POWER ELECTRONICS LAB MANUAL

Subject: Power Electronics Lab

Subject Code: ELPC 453

B.Tech IV Semester

Department of Electrical Engineering
J. C. Bose University of Science and Technology
YMCA, Faridabad-121 006

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION OF THE DEPARTMENT

Electrical Engineering Department congregates the challenges of new technological advancements to provide comprehensively trained, career-focused, morally strong accomplished graduates, cutting-edge researchers by experimental learning which contribute to ever-changing global society and serve as competent engineers.

MISSION OF THE DEPARTMENT

- To commit excellence in imparting knowledge through incubation and execution of high-quality innovative educational programs.
- To develop the Research-oriented culture to build national capabilities for excellent power management.
- To inculcate and harvest the moral values and ethical behavior in the students through exposure of self -discipline and personal integrity.
- To develop a Centre of Research and Education generating knowledge and technologies which lay ground work in shaping the future in the field of electrical engineering.

PROGRAM OUTCOMES (POs)

Graduates of the Electrical Engineering program at JCBUST, YMCA will be able to:

PO1. Apply knowledge of mathematics, science, engineering fundamentals, and electrical engineering specialization to the solution of engineering problems.

PO2. Identify, formulate, review literature, and analyze electrical engineering problems to design, conduct experiments, analyze data, and interpret data.

PO3. Design solutions for electrical engineering problems and design system components of processes that meet the desired needs with appropriate consideration for public health and safety and cultural, societal, and environmental considerations.

PO4. 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 in electrical engineering.

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

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

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

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

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

PO10. Communicate effectively on complex engineering activities with the engineering committee and with society at large, such as being able to comprehend and write effective reports and design documentation, and make effective presentations in electrical engineering.

PO11. Demonstrate knowledge and understanding of the engineering principles 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. Recognize the need for, and the preparation and ability to engage in independent research and lifelong learning in the broadest context of technological changes in electrical engineering.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1. To apply state-of-the-art knowledge in analysis design and complex problem solving with effective implementation in the multidisciplinary area of Electrical Engineering with due regard to environmental and social concerns.

PSO2. To prepare graduates for continuous self-learning to apply technical knowledge and pursue research in advanced areas in the field of Electrical Engineering for a successful professional career to serve society ethically.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1. To produce competent electrical engineering graduates with a strong foundation design, analytics and problem solving skills for successful professional careers in industry, research and public service.

PEO2. To provide a stimulating research environment so as to motivate the students for higher studies and innovation in the specific and allied domains of electrical engineering.

PEO3. To encourage the graduates to practice the profession following ethical codes, social responsibility and accountability.

PEO4. To train students to communicate effectively in multidisciplinary environment.

PEO5. To imbibe an attitude in the graduates for life-long learning process.

Syllabus

Power Electronics Lab (ELPC-453)

L-T-P	**Internal Marks-15**
0-0-2	**ExternalMarks-35**
	Total-50

List of Experiments

1. Simulation of single phase half wave and full wave diode rectifier with R and R-L load on MATLAB
2. Simulation of single phase half wave phase controlled converter with R and R-L load on MATLAB
3. Simulation of single phase full wave phase controlled converter with R and R-L load on MATLAB.
4. Simulation of single phase full bridge inverter with R load on MATLAB
5. Simulation of single phase full wave AC voltage regulator with R load on MATLAB
6. Simulation of single phase half wave AC voltage regulator with R& RL load on MATLAB.
7. Simulation of DC to DC Buck converter.
8. Thyristor firing circuit based on Resistance Firing Circuit.
9. RC half wave and full wave Firing Circuits of thyristor
10. TRIAC and DIAC based firing circuit of thyristors
11. AC phase control circuit using UJT and pulse Transformer
12. To study the operation of UJT firing circuit
13. To study the operation of Series Inverter.
14. Operation of single phase to single phase mid point cycloconverter

COURSE OBJECTIVES & OUTCOMES

Course objectives:

1. To impart the knowledge of operation and basic characteristics of switching devices
2. To describe the working of AC to AC and AC to DC converters practically.
3. To explain the simulation of power electronic converters on MATLAB.
4. To make student design various types of firing circuits for thyristor.

Course outcomes:

CO1. To Observe and analyze the operation and basic characteristics of various types of switching devices.

CO2. To know about industrial applications of power electronics converter such as AC-AC and AC-DC converter.

CO3. To analyze various firing circuits of thyristor.

CO4. To design and simulate AC/DC and DC/AC converters on MATLAB software.

CO5. To be enable to Simulate DC to DC and AC to AC converters on MATLAB.

Mapping of Course Outcomes (COs) with POs and PSOs

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	2	2	1	1	2	1	1	1	2	2	2
CO2	3	3	3	2	3	1	1	2	1	2	2	2	3	2
CO3	3	2	2	2	2	1	1	2	1	1	2	2	2	2
CO4	3	3	3	3	3	1	2	2	2	2	2	2	3	3
CO5	3	3	3	3	3	1	2	2	2	2	2	2	3	3

Justification:

- **CO1** Focuses on observing and analyzing the characteristics of switching devices, which is closely related to applying engineering knowledge and analysis (PO1, PO2) and partially connected to ethics (PO8), and societal/environmental aspects (PO7).

- **CO2** Involves understanding industrial applications of converters, which aligns well with problem-solving and design (PO3), use of modern tools (PO5), and multidisciplinary applications (PSO1).

- **CO3** Relates to analyzing thyristor firing circuits, closely linked to problem formulation and analysis (PO2) and electrical engineering solutions (PO3, PSO1).

- **CO4** Emphasizes designing and simulating converters in MATLAB, highly aligned with design and experimentation (PO4), modern tools (PO5), and both PSOs, especially with advanced areas of electrical engineering.

- **CO5** Focusing on simulation work with DC and AC converters, strongly connected with applying knowledge (PO1), technical tools (PO5), and pursuing advanced knowledge (PSO2).

||General Instructions||

1. Students should come well-prepared for the experiment they will be conducting.
2. Usage of mobile phones in the laboratory is strictly prohibited.
3. In the lab, wear shoes and avoid loose-fitting clothes.
4. Read and understand the experiment manual thoroughly before starting the experiment. Know the objectives, procedures, and safety precautions.
5. Before starting the experiment, check the condition of the equipment, wiring, and connections. Report any damaged or malfunctioning equipment to the lab instructor immediately.
6. Ensure all connections are made as per the circuit diagram. Double-check all connections before powering the equipment.
7. Do not switch on the power supply until the instructor has approved your setup. Always start with the minimum voltage/current required and gradually increase as needed.
8. Do not overload machines beyond their rated capacity. Overloading can damage the equipment and pose safety risks.
9. Familiarize yourself with the lab’s emergency shutdown procedures, including the location of emergency switches and fire extinguishers.
10. Do not bring food or drinks into the lab to avoid accidental spills, which can lead to electrical hazards.
11. Stay attentive during the experiment. Avoid distractions like mobile phones, and do not engage in unnecessary conversation during lab work.
12. Accurately record all measurements and observations during the experiment. Ensure that all data is properly noted in your lab report.
13. If you are unsure about any procedure or face difficulties during the experiment, do not hesitate to ask the lab instructor for guidance.
14. After completing the experiment, switch off the power supply, disconnect the setup, and return all equipment to its proper place. Ensure the workspace is clean and organized.

Power Electronics Lab
(ELPC-453)

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Experiment No.1

Aim: - 1. Simulation of single-phase half wave and full wave diode rectifier with R load on MATLAB

Software used: - MATLAB

Theory: -

Single Phase Half Wave Rectifier: -

The circuit diagram of a single-phase half wave rectifier is shown in figure 1. During the positive half cycle, diode is forward biased, it therefore conducts from ωt = 0 to Π. During the positive half cycle, output voltage v_o = source voltage v_s and load current $i_o = {}^{v_o}/_{R}$.At ωt = $\Pi, v_o = 0$ and for R load,i_0 is also zero. As soon as v_s tends to become negative after wt = Π, diode D is reverse biased, it is therefore turned off and goes into blocking state. Output voltage as well as output current, are zero from $\omega t = \Pi \ to \ 2\Pi.$ After $\omega t = \Pi \ to \ 2\Pi.$ After ωt = 2Π, diode is again forward biased and conduction begins.

For a Resistive load, output current i_o has the same waveform as that of the output voltage v_0.Diode voltage $v_D$is zero when diode conducts. Diode is reverse biased from ωt =Π to 2Π as shown. The waveform of $v_s, v_0 \ and \ i_o$ .Here source voltage is sinusoidal i.e., $v_s = v_m$sinωt. The output waveforms of half wave rectifier is shown in figure 2.

Average value of output (or load) voltage,

$$V_o = \frac{1}{2\Pi}\left[\int_0^{\Pi} V_m sin\omega t d(\omega t)\right]$$

$$= \frac{V_m}{2\Pi}|\text{-cos } \omega t|_0^{\Pi} \quad = \frac{V_m}{\Pi}$$

Rms value of output voltage,

$$V_{or} = \left[\frac{1}{2\Pi}\int_0^{\Pi} V_m^2 sin^2\omega t.d(\omega t)\right]$$

$$= \frac{V_m}{2}$$

Average Value of load current,

$$I_o = \frac{V_o}{R} = \quad \frac{V_m}{\Pi R}$$

Rms value of load current,

$$I_{or} = \frac{V_m}{2R} =$$

Peal value of load or diode current

$$= \frac{V_m}{R}$$

Single Phase Full Wave Rectifier: -

Primary function of full wave diode rectifier simulation is to establish a dc level from a sinusoidal input voltage that has zero voltage. Single phase supply, is a fully controlled bridge- circuit. In the bridge circuit, diagonally opposite pairs of diodes are made to conduct, and are commutated, simultaneously. Full wave rectifier with R load is shown in figure 3.

During the first positive half-cycle, diodes D1 and D2 are forward biased and if they are triggered simultaneously, then current flows through the path L-D1-R-D2-N. Hence, in the positive cycle, diodes D1 and D2 are conducting.

During the negative half cycle of the a. c. input, diodes D3 and D4 are forward biased and if they are triggered simultaneously, current flows through the path N-D3-R-D4-L. Diodes D1, D2 and D3, D4 are triggered at the same firing angle α in each positive and negative half-cycles of the supply voltage, respectively.

When the supply voltage falls to zero, the current also goes to zero. Hence, diodes D1 and D2 in positive half cycle and D3, D4 in negative half cycle turn off by natural commutation.

The related voltage and current waveforms for the circuit are shown in the figure 4 given below the circuit diagram;

Procedure: -

1) Start the MATLAB software.
2) Open a new simulation window by clicking on Simulink button.
3) Window that appears in Simulink library browser the window contains component that can be plotted into Simulink or design window.
4) Drag & drop the components from library.
5) Run the simulation.

Figure: -

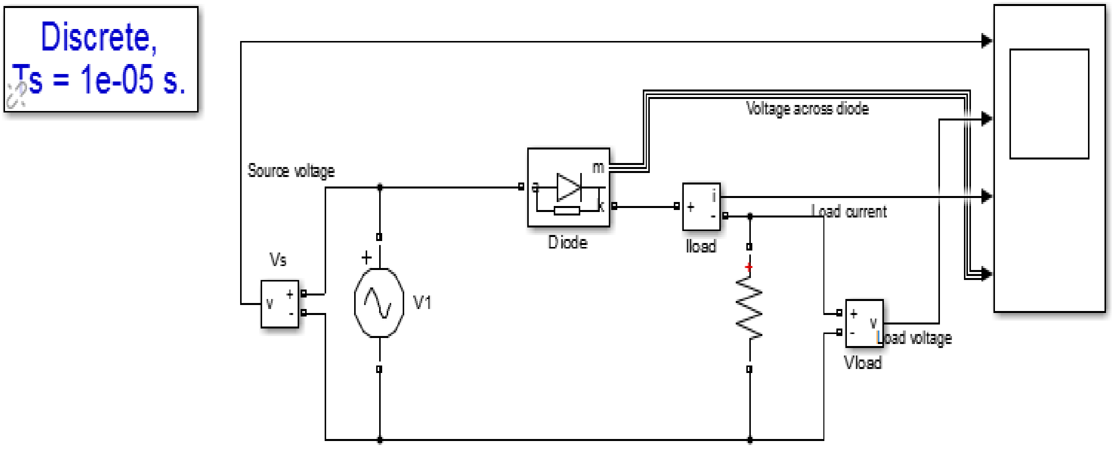


Figure 1 Simulink model of half wave rectifier

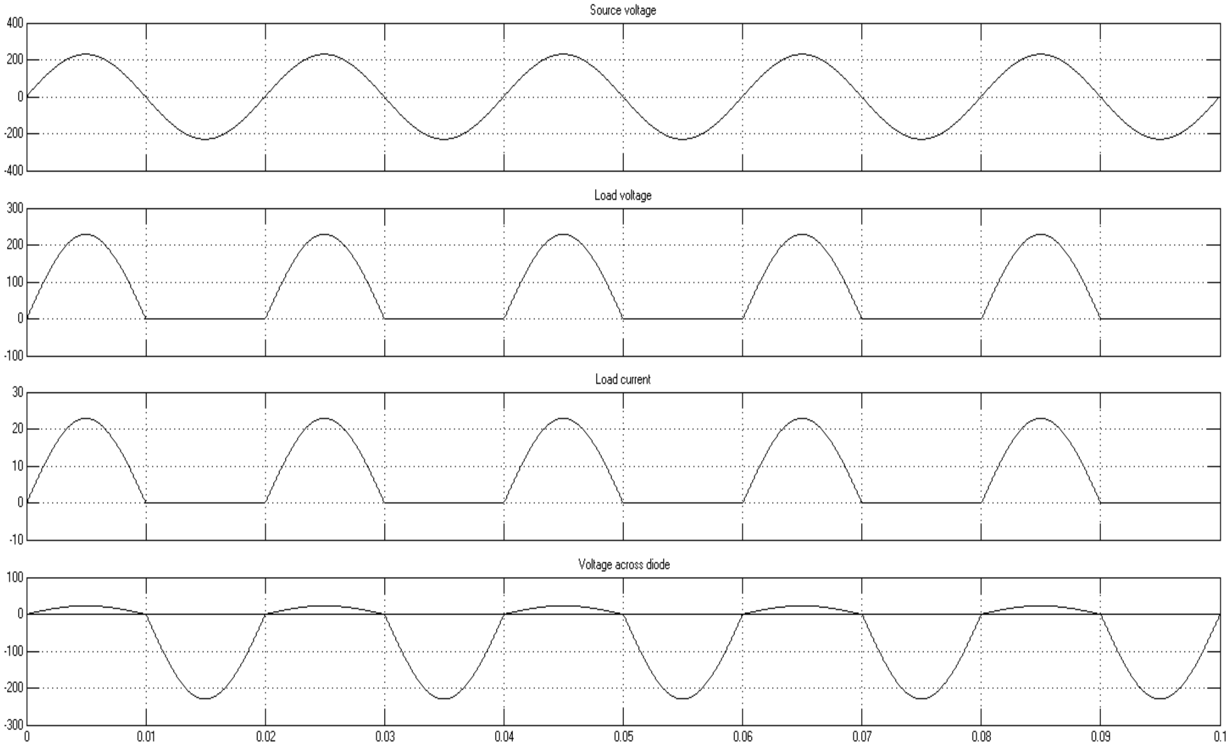


Figure 2 Wave forms of half wave rectifier in terms of input voltage, load voltage, load current and voltage across diode

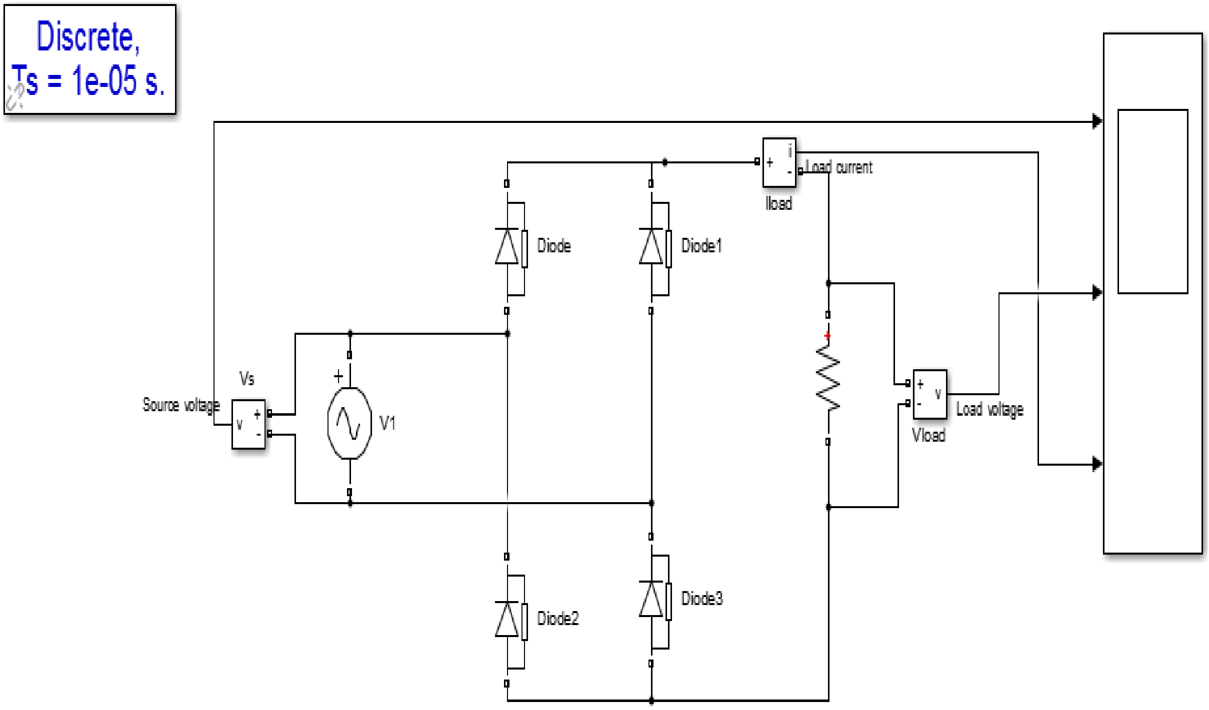


Figure 3 Simulink model of full wave rectifier

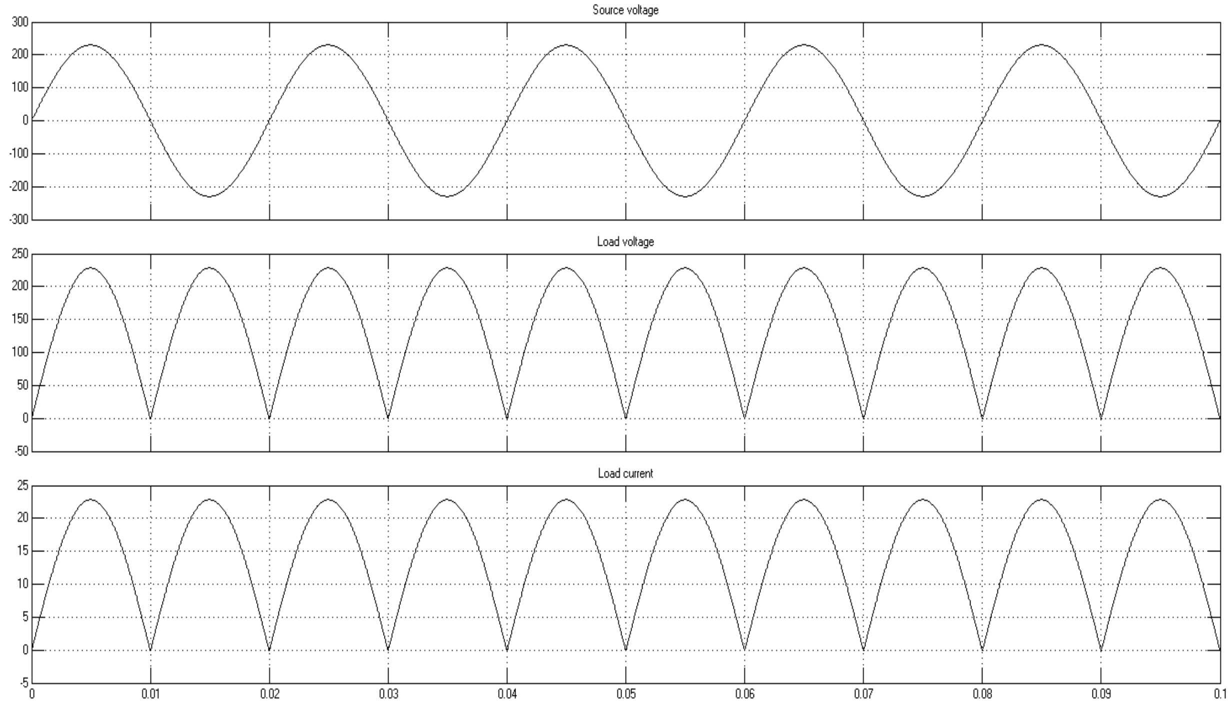


Figure 4 Wave forms of full wave rectifier in terms of input voltage, load voltage, load current and voltage across diode

Result: -

Single phase Half wave and full wave diode rectifier has been studied.

Precautions: -

1) Connections must be properly alone.
2) Don’t forget to drag powergui beside circuit diagram.

Experiment No. 2

Aim: Simulation of single-phase half wave phase-controlled converter with R and R-L load on MATLAB.

Apparatus Required: MATLAB software.

Theory:

The phase-controlled rectifiers using SCRs are used to obtain controlled dc output voltages from the fixed ac mains input voltage. A single-phase half wave-controlled converter only has one SCR is employed in the circuit. The performance of the controlled rectifier very much depends upon the type and parameters of the output (load) circuit.

For R load:

The output voltage is varied by controlling the firing angle of SCR. The simulation circuit of the half wave converter is shown in figure 1. During the positive half-cycle of input voltage, the thyristor anode voltage is positive with respect to cathode and the thyristor is said to be forward biased. When thyristor T_1 is fired at wt=α, thyristor T_1 **i**s conducts and input voltage appears the load. When the input voltage starts to be negative at wt=∏, the thyristor anode is negative with respect to cathode and thyristor is said to be reverse biased; and it is turned off. The time after the input voltage starts to go positive until the thyristor is fired is called the delay or firing angle α. If the load is resistive, the load voltage and load current are similar. Average output voltage is half controlled converter with R load is given by.

$$V_{dc\ (av)} = \frac{Vm}{2\Pi} [1+\cos\alpha]\ \text{(volts)}$$

Where

Vm is the maximum input voltage α is the firing angle of the SCR

The simulation waveforms for half wave phase-controlled converter with R load for firing angle (30^0&60^0) in terms firing pulse, input voltage, output voltage and load current are shown in figure 2 & figure3 respectively. This converter is not used in industrial applications because its output has high ripple content and low ripple frequency

For RL load:

When the load is resistive, SCR1 conduct from α to π. The nature of the load current depends on the values of R and L in the inductive load. The simulation circuit of the half wave converter with RL load is shown in figure 4. Because of the inductance, the load current keeps on increasing and becomes maximum at π. At π, the supply voltage reverses but SCRs 1 does not turn off. This is because the load inductance does not allow the current to go to zero instantly. Thus, the energy stored in the inductance flows against the supply mains. The output voltage is negative from π to π + α since supply voltage is negative.

$$V_{dc\ (av)} = \frac{Vm}{2\Pi} [\cos\beta - \cos\alpha]\ \text{(volts)}$$

Where

Vm is the maximum input voltage

α is the firing angle of the SCR

The simulation waveforms for half wave phase-controlled converter with RL load for firing angle (30^0 & 60^0) in terms firing pulse, input voltage, output voltage and load current are shown in figure

5 &figure 6 respectively. This converter is not used in industrial applications because its output has high ripple content and low ripple frequency

Procedure:

1. Make the connections as per circuit diagram with elements taken from the MATLAB library for both R & RL load.
2. Simulate them.
3. Observe the waveform carefully on scope.

Result:

Simulation of half wave-controlled rectifier with R & RL load have been simulated.

Circuit Diagram:

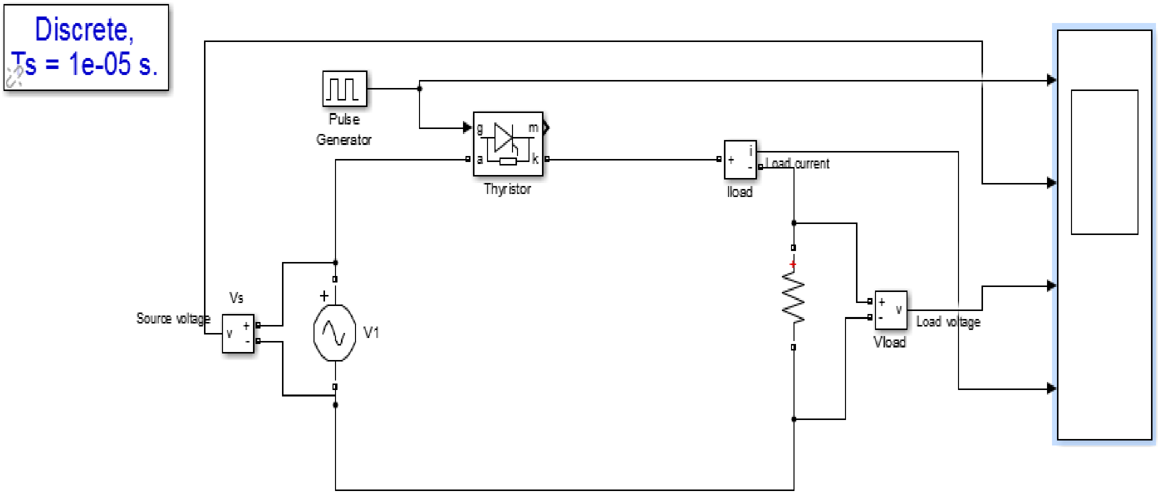


Figure1Simulink model of single-phase half wave phase-controlled converter with R load

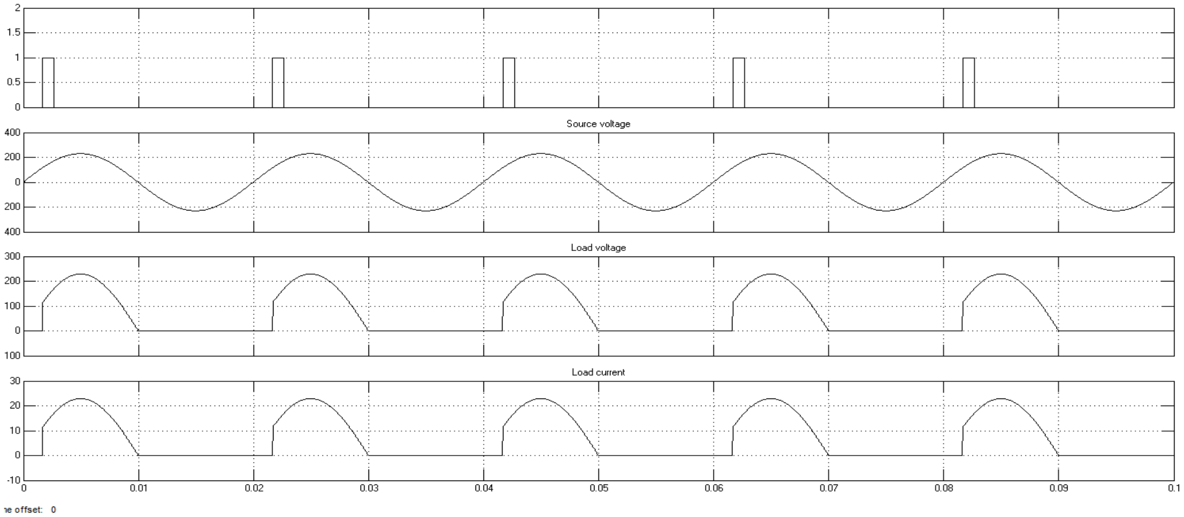


Figure2 Wave forms of gate pulse, input voltage, output voltage and load current of single-phase half wave phase-controlled converter with R load with firing angle 30^{0}

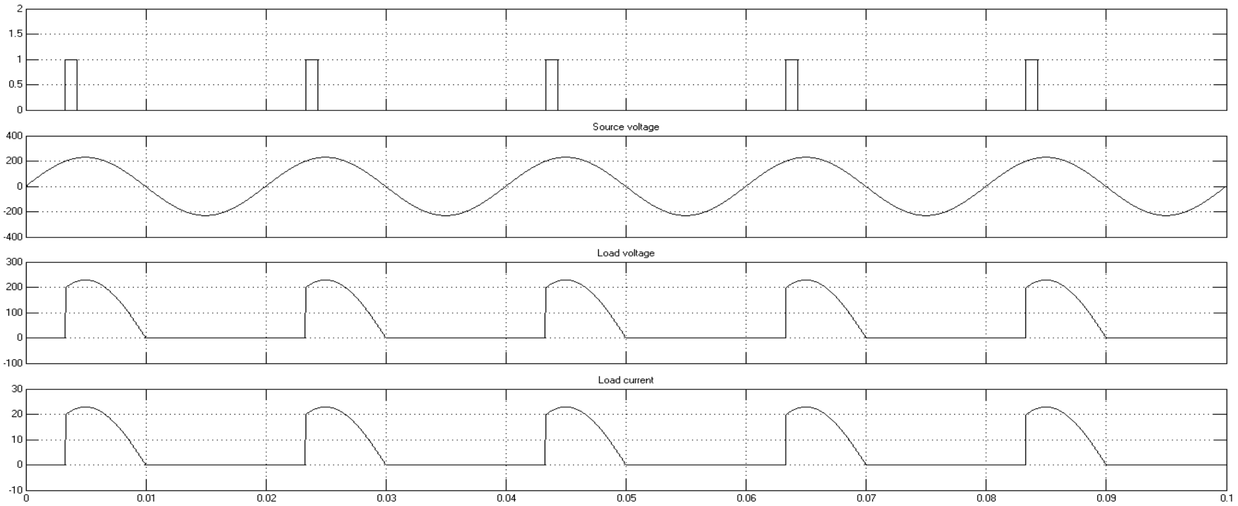


Figure3Wave forms of gate pulse, input voltage, output voltage and load current of single-phase half wave phase-controlled converter with R load with firing angle 60^0

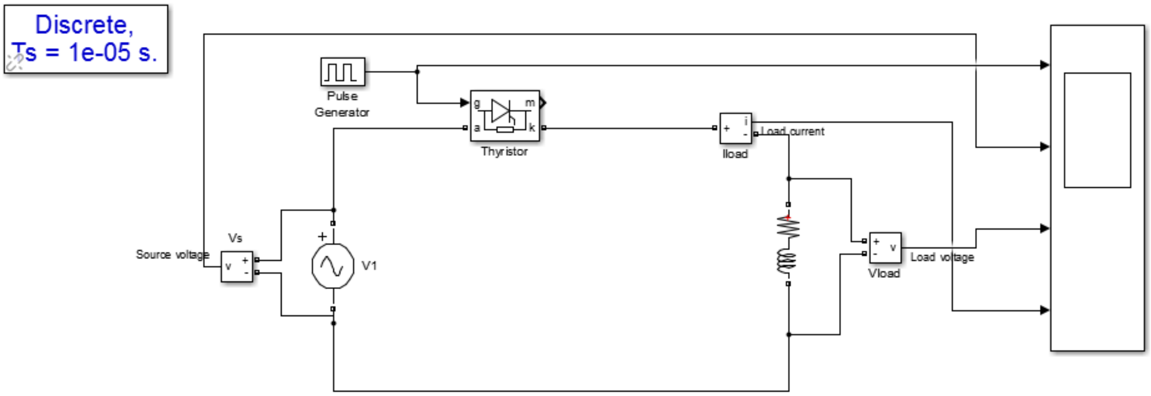


Figure 4Simulink model of single-phase half wave phase-controlled converter with RL load

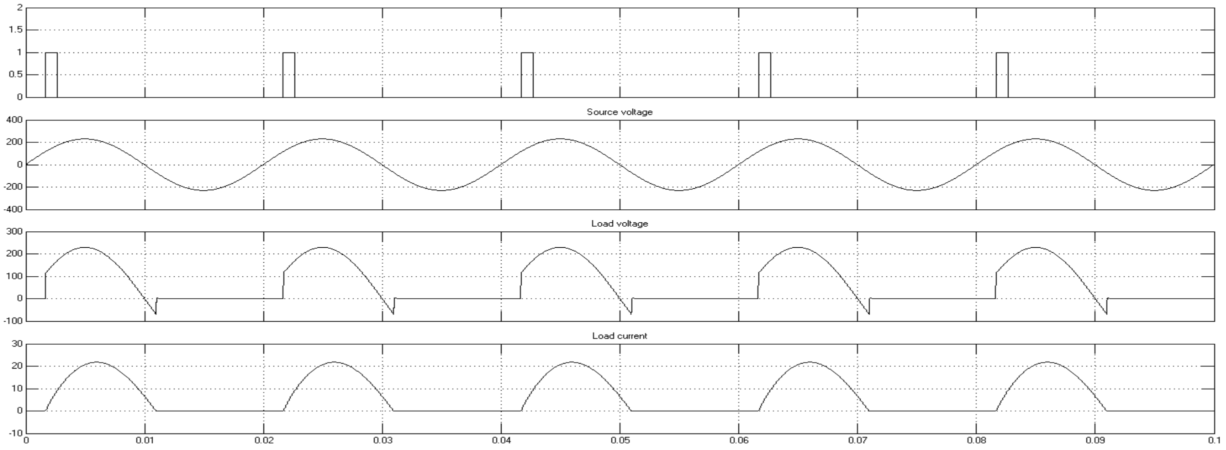


Figure5Wave forms of gate pulse, input voltage, output voltage and load current of single-phase half wave phase-controlled converter with RL load with firing angle 30^0

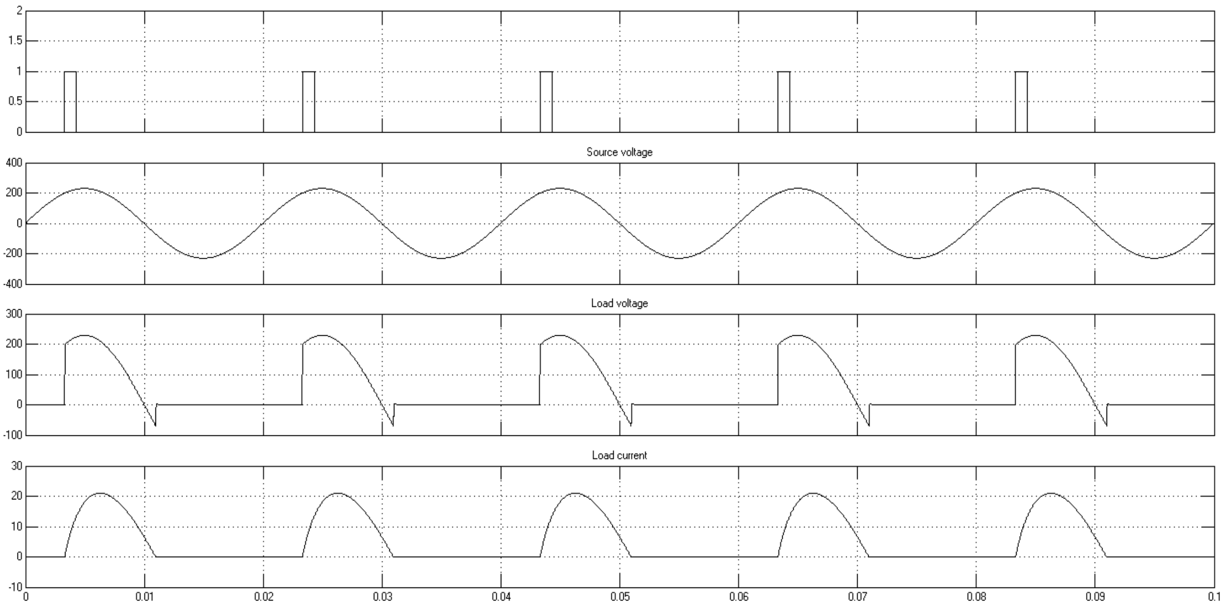


Figure6 Wave forms of gate pulse, input voltage, output voltage and load current of single-phase half wave phase-controlled converter with RL load with firing angle 60^0

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

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

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

Experiment No. 3

Aim: Simulation of single-phase full wave phase-controlled converter with R and R-L load on MATLAB

Apparatus Required: MATLAB Software.

Theory:

The phase-controlled rectifiers using SCRs are used to obtain controlled dc output voltages from the fixed ac mains input voltage. The performance of the controlled rectifier very much depends upon the type and parameters of the output (load) circuit.

For R load:

The output voltage is varied by controlling the firing angle of SCRs. The single phase fully controlled converter consists of four SCRs. The simulation circuit of the full wave converter with R is shown in figure 1. During positive half cycle, SCR1 and SCR2 are forward biased. Current flows through the load when SCR1 and SCR2 are triggered into conduction. During negative half cycle, SCR3 and SCR4 are forward biased. If the load is resistive, the load voltage and load current are similar.

$$V_{dc\ (av)} = \frac{Vm}{\Pi}[1+\cos\alpha]\ \text{(volts)}$$

Where,

Vm is the maximum input voltage

α is the firing angle of the SCR

The simulation waveforms for full wave phase-controlled converter with R load for firing angle (30^0&60^0) in terms firing pulse, input voltage, output voltage and load current are shown in figure 2 & figure 3 respectively. This converter is not used in industrial applications because its output has high ripple content and low ripple frequency

For RL load:

When the load is inductive, SCR1 and SCR2 conduct from α to β. The nature of the load current depends on the values of R and L in the inductive load. The simulation circuit of the full wave converter is shown in figure5. Because of the inductance, the load current keeps on increasing and becomes maximum at π. At π, the supply voltage reverses but SCRs 1 and 2 does not turn off. This is because the load inductance does not allow the current to go to zero instantly. Thus, the energy stored in the inductance flows against the supply mains. The output voltage is negative from π to $\pi + \alpha$ since supply voltage is negative.

$$V_{dc\ (av)} = \frac{Vm}{\Pi}\ [\cos\beta - \cos\alpha]\ \text{(volts)}$$

Where   Whe

Vm is the maximum input voltage

α is the firing angle of the SCR

The simulation waveforms for half wave phase-controlled converter with RL load for firing angle (30^0 & 60^0) in terms firing pulse, input voltage, output voltage and load current are shown in figure 5 &figure 6 respectively.

Procedure:

1. Make the connections as per circuit diagram with elements taken from the MATLAB library for both R & RL load.
2. Simulate them.
3. Observe the waveform carefully on scope.

Result:

Simulation of full wave-controlled rectifier with R & RL load have been simulated.

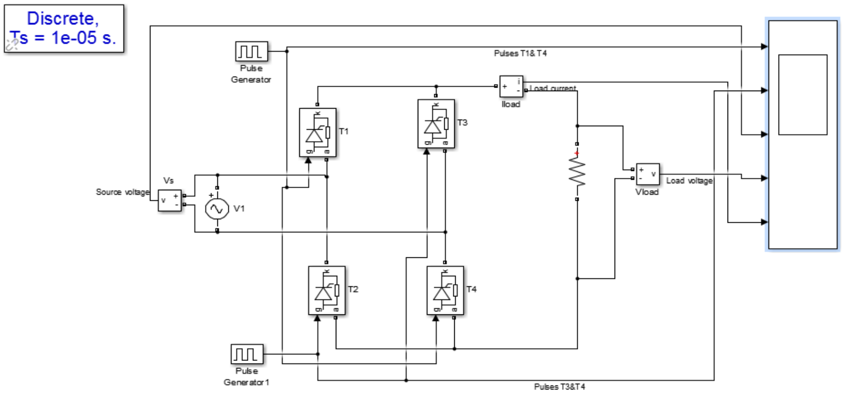


Figure1. shows Simulink model Single phase full wave phase-controlled converter with R Load

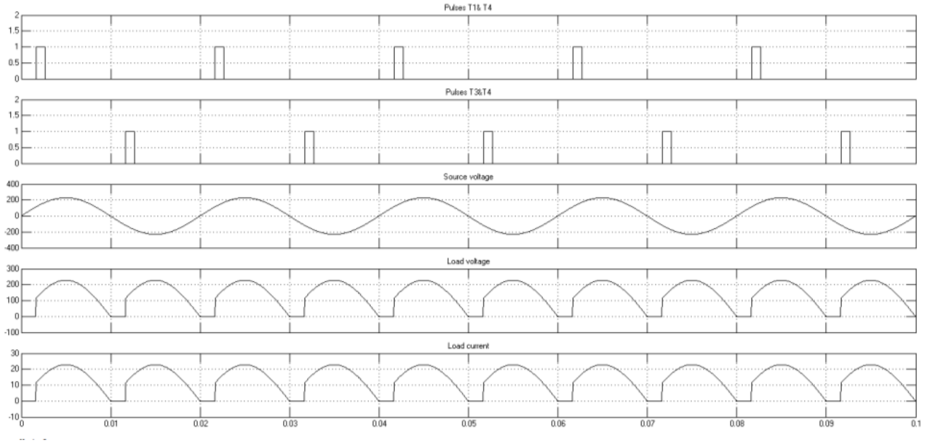


Figure2. shows Waveforms of gate pulses, input voltage, output voltage and output current of Single-phase full wave phase-controlled converter with R load at firing angle 30^0.

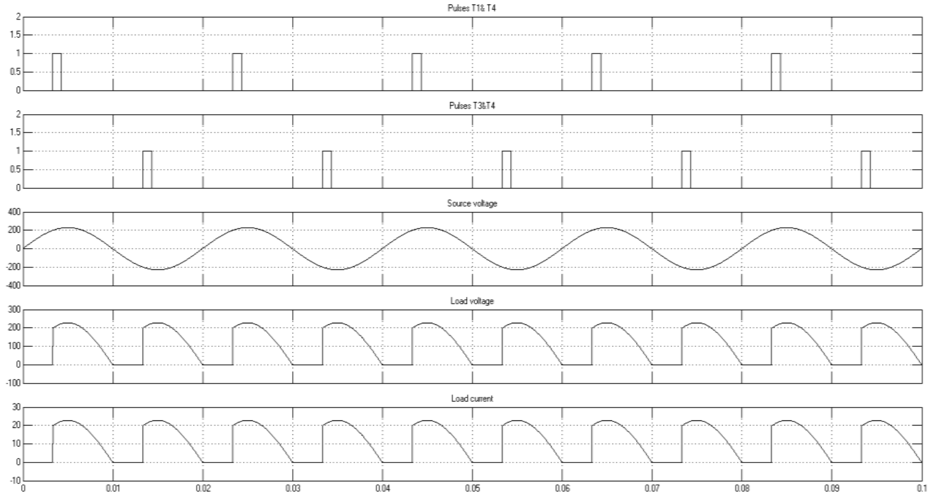


Figure3 shows Waveforms of gate pulses, input voltage, output voltage and output current of Single-phase full wave phased controller converter with R load at firing angle 60^0

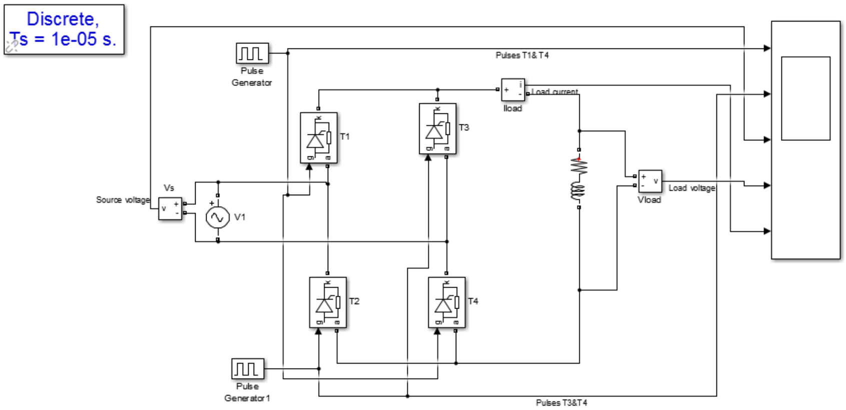


Figure4 shows Simulink model Single phase full wave phase controller converter with RL Load

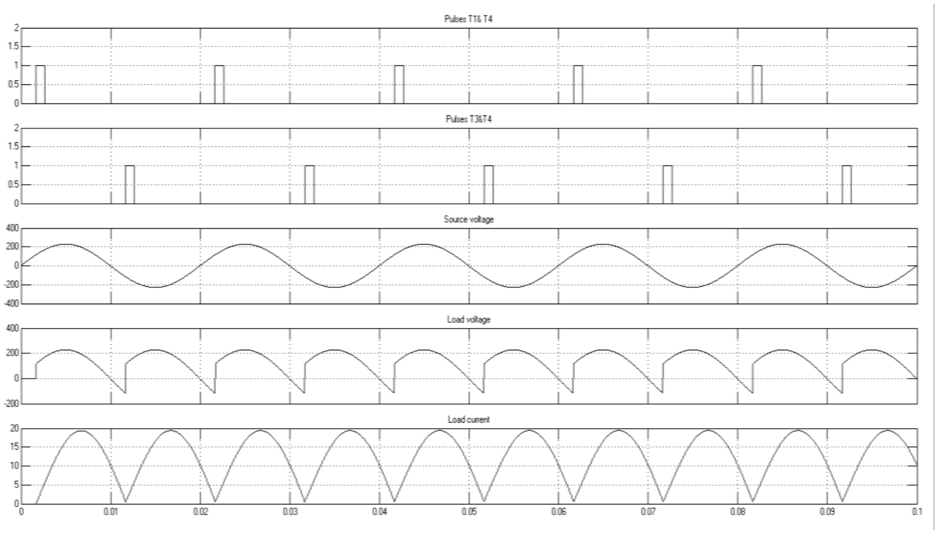


Figure 5 shows Waveforms of gate pulses, input voltage, output voltage and output current of Single-phase full wave phase-controlled converter with RL Load at firing angle 30^0

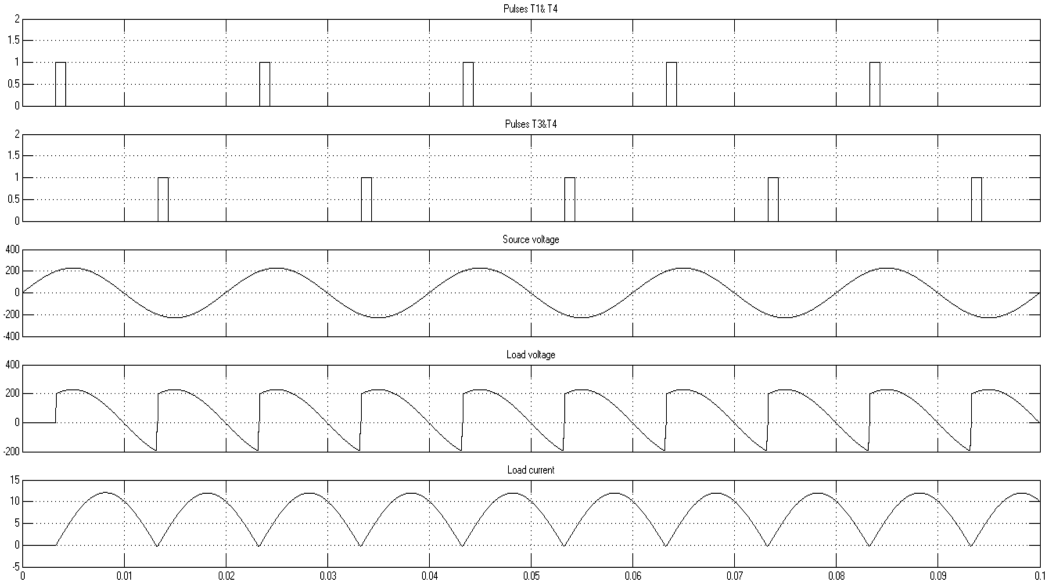


Figure 6 shows Waveforms of gate pulses, input voltage, output voltage and output current of single-phase full wave phase-controlled converter with RL Load at firing angle 60^0

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

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

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

Experiment no. 4

Aim: Simulation of single-phase full bridge inverter with R load on MATLAB.

Apparatus Required: MATLAB Software**.**

Theory:

A single-phase bridge inverter converts DC power into AC power using power electronic switches arranged in a bridge configuration. Pulse Width Modulation (PWM) is a technique used to control the output voltage and frequency of the inverter by varying the duty cycle of the switches. Figure 1 and Figure 2 shows the block diagram of Single-phase bridge inverter with Bipolar and Unipolar PWM techniques respectively. In Bipolar PWM the Switches S1 and S2 are connect together and S3 and S4 connect together. In Unipolar PWM, the output voltage switches between zero and a positive value (or zero and a negative value). It does not switch between positive and negative values. This contrasts with Bipolar PWM, where the output switches between positive and negative values. In bipolar PWM the S1 and S4 and S2 and S3 connect simultaneously. Figure 3 and figure 4 shows the simulation for single phase bridge inverter with Biploar and Unipolar PWM respectively.

Procedure:

1. Click File – New –Model
2. Click on Simulink library browser.
3. Search the components required and add them to the model.
4. Connect components to form correct circuit diagram.
5. Run simulation.
6. Observe waveform and compare it with the theoretical waveform.

Result:

The output waveform of Single Phase Full-Wave Bridge inverter obtained on MATLAB is same as the theoretical waveform.

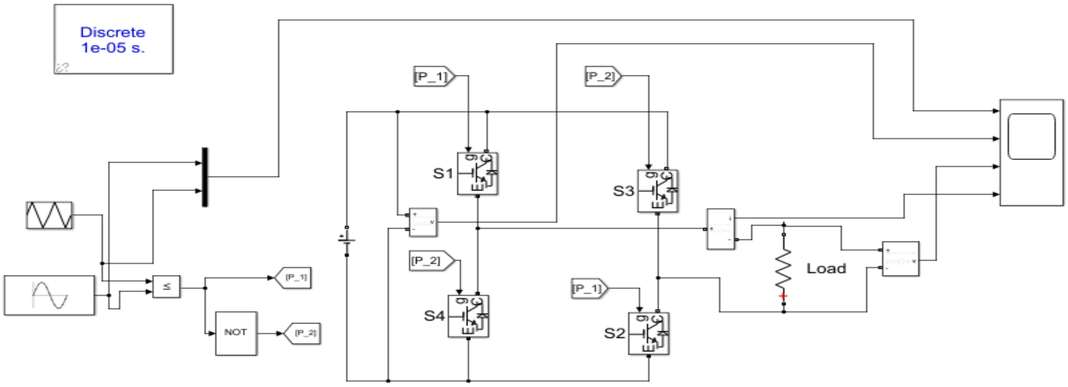


Figure 1 Single phase Inverter with Bipolar PWM

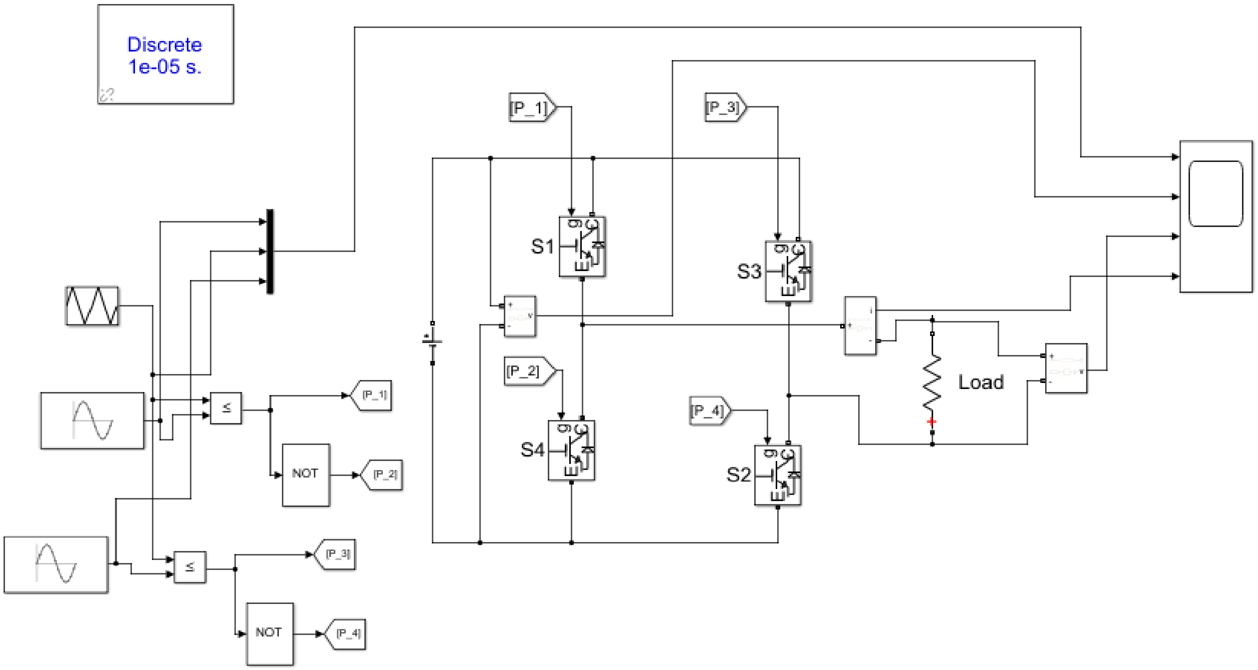


Figure 2. Single phase Inverter with Unipolar PWM

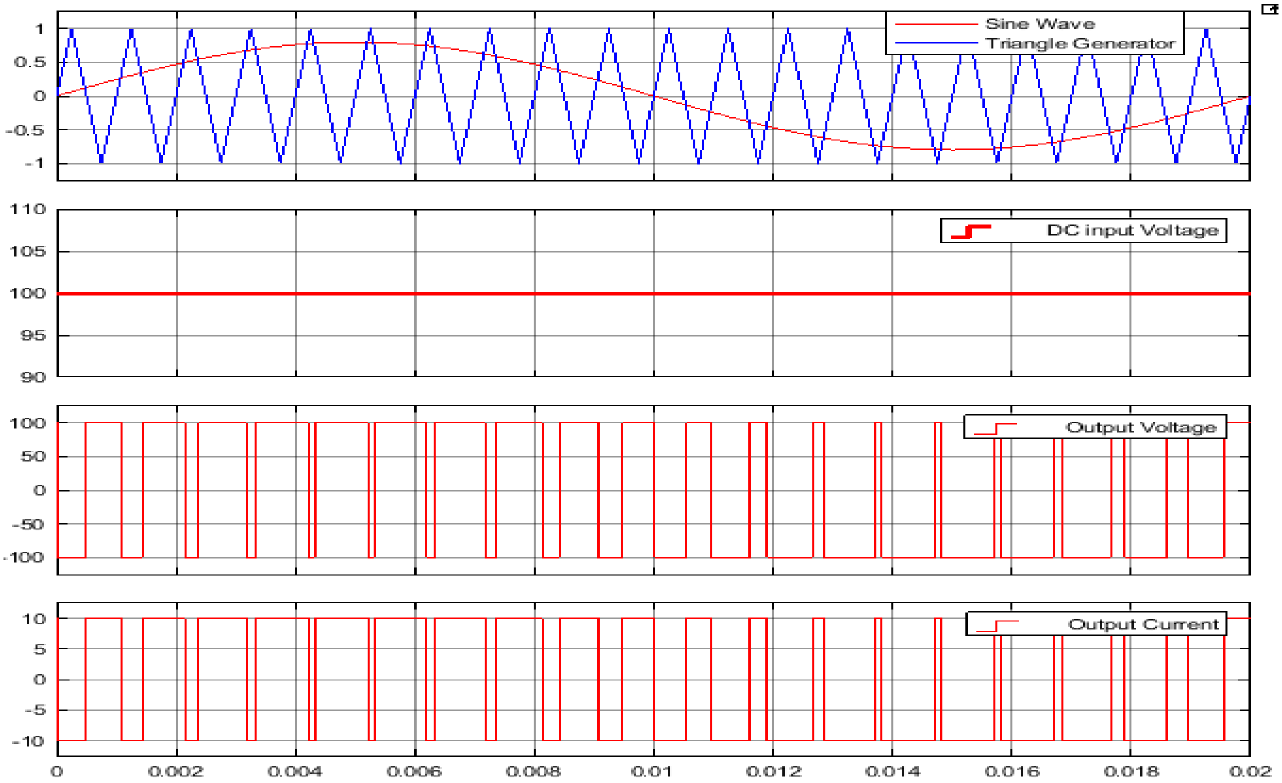


Figure3. Single Phase Inverter Output with Bipolar PWM

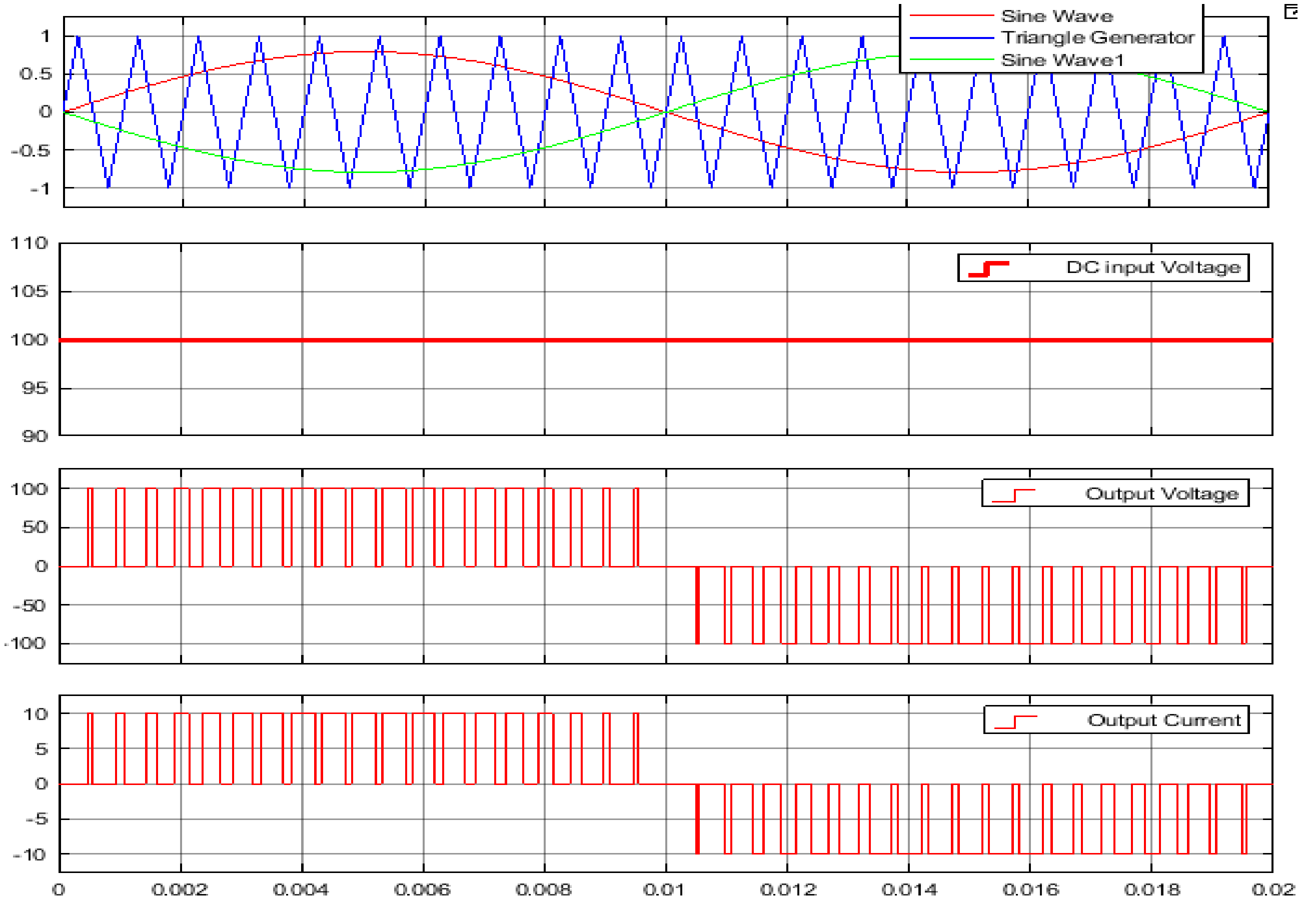


Figure4. Single Phase Inverter Output with Unipolar PWM

Experiment No:5

Aim: Simulation of single-phase full wave AC voltage regulator with R load on MATLAB.

Apparatus Required: MATLAB SOFTWARE

Theory:

AC voltage regulator is thyristor-based devices which convert alternating voltage directly to variable alternating voltage without change in frequency. Some application of ac voltage regulator is for domestic and induction heating, transformer tap-changing speed control of AC motors derives. Figure 1shows the single-phase AC voltage regulator feeding power to a resistive load R. It consist of two thyristor are connected in anti-parallel. Waveforms for source voltage Vs, gating pulses Ig1, Ig2, load current Io, source current Is, load voltage Vo, voltage Across T1 anT2 in figure 2. T1 conduct for +ve half cycle from α to π and T2 conduct for –ve half cycle from π+α to 2π. Figure 3 and figure 4 show the Simulink model for the single-phase AC voltage regulator feeding power to a R &RL load respectively. Its corresponding Waveforms is shown in figure 5& figure 6 respectively.

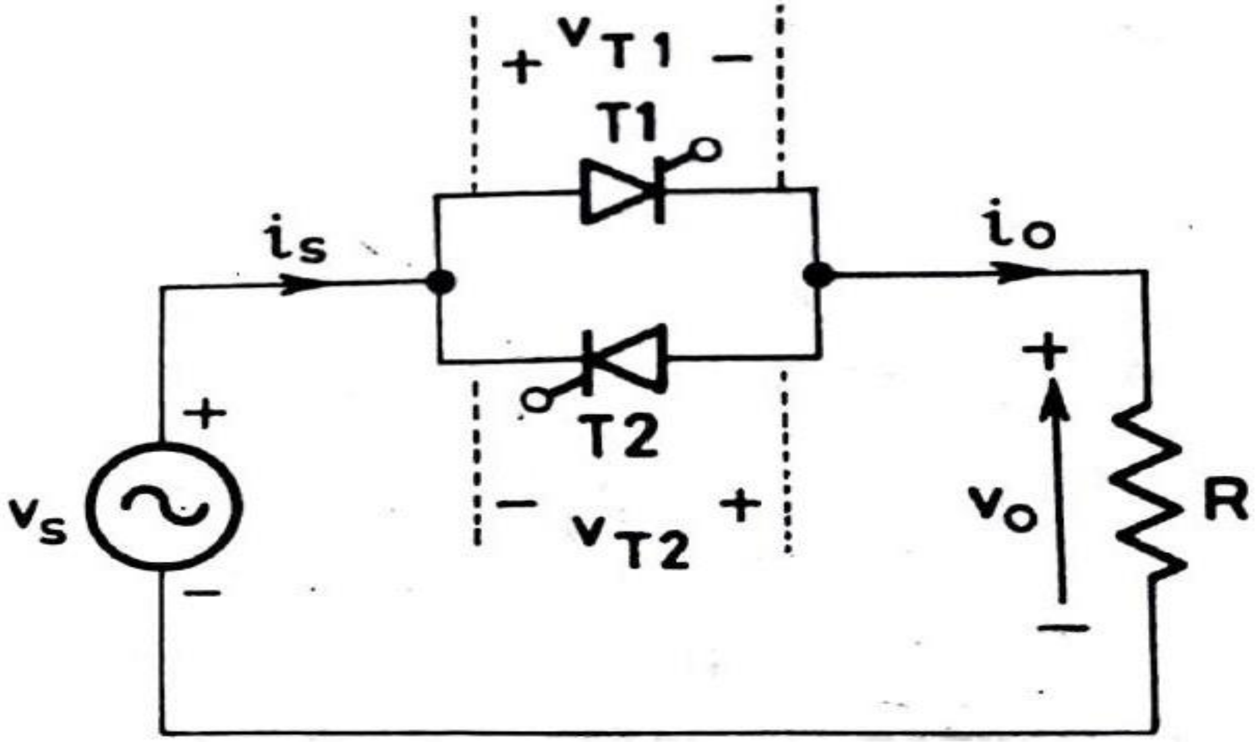


Figure1 Single phase AC regulator

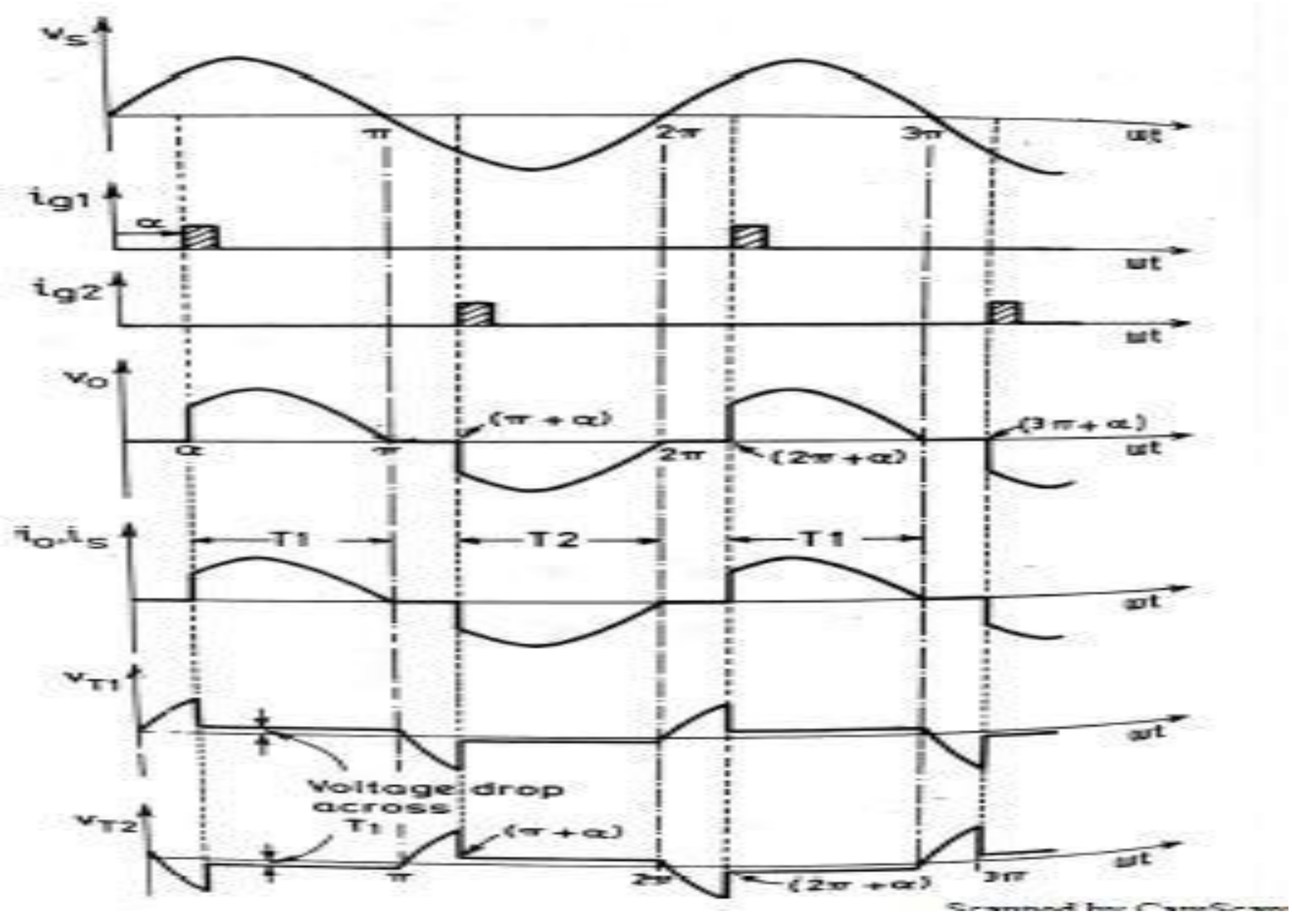


Figure2 Waveforms for source voltage Vs, gating pulses Ig1, Ig2, load current Io, source current Is, load voltage Vo, voltage Across T1 anT2

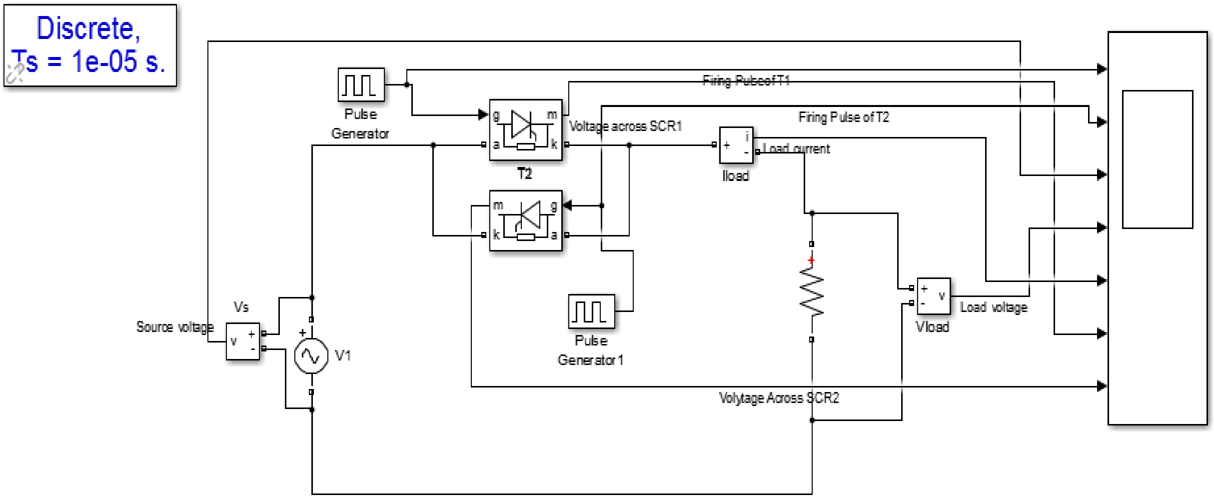


Figure3 Simulink model of AC regulator with R load

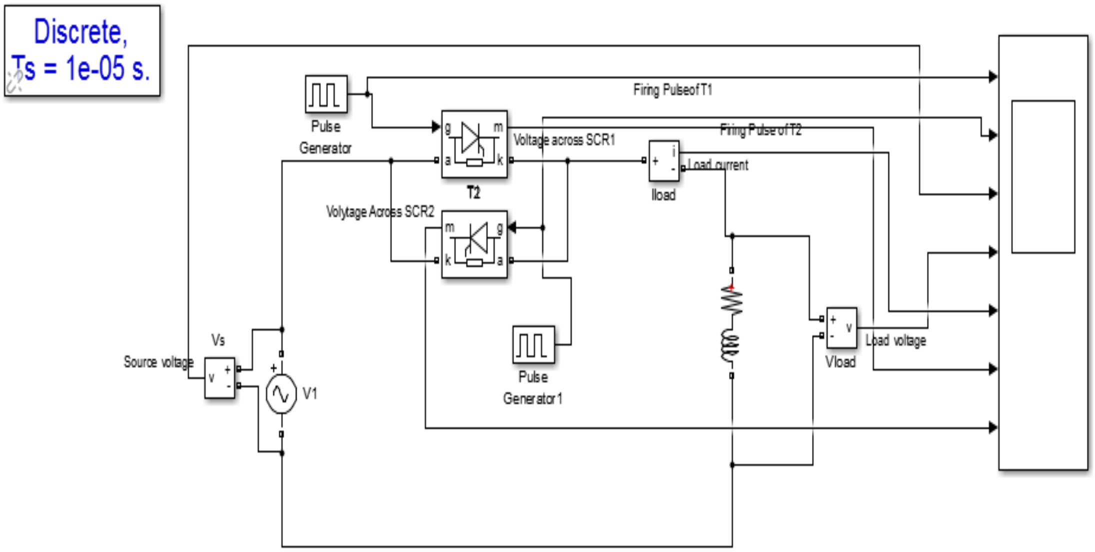


Figure4 Simulink model of AC regulator with RL load

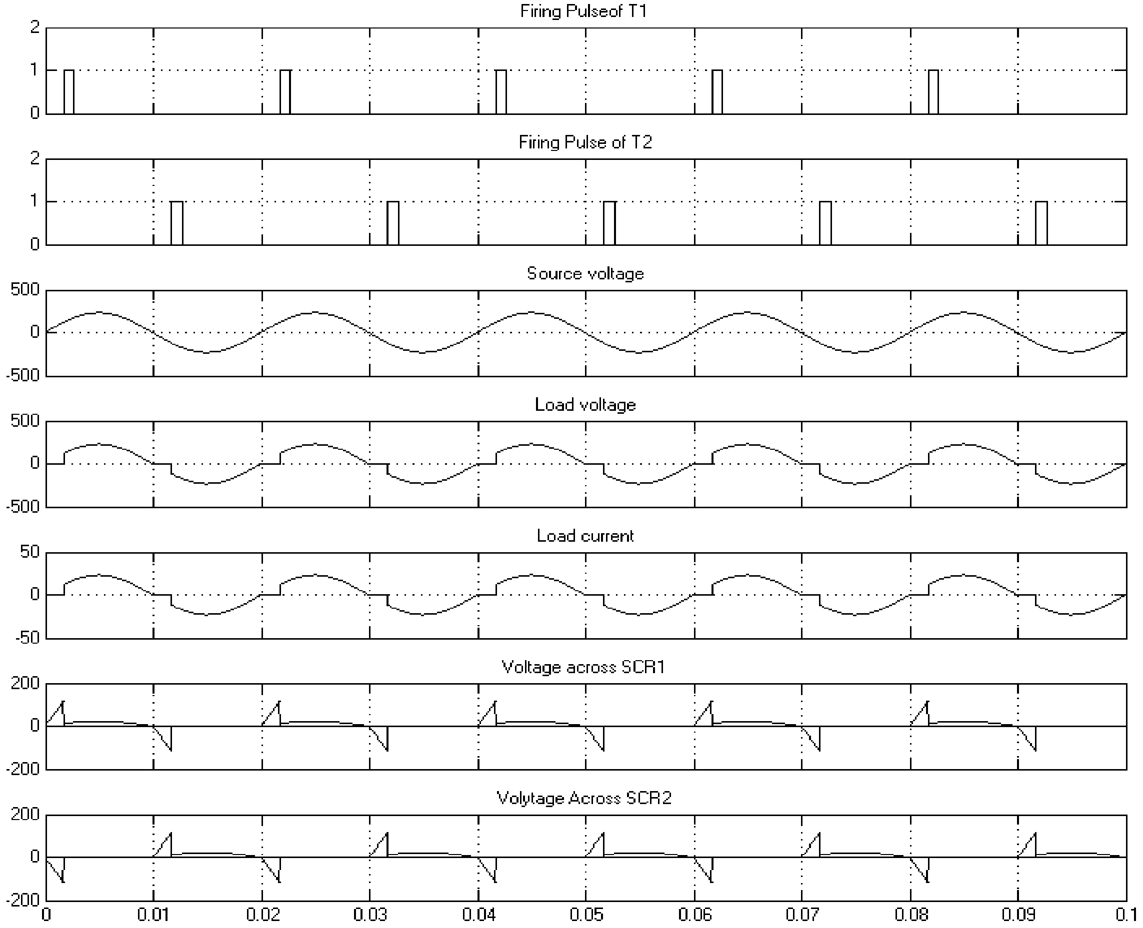


Figure5 Waveforms for, gating pulses Ig1, Ig2, source voltage Vs, load voltage Vo, Load current Io, Voltage Across T1 anT2 with r load

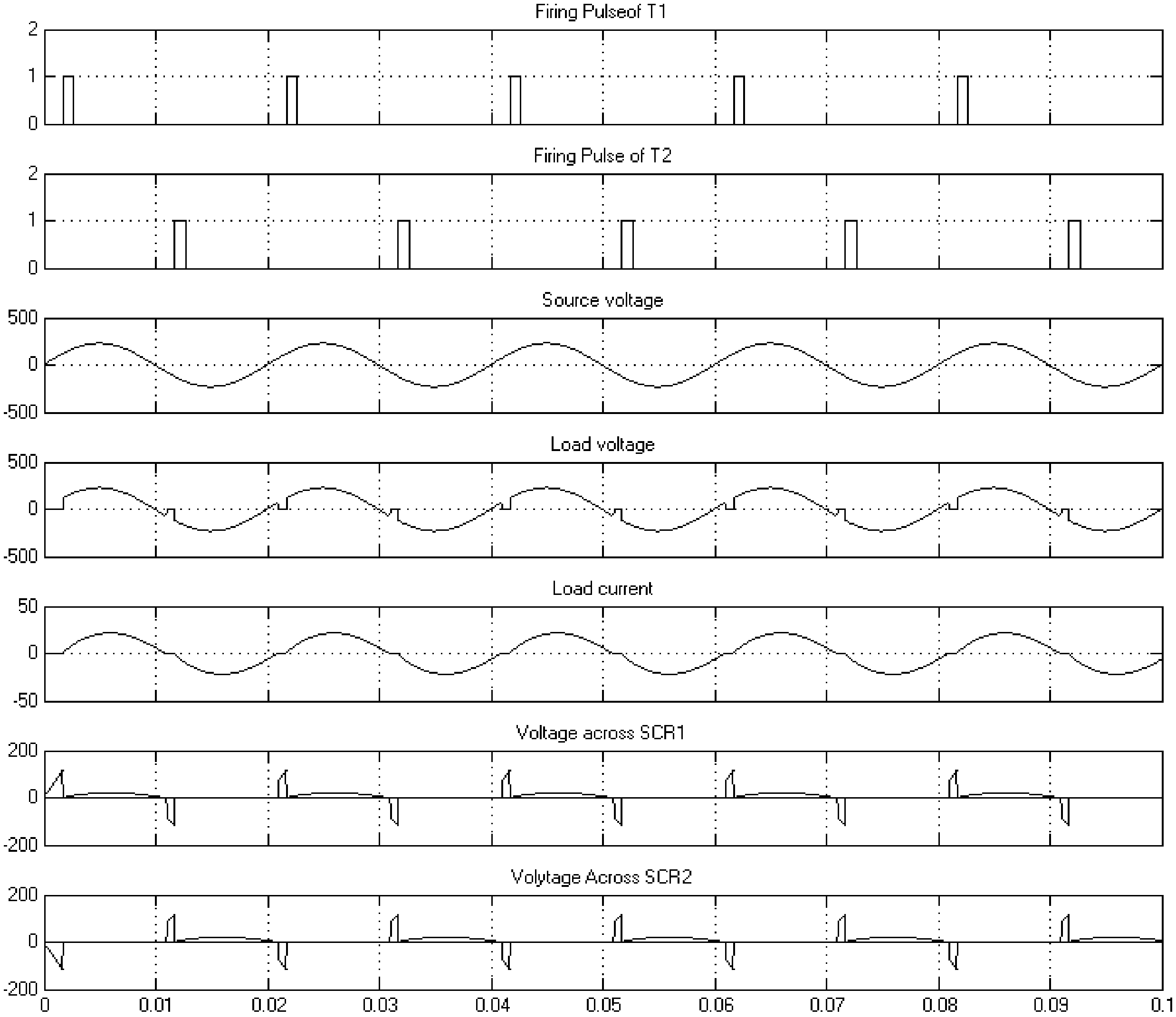


Figure6 Waveforms forgating pulses Ig1, Ig2, source voltage Vs , load voltage Vo ,Load current Io ,Voltage Across T1 anT2 with RL load

Procedure

1. Open a new model window in MATLAB and Simulink.
2. Take the entire component according to requirements.
3. Connect them according to circuit.
4. Set the values of input DC source.
5. Set the value of Pulse Generator.

Result:

AC regulator circuit and its output waveforms are studied

Experiment No:6

Aim: Simulation of single-phase half wave AC voltage regulator with R& RL load on MATLAB.

Apparatus Required: Matlab Software.

Theory:

AC voltage regulator is thyristor-based devices which convert alternating voltage directly to variable alternating voltage without change in frequency. Some application of ac voltage regulator is for domestic and industrials heating, transformer tap-changing speed control of AC motors derives. Figure 1shows the single-phase half AC voltage regulator feeding power to a resistive load R. It consists of one thyristor are connected in anti-parallel with one diode. Waveforms for source voltage Vs, gating pulses Ig1, Ig2, load current Io, source current Is, load voltage Vo, Voltage Across T1 anT2 in figure2. T1 conduct for +ve half cycle from α to π and diode D1conduct for –ve half cycle from π to 2π+ α. Figure 3 and figure 4 show the Simulink model for the single-phase AC voltage regulator feeding power to R &RL load respectively. Its corresponding Waveforms is shown in figure5& figure6 respectively.

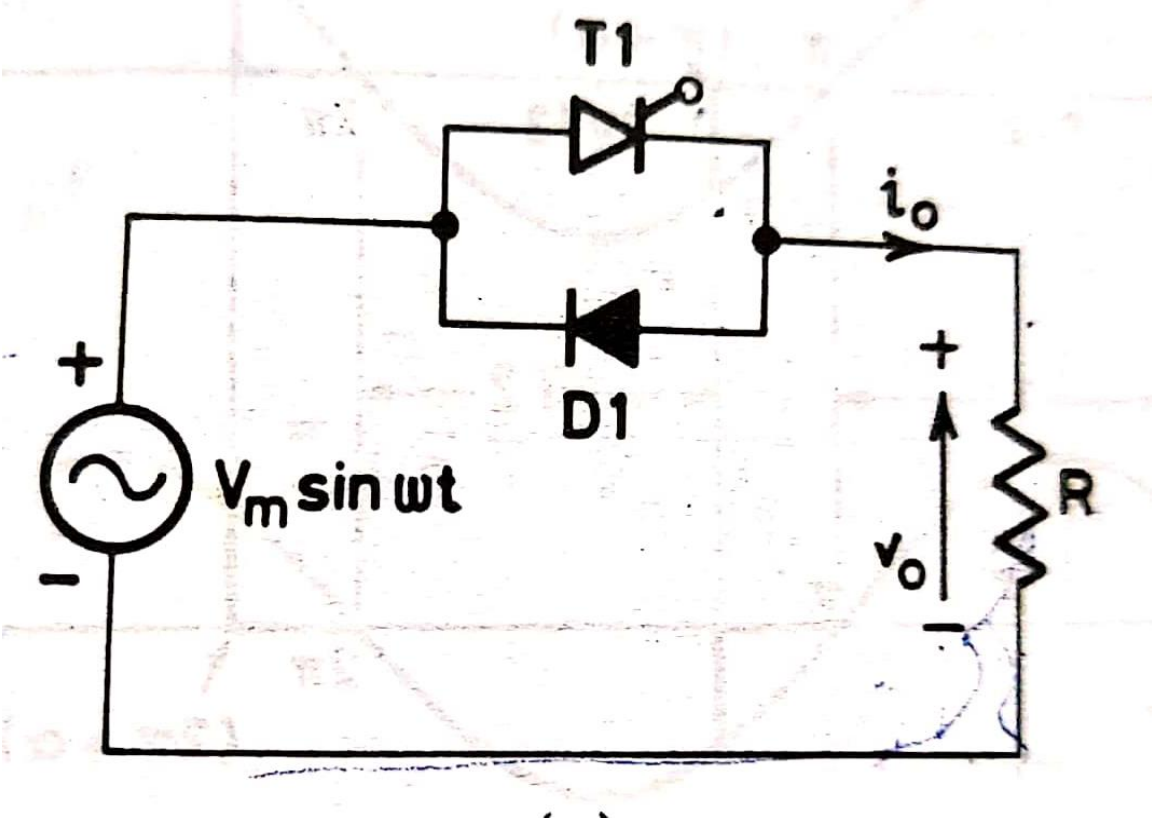


Figure1 Single phase half wave AC regulator

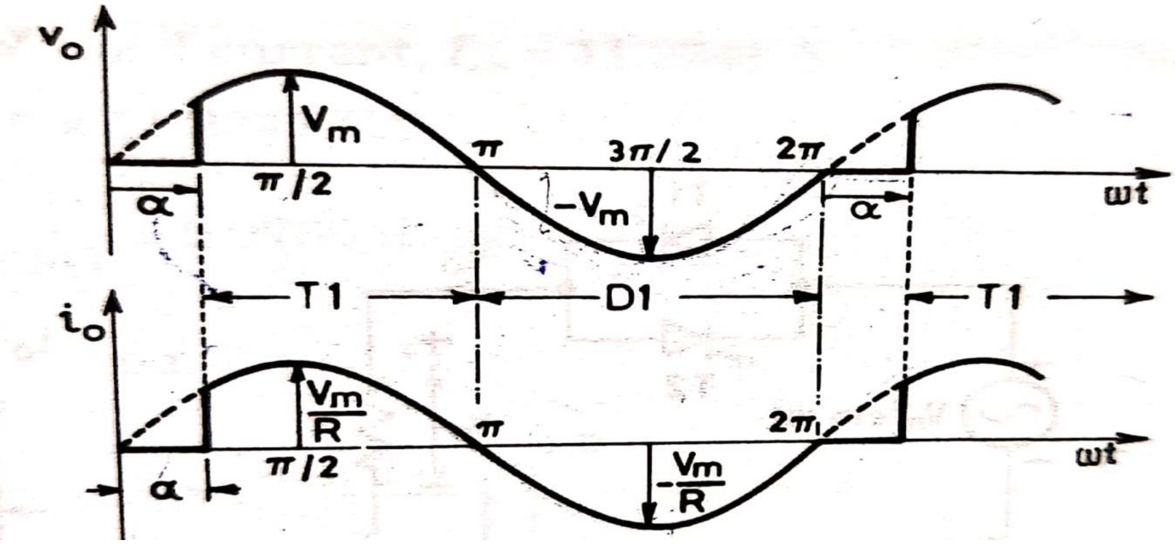


Figure2 Waveforms of voltage Vo, Load current of half wave AC regulator

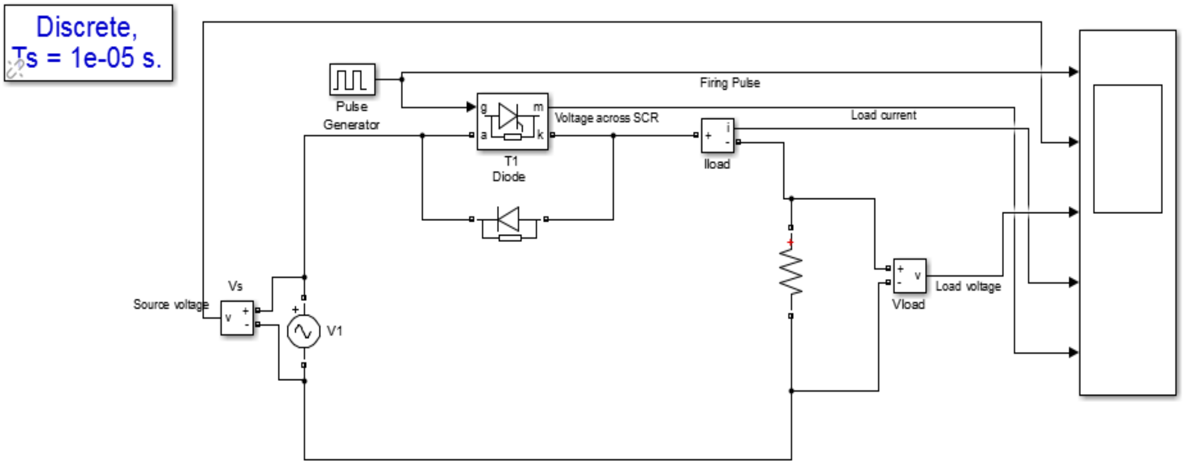


Figure3 Simulink model of half wave AC regulator with R load

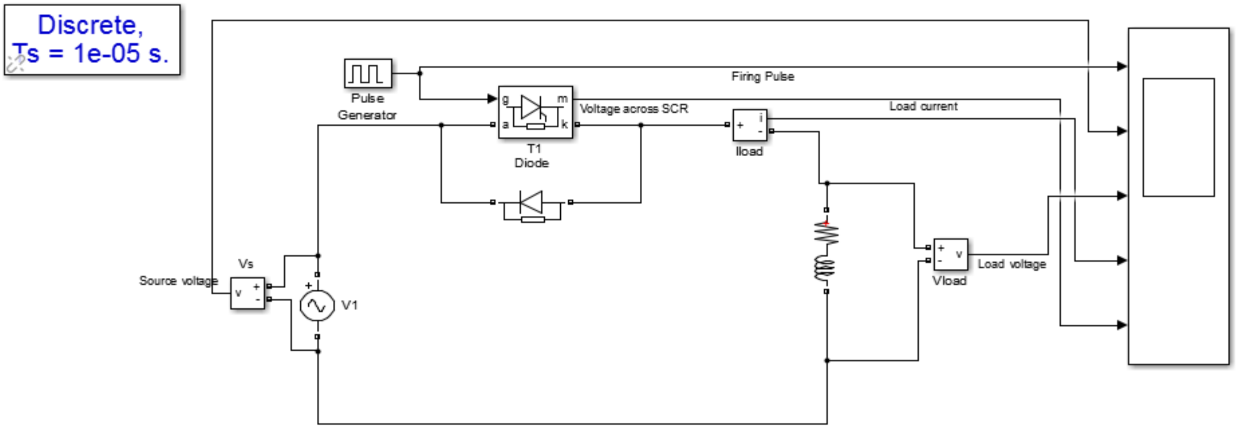


Figure4 Simulink model of half wave AC regulator with RL load

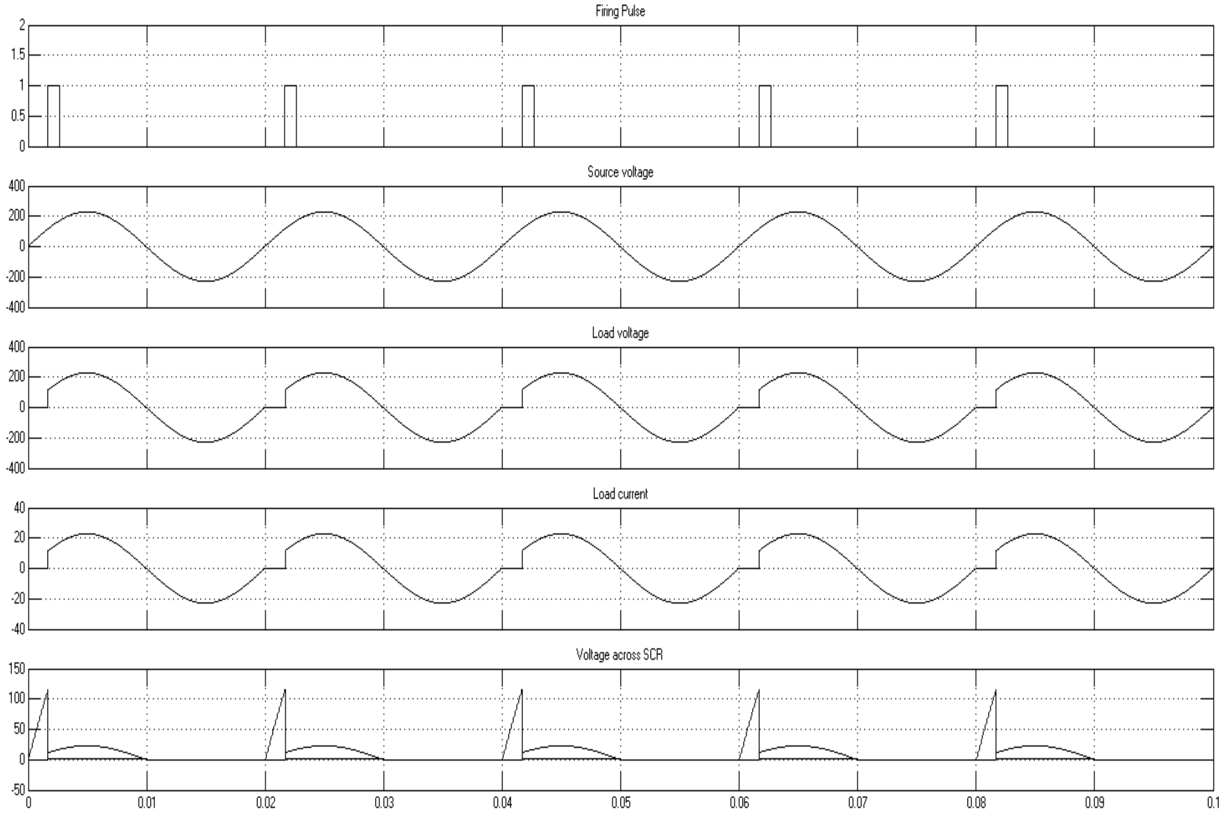


Figure5 Waveforms for, gating pulses Ig1, source voltage Vs, load voltage Vo, load current Io, Voltage Across SCR T1 with r load

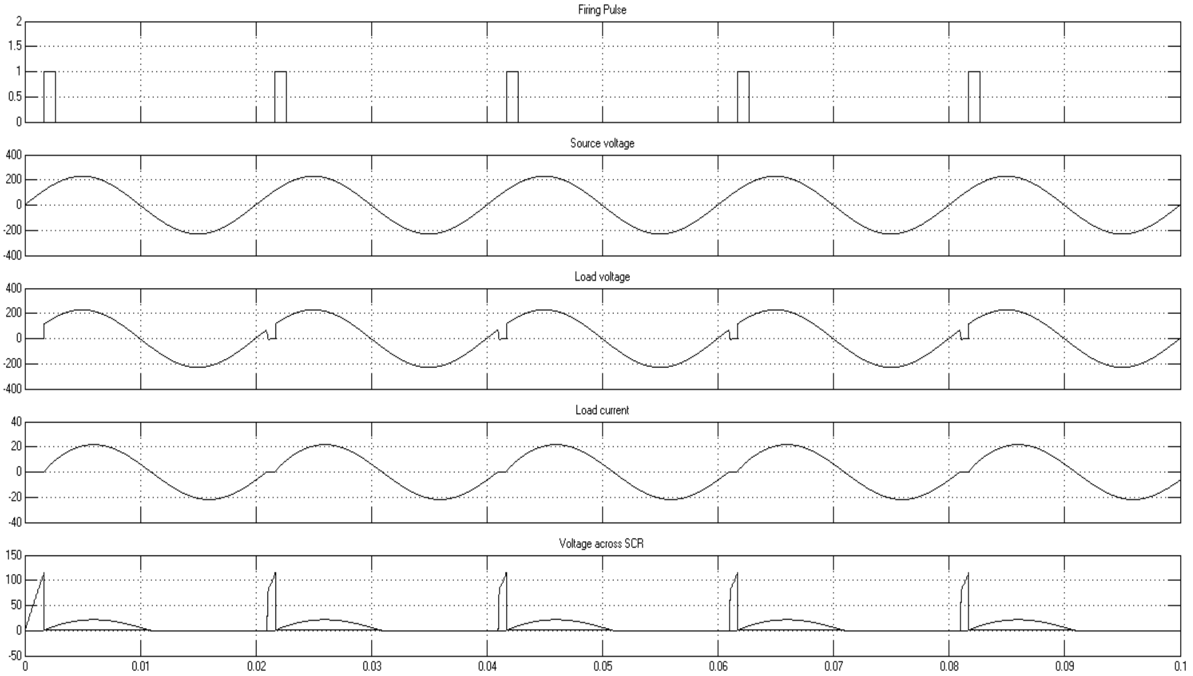


Figure6 Waveforms for gating pulses Ig1, source voltage Vs, load voltage Vo, Load current Io, Voltage Across SCR T1 RL load

Procedure

1. Open a new model window in MATLAB and Simulink.
2. Take the entire component according to requirements.
3. Connect them according to circuit.
4. Set the values of input DC source.
5. Set the value of Pulse Generator.

Result:

AC regulator circuit and its output waveforms are studied.

Experiment No.7

Aim: Simulation of DC-DC Buck Converter.

Apparatus required: MATLAB Software.

Theory: -

Theory: The power semiconductor device used for a chopper circuit can be forced commutated thyristor, BJT, power MOSFET into an IGBT. A power MOSFET has three terminals called drain(D), source(S) and gate (G). In place of corresponding 3 terminals collector, emitter and base BJT. The arrow in circuit diagram of MOSFET indicates the direction of electron flow. A power MOSFET is basically voltage-controlled device as its operation depends upon the flow of majority charge carrier only. MOSFET is a unipolar device. As the gate circuit impedance is extremal high of the order of 10 ohm and the control signal is much larger. Power MOSFET'S are of two types: n- channel and p-channel enhancement. Out of two, n-channel is more common because of higher mobility electrons. A chopper is a static device that convert fixed input DC voltage into variable DC output voltage directly. A chopper may be thought of a dc equivalent of a transformer in an identical manner. The power semiconductor device used for chopper circuit can be force commutated thyristor, BJT, power MOSFET into an IGBT.

Procedure:

1. Make the connections as per circuit diagram with elements taken from the MATLAB library for both R & RL load.

2. Simulate them.

3. Observe the waveform carefully on scope.

Working of Step-down Chopper with RL load:

1. When MOSFET is ON, supply is connected across load.

2. Current flows from supply to load.

3. When Chopper is OFF, load current continues to flow in the same direction through FWD due to energy stored in inductor 'L'.

4. Load current can be continuous or discontinuous depending on the value of 'L' and duty cycle 'd'.

5. For a continuous current operation, load current varies between two limits Imax and Imin.

6. When current becomes equal to Imax the chopper is turned off and it is turned on when current reduces to Imin.

Circuit Diagram of Buck converter

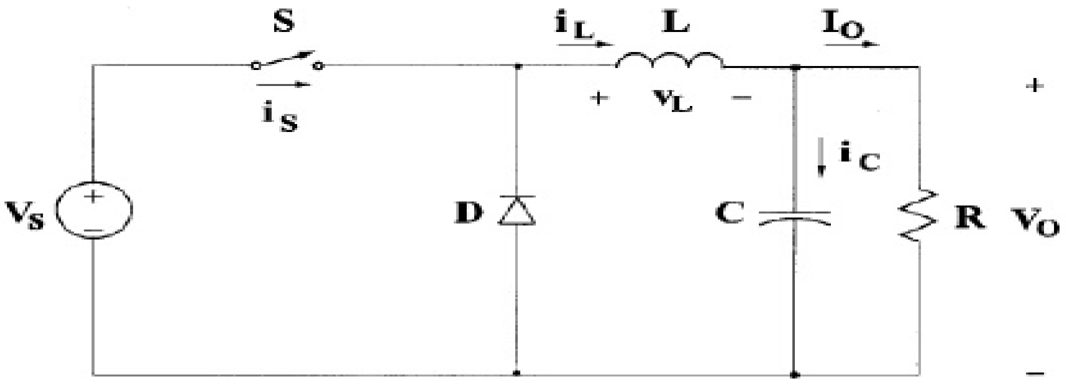


Figure1 Circuit Diagram of Buck converter

Waveforms

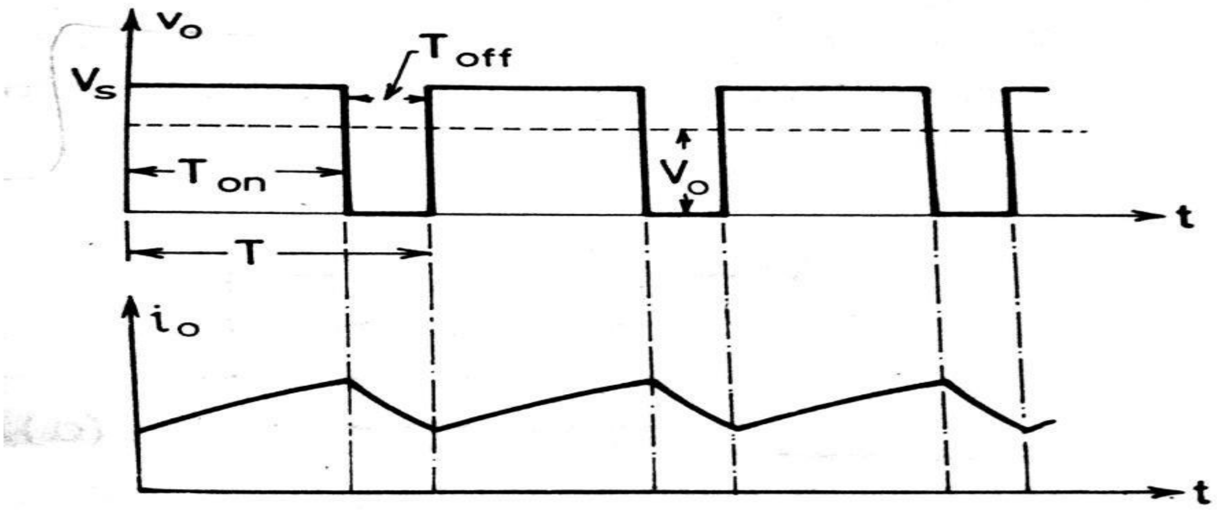


Figure2. Wave form of buck converter

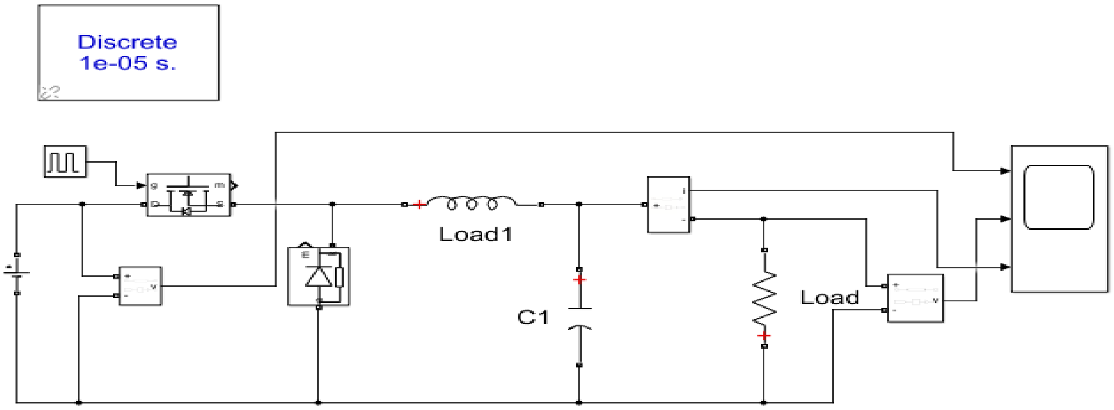


Figure3 simulink model of Buck converter

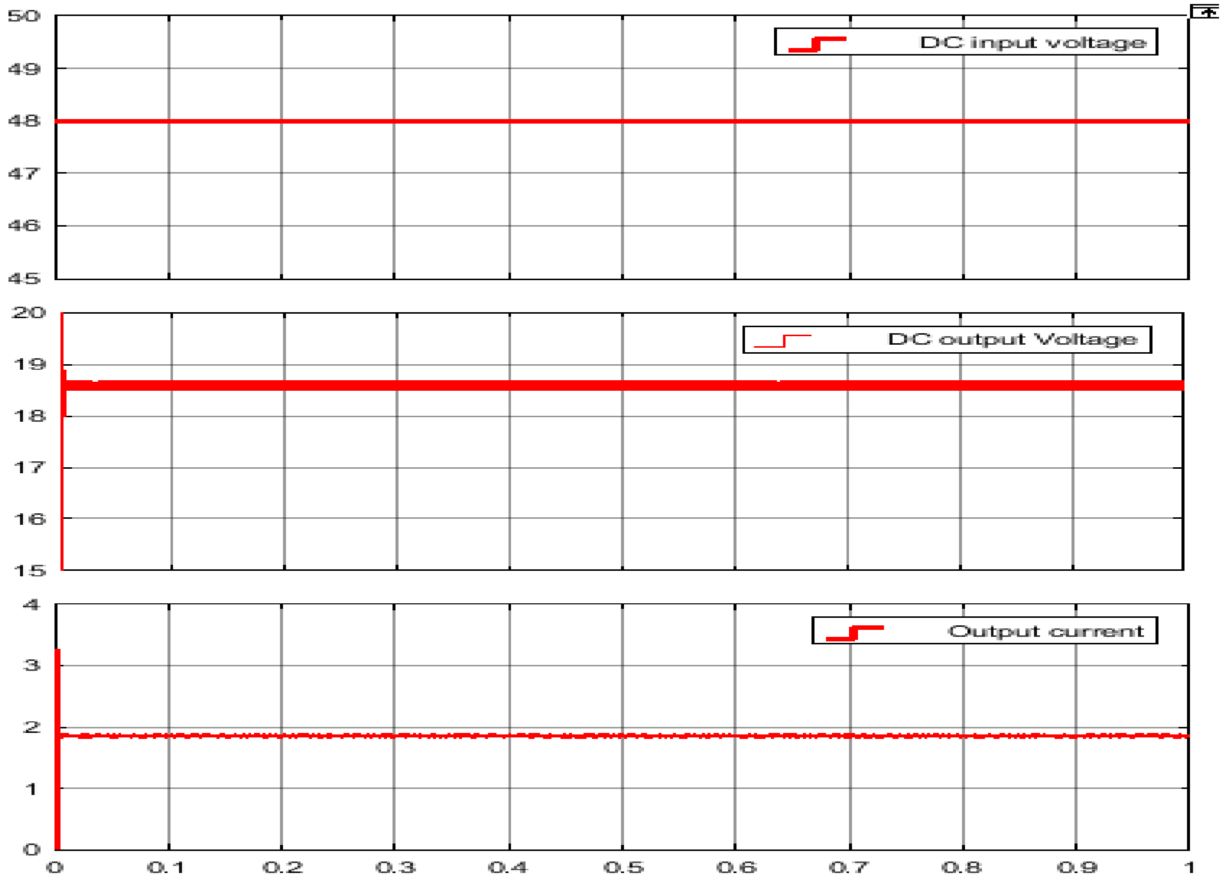


Figure 4 waveform of input voltage,load voltage and load current of buck converter.

Result:

Simulation of step-down chopper with R load on MATLAB has been simulated.

Experiment:8

Aim: Simulation of three-phase bridge inverter with RL load on MATLAB.

Apparatus Required: MATLAB software

Theory:

Three-phase inverters are commonly used in various applications such as motor drives, renewable energy systems, and uninterruptible power supplies (UPS). Pulse Width Modulation (PWM) is a popular technique used to control the output of these inverters due to its ability to produce a high-quality AC waveform with adjustable frequency and amplitude. PWM involves switching the inverter's power electronic devices (typically IGBTs or MOSFETs) on and off at high frequencies. The width (duration) of each pulse is varied to control the average voltage and current supplied to the load

Sinusoidal PWM (SPWM): The reference signal is a sine wave, and the carrier signal is a high-frequency triangular wave. The intersection points determine the switching instants.

In SPWM, each switch is controlled based on the comparison of a sinusoidal reference signal with a high-frequency triangular carrier signal.

- **Reference Signals:**

$V_a^*=V_m\sin(\omega t)$, $V_b^*=V_m\sin(\omega t-120^0)$, $V_c^*=V_m\sin(\omega t-240^0)$

- **Carrier Signal:**

A high-frequency triangular wave.

Switching Logic:

S_1, S_3,S_5 are controlled by comparing the reference signals with the carrier signal.

S_4, S_6, S_2 are the complementary switches (turned off when the corresponding top switch is on, and vice versa).

The block diagram of three phase bridge inverter with PWM control is shown in figure1. The PWM pulses for Switches S_1 to S_6 is shown in figure2. Figure 3 and figure 4 shows the output voltage and output current respectively.

Procedure:

1. Click File – New –Model
2. Click on Simulink library browser.

3. Search the components required and add them to the model.
4. Connect components to form correct circuit diagram.
5. Run simulation.
6. Observe waveform and compare it with the theoretical waveform.

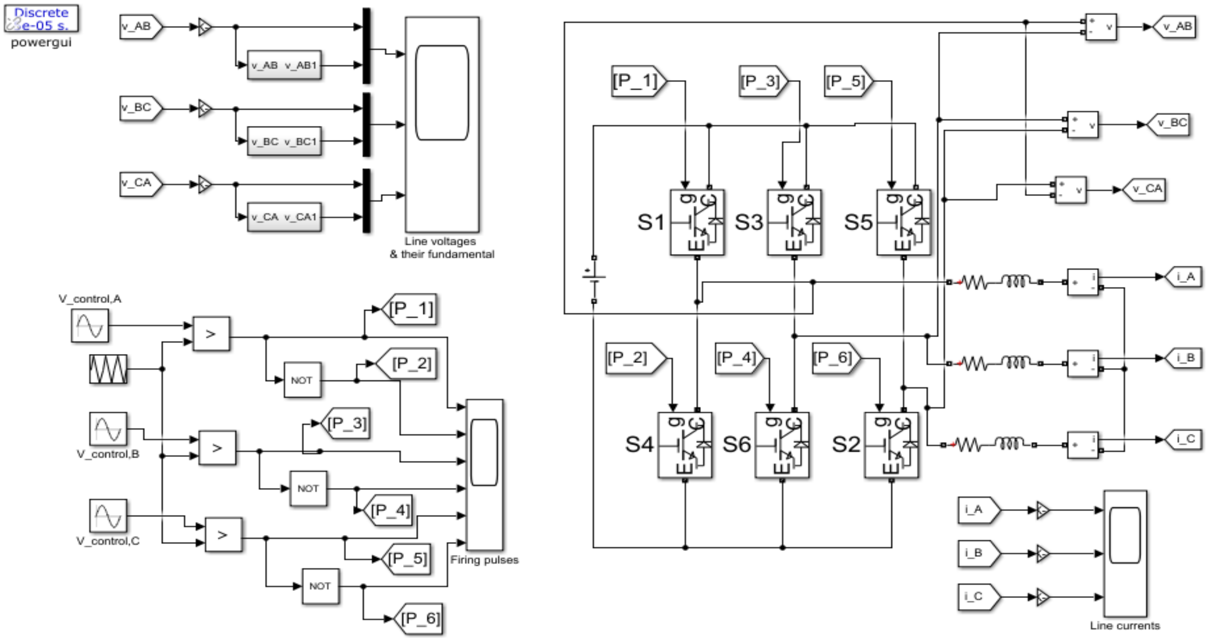


Figure1. Three phase bridge inverter with PWM control

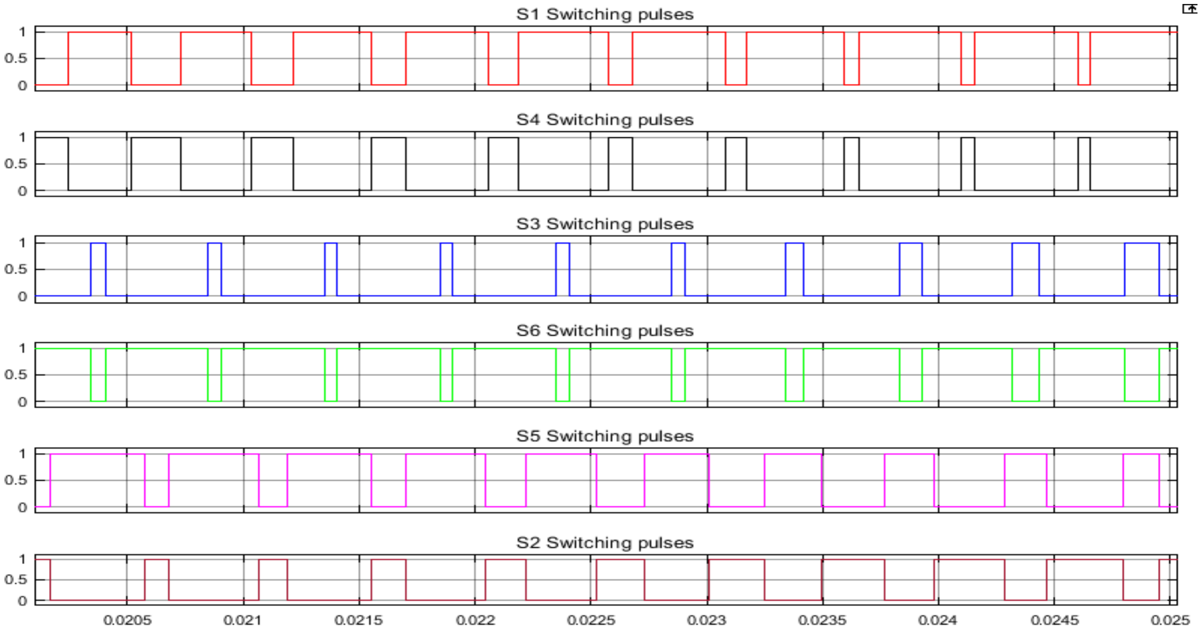


Figure 2. PWM pulses for S1 to S6

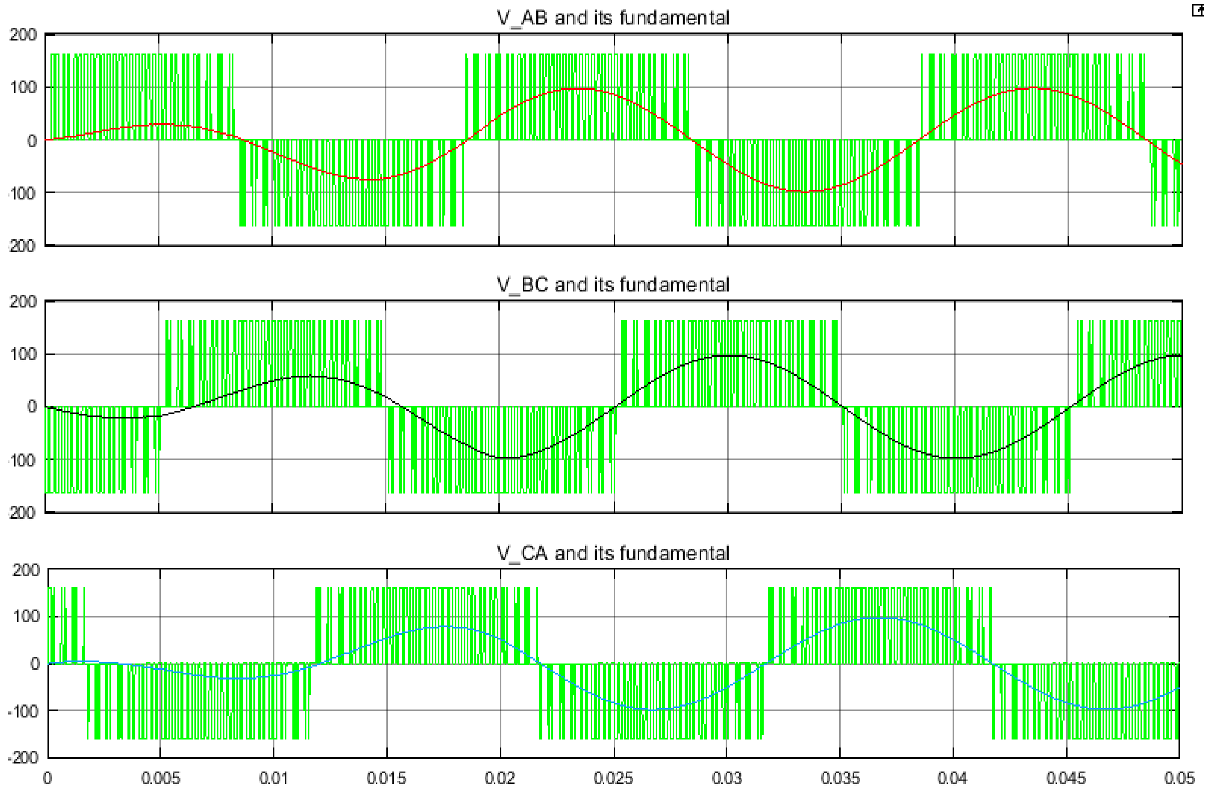


Figure 3 shows the Fundamental and line output voltage for three phase bridge inverter

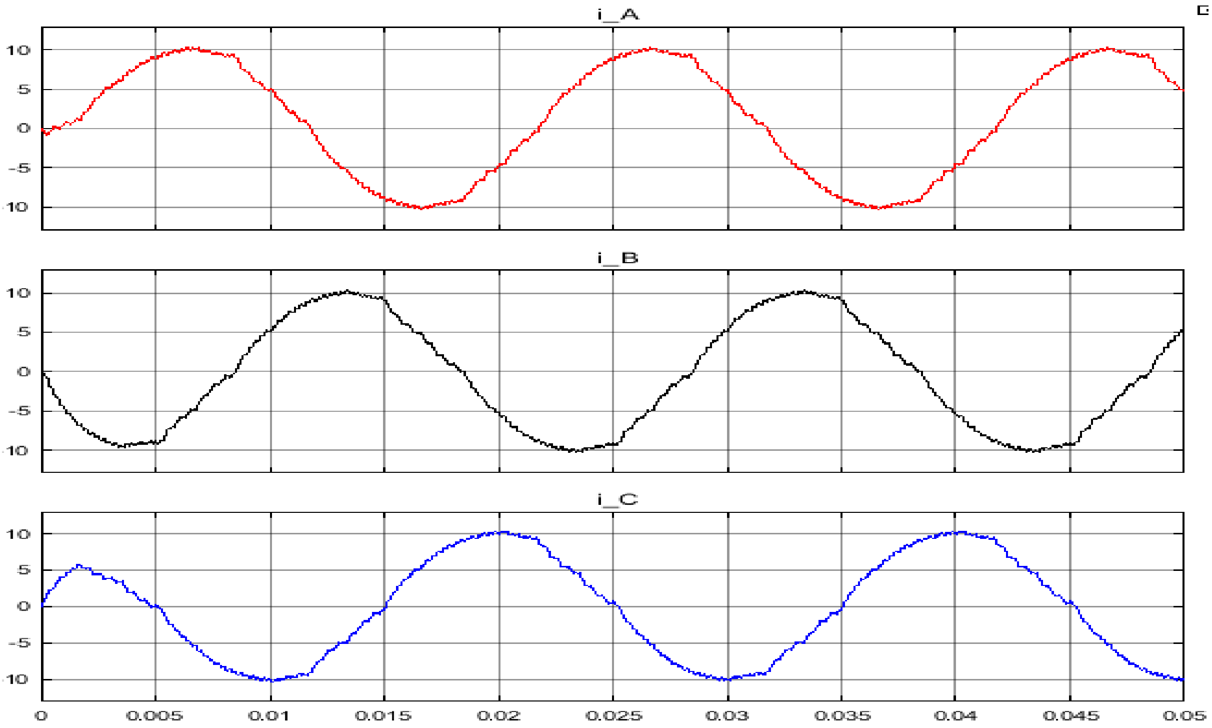


Figure 4. Shows the each phase load current for three phase bridge inverter.

Experiment No: 9

Aim: Thyristor firing based on Resistance Firing Circuit.

Apparatus Required:

Trainer kit of R firing circuit, 40W lamp load, CRO, Connecting wires.

Theory:

Resistance Triggering:

Resistance trigger circuit is the simplest & most economical method. During the positive half cycle of the input voltage, SCR become forward biased but it will not conduct until its gate current exceeds Igmin. Diode D allows the flow of current during +ve half cycle only. R2 is the variable resistance & R is the stabilizing resistance. R1 is used to limit the gate current. During the +ve half cycle current Ig flows. Ig increases and when Ig = Igmin the SCR turn ON. The firing angle can be varied from 0-90° by varying the resistance R2. A relationship between peak gate voltage and gate trigger voltage Vgt may be expressed as follows:

$$Vgp\times \sin\alpha = Vgt \quad \text{or } \alpha = \sin^{-1}\left(\frac{Vgt}{Vgp}\right) \qquad \ldots.\ (1)$$

Since

$$Vgp = \frac{Vm\times R}{(R1+R2+R)}$$

$$A = \sin^{-1}\left(\frac{Vgt(R1+R2+R)}{Vm\times R}\right)$$

As Vgt, R1, R and Vm are fixed, $\alpha \infty R2$

This shows that firing angle is proportional to R2. As firing angle is control from 0 ° to 90°, the half- wave power can be controlled from 100% down to 50%.

Circuit Diagram:

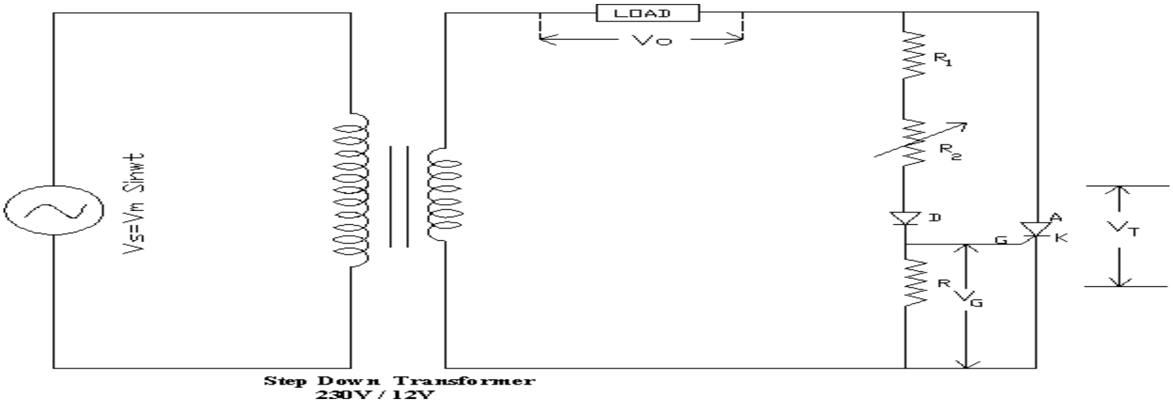


Figure1 Resistance firing circuit

Procedure:

R Firing

1. Connecting are made as shown in fig.
2. Switch on the power to the CRO.
3. Set the CRO to the line trigger mode.
4. Switch on power supply to the SCR trainer.
5. Observe the waveform on the CRO.
6. Study the waveform for various firing angle by varying the pot in R trigger circuit.
7. Observe the range of firing angle control.
8. For any one particular firing angle plot the waveform of the ac voltage, voltage across the load and the SCR using trace paper.

Output Waveform:

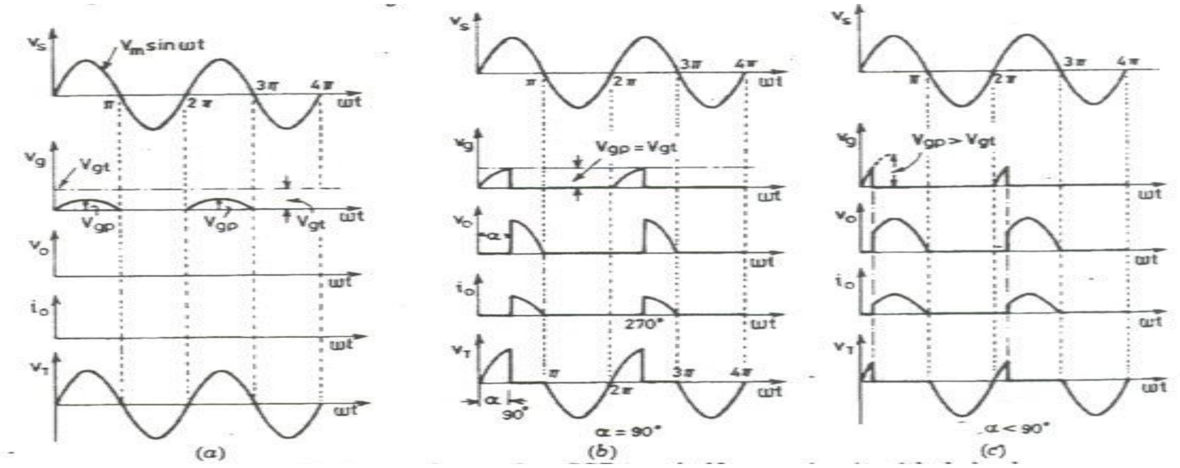


Figure2 Output waveform of R firing circuit

Precaution:

1. Connections should be proper and tight to avoid distortion of waveforms.
2. Power supply should be given to kit only when circuit is complete.
3. Do not touch bar wire on kit while taking waveforms.
4. CRO should be calibrated.

DISCUSSIONS:

Q1. Discuss the features that the firing circuits for thyristor should possess?

Q2. Is it possible to get a firing angle greater than 90 ° with Resistance firing?

Results: Thus, the operation of resistance triggering circuit of SCR has been studied.

Experiment No. 10

Aim: RC half wave and full wave Firing Circuit of thyristor.

Apparatus Required:

Trainer kit of R-C firing circuit, 40W lamp load, CRO, Connecting wires

Theory:

By varying the variable resistance R, the firing angle can be varied from 0-180°. In the –ve half cycle the capacitance C charges through the diode D2 with lower plate +ve to, the peak supply voltage Emax. This Capacitor voltage remains constant at until supply voltage attains zero value. During the +ve half cycle of input voltage, C begins to charge through R. When the capacitor voltage reaches the minimum gate trigger voltage SCR will turn ON.

R-C Half Wave Trigger Circuit:

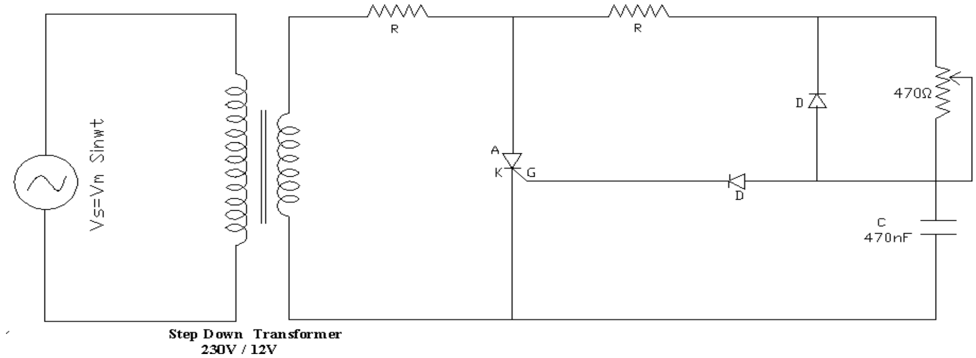


Fig 1. Simple Half- Wave RC Phase Control Circuit Schematic

In –ve half cycle, capacitor charges through D2 with lower plate +ve to the peak supply voltage Vm at wt=-90°. After wt=-90°, source voltage decreases from –Vm at wt=-90° to zero at wt=0. When capacitor charges to Vgt, SCR is fired and after this capacitor hold a small +ve voltage.

RC Full Wave Firing Circuit.

Diode D1-D4 from a full wave diode bridge. In this circuit, the initial voltage from which the capacitor C charges is almost zero. The capacitor is set to this low +ve voltage by the clamping action of SCR gate. When capacitor charges to voltage equal to Vgt, SCR triggers and rectified voltage Vd appears across load as Vo.

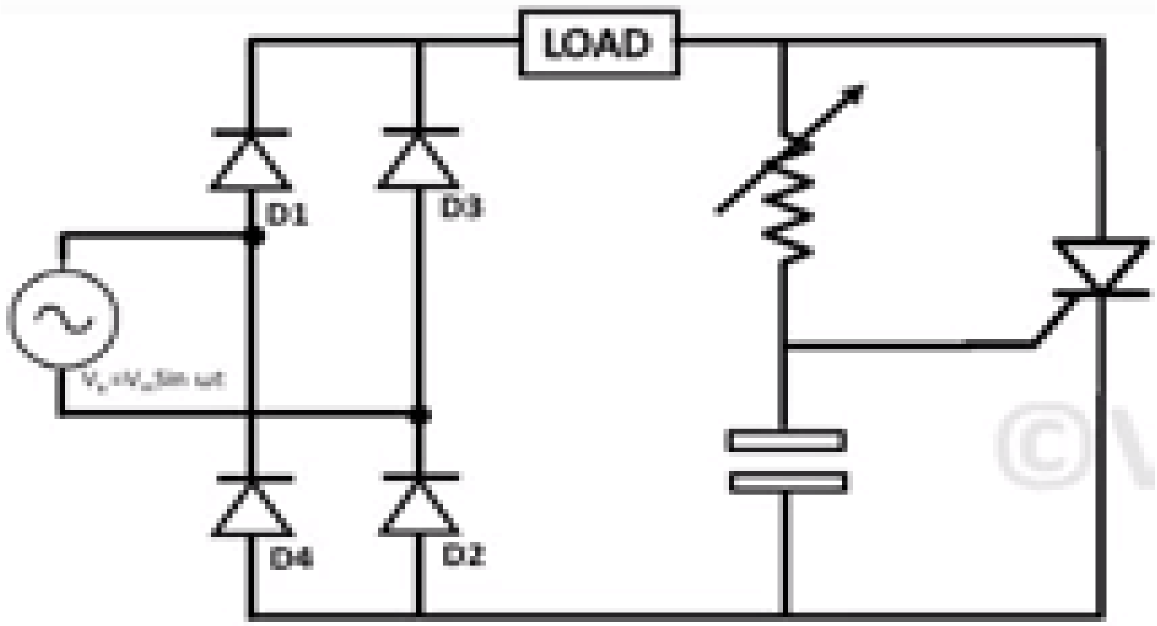


Fig. 2. RC Full- wave trigger circuit

Procedure:

1. Connections are made as shown in fig.
2. Switch on the power supply to the CRO.
3. Switch on the power supply to the SCR trainer.
4. Observe the waveform on the CRO.
5. Study the waveform for various firing angle by varying the pot. in R trigger circuit.
6. Observe the range of firing angle control.
7. For any one particular firing angle trace the waveforms of the ac voltage, voltage across the load and the SCR using trace paper.

RC half wave Waveforms

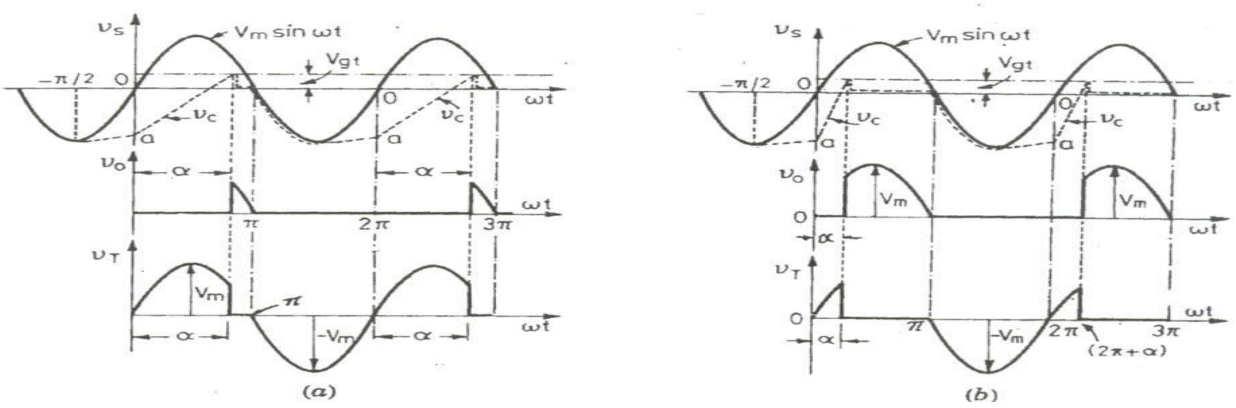


Fig.3. RC HALF-WAVE TRIGGER CIRCUIT WAVEFORM

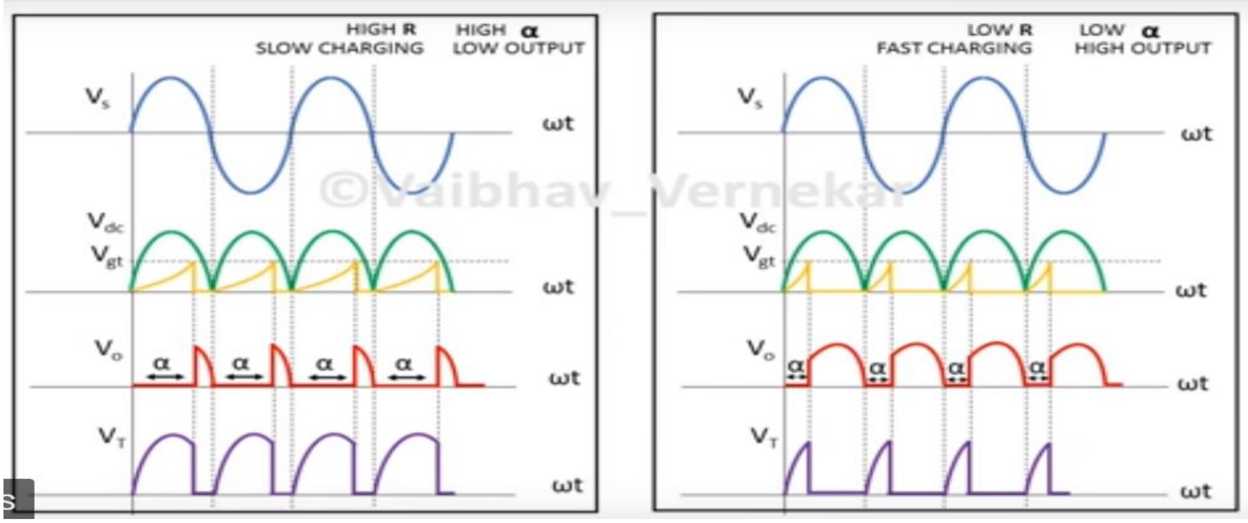


Fig.4. RC FULL-WAVE TRIGGER CIRCUIT WAVEFORM

Result: -

The operation of R-C triggering circuit of SCR has been studied.

Precautions:

1. Connection should be tight.
2. Power supply should be given to kit only when circuit is complete.
3. Do not touch bare wire on kit while taking waveforms.
4. CRO should be calibrated.

Discussions:

Q1. What is commutation in thyristor circuits?

Q2. What is natural Commutation?
Q3. Compare the current commutation with voltage Commutation?
Q4. Enumerate the advantages offered by Class E Commutation?

Experiment No. 11

Aim: TRIAC and DIAC based Firing Circuit of SCR.

Apparatus Required:

TRIAC firing circuit trainer kit, CRO, 40W lamp load, CRO probes, connecting wires.

Theory:

In this circuit, variable resistor R controls the charging time of capacitor C and hence the firing angle of the TRIAC. When C (with upper plate positive) charges to breakdown voltage Vdt of DIAC, DIAC turns on. As a consequence, capacitor charges rapidly to thereby applying capacitor voltage Vc in the form of pulse across the TRIAC gate to turn it on. After TRIAC turns on at firing angle α, source voltage appears across the load during positive half cycle for (π-α) radians.

When Vs becomes zero at Wt =π, TRIAC turns off. After this, Vs become negative, C now charges with lower plate positive and the same cycle is repeated. When R is small, charging time constant (R1+R)C is small . Hence capacitor charges earlier and TRIAC firing angle is small. Likewise, when R is high, firing angle is high.

R1 protects the DIAC and TRIAC gate from getting exposed to almost fully supply voltage if R becomes zero. R2 limits the current in DIAC and TRIAC gate when DIAC turns on.

Circuit Diagram:

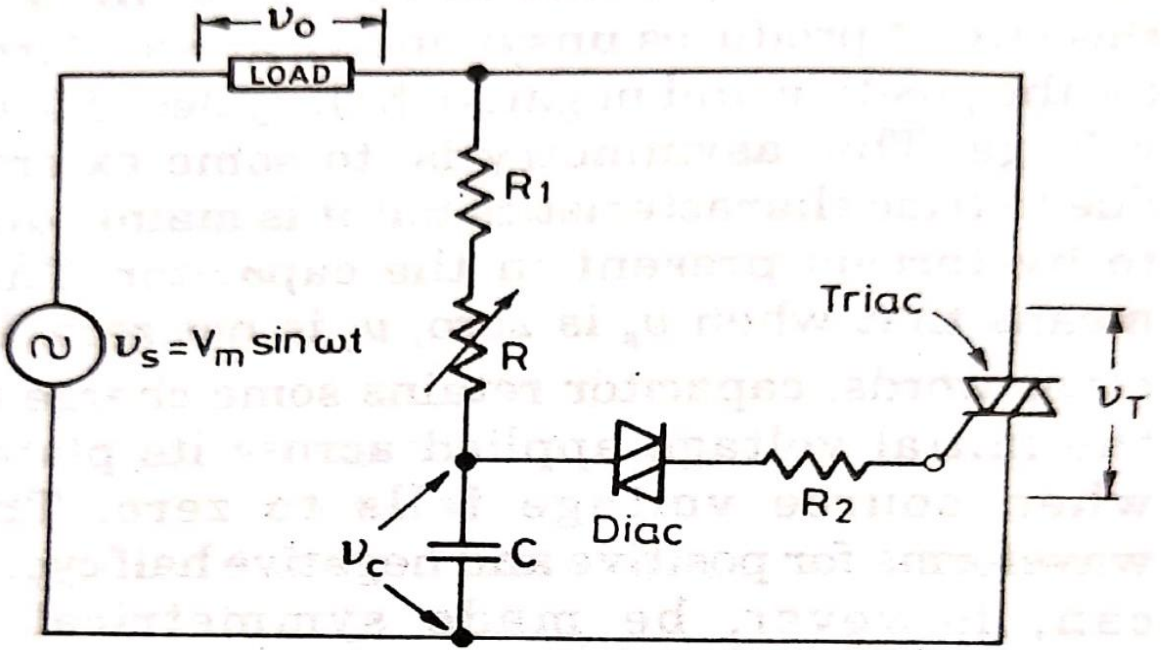


Figure1 TRAIC firing circuit

Procedure:

1. Connections are made as shown in fig.
2. Switch on power supply to the CRO.
3. Switch on the power supply of trainer kit.
4. Observe the waveform on the CRO.
5. Study the waveforms for various firing angle by varying the pot in R trigger circuit and observe the firing angle control.
6. Trace the waveforms on the CRO when R is maximum and minimum.

Waveform:

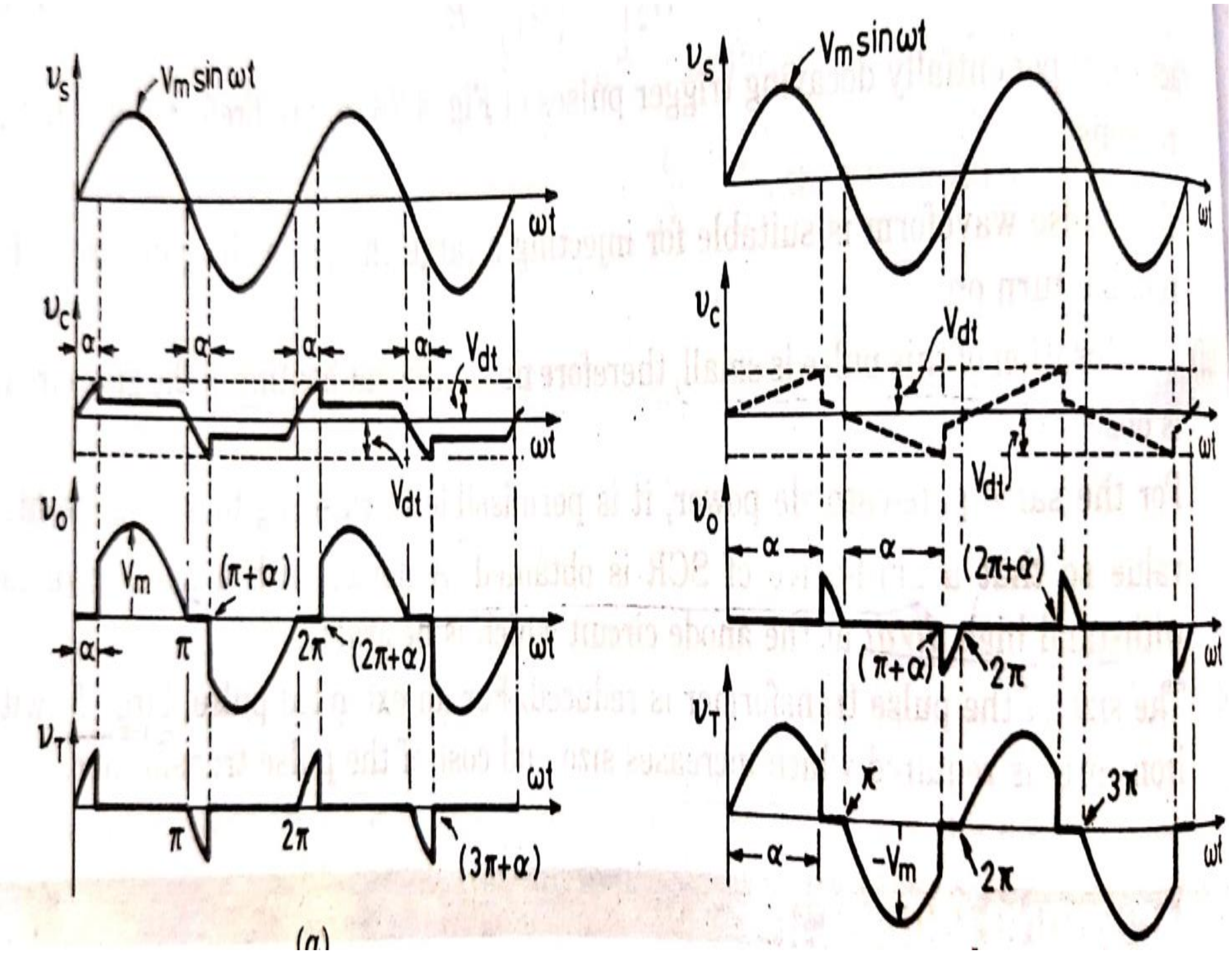


Figure2. Waveforms of TRAIC firing circuit.

Precautions:

- Connections should be proper and tight to avoid distortion of waveforms.
- Power supply should be given to kit only when circuit is complete.
- Do not touch bare wire on kit while taking waveforms.
- CRO should be calibrated.

Discussions:

Q1 Write the advantages of TRIAC firing circuit.
Q2 Differentiate between TRIAC and DIAC.

Result: -

Thus, the operation of TRIAC triggering circuit of DIAC has been studied.

Experiment No.12

Aim: AC phase control circuit using UJT and pulse Transformer.

Apparatus Required:

UJT firing circuit trainer kit, CRO, 40W lamp load, CRO probes, Connecting wires.

Theory:

Pulse Transfer are used quit often in firing circuits for SCRs. The method to control output via UJT and pulse T/F is called Ramp and pedestal triggering. In this circuit, AC input is converted into variable DC through a bridge rectifier and then held constant via Zener diode. R2 acts as a potential divider & controls the value of pedestal voltage Vpd. Diode D allows C to be quickly charged to Vpd through low resistance of upper portion of R2. The setting of wiper on R2 is such that this value of Vpd is always less than UJT firing point voltage ƞVz. When Vpd is small voltage Vz charges C through R. When this ramp voltage Vc reaches ƞVz, UJT fires and voltage Vz, through pulse transformer is transmitted, to the gate circuits of both SCR T1 and T2. The forward biased SCR T1 is turn ON. After this Vc reduces to Vpd and then to zero at wt = π. As Vc is more than Vpd, during the charging of capacitor C through charging resistor R, Diode D is reverse biased and turned OFF. From 0 to π, T1 is forward biased and turned ON. Form π to 2π, T2 is forward biased and turned ON.

Pedestal voltage on C can be adjusted by varying R2. With low voltage across C, ramp charging of C to ƞVz takes longer time and firing angle delay is therefore more and output voltage is low. With high pedestal voltage, charging of C is faster, firing angle delay is small and output is high.

Time required for charging,

$$T = RCln(\frac{1}{1-\eta})$$

and firing angle delay α2 is given by

$$\alpha 2 = WRCln(\frac{1}{1-\eta})$$

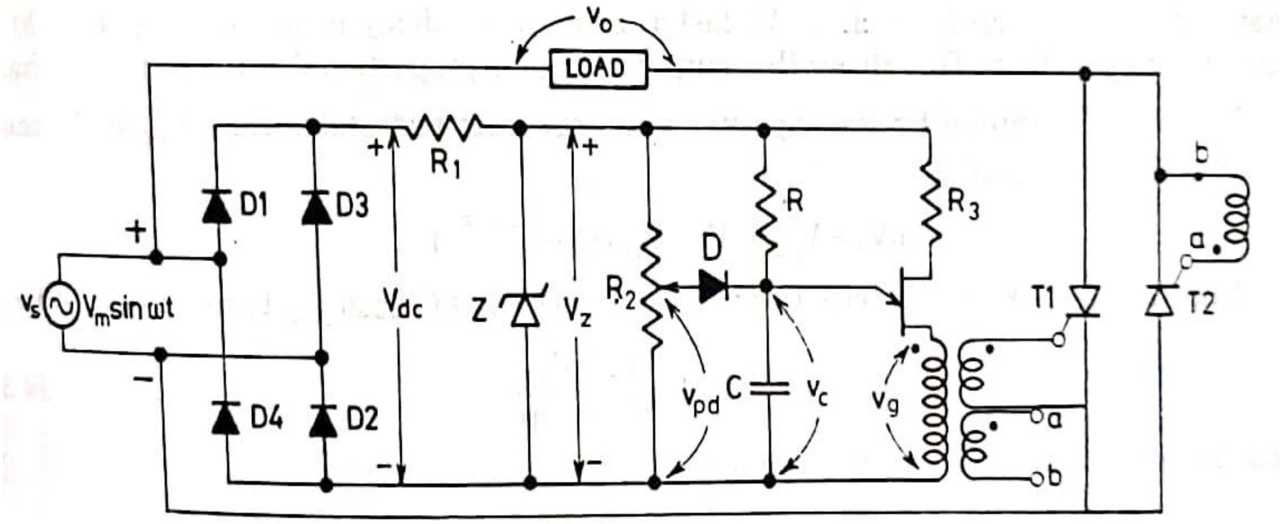


Figure1 Show the circuit diagram of UJT and pulse transformer

Procedure:

1. Connections are made as shown in figure.
2. Switch on the power supply to the CRO.
3. Switch on the power supply of the trainer kit.
4. Observe the waveform on the CRO.
5. Study the waveforms for various firing angle by varying the pot in R trigger circuit and observe the range of firing angle control.
6. Trace the waveforms on the CRO when R is maximum and minimum.

Waveforms:

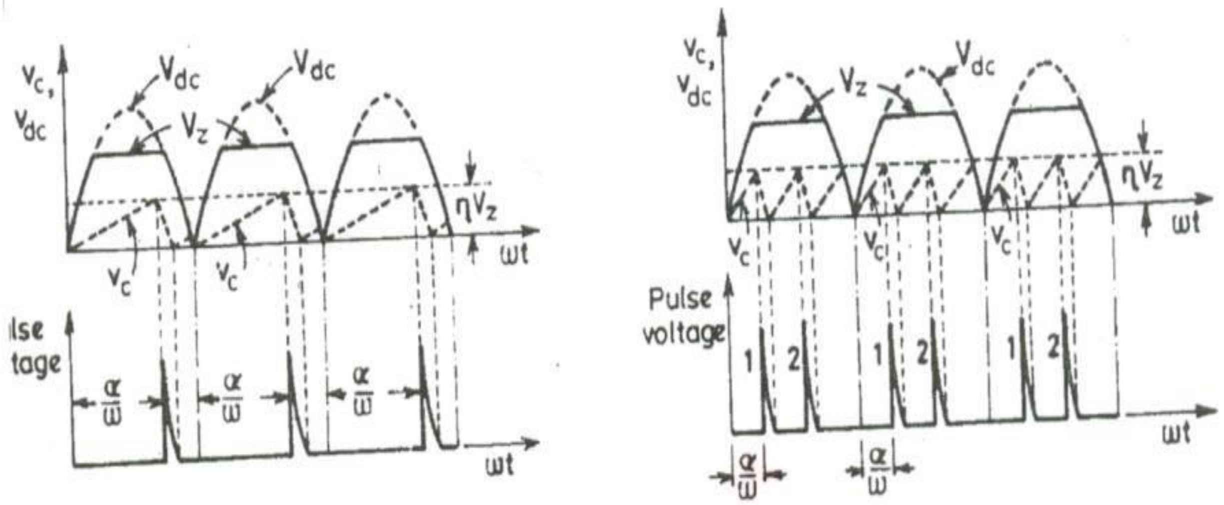


Figure2 Show the waveforms of output of UJT and pulse transformer

Precautions:

1. Connection should be proper and tight to avoid distortion of waveforms.
2. Power supply should be given to kit only when circuit is complete.
3. Do not touch bare wire on kit while taking waveforms.
4. CRO should be calibrated.

Discussions:

Q1. Define intrinsic stand-off ratio.
Q2. What is the peak point and valley point for a UJT?

Result: -

Thus, the operation of UJT and Pulse Transformer triggering circuits of SCR has been studied.

Experiment No:13

Aim: To study the operation of UJT firing circuit.

Apparatus used:

TRIAC firing circuit trainer kit, CRO, 40W lamp load, CRO probes, connecting wires.

Theory:

UJT is a highly efficient switch, its switching time is in range of nano seconds. Since, UJT exhibits negative resistance characteristics, it can be used as a relaxation oscillator. The changing resistance R should be such that its load line intersects the device characteristics only in negative resistance region.

When source voltage V_{BB}. During this charging, emitter circuits of UJT are an open circuit. The capacitor voltage V_C is equal to emitter voltage $V_{E.}$

$$V_c = V_E = V_{BB}\,(1-e^{-t/RC})$$

When the emitter voltage V_E reaches peak point voltage V_P ($\eta V_{BB} + V_D$), the unijuction between E-B_1 breaks down. as a result, UJT turns on and capacitor C rapidly discharges through low resistance R, with a time constant $\tau_2 = R_1C$. τ_2 is much smaller than τ_1. The voltage drop across R_1, equal to V_0, is applied to gate – cathode circuit of an SCR to turn it on. When the emitter voltage decays to the valley point voltage, V_{v1} emitter current falls below I_V & UJT turns off.

$$V_p = \eta V_{BB} + V_D$$

$$\alpha_1 = \omega t = \omega RC \ln (1/1-\eta)$$

Where, ω is the angular frequency of UJT

oscillator. $V_{BB}.R_1/(R_{BB}+R_1+R_2) < V_{GT}$ (SCR

trigger voltage).

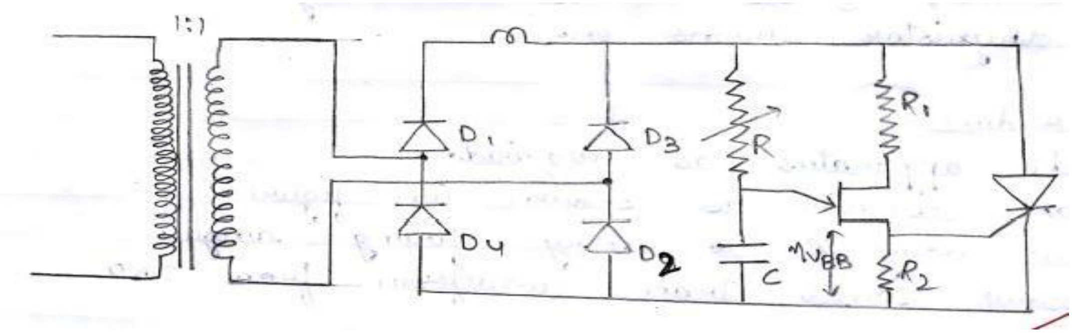


Figure1 Shows the UJT Firing Circuit

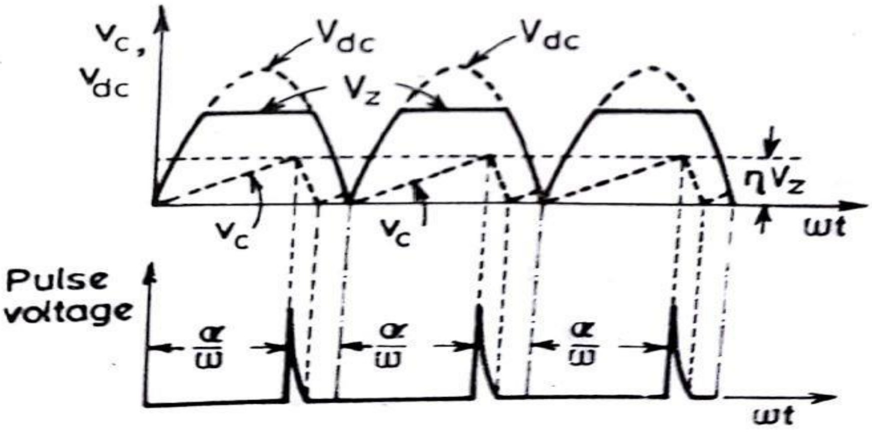


Figure2 Output Waveforms of UJT Firing Circuit

Procedure

1. Take the apparatus required.
2. Make the connections as shown in figure.
3. Now vary the value of R to get $\alpha = 0^0$ to $\alpha = 180^{0.}$
4. Observe the various waveforms on CRO and trace it.

Result:

The waveforms obtained are shown in figure.

Precaution:

1. Connections should be tight and neat.
2. Calibrate CRO carefully.

Experiment no.14

Aim: - To Study of the operation of Series Inverter

Theory: -

The DC to AC power converters is known as Inverters. An inverter is a circuit, which converts a DC power into an ac power at desired output voltage and frequency. The ac output voltage could be fixed or variable frequency. This conversion can be achieved either by controlled turn on and turn off devices (e.g. BJT's, MOSFETs, IGBTs, MCTs, SITs, GTOs, and SITHs) or by forced commutated thyristors, depending on applications. The output voltage waveforms of ideal inverter should be sinusoidal. The voltage waveforms of practical inverters are, however, non-sinusoidal and contain certain harmonics. Square wave or quasi-square wave voltages are acceptable for low and medium power applications, and for high power applications low, distorted, sinusoidal waveforms are required. The output frequency of the inverter is determined by the rate at which the semiconductor devices are switched on and off by the inverter control circuitry and consequently, an adjustable frequency ac output is readily provided.

In this type of inverters, the commutating elements, viz. L and C are connected in series with the load. This constitutes a series R-L-C resonant circuit. If the load is purely resistive, it only has resistance in the circuit. In case of load being inductive or capacitive in nature, its inductance or capacitance part is added to the commutating elements (being in series). This type of thyristor inverter produces an approximately sinusoidal waveform at a high output frequency, ranging from 200Hz to 100 KHz and is commonly used in relatively fixed output applications such as ultrasonic generators; induction heating etc., Due to the high switching frequency the size of commutating components is small. The circuit diagram of basic series inverter is shown in Figure 1. Two thyristors T1 and T2 are used to produce the two halves (positive and negative respectively) in the output. The commutating elements are connected in series with the load R to form the series R-L-C circuit. The values of L and C are chosen such that they form an under damped circuit. This is necessary to produce the required oscillations. This condition is fulfilled by selecting L and c such that

$$R^2 < 4L / C$$

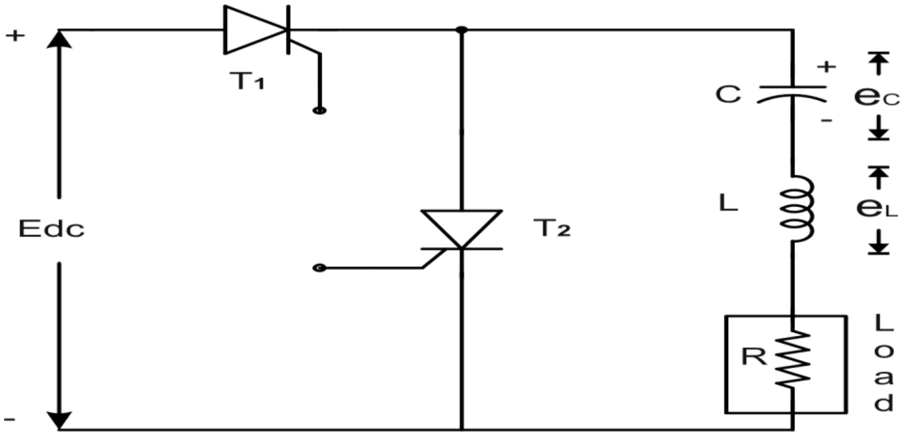


Figure 1 Basic Series Inverter

The operation of a basic series inverter circuit can be divided into three operating modes.

Mode 1: This mode begins when a DC voltage is applied to the circuit and thyristor T1 is triggered by giving external pulse to its gate. As soon as SCR T1 is triggered, it starts conducting and resulting in some current to flow through the R-L-C series circuit.

Capacitor C gets charged up to the voltage, Ec, with positive polarity on its left plate and negative polarity on its right plate. The load current is alternating in nature. This is due to the under damped circuit formed by the commutating elements. It starts building up in the positive half and goes gradually to its peak value, then starts returning and again becomes zero as shown in Figure 2. When the current reaches its peak-value the voltage across the capacitor is approximately the supply voltage E_{dc}. After this the current starts decreasing but the capacitor voltage still increases and finally the current becomes zero but the capacitor retains the highest voltage i.e. $(E_{dc} + E_c)$, where E_c is the initial voltage across the capacitor at the instant SCR T1 was turned-on. At P, SCR T1 is automatically turned off because the current flowing through it becomes zero.

Mode 2: During this mode, the load current remains at zero for a sufficient time (T_{off}). Therefore, both the thyristors T1 and T2 are off. During this period PQ capacitance voltage will be held constant.

Mode 3: Since the positive polarity of the capacitor C appears on the anode of SCR T2, it is in conducting mode and hence triggers immediately. At Q, SCR T2 is triggered. When SCR T2 starts conducting, capacitor C gets discharged through it. Thus, the current through the load flows in the opposite direction forming the negative alteration. This current builds up to the negative maximum and then decreases to zero at the point R.SCR T2 will then be turned off. Now the capacitor voltage reverses to some value depending upon the values of R, L and C. Again, after some time delay (T_{off}), SCR T1 is triggered and in the same fashion other cycles are produced. This is a chain of process giving rise to alternating output almost sinusoidal in nature and the DC source is intermittent in nature. Positive alteration of the ac output is drawn from the DC input source, whereas for the negative alteration the current is drawn from the capacitor.

It is necessary to maintain a time delay between the point when one SCR is turned off and the other SCR is triggered. If this is not done, both the SCRs will start conducting simultaneously resulting in a short circuit of the DC input source. This time delay (T_{off}) must be more than the turn off time of the SCRs. The output frequency is given by

$$F = 1/((T/2) + T_{off}) \text{ Hz Where}$$

T is the time period of oscillations and is given by

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

and T_{off} is the time-delay between turn-off of one SCR and turn-on of the other SCR. Thus, by changing the value of T_{off}, frequency can be changed without changing the commutating elements.

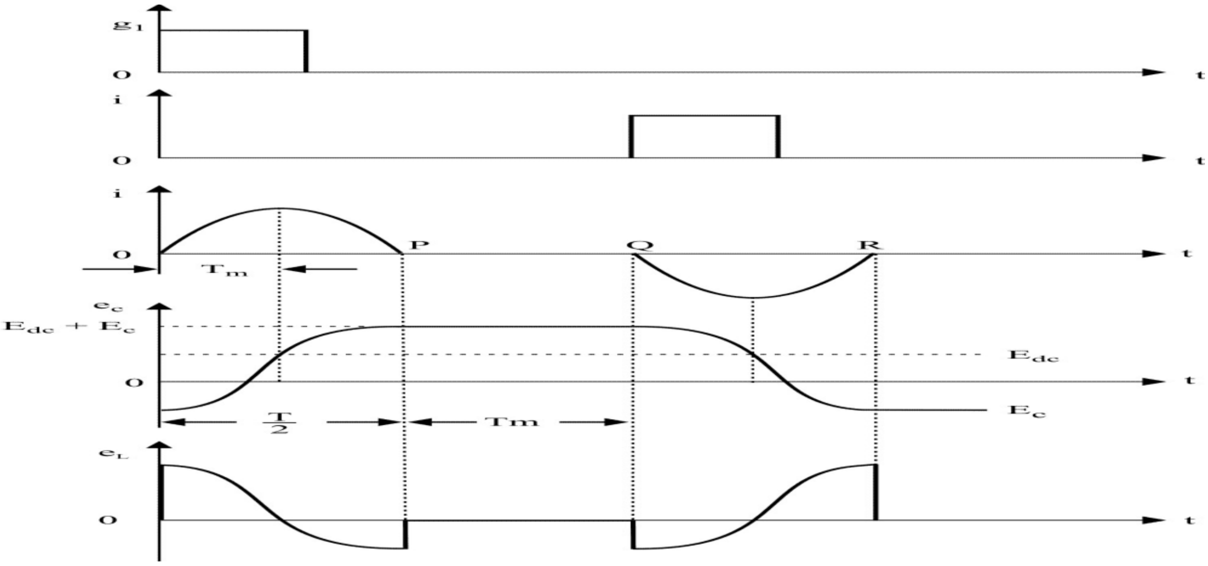


Figure2 Voltage and Current Waveforms

Circuit diagram:

The circuit diagram of basic series inverter is shown in the following Figure 3

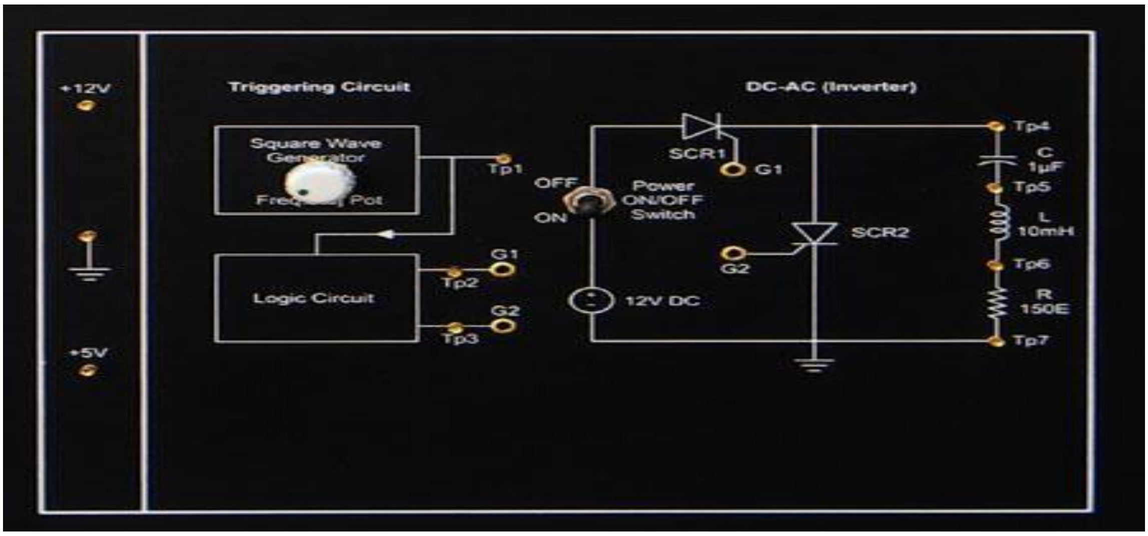


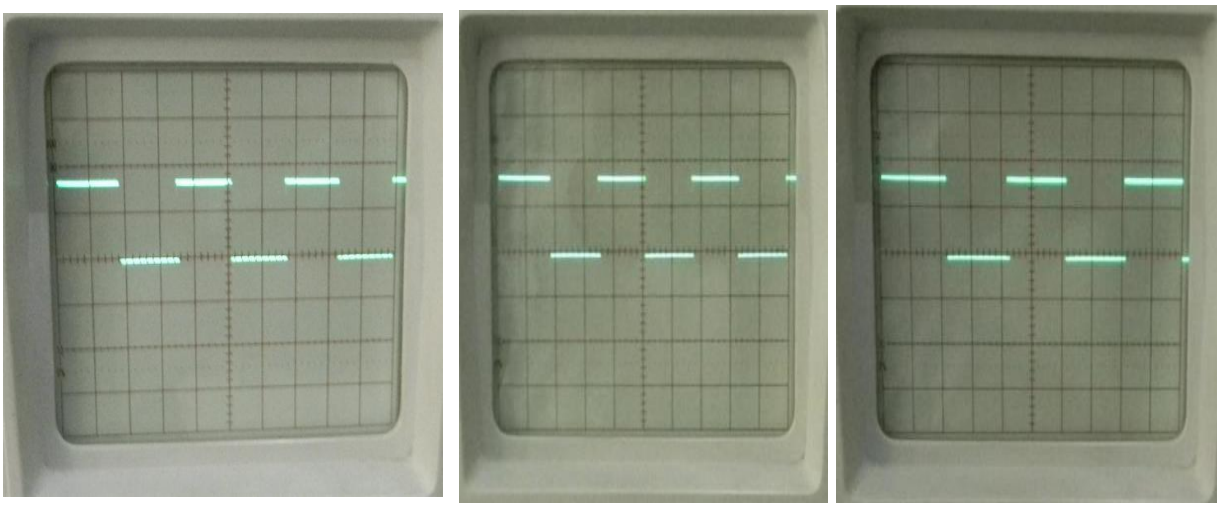
Figure 3 series inverter

Procedure:

Rotate the frequency adjusting potentiometer ‘P1’ in the counter clock wise direction.

1. Toggle switch (Power on\off switch) initially should be switch off
2. Switch ‘On’ the power supply. Set the frequency of the pulse by varying the potentiometer ‘P1’.

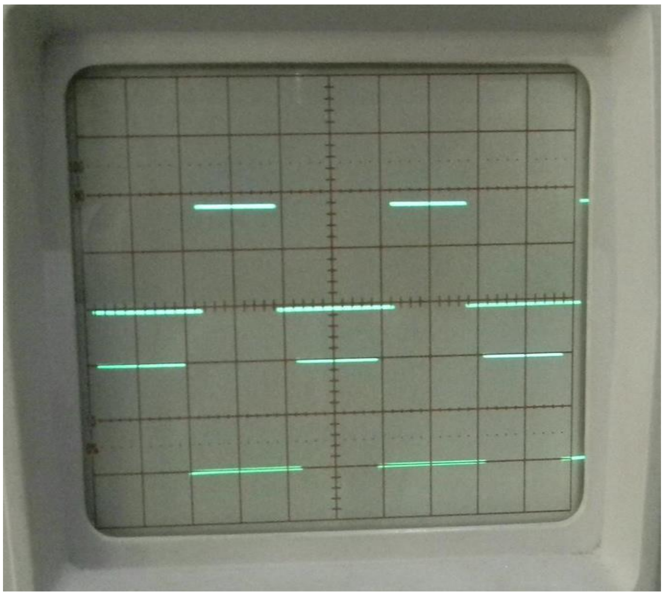
3. Observe the frequency and amplitude of pulse at point 1 w.r.t ground (Gnd), by varying frequency adjustment potentiometer frequency of square wave vary.



(a) (b) (c)

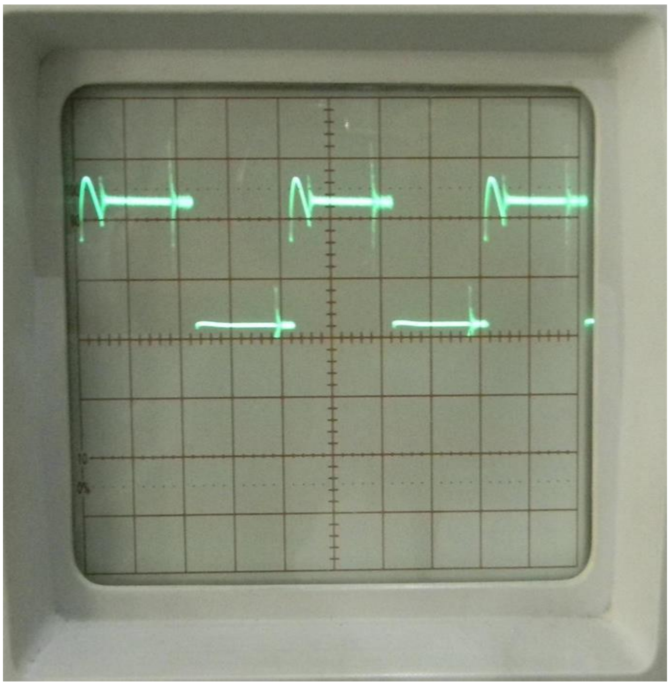
Waveform at Point 1 w.r.t ground (Gnd)

4. Observe the frequency and amplitude of the Pulse at test point ‘TP_1’ and ‘TP_2’.



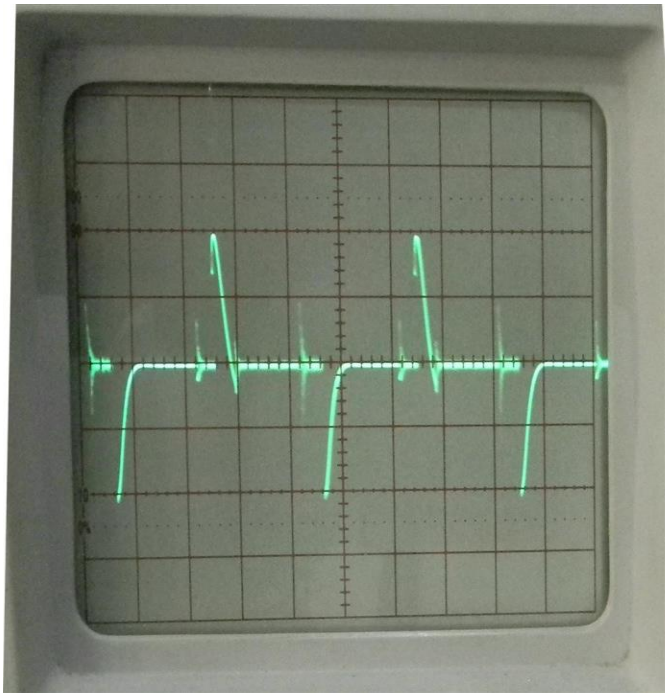
Waveform at G1 and G2 w.r.t. to ground (Gnd)

5. Now, connect the points ‘G1’ to gate of SCR1 at ‘G1’ and connect the point ‘G2’ to gate of SCR2 at ‘G2’ on the board.
6. Now, Switch ‘On’ the power.
7. Now switch on the SCR power (+12 V DC) by Toggle switch.
8. Observe waveform at capacitor terminal at point 4 w.r.t. ground.



Waveform at point 4 w.r.t. ground (Gnd)

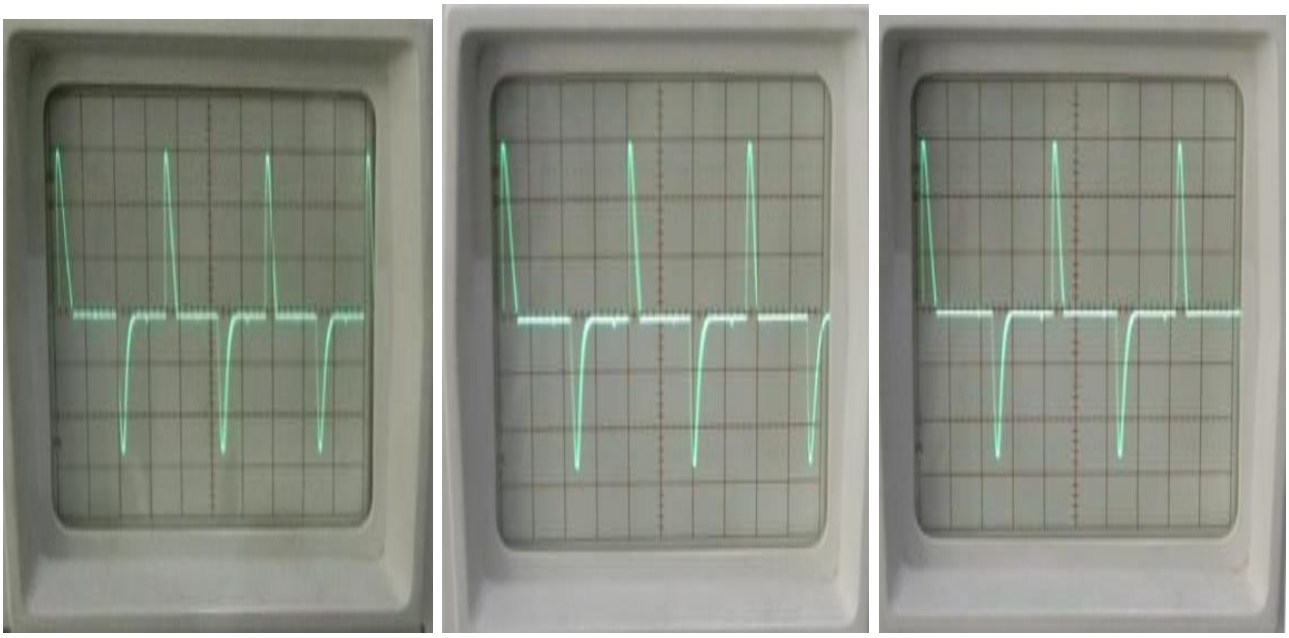
9. Observe waveform at inductor terminal at point 5 w.r.t. ground.



Waveform at point 5 w.r.t. ground (Gnd)

10. Observe the output waveform across the Load resistor and plot the waveform in the

11. graph sheet,by varying frequency adjustment potentiometer and observe output waveform .



(a) (b) (c)

Output waveform at load Resistor point 6 w.r.t.ground (Gnd)

Experiment No.15

Aim: - Operation of single phase to single phase midpoint Cycloconverter.

Theory

Cycloconverters: Convert single-phase or three-phase AC to variable magnitude and variable frequency AC. A cycloconverter or a cyclo-inverter converts an AC waveform, such as the mains supply, to another AC waveform of a lower or higher frequency. They are most commonly used in three phase applications - while single phase cycloconverter are possible, they are so impractical that they are never used in real systems. The amplitude and the frequency of input voltage to a cycloconverter tend to be fixed values, whereas both the amplitude and the frequency of output voltage of a cycloconverter tend to be variable. A circuit that converts an AC voltage to another AC voltage at the same frequency is known as an AC/AC chopper.

A typical application of a cycloconverter is for use in controlling the speed of an AC traction motor and starting of synchronous motor. Most of these cycloconverters have a high-power output - in the order of few megawatts - and silicon-controlled rectifiers (SCRs) are used in these circuits. By contrast, low cost, low-power cycloconverters for low-power AC motors are also in use, and many such circuits tend to use TRIACs in place of SCRs. Unlike an SCR which conducts in only one direction, a TRIAC is capable of conducting in either direction, but it is also a three-terminal device. It may be noted that the use of a cycloconverter is not as common as that of an inverter and a cyclo-inverter is rarely used. However, it is common in very high-power applications.

Traditionally, AC-AC conversion using semiconductor switches is done in two different ways: 1- in two stages (AC-DC and then DC-AC) as in DC link converters or 2- in one stage (AC-AC) cycloconverters (figure 1). Cycloconverters are used in high power applications driving induction and synchronous motors. They are usually phase-controlled and they traditionally use thyristors due to their ease of phase commutation.

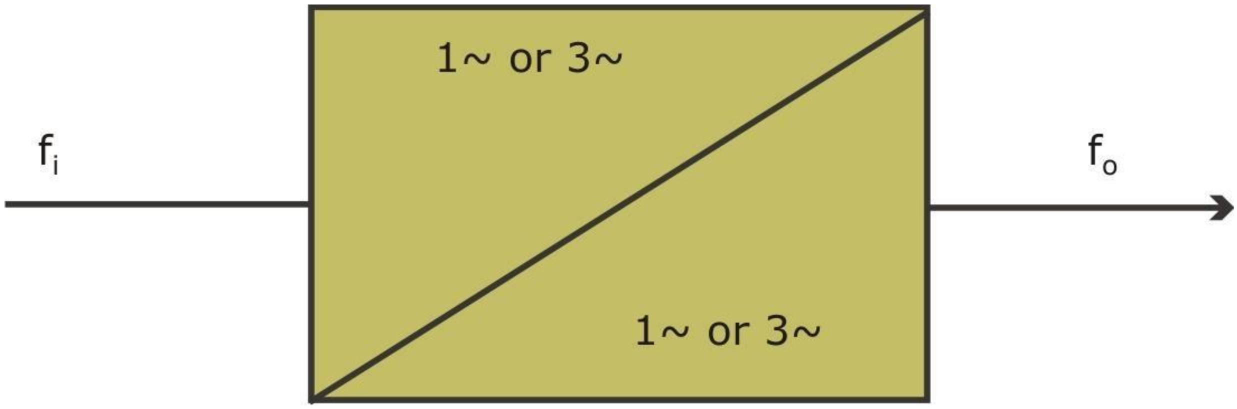


Figure1 Block diagram of a Cycloconverter

There are other newer forms of cycloconversion such as AC-AC matrix converters and high Frequency AC-AC (hf AC-AC) converters and these use self-controlled switches. These converters, however, are not popular yet.

Some applications of cycloconverters are:

- Cement mill drives
- Ship propulsion drives
- Rolling mill drives
- Scherbius drives
- Ore grinding mills
- Mine winders

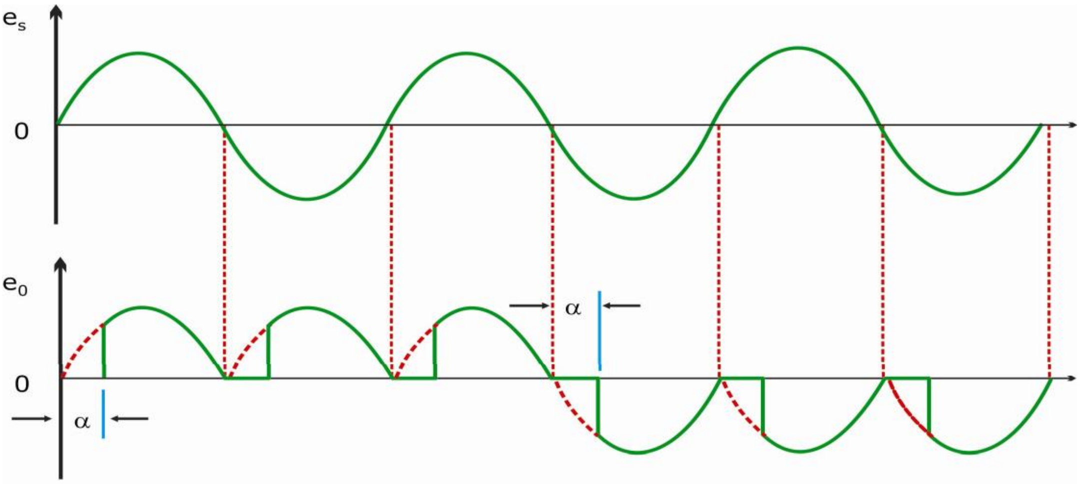
Single-phase to Single-phase Cycloconverter:

To understand the operation principles of cycloconverters shows the power circuit of a single-phase-to-single-phase Cycloconverter employing a centre tapped transformer. There are four thyristors namely, P1, N1, P2 and N2. Out of the four SCRs, SCRs P1 and P2 are responsible for generating the positive halves forming the positive group. The other two SCRs, N1 and N2, are responsible for producing the negative halves forming the negative group. This configuration is meant for generating 1/3 of the input frequency, i.e. this circuit generates a frequency of 16 ⅔ Hz at its output.

Depending upon the polarities of the points P and Q of the transformer, SCRs are gated. Natural commutation process is used for turning off the SCRs. This circuit configuration can be analyses for purely resistive load and R-L load.

1 with Resistive load

Let us analyze the configuration of figure 2 for a purely resistive load. During the positive half-cycle, when point 7 is positive and point 11 is negative, SCR P1 being in conducting mode is gated. The current flows through positive point 7, load and the negative point 11. In the negative half cycle, when point 11 is positive and point 7 is negative, SCR P1 is automatically turned-off and SCR P2 is triggered simultaneously. Path for the current flow in this condition will be from positive point 11, SCR P2, load and the negative point 9. Direction of flow of current through the load remains the same as in the positive half cycle. Next moment, again point 7 becomes positive and point 11 becomes negative, thus, SCR P2 is automatically line commutated. SCR P1 is gated simultaneously. The current path again becomes same as was in the previous case when SCR P1 was conducting. Thus, it is seen that the direction of flow of current through the load remains same in all the three-half cycle, or, in other words, the three-positive half – cycles are being obtained across the load to produce one combined positive half-cycle as output. Similarly, in the next negative half-cycle of the a.c. input, when point 11, is again positive and point 7 is negative, SCR P1 is automatically switched off. Now instead of SCR P2, SCR N1 is gated. The path for the current flow will be from point 11, load, SCR N1 and back to negative point 7. Thus, the direction of flow of current through the load is reversed. In the next positive half cycle, point 7 is positive and point 11 is negative. SCR N1 is automatically turned off. SCR N2 which is in the conducting mode is simultaneously turned on. The path for the current flow becomes from positive point 7, load, SCR N2 to the negative point 11. Thus, the direction of flow of current through the load remains the same. For the next negative half cycle of a.c. input when point 11 is positive and point 7 is negative, SCR N2 is automatically switched off and SCR N1 is gated. The current flow through the load again remains in the same direction. We can analyse it as producing one negative half-cycle at the output by combining three negatives halves of the input. In other words, it can be said that, three positive half cycles of the input a.c. have been combined to produce one cycle at the output, i.e. three positive half cycles at the output by the SCRs P1 and P2 whereas, three negative half cycle of the input a.c. are combined to produce one negative half cycle at the output by SCRs N1 and N2. This clearly indicates that the input frequency 50Hz is reduced to 1/3 rd (16 ⅔ Hz) at the output across the load.



Input and Output waveforms of a $16\frac{2}{3}$ Hz Cycloconverter

Figure 2 input and output of single phase cycloconverter.

With inductive load:

Let us now analyze the case of an R-L load. When point 7 is positive with respect to point 9 in figure, forward biased SCR P1 is triggered at ωt =α, positive output voltage appears across load and load current builds up. At ωt = π, supply and load voltages are zero. After ωt = π, SCR P1 is reverse biased. As load current is continuous, SCR P1 is not turned off at ωt = π. When SCR P2 is triggered in sequence at (π + α), a reverse voltage appears across SCR P1; it is therefore turned off by natural commutation. When SCR P1 is commutated, load current has built up to some value. With the turning on of SCR P2 at (π + α), output voltage is again positive as it was with SCR P1 on. As a consequence, load current builds up further. At (2π + α), when SCR P1 is again turned on, SCR P2 is naturally commutated and load current through SCR P1 builds up to beyond. At the end of four positive half –cycles of output voltage. When SCR N2 is now triggered after SCR P2, load is subjected to a negative voltage cycle and load current Io decreases from positive to negative. Now, SCR N2 is commutated and SCR N1 is gated at (5π + α). Load current becomes more negative. So, with inductive load, SCRs on in reverse biased condition for some time because voltage store in inductor.

Firing circuit:

The function of the control circuit is to deliver correctly timed, properly shaped, and firing pulses to the gates of the thyristors in the power converter so as to generate a voltage of the desired wave shape at the output terminals of a cycloconverter. The control circuit can be arranged in eight functional blocks:

1. Synchronizing circuit.
2. Zero cross detectors.
3. Ramp generator.
4. Ramp comparator.
5. Group selector logic circuit.
6. Pulse transformer.
7. P converter gate signal.
8. N converter gate signal.

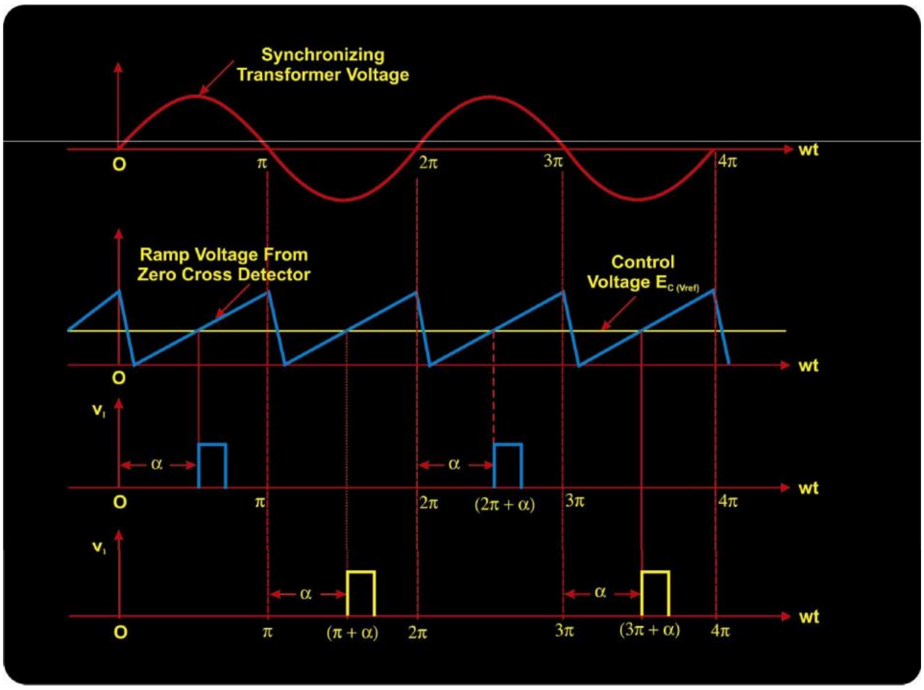


Figure 3

Synchronize signal:

The main function of the synchronizing circuit is to derive low voltage signals to the control circuit which operates at low voltages. These low voltage signals must be synchronized to the voltages supplied to the main power circuit. Step down transformers may be used for this purpose with filter circuit to avoid waveform distortion if any.

Zero cross detector:

The main function of the zero cross detector is to convert synchronize signal to square wave signal.

Ramp generator:

The main function of this section is to generate the ramp signal using the zero cross detector output.

Ramp comparator:

The main function of this section is to compare the ramp signal with the reference voltage signal and generate the gate signal with variable angle.

Group selector logic circuit:

The main function of this section is to select the group of the gate signal for P and N converters.

Pulse transformer:

The pulse transformer section provides isolation between firing circuit and the cycloconverter circuit.

P & N converter gate signal:

These sections provide the gate signal for P & N converter thyristors.

Circuit diagram:

The basic firing circuit block diagram is shown in the figure 4 given below:

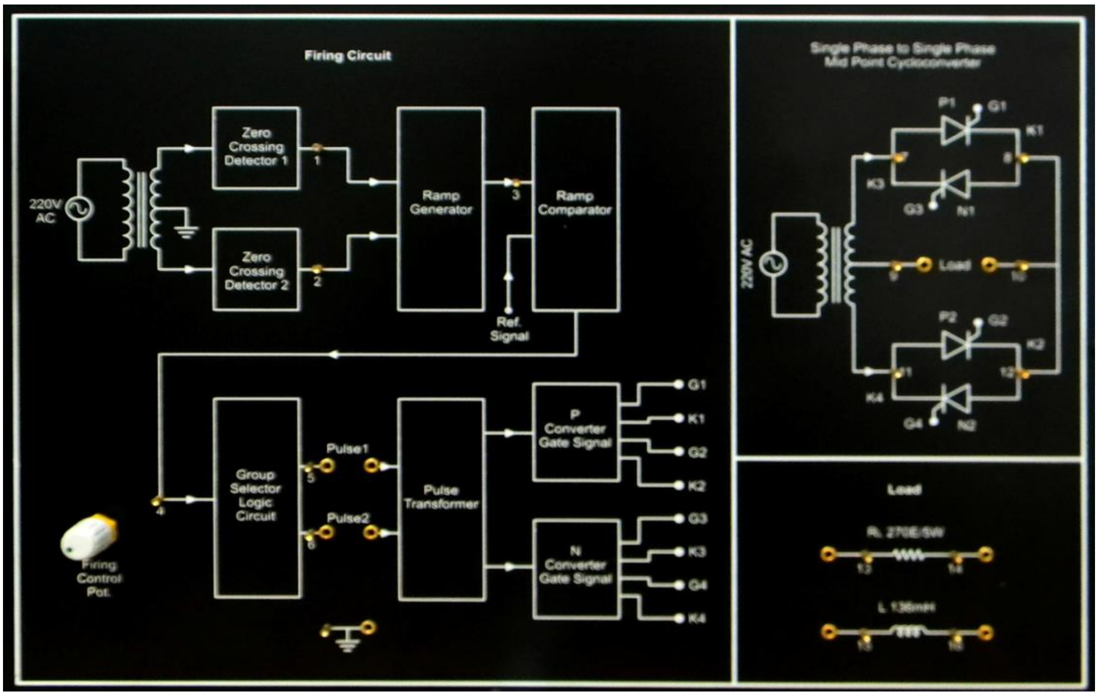


Figure4 basic firing circuit block diagram of Cycloconverter

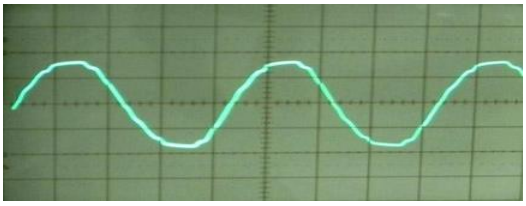
Procedure:

- **Make sure that there should not be any connections by patch cord on the board.**

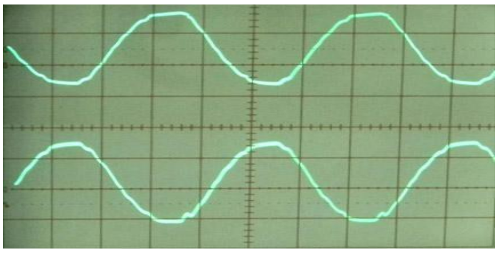
1. Rotate the firing control potentiometer in full counter clockwise direction.
2. Connect BNC to Test probe cable at CH1 of oscilloscope and switch on the oscilloscope.
3. Switch ‘On’ the power supply.
4. Observe the sine wave AC signal between point 7 and 9 point at single phase cycloconverter mid point configuration section and note reading, amplitude of sine wave and time period.

Sinewave waveform at point 7 w.r.t. 9

5. Observe the sine wave AC signal between point 11 and 9 point at single phase cycloconverter mid point configuration section and note reading, amplitude of sine wave and time period.

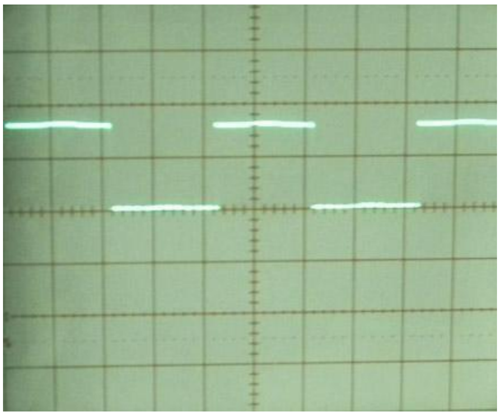


6. Observe the sinewave signal at both points 7 and 11 w.r.t. point 9 at CH1 and CH2 channel of oscilloscope.



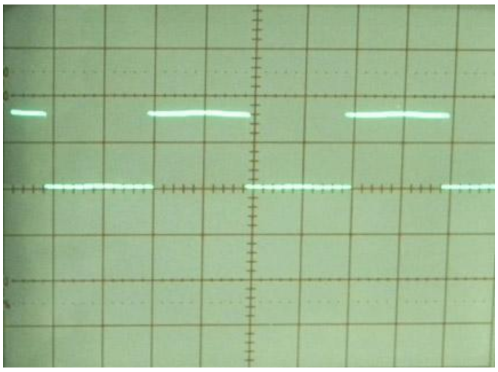
Sinewave waveform at point 7 and 11 w.r.t.

7. Observe the output of Zero crossing detector 1 at point 1 with respect to ground square wave obtained and note readings, amplitude of square wave and time period.



Output of Zero crossing detector 1 at point 1 w.r.t. ground

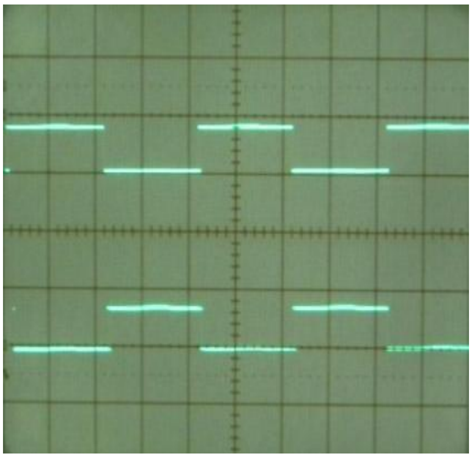
8. Observe the output of Zero crossing detector 2 at point 2 with respect to ground



square wave obtained and note reading, amplitude of square wave and time period.

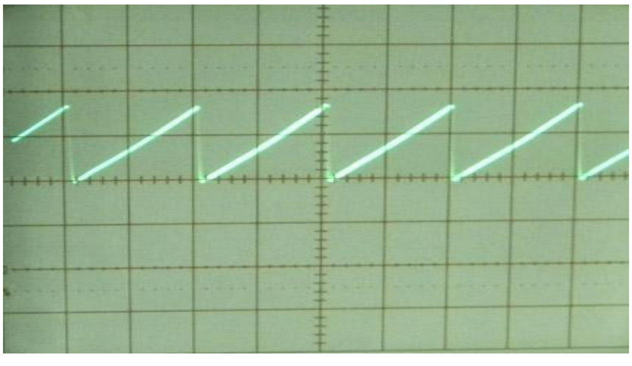
Output of Zero crossing detector 2 at point 2 w.r.t. ground

9. Observe the output waveform of both Zero crossing detectors between point 1 and point 2 with respect to ground at CH1 and CH2 channel of oscilloscope.



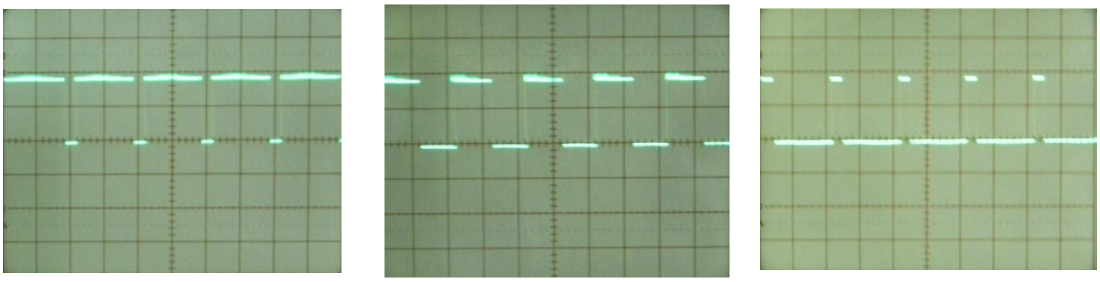
Output waveform at Zero crossing detector 1 and 2 w.r.t. ground

10 Observe the output waveform of ramp generator at point 3 with respect to ground triangular wave (ramp waveform) obtained and note readings, amplitude of ramp waveform and time period.



Ramp waveform at point 3 w.r.t. ground

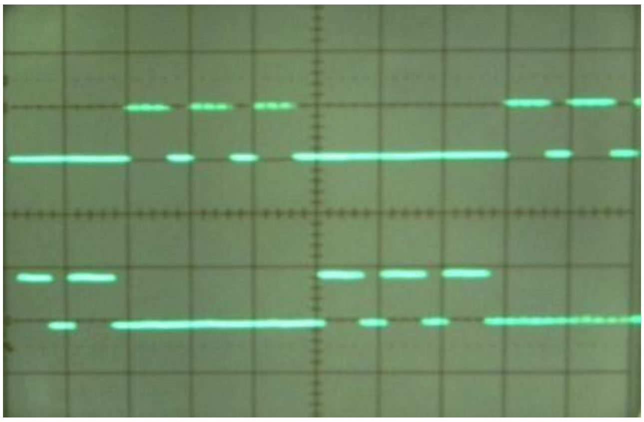
11 Observe the output waveform of ramp comparator at point 4 with respect to ground



12 square wave waveform obtained and note readings, amplitude of square wave and time period.

Output of Ramp comparator at point 4 w.r.t. ground

13 Observe the output of Group selector logic circuit at point 5 and point 6 with respect to ground pulse train square wave waveform obtained and note readings, amplitude of square wave and time period.



Output of Group selector logic circuit at point 5 and 6 w.r.t. ground

10 Connect point 5 and point 6 to input of pulse transformer from Group selector logic circuit at their respective terminal by 2mm patch cord.

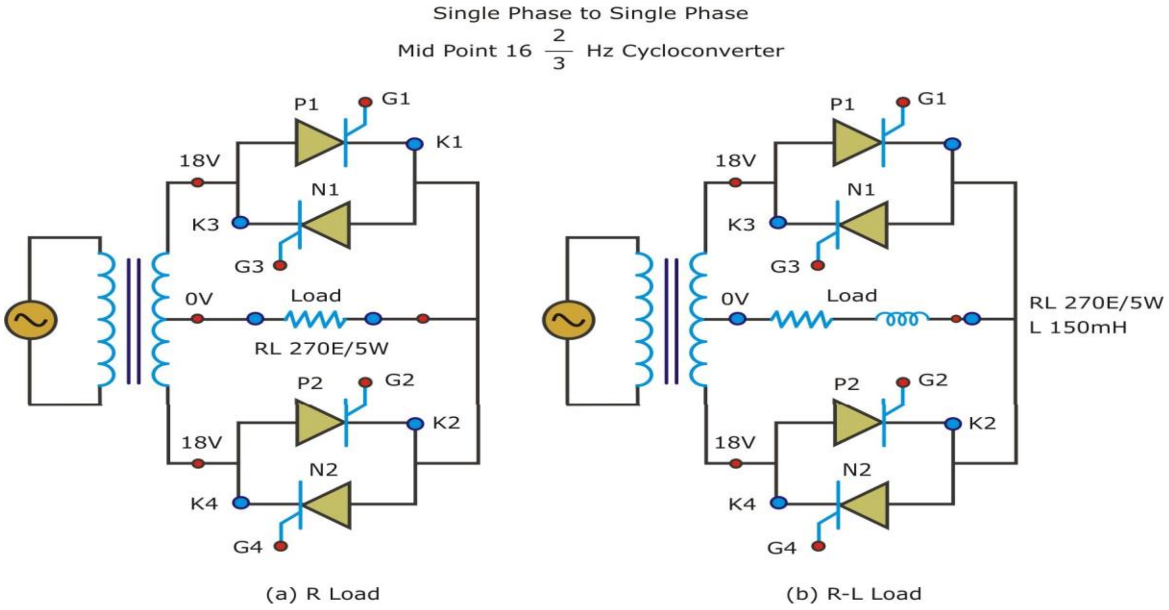
Conclusion: By varying the firing angle control potentiometer of cycloconverter firing circuit, pulse width of group selector logic circuit waveforms changes simultaneously.

Objective:

Study of single phase cycloconverter (mid-point configuration) with resistive and inductive load

Circuit diagram:

The basic circuit diagram is shown in the figure 5 given below:



(a) R Load

(b) R-L Load

Figure 5 single phase cycloconverter (mid point configuration) with resistive and inductive load

Procedure:

Make sure that there should not be any connections by patch cord on the board.

1- Rotate the firing angle control potentiometer in full clockwise direction.

2- Connect point 5 and point 6 to input of pulse transformer from Group selector logic circuit at their respective terminal by 2mm patch cord.

3- Connect one terminal of R load (point 13) to point 9 terminals at single phase cycloconverter mid-point configuration load terminal.

4- Connect another terminal of R load (point 14) to point 10 terminals at single phase cycloconverter midpoint configuration load terminal.

5- Connect BNC to Test probe cable at CH1 of oscilloscope and switch on the oscilloscope.

6- Verify the connection before switch on the power.

7- Switch on the power.

8- Connect oscilloscope and multimeter across the load.

9- Vary the firing angle control potentiometer and set on 0º, 18º, 36º, 54º, 72º, 90º, 108º, 126º and 162º firing angles.

10- Observe the output waveforms and note readings of voltage across load on different firing angle.

11- Now, switch off the power and remove the R load connection.

12- Connect one terminal of R load (point 13) to point 9 terminals at single phase cycloconverter midpoint configuration load terminal.

13- Connect another terminal of R load (point 14) to one terminal of inductor L (point 15).

14- Connect other terminal of inductor L (point 16) to point 10 terminals at single phase cycloconverter mid-point configuration load terminal.

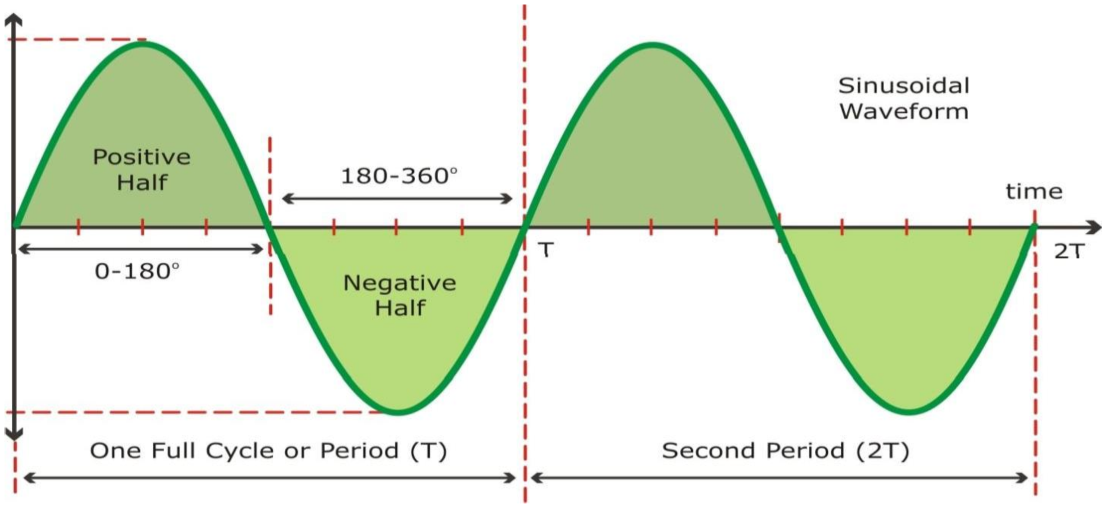
15- Verify the connection before switch on the power.

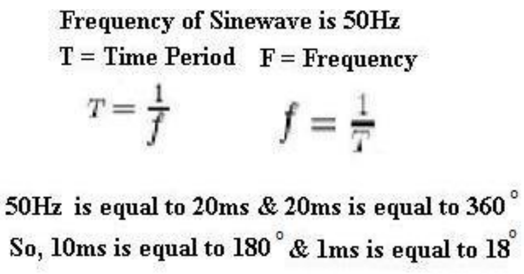
16- Switch on the power.

17- Connect oscilloscope and multimeter across the load.

18- Vary the firing angle control potentiometer at different firing angles and observe the output waveforms and note readings of voltage

Firing Angle Calculation:





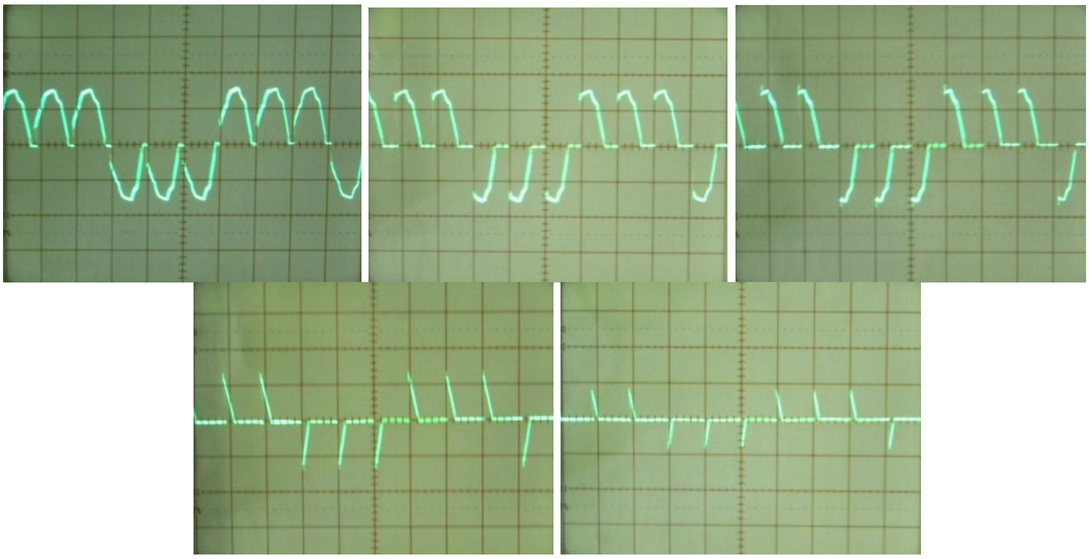
Frequency of Sinewave is 50Hz

T = Time Period F = Frequency

$$T = \frac{1}{f} \qquad f = \frac{1}{T}$$

50Hz is equal to 20ms & 20ms is equal to 360°

So, 10ms is equal to 180° & 1ms is equal to 18°


Output waveform at Load terminal