DEPARTMENT
OF
ELECTRICAL AND ELECTRONICS ENGINEERING

NAME OF THE LABORATORY: POWER ELECTRONICS
YEAR AND SEM: III B.TECH II SEM (R16)
REGULATION/LAB CODE: R16/ EE605PC

POWER ELECTRONICS LABORATORY MANUAL

HOD

PRINCIPAL

Department Of Electrical And Electronics Engineering
DEPARTMENT VISION

To be renowned department imparting both technical and non-technical skills to the students through implementing new engineering pedagogy and research to produce competent new age electrical engineers.

DEPARTMENT MISSION

- To transform the students into motivated and knowledgeable new age electrical engineers.
- To advance the quality of education to produce world class technocrats with an ability to adapt to the academically challenging environment.
- To provide a progressive environment for learning through organized teaching methodologies, contemporary curriculum and research in the thrust areas of electrical engineering.
Program Educational Objectives (PEO’s):

PEO 1: Apply knowledge and skills to provide solutions to Electrical and Electronics Engineering problems in industry and governmental organizations or to enhance student learning in educational institutions

PEO 2: Work as a team with a sense of ethics and professionalism, and communicate effectively to manage cross-cultural and multidisciplinary teams

PEO 3: Update their knowledge continuously through lifelong learning that contributes to personal, global and organizational growth
Program Outcomes (PO’s):

A graduate of the Electrical and Electronics Engineering Program will demonstrate:

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
Program Specific Outcomes (PSO’s)

**PSO-1:** Apply the engineering fundamental knowledge to identify, formulate, design and investigate complex engineering problems of electric circuits, power electronics, electrical machines and power systems and to succeed in competitive exams like GATE, IES, GRE, TOEFL, GMAT, etc.

**PSO-2:** Apply appropriate techniques and modern engineering hardware and software tools in power systems and power electronics to engage in life-long learning and to get an employment in the field of Electrical and Electronics Engineering.

**PSO-3:** Understand the impact of engineering solutions in societal and environmental context, commit to professional ethics and communicate effectively.
Course Outcomes (CO’s)

After completion of this course, the student is able to:

Co1) Apply the concepts of power electronics converters for efficient conversion/ control of power from source to load.
Co2) Choose the appropriate converters for various applications.
Co3) Analyze the different converters output waveforms for R and RL loads.
Co4) Use the power electronics simulation packages and hardware to develop the power converters.
EE605PC: POWER ELECTRONICS LAB

B.Tech. III Year II Sem.  

Prerequisite: Power Electronics

Course Objectives:

- Apply the concepts of power electronic converters for efficient conversion/control of power from source to load.
- Design the power converter with suitable switches meeting a specific load requirement.

Course Outcomes: After completion of this course, the student is able to

- Understand the operating principles of various power electronic converters.
- Use power electronic simulation packages & hardware to develop the power converters.
- Analyze and choose the appropriate converters for various applications

Any eight experiments should be conducted

1. Study of Characteristics of SCR, MOSFET & IGBT.
2. Gate firing circuits for SCR’s
3. Single Phase AC Voltage Controller with R and RL Loads
4. Single Phase half controlled & fully controlled bridge converter with R and RL loads
5. Forced Commutation circuits (Class A, Class B, Class C, Class D & Class E)
6. Single Phase Cycloconverter with R and RL loads
7. Single Phase series & parallel inverter with R and RL loads
8. Single Phase Bridge inverter with R and RL loads

Any two experiments should be conducted

1. DC Jones chopper with R and RL Loads
2. Three Phase half controlled bridge converter with R-load
3. Single Phase dual converter with RL loads
4. (a) Simulation of single-phase Half wave converter using R and RL loads
   (b) Simulation of single-phase full converter using R, RL and RLE loads
   (c) Simulation of single-phase Semi converter using R, RL and RLE loads
5. (a) Simulation of Single-phase AC voltage controller using R and RL loads
   (b) Simulation of Single phase Cyclo-converter with R and RL-loads
6. Simulation of Buck chopper
7. Simulation of single phase Inverter with PWM control
8. Simulation of three phase fully controlled converter with R and RL loads, with and
   without freewheeling diode. Observation of waveforms for Continuous and
   Discontinuous modes of operation.
9. Study of PWM techniques

Reference Books:
1. M. H. Rashid, Simulation of Electric and Electronic circuits using PSPICE – by M/s
   PHI Publications.
2. User’s manual of related softwares
3. Reference guides of related softwares
4. Rashid, Spice for power electronics and electric power, CRC Press
# List of Experiments

<table>
<thead>
<tr>
<th>S. No</th>
<th>Name of the Experiment</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Study of Characteristics of SCR, MOSFET &amp; IGBT,</td>
</tr>
<tr>
<td>2</td>
<td>Gate firing circuits for SCR’s</td>
</tr>
<tr>
<td>3</td>
<td>Single Phase AC Voltage Controller with R and RL Loads</td>
</tr>
<tr>
<td>4</td>
<td>Single Phase half controlled &amp; fully controlled bridge converter with R and RL loads</td>
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<tr>
<td>5</td>
<td>Forced Commutation circuits (Class A, Class B, Class C, Class D &amp; Class E)</td>
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<td>6</td>
<td>Single Phase Cycloconverter with R and RL loads</td>
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<tr>
<td>7</td>
<td>Single Phase series &amp; parallel inverter with R and RL loads</td>
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<td>8</td>
<td>Single Phase Bridge inverter with R and RL loads</td>
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<tr>
<td>9</td>
<td>DC Jones chopper with R and RL Loads</td>
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<tr>
<td>10</td>
<td>Three Phase half controlled bridge converter with R-load</td>
</tr>
<tr>
<td>11</td>
<td>Single Phase dual converter with RL loads</td>
</tr>
</tbody>
</table>
| 12    | (a) Simulation of single-phase Half wave converter using R and RL loads  
(b) Simulation of single-phase full converter using R, RL and RLE loads  
(c) Simulation of single-phase Semi converter using R, RL and RLE loads |
| 13    | (a) Simulation of Single-phase AC voltage controller using R and RL loads  
(b) Simulation of Single phase Cyclo-converter with R and RL-loads |
| 14    | Simulation of Buck chopper |
| 15    | Simulation of single phase Inverter with PWM control |
| 16    | Simulation of three phase fully controlled converter with R and RL loads, with and without freewheeling diode. Observation of waveforms for Continuous and Discontinuous modes of operation. |
| 17    | Study of PWM techniques |
Experiment- 1

1. Study of Characteristics of SCR, MOSFETs & IGBTs

AIM:

1. To plot the characteristics of SCR and to find the forward resistance, holding current and latching current.
2. To plot the input and transfer characteristics of MOSFET and to find on state resistance and trans-conductance.
3. To plot the static characteristics of IGBT

APPARATUS REQUIRED:

For SCR
1. Characteristics study unit
2. 0-50V DC voltmeter
3. 0-500 mA DC Ammeter
4. 0-25mA DC ammeter

For MOSFET
1. Characteristics study unit
2. 0-50 volts DC voltmeter
3. 0-15 volts DC voltmeter
4. 0-50 mA DC Ammeter

For IGBT
1. Characteristics study unit
2. 0-50 volts DC voltmeter
3. 0-15 volts DC voltmeter
4. 0-50 mA DC Ammeter
Circuit diagrams:

i. **SCR circuit diagram:**

![SCR circuit diagram](image1)

Fig. 1

ii. **MOSFET circuit diagram:**

![MOSFET circuit diagram](image2)

Fig. 2
iii. IGBT circuit diagram:

![IGBT Circuit Diagram](image)

**Fig. 3**

**THEORY:**

**SILICON CONTROLLED RECTIFIER:** Silicon Controlled Rectifier is a four-layer three junction p-n-p-n switching device. It has three terminals, Anode, cathode and gate. In normal operation of thyristor anode held with high positive potential with respect to cathode and gate has a small positive with respect to cathode.

When Anode is made positive with respect to cathode and switch is open in the gate circuit, then p-n junction j1 and j3 are forward biased, whereas j2 becomes wider and j1 thinner at j1 and j3. There is no base current in transistor t2 and hence that of t1. Under such conditions the SCR is in a state of blocking forward direction. If now gate is made positive w.r.t. cathode or switch is closed, a small gate current will flow through junction j2 as a result anode starts flows if anode current is greater than latching current of SCR. SCR is forward conduction state or simply SCR is closed state.

**MOSFET:** A Power MOSFET has three terminal called drain, source and gate. MOSFET is a voltage controlled device. As its operation depends upon the flow of majority carriers only, MOSFET is uni-polar device. The control signal or gate current is less than a BJT. This is because of fact that gate circuit impedance in MOSFET is very high of the order of $10^9$ ohm. This larger impedance permits the MOSFET gate be driven directly from microelectronic circuits. Power MOSFET's are now finding increasing applications in low-power high frequency converters.
**IGBT:** IGBT is a new development in the area of Power MOSFET Technology. This device combines into its the advantages of both MOSFET and BJT. So an IGBT has high input impedance like a MOSFET and low-on-state power loss in a BJT. IGBT is also known as metal oxide insulated gate transistor (MOSIGT). Conductively modulated field effect transistor

<table>
<thead>
<tr>
<th>Device</th>
<th>Power capability</th>
<th>Switching speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>BJT</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>MOSFET</td>
<td>low</td>
<td>Fast</td>
</tr>
<tr>
<td>GTO</td>
<td>High</td>
<td>Slow</td>
</tr>
<tr>
<td>IGBT</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>MCT</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

**PROCEDURE:**

**For SCR**

**V-I Characteristics:**

1. Make the connections as given in the circuit diagram including meters.
2. Now switch ON the main supply to the unit and initially keep $V_1$ & $V_2$ at minimum.
3. Set load potentiometer $R_1$ in the minimum position. Adjust $I_G-I_{G1}$ say 10 mA by varying $V_2$ or gate current potentiometer $R_2$.
4. Slowly vary $V_1$ and note down $V_{AK}$ and $I_A$ readings for every 5V and enter the readings in the tabular column. Further vary $V_1$ till SCR conducts. This can be noticed by sudden drop of $V_{AK}$ and rise of $I_A$ readings note down this reading and tabulated. Vary $V_1$ further and note down $I_A$ and $V_{AK}$ readings.
5. Draw the graph of $V_{AK}$ Vs $I_L$.
6. Repeat the same for $I_G = I_{G2}/I_{G3}$ mA and draw the graph.
To find $V_G$ and $I_G$:

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 $I_G$ & $V_{GK}$ values.
4. Repeat the procedure 2-3 times to accurately get the $V_G$ and $I_G$ values.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>$I_{G1}$ = $I_G$ = (mA)</th>
<th>$I_{G2}$ = (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_{AK}$ (volts)</td>
<td>$I_A$ (mA)</td>
</tr>
</tbody>
</table>

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 and device must be in the OFF state with Gate open.
3. Gradually increase Gate voltage $V_2$ till the device turns ON. This is the minimum Gate current ($I_G$ minimum) required to turn ON the device.
4. Adjust the Gate voltage to a slightly higher and set the load potentiometer at the maximum resistance position. The device should come to OFF state. Otherwise decrease V1 till the devise comes to OFF state.
5. The Gate voltage should be kept constant in this experiment.
6. By varying R1, gradually increase anode current $I_A$ in steps
7. Open and close the Gate voltage $V_2$ switch after each step.
8. If the anode current is greater than the latching current of the devise the device says ON even after the Gate switch is opened. Otherwise the devise goes in to blocking mode as soon as the Gate switch is opened.
9. Note the latching current obtain more accurate value of the latching current by taking small steps of 1A near the latching current values.

**To find Holding current:**
1. Increase the anode 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 anode current gradually by adjusting R1. If the thyristor does not turns OFF even after the R1 at maximum position, then reduce V11
4. Observe when the device goes to blocking mode. The anode 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 \( I_h < I_L \).

**For Power MOSFET**

**Trance conductance characteristics:**
1. Make the connections as shown in the circuit diagram with meters initially keep V1 and V2 zero.
2. Set V1 = VDS1 = say 10v. Slowly vary V2 (VGS) and note down ID and VGS readings for every 0.5 volts enter in the tabular column.
3. The minimum Gate voltage VGS that is required for conduction to start in the MOSFET is called threshold voltage VGS is greater than VGS (Th).
4. If VGS is less than VGS (Th) the drain current depends on magnitude of the Gate voltage VGS varies from 2 to 5 volts.
5. Repeat the same for different values of VDS and draw the graph of ID/VGS.

**Tabular column:**

<table>
<thead>
<tr>
<th>S.No</th>
<th>V1=VDS1 (volts) =10v</th>
<th>V1=VDS2=30volts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VGS (volts)</td>
<td>ID (mA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**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 ID v/s VDS for different values of VGS.

**Tabular column:**

<table>
<thead>
<tr>
<th>S.No</th>
<th>V2=VGS1 = 3.5volts</th>
<th>V2= VGS2=3.8(volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDS (volts)</td>
<td>ID(mA)</td>
<td>VDS (volts)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**For IGBT**

**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 is less than 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 6 volts.
6. Repeat the same for different values of VDS and draw the graph of ID/VGS.
Tabular column:

<table>
<thead>
<tr>
<th>S.No</th>
<th>V1=VCE1=10V</th>
<th>V2=VCE2=30V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VGE (volts)</td>
<td>IC (mA)</td>
</tr>
</tbody>
</table>

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 if VGE is more than Vp. Constant IC flows from the device and this operating region is called constant current region.
4. Repeat the above for different values of VGE and note down IC v/s VGE
5. Draw the graph of IC v/s VGE for different values of VGE

Tabular column:

<table>
<thead>
<tr>
<th>S.No</th>
<th>VGE1=5 V</th>
<th>VGE2=5.4 V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VCE (volts)</td>
<td>IC (mA)</td>
</tr>
</tbody>
</table>

Department Of Electrical And Electronics Engineering
MODEL GRAPHS:

SCR CHARACTERISTICS

MOSFET OUTPUT CHARACTERISTIC

MOSFET TRANSFER CHARACTERISTIC
RESULTS:

VIVA – VOCE QUESTIONS:

1. What is latching current and holding current
2. Distinguish IGBT and MOSFET
3. What is mean by gate pulse
4. What is voltage triggering method
5. Classify different types of triggerings
Experiment-2

2. GATE FIRING CIRCUITS FOR SCRs

**AIM:**
To study various firing schemes for triggering SCRs when they are used in different converter topologies employ line commutation.

1. Resistance firing circuit.
2. Resistance capacitance (RC) firing circuit.

**APPARATUS REQUIRED:**
1. R, RC triggering module
2. Resistive load.
3. Dual trace oscilloscope with probes.

**FRONT PANEL DETAILS:**
1. POWER : 400V, 4A, type 106 D
2. AC : 20volts /1A AC Supply
3. RC : Control potentiometer-5k ohms
4. D1 & D2 : Diodes IN 5402
5. C : Capacitor 4.7μf/1000v for R-C triggering
6. T : SCR-TYN 612 12Amps/600V
7. RG : Gate current limiting resistor
8. LOAD : Terminals to connected load
CIRCUIT DIAGRAM:

R-Triggering Circuit.

R-C Triggering
THEORY:

This is the most commonly used method for triggering SCR’s. In laboratories almost all the SCR devices are triggered by this process. By applying the positive signal at the gate terminal of the device, it can be triggered much before the specified break over voltage.

The conduction period of the SCR can be controlled by varying the gate signal within specified values of the maximum and minimum gate currents.

FOR R&RC CIRCUIT:

PROCEDURE:

1. Make the connections as per the circuit diagram.
2. Vary the control pot and observe the voltage wave forms across load, SCR and at different points in the circuit, using oscilloscope.
3. Draw the wave forms in the graph at firing angles 0°, 45°, 90°, 135° and 180°

WAVEFORMS FOR RESISTANCE TRIGGERING:
R-C Triggering Waveforms:

For Large Value of $R$

For Small Value of $R$
PRECAUTIONS:

1. Make sure all the connections are tight.
2. Ensure all the controlling knobs are kept in fully counter clock wise position before starting experiment.
3. Handle everything with care

RESULT:

VIVA QUESTIONS:

1. What is gate firing circuit
2. What is RC and RL triggering
3. Define commutation in power electronics
4. How many types of turn on methods are available
5. What is forward voltage and reverse blocking voltage
Experiment-3

SINGLE PHASE AC VOLTAGE CONTROLLER WITH R AND RL LOADS

AIM:
To study the module and waveforms of a 1-Φ A.C Voltage controller with R and RL loads.

APPARATUS REQUIRED:
1. 1Φ A.C regulated power supply
2. Loading rheostat : 50 Ohms, 2A
3. Loading inductor : 50 mH,
4. Voltmeter : 0 – 150 V.MI.
5. 20 MHz dual trace oscilloscope with 1:10 BNC probes.

SPECIFICATIONS:

1. Input : 0 -230 V 1- phase AC supply
2. Load : Rand RL.
3. Thyristor : 12 A, 600V, type 25 RIA120.
4. Triacs : 10 A, 600 V.
5. MCB : Two pole 230 V/16A.
6. Fuses : 16A HRC.
CIRCUIT DIAGRAM:

Fig-1 Single Phase AC Voltage controller with R-load

Fig-2 Single Phase AC Voltage controller with RL-load
THEORY:

Voltage controllers convert fixed ac voltage directly to variable ac voltage at the same frequency. When the supply is given thyristor $T_1$ & $T_2$ are forward biased during positive & negative half cycle, respectively.

During positive half cycle, $T_1$ is triggered at a firing angle $\alpha$; $T_1$ starts conducting and source voltage is applied to load from $\alpha$ to $\pi$. After $\pi$, $T_1$ is subjected to reverse bias and it is triggered at $(\pi + \alpha)$. $T_2$ conducts from $(\pi + \alpha)$ to $2\pi$. Soon after $2\pi$, $T_2$ is subjected to a reverse bias and it is therefore commutated.

PROCEDURE:

1. Switch ON the main 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 connection as per the circuit diagram.

3. Connect firing pulses from the 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 waveform across load using oscilloscope.

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

7. Draw the waveforms in the graph at $0^\circ$, $45^\circ$, $90^\circ$, $135^\circ$ and $180^\circ$ firing angles.

Tabular Column:

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Input voltage(v)</th>
<th>Firing angle (°)</th>
<th>Output voltage(V)</th>
<th>Output current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
With R Load

With RL Load:
**PRECAUTIONS:**

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

2. Ensure all the controlling knobs in fully counter clock wise 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 corresponding SCRs / TRIAC in the power circuit.

**RESULTS:**

**VIVA – VOCE QUESTIONS:**

1.

2.

3.

4.

5.
Experiment-4

SINGLE PHASE HALF CONTROLLED & FULLY CONTROLLED BRIDGE CONVERTER WITH R AND RL LOADS

AIM: To obtain the output waveform of single phase half controlled bridge converter with R and RL Loads

APPARATUS:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Name of the Equipment</th>
<th>Type</th>
<th>Range</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Single phase half controlled converter power circuit</td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Firing Unit</td>
<td></td>
<td></td>
<td>1</td>
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<tr>
<td>3.</td>
<td>Voltmeter</td>
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<td>(0-60V)</td>
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<tr>
<td></td>
<td></td>
<td>MC</td>
<td>(0-50V)</td>
<td>1</td>
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<tr>
<td>4.</td>
<td>1:1 Isolation Transformer</td>
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<td>1KVA</td>
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<td>5.</td>
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<td>7.</td>
<td>CRO</td>
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<td>8.</td>
<td>Patch Chords</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CIRCUIT DIAGRAM:

Fig-1 for R-load

Fig-2 for RL-load
PROCEDURE:

R-load:

1. Make connections as per the circuit diagram.
2. Verify the connections from the lab instructor before switching ON the supply.
3. Keep the rheostat position and variac position as the value given by the lab instructor.
4. Switch ON the CRO and calibrate it with the input voltage.
5. Switch ON the power circuit and firing circuit.
6. Observe the output voltage wave form in the CRO.
7. Note down the readings of $\alpha$ from the CRO and $V_0$ from the voltmeter.
8. Also calculate the theoretical value of the output voltage from the formula and compare it with the practical value of the output voltage, which is observed from the voltmeter.
9. Repeat the above process for various firing angle.

RL-load:

10. Switch off the supply and connect an inductance of given value in series with the load resistance.
11. Repeat steps 2 to 9 and also note down the readings of $\beta$. 
**OBSERVATIONS:**

For R-Load:

Input voltage $V_{ph} =$

Load resistance $R =$

<table>
<thead>
<tr>
<th>S.No</th>
<th>Firing angle $\alpha$ in msec</th>
<th>Firing angle in Degrees</th>
<th>Firing angle in radians</th>
<th>$V_o$ (theoretical)</th>
<th>$V_o$ (practical)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RL Load:

Input voltage $V_{ph} =$

Load resistance $R =$

Value of Inductance $L =$

Theoretical Extinction angle $\beta =$

Practical Extinction angle $\beta =$

<table>
<thead>
<tr>
<th>S.No</th>
<th>Firing angle $\alpha$ in msec</th>
<th>Firing angle in Degrees</th>
<th>Firing angle in radians</th>
<th>$V_o$ (theoretical)</th>
<th>$V_o$ (practical)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Model Graphs:

R-Load:

FOR RL LOAD
SINGLE PHASE FULLY CONTROLLED BRIDGE CONVERTER WITH R AND RL LOADS

AIM:
To study the operation and waveforms of a 1Φ Full Bridge converter

APPARATUS REQUIRED:
1. 1Φ Full Bridge converter firing circuit and power circuit units.
2. 1Φ isolation transformer : 230V/30V.
3. Loading inductor : 150 mH,
4. Loading Rheostat : 150 Ohm/5A.
5. DC Motor load (RLE) : 230 V, 0.5 HP, Field 220 V @ 2A.
6. 20 MHz dual trace oscilloscope with 1:10 BNC probes.

SPECIFICATIONS:
1. Input : 0 -230 V 1- phase AC supply
2. Load : R RL and RLE load
3. Thyristor : 25A, 1200V, type 25 RIA 120.
4. Diodes : 25A 1200V.
5. MCB : Two pole 230 V/16A.
6. Fuses : 16A HRC.
7. Field supply Bridge rectifier: 10A, 600 V.
8. Field supply : 220 V +10 %
CIRCUIT DIAGRAM:

1-Phase Full Bridge Converter

With RL-Load:
THEORY:

In the single phase full bridge circuit, diagonally opposite pair of thyristor are made to conduct and are commutated simultaneously. The advantage of single phase bridge converter over single phase mid-point converter is

i) SCR’s are subjected to a peak inverse voltage of $2E_{m}$ in mid-point converter $K E_{m}$ is fully converter – bridge converter.

ii) In midpoint configuration each secondary should be able to supply the load power. As such, the rating in mid-point converter is double the load-rating this however is not the case in single phase bridge converter.

PROCEDURE:

1. Make the connection as per the circuit diagram.
2. Switch ON the main supply to the firing circuit.
3. Observe the trigger outputs by varying firing angle potentiometer and by operating ON/OFF switch and their phase sequence. Make sure the firing pulses are proper before connecting to the power circuit.
4. The trigger output pulse width varies as we vary the firing angle.
5. Next make the connections as in the power circuit.
6. Connect 30 V tapping of the transformer secondary to the power circuit.
7. Connect firing pulses from the firing circuit to the corresponding SCRs/TRIAC in the power circuit.
8. Switch ON the MCB and now switch ON the trigger pulses and note down the voltage waveforms across load and devices.
10. Note down the input voltage, firing angle, output voltage and output current readings in the tabular column.
11. Repeat the same for different input voltage up to max. Voltage as provided in the isolation transformer.
12. Repeat the same for RL and RLE loads with and with out free wheeling diode.
10. Draw the wave forms in the graph at firing angles $0^\circ$, $45^\circ$, $90^\circ$, $135^\circ$ and $180^\circ$. 
### OBSERVATION TABLE FOR R LOAD:

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Input voltage (v)</th>
<th>Firing angle (°)</th>
<th>Output voltage (Vo)</th>
<th>Output current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Theoretically</td>
<td>practically</td>
</tr>
</tbody>
</table>

### TABLE FOR RL LOAD WITH OUT FREEWHEELING DIODE:

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Input voltage (v)</th>
<th>Firing angle (°)</th>
<th>Output voltage (Vo)</th>
<th>Output current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Theoretically</td>
<td>practically</td>
</tr>
</tbody>
</table>
# TABLE FOR RL LOAD WITH FREEWHEELING DIODE:

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Input voltage (v)</th>
<th>Firing angle (°)</th>
<th>Output voltage (Vo)</th>
<th>Output current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Theoretically</td>
<td>practically</td>
</tr>
</tbody>
</table>

## MODEL GRAPH

![Model Graph](image)

The waveforms illustrate the input, output with R load, and output with RL load. The firing angle is indicated by π and 2π, and the frequency is 50 Hz.
**PRECAUTIONS:**

1. Make sure all the connecting links are tightly fixed.
2. Ensure all the controlling knobs in fully counter clock wise position before starting experiment.
3. Handle everything with care.
4. Make sure the firing pulses are proper before connecting to the power circuit.
5. 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 the power circuit to synchronize.

**RESULT:**

**VIVA – VOCE QUESTIONS:**

1.
2.
3.
4.
5.
Experiment 5
FORCED COMMUTATION CIRCUITS

AIM:
To study the module and waveforms of forced commutation circuits
1. Class A commutation – Self commutation by resonating load
2. Class B commutation – self commutation by LC circuit
3. Class C commutation – Complementary SCR commutation.
4. Class D commutation – Auxiliary commutation.

APPARATUS REQUIRED:
1. Forced commutation unit.
2. Loading Rheostat : 100 Ohms, 2A.
3. Regulated power supply : 0-30VDC, 2A.
4. 20 MHz dual trace oscilloscope with 1:1 probes.

SPECIFICATIONS:
1. Thyristors : TYN 612.
2. Diodes : BYQ 28-200
3. Transistor : TIP 122.
4. Capacitor : C1= 4.7μf/100V C2= 10μf/ 100V
5. Inductor : L1=250 μH, 2A. L2=500 μH, 2A. L3 = 1m H.
6. Fuses : 2A Glass fuse
CIRCUIT DIAGRAM:

CLASS-A COMMUTATION:

CLASS-B COMMUTATION:

CLASS-C COMMUTATION:

CLASS-D COMMUTATION:

Class E Commutation Circuit
**THEORY:**

**Class A- Self commutation by resonating load:**

This is also known as resonant commutation. This type of commutation circuit using L-C components is in series with load.

In this process of commutation, the forward current passing through the device is reduced to less than the level of holding current of the device. Hence this method is also known as the current commutation method.

**Class B- self commutating by an LC circuit:** In this method, the LC resonating circuit is across the SCR and not in series with the load.

Initially as soon as the supply voltage $E_{dc}$ is applied, the capacitor $C$ starts getting charged with its upper plate positive and lower plate negative, and it charges up to the voltage $E_{dc}$.

When thyristor $T$ is triggered, the circuit current flows in two directions:

i) The load current $I_L$ flows through the path $E_{dc}+T-R_L-E_{dc}$.

ii) Commutating current $I_c$.

**Class D – auxiliary commutation:**

In this commutation method, an auxiliary thyristor is required to commutate the main thyristor ($T_1$), assuming ideal thyristor and the lossless components; here inductor $L$ is necessary to ensure the correct polarity on capacitor $C$.

Thyristor $T_1$ and load resistor $R_L$ from the power circuit, Where as $LDK T_2$ from the commutation circuit.

**Class E – External pulse commutation:**

In this type of commutation method, the reverse voltage is applied to the current carrying thyristor from an external pulse source.

Here, the commutating pulse is applied through a pulse – transformer which is suitably designed to have tight coupling between the primary and secondary

This type of commutation method is capable of very high efficiency as minimum energy is required and both time ratio and pulse width regulation are easily incorporated.
**PROCEDURE:**
1. Switch ON the mains supply to the firing circuit. Observe the trigger outputs in the firing circuit by varying frequency potentiometer and duty cycle potentiometer. Make sure the firing pulses are proper before connecting to the power circuit.
2. Check the DC power supply between the DC input points.
3. Check the resistance between anode and cathode of all SCRs.
4. Check the resistance between the Gate and cathode of SCRs.
5. Check the diode and Transistor and their polarities.
6. Check the fuse in series with the DC input.
7. Make sure that all the components are good and firing pulses are correct before starting the experiment.

For class A&B:
1. Make the connections as per the circuit diagram.
2. Connect the trigger output T1 from the firing circuit to the Gate and cathode of SCR T1.
3. Switch ON the DC supply to the power circuit.
4. Observe the voltage waveform across load using oscilloscope by varying the frequency potentiometer.
5. Duty cycle potentiometer is of no use in this experiment.
6. Repeat the same for different values of R, L and C.
7. Draw the waveforms in the Graph for different R, L and C.

For class C:
1. Make the connections as per the circuit diagram.
2. Connect the trigger output T1 & T2 from the firing circuit to the Gate and cathode of SCR T1 & T2.
3. Switch ON the DC supply and switch ON the trigger pulses by operating ON/OFF switch in the firing circuit.
4. Observe the voltage waveform across R1, R2 and C using oscilloscope by varying the frequency and duty cycle potentiometers.
5. Repeat the same for different values of R & C.
6. L is of no use in this circuit.
7. Draw the waveforms in the graph for different R & C.

For Class D:
1. Make the connections as per the circuit diagram.
2. Connect the trigger outputs T1 and T2 from the firing circuit to gate and cathode of SCRs T1 & T2.
3. Initially keep the trigger ON/OFF switch at OFF position to charge the capacitor. This can be observed by connecting CRO across the capacitor.
4. Switch ON the DC supply and switch ON the trigger pulses by operating ON/OFF switch in the firing circuit.
5. Observe and note down the voltage waveform across the load. T1, T2 and C using oscilloscope by varying the frequency and duty cycle potentiometers.
6. Repeat the same for different values of load. L & C.

For Class E:

1. Make the connections as per the circuit diagram.
2. Connect V2 supply from an external DC power supply unit.
3. Connect the trigger output T1 from the firing circuit to gate and cathode of SCR T1.
4. Connect T2 to the transistor base and emitter points.
5. Switch ON the DC supply, external DC supply and the trigger pulses by operating ON/OFF switch in the firing circuit.
6. Observe and note down the voltage waveform across the load.
7. Repeat the same by varying the frequency and duty cycle potentiometers.
8. Draw the waveforms in the graph for different frequency and duty cycle.

CLASS A COMMUTATION:
CLASS-B COMMUTATION:

\[ I_s \]
\[ I_L \]
\[ I_{\text{SCR}} \]
\[ V_{\text{SCR}} \]

\[ t_{\text{off}} \]

CLASS-C COMMUTATION:

\[ I_{\text{ss}} \]
\[ I_{\text{sa}} \]
\[ I_{\text{sb}} \]
\[ I_{\text{sc}} \]
\[ E_{\text{bc}} \]
\[ E_{\text{bc}} \]

Time constant: \( \tau = R_1 C \)
CLASS D COMMUTATION WAVEFORMS:

CLASS-E COMMUTATION:
PRECAUTIONS:

1. Make sure all the connecting links are tightly fixed.
2. Ensure all the controlling knobs in fully counter clock wise 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 SCRs in the power circuit.
6. Ensure switch OFF the input supply first and then trigger pulses to avoid short circuit.

RESULT:

VIVA - VOCE QUESTIONS:

1.
2.
3.
4.
5.
Experiment 6

SINGLE PHASE CYCLOCONVERTER WITH R AND RL LOADS

AIM:
To study the module and wave forms of a 1-Φ center tapped cyclo-converter with R and RL loads.

APPARATUS REQUIRED:

1. 1Φ cyclo-converter firing circuit and power circuit units.
3. 1Φ 230 V / 0-270 V auto transformer.
4. Loading Rheostat: 50 Ohms, 2 A.
5. Loading inductor; 50 mH, 2 A.
6. 20 MHz dual trace oscilloscope with 1:10 BNC probes.

SPECIFICATIONS:

1. Input : 0-230 V 1- Φ AC supply.
2. Load : 15 A
3. Thyristor : 25 A, 1200 V, type 25 RIA 120
4. MCB : two pole 230 V / 16A.
CIRCUIT DIAGRAM:

![Circuit Diagram](image)

THEORY:

In a single phase cyclo-converter employing a center tapped transformer has four thyristors, namely T₁, T₂, T₃, T₄. Out of four SCR’s, SCR’s T₁, T₂ are responsible for generating their positive halves forming the positive group. The other two SCR’s T₃ & T₄ are responsible for producing negative halves forming the negative group. This configuration is meant for generating 1/3 of the input frequency i.e., this generates a frequency of 16 2/3 Hz at its output.

Depending upon the polarities of the transformer, SCR’S are gated.

Natural commutation process is used for turning off the SCR’S. The circuit configuration is analyzed for purely resistive load.

PROCEDURE:

1. Switch ON the main supply to the firing circuit and power circuit. Observe the trigger outputs by changing frequency division push buttons and varying the firing angle control knob. 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 respective SCRs in the power circuit.

4. Initially connect the input terminals to the 30V-0-30V terminals of the center tapped transformer.

5. Set the frequency division to 2. Switch ON the trigger pulses. And switch ON the MCB.

6. Vary the firing angle potentiometer and observe the voltage wave forms across load using oscilloscope.

7. Note down the reading in the tabular column.

8. After ensuring correct output at low voltage, increase the input voltage to 230V-0-230V in steps and note down the corresponding readings.

9. Follow the above procedure for frequency divisions 3 to 9.

10. Draw the wave forms in the graph at firing angles 0°, 45°, 90°, 135°, and 180°.

Table:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Input voltage(V)</th>
<th>Frequency divisions</th>
<th>Firing angle (°)</th>
<th>Output voltage (V)</th>
<th>Output current (A)</th>
<th>Input frequency (fs)</th>
<th>Output frequency (fo)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MODEL WAVEFORMS:

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

RESULT:
VIVA – VOCE QUESTIONS:

1.
2.
3.
4.
5.
Experiment 7
Single Phase series& parallel inverter with R and RL loads

SINGLE PHASE SERIES INVERTER WITH R AND RL LOADS

AIM:
To study the operation and waveforms of a 1Φ series inverter with R and RL loads.

APPARATUS REQUIRED:

1. 1Φ series inverter firing circuit and power circuit units.
2. Inductor : 10mH-5mH-0-5mH-10mH, 2A
3. Capacitors : 6.8 µf and 10 µf, 100V
4. Loading Rheostat : 50 Ohms 2A.
5. 20 MHz dual trace oscilloscope with 1:10 BNC probes.

SPECIFICATIONS:

1. Input : 0 -230 V 1- phase AC supply
2. Load : R and RL
3. Thyristor : 12A, 600V, type TY 621.
5. Capacitors (C1&C2): 6.8 µf and 10 µf, 100V
6. Capacitors (C1&C2): 10 µf, 100V.
7. Inductor : 10mH-5mH-0-5mH-10mH, 2A
5. MCB : Two pole 230 V/16A.
6. Fuses : 16A HRC.
CIRCUIT DIAGRAM

Fig. Single-phase Series Inverter

THEORY:

In some inverters, the commutating elements may come in series with the load or in parallel with the load during operation.

In series inverters as indicated by the name, the commutating elements viz LKC are connected in series with the load. This constitutes a series R-L-C resonant circuit. If the load is purely resistive, if only has resistance in the circuit.

PROCEDURE:

1. Make the connection as per the circuit diagram.
2. Switch ON the main supply to the firing circuit. Observe the trigger outputs in the firing circuit. Make sure that firing pulses are proper before connecting to the power circuit.
3. Connect firing pulses from the firing circuit to the corresponding SCRs in the power circuit.
4. Connect the DC input from a 30 V, 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 across load and devices 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 loads.

9. Observe the voltage wave forms across load with and without freewheeling diode.

10. Draw the wave forms in the graph at different frequencies.

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

Model Waveforms:-

![Waveforms Diagram]
PRECAUTIONS:

1. Make sure all the connecting links are tightly fixed.
2. Ensure all the controlling knobs in fully counter clock wise 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 SCRs in the power circuit.
6. Ensure to switch OFF the input supply first and then trigger pulses.

RESULT:

VIVA - VOCE QUESTIONS:

1. 
2. 
3. 
4. 
5.
SINGLE PHASE PARALLEL INVERTER WITH R AND RL LOADS

AIM: To study the operation of parallel inverter and observe the waveforms across loads.

APPARATUS REQUIRED:

i) Parallel inverter kit
ii) Inductor
iii) Transformer
iv) CRO
v) This module consists of two units – (1) Firing circuit and (2) Power circuit.

Circuit Diagram:
Model Graph

Tabular Column:

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Frequency</th>
<th>Voltage Amplitude(V)</th>
<th>Time period(ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Maximum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Theory:

The circuit is a typical class C Parallel inverter. Assume TN to be ON and TP to be OFF. The bottom of the commutating capacitor is charged to twice the supply voltage and remains at this value until TP is turned on. When TP is turned on, the current flows through lower half of the primary TP and commutating inductance L. Since voltage across C cannot instantaneously, the common SCR cathode point rises approximately to 2V dc and reverses bias TN Thus TN turns off and C discharges through L, the supply circuit and then recharges in the reverse direction. The autotransformer action makes C to charge making now its upper point to reach +2V dc volts ready to commutate Tp. When TN is again turned on and the cycle repeats.
Freewheeling diodes \( D_p \) and \( D_N \) assist the inverter in handling a wide range of loads and the value of \( C \) may be reduced since the capacitor now does not have to carry the reactive current. To dampen the feedback diode currents within the half period, feedback diodes are connected to tapping of the transformer at 25V tapping.

(1) **Firing Circuit:**
This unit generates two pairs of pulse transformer isolated trigger pulses to trigger two SCR’s connected in center tapped transformer type parallel inverter. Frequency of the inverter can be varied from 75Hz to 200 Hz approximately.

(2) **Power Circuit:**
This unit consists of two SCR’s, two free wheeling diodes, commutation inductor, commutation capacitor and a center tapped transformer to be inter connected to make parallel inverter. All the points are brought out to the front panel. A switch and fuse is provided for input DC supply. All the devices are mounted on proper heat sink. Each device is protected by snubber circuit.

**Procedure:**
1. Switch on the firing circuit. Observe the trigger output \( T_P \) and \( T_N \) by varying frequency potentiometer and by operating ON/OFF switch.
2. Then connect input DC supply to the power circuit. Connect trigger outputs to Gate and Cathode of SCR \( T_P \) & \( T_N \).
3. Apply trigger pulses to SCR
4. Observe voltage waveforms across load. Output voltage is square wave only.
5. Vary the load, vary the frequency and observe waveforms.

**RESULT:**
VIVA –VOCE QUESTIONS:

1.
2.
3.
4.
5.
EXPERIMENT 8
SINGLE PHASE BRIDGE INVERTER WITH R AND RL LOADS

AIM: To obtain controlled output waveforms of a single phase fully controlled bridge Converter with R and RL Loads.

APPARATUS REQUIRED:

<table>
<thead>
<tr>
<th>S.No</th>
<th>EQUIPMENT</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>I-φ Transformer</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>I-φ fully controlled power circuit with firing unit</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>Voltmeter(MI meter)</td>
<td>1</td>
</tr>
<tr>
<td>4.</td>
<td>Voltmeter(MC meter)</td>
<td>1</td>
</tr>
<tr>
<td>5.</td>
<td>Rheostat</td>
<td>1</td>
</tr>
<tr>
<td>6.</td>
<td>Inductive load</td>
<td>1</td>
</tr>
<tr>
<td>7.</td>
<td>CRO with (1:10) Probe</td>
<td>1</td>
</tr>
<tr>
<td>8.</td>
<td>Patch cards</td>
<td></td>
</tr>
</tbody>
</table>

THEORY:

A) **For R-Load**: A fully controlled bridge converter using four SCR’s is shown in the circuit diagram. In the bridge circuit diagonally opposite pair of SCR’s are made to conduct and are commutated simultaneously. During the first positive half cycle SCR’s T1 and T2 are forward biased and they are triggered simultaneously at \( wt = \alpha \) then the current flowing through the path A-T1-R-T2-B. During the negative half cycle of the input SCR’s T3 and T4 are forward biased and they are triggered at \( wt = (\pi + \alpha) \) simultaneously then the current flows through B-T3-R-T4-A. Thyristors T1,T2 and T3,T4 are triggered at same firing angle \( \alpha \) in each positive and negative half cycle of the input voltage respectively.
When the output voltage falls to zero, the output current also falls to zero because of resistive load. Hence SCR’s T1, T2 in positive half cycle and T3, T4 in negative half cycle turn off by natural commutation.

The related voltage and current wave forms are shown in the diagram.

The theoretical value of the average DC output voltage can be calculated by

\[ V_{oth} = (V_m/\pi)(1+\cos\alpha). \]

Where \( V_{oth} \) is the theoretical value of the output voltage

\( V_m \) is the maximum value of the AC input voltage and

\( \alpha \) is the firing angle.

B) For RL-Load:

A fully controlled bridge converter using four SCR’s is shown in the circuit diagram. To conduct the SCR’s simultaneously firing of SCR’s T1, T2 in the first half cycle and T3, T4 in the next half cycle is necessary. To ensure this both T1, T2 are fired from the same firing angle.

As shown in the diagram when \( \omega t=\alpha \), SCR’s T1, T2 are triggered simultaneously. The current flow through A-T1-R-L-T2-B. Supply voltage from this instant appears across output terminals and forces the current through load. At \( \omega t=\pi \), the output voltage tends to reverse its direction where as the output current tries to flows on the same direction because of inductive load. The output current becomes zero at a angle of \( \omega t=\beta \).

At an angle \( \omega t=(\pi+\alpha) \) SCR’s T3, T4 are triggered, with this negative line voltage reverse biases SCR’s T1 and T2 hence the SCR’s T1 and T2 are commutated. Now the current flows through the path B-T3-R-L-T4-A. This continue in every half cycle and we get output voltage as shown in waveforms.

The theoretical value of the average DC output voltage can be calculated by

\[ V_{OTH} = \left(2V_m / \pi\right)(\cos \alpha - \cos \beta) \]
CIRCUIT DIAGRAM:

With R-Load:

![Circuit diagram with R-Load](image1)

With RL-Load:

![Circuit diagram with RL-Load](image2)
PROCEDURE:

B) For R-Load:

1. Connect the circuit as shown in figure.
2. Verify the connections from the lab instructor before switch on the supply.
3. Keep the rheostat position value given by the lab instructor
4. Switch ON the CRO and calibrate it with the input voltage.
5. Switch on the power circuit and firing circuit.
6. Observe the output voltage waveform in the CRO.
7. Note down the reading of α from the CRO and V₀ from the voltmeter
8. Also calculate the theoretical value of output voltage from the formula and compare it with the practical value of the output voltage, which is observed from the voltmeter.
9. Repeat the above process from step 6 to 8 for various firing angles.

For RL-Load:

1. Switch off the power supply and connect an inductance of given value in series with the load resistance.
2. Repeat steps 2 to 9 in this case and also note down the reading of β.
MODEL GRAPHS:

R LOAD

Supply Voltage

Triggering Pulse

Output Voltage

Output Current

\[ \omega t \]

\[ \alpha \]

\[ T_1 T_1' \]

\[ T_2 T_2' \]

\[ T_3 T_4' \]
**TABULAR COLUMN:**

**B) For R-Load:**

The input voltage $V_{ph} = V$ (As given by the instructor) Value of load resistance $R_L = \Omega$ (As given by the instructor) CRO calibration: 180 degrees = msec $= \pi$ radians

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Firing angle($\alpha$) in milli seconds</th>
<th>Firing angle($\alpha$) in degrees</th>
<th>Firing angle($\alpha$) in radians</th>
<th>$V_o$ (Practical)</th>
<th>$V_o$ (Theoretical)</th>
</tr>
</thead>
</table>

**B) For RL-Load:**

The input voltage $V_{ph} = V$ (As given by the instructor) Value of load resistance $R_L = \Omega$ (As given by the instructor)

CRO calibration: 180 degrees = msec $= \pi$ radians

Theoretical Extinction angle $\beta =$ (in msec) = (degrees) = (radians)

Practical Extinction angle $\beta =$ (in msec) = (degrees) = (radians)
<table>
<thead>
<tr>
<th>S.N O.</th>
<th>Firing angle(α)</th>
<th>Firing angle(α)</th>
<th>Firing angle(α)</th>
<th>$V_o$ (Practical)</th>
<th>$V_o$ (Theor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

**RESULT:**

**VIVA –VOCE QUESTIONS:**

1.
2.
3.
4.
5.
EXPERIMENT 9

DC JONES CHOPPER WITH R AND RL LOADS

AIM:
To study the SCR based DC-Jones chopper

APPARATUS REQUIRED:
1. Jone’s chopper firing circuit unit and power circuit unit
2. Loading Rheostat : 50 Ohms, 2A.
3. Loading Inductor : 0-150 mH/2A.
5. 20MHz dual trace oscilloscope with 1:10 BNC probes.

SPECIFICATIONS:
1. Input : 0 -230V 1-ϕ AC supply.
2. Load : R and R-L loads.
3. Thyristor : 25A, 1200V, type 25 RIA 120.
4. Diodes : 25A, 1200V.
5. Communicating capacitors : 25μf, 440 V.
6. Commutating Inductor : 500 – 0 - 500μH, 10A.
7. MCB : Two pole 230V/16A.
8. Fuses : 16A HRC.
CIRCUIT DIAGRAM:

Fig-1: Circuit Diagram of DC Jones Chopper with R Load

Fig-2: Circuit Diagram of DC Jones Chopper with RL Load

THEORY:

In all the other chopper configurations, recharging of the capacitance to supply voltage is necessary before the main thyristor is fired. When the circuit is started, the control considers this. Jon’s Chopper makes use of an LC arrangement where this requirement is not necessary. However it makes use of an auxiliary thyristor to reverse bias the conducting thyristor with capacitor voltage.

Jon’s chopper has the advantage that it permits the use of smaller capacitors even though the supply voltage is high due to the blocking diode which traps the capacitor voltages. As no pre-charging of capacitor is required, the circuit doesn’t pose any starting problem. Any of the two
thyristor can be fired. Thyristor of higher ratings are required. The values of ON and OFF can be varied independently. The circuit has greater flexibility of operation.

The specific features of Jone’s chopper circuit may be summarized as follows.

1. An auxiliary thyristor is required for initiation of the commutation process. The ON time can be varied without reference to the values of L and C.

2. The mutual inductance principle is made use of for charging of capacitor.

3. Time Ratio Control (TRC) strategy can be employed. Pulse Width Modulation (PWM) and Pulse rate Modulation (PRM) is possible.

4. Diode $D_1$ prevents discharge of the capacitor through the load which is a significant feature in deciding the size of the capacitance.

5. Commutation is load dependent. Higher load currents mean higher Capacitor voltages.

6. Jones’s circuit has a wide application in motor control.

**PROCEDURE:**

1. Switch on the DC-chopper firing circuit

2. Observe the test point signals and trigger output signals by varying duty cycle and frequency potentiometer by keeping the control switch into INT POSITION. Be sure the trigger output is proper before connecting to the power circuit.

3. Now make the interconnections in the power circuit as given in the circuit diagram.

4. Connect DC supply from a variable DC source.

5. Initially set the input DC supply to 10 volts.

6. Connect a R-load.

7. Connect respective trigger outputs from the firing circuit to the respective in the power circuit.

8. Initially keep the ON/OFF switch in the firing circuit in the OFF position.

9. Switch ON the DC supply. Apply main SCR trigger pulses by pressing the ON/OFF switch to ON position.

10. Observe the voltage waveforms across load.

11. We can observe the chopped DC waveform.

12. If the commutation fails we can see only the DC voltage.

13. In this case switch OFF the DC supply, switch OFF pulses and check the connections and try again.

14. Observe the voltage across load, across capacitor, across main SCR and auxiliary SCR by varying the duty cycle and frequency potentiometer.
15. Now vary the DC supply up to the rated voltage.
16. Draw the waveforms at different duty cycle and at different frequency.
17. Connect voltmeter and ammeter and note down values.
18. Connect RL load and repeat the above procedure for with and without freewheeling diode.

**Table:**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Input voltage (V)</th>
<th>Ton (sec)</th>
<th>Toff (sec)</th>
<th>Duty cycle (%)</th>
<th>Output voltage (V)</th>
<th>Output current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PRECAUTIONS:

1. Make sure all the connecting links are tightly fixed.
2. Ensure all the controlling knobs in fully counter clock wise 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 SCRs in the power circuit.

RESULT:

VIVA –VOCE QUESTIONS:

1.
2.
3.
4.
5.
EXPERIMENT 10
THREE PHASE HALF CONTROLLED BRIDGE CONVERTER WITH R-LOAD

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

APPARATUS REQUIRED:
1. 3-PHASE HALF CONTROLLED BRIDGE CONVERTER Unit
2. C.R.O
3. Patch Cords
4. Differential Module
5. R: 0-200E/5A variable Rheostat. L: 0-150mH/5A Inductor.

THEORY:

3-PHASE HALF CONTROLLED RECTIFIER:
Among the 3-Phase, the one which has the highest +Ve with respect to neutral will conduct it the SCR connected to that phase is triggered. No SCR can be triggered below a phase angle of 30° because it remains reverse biased by the other conducting phase. The SCR1 connected to phase A cannot be fired below an angle of 30° because it is reverse biased by the already conducting SCR3. Hence the minimum firing angle is a/6. When the firing angle is retarded, the conduction period of the same SCR is extended towards the end of the cycle and at the firing angle of 60°; the SCR would continue to conduct up to 180° which is the maximum angle through which it can conduct, after which the phase voltage becomes –Ve with respect to the neutral. Therefore the maximum value of conduction angle of an SCR is 120°. If the firing angle is more than a/3. The conduction angle is less than 120° and the output voltage and current are discontinuous pulses, i.e., during some part of the cycle the voltage of current remain at zero.
PROCEDURE:

1. All connections are made as per circuit diagram, check all connections one or two times for any lose connections and missed connections.

2. Connect the three phase 440Volts supply to the instrument using the terminals marked R, Y, B. Connect 200W lamps to the point marked load. A load bank is provided for that purpose.

3. Switch ON the supply, observe the various waveforms on C.R.O by approximately connecting test points.

4. Now connect the differential module for observing the output voltage by varying the firing angle plot.

5. Calculate output voltage:

R and Lamp Load Circuit Diagram

RL Load Circuit Diagram
CALCULATIONS:
Examples:

Line to line voltage i.e., \( V_L = 81 \text{Volts (rms)} \)

\[
E_{de} \text{ (Output)} = \frac{3\sqrt{3}}{\pi} \frac{1 + \cos \alpha}{E_i}
\]

Where, \( E_{ph} \) is the peak value of phase to neutral voltage \( \alpha \).

\( \alpha \) is the delay angle

\[ \alpha = 36, \text{ i.e., 2 division on C.R.O for 1 mSec/Div. setting} \]

[Please note 1 mSec = 18° (electrical)]

Hence,


**TYPICAL TIME DIVISION FOR MEASUREMENT OF ‘\( \alpha \)’**

\( \alpha = 36 \), i.e., 2 division on C.R.O for 1 mSec/div. setting

[Please note 1 mSec = 180° (electrical)]

Hence,

\[
E_{de} = \frac{3\sqrt{3}}{\pi} \times 81 \times \sqrt{2} \left( \frac{1 + 0.8}{2} \right)
\]

Hence,

\[
E_{de} = \frac{3\sqrt{3}}{\pi} \times 81 \times \sqrt{2} \left( \frac{1 + 0.8}{2} \right) = \frac{3 \times 1.732 \times 81 \times 1.414 \times 1.8}{3.14 \times 1.732 \times 2} \times 1.8
\]

\[
= \frac{618.484}{6.28} = 98.49 \text{ V}
\]

Verify the \( E_{de} \) as shown from the panel voltmeter for this setting.

**PRECAUTIONS:**

1. Before switch ON, recheck the connections, there should not be mistakes about connections on the front panel.

2. See the output voltage on C.R.O by using Differential module.

3. While connecting C.R.O always start with minimum sensitivity side for vertical amplifier.

**RESULT:**
VIVA – VOCE QUESTIONS:

1.
2.
3.
4.
5.
EXPERIMENT 11
SINGLE PHASE DUAL CONVERTER WITH RL LOADS

AIM: To study the Dual Converter and observe the output waveforms across load

APPARATUS REQUIRED:


   Firing circuit & Power Circuit Using.

2. Isolation transformer with tapping from 30V to 230V of 5A.

3. C.R.O and it connecting Probes.

4. Patch cords for connection.

5. Ammeter - 5-0-5A DC Ammeter

6. Voltmeter - 300-0-300V DC Voltmeter

7. Center tapped Inductors - 500-0-500mH/5A center tapped Inductors - 2No’s

8. Loads - 200Ω/5A Rheostat,
THEORY:

In this experiment now we are going to study and observing the output signal wave forms and working of Dual Converter in circulating and non-circulating current modes.

1. NON-CIRCULATOR CURRENT MODE:

In this dual converter without circulating current mode the flow of circulating current completely. In unibited through appropriate automatic control of the firing. Pulses, so that only that converter which carries the load current is in conduction and other converter is temporarily blocked. No reactor is required between the converters.

Suppose converter P operates as a rectifier that is supplying the load current while pulses to second converter are blocked. When reversal of output voltage required converter P is fixit blocked by removing firing pause and reduce load current to zero and converter N is made to conduct by applying the firing pulse to it. The current builds up in reverse direction through the load in converter N. When converter N is in conduction converter P is in blocking state the pages to converter N are applied after a delay time.

The delay time 10-20 ms ensures reliable commutation of thyristors in converter P, other wise a large circulating current flows between the two converters, means AC input will be shorted through the two bridges.

2. DUAL CONVERTER WITH CIRCULATING CURRENT:

Some difficulties may arise in dual converter without circulating current mode. That was overcome in circulating current mode. In this mode a current limiting rector is inserted between the dc terminals of the two converters. On this mode both converters are in conducting state one operates as a rectifier producing a given average voltage at its DC terminals and the other operates as an inverter producing the same average converter voltage the operation of the two converters are interchanged if the load current is to be reversed. Then converter as a rectifier is changed to inverter and vice versa. Two separate firing pulse for two converter are needed.

Over the whole control range, the circulating current keeps both converters in virtually continuous conduction. The power flow is continues in either direction. It independent of external load current. The time delay is not required as in non circulating current mode.
The time response for changing from one converter to another is faster.

The Firing angles of two converters is so adjusted that \( \theta_1 + \theta_2 = 180^0 \) for example P converter angle is \( 60^0 \) then the Firing angle of Non Converter must be maintained \( 120^0 \) therefore P converter working as a rectifier N converter working of line commutated inverter.

\[ \theta_1 + \theta_2 = \theta. \]

If converter P operates with a delay angle of \( \theta_1 \) which gives the load voltage \( V_L = 2V_m/\theta \cos \theta_1 \). (For \( 0 \leq \theta_1 \leq \theta \))

If converter N operates with a delay angle of \( \theta_2 \) which gives the load voltage,

\[ V_L = 2V_m/\theta \cos \theta_2. \] (for \( 0 \leq \theta_2 \leq \theta \))
SINGLE PHASE DUAL CONVERTER NON-CIRCULATORY MODE POWER CIRCUIT:
SINGLE PHASE DUAL CONVERTER CIRCULATORY-MODE POWER CIRCUIT:

P-CONVERTER

N-CONVERTER

\[ T_{P1} \quad T_{P2} \quad T_{N2} \]

\[ L_1 \text{ Input } 0-300V \]

\[ L_2 \text{ Load } 0-5A \]

\[ V \text{ Output} \]

CIRCULATORY CURRENT MODE
\[ V_r(t) = V_{o1} + V_{o2} \]
For N Converter

**NON-CIRCULATING CURRENT MODE:**

1. At the beginning Switch ON the Firing circuit power switch and check all the test points in CRO and conform all at signals are proper and exact as given waveform signals and also check trigger outputs in P & N converter by varying Firing angle.

2. Check all SCR’s in power circuit.

3. Make all connections as per the Non circulatory circuit diagram.
4. Connect Firing Pulses from firing circuit to Gate and Cathode of every SCR in power circuit. Follow the indications given in Firing circuit and power Circuit to choose related Firing Pulse for SCR.

5. Connect the input AC supply to the power circuit through an Isolation transformer for safety and for measurement, initially set input voltage at 30V.

6. Connect suitable Rheostat at output terminals as indicated in power circuit.

7. Select the NCC mode in Firing circuit and keep P-converter in ON position and also put on the MCB switch.

8. By varying the Firing angle observe the voltage waveforms in CRO across load and devices also observe by varying load resistances.

9. And also measure voltage and current readings by connecting suitable meters at relevant points and note down values in tabular column by varying Firing angle.

10. Now change the switch to N-converter position and observe all as in P-converter.

11. If the all waveforms and voltage and current readings are proper as given the increase the input supply to rated 230V by changing tapings in Isolation transformer.

12. Repeat all above procedure for R-L Load, Lamp Load and DC Motor Load.

**CIRCULATORY CURRENT MODE:**

1. Make all circuit connections as shown and center tapped inductors placed between two converters. And connect appropriate load across output terminals.

2. Switch ON the power supply. Put the CC/NCC switch in CC mode and P/N or ON/OFF switching ON position.

3. Initially keep firing angle at $90^0$, switch ON and check output in CRO.

   The output will be zero when the firing angle is at $90^0$.

4. If firing angle varies from $0^0$ to $90^0$ the output will varies to maximum in forward direction and varies from $90^0$ to $180^0$ output will varies to maximum in reverse direction.
5. Check all output signals at different output points and devices also. By connecting related voltmeter and Ammeter observe and note down all.

6. Readings at different points in tabular form.

7. Verify the outputs by changing different loads and by increasing input supply to rated voltage.

**PRECAUTIONS:**

The following instructions will be followed by students before and while conducting experiments.

1. Before making circuit connections check the power switch and MCB switch if you find any fault check fuses at mains sockets and check supply connections.

2. If you are not getting the output with all proper connections Switch OFF the MCB just interchange the connections in the AC output terminals. This is to make both the Firing circuit and power circuit synchronize.

3. Connect same AC supply points to inputs of both converters as shown.

4. Do not operate circuit in circulatory current mode when the inductors are not connected in the power circuit. This will load to short circuit since both the converters are ON at a full time. So do not change CC/NCC switch to CC mode, when working under NCC mode without connecting reactors in between 2 converters.

5. Inductors in the range of few mH. When operating in CC mode the P/N or ON/OFF switch is operated as a ON/OFF switch for dual converter. So by keeping it ON and conduct experiment. Keep CC/NCC switch in CC mode only.

6. In NCC mode P/N or ON/OFF switch selects either P Converter or N converter, so by selecting this switch output will switches from one direction to another direction.
TABULAR COLUMN

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Input</th>
<th>Firing Angle</th>
<th>Output Voltage (V)</th>
<th>Output Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Theoretical</td>
<td>Practical</td>
</tr>
</tbody>
</table>

PRECAUTIONS WHILE DOING EXPERIMENT:

1. If not setting output change the connection.

2. Do not operate the circuit in circulatory current mode when inductors are not connected in the power circuit. This will lead to short circuit since both the converters are ON at a time.

3. Without connecting center taped inductors between P-N converters, don’t switch from NCC to CC mode and don’t work on circulatory current mode.

RESULT:

VIVA – VOCE QUESTIONS:

1.
2.
3.
4.
5.
EXPERIMENT 12

SIMULATION OF SINGLE-PHASE FULL CONVERTER USING R, RL AND RLE LOADS

AIM: To study the output waveforms of AC voltage controller using RLE loads using NGSPICE simulation.

APPARATUS REQUIRED:
NGSPICE SOFTWARE
AC VOLTAGE CONTROLLER

PROGRAM: *ac voltage controller
VS 1 0 SIN (0 169.7V 60HZ)
Vg1 2 4 PULSE (0V 10V 4166.7US 1NS 1NS 100US 16666.7US)
Vg2 3 1 PULSE (0V 10V 12500.0US 1NS 1NS 100US 16666.7US)
R 4 5 2.5
L 5 6 6.5MH
VX 6 0 DC 0V; VOLTAGE SOURCE TO MEASURE THE LOAD CURRENT
*C 4 0 1245.94UF; OUTPUT FILTER CAPACITANCE
CS 1 7 0.1UF
RS 7 4 750
* SUBCIRCUIT CALL FOR THYRISTOR MODEL
Xt1 1 2 4 SCR; THYRISTOR T1
Xt2 4 3 1 SCR; THYRISTOR T2
*subcircuit for ac thyristor model

Department Of Electrical And Electronics Engineering
.SUBCKT SCR 1 3 2
  * model anode +control cathode
  * name voltage
S1 1 5 6 2 SMOD ;switch
RG 3 4 50
VX 4 2 DC 0V
VY 5 2 DC 0V
DT 7 2 DMOD; Switch diode
RT 2 6 1
CT 6 2 10UF
F1 2 6 POLY(2) VX VY 0 50 11
.MODEL SMOD SW RON=0.01 ROFF=10E+5 VT=1 VH=0.2
.MODEL DMOD D(IS=2.2E-15 BV=1200V TT=0) ; Diode model parameters
.ENDS SCR ; Ends subcircuit definition
.TRAN 10US 33.3MS
.PROBE
.OPTIONS ABSTOL=1.00n RELTOL=1.0m VNTOL=1.0m
.FOUR 60HZ I(VX)
.END

**OUTPUT WAVE FORMS:**

---

**RESULT:**
VIVA –VOCE QUESTIONS:

1.
2.
3.
4.
5.
EXPERIMENT 13

SIMULATION OF SINGLE-PHASE AC VOLTAGE CONTROLLER USING R AND RL LOADS

AIM: To study the output waveforms of single-phase full converter using RLE Loads NGSPICE simulation.

AC VOLTAGE CONTROLLER

![Diagram of the AC voltage controller circuit]

PROGRAM: *ac voltage controller
VS 1 0 SIN (0 169.7V 60HZ)
Vg1 2 4 PULSE (0V 10V 4166.7US 1NS 1NS 100US 16666.7US)
Vg2 3 1 PULSE (0V 10V 12500.0US 1NS 1NS 100US 16666.7US)
R 4 5 2.5
L 5 6 6.5mH
VX 6 0 DC 0V; VOLTAGE SOURCE TO MEASURE THE LOAD CURRENT
*C 4 0 1245.94UF; OUTPUT FILTER CAPACITANCE
CS 1 7 0.1UF
RS 7 4 750
* SUBCIRCUIT CALL FOR THYRISTOR MODEL
Xt1 1 2 4 SCR; THYRISTOR T1
Xt2 4 3 1 SCR; THYRISTOR T2

Department Of Electrical And Electronics Engineering
*subcircuit for ac thyristor model
.SUBCKT SCR 1 3 2
* model anode +control cathode
* name voltage
S1 1 5 6 2 SMOD ;switch
RG 3 4 50
VX 4 2 DC 0V
VY 5 2 DC 0V
DT 7 2 DMOD; Switch diode
RT 2 6 1
CT 6 2 10UF
F1 2 6 POLY(2) VX VY 0.50 11
.MODEL SMOD SW RON=0.01 ROFF=10E+5 VT=1 VH=0.2
.MODEL DMOD D(IS=2.2E-15 BV=1200V TT=0) ; Diode model parameters
.ENDS SCR ; Ends subcircuit definition
.TRAN 10US 33.3MS
.PROBE
.OPTIONS ABSTOL=1.00n RELTOL=1.0m VNTOL=1.0m
.FOUR 60HZ I(VX)
.END

OUTPUT WAVE FORMS:

RESULT:
VIVA –VOCE QUESTIONS:

1.
2.
3.
4.
5.
EXPERIMENT 14

SIMULATION OF BUCK CHOPPER

PULSE COMMUTATION

AIM: To Study of resonant pulse commutation circuit and Buck chopper with NGSPICE simulation.

APPARATUS REQUIRED:

NGSPICE SOFTWARE

PROGRAM:

*BUCK CHOPPER
VS 1 0 DC 110V
VY 1 2 DC 0V
VG 7 3 PULSE(0 20 0 0.1NS 0.1NS 27.28US 50US)
RB 7 6 250OHMS
LE 3 4 681.28UH
CE 4 0 8.33UF IC=60V
L 4 8 40.91UH
R 8 5 3OHMS
VX 5 0 DC 0V
DM 0 3 DMOD
.MODEL DMOD D(IS=2.2E-15 BV=1000V TT=0)
XT1 2 3 6 3 DCSCR
.SUBCKT DCSCR 1 2 3 4
DT 5 2 DMOD
ST 1 5 3 4 SMOD
.MODEL DDMOD D(IS=1E-25 BV=1000V)
.MODEL SMOD SW RON=0.1 ROFF=10E+8 VT=10V VH=5V
.ENDS DCSCR
.TRAN 1US 1.6MS 1.5MS 1US
.PROBE
.END
CIRCUIT DIAGRAM:

MODEL WAVEFORMS:

INPUT & OUTPUT WAVEFORMS

RESULT:
VIVA –VOCE QUESTIONS:

1.

2.

3.

4.

5.
EXPERIMENT 15

SIMULATION OF SINGLE PHASE INVERTER WITH PWM CONTROL

AIM: To study the output wave forms of single phase inverter with PWM control.

APPARATUS REQUIRED:
NGSPICE SOFTWARE

PROGRAM:
* single-phase inverter
VS 1 0 DC 100V
Vr 17 0 PULSE(50V 0V 0 833.33US 833.33US 1NS 16666.67US)
Rr 17 0 2Meg
Vcr1 15 0 PULSE(0 -30V 0 1NS 1NS 8333.33US 16666.67US)
Rc1 15 0 2Meg
Vcr3 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=0)
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
*SUBCIRCUIT CALL FOR PWM CONTROL
XPW1 17 15 8 3 PWM
XPW2 17 15 10 0 PWM
XPW3 17 16 12 6 PWM
XPW4 17 16 14 0 PWM
*SUBCIRCUIT FOR PWM CONTROL
.SUBCKT PWM 1 2 3 4
R1 1 5 1K
R2 2 5 1K
RIN 5 0 2Meg
RF 5 3 100K
CIRCUIT DIAGRAM:

[Diagram of a power electronics circuit with components labeled and connections indicated]
OUTPUT WAVEFORMS:

RESULT:

VIVA – VOCE QUESTIONS:

1.
2.
3.
4.
5.
EXPERIMENT 16

SIMULATION OF THREE PHASE FULLY CONTROLLED CONVERTER WITH R AND RL LOADS, WITH AND WITHOUT FREEWHEELING DIODE. OBSERVATION OF WAVEFORMS FOR CONTINUOUS AND DISCONTINUOUS MODES OF OPERATION

AIM: To study the output waveforms of single-phase full converter using RLE loads using NGSPICE simulation.

APPARATUS REQUIRED:

NGSPICE SOFTWARE

PROGRAM:

*single phase full converter
VS 10 0 SIN (0 169.7V 60HZ)
VG1 6 2 PULSE (0V 10V 2777.8US 1NS 1NS 100US 16666.7US)
VG2 7 0 PULSE (0V 10V 2777.8US 1NS 1NS 100US 16666.7US)
VG3 8 2 PULSE (0V 10V 11111.1US 1NS 1NS 100US 16666.7US)
VG4 9 1 PULSE (0V 10V 11111.1US 1NS 1NS 100US 16666.7US)
R 2 4 10
L 4 5 20MH
C 2 11 793UF
RX 11 3 0.1
VX 5 3 DC 10V
VY 10 1 DC 0V
* SUBCIRCUIT CALLS FOR THYRISTOR MODEL
XT1 1 6 2 SCR
XT3 0 8 2 SCR
XT2 3 7 0 SCR
XT4 3 9 1 SCR
.SUBCKT SCR 1 3 2
S1 1 5 6 2 SMOD
RG 3 4 50
VX 4 2 DC 0V
VY 5 2 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 SW RON=0.01 ROFF=100E+5 VT=1 VH=0.2
.MODEL DMOD D(IS=2.2E-15 BV=1200V TT=0) ; Diode model parameters
.ENDS SCR ; Ends subcircuit definition
.TRAN 100US 35MS 16.67MS
.PROBE
.OPTIONS ABSTOL=1.00U RELTOL=1.0M VNTOL=0.1
.FOUR 120HZ I(VX)
.END

CIRCUIT DIAGRAM:

Sub circuit of scr
OUTPUT WAVE FORMS:

RESULT:

VIVA –VOCE QUESTIONS:

1.
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EXPERIMENT 17

STUDY OF PWM TECHNIQUES

AIM:

PWM is a technique that is used to reduce the overall harmonic distortion (THD) in a load current. It uses a pulse wave in rectangular/square form that results in a variable average waveform value $f(t)$, after its pulse width has been modulated.

PROCEDURE:

The time period for modulation is given by $T$. Therefore, waveform average value is given as

$$
y = \frac{1}{T} \int_{0}^{T} f(t) \, dt
$$

Sinusoidal Pulse Width Modulation

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

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

**Modified Sinusoidal Waveform PWM**

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

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

RESULT:

The waveform below is a sinusoidal wave produced by a multiple PWM

VIVA - VOICE QUESTIONS:

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