUAL CONVERTER WITH RL LOADS

9.1 AIM:

To study the operation of single phase dual converter with RL loads.

9.2 APPARATUS:

S.No	Equipment	Range	Type	Quantity
1	Single phase dual converter power circuit and firing circuit			
2	CRO with deferential module			
3	Patch chords and probes			
4	Isolation Transformer			
5	Variable Rheostat			
6	Inductor			
7	DC Voltmeter			
8	DC Ammeter			

9.3   CIRCUIT DIAGRAM:
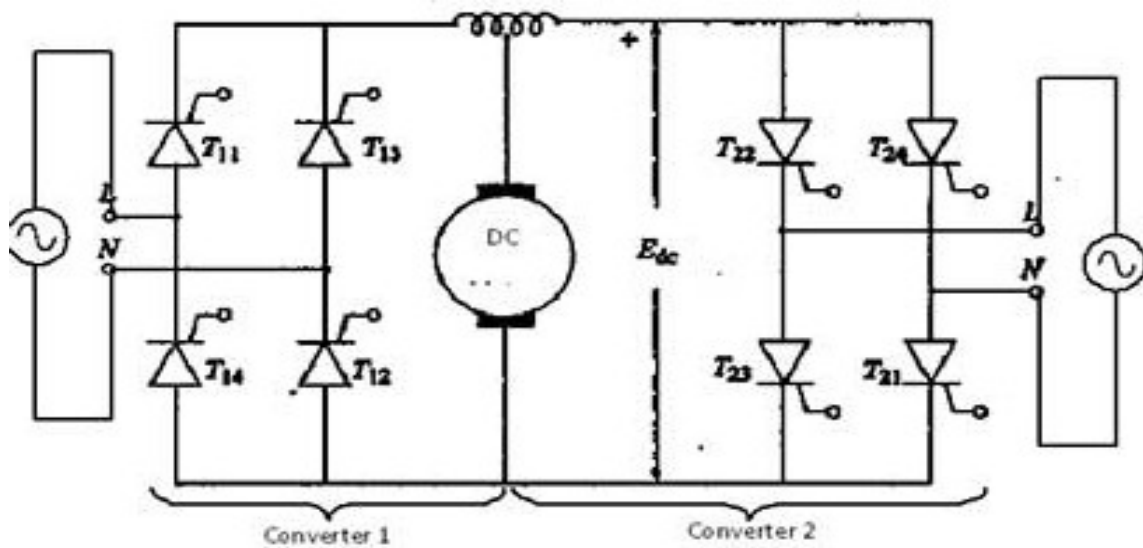
Fig – 9.1 Single Phase Dual Converter

9.4   PROCEDURE:

1. Make all connections as per the circuit diagram.
2. Connect firstly AC supply from Isolation Transformer to circuit.
3. Connect firing pulses from firing circuit to Thyristors as indication in circuit.
4. Connect resistive load 200Ω / 5A to load terminals and switch ON the MCB and IRS switch and trigger output ON switch.
5. Connect CRO probes and observe waveforms in CRO across load and device in single phase dual converter.
6. By varying firing angle gradually up to 180^0 and observe related waveforms.
7. Measure output voltage and current by connecting AC voltmeter & Ammeter.
8. Tabulate all readings for various firing angles.
9. For RL Load connect a large inductance load in series with Resistance and observe all waveforms and readings as same as above.
10. Observe the various waveforms at different points in circuit by varying the Resistive Load and Inductive Load.
11. Calculate the output voltage and current by theoretically and compare with it practically obtained values.

9.5 TABULAR COLUMN:

S. No	Input Voltage (V_{in})	Firing angle in Degrees	Output voltage (V_0)		Output Current (I_0)	
			Theoretical	Practical	Theoretical	Practical
1						
2						
3						
4						
5						
6						

9.6   **MODEL CALCULATIONS:**

V_0 $= (2\sqrt{2}V/\Pi) * Cos\ \alpha\ I_0$

$= (2\sqrt{2}V/\Pi R) * Cos\ \alpha$

α $=$ Firing Angle

V $=$ RMS Value across transformer output

9.7   **MODEL GRAPH:**
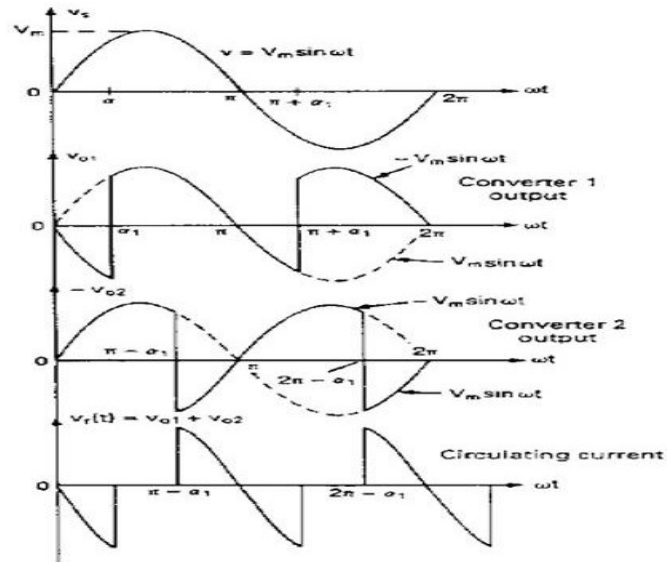
Fig – 9.2 Single Phase Dual Converter output waveforms

9.8   RESULT:

9.9   PRE LAB VIVA QUESTIONS:

1. What is the condition for ideal dual converter operation?
2. What are the four quadrant operations are possible with dual converter drives?
3. What is the purpose of inductor in dual converters?
4. What are the modes of operations for a dual converter?

9.10   POST LAB VIVA QUESTIONS:

1. What are the applications of dual converters?
2. Which mode of operation is suitable for four quadrant operation of dual converter?

EXPERIMENT

SINGLE PHASE CYCLO-CONVERTER WITH R AND RL LOADS

10.1 AIM:

To study the single - phase Cyclo Converter with R & RL Load.

10.2 APPARATUS:

S. No	Equipment	Range	Type	Quantity
1	Single phase Cycloconverter power circuit and firing circuit			
2	CRO with deferential module			
3	Patch chords and probes			
4	Isolation Transformer(Centre-Tapped)			
5	Variable Rheostat			
6	Inductor			
7	AC Voltmeter			
8	AC Ammeter			

10.3 CIRCUIT DIAGRAM :
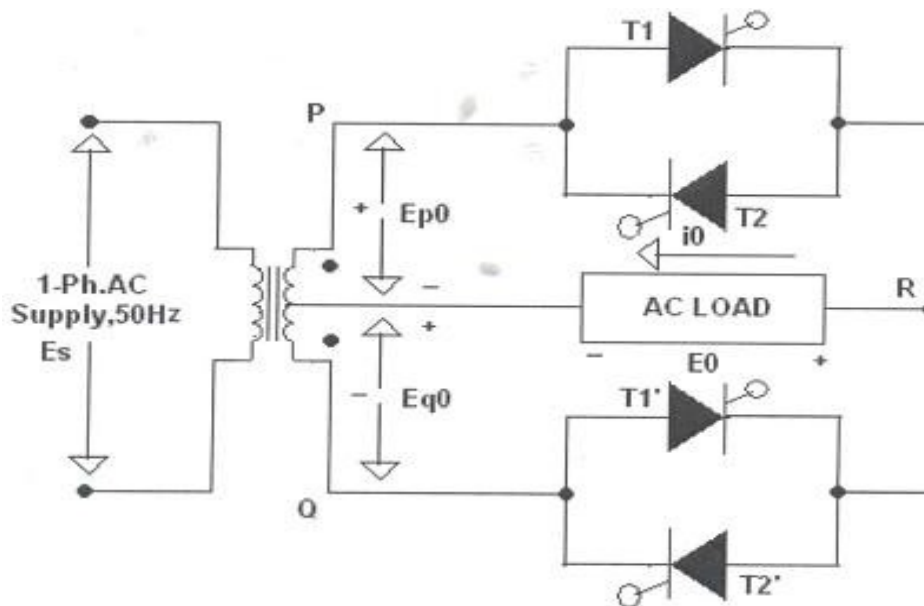
Fig – 10.1 Circuit Diagram of Single Phase Cyclo - Converter

10.4   PROCEDURE:

1. Make all connections as per the circuit diagram.
2. Connect firstly (30V-0-30V) AC supply from Isolation Transformer to circuit.
3. Connect firing pulses from firing circuit to Thyristors as indication in circuit.
4. Connect resistive load 200Ω / 5A to load terminals.
5. Set the frequency division switch to (2, 3, 4…9) your required output frequency.
6. Switch ON the MCB and IRS switch and trigger output ON switch.
7. Observe waveforms in CRO, across load by varying firing angle gradually up to 180^0 and also for various frequency divisions (2, 3, 4…9).
8. Measure output voltage and current by connecting AC voltmeter & Ammeter.
9. Tabulate all readings for various firing angles.
10. For RL Load connect a large inductance load in series with Resistance and observe all waveforms and readings as same as above.
11. Observe the various waveforms at different points in circuit by varying the Resistive Load and Inductive Load.
12. Calculate the output voltage and current by theoretically and compare with it practically obtained values.

10.5 TABULAR COLUMN:

S. No	Input Voltage (V_{in})	Firing angle in Degrees	Frequency Division	V_o (V)	I_o (A)	Input frequency f_s	Output frequency f_o	f_o/f_s

10.6   MODEL CALCULATIONS:

V_{0r} =

I_{0r} $= V_{0r}/R$

θ = Firing Angle

V   = RMS Value across transformer output

10.7 MODEL GRAPH:
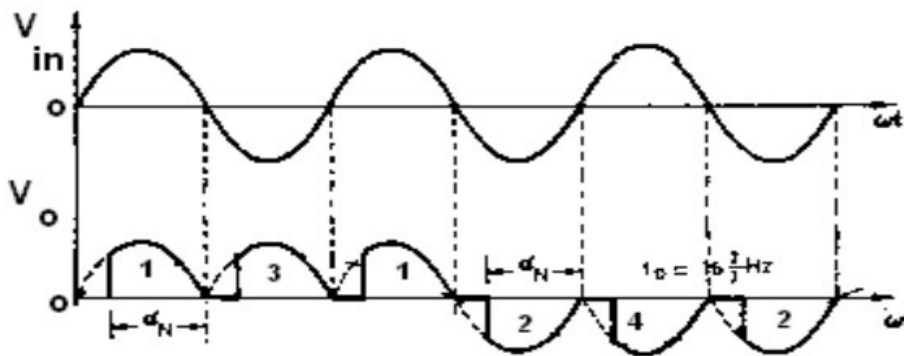
Fig – 10.2 Output Wave Forms of Single Phase Cyclo - Converter

10.8   RESULT:

10.9   PRELAB VIVA QUESTIONS:

1. What is meant by Cycloconverter? What are the types of Cycloconverters?
2. Classify Cycloconverters.
3. Differentiate step-down cycloconverter and step-up cycloconverter.
4. Why forced commutation circuit is employed in case of Cycloconverter?
5. Draw the circuit diagram of three phase to single phase bridge configuration of Cycloconverter.

10.10   POSTLAB VIVA QUESTIONS:

1. What are the Applications of Cycloconverter?
2. What is meant by Positive & negative converter groups in Cycloconverter?
3. List the applications of Cycloconverter.
4. List the advantages & disadvantages of Cycloconverters.
5. What are the factors affecting the harmonics in Cycloconverters?
6. Why the output frequency of a Cycloconverter is significantly lower than the input frequency?

EXPERIMENT

THREE PHASE HALF CONTROLLED BRIDGE CONVERTER WITH R LOAD

11.1 AIM:

To study the three phase half controlled bridge converter with R load.

11.2 APPARATUS:

S. No	Equipment	Range	Type	Quantity
1	Three phase half controlled bridge converter power circuit and firing circuit			
2	CRO with deferential module			
3	Patch chords and probes			
4	Three phase transformer			
5	Rheostat			
6	DC Voltmeter			
7	DC Ammeter			

10.3 CIRCUIT DIAGRAM:
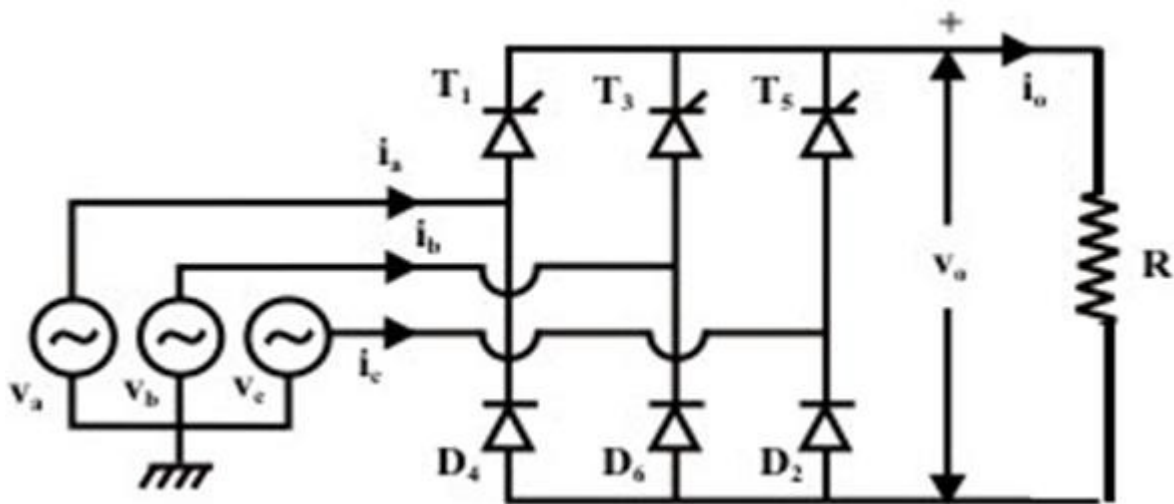
Fig – 11.1Half Controlled bridge converter with R load

11.4 PROCEDURE:

1. Make all connections as per the circuit diagram.

2. Connect firstly 3 phase AC supply from three phase transformer to circuit.

3. Connect firing pulses from firing circuit to Thyristors as indication in circuit.

4. Connect resistive load 200Ω / 5A to load terminals and switch ON the MCB and IRS switch and trigger output ON switch.

5. Connect CRO probes and observe waveforms in CRO across load and device in three phase half controlled bridge converter.

6. By varying firing angle gradually up to 180^0 and observe related waveforms.

7. Measure output voltage and current by connecting DC voltmeter & Ammeter.

8. Tabulate all readings for various firing angles.

9. Calculate the output voltage and current by theoretically and compare with it practically obtained values.

11.5 TABULAR COLUMN:

S. No	Input Voltage (V_{in})	Firing Angle in Degrees	Output voltage (V_0)		Output Current (I_0)	
			Theoretical	Practical	Theoretical	Practical
1						
2						
3						
4						
5						
6						

11.6 MODEL CALCULATIONS:

$Vo = 3\ Vml*(1+cos\alpha)/2\pi$

$Io = 3\ Vml*(1+cos\alpha)/2\pi R$

α= firing angle

Vml = line to line voltage

11.7 MODEL GRAPHS:
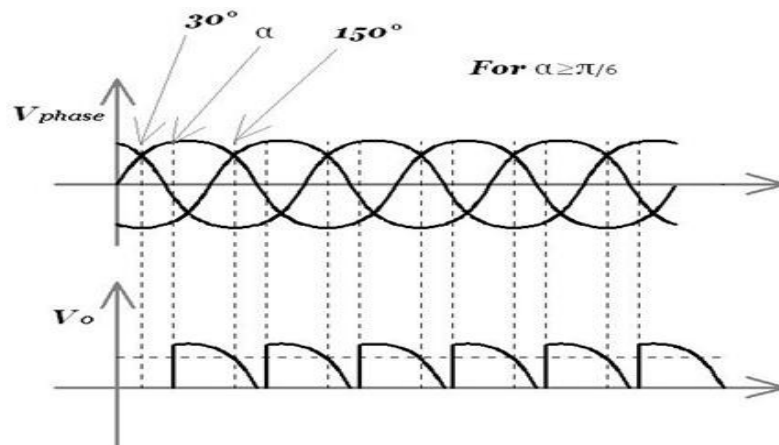
Fig – 11.2 Input and output wave forms of a three phase half controlled bridge converter

11.8   RESULT:

11.9   PRE LAB VIVA QUESTIONS

1. A converter which can operate in both 3 pulse and six pulse modes is?
2. What is the interval for SCRs triggering in three phase semi converter?
3. What is the interval for SCRs triggering in three phase full converter?
4. What is the function of freewheeling diode in three phase converters?

11.10   POST LAB VIVA QUESTIONS

1. What are the advantages of three phase half controlled converters?

2. Which quadrant operation is possible with three phase half controlled converter?

EXPERIMENT - 12 OPERATION OF MOSFET BASED CHOPPER

Aim: To study the operation of chopper with MOSFET

12.1   APPARATUS:

S. No	Equipment	Range	Type	Quantity
1	MOSFET based chopper power circuit and firing circuit			
2	CRO with deferential module			
3	Patch chords and probes			
4	Regulated Power Supply			
5	Variable Rheostat			
7	DC Voltmeter			
8	DC Ammeter			

12.2   CIRCUIT DIAGRAM:
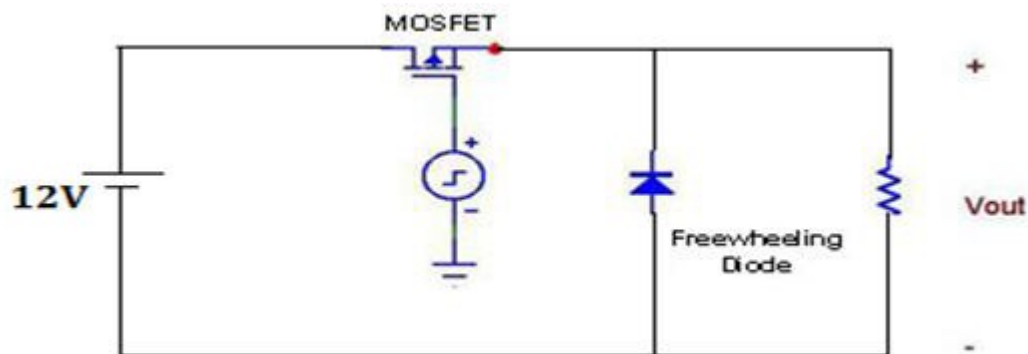
Fig – 12.1 MOSFET based chopper

12.3   PROCEDURE:

1. Connections are made as shown in the figure. Use 50Ω Rheostat for R - Load (Freewheeling diode (DM) is to be connected only for RL load).
2. Adjust VRPS output to 10v and connect to DC chopper module.
3. Switch on DC toggle switch of chopper module.
4. Switch on the trigger input by pushing- in pulse switch.
5. Observe the output waveform across load on CRO.

6. Keep the duty cycle at mid position and vary the frequency from minimum to maximum and

record the output voltage readings.

7. Keep the frequency at mid position, vary duty cycle from minimum to maximum and output voltage readings.

8. Note down the output waveform for mid value of frequency and duty cycle.

12.4 TABULAR COLUMN:

Constant Duty Cycle

Duty Cycle: 50%, V_{IN}=10 to 15 V

S.No	Frequency(Hz)	V0(Volts)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Constant Frequency, Frequency control

S. No	T_{ON}(sec)	T_{OFF}(sec)	Duty Cycle (%)	V_O(Volts)
1				
2				
3				
4				
5				
6				
7				
8				
9				

12.5 MODEL GRAPH:

Fig – 12.2Chopper output waveforms

12.6 RESULT:

12.7 PRE-LAB VIVA QUESTIONS:

1. What are the different control strategies found in choppers?
2. Explain the principle of operation of a chopper?
3. What is the function of chopper?
4. What are the advantages of DC choppers?

12.8 POST LAB VIVA QUESTIONS:

1. How can ripple current be controlled?
2. What is step up chopper?
3. On what does the commutating capacitor value depend on?
4. What are the disadvantages of choppers?
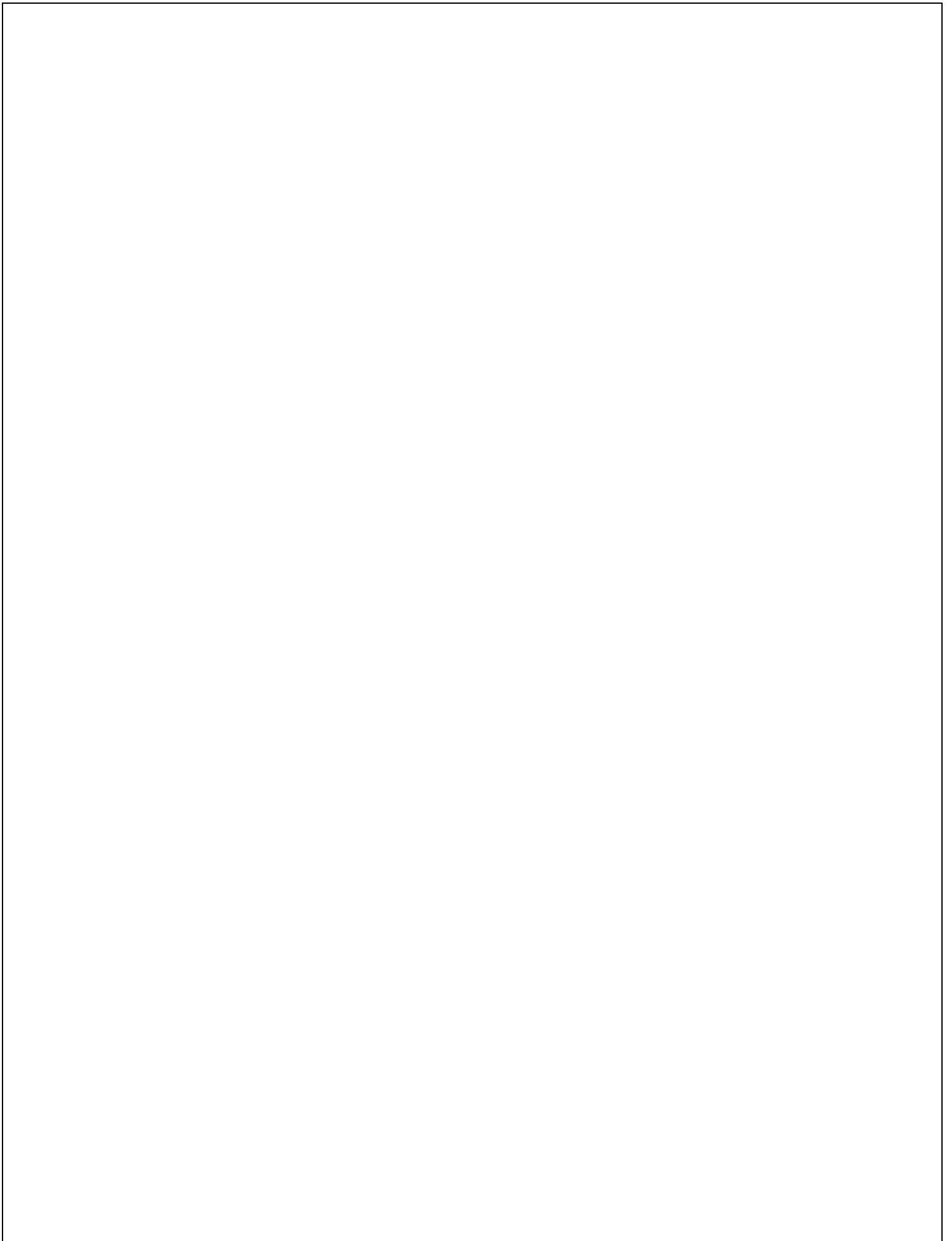
PSPICE PROGRAMS

Subcircuit for AC thyristor model

```
.SUBCKT  SCRMOD   1  2  3  2
* Model name anode    cathode   positive control voltage   cathode
S1    1  5  6  2  SMOD; Switch
RG   3  4  50
VX  4  2  DC 0V
VY  5  7  DC 0V
DT  7  2  DMOD; Switch diode
RT  6  2  1
CT  6  2  10UF
F1   2  6   POLY (2)  VX  VY  0  50  11
.MODEL  SMOD  VSWITCH (RON=0.0105  ROFF=10E+5  VON=0.5V  VOFF=0V) ;
Switch model
.MODEL  DMOD  D (IS=2.2E.15  BV=1200V  TT=0  CJO=0) ; Diode model parameters
.END SCRMOD; Ends subcircuit definition
```
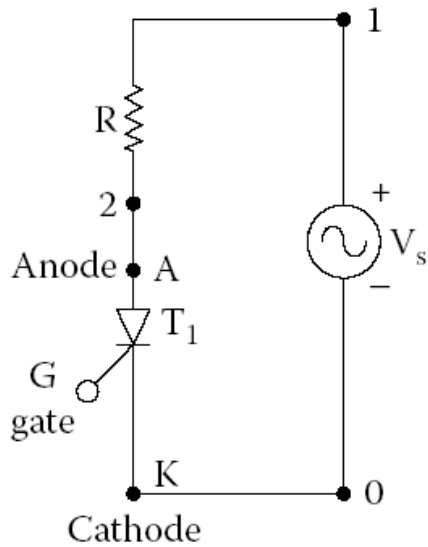

(a) Thyristor circuit
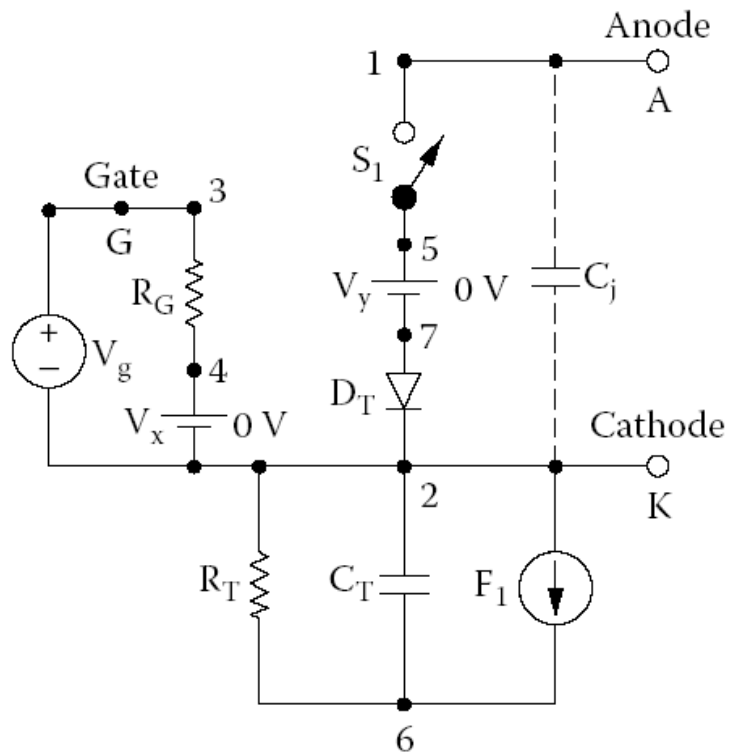
(b) Thyristor model

SIMULATION OF SINGLE PHASE VOLTAGE CONTROLLER& SINGLE PHASE RECTIFIER

Aim: to simulate the single phase AC voltage controller and single phase bridge rectifier

Software :   Pspice ORCAD version 9.0

Circuit Diagram:
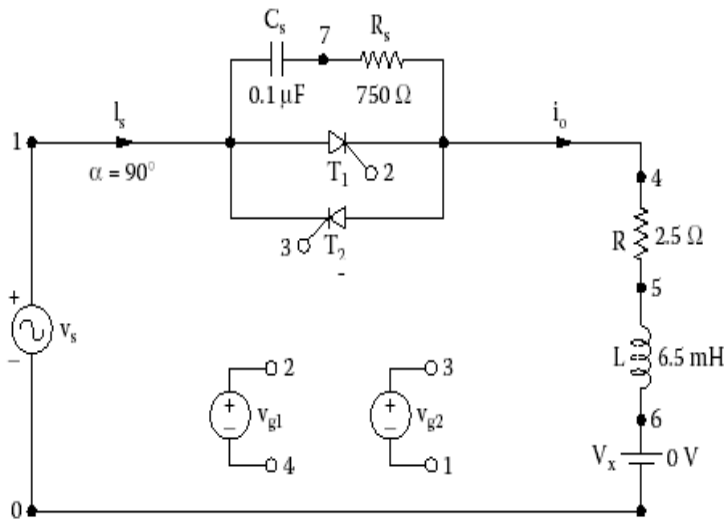
(a) Circuit
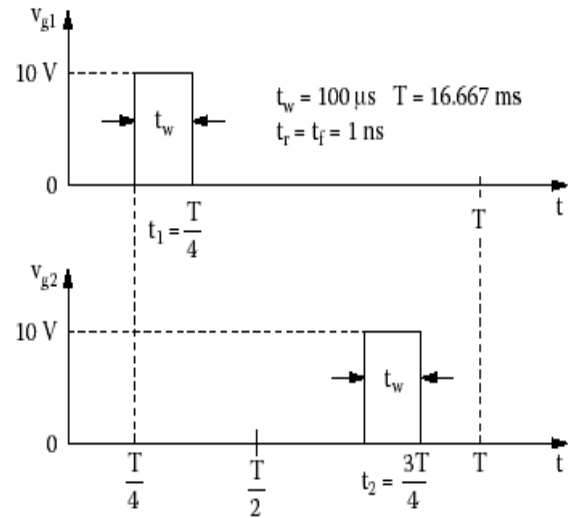
(b) Gate voltages

for firing angle= 60°

$$t_1 = \frac{60^{\circ}}{360^{\circ}} \times \frac{1000}{50Hz} \times 1000 = 3333.33 \text{ US}$$

for firing angle= 240°

$$t_2 = \frac{240^{\circ}}{360^{\circ}} \times \frac{1000}{50Hz} \times 1000 = 13333.33 \text{ US}$$

Spice program for AC Voltage Controller

*AC VOLTAGE CONTROLLER

VS		1	0	SIN (0 325V 50HZ)

VS   1   0   SIN (0 325V 50HZ)

VG1   2   4   PULSE (0 10 3333.33US 1NS 1NS 100US 20000US)

VG2   3   1   PULSE (0 10 13333.33US 1NS   1NS   100US 20000US)

R   4   5   2.5

L   5   6   6.5MH

VX	6	0	DC 0V
CS	1	7	0.1UF
RS	7	4	750

*SUBCIRCUIT CALL FOR THYROSTOR MODEL;

XT1	1	4	2	4	ASCR ;THYRISTOR T1
XT2	4	1	3	1	ASCR ;THYRISTOR T2

*SUBCIRCUIT FOR AC THYRISTOR MODEL

.SUBCKT ASCR	1	2	3	2	
S1	1	5	6	2	SMOD
RG	3	4	50		
VX	4	2	DC	0V	
VY	5	2	DC	0V	
RT	2	6	1		
CT	6	2	10UF		
F1	2	6	POLY(2) VX VY 0 50 11		

.MODEL SMOD VSWITCH (RON=0.01 ROFF=10E+5 VON=0.1 VOFF=0V)

.ENDS ASCR

.TRAN   50US 100MS 0MS 50US

.PROBE

.FOUR 50HZ I(VX)

.END

Waveforms:
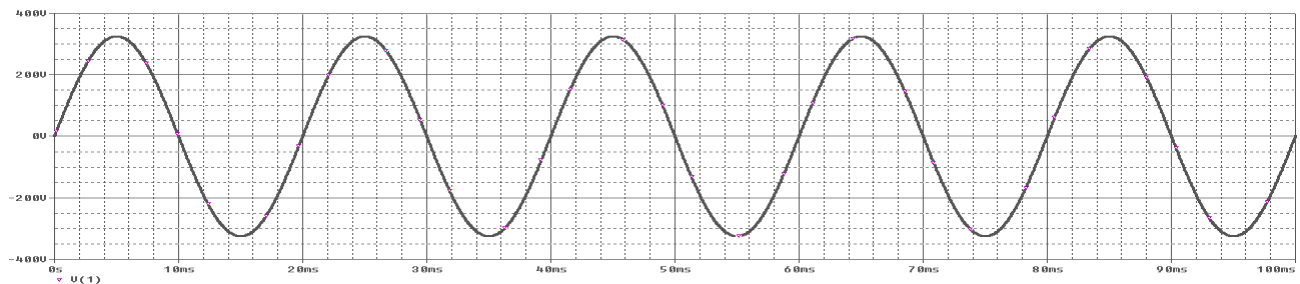
Voltage with R-load V (4,0)
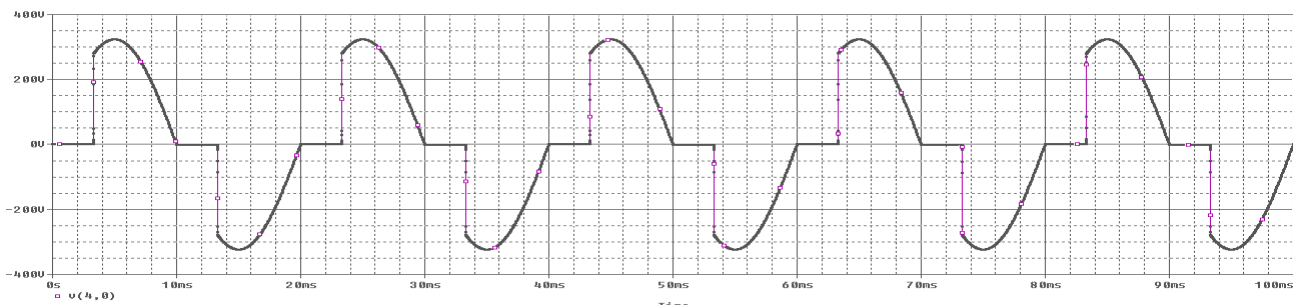
Current through load I(Vx)
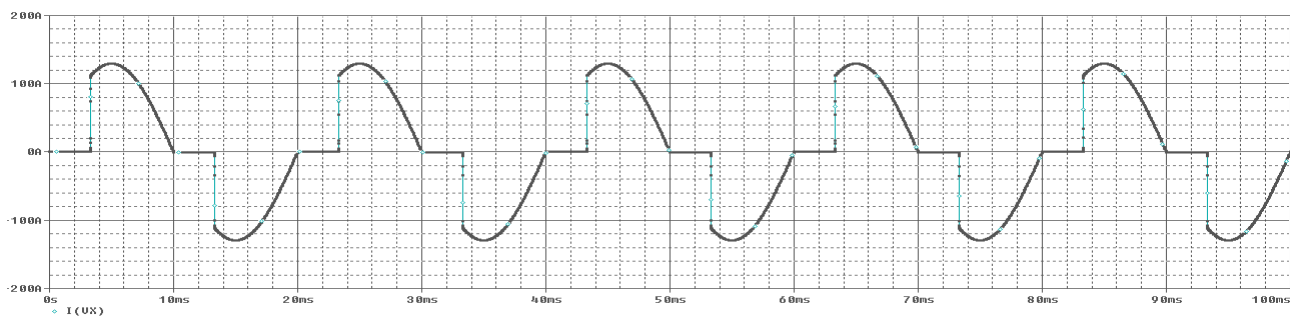
For R-L load

Voltage across load V(4,0)
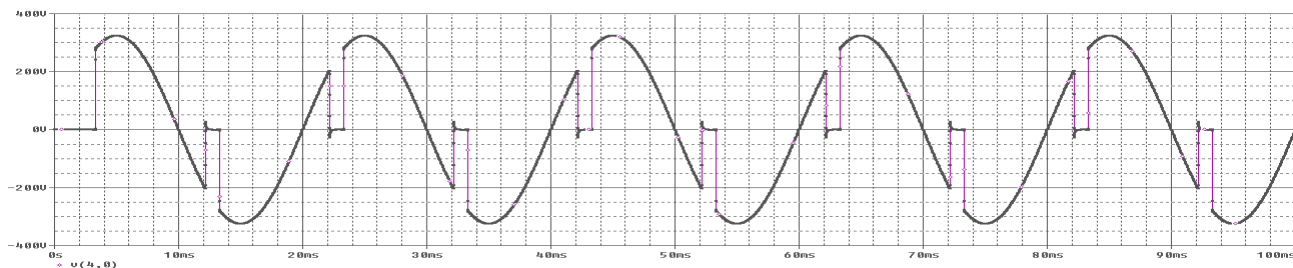
Current through load I(VX)
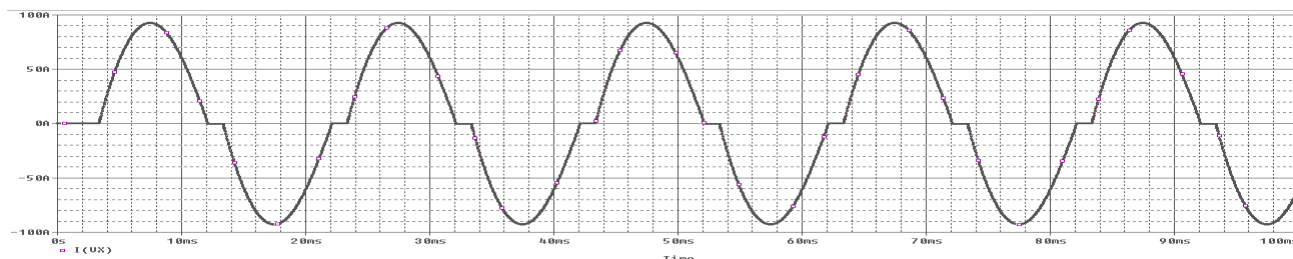
Results:

SINGLE PHASE FULL WAVE BRIDGE CONVERTER

Aim: to simulate the full wave rectifier using spice

Software used: PSPICE ORCAD 9.0 version

Circuit diagram:
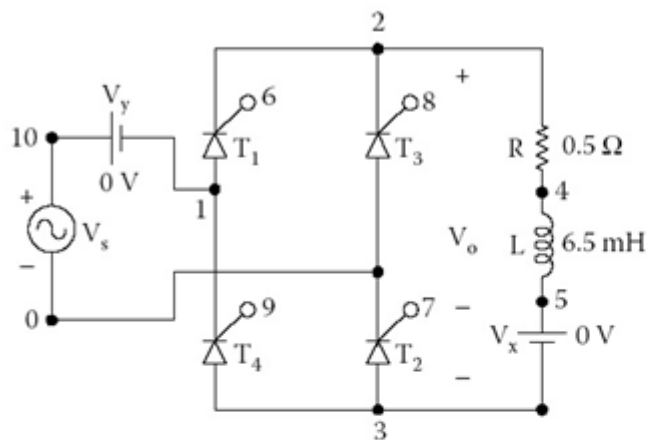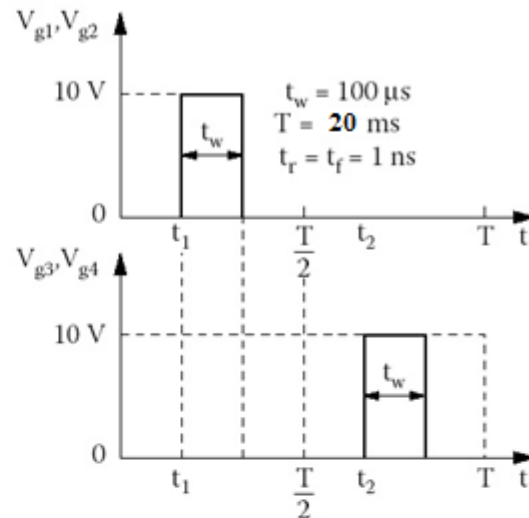
(a) Circuit   (b) Gate voltages

Single-phase full converter for PSpice simulation. (a) Circuit, (b) gate voltages.

for firing angle=30°

$$t_1 = \frac{30^{\circ}}{360^{\circ}} \times \frac{1000}{50Hz} \times 1000 = 1666.66 \text{ US}$$

for firing angle= 210°

$$t_2 = \frac{210^{\circ}}{360^{\circ}} \times \frac{1000}{50Hz} \times 1000 = 11666.67 \text{ US}$$

Program:

*SINGLE PHASE FULL BRIDGE CONVERTER

VS 10 0 SIN (0 325V 50HZ)

VG1 6 2 PULSE (0V 10V 1666.67US 1NS 1NS 100US 20000US)

VG2 7 0 PULSE (0V 10V 1666.67US 1NS 1NS 100US 20000US)

VG3 8 2 PULSE (0V 10V 11666.67US 1NS 1NS 100US 20000US)

VG4 9 1 PULSE (0V 10V 11666.67US 1NS 1NS 100US 20000US)

R 2 4 10

L 4 5 20MH

VX 5 3 DC 10V

VY 10 1 DC 0V

XT1 1 2 6 2 SCR

XT2 3 0 7 0 SCR

```
XT3  0  2  8  2  SCR

XT4  3  1  9  1  SCR

.SUBCKT  SCR  1  2  3  2

S1  1  5  6  2  SMOD

RG  3  4  50

VX  4  2  DC  0V

VY  5  7  DC  0V

DT  7  2  DMOD

RT  6  2  1

CT  6  2  10UF

F1  2  6  POLY(2) VX  VY  0  50  11

.MODEL  SMOD  VSWITCH ( RON=0.0125  ROFF=10E+5  VON=0.5V  VOFF=0V)

.MODEL DMOD D ( IS=2.2E-15  BV =1200V  TT=0 )

.ENDS  SCR

.TRAN  50US  100MS  50MS

.PROBE

.OPTIONS  ABSTOL=1.00U  RELTOL=1.0M  VNTOL=0.1  ITL5=10000

.END
```

Waveforms for Rl load:

Supply Voltage V(10,0)
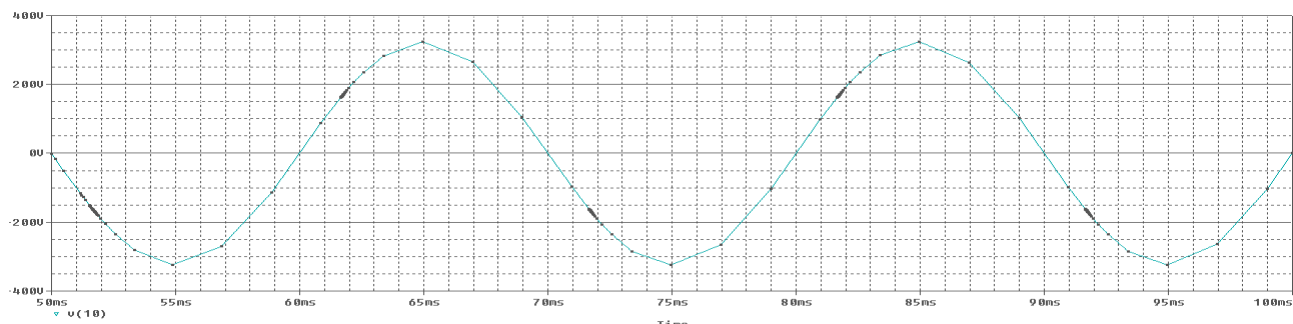
Voltage across load V(2,3)
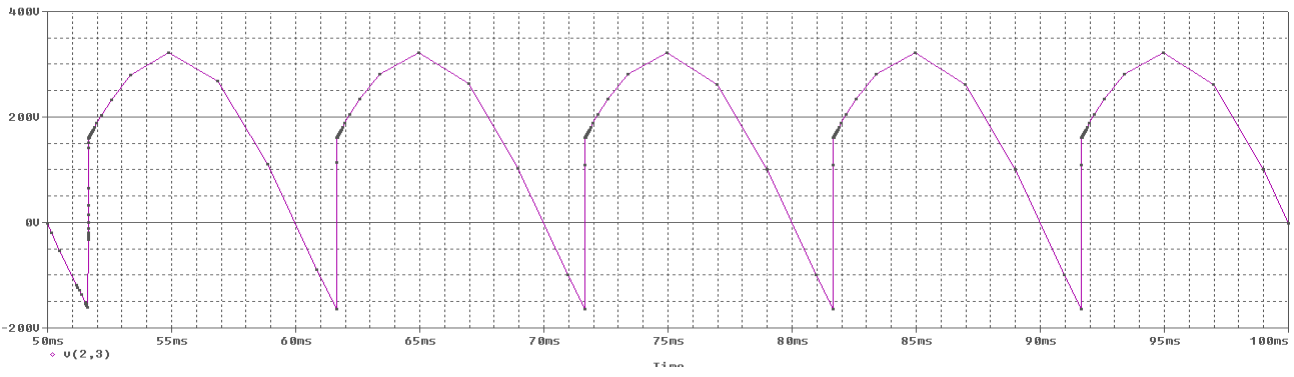
Load Current waveform: I(Vx)
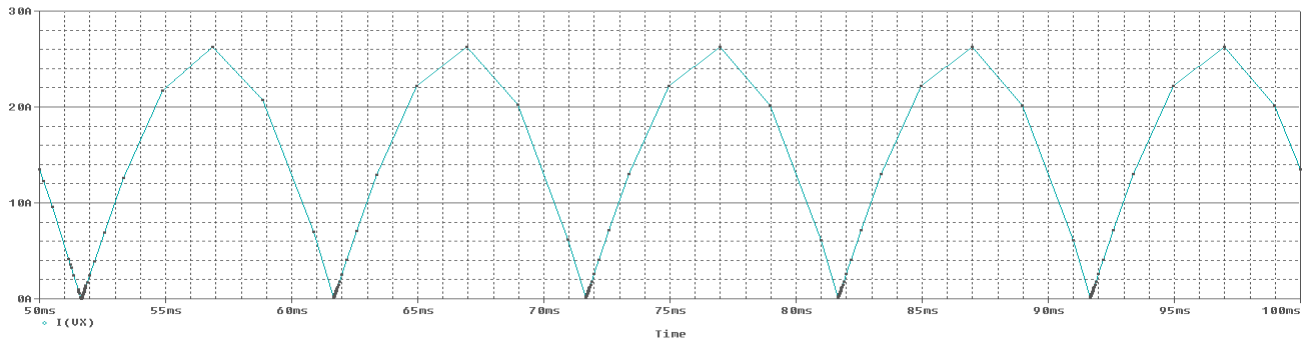
Voltage across thyristor1 V(1,2)
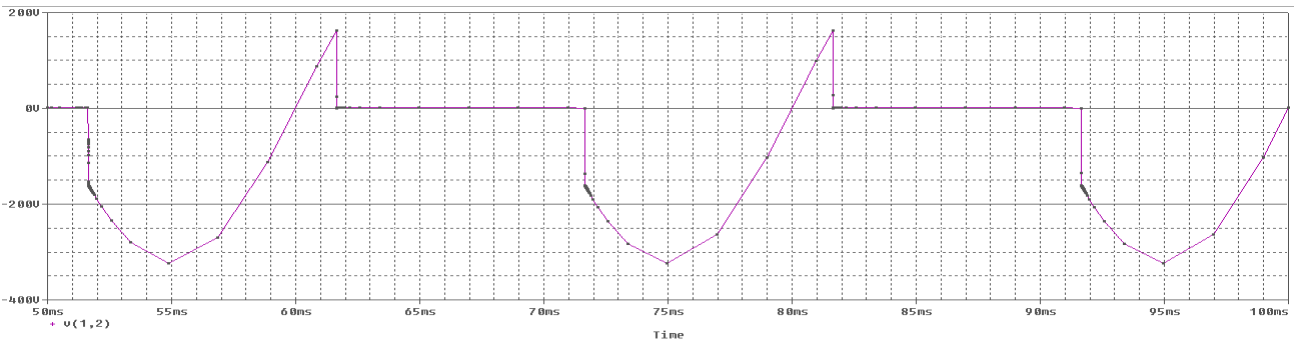
Voltage across thyristor3 V(0,2)
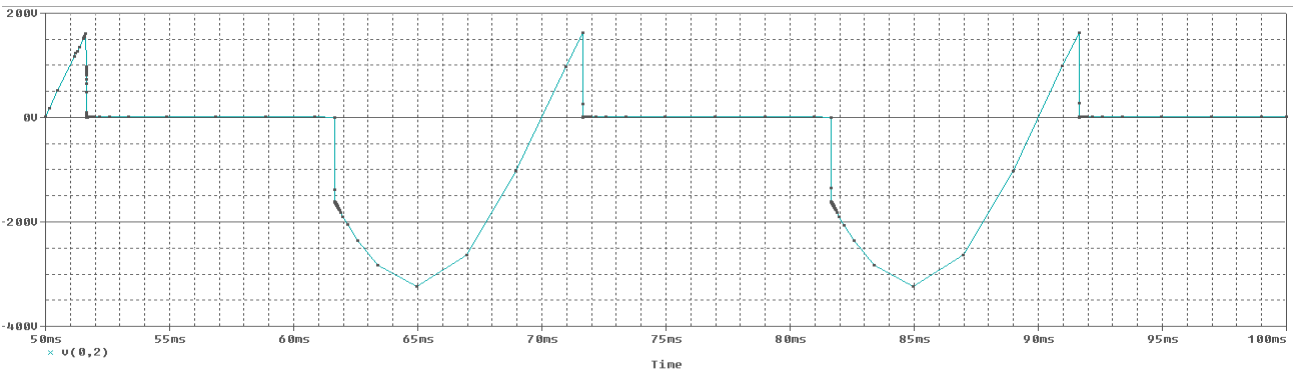
Result:

BUCK CONVERTER (STEP DOWN CHOPPER)

Aim: To simulate step-down chopper (buck converter) using PSPICE

Software: PSpice ORCAD 9.0 version

Circuit diagram:
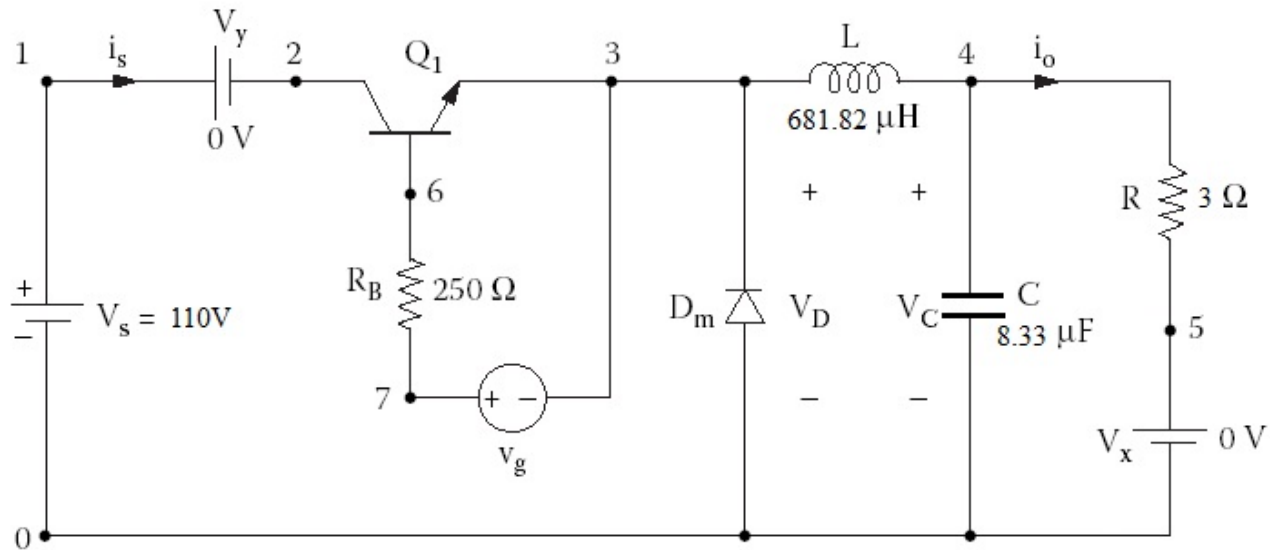
(a) Circuit
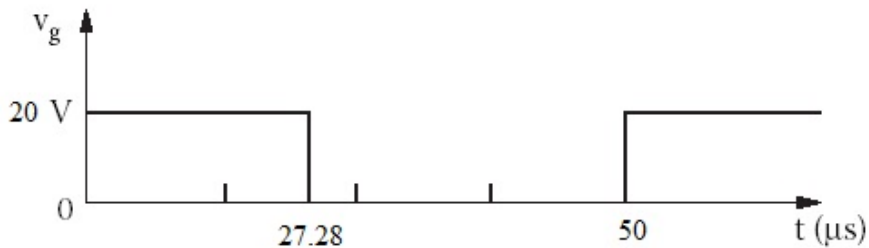
(b) Control voltage

PROGRAM:

```
*BUCK CONVERTER

VS  1  0  DC  110V

VY  1  2  DC  0V

VG  7  3  PULSE ( 0V  20V  0  0.1NS  0.1NS  27.28US  50US)

RB  7  6  250

LE  3  4  681.82UH
```

CE 4 0 8.33UF IC=60V

L 4 8 40.91UH

R 8 5 3

VX 5 0 DC 0V

DM 0 3 DMOD

.MODEL DMOD D (IS=2.2E-15 BV=1800V TT=0)

Q1 2 6 3 QMOD

.MODEL QMOD NPN (IS=6.734F BF=416.4 BR=0.7371 CJC=3.638P CJE=4.493P TR=239.5N -

TF=30.2P)

.TRAN 1US 1.6MS 1.5MS 1US UIC

.PROBE

.OPTIONS ABSTOL=0.01N RELTOL=0.01 VNTOL=0.1 ITL5=50000

.END

WAVEFORMS:

VOLTAGE ACROSS LOAD V(4)
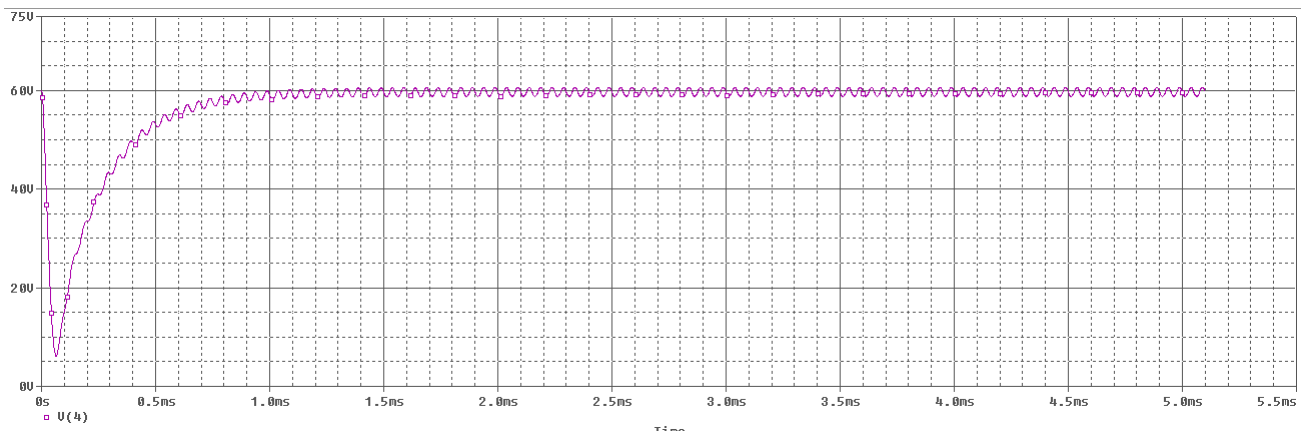
Load current I(Vx)
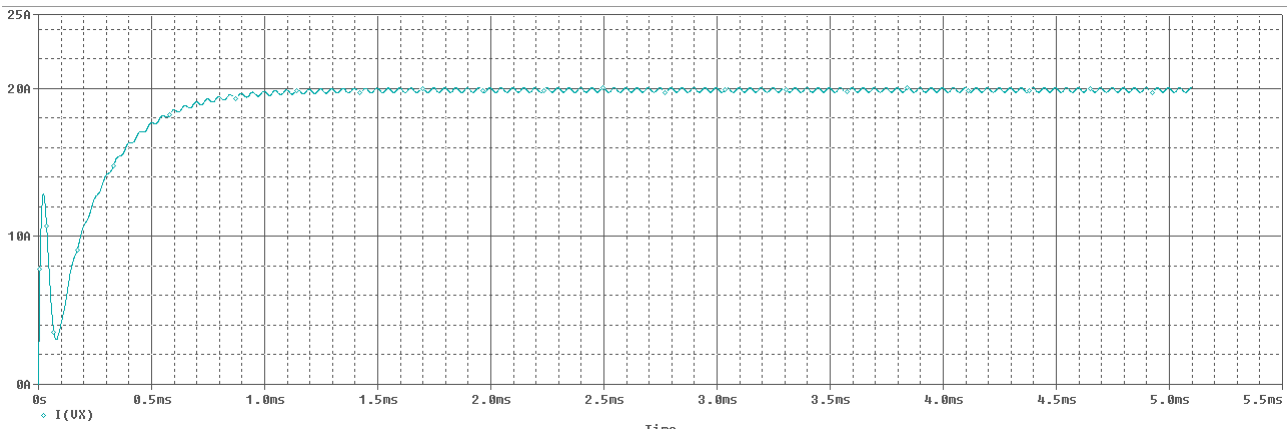
Current through inductor I (Le)
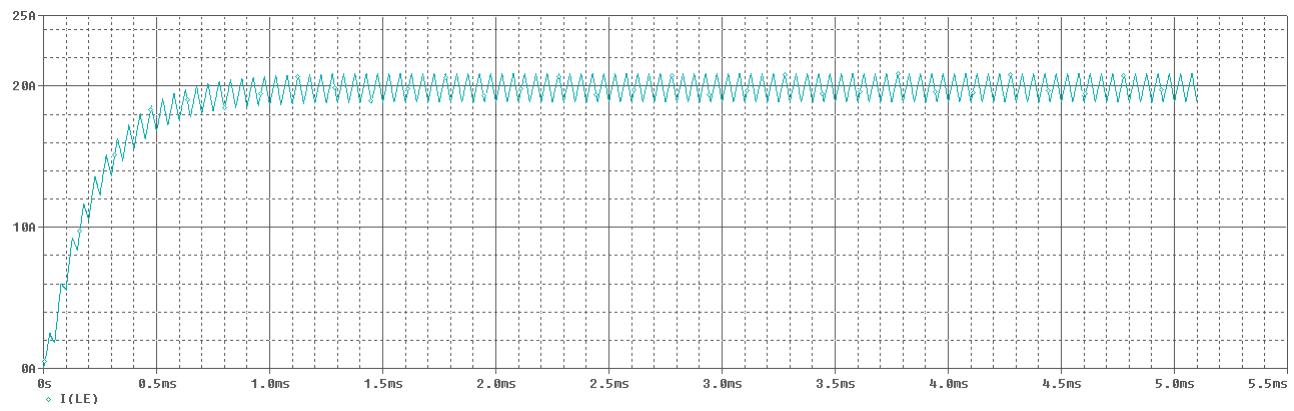
Pulses at transistor base V(7,3)
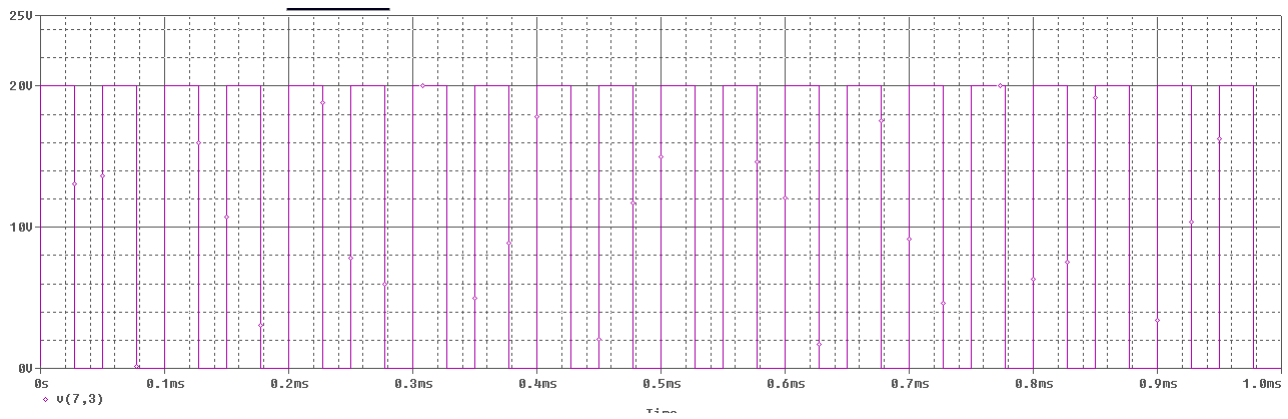
Result:

SINGLE PHASE INVERTER WITH PWM CONTROL

Aim: To simulate the single phase inverter using PWM control by pspice.

Software : PSPICE ORCAD version 9.0

Circuit diagram:
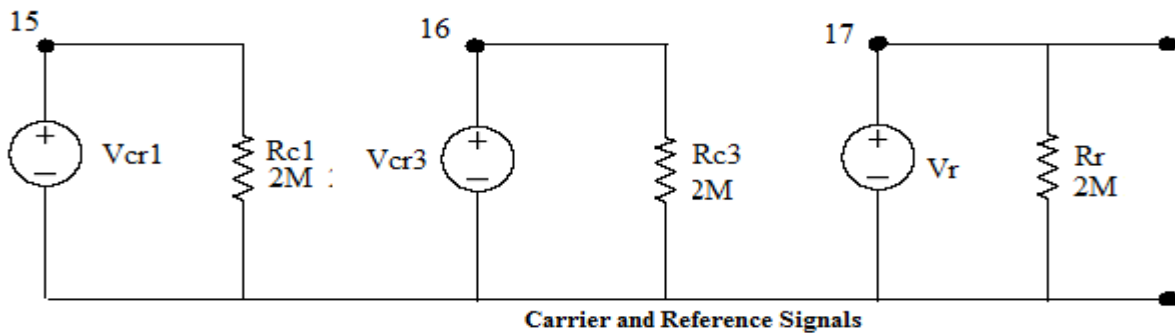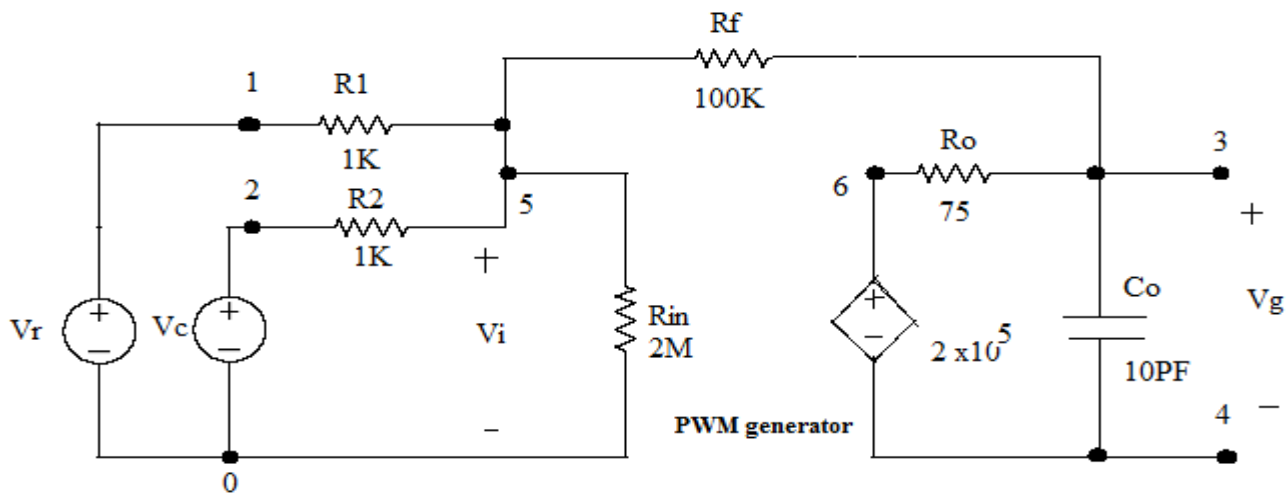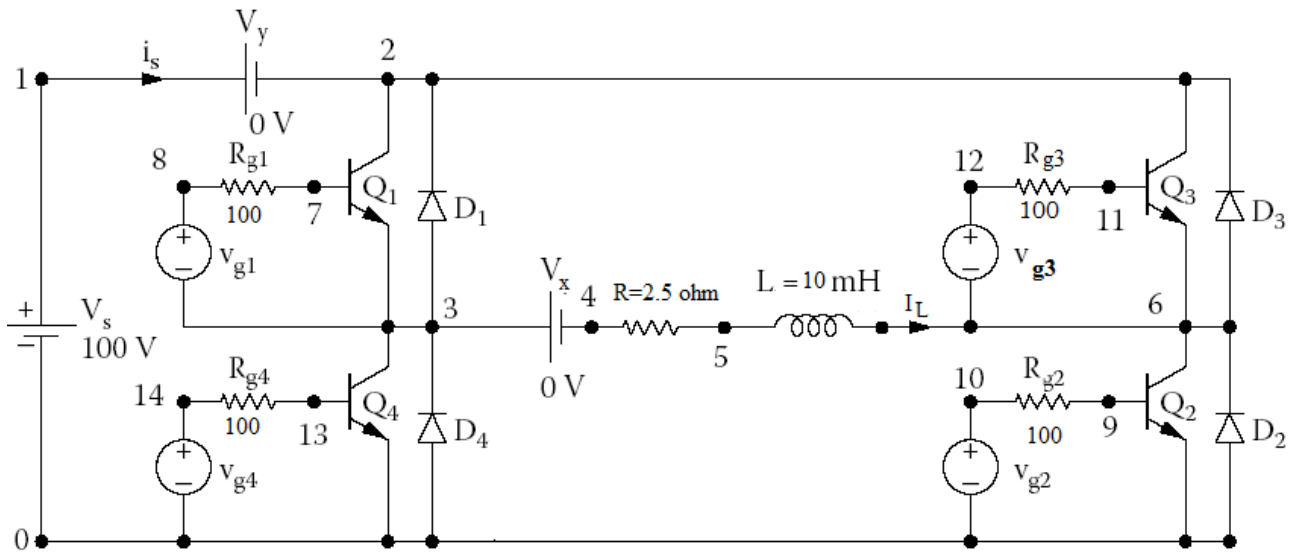
Program :

* SINGLE PHASE PWM INVERTER

```
VS   1   0   DC 100V

VR   17 0   PULSE ( 50V   0V   0   833.33US   833.33US   1NS   1666.67US)

RR   17 0   2MEG

VC1 15 0   PULSE ( 0  -30V   0   1NS   1NS   8333.333US   16666.67US)

RC1 15 0   2MEG

VC3 16 0   PULSE (0  -30V   8333.33US   1NS   1NS   8333.33US   16666.67US)

RC3 16 0   2MEG

R   4   5  2.5

L   5   6  10MH

VX   3   4   DC 0V

VY   1   2   DC 0V

D1   3   2   DMOD

D2   0   6   DMOD

D3   6   2   DMOD

D4   0   3   DMOD

.MODEL DMOD D ( IS=2.2E-15   BV=1800V   TT=0V )

Q1   2   7   3   QMOD

Q2   6   9   0   QMOD

Q3   2   11  6   QMOD

Q4   3   13  0   QMOD

.MODEL QMOD NPN ( IS = 6.734F   BF=416.4   CJC=3.638P   CJE=4.493P )

RG1   8   7   100

RG2   10  9   100

RG3   12  11  100

RG4   14  13  100

XPW1   17  15  8   3   PWM

XPW2   17  15  10  0   PWM

XPW3   17  16  12  6   PWM
```

XPW4   17   16   14   0   PWM

.SUBCKT   PWM   1   2   3   4

R1   1   5   1K

R2   2   5   1K

RIN 5   0   2MEG

RF   5   3   100K

RO   6   3   75

CO   3   4   10PF

E1   6   4   0   5   2E+5

.ENDS PWM

.TRAN   10US   16.67MS   0   10US

.PROBE

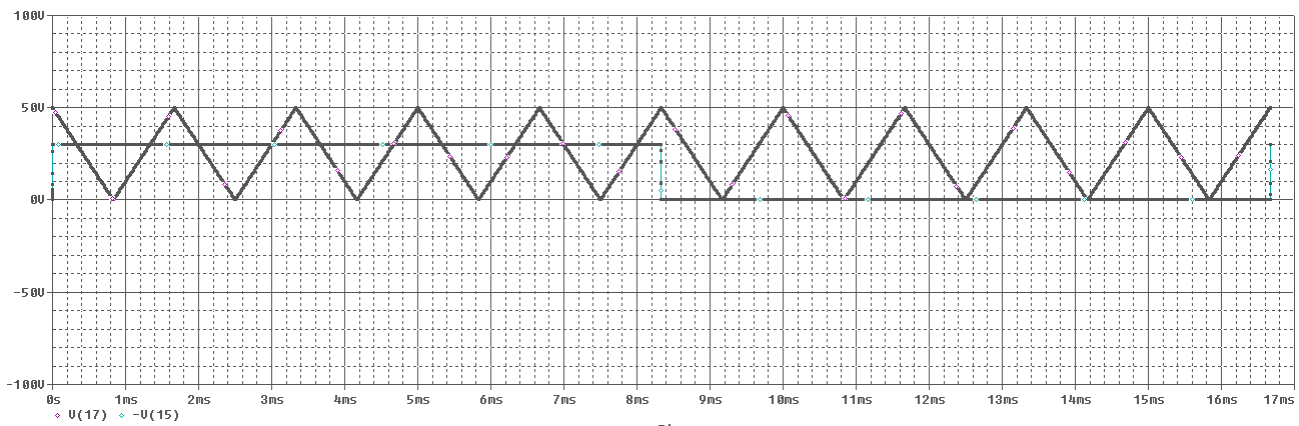.OPTIONS ABSTOL=1.00N   RELTOL=0.01   VNTOL=0.1   ITL5=20000
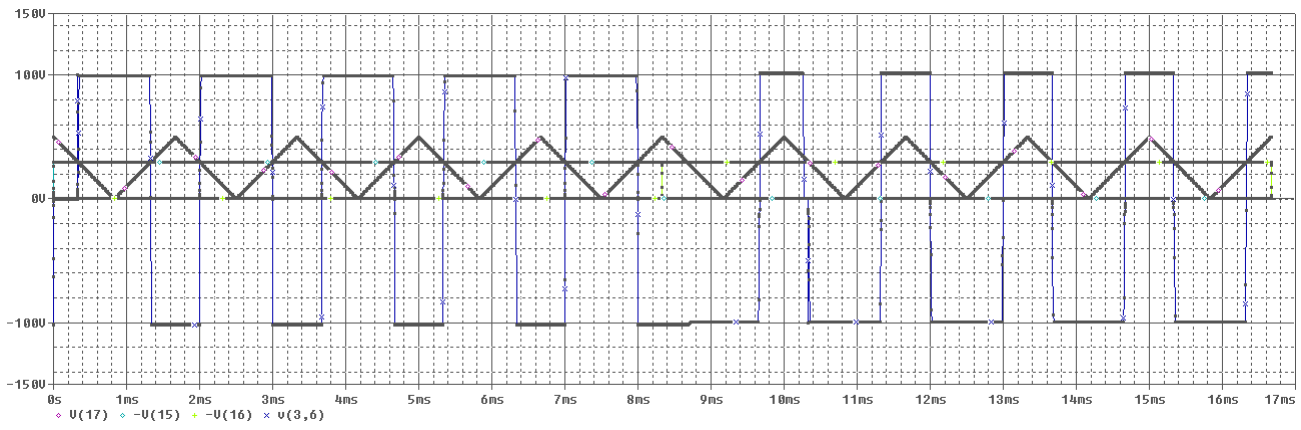
.END

Waveform:

Output AC voltage across load: V(3,6)
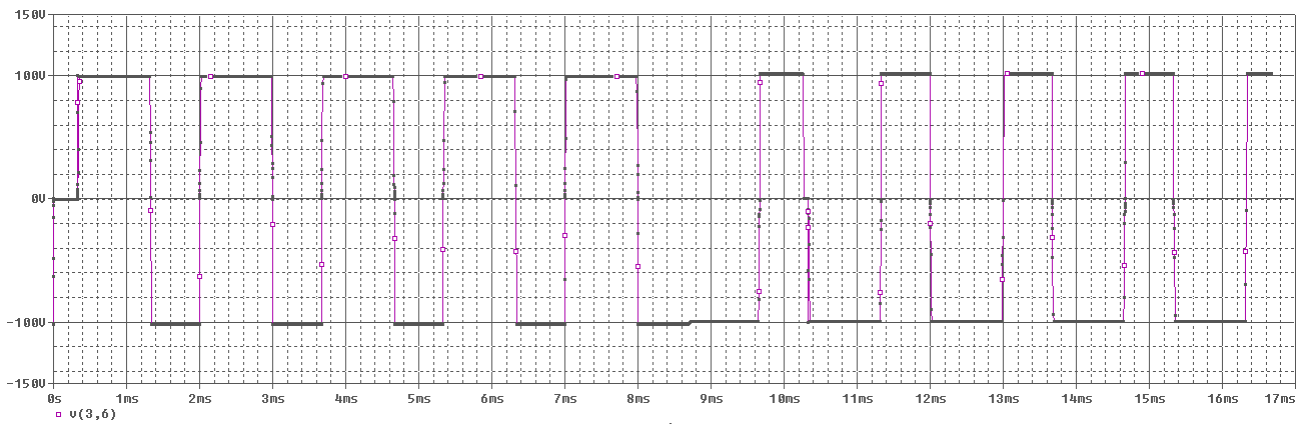
Reference signal V(17), -V(16)
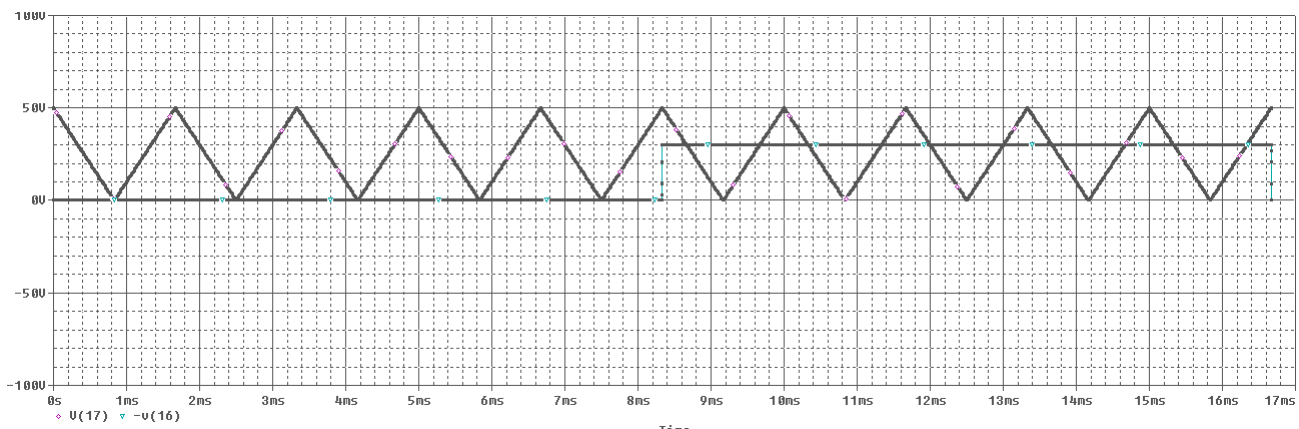
Reference signal V(17), -V(15)

Combined waveform:

Results:

EXPERIMENT- 13
SIMULATION OF THREE PHASE FULL CONVERTER AND PWM INVERTER

13.1 AIM:
Simulation of three phase full converter and PWM inverter with R and RL loads by using MATLAB.

13.2 APPARATUS:

S.NO	EQUIPMENT	QUANTITY
1	DESKTOP WITH MATLAB	1

13.3 THEORY:
Three phase full converter:

Three phase bridge controlled rectifier consist of upper group (T_1, T_3, T_5) and lower group (T_2,T_4,T_5) of thyristors. Thyristor T1 is forward biased ad can be triggered for conduction only when V_A is greater than both V_B and V_C. From figure this condition occurs at $w_t=30^0$. Hence T_1 can be triggered only at $w_t=30^0$.If firing angle is α, then T_1 starts conduction at $w_t=30^0$ + α and conducts for 120^0 where it get commutated by turning on of next thyristor ie,T_3.Similarly triggering instant for T_3 and T_5 are determined when considering V_B and V_C respectively. For lower group T_4,T_6 and T_2, negative voltages,$-V_A$,$-V_B$ and $-V_C$ respectively are considered.

Average Value of output voltage is given by

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

Average Value of output current is given by

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

Three Phase PWM Inverter:

Three phase inverter consists of on and off controlled switches such as MOSFET or IGBT. Sine PWM pulses are used to gate the switches. Upper switches are gated with signals obtained by comparing three reference sine waves each are phase shifted with 1200 with a high frequency triangular carrier wave. Thus, switches are ON when amplitude of corresponding reference sine wave is greater than amplitude of triangular carrier wave. Lower switches are gated with a gate signal which is complement of upper switches of same leg.

Rms Value of phase to neutral output voltage is given by

$$V_{ph.rms} = \frac{mV_{dc}}{2\sqrt{2}}$$

Rms Value of line to line output voltage is given by

$$V_{line.rms} = \frac{\sqrt{3}\,mV_{dc}}{2\sqrt{2}}$$

13.4 CIRCUIT DIAGRAM: Three phase full converter:
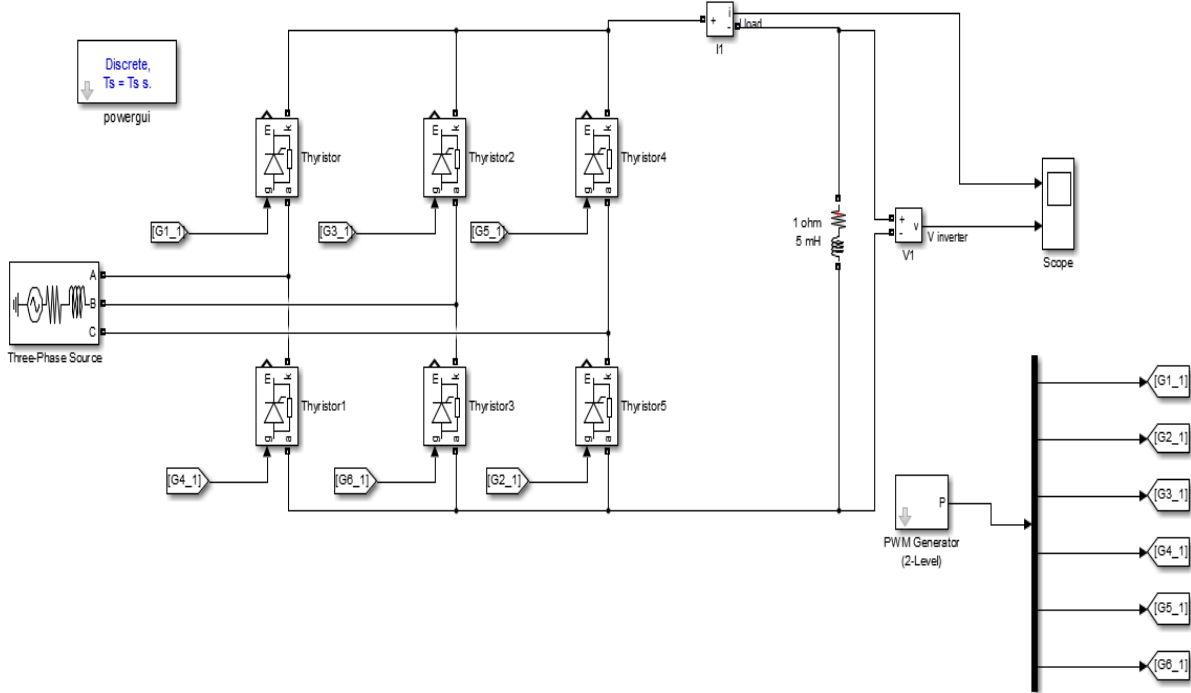
Fig : circuit diagram for Three phase full converter

Three Phase PWM Inverter:
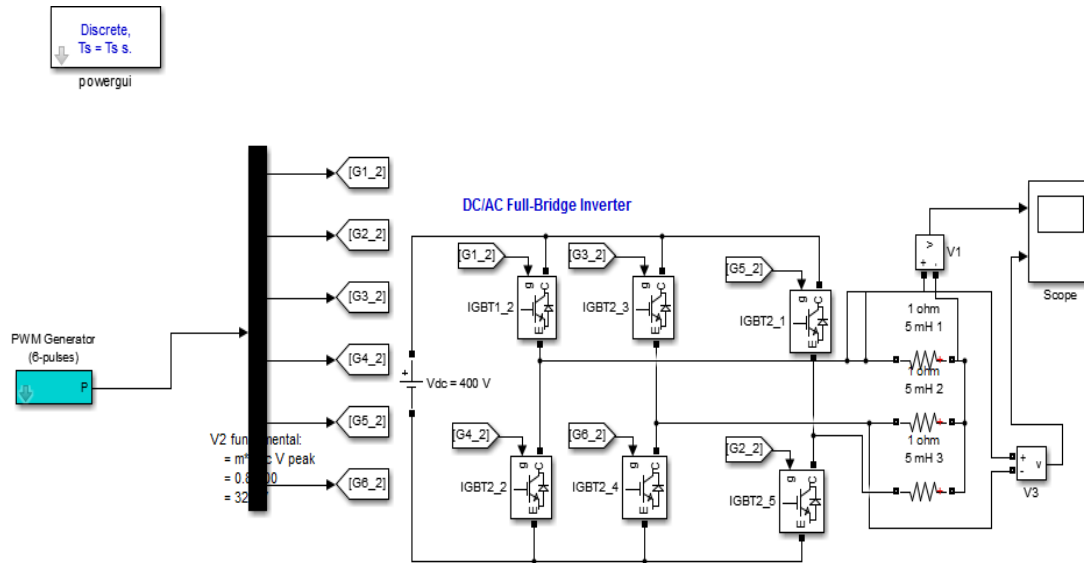
Fig : circuit diagram for Three phase PWM Inverter

13.5   PROCEDURE:

1. Make the connections as shown in the figures 13.1 and 13.2 by using MATLAB Simulink.

2. Set the parameters in PWM generator for firing the switches, set the values for load and input voltage.

3. Check the scope wave forms in each circuit.

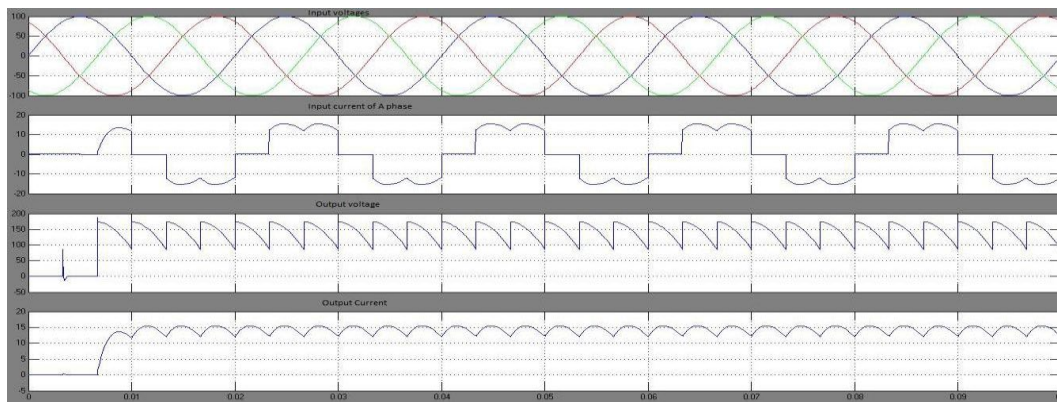## 13.6   EXPECTED GRAPH Three phase full converter:

Fig : output voltage and current waveforms of Three Phase Full Converter

Three Phase PWM Inverter:
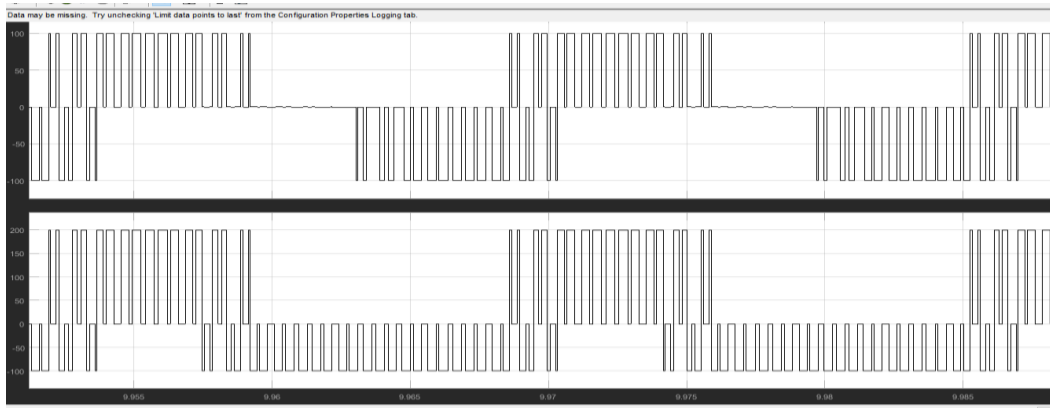
Fig : output voltage and current waveforms of Three Phase PWM Inverter

13.7   Result:

13.8   PRE-LAB VIVA QUESTIONS:
1. What is PWM?
2. What is Duty cycle?
3. What is three phase converter?
4. Define inverter

13.9   POST LAB VIVA QUESTIONS:

1. What are the advantages of PWM inverters?
2. What is the difference between three phase and single phase inverters?
3. What is the time delay for each thyristor conduction in three phase full converter?

14.1 AIM:

Simulation of boost, buck, buck boost converter with R and RL loads by using MATLAB.

14.2 APPARATUS:

S.NO	EQUIPMENT	QUANTITY
1	DESKTOP WITH MATLAB	1

14.3 THEORY:

Boost Converter:

Figure below shows the circuit diagram of step-up DC-DC converter, commonly known as boost converter. When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive. When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

$$V_o = \frac{1}{(1-D)} V_s$$ Where D is duty cycle and V_s is input voltage

Buck converter:

Figure below shows the circuit diagram of step down DC-DC converter, commonly known as buck converter. When switch S is ON, diode D is reverse biased and voltage across inductor will be Vs-Vo. So inductor current increases and attains peak. When switch S is OFF, diode D is forward biased and voltage across inductor will be -Vo. So, inductor current decreases. Hence inductor with diode ensures an uninterrupted current flow and hence a constant output voltage with capacitor for removing voltage ripples.

Output voltage is given by

$$V_o = D V_s$$ Where D is duty cycle and V_s is input voltage

Buck Boost converter:

Figure below shows the circuit diagram of Buck Boost Converter. When Switch is ON, inductor stored energy. Diode isolates input from the output. Capacitor supplies the load. When the switch is OFF, the inductor stored energy charges the capacitor and supplies the load through the diode. As the inductance polarity is reversed when it transfers power, the output has a reverse polarity compared to the input.

Output voltage is given by

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

Where D is duty cycle and V_S is input voltage
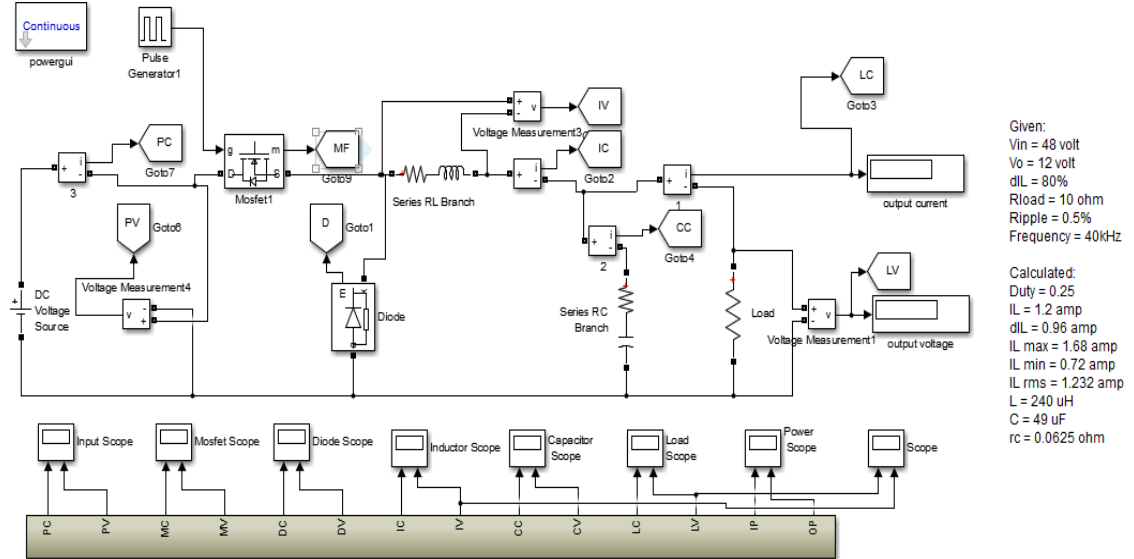
14.4   CIRCUIT DIAGRAM: Buck converter:

Given:
Vin = 48 volt
Vo = 12 volt
dIL = 80%
Rload = 10 ohm
Ripple = 0.5%
Frequency = 40kHz

Calculated:
Duty = 0.25
IL = 1.2 amp
dIL = 0.96 amp
IL max = 1.68 amp
IL min = 0.72 amp
IL rms = 1.232 amp
L = 240 uH
C = 49 uF
rc = 0.0625 ohm

Fig : circuit diagram for Buck converter
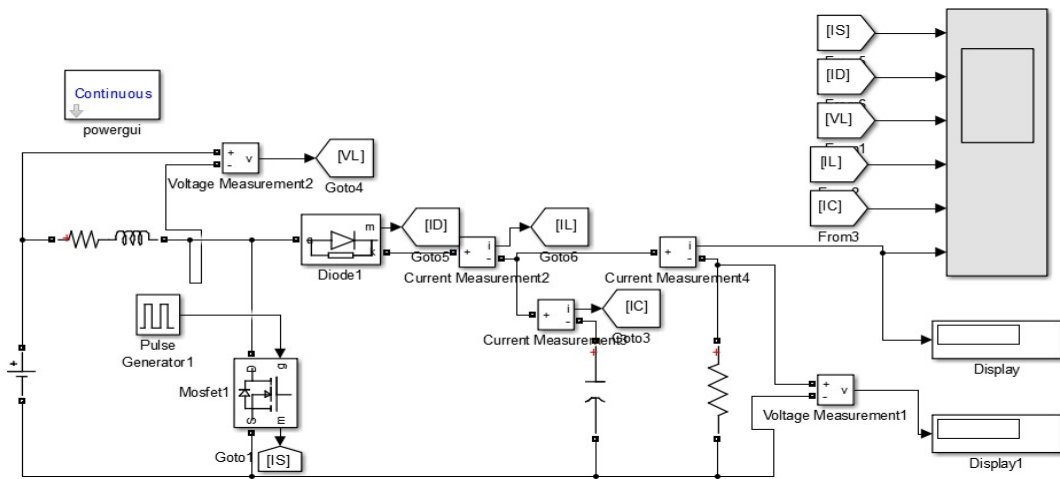
Boost Converter:

Fig : circuit diagram for Boost converter

Buck Boost Converter:
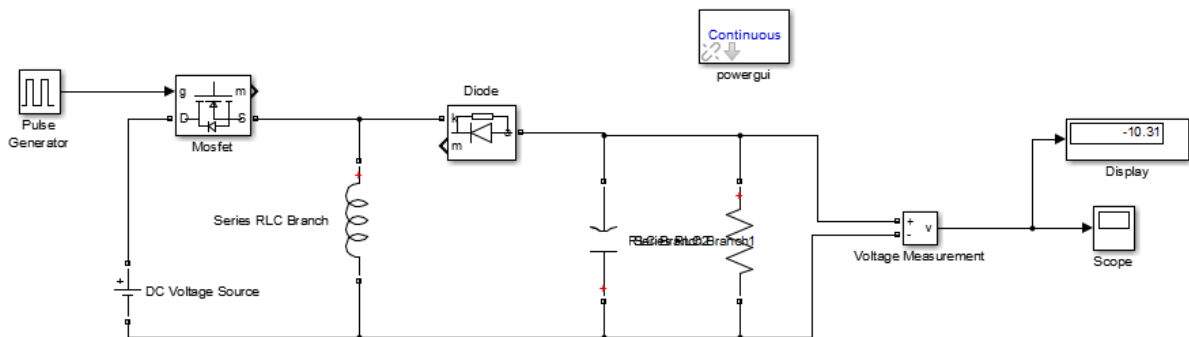
Fig : circuit diagram for Buck Boost converter

14.5.1 PROCEDURE:

1 Make the connections as shown in the figures 13.1 and 13.2 by using

   MATLAB Simulink.

2 Set the parameters in PWM generator for firing the switches, set the values

   for load and input voltage.
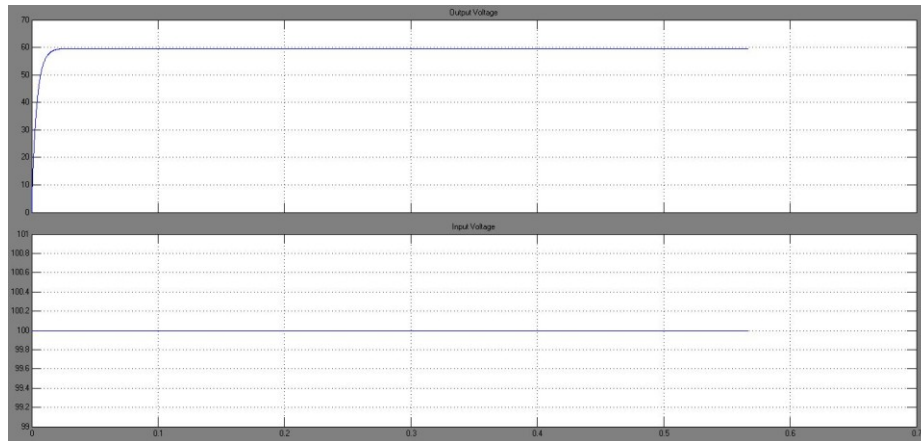
3 Check the scope wave forms in each circuit.

14.6 EXPECTED GRAPH Buck converter:
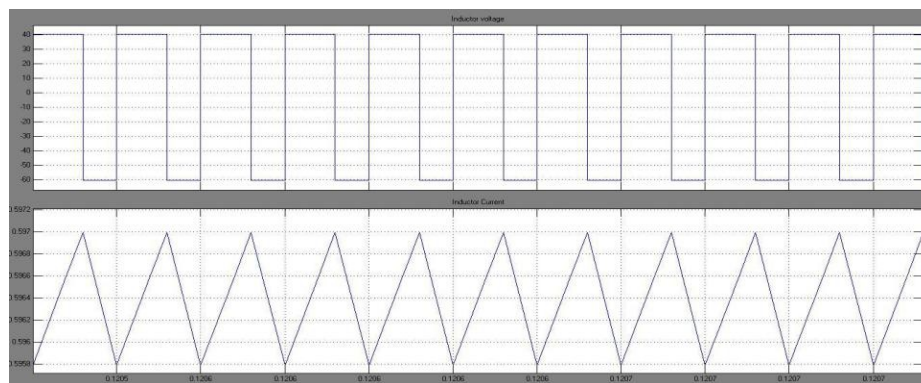

Fig : output and input voltage for buck converter

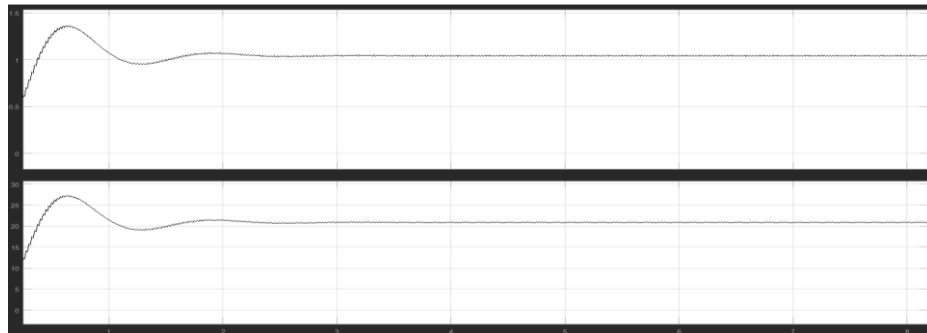Fig : Inductor voltage and current for buck converter

Boost converter:

Fig :Output voltage and current waveforms for boost converter
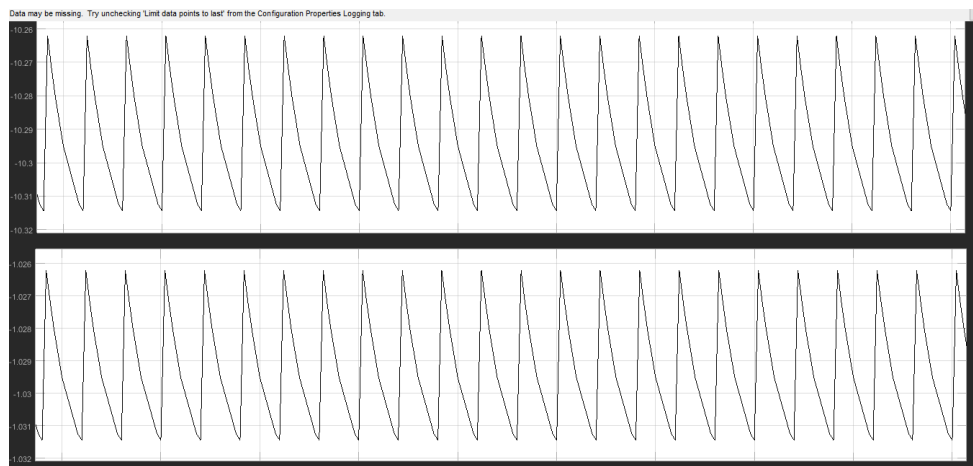
Buck boost converter:

Fig: Output voltage and current waveforms for Buck Boost Converter

14.7 Result:

14.8 PRE-LAB VIVA QUESTIONS:

1 What is DC-DC step up converter?
2 What is buck converter?
3 What is principle of operation of buck boost converter?
4 What is the function of MOSFET?

14.9 POST LAB VIVA QUESTIONS:

1. Which type of control strategy is best suited for buck and boost converters?
2. What are the disadvantages of choppers?