NRI INSTITUTE OF INFORMATION SCIENCE AND TECHNOLOGY ,BHOPAL

LAB MANNUAL
Electrical Drive

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

NRI INSTITUTE OF INFORMATION SCIENCE AND TECHNOLOGY , BHOPAL

DEPARTMENT OF ELECTRICAL AND ELECTRONICS

LIST OF EXPERIMENT

1. To study the application of TRIAC for speed control of AC motor with DIAC firing circuit
2. Study of Three Phase Half Wave AC Voltage Controller.
3. Study of Step down Chopper with RL load.
4. Study of Step down Chopper with inductive (motor) load.
5. To study of the firing circuit of single-phase Cyclo converter
6. To study the single phase cyclo converter with resistive and inductive load
7. To simulate a TRIAC based voltage controller for speed control of AC motor
8. To simulate a Three Phase Half Wave AC Voltage Controller.
9. To simulate a Step down Chopper with inductive (motor) load.

EXPERIMENT NO 1

Objective

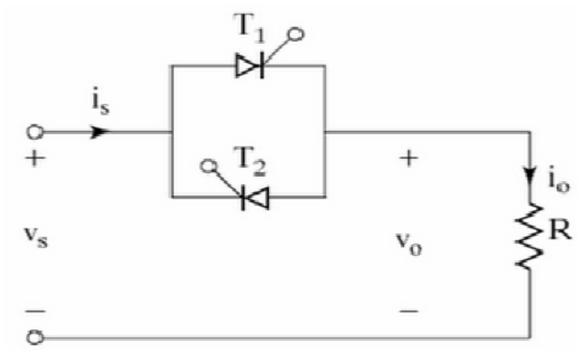
To study the application of TRIAC for speed control of AC motor with DIAC firing circuit.

Equipment's needed:

1. Power Electronics Board **ST2715**
2. Multi-meter
3. CRO probe BNC-BNC.
4. AC motor

Theory:

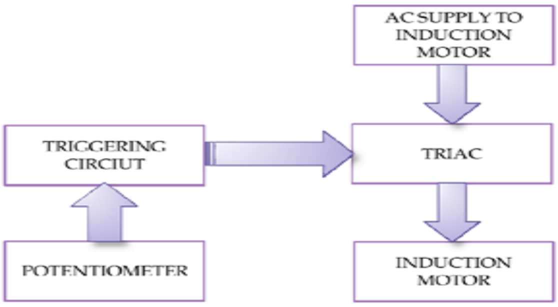
For the speed control of single phase induction motor, method is called as "STATOR VOLTAGE CONTROL OF SINGLE PHASE INDUCTION MOTOR." In speed control by stator voltage control, the stator voltage is reduced from base value of rated speed to a lower value. As torque is proportional to voltage square the torque speed characteristics goes down proportional to voltage square.With shifting of torque characteristics the operating point will also move to givea reduce motor speed. For a well-designed machine with low value of slip the reduction in speed with reduced voltage is very small. Therefore if a large drop in speed I required with reduction in stator voltage, the motor is specially designed with high full load slip.



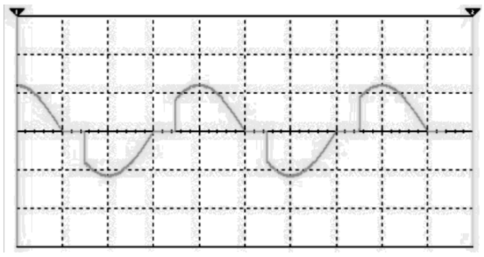
Using thyristor the control of stator voltage can be obtained by using AC voltage controller where reverse-parallel connected thyristors are used in each phase between supply and motor. The stator voltage reduced from its base value by increase of firing angle of thyristor from 0 to 180.

For speed control of AC motor that utilizes the current-regulating property of a TRIAC. Prior to being triggered, the TRIAC provides the barrier in the circuit**,** preventing current flow through AC source through motor. During this time voltage across the capacitor within the circuit builds up until it exceeds the break over voltage of a TRIAC.

Once the break over voltage is exceeded, the DIAC fires the TRIAC into a conduction state and current flows through the motor. The amount of voltage seen over the motor is determined by the firing angle of the TRIAC which is set by the RC time constant of the circuit. This process then repeats every half cycle. Finally, it can be seen that this switching introduces high order harmonics into the system.

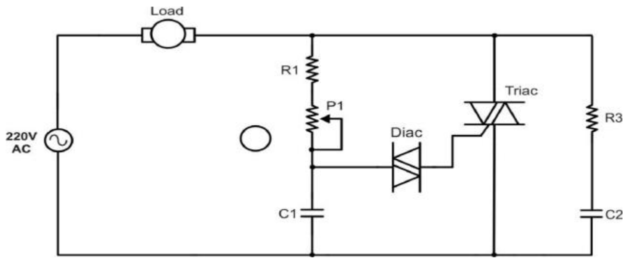


A triac has a complex multiple-junction structure, but functionally, it is an integration of a pair of phase-controlled thyristors connected in inverse-parallel on the same chip. Figure 1.8(a) shows the triac symbol and (b) shows its volt-ampere characteristics. The three-terminal device can be triggered into conduction in both positive and negative half-cycles of supply voltage by applying gate trigger pulses. In I+ mode, the terminal T2 is positive and the device is switched on by positive gate current pulse. In III- mode, the terminal T1 is positive and it is switched on by negative gate current pulse.



A triac is more economical than a pair of thyristors in anti-parallel and its control is simpler, but its integrated construction has some disadvantages. The gate current sensitivity of a triac is poorer and the turn-off time is longer due to the minority carrier storage effect. For the same reason, the reapplied dv/dt rating is lower, thus making it difficult to use with inductive load. A well-designed RC snubber is essential for a triac circuit. Triacs are used in light dimming, heating control, appliance-type motor drives, and solid-state relays with typically 50/60 Hz supply frequency.

Construction and Working of AC motor using DIAC-TRIAC:

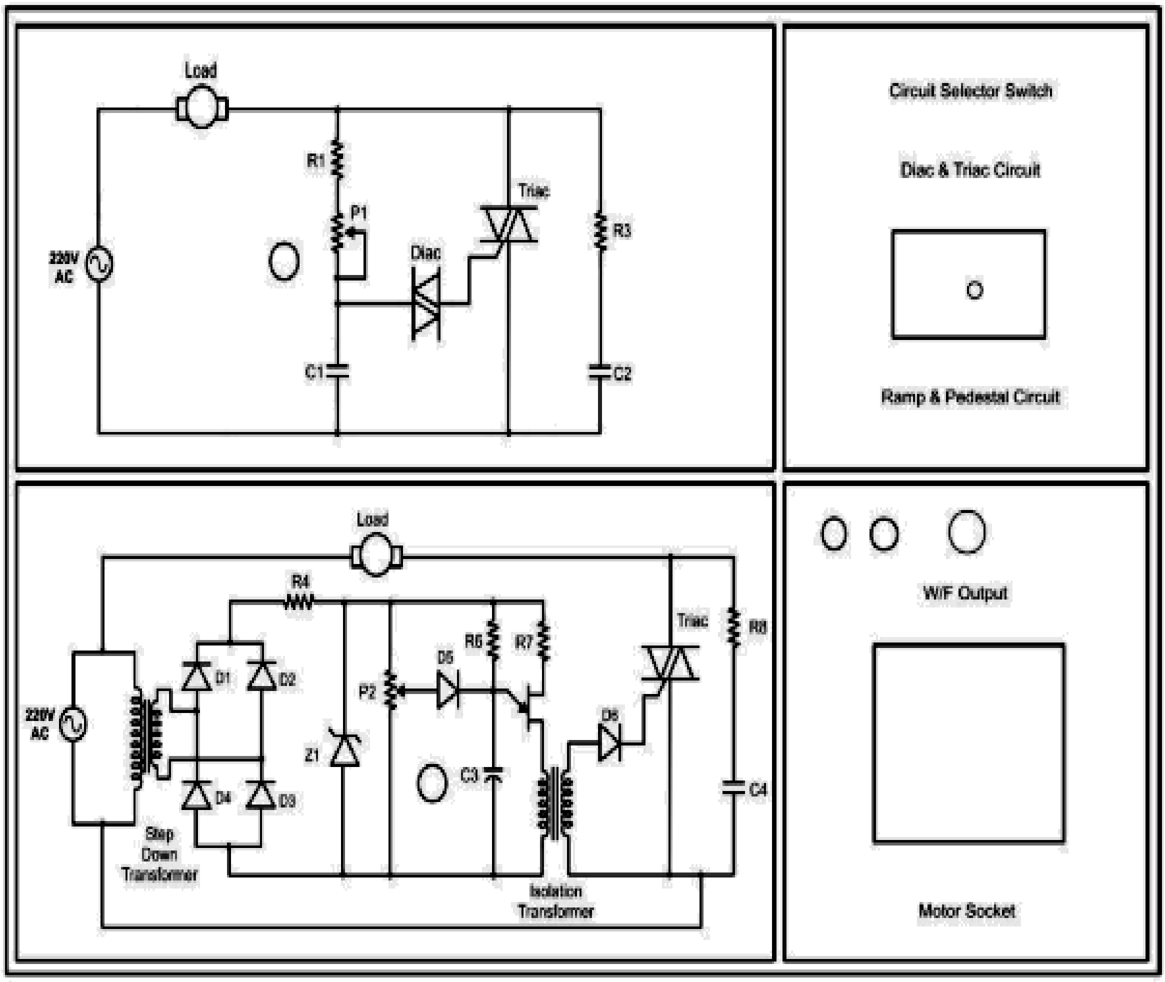


Above figure shows the construction of speed control of AC motor using DIACTRIAC. The circuit is designed in such that only a portion of the sine wave passes through the motor. To accomplish this, a bilateral DIAC is used to control the current flow to the TRIAC. Initially the capacitor is discharge, and during each half cycle of the input the capacitor is charge to its break over voltage. When this occurs the DIAC begins to conduct and discharges the capacitor through the TRIAC gate.

The Speed of motor is controlled by varying the firing angle for the circuit. This is accomplished by controlling the rate at which the capacitor charges, and is determined by the RC time constant of the series potentiometer and capacitor. As shown in the figure the resistance R1 plus value of the potentiometer times the capacitor C1. So to control the speed of motor, one simply controls the value of resistance on the potentiometer, which determines the rate at which the capacitor reaches the break over voltage. Smaller the RC time constant, quicker the capacitor reaches to break over voltage and thus more part of sine wave that is applied over the motor.

Circuit diagram:

The circuit diagram for speed control of AC motor with DIAC firing circuit is as follows:



Procedure:

CRO Settings

- Time (X) Axis: 5ms/div
- Voltage (Y) Axis: 20V/div
- Probe: 1:10 CRO Probe is suitable one.

Initial Settings

- Ensure the CRO is working properly with probe checking and proper ground line axis.
- Ensure the 230V Power Supply is in proper with Tester.

Experimental Procedure:

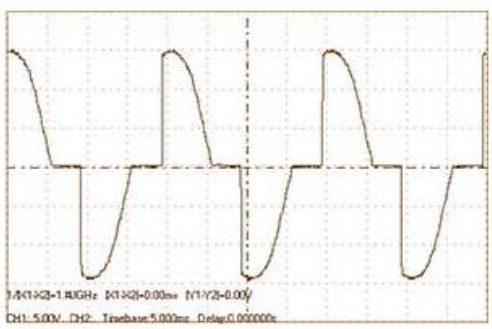
1. Apply the circuit selection switch towards the DIAC-TRIAC circuit.
2. Rotate the intensity control pot P1 to fully anti clockwise direction.
3. Connect Multi-meter between motor loads to measure voltage across the load.
4. Switch ON the power supply.
5. Set the firing angle using intensity control pot at 30˚, 60˚, 90˚, 120˚, 150˚ and observe the waveform across load on oscilloscope(1ms = 18˚).
6. Note the readings of output voltage across the load at different firing angles. Since the output voltage VO is attenuated by X100 attenuator therefore total output voltage Vout across the load is equal to VOUT=VO X 100.

Observation table:

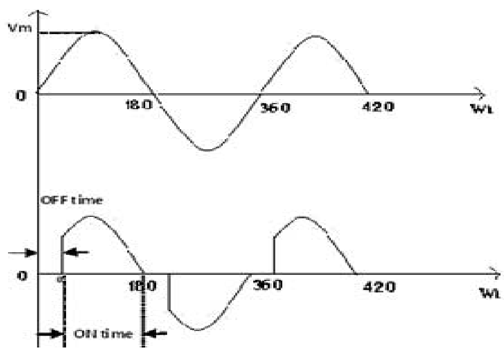
S.NO	OFF Time(ms)	ON Time(ms)	Alpha(α in Degree)	Vo(Volts)
1				
2				
3				
4				
5				

Model Waveform

Across Load



Input voltage and Load voltage



Calculations:

1. Total Time Period

$$T = 2x(ontime + off\ time)$$
$$if\ F = 50\ Hz,$$
$$T = 20ms$$
$$360\text{degree} = 20ms$$
$$1ms = 360/20$$
$$= 18\ \text{degree}$$
$$0.1ms = 1.8\ \text{degree}$$

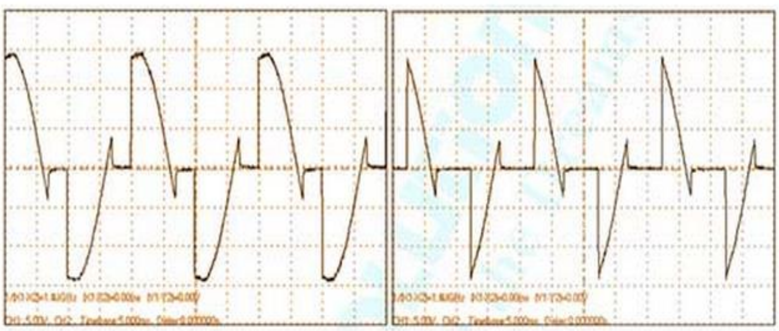
$$when\ \ off\ time\ is\ 4ms$$
$$alpha\ \ \alpha = (4/0.1)*1.8$$
$$= 72\ \text{degree}$$

2. Output Voltage

$$Vo = Vs\ x\ D$$
$$D = on\ time/(off\ time + ontime)$$

$$if,\ \ Vs = 110V,\ off\ time = 4ms,\ on\ time = 6ms;$$
$$D = \frac{12}{20}$$
$$Vo = 110\ x\ 0.6$$
$$= 66\ Volts.$$

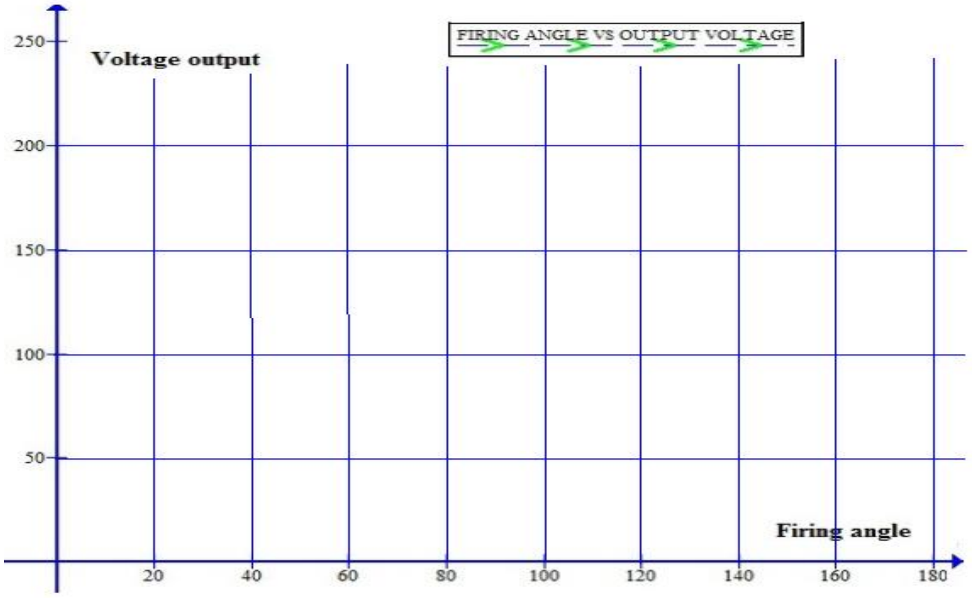
Sample Waveform:



Result:

Speed control of 1-Ø induction motor is performed using triac, observations are noted and a graph between firing angle & output voltage is plotted.

Graph:



Precautions:

1. Do not operate the instrument if you suspect any damage within.
2. Use proper Mains cord : Use only the mains cord designed for this instrument.
3. Ground the Instrument : This instrument is grounded through the protective earth conductor of the mains cord. To avoid electric shock the grounding conductor must be connected to the earth ground. Before making connections to the input terminals, ensure that the instrument is properly grounded.
4. Observe Terminal Ratings : To avoid fire or shock hazards, observe all ratings and marks on the instrument.
5. Use only the proper Fuse : Use the fuse type and rating specified for this instrument.
6. Do not operate in wet / damp conditions.
7. Do not operate in an explosive atmosphere.
8. Keep the product dust free, clean and dry.

EXPERIMENT 2

Objective:

Study of Three Phase Half Wave AC Voltage Controller.

Equipment's needed:

1. PowerModule PM07
2. Three Phase Firing Circuit
3. Oscilloscope With Power Scope
4. 4mm and 2mm patch cords

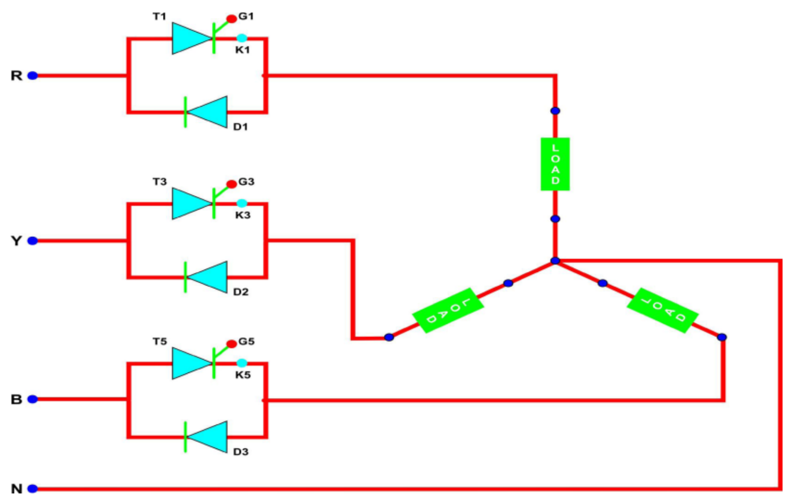
Theory:

Three Phase AC Voltage Controller: Three phases AC voltage controller are thyristorized based controller which convert fixed three phase alternating voltage directly to variable alternating voltage without a change in the frequency. Three phase AC voltage controller are two types:

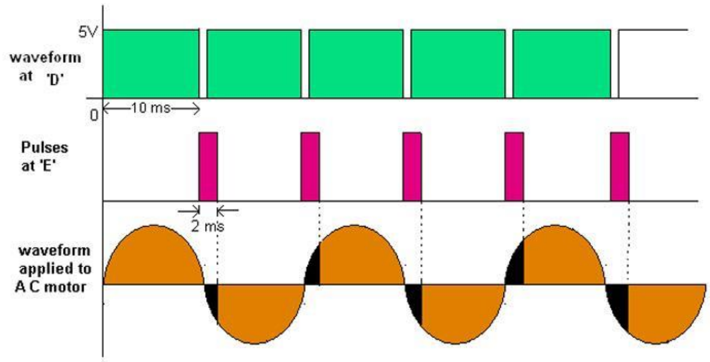
(a) Three phase half wave AC voltage controller

(b) Three phase full wave AC voltage controller

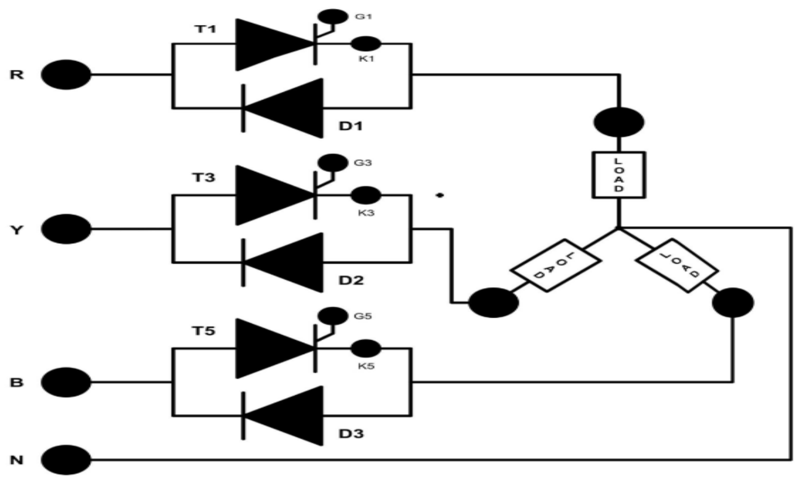
Three Phase Half Wave AC Voltage Controller: Three phase half wave AC voltage controller configuration is consists of three SCR in antiparallel with three diodes.The power flow to the load is controlled by delaying the firing angle of SCRs.Three phase half wave AC voltage conroller configuration is shown in figure with a star load connected.



In three phase half wave AC voltage controller control the positive half cycle of input voltage. Since the power flow is controlled during the positive half cycle of input voltage this type of controller is also known as a unidirectional controller or three phases half wave AC voltage controller. In three phase half wave AC voltage controller the current flow to the load is controlled by SCR, T1, T3, T5 and diode D1, D2, D3 provide the return current path the firing sequence of SCR's is T1, T3, T5 we may recall that a SCR will conduct if it's anode voltage is higher than that of its cathode and it is triggered. Once a thyristor starts conducting, it would be turned off only when its current falls to zero.



Circuit Diagram:



Procedure:

CRO Settings

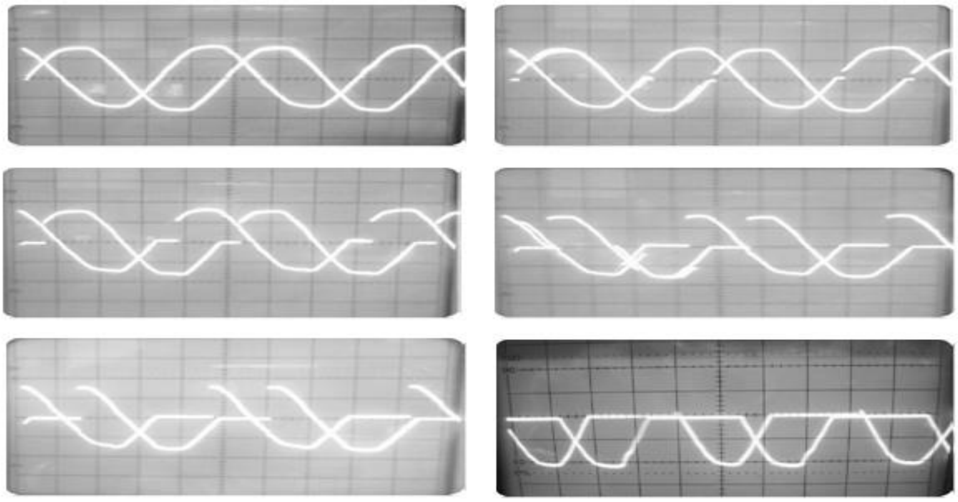
- Time (X) Axis: 5ms/div
- Voltage (Y) Axis: 20V/div
- Probe: 1:10 CRO Probe is suitable one.

Initial Settings

- Ensure CRO is working properly, check probe and proper ground line axis.
- Ensure the 230V Power Supply is in proper with Tester.

Experimental Procedure:

1. Connect low voltage DC supply (+12V and ground) and low voltage three phase AC supply (R, Y, B and N) at the indicated position at three phase firing circuit from external source.
2. Connect the gate pulse G1 at gate (G) of SCR T1 and connect K1 at cathode of SCR T1 from three phase firing circuit to PM07 three phase half wave AC voltage controller at indicated position.
3. Connect the gate pulse G3 at gate (G) of SCR T3 and connect K3 at cathode of SCR T3 from three phase firing circuit to PM07 three phase half wave AC voltage controllers at indicated position.
4. Connect the gate pulse G5 at gate (G) of SCR T5 and connect K5 at cathode of SCR T5 from three phase firing circuit to PM07 three phase half wave AC voltage controllers at indicated position.
5. Connect R phase, Y phase, B phase and N (neutral) from three phase supply to PM07 three phase half wave AC voltage controller at (three phase AC supply terminal) their indicated position.
6. Connect star load configuration to PM07 three phase half wave AC voltage controller at their indicated position and connect common terminal of three phase star load configuration to neutral terminal of three phase supply.
7. Verify the connection before switch on the three phase supply.
8. Connect BNC to BNC cable at CH1 of oscilloscope to output of power scope A.
9. Connect BNC to BNC cable at CH2 of oscilloscope to output of power scope B.
10. Switch of ATT of A is x100 position and switch of coupling of A is DC position.
11. Switch of ATT of B is x100 position and switch of coupling of B is DC position.
12. Connect input of power scope A to star load configuration at PM07 at indicated position.
13. Connect input of power scope B to star load configuration at PM07 at indicated position
14. We can observe the output of three phase half wave AC voltage controller on oscilloscope by connecting CH1 & CH2 between R&Y or Y&B or B&R phase waveform w.r.t neutral (N).
15. Switch on the three phase supply and three phase low voltage power supply and observe the output waveform of three phase half wave AC voltage controller on the oscilloscope.
16. Vary the firing angle control pot from three phase firing circuit and observe variation in waveform with change in firing angle control pot.
17. Connect AC voltmeter at the star load configuration and measure the output AC voltage of three phase half wave AC voltage controller.



Output Waveform

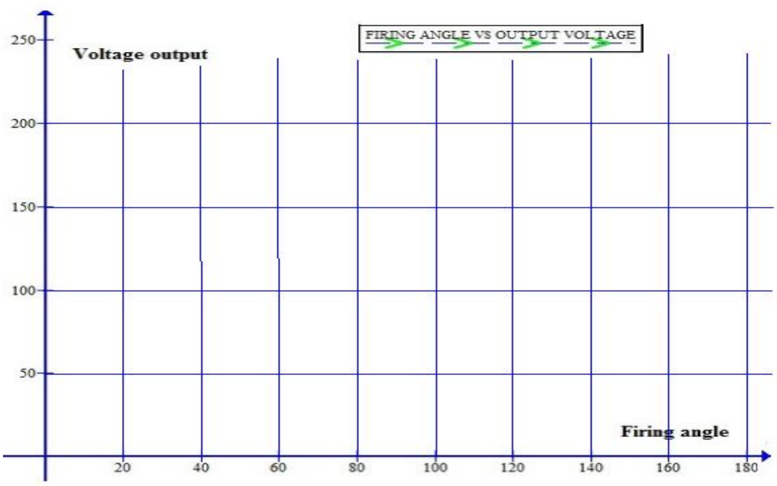
Observation Table

S.NO	OFF Time(ms)	ON Time(ms)	Alpha(α in Degree)	Vo(Volts)
1				
2				
3				
4				
5				

Result:

By varying the firing angle control potentiometer of three phase firing circuit, output voltage across the load terminal, their waveform changes simultaneously.

Graph:



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7. Do not operate in an explosive atmosphere.
8. Keep the product dust free, clean and dry.

EXPERIMENT 3

Objective:

Study of Step down Chopper with RL load.

Equipment's needed:

1. Oscilloscope: 20 MHz; ST201/ Caddo 802 or equivalent

2. Multimeter: Scientech 4011 Handheld

3. ST2722 Step Down Chopper

4. Patch Cords & Instruction manual

5. BNC to Test Probe

Theory:

Overview of choppers:

Modern electronic systems require high-quality, small, lightweight, reliable, and efficient power supplies. Linear power regulators, whose principle of operation is based on a voltage or current divider, are inefficient. This is because they are limited to output voltages smaller than the input voltage, and also their power density is low because they require low frequency (50 or 60 Hz) line transformers and filters.

The higher the operating frequency, the smaller and lighter the transformers, filter inductors, and capacitors. In addition, the dynamic characteristics of converters improve with increasing operating frequencies. High-frequency electronic power processors are used in dc-dc power conversion. The functions of dc-dc converters are:

- to convert a dc input voltage **VS** into a dc output voltage **VO**;

- to regulate the dc output voltage against load and line variations;

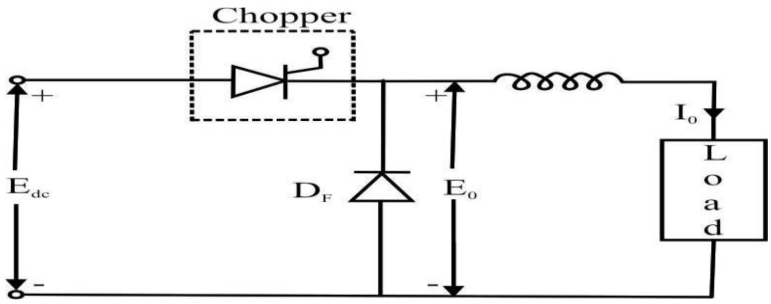
- to reduce the ac voltage ripple on the dc output voltage below required level;

- to provide isolation between input source and load;

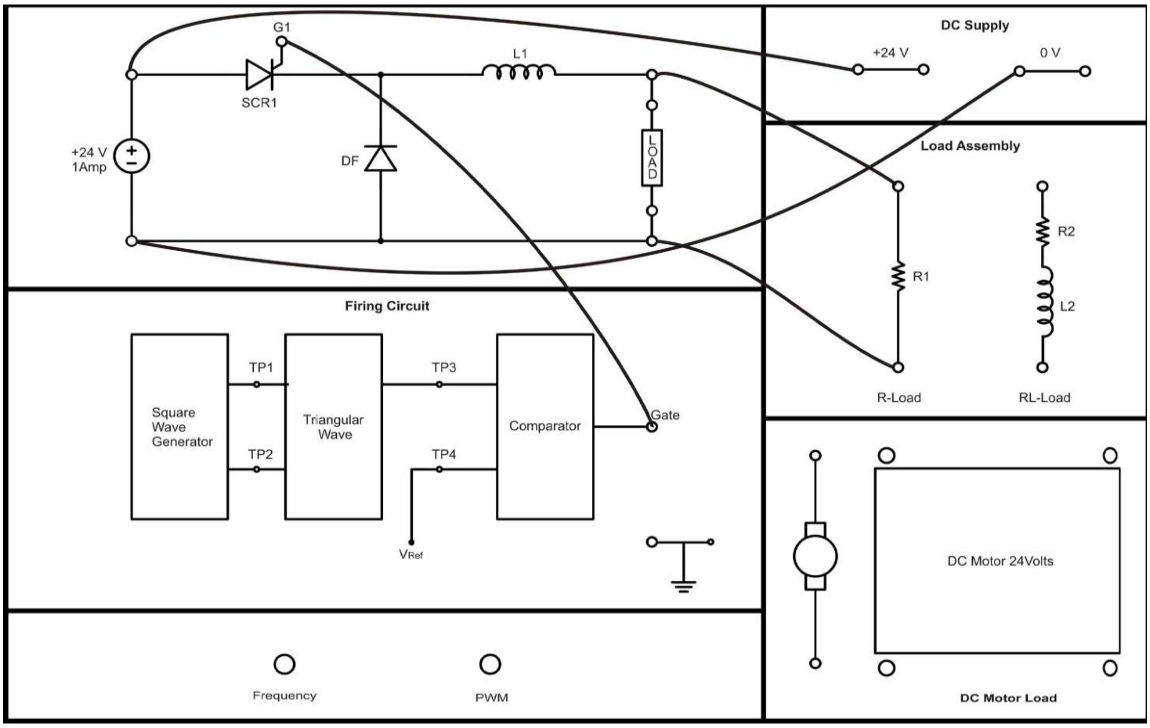
Many industrial applications require a variable DC voltage source; therefore it is necessary to convert fixed voltage into a variable voltage. This variable voltage can be obtained either from AC supply voltage or from a fixed DC voltage. A variable DC output voltage can be obtained either by an AC link choppers or a DC chopper.

In AC link chopper, a fixed DC input is first converted into an AC by an inverter then the output of the inverter is stepped-up or stepped-down by a transformer which is then converted back by an uncontrolled rectifier. However in DC chopper direct DC to- DC conversion is done. Thus, a chopper can be used as a stepped-down or stepped up DC input voltage. If we compare both the choppers AC link & DC choppers, design of DC chopper is efficient, smaller in size, & low in cost because of the single stage conversion. Therefore, it is widely used in regulated Switched Mode Power Supplies.

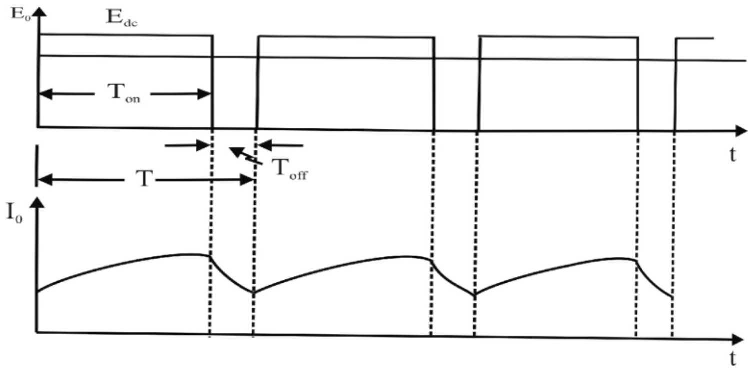
Step down Chopper: A Chopper is simply an 'on-off' switch that either connects load to the supply or disconnects load from the supply and produces a chopped load voltage from a constant input supply. Figure no.7 shows the basic principle of Choppers.



Chopper Circuit



From the above figure it is clear that the SCR is triggered periodically and is kept conducting for a period Ton & is blocked for a period Toff. The chopped load voltage waveform is as shown in figure no. 6.



During the period Ton, when the chopper is on, the supply terminals are connected to the load terminals. & During the period Toff, when the chopper is 'Off', the load current flows through the Freewheeling Diode DF. As a result, load terminals are short circuited by DF & voltage therefore becomes zero during Toff. In this manner, a chopped DC voltage is produced at the load terminals. The average load-voltage Eo is given by

Eo = Edc (Ton/Ton+Toff) Where

Ton = 'On' time of the chopper. & Toff = 'Off' time of the chopper.

T (Ton+Toff) = Chopping period

If α =Ton/T be the duty cycle then above equation becomes,

Eo = Edc x (Ton/T) or Eo = Edc x α

Thus the load voltage can be controlled by varying the duty cycle of the chopper.

Procedure:

1. Connect the power supply +24V & ground at their indicated positions.

2. Connect the gate signal from the SCR firing circuit to the gate of the SCR.

3. Connect the RL load at its indicated position.

4. Switch 'On' the power supply.

5. Set the frequency control potentiometer at 1 KHz.

6. Vary PWM control potentiometer & observe output waveform across load.

7. Record the output voltage across the load by varying the PWM control potentiometer.

8. Verify the output DC voltage with the theoretical value.

9. Switch off the power supply.

10. Disconnect all the connections from the board & switch 'On' the instrument.

11. Set frequency control potentiometer at 1.5 KHz & repeat experiment from step 6.

Observation Table:

S.NO.	FREQUENCY (Hz)	PWM(%)	MEASURED OUTPUT VOLTAGE (V)	THEORETICAL OUTPUT VOLTAGE (V)	% ERROR
1.					
2.					
3.					
4.					
5.					
6.					

Calculation:

The output DC voltage EO is given by the following equation :

$$E = \frac{E_{DC} \times T_{ON}}{T_{ON} + T_{OFF}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where

Edc = input DC voltage

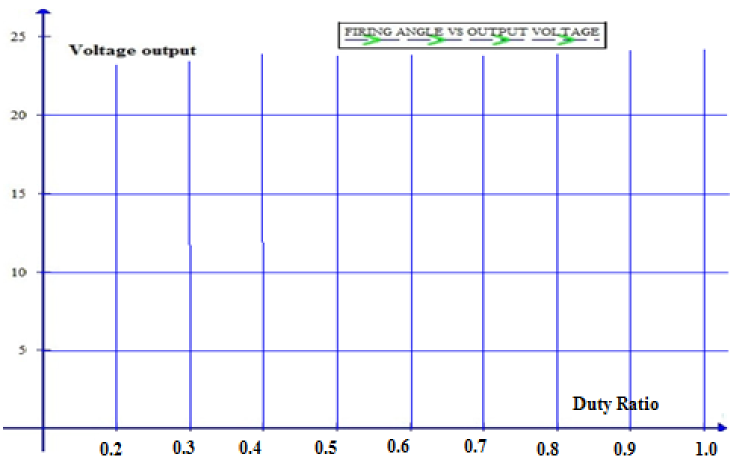
TON = 'On' time of the gate signal

TOFF = 'Off' time of the gate signal

Result:

By changing the PWM Control Potentiometer from minimum to maximum the output DC voltage across the load increases which is shown in the graph below.

Graph:



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EXPERIMENT 4

Objective:

Study of Step down Chopper with inductive (motor) load.

Equipment's needed:

1. Oscilloscope: 20 MHz; ST201/ Caddo 802 or equivalent
2. Multimeter: Scientech 4011 Handheld
3. ST2722 Step Down Chopper
4. Patch Cords & Instruction manual
5. BNC to Test Probe

5. BNC to Test Probe

Theory:

Overview of choppers: Many industrial applications require a variable DC voltage source; therefore it is necessary to convert fixed voltage into a variable voltage. This variable voltage can be obtained either from AC supply voltage or from a fixed DC voltage. A variable DC output voltage can be obtained either by an AC link choppers or a DC chopper. In AC link chopper, a fixed DC input is first converted into an AC by an inverter then the output of the inverter is stepped-up or stepped-down by a transformer which is then converted back by an uncontrolled rectifier. However in DC chopper direct DC to DC conversion is done. Thus, a chopper can be used as a stepped-down or stepped up DC input voltage. If we compare both the choppers AC link & DC choppers, design of DC chopper is efficient, smaller in size, & low in cost because of the single stage conversion. Therefore, it is widely used in regulated Switched Mode Power Supplies.

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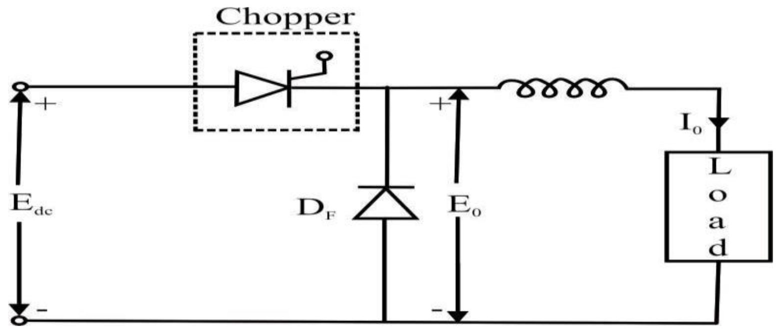
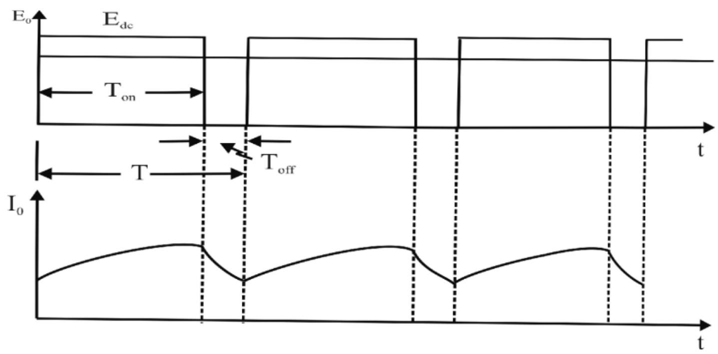


Chopper Circuit

From the above figure it is clear that the SCR is triggered periodically and is kept conducting for a period Ton & is blocked for a period Toff. The chopped load voltage waveform is as shown in figure no. 6.



The step-down dc-dc converter, commonly known as a buck converter, is shown in Figure below. It consists of dc input voltage source **VS**, controlled switch **S**, diode **D**, filter inductor **L**, filter capacitor **C**, and load resistance **R**. The state of the converter in which the inductor current is never zero for any period is called the ***continuous conduction mode*** **(CCM)**. It can be seen from the circuit that when the switch **S** is commanded to the on state, the diode **D** is reverse-biased. When the switch **S** is off, the diode conducts to support an uninterrupted current in the inductor.

$$(V_s - V_o)\,DT = V_o(1 - D)T$$

The output voltage and current are:

$$V_o = D\,V_s$$

$$I_s = DI_o$$

The ripple inductor current ΔI is:

$$\Delta I = \frac{DV_s(1-D)}{fL}$$

The ripple capacitor voltage is:

$$\Delta V_c = \frac{DV_S(1-D)}{8CLf^2}$$

During the period Ton, when the chopper is on, the supply terminals are connected to the load terminals. & During the period Toff, when the chopper is 'Off', the load current flows through the Freewheeling Diode DF. As a result, load terminals are short circuited by DF & voltage therefore becomes zero during Toff. In this manner, a chopped DC voltage is produced at the load terminals. The average load-voltage Eo is given by

Eo = Edc (Ton/Ton+Toff) Where

Ton = 'On' time of the chopper.

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If α =Ton/T be the duty cycle then above equation becomes,

Eo = Edc x (Ton/T)

Eo = Edc x α

Thus the load voltage can be controlled by varying the duty cycle of the chopper.

Procedure:

1. Connect the power supply +24V & ground at their indicated positions.

2. Connect the gate signal from the SCR firing circuit to the gate of the SCR.

3. Connect the resistive load at its indicated position.

4. Switch 'On' the power supply.

5. Set the frequency control potentiometer at 1 KHz.

6. Vary the PWM control potentiometer & observe the output waveform across the load.

7. Record the output voltage across the load by varying the PWM control potentiometer.

8. Verify the output DC voltage with the theoretical value.

9. Switch 'Off' the power supply.

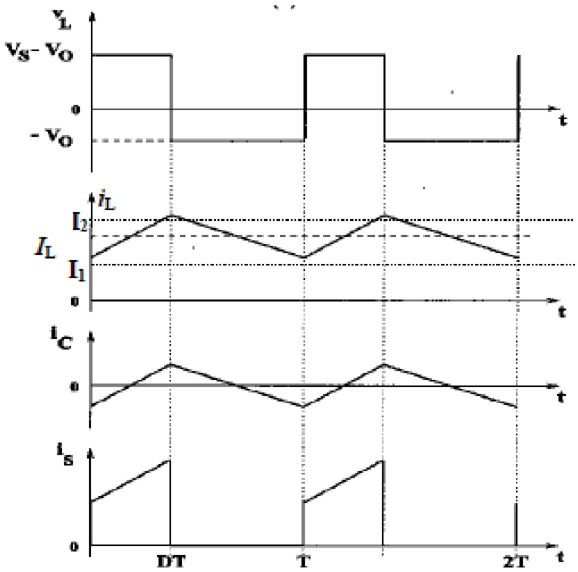
10. Disconnect all the connections from the board & switch 'On' the instrument.

11. Set frequency control potentiometer at 1.5 KHz & repeat experiment from step 6.

Observation Table:

S.NO.	FREQUENCY (Hz)	PWM(%)	MEASURED OUTPUT VOLTAGE (V)	THEORETICAL OUTPUT VOLTAGE (V)	% ERROR
1.					
2.					
3.					
4.					
5.					
6.					

Sample Waveforms



(b)

Calculation:

The output DC voltage EO is given by the following equation :

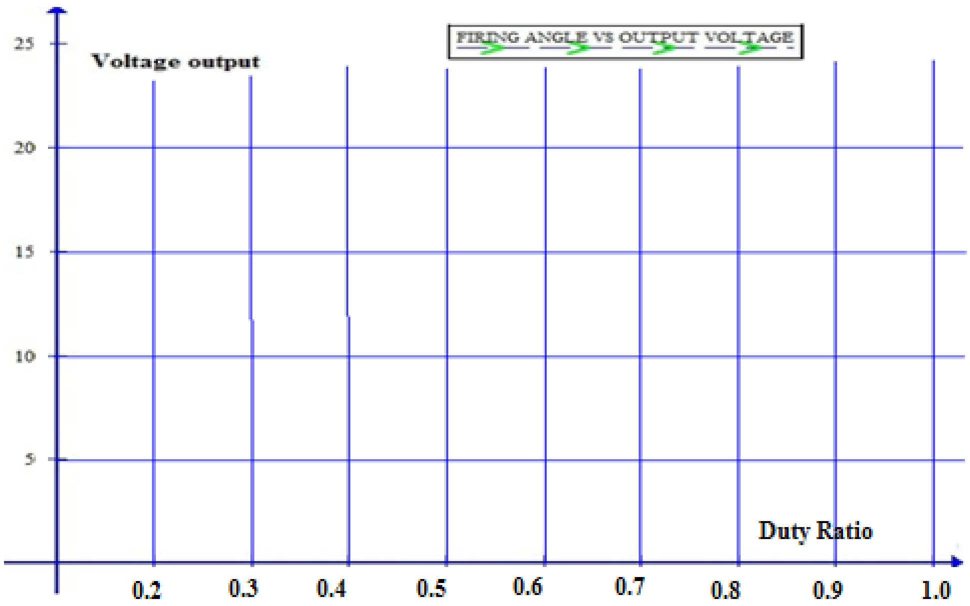
$$E = \frac{E_{DC} \times T_{ON}}{T_{ON} + T_{OFF}}$$

Where; Edc = input DC voltage; TON = gate signal ‘On’ time; TOFF = gate signal ‘Off’ time

Conclusion:

By changing the PWM Control Potentiometer from minimum to maximum the output DC voltage across the load increases.

Graph



Precautions:

1. Do not operate the instrument if you suspect any damage within.
2. Use proper Mains cord : Use only the mains cord designed for this instrument.
3. Ground the Instrument : This instrument is grounded through the protective earth conductor of the mains cord. To avoid electric shock the grounding conductor must be connected to the earth ground. Before making connections to the input terminals, ensure that the instrument is properly grounded.
4. Observe Terminal Ratings : To avoid fire or shock hazards, observe all ratings and marks on the instrument.
5. Use only the proper Fuse : Use the fuse type and rating specified for this instrument.
6. Do not operate in wet / damp conditions.
7. Do not operate in an explosive atmosphere.
8. Keep the product dust free, clean and dry.

EXPERIMENT 5

Objective:

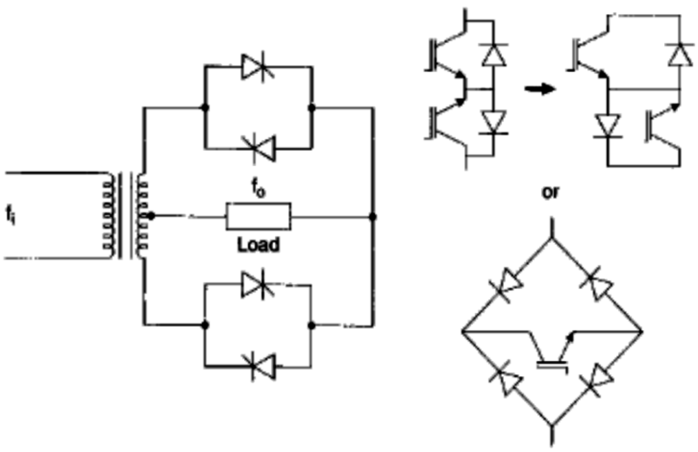
To study of the firing circuit of single-phase Cycloconverter.

Equipments Needed:

1. Power Electronics board, ST2713
2. Oscilloscope
3. 2 mm patch cords.

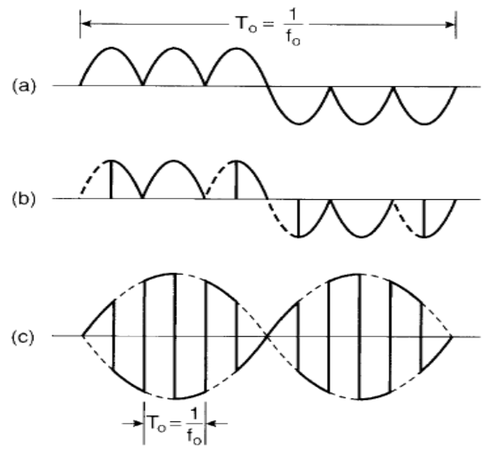
Theory:

In a cyclo-converter driving an ac motor, the input 50/60 Hz power is converted to variable-frequency, variable-volt-age ac at the output to control the motor speed. The output frequency may vary from zero (recti-fier operation) to an upper limit, which is always lower than the input frequency (step-down cycloconverter), and the power flow can be in either direction for four-quadrant motor speed control. In a VSCF system, the input power is usually generated by a synchronous machine that is coupled to a variable-speed turbine. The generated voltage can be regulated if the synchronous machine is wound field, but the output frequency is always proportional to the turbine speed.



The function of the cycloconverter is to regulate the output frequency to be constant (typically 60 or 400 Hz). Figure 4.2 shows alternate-frequency conversion schemes. Figure 4.2(a) is a commonly used scheme where the input ac is rectified to dc and then inverted to variable-frequency ac through an inverter. In Figure 4.2(b), the input ac is converted to high-frequency ac through a step-up cycloconverter, and then converted to variable-frequency ac by a step-down cycloconverter. If the input power is dc, then the step-up cycloconverter is replaced by a high-frequency inverter.

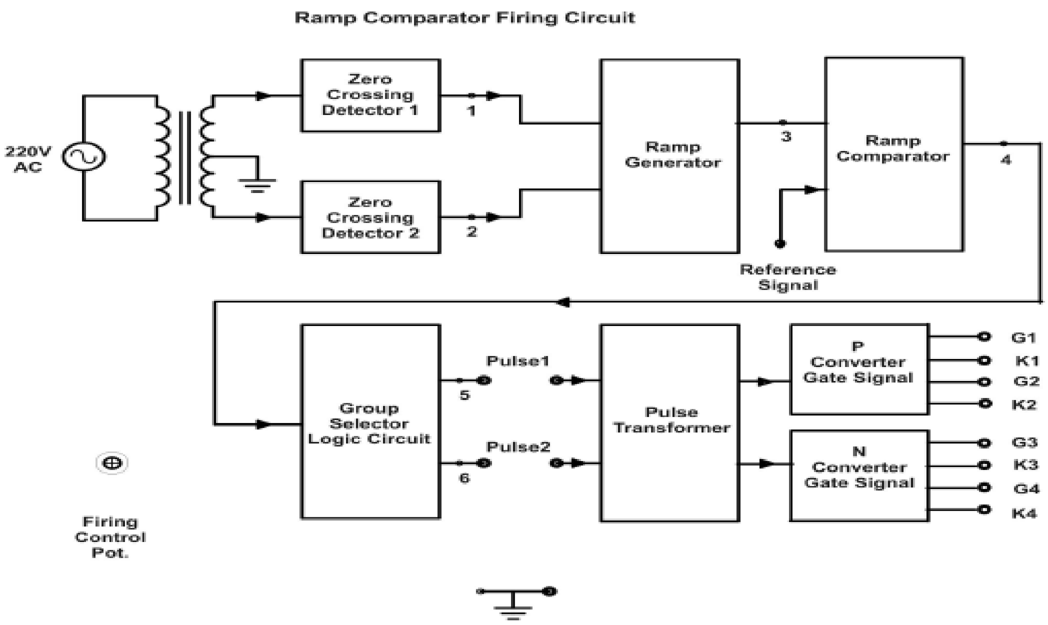
The basic principle of cycloconversion can be explained with the help of the single-phase-to-single-phase converter circuit shown in Figure 4.3. A positive center-tap thyristor converter (see Figure 3.2) is connected in anti-parallel with a negative converter of a similar type so that the voltage and current of either polarity can be controlled in the load. The waveforms are shown in Figure 4.4, assuming ideal resistive load. In Figure 4.4(a), an integral half-cycle output wave is fabricated, which has a fundamental frequency.fo = (1/n)f,., where n (n = 3 in this case) is the number of input half-cycles per half-cycle of the output.



The thyristor firing angle can be modulated to control the fundamental component output voltage, as shown in part (b). Instead of step-down frequency conversion, step-up frequency conversion is also possible, as indicated in (c) of the same figure. In this case, the devices are switched alternately between the positive and negative envelopes at a high frequency to generate carrier-frequency, modulated output. Here, the antiparallel thyristor pair is replaced by a high-frequency ac switch, as indicated at the right of Figure 4.3. The ac switch is basically an anti-parallel connection of IGBTs with a series diode and connected at center point, as shown, so that voltage can be blocked in either polarity, but current can flow in either direction. It can also be a diode bridge with a single IGBT as shown in the figure.

Circuit Diagram:

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



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. Switch on the power supply.
3. Observe the sine wave AC signal between point 7 & 11 and note readings of amplitude and time.
4. Observe the output waveforms of zero cross detector 1 & 2 at point ‘1’and ‘2’ with respect to ground and note readings of amplitude and time base.
5. Observe the output waveforms of ramp generator at point ‘3’ w.r.t. ground and note the note readings of amplitude and time base.
6. Observe the output waveforms of clock ramp comparator at point ‘4’ and note readings of amplitude and time base.
7. Observe the output waveforms of gate pulse 1 and 2 between point ‘5’and ground and ‘6’and ground and note readings of amplitude and time base.
8. Plot the waveforms of input signal, ZCD1 & ZCD2 output, ramp signal, comparator output, gate pulse 1 and 2.

Observation Table:

S. No.	Input sine signal		ZCD 1 **Output**		ZCD 2 Output		Ramp Output		Ramp comparator output		Gate pulse 1			Gate pulse 2	
	A	T	A	T	A	T	A	T	A	T	A	A	T	A	T

Result:

A study of observed readings on a cyclo-converter is performed and different firing schemes are verified.

EXPERIMENT 6

Objective:

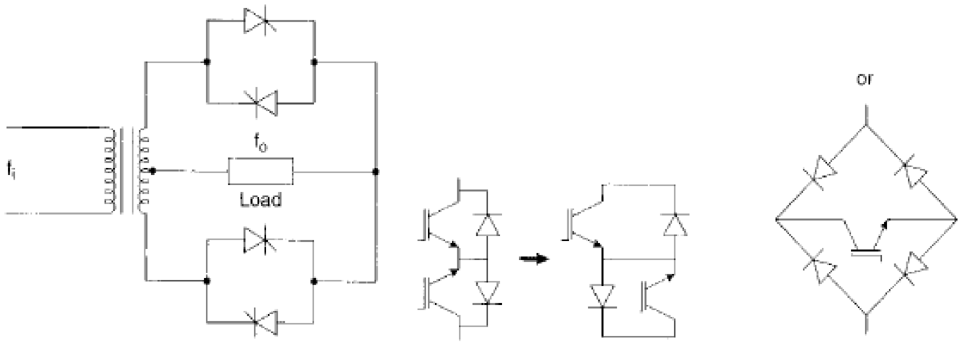
To study the single phase cycloconverter with resistive and inductive load

Equipments Needed:

1. Power Electronics board, **ST2713**
2. Oscilloscope
3. 2 mm patch cords.
4. Multimeter.

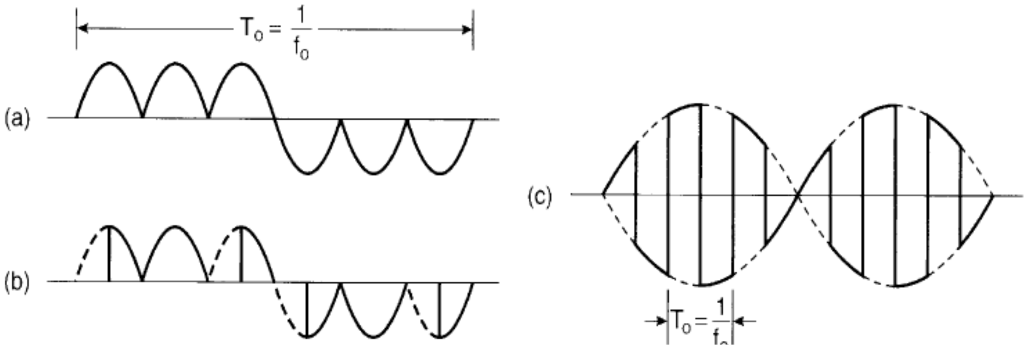
Theory:

In a cyclo-converter driving an ac motor, the input 50/60 Hz power is converted to variable-frequency, variable-volt-age ac at the output to control the motor speed. The output frequency may vary from zero (recti-fier operation) to an upper limit, which is always lower than the input frequency (step-down cycloconverter), and the power flow can be in either direction for four-quadrant motor speed control. In a VSCF system, the input power is usually generated by a synchronous machine that is coupled to a variable-speed turbine. The generated voltage can be regulated if the synchronous machine is wound field, but the output frequency is always proportional to the turbine speed.



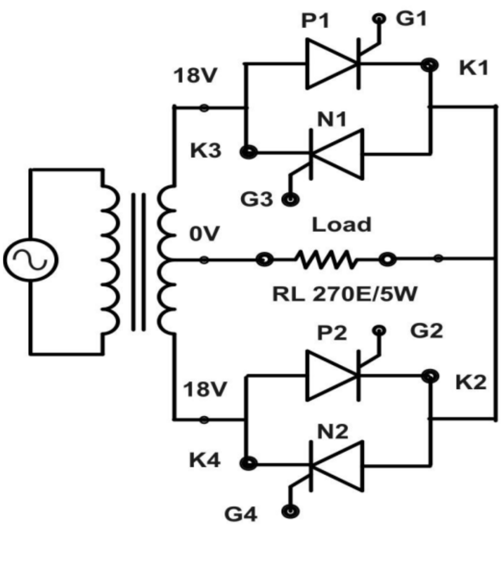
The function of the cycloconverter is to regulate the output frequency to be constant (typically 60 or 400 Hz). Figure 4.2 shows alternate-frequency conversion schemes. Figure 4.2(a) is a commonly used scheme where the input ac is rectified to dc and then inverted to variable-frequency ac through an inverter. In Figure 4.2(b), the input ac is converted to high-frequency ac through a step-up cycloconverter, and then converted to variable-frequency ac by a step-down cycloconverter. If the input power is dc, then the step-up cycloconverter is replaced by a high-frequency inverter.

The basic principle of cycloconversion can be explained with the help of the single-phase-to-single-phase converter circuit shown in Figure 4.3. A positive center-tap thyristor converter (see Figure 3.2) is connected in anti-parallel with a negative converter of a similar type so that the voltage and current of either polarity can be controlled in the load. The waveforms are shown in Figure 4.4, assuming ideal resistive load. In Figure 4.4(a), an integral half-cycle output wave is fabricated, which has a fundamental frequency.fo = (1/n)f,., where n (n = 3 in this case) is the number of input half-cycles per half-cycle of the output.

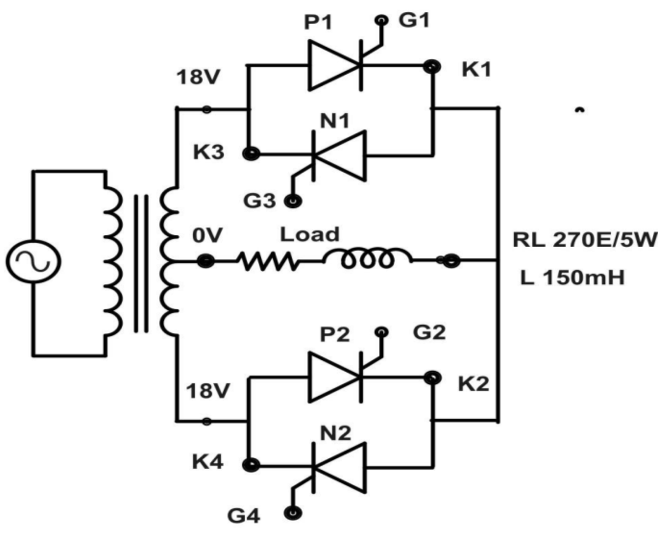


The thyristor firing angle can be modulated to control the fundamental component output voltage, as shown in part (b). Instead of step-down frequency conversion, step-up frequency conversion is also possible, as indicated in (c) of the same figure. In this case, the devices are switched alternately between the positive and negative envelopes at a high frequency to generate carrier-frequency, modulated output. Here, the antiparallel thyristor pair is replaced by a high-frequency ac switch, as indicated at the right of Figure 4.3. The ac switch is basically an anti-parallel connection of IGBTs with a series diode and connected at center point, as shown, so that voltage can be blocked in either polarity, but current can flow in either direction. It can also be a diode bridge with a single IGBT as shown in the figure.

Circuit Diagram :
The basic diagram is shown in the below figure



(A) R load



(B) R-L load

Procedure:

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

1. Rotate the firing control Potentiometer in full clockwise direction.

2. Connect pulse1 and pulse2 to the pulse transformer section and connect the R load.

3. Connect the oscilloscope across the load.

4. Switch on the power.

5. Vary the firing control Potentiometer and note the AC voltage across the load at different firing angle 30º, 60º, 90º, 120º, 150º and 180º.

6. Observe the output waveform across R and RL load, when the firing angle is 90º.

Observation Table :

S. No.	Firing angle	Output voltage across load

Result:
Frequency of the input signal can be varying using cycloconverter.

Precautions:

1. Do not operate the instrument if you suspect any damage within.
2. Use proper Mains cord : Use only the mains cord designed for this instrument.
3. Ground the Instrument : This instrument is grounded through the protective earth conductor of the mains cord. To avoid electric shock the grounding conductor must be connected to the earth ground. Before making connections to the input terminals, ensure that the instrument is properly grounded.
4. Observe Terminal Ratings : To avoid fire or shock hazards, observe all ratings and marks on the instrument.
5. Use only the proper Fuse : Use the fuse type and rating specified for this instrument.
6. Do not operate in wet / damp conditions.
7. Do not operate in an explosive atmosphere.
8. Keep the product dust free, clean and dry.

Experiment 7

OBJECTIVE

To simulate Triac based voltage controller for speed control of single phase AC motor.

PREREQUISITES

1. Dual Core P.C.
2. Matlab v2010 with Simpower Library
3. Schematic Diagram

THEORY

2.1 Single Phase Induction Motor Control Theory

For the speed control of single phase induction motor we have only one method called as “STATOR VOLTAGE CONTROL OF SINGLE PHASE INDUCTION MOTOR.” In speed control by stator voltage control, the stator voltage is reduced from base value of rated speed to a lower value. As torque is proportional to voltage square, the torque speed characteristics goes down proportional to voltage square. With shifting of torque characteristics the operating point will also move to give a reduce motor speed. For a well-designed machine with low value of slip the reduction in speed with reduced voltage is very small. Therefore if a large drop in speed I required with reduction in stator voltage, the motor is specially designed with high full load slip.

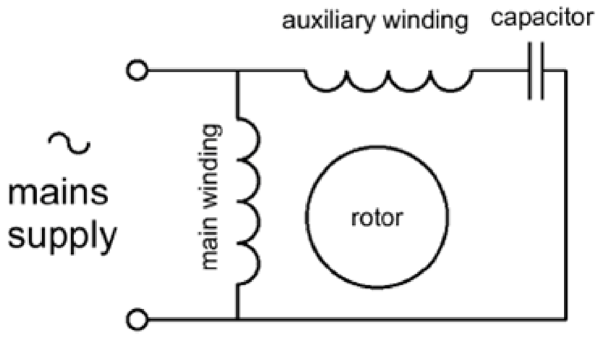


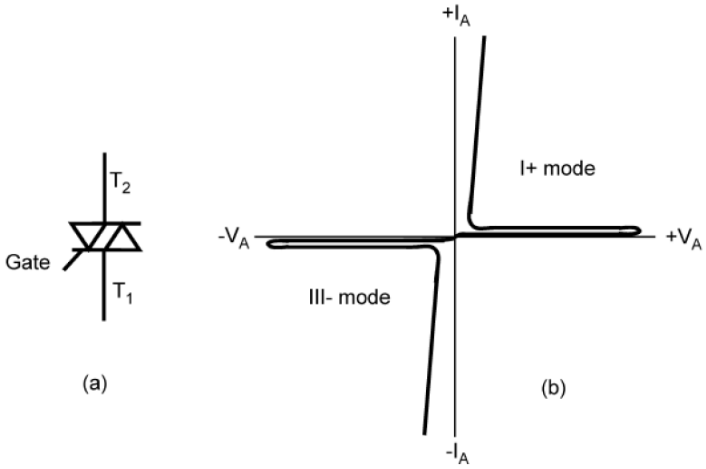
Figure 1: Capacitor Start / Run Motor

Using thyristor the control of stator voltage can be obtained by using AC voltage controller where reverse-parallel connected thyristors are used in each phase between supply and motor. The stator voltage is reduced from its base value by increase of firing angle of thyristor from 0 to 180.

The auxiliary winding current from the main winding is phase-shifted. Connecting a capacitor in series with the auxiliary winding causes the motor to start rotating. Using a centrifugal switch disconnects the capacitor and the auxiliary winding at 75% of the motor nominal speed. This topology is used if high torque is required. In most fan motors, the capacitor and the auxiliary winding remain connected. This configuration is called permanent split capacitor (PSC) AC induction motor. No centrifugal switch is used and is considered to be the most reliable single-phase motors. At rated load, they can be designed for optimum efficiency and high power factor (PF).

TRIAC and SNUBBER

The TRIAC is an electronic bi-directional switch. If there is voltage on the gate, it transmits over its terminals until the current through it drops below a certain threshold value. A snubber network is used to assist the turn off and prevent premature triggering. In this circuit the combination of resistors and capacitors are used to suppress the rapid rise and fall of the voltage. The PWM output signal starts with 0, after a certain time it triggers the TRIAC and conducts until AC reaches 0 again. Starting with one on the cross detection, the motor always runs at a certain speed.



Phase Angle Control

When the TRIAC switch is connected between the AC power supply and the motor, the power flow can be controlled by varying the RMS of the AC voltage. This is called an AC voltage controller. There are two types of control normally used:

— On-off control —

TRIAC switches connect the load to the AC source for a few cycles and then disconnect it for another few cycles of the source voltage

— In phase control —

TRIAC switches connect the load to the AC source for a moment in each cycle Figure 3 A reliable speed control of a ceiling fan AC motor can be accomplished by combining the a fig circuitary and the phase angle control using a TRIAC. A benefit of this approach is avoiding non-linearity that is present if using only the TRIAC. Another benefit is, it can replace the mechanical speed variation commonly used in ceiling fans.

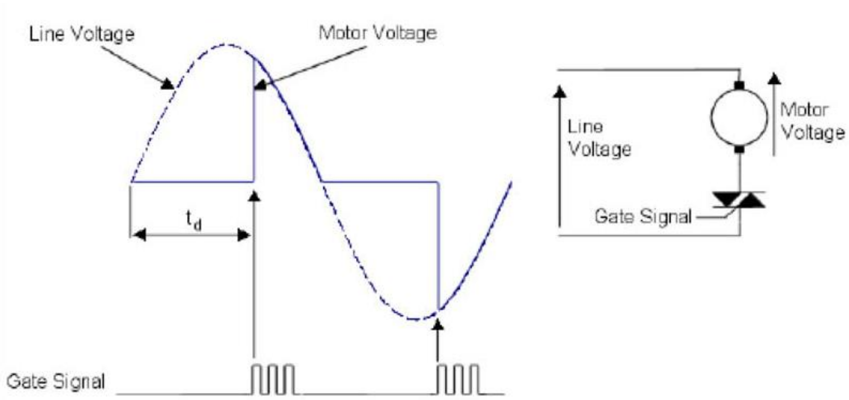


Figure 2. Line Voltage vs. Motor Voltage

SCHEMATIC DIAGRAM

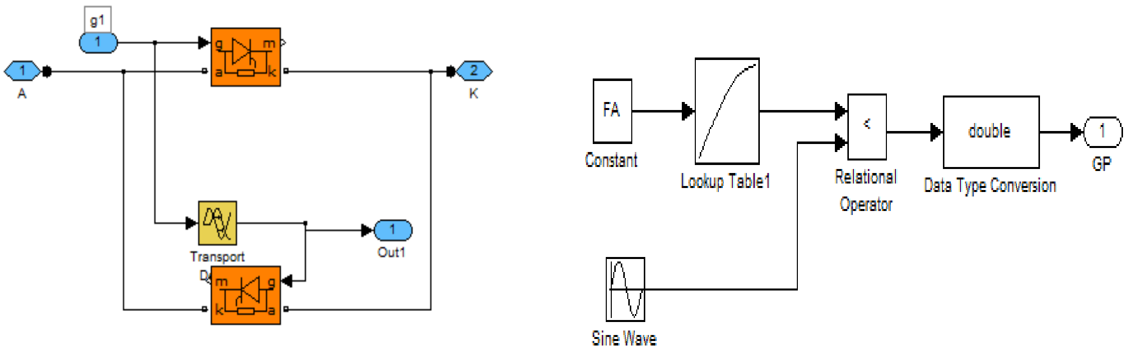


Figure : (a) Triac Equivalent (b) Firing angle calculator

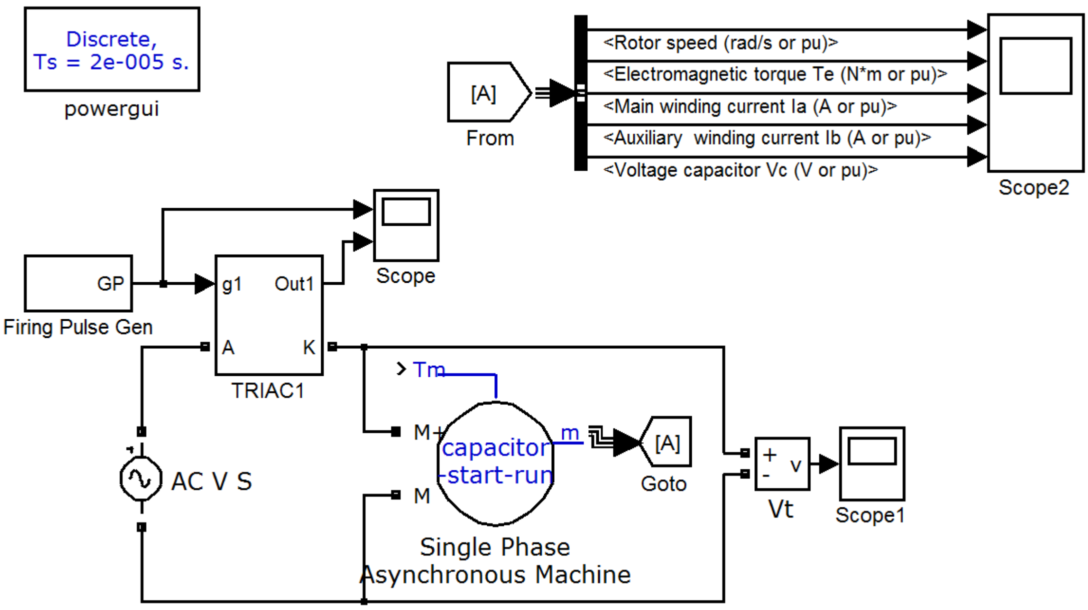


Figure: Triac based control of Single phase AC motor

Procedure

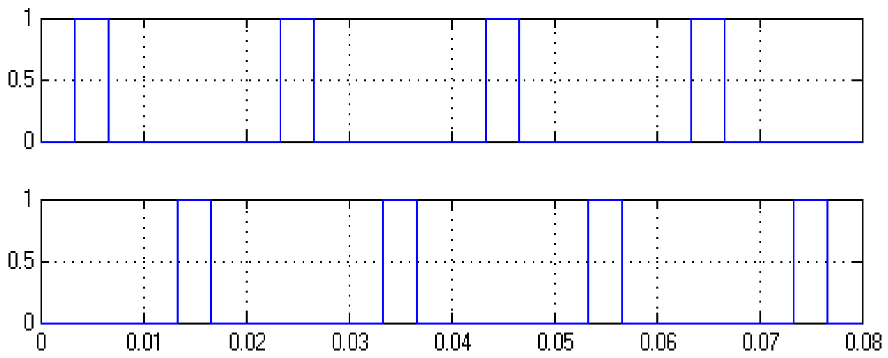
1. Open the Matlab© program from the start menu or by clicking on Matlab© icon on the desktop
2. To open a blank model file in .mdl format, goto
   File menu > New > Model
3. Once the model file is created save it with a desired name from the task bar menu.
4. Now click on the Simulink icon (red/pink and green/blue coloured depending on version used) and on the taskbar to open the simulink library.
5. Now browse the library components to goto Simpower library and double click on it.
6. A dropdown menu appears, now select
   SimPowerSystems > Electrical Sources > AC Voltage Source
7. Double Click on source to open and configure voltage source parameters.
   Peak amplitude of [220*sqrt(2)], phase "0", frequency "50" Hz and leave sample time as it is.
8. Now select single phase asynchronous machine and select
   SimPowerSystems > Machines > Single Phase Asynchronous Machine
9. Double click on single phase asynchronous machine to configure machine type and parameters
   Type of machine "Capacitor Start/Run" , Leave rest ratings and specification as it is.

10. Now select thyristor twice by refering
    SimPowerSystems/Power Electronics/Thyristor
    Leaving all the specifications as specified.
11. Thereafter goto measurement library as
    SimPowerSystems/Measurements/Voltage Measurement
    And drag the component in intended model
12. Now make select the different components as indicated below
    - **Simulink/Commonly Used Blocks/Constant**
    - **Simulink/Commonly Used Blocks/Bus Selector**
    - **Simulink/Sinks/Scope**
    - **Simulink/Commonly Used Blocks/Relational Operator**
    - **Simulink/Commonly Used Blocks/Data Type Conversion**
    - **Simulink/Sources/Sine Wave**
    - **Simulink/Signal Routing/From**
    - **Simulink/Signal Routing/Goto**
    - **Simulink/Commonly Used Blocks/In1**
    - **Simulink/Commonly Used Blocks/Out1**
    - **Simulink/Continuous/Transport Delay**
    - **Simulink/Lookup Tables/Lookup Table**

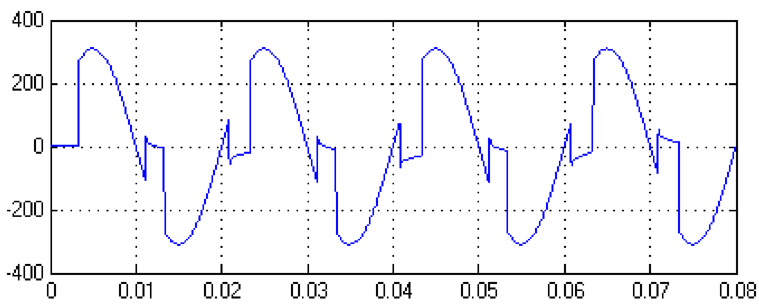
    And connect as indicated in the figures above.
13. Finally place PowerGUI as **SimPowerSystems/powergui** and configure for discrete mode with sample time of 2μs.
14. Now Run the simulation and observe output waveforms.

OUTPUT WAVEFORMS

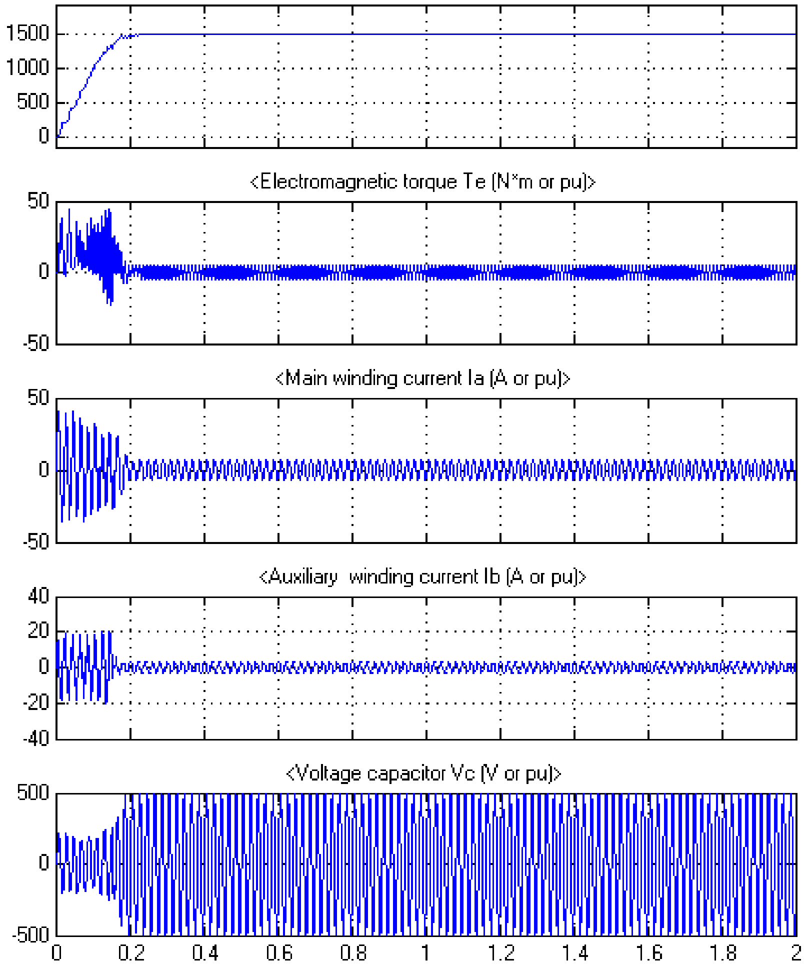
Firing Pulses



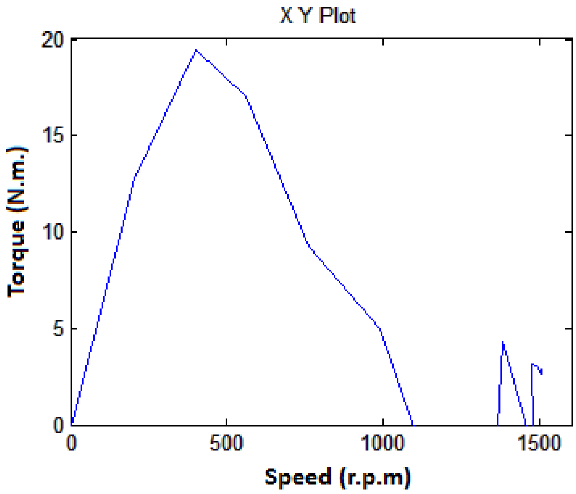
Machine Terminal Voltage



Machine Parameters



Speed torque Characteristic



Result

The simulation model prepared is simulated and the single phase voltage controlled ac drive and the simulation results are observed for various firing angles.

Experiment 8

OBJECTIVE

To simulate three phase half wave AC voltage controller. .

PREREQUISITES

1. Dual Core P.C.
2. Matlab v2010 with Sim power Library
3. Schematic Diagram

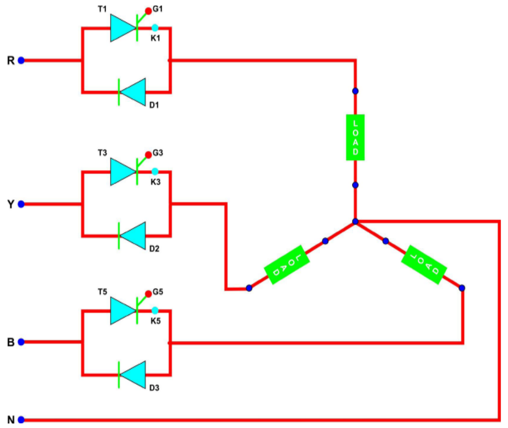
THEORY

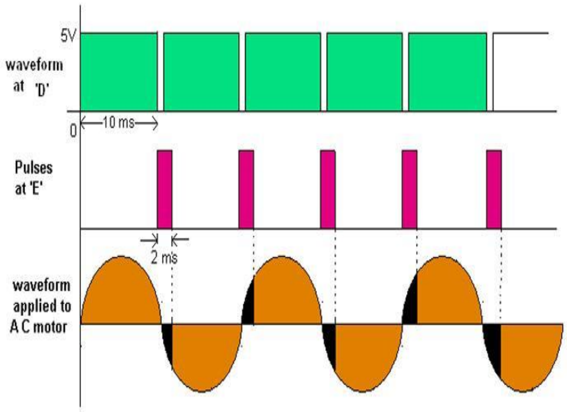
Three Phase AC Voltage Controller: Three phases AC voltage controller are thyristorized based controller which convert fixed three phase alternating voltage directly to variable alternating voltage without a change in the frequency. Three phase AC voltage controller are two types:

(a) Three phase half wave AC voltage controller

(b) Three phase full wave AC voltage controller

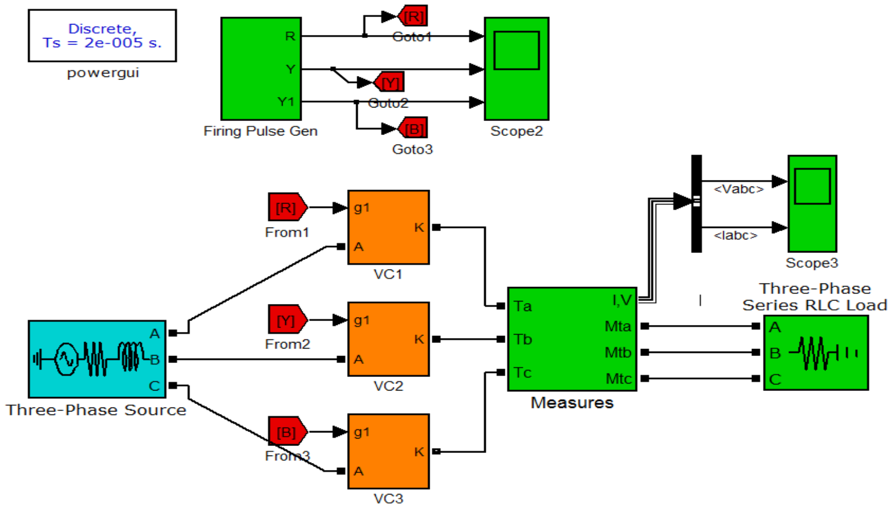
Three Phase Half Wave AC Voltage Controller: Three phase half wave AC voltage controller configuration is consists of three SCR in antiparallel with three diodes.The power flow to the load is controlled by delaying the firing angle of SCRs.Three phase half wave AC voltage conroller configuration is shown in figure with a star load connected.



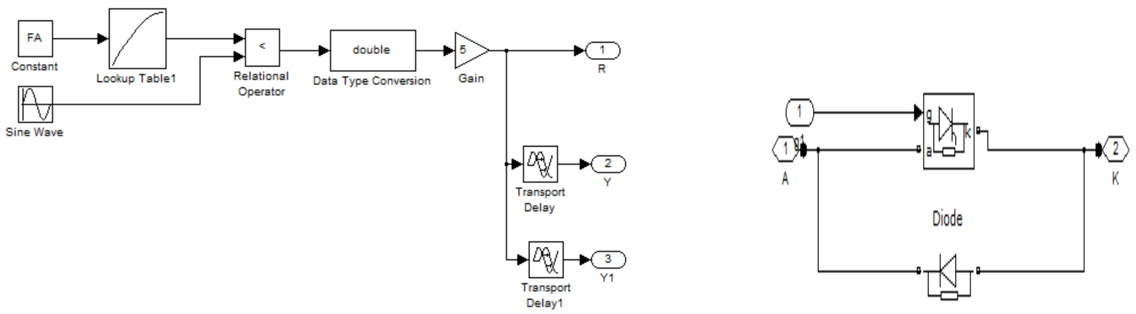


In three phase half wave AC voltage controller control the positive half cycle of input voltage. Since the power flow is controlled during the positive half cycle of input voltage this type of controller is also known as a unidirectional controller or three phases half wave AC voltage controller. In three phase half wave AC voltage controller the current flow to the load is controlled by SCR, T1, T3, T5 and diode D1, D2, D3 provide the return current path the firing sequence of SCR’s is T1, T3, T5 we may recall that a SCR will conduct if it’s anode voltage is higher than that of its cathode and it is triggered. Once a thyristor starts conducting, it would be turned off only when its current falls to zero.

SCHEMATIC DIAGRAM



Three phase half wave AC voltage controller



(a) Firing Pulse Generator (b) Voltage controller

Procedure

1. Open the Matlab© program from the start menu or by clicking on Matlab© icon on the desktop
2. To open a blank model file in .mdl format, goto
   i. *File menu > New > Model*
3. Once the model file is created save it with a desired name from the task bar menu.
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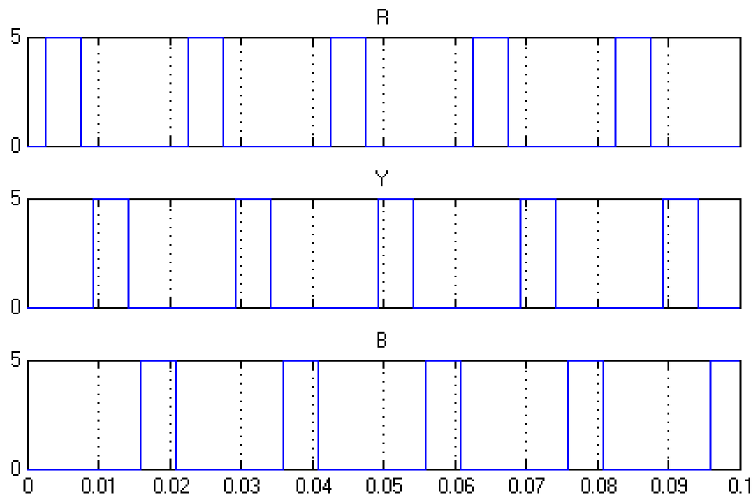
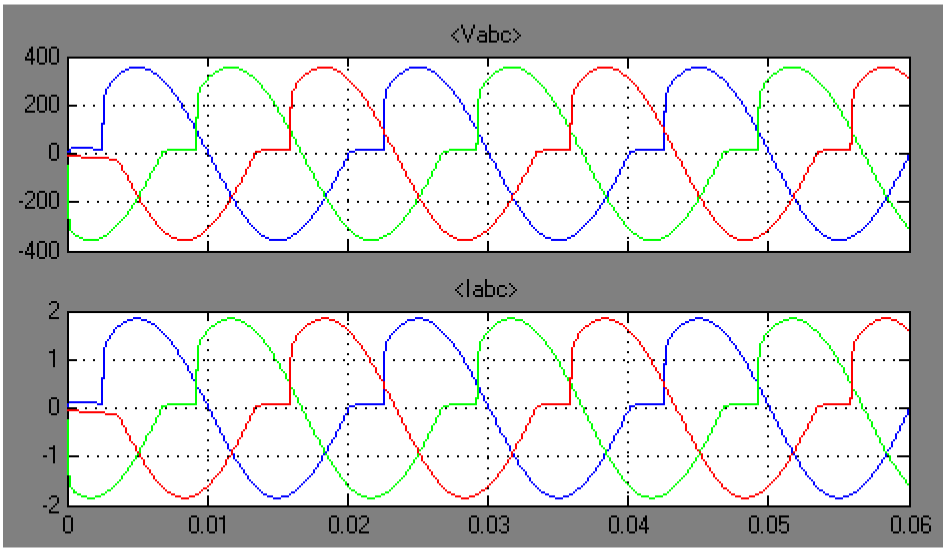
5. Now browse the library components to goto Simpower library and double click on it.
6. A dropdown menu appears, now select
   i. **SimPowerSystems > Electrical Sources > AC Voltage Source**

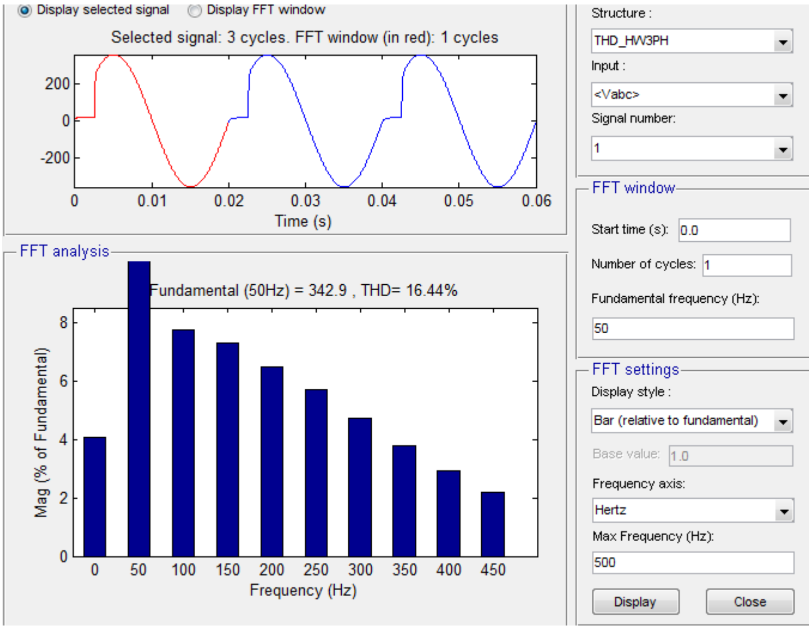
7. Double Click on source to open and configure voltage source parameters.
    a. Peak amplitude of [220*sqrt(2)], phase “0”, frequency “50” Hz and leave sample time as it is.
8. Now select the load as three phase series RLC load
    a. **SimPowerSystems/Elements/Three-Phase Series RLC Load**
9. Double click on block to configure machine type and parameters
    a. Type of Load “R, L, C”, active power, reactive power etc Leave rest ratings and specification as it is.
10. Now select thyristor twice by refering
    a. **SimPowerSystems/Power Electronics/Thyristor**
    b. Leaving all the specifications as specified.
11. Thereafter goto measurement library as
    a. SimPowerSystems/Measurements/Voltage Measurement
    b. And drag the component in intended model
12. Now make select the different components as indicated below
        i. **Simulink/Commonly Used Blocks/Constant**
        ii. **Simulink/Commonly Used Blocks/Bus Selector**
        iii. Simulink/Sinks/Scope
        iv. Simulink/Commonly Used Blocks/Relational Operator
        v. Simulink/Commonly Used Blocks/Data Type Conversion
        vi. Simulink/Sources/Sine Wave
        vii. Simulink/Signal Routing/From
        viii. Simulink/Signal Routing/Goto
        ix. Simulink/Commonly Used Blocks/In1
        x. Simulink/Commonly Used Blocks/Out1
        xi. Simulink/Continuous/Transport Delay
        xii. Simulink/Lookup Tables/Lookup Table
    b. And connect as indicated in the figures above.
13. Finally place PowerGUI as **SimPowerSystems / powergui** and configure for discrete mode with sample time of 2µs.
14. Now Run the simulation and observe output waveforms.

OUTPUT WAVEFORMS



Firing Pulses





Result

The simulation model prepared is simulated for a three phase half wave ac voltage controller and the simulation results are observed for various firing angles.

Experiment 9

OBJECTIVE

To simulate step down chopper with inductive load.

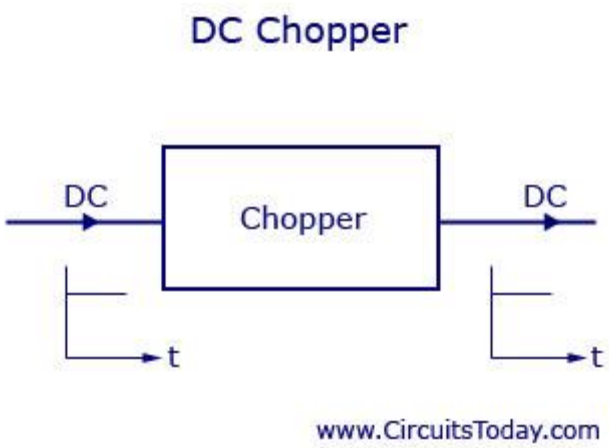
PREREQUISITES

1. Dual Core P.C.
2. Matlab v2010 with Simpower Library
3. Schematic Diagram

Theory:

DC Chopper

A DC chopper is a static device that converts fixed dc input voltage to a variable dc output voltage directly. A chopper can be said as dc equivalent of an ac transformer as they behave in an identical manner. This kind of choppers are more efficient as they involve one stage conversion. Just like a transformer, a chopper can be used to step up or step down the fixed dc output voltage. Choppers are used in many applications all over the world inside various electronic equipments. A chopper system has a high efficiency, fast response and a smooth control.



Principle of Chopper Operation

A chopper can be said as a high speed on/off semiconductor switch. Source to load connection and disconnection from load to source happens in a rapid speed. Consider the figure, here a chopped load voltage can be obtained from a constant dc supply of voltage, which has a magnitude $V_{S.}$ Chopper is the one represented by "SW" inside a dotted square which can be turned on or off as desired.

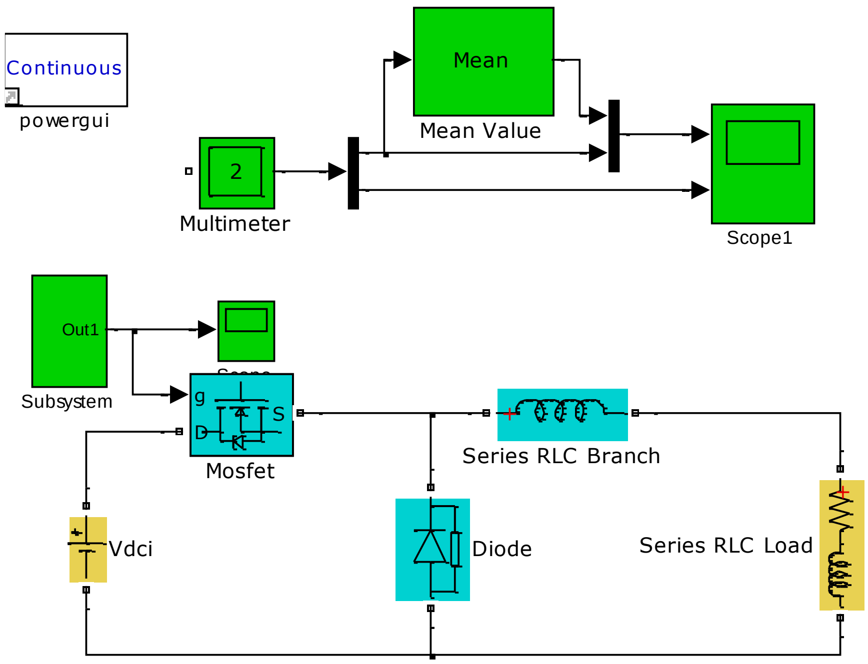


Figure 2: Step Down Chopper Circuit

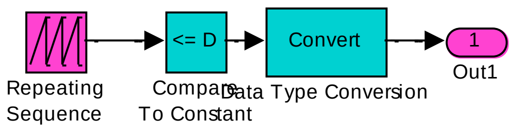
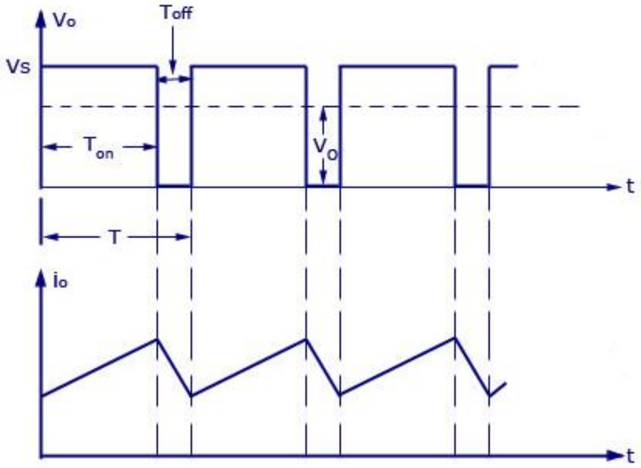


Figure 3: Chopper Firing Circuit

Output Voltage and Current Waveforms



Let us now take a look of the output current and voltage wave forms of a chopper. During the time period T_{on} the chopper is turned on and the load voltage is equal to source voltage V_s. During the interval T_{off} the chopper is off and the load current will be flowing though the freewheeling diode FD . The load terminals are short circuited by FD and the load voltage is therefore zero during T_{off}. Thus, a chopped dc voltage is produced at the load terminals. We can see from the graph that the load current is continuous. During the time period T_{on}, load current rises but during T_{off} load current decays .

Average load Voltage is given by

$V_0 = T_{on}/ (T_{on} + T_{off}) * Vs = (T_{on}/T) V = A V_s$

T_{on} : on -time

T_{off} : off- time

$T = T_{on} + T_{off}$= chopping period

$A = T_{on} /T$ = duty cycle

So we know that the load voltage can be controlled by varying the duty cycle A. equation 1.0 shows that the load voltage is independent of load current it can be also written as

$V_0 = f. T_{on} .V_s$

f= 1/T = chopping frequency

Procedure

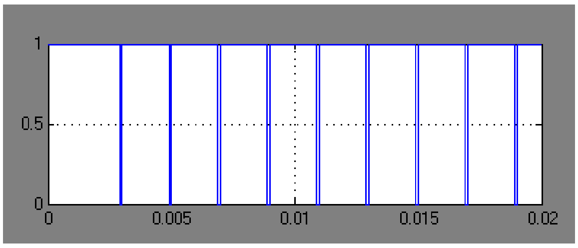
1. Open the Matlab© program from the start menu or by clicking on Matlab© icon on the desktop
2. To open a blank model file in .mdl format, goto
    i. *File menu > New > Model*
3. Once the model file is created save it with a desired name from the task bar menu.
4. Now click on the Simulink icon (red/pink and green/blue coloured depending on version used) and on the taskbar to open the simulink library.
5. Now browse the library components to goto Simpower library and double click on it.
6. A dropdown menu appears, now select
    i. **SimPowerSystems > Electrical Sources > AC Voltage Source**
7. Double Click on source to open and configure voltage source parameters.
    a. Peak amplitude of [220*sqrt(2)], phase “0”, frequency “50” Hz and leave sample time as it is.
8. Now select the load as three phase series RLC load
    a. **SimPowerSystems/Elements/Three-Phase Series RLC Load**
9. Double click on block to configure machine type and parameters
    a. Type of Load “R, L, C”, active power, reactive power etc Leave rest ratings and specification as it is.
10. Now select thyristor twice by refering
    a. **SimPowerSystems/Power Electronics/Thyristor**
    b. Leaving all the specifications as specified.
11. Thereafter goto measurement library as
    a. SimPowerSystems/Measurements/Voltage Measurement
    b. And drag the component in intended model
12. Now make select the different components as indicated below
    i. **Simulink/Commonly Used Blocks/Constant**
    ii. **Simulink/Commonly Used Blocks/Bus Selector**
    iii. Simulink/Sinks/Scope
    iv. Simulink/Commonly Used Blocks/Relational Operator
    v. Simulink/Commonly Used Blocks/Data Type Conversion
    vi. Simulink/Sources/Sine Wave
    vii. Simulink/Signal Routing/From
    viii. Simulink/Signal Routing/Goto
    ix. Simulink/Commonly Used Blocks/In1
    x. Simulink/Commonly Used Blocks/Out1

xi. **Simulink/Continuous/Transport Delay**
xii. **Simulink/Lookup Tables/Lookup Table**

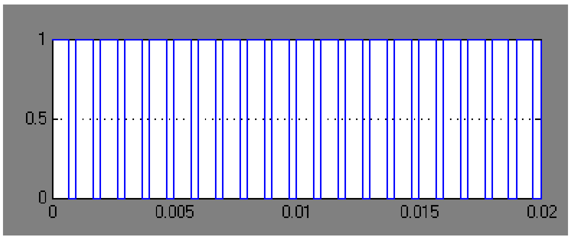
And connect as indicated in the figures above.

13. Finally place PowerGUI as **SimPowerSystems / powergui** and configure for discrete mode with sample time of 2μs.
14. Now Run the simulation and observe output waveforms.

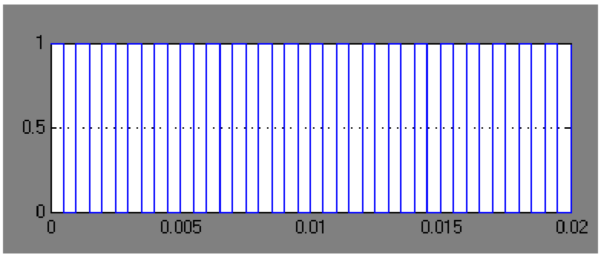
OUTPUT WAVEFORMS



(a) Duty Ratio: 0.9

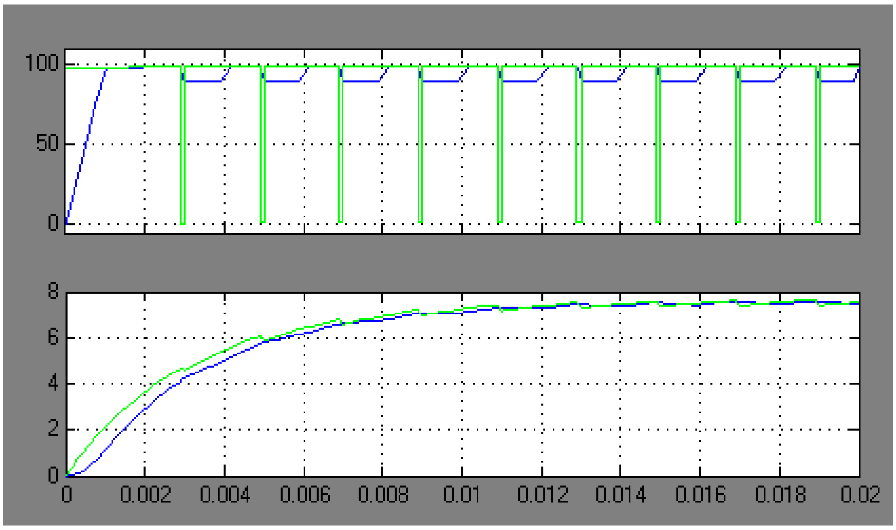


(b) Duty Ratio: 0.7

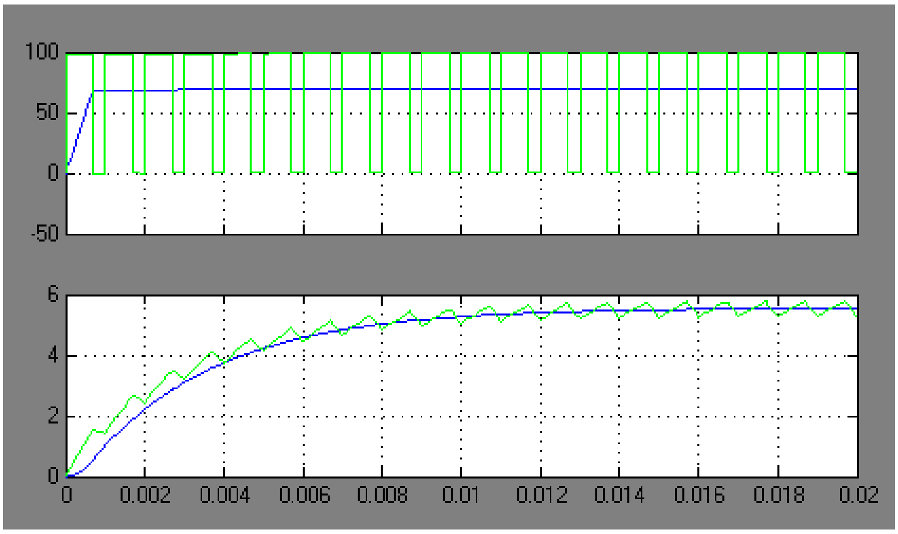


(c) Duty Ratio: 0.5

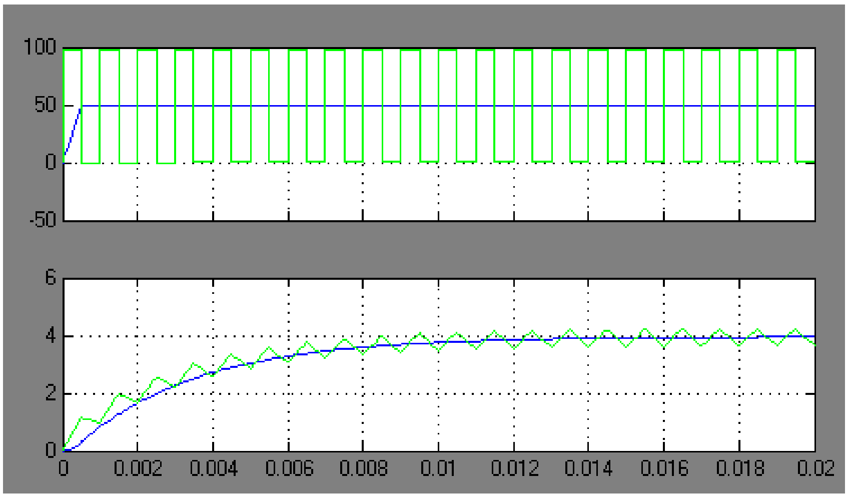
Figure 4: Duty Ratio Used



(a) Duty Ratio 0.9



(b) Duty Ratio 0.7



(c) Duty Ratio 0.5

Figure 5: Output Voltage & Currents

Conclusion:

The simulation performed verified that the output voltage of a chopper varies as a function of duty cycle.