Varuvan Vadivelan
Institute of Technology

Dharmapuri – 636 703

LAB MANUAL

Regulation : **2013**

Branch : ***B.E*** **- EEE**

Year & Semester : **III Year / VI Semester**

EE6611- POWER ELECTRONICS AND DRIVES LABORATORY

ANNA UNIVERSITY

SYLLABUS (2013 REGULATION)

SEMESTER VI

EE6611 - POWER ELECTRONICS AND DRIVES LABORATORY

LIST OF EXPERIMENTS:

1. Gate Pulse Generation using R, RC and UJT.
2. Characteristics of SCR and Triac
3. Characteristics of MOSFET and IGBT
4. AC to DC half controlled converter
5. AC to DC fully controlled Converter
6. Step down and step up MOSFET based choppers
7. IGBT based single phase PWM inverter
8. IGBT based three phase PWM inverter
9. AC Voltage controller
10. Switched mode power converter.
11. Simulation of PE circuits (1Φ&3Φsemiconverter, 1Φ&3Φfullconverter, dc-dc Converters, ac voltage controllers).

TOTAL :45 Hours

CYCLE I

1. Gate Pulse Generation using R, RC and UJT.
2. Characteristics of SCR and Triac
3. Characteristics of MOSFET and IGBT
4. AC to DC half controlled converter
5. AC to DC fully controlled Converter
6. Step down and step up MOSFET based choppers

CYCLE II

7. IGBT based single phase PWM inverter
8. IGBT based three phase PWM inverter
9. AC Voltage controller
10. Switched mode power converter.
11. Simulation of PE circuits (1Φ&3Φsemiconverter, 1Φ&3Φfullconverter, dc-dc Converters, ac voltage controllers).

INDEX

S. No.	DATE	NAME OF THE EXPERIMENT	SIGNATURE	REMARKS
1		Gate Pulse Generation using R, RC and UJT		
2		Characteristics of SCR		
3		Characteristics of Triac		
4		Characteristics of MOSFET and IGBT		
5		AC to DC half controlled converter		
6		AC to DC fully controlled Converter		
7		Step down and step up MOSFET based choppers		
8		IGBT based single phase PWM inverter		
9		IGBT based three phase PWM inverter		
10		AC Voltage controller		
11		Switched mode power converter		
12		Simulation of Single Phase semi converter		
13		Simulation of Single Phase Full Converter		
14		Simulation of Single Phase AC Voltage Control Using TRIAC		
15		Simulation of DC-DC Converter		
16		Simulation of Three Phase Converter		

General Instructions to students

- Be punctual to the lab class.
- Attend the laboratory classes wearing the prescribed uniform and shoes.
- Avoid wearing any metallic rings, straps or bangles as they are likely to prove dangerous at times.
- Girls should put their plait inside their overcoat
- Boys students should tuck in their uniform to avoid the loose cloth getting into contact with rotating machines.
- Acquire a good knowledge of the surrounding of your worktable. Know where the various live points are situated in your table.
- In case of any unwanted things happening, immediately switch off the mains in the worktable.
- This must be done when there is a power break during the experiment being carried out.
- Before entering into the lab class, **you must be well prepared for the experiment** that you are going to do on that day.
- You must bring the related text book which may deal with the relevant experiment.
- Get the circuit diagram approved.
- Prepare the list of equipments and components required for the experiment and get the indent approved.
- Plan well the disposition of the various equipments on the worktable so that the experiment can be carried out.
- **Make connections as per the approved circuit diagram and get the same verified. After getting the approval only supply must be switched on.**
- For the purpose of speed measurement in rotating machines, keep the tachometer in the extended shaft. Avoid using the brake drum side.
- Get the reading verified. Then inform the technician so that supply to the worktable can be switched off.
- You must get the observation note corrected within two days from the DATE of completion of experiment. Write the answer for all the discussion questions in the observation note. If not, marks for concerned observation will be proportionately reduced.
- Submit the record note book for the experiment completed in the next class.
- If you miss any practical class due to unavoidable reasons, intimate the staff in charge and do the missed experiment in the repetition class.
- Such of those students who fail to put in a minimum of 75% attendance in the laboratory class will run the risk of not being allowed for the University Practical Examination. They will have to repeat the lab course in subsequent semester after paying prescribed fee.
- **Use isolated supply for the measuring instruments like CRO in Power Electronics and Drives Laboratory experiments.**

INTRODUCTION

Power electronics studies the application of semiconductor devices to the conversion and control of electrical energy. The field is driving an era of rapid change in all aspects of electrical energy. Power electronics is a broad area. Experts in the field find a need for knowledge in advanced circuit theory, electric power equipment, electromagnetic design, radiation, semiconductor physics and processing, analog and digital circuit design, control systems, and a tremendous range of sub-areas. Major applications addressed by power electronics include: Energy conversion for solar, wind, fuel cell, and other alternative resources. Advanced high-power low-voltage power supplies for computers and integrated electronics. Efficient low-power supplies for networks and portable products. Hardware to implement intelligent electricity grids, at all levels.

Power conversion needs and power controllers for aircraft, spacecraft, and marine use. Electronic controllers for motor drives and other industrial equipment. · Drives and chargers for electric and hybrid vehicles. · Uninterruptible power supplies for backup power or critical needs. High-voltage direct current transmission equipment and other power processing in utility systems. Small, highly efficient, switching power supplies for general use. Such a broad range of topics requires many years of training and experience in electrical engineering.

Power electronics is the application of solid-state electronics to the control and conversion of electric power. It also refers to a subject of research in electronic and electrical engineering which deals with the design, control, computation and integration of nonlinear, time-varying energy-processing electronic systems with fast dynamics.

The first high power electronic devices were mercury-arc valves. In modern systems the conversion is performed with semiconductor switching devices such as diodes, thyristors and transistors, pioneered by R. D. Middle brook and others beginning in the 1950s. In contrast to electronic systems concerned with transmission and processing of signals and data, in power electronics substantial amounts of electrical energy are processed. An AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices, e.g. television sets, personal computers, battery chargers, etc. The power range is typically from tens of watts to several hundred watts. In industry a common application is the variable speed drive (VSD) that is used to control an induction motor. The power range of VSDs start from a few hundred watts and end at tens of megawatts.

The power conversion systems can be classified according to the type of the input and output power

- AC to DC (rectifier)
- DC to AC (inverter)
- DC to DC (DC-to-DC converter)
- AC to AC (AC-to-AC converter)

The objectives of the Power Electronics Laboratory course are to provide working experience with the power electronics concepts presented in the power electronics lecture course, while giving students knowledge of the special measurement and design techniques of this subject. The goal is to give students a "running start," that can lead to a useful understanding of the field in one semester. The material allows students to design complete switching power supplies by the end of the semester, and prepares students to interact with power supply builders, designers, and customers in industry.

Power electronics can be defined as the area that deals with application of electronic devices for control and conversion of electric power. In particular, a power electronic circuit is intended to control or convert power at levels far above the device ratings. With this in mind, the situations encountered in the power electronics laboratory course will often be unusual in an electronics setting. Safety rules are important, both for the people involved and for the equipment. Semiconductor devices react very quickly to conditions -- and thus make excellent, expensive, "fuses."

Ex. No: 1 DATE:	SCR Gate Pulse Generation using R, RC and UJT

AIM:

To construct the R, RC &UJT triggering circuit for SCR and plot its output waveforms.

APPARATUS REQUIRED:

S.NO	APPARATUS	RANGE	TYPE	QUANTITY
1	SCR Triggering Trainer Kit		LT9007A	1
2	CRO	30MHz		1
3	Digital Multimeter			1
4	Patch Chords			10

PROCEDURE: (R-TRIGGERING)

1. Make the connections as per the circuit diagram.
2. Switch ON the trainer.
3. To find the Vgt (Gate Trigger Voltage) connect the CRO probe across the gate and cathode terminal.
4. If peak gate voltage Vg is less than Vgt, SCR will not turn on.
5. Further fine adjustment of firing angle makes the gate voltage to reach gate trigger voltage. (Vgt=Vg). Vgt = nearly 0.7V
6. Vary the potmeter and observe the output load waveform across the load.
7. To find the value α from output waveform.
8. Find time period (T in ms) and multiply with 18^0 which gives the α value.
9. To measure the R_2 value, remove the patching connections and measure across second end of R_1 and anode of the diode terminal.

PROCEDURE: (RC-TRIGGERING)

1. Make the connections as per the circuit diagram.
2. Switch on the trainer.
3. Observe the waveform across the load and SCR.
4. To find α using the following relationship. One full cycle of 50 Hz is 360^0.

5. 20ms = 360^0.For example, say 5ms is 5*18=90^0.

6. Theoretically α value can be found from the following relationship.

$$\alpha = (T_1 * 180^0) / \text{Half cycle}$$
$$\alpha = (T_1 * 180^0) / 10 \text{ ms}$$

Where,

T1 = RC

C= 1 uF

7. R is a variable resistance; this can be found from the terminals A and G. At the time of measuring the R values the patching connections should be removed.

8. Verify the theoretical value with practical value both more or less equal value.

9. Switch off trainer.

PROCEDURE: (UJT-Triggering)

1. Make the connections as per circuit diagram.
2. Switch On the trainer.
3. Observe the waveform across emitter with respect to ground.
4. To vary the firing angle vary the control pot and observe the output variation in load.
5. To observe the output waveform. Connect the CRO Probe across the load.
6. Find the α value theoretically using the relationship $T_1 = RC_1$.
   R value can be managed from the terminal provided in the front panel.
   The series resistance connected is 150Ω, C_1 = 1 uF.

$$\alpha = \omega T1 \ln(1/1 - \eta)$$
$$T1 = (R\ \text{measure} + R_1) * C_1$$

Where,

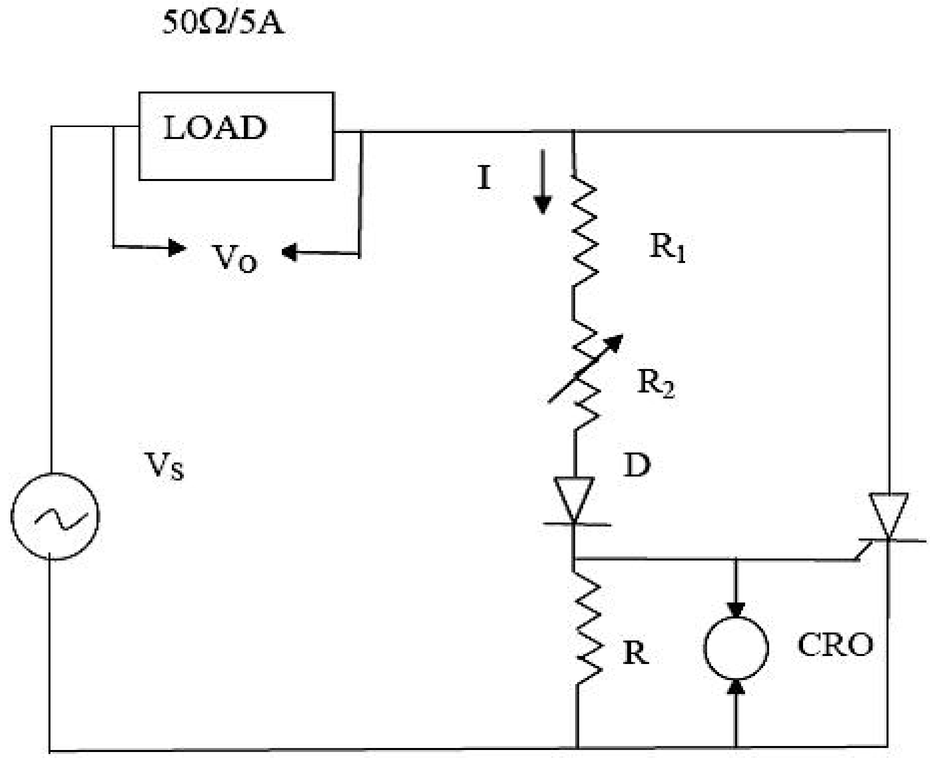
η = 0.72,

ω = 3 rad/sec

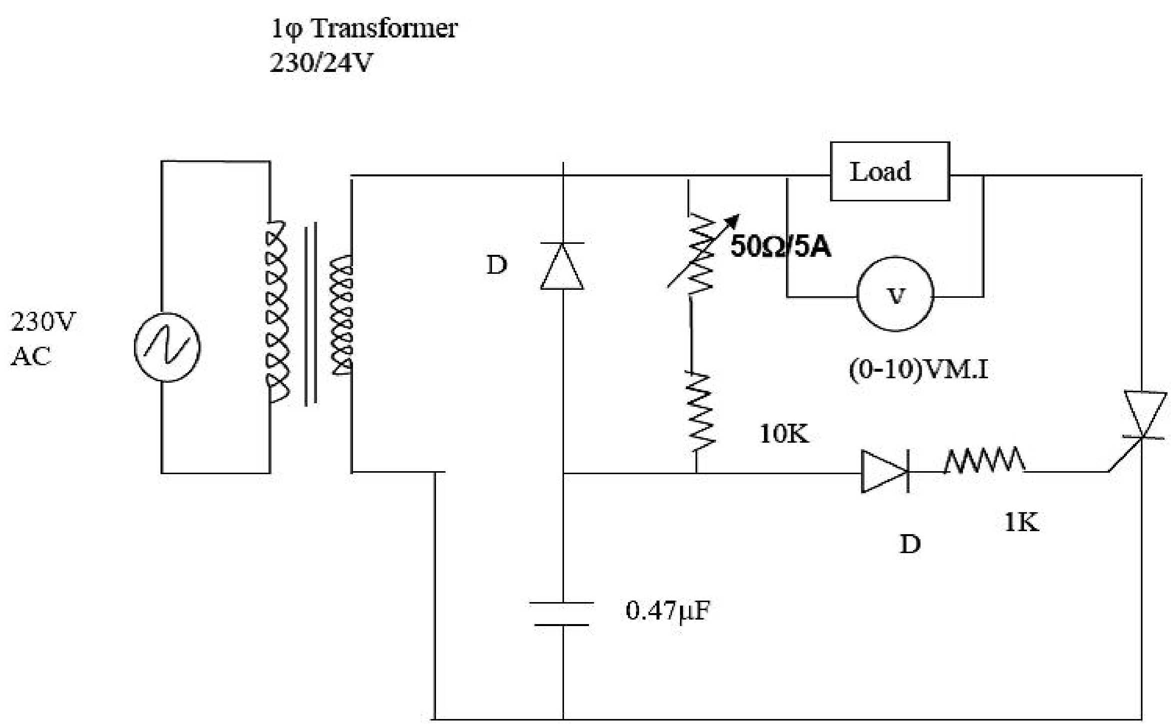
R1 = 150 Ω

7. Verify the theoretical value with the practical value.

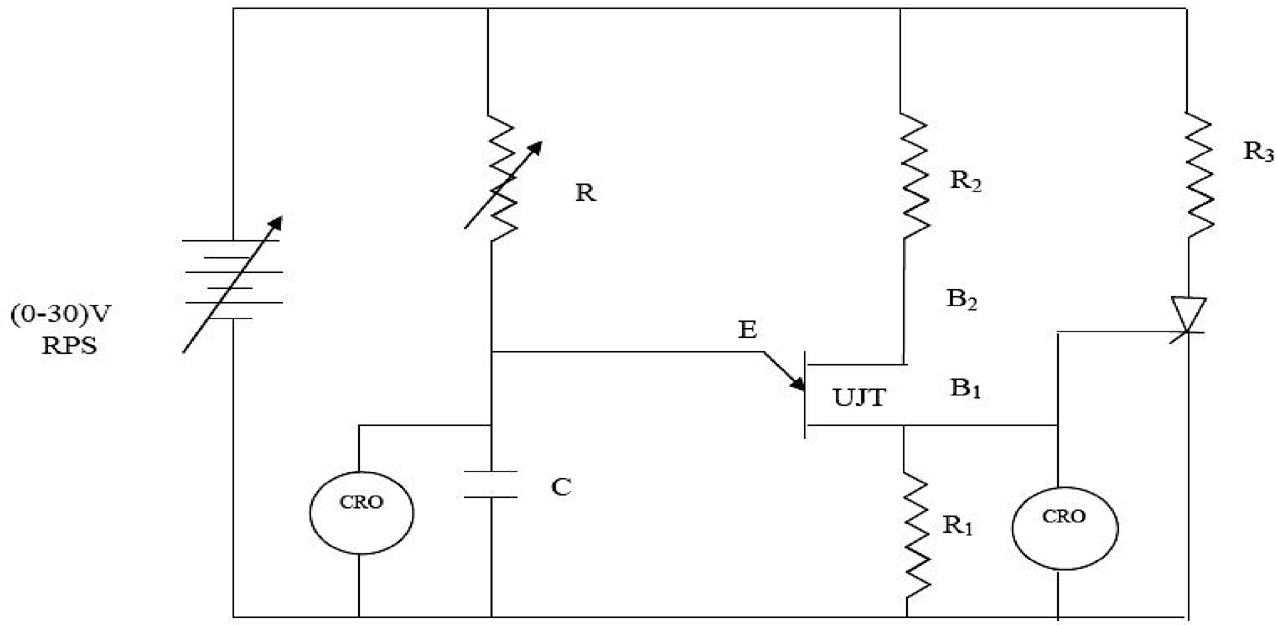
CIRCUIT DIAGRAM: (Resistance Firing Circuit)



CIRCUIT DIAGRAM: (RC-Triggering)



CIRCUIT DIAGRAM: (UJT-TRIGGERING)



TABULAR COLUMN: (R-Triggering)

SL. No	Resistance. (R2) *Ω*	Theoretical Firing angle(α) *Degree*	Practical Firing angle(α) *Degree*

Firing angle (α) = ————

Where,

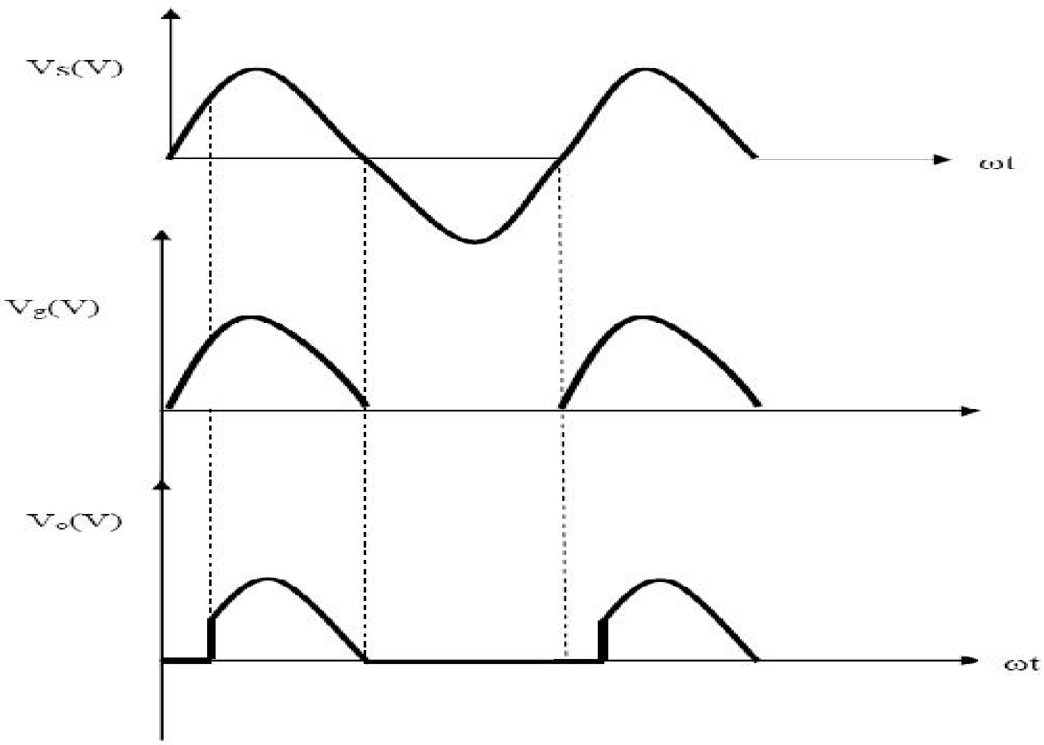
Vgt = 0.7 v

R1 = 1000 Ω

R = 220 Ω

Vm = – v

MODEL GRAPH (R-TRIGGERING) :



TABULATOR COLUMN: (RC-Triggering)

SL .No	T_1 = RC *ms*	α (Theoretical) *Degree*	Time Period from CRO *ms*	α (Practical) α = T * 180 *Degree*

Firing angle (α) = $\frac{T_1}{10\,ms} * 180^0$

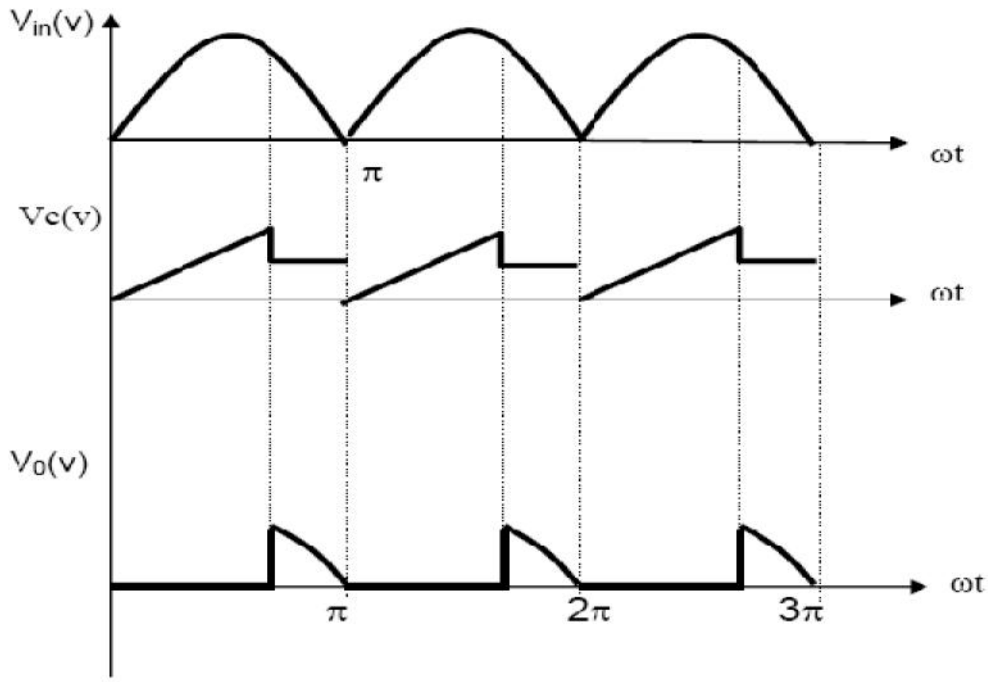
Where

T_1 = RC

R= 2000 Ω

C = 1 uF

MODEL GRAPH (RC-TRIGGERING):



TABULAR COLUMN: (UJT-Triggering)

S. No	**Time Period from CRO** *ms*	**$R = R_m + R_1$** *Ω*	**$T_1 = RC_1$** *ms*	**$\alpha_{the} = \omega T_1(1/1-\eta)$** *Degree*

Firing angle $(\alpha_{the}) = \omega T_1(1/1-\eta)$

Where

R_m =Measured Resistance in Ω

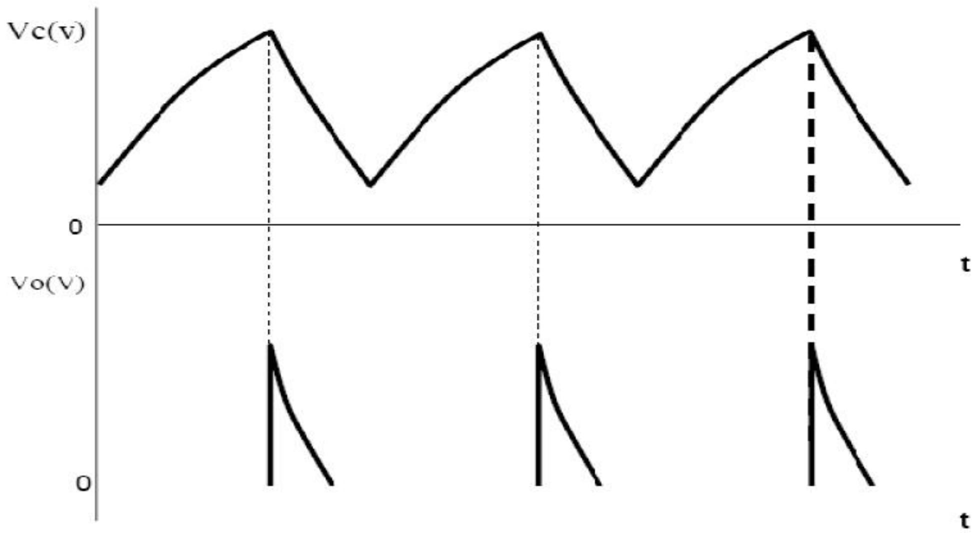
C_1 =Capacitance =1μF

R_1 =Resistance =150 Ω

η =Intrinsic standoff ratio =0.72

ω =Angular Frequency =3 Rad/sec

MODEL GRAPH (UJT-TRIGGERING) :



RESULT:

Thus the R, RC &UJT triggering circuit for SCR was studied and its output waveforms were plotted.

Ex. No: 2	CHARACTERISTICS OF SCR
DATE:	

AIM :

To determine the characteristics of SCR and to study the operation of Single Phase Single Pulse Converter using SCR.

APPARATUS REQUIRED:

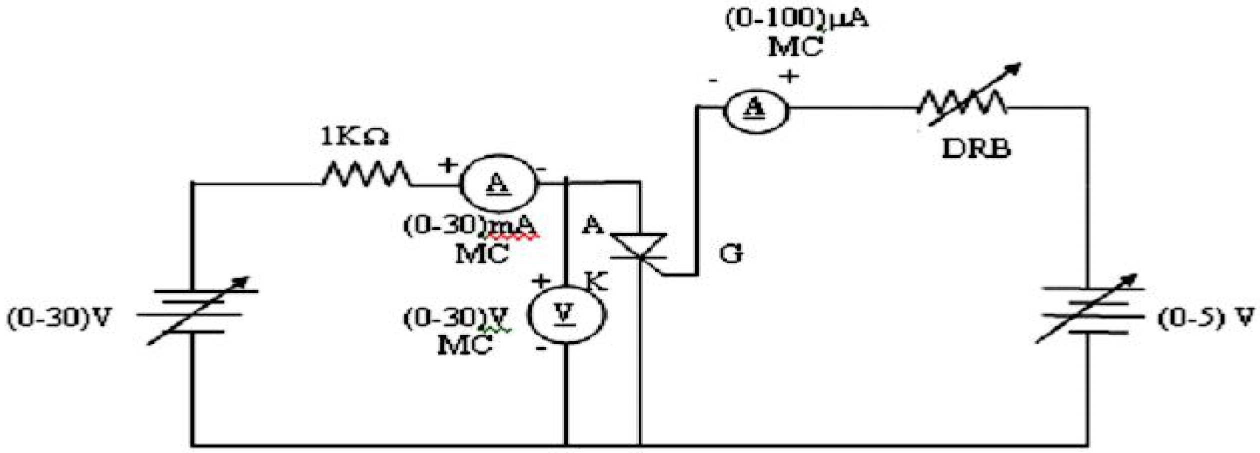
S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	SCR Characteristics Trainer Kit			1
2	Voltmeter	(0-30) V	MC	1
3	Ammeter	(0-30)mA	MC	1
4	Ammeter	(0-100)μA	MC	1
5	CRO	30 MHZ		1
6	Patch Chords			10

PROCEDURE:

To determine the Characteristics of SCR

1) Make the connections as per the circuit diagram.
2) Switch on the supply
3) Set the gate current (I_G) at a fixed value by varying RPS on the gate-cathode side.
4) Increase the voltage applied to anode-cathode side from zero until breakdown occurs.
5) Note down the breakdown voltage.
6) Draw the graph between anode to cathode voltage (V_{AK}) and anode current (I_A).

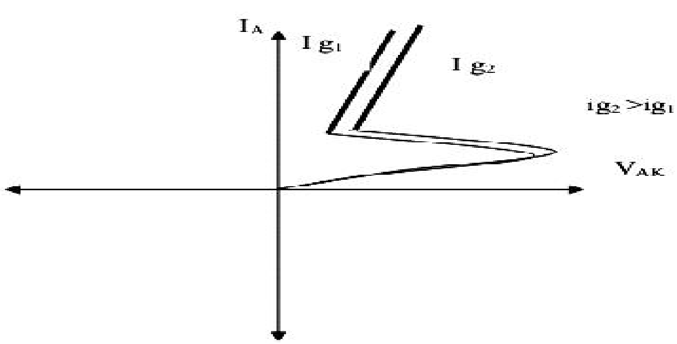
CIRCUIT DIAGRAM: (SCR)

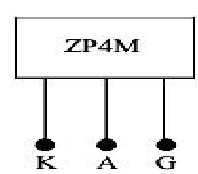


TABULAR COLUMN: (SCR)

S. No.	**IG____________** *µA*		**IG =_________** *µA*	
	V_{AK} *V*	**I_A** *mA*	**V_{AK}** *V*	**I_A** *mA*

MODEL GRAPH: (SCR) **Pin configuration**





RESULT:

Thus the Characteristics of SCR and the Output waveforms were obtained.

Ex. No: 3	CHARACTERISTICS OF TRIAC
DATE:	

AIM :

To determine the characteristics of TRIAC.

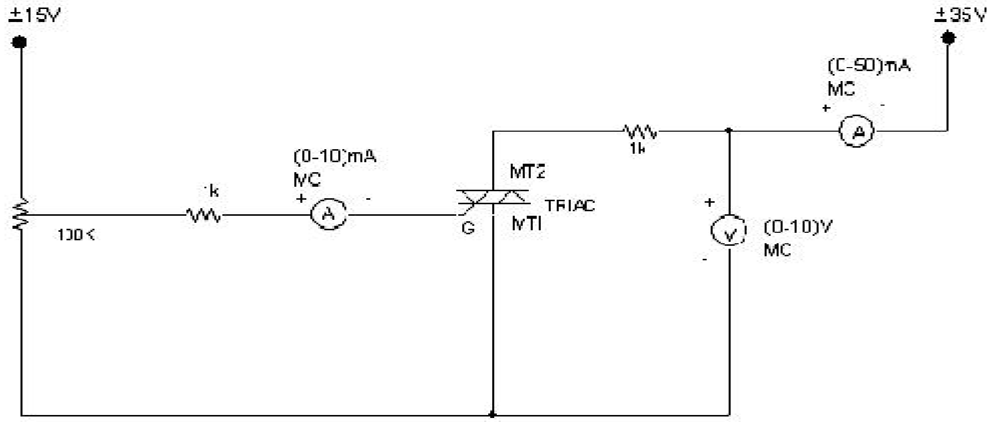
APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	TRIAC Characteristics Trainer Kit		LT-9002	1
2	Voltmeter	(0-30) V	MC	1
3	Ammeter	(0-30)mA	MC	1
4	Ammeter	(0-50)mA	MC	1
5	CRO	30 MHZ		1
6	Patch Chords			10

PROCEDURE:

1. Make the connections as per the circuit diagram.
2. Switch on the supply.
3. Set the gate current (I_G) at a fixed value by varying RPS on the gate- cathode side.
4. Increase the voltage applied across anode and corresponding current is noted.
5. The above steps are repeated for different values of IG.
6. Draw the graph between anode to cathode voltage (V_{MT2}) and anode Current (I_{MT2}).

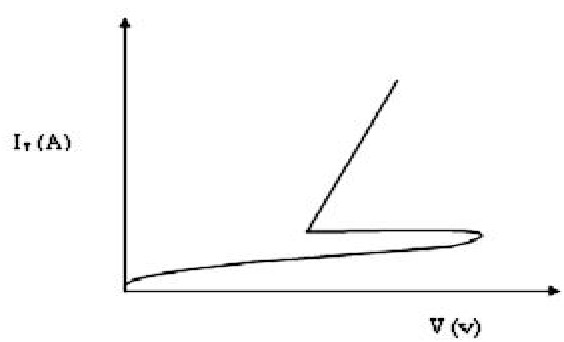
CIRCUIT DIAGRAM: (TRIAC)



TABULAR COLUMN: (TRIAC)

S. No.	IG__________ *μA*		IG__________ *μA*	
	V_{MT2} *V*	I_{MT2} *mA*	V_{MT2} *V*	I_{MT2} *mA*

MODEL GRAPH: (Triac)



RESULT:

Thus the Characteristics of TRIAC was obtained.

Ex. No: 4	CHARACTERISTICS OF MOSFET & IGBT
DATE:	

AIM :

To determine the characteristics of MOSFET & IGBT.

APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	MOSFET Characteristics Trainer Kit		LT-9002	1
2	IGBT Characteristics Trainer Kit			1
3	Voltmeter	(0-5) V	MC	1
4	Voltmeter	(0-30) V	MC	1
5	Ammeter	(0-5)mA	MC	1
6	CRO	30 MHZ		1
7	Patch Chords			10

PROCEDURE: (MOSFET CHARACTERISTICS)

Drain characteristics:

1. Make the connection as per circuit diagram
2. Switch on the trainer
3. Gate- Source voltage (V_{GS}) is kept at constant value by varying the gate bias voltage
4. Now slowly increase Drain- Source voltage (V_{DS}) till MOSFET get turned on with the indication that drain- source voltage decreases to it on state voltage drop
5. During this turn on period the load current is increased to higher value (28mA) and load voltage is decreased to a minimum value (1V)
6. Note down the values of Drain – Source voltage (V_{DS}) and drain current (I_D)
7. For various Gate- Source voltage (V_{GS}) take the different set of readings and tabulate it
8. Plot the graph between Drain- Source voltage (V_{DS}) and Drain current (I_D) for various gate voltage

TRANSFER CHARACTERISTICS: (MOSFET)

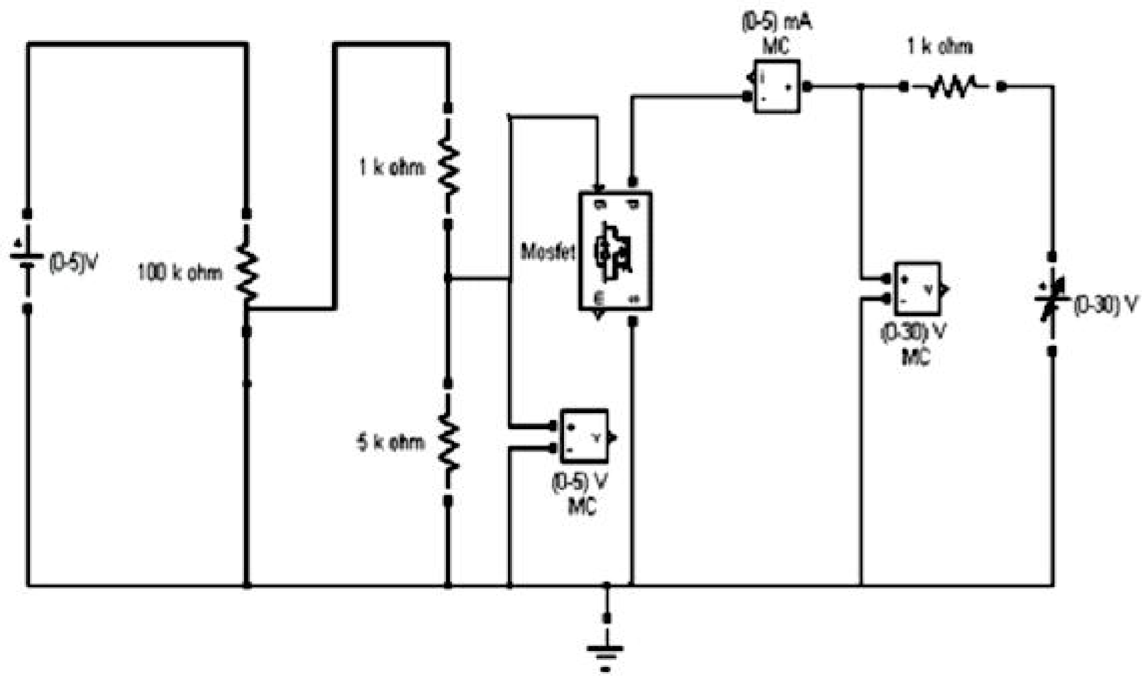
1. Make the connection as per circuit diagram
2. Switch on the trainer
3. Drain- Source voltage (VDS) is kept constant value by varying the variable DC supply
4. Now slowly increase Gate- Source voltage (VGS) till MPOSFET get turned on with the indication that drain current getting constant.
5. During this turn on period the current is increased to higher value (28mA) and load voltage is decrease to a minimum value (1V)
6. During this turn OFF period the load current is minimum and load voltage is increased to minimum value
7. Note down the value of Gate- Source voltage (VGS) and Drain current I_D
8. For various Gate- Source voltage (VGS) take the different set of readings and tabulate it.
9. Plot the graph between Gate- Source voltage (VGS) and drain current ((I_D) for various drain voltages.

PROCEDURE: (IGBTCHARACTERISTICS)

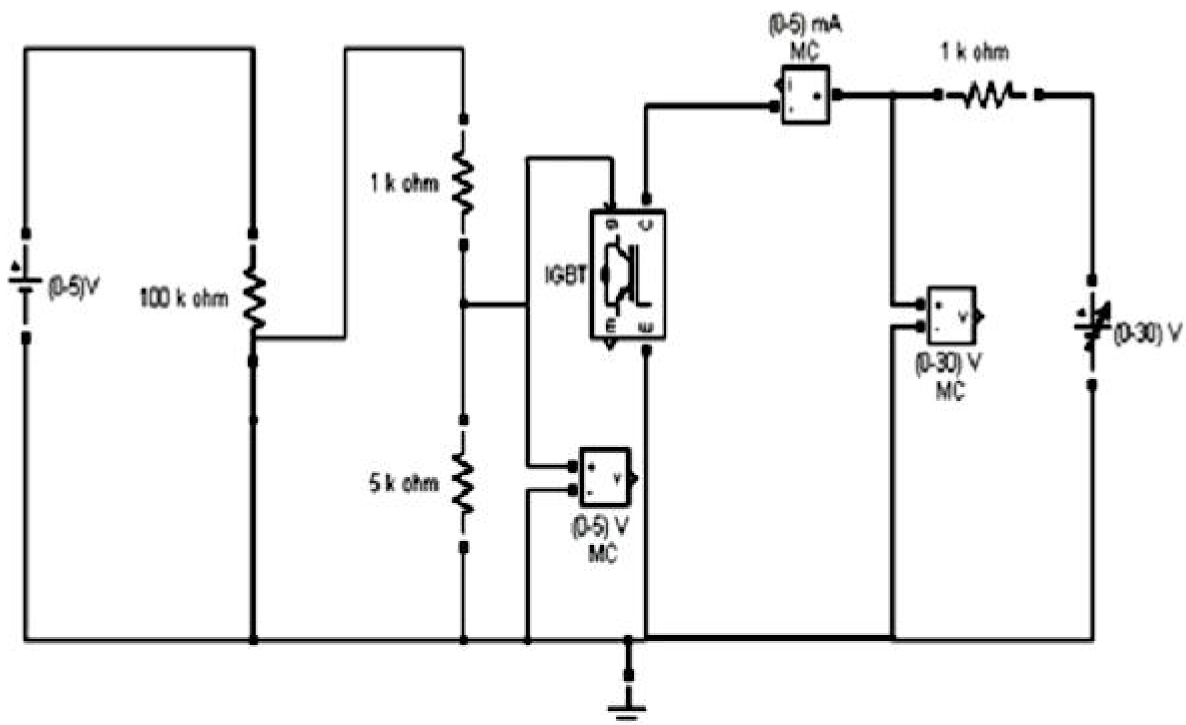
Transfer Characteristics (IGBT)

1. Make the connection as per circuit diagram.
2. Connect the external (0-10V)DC meter to measure the gate voltage.
3. Connect the external (0-300 mA) DC,(0-30V) DC meter to measure the load current and load voltage.
4. Keep the gate bias voltage potmeter in minimum position. Also maintain the load voltage as in maximum.
5. Switch on the trainer.
6. Increase the gate voltage to 1V.
7. Vary the load voltage from minimum to maximum value.
8. Observe the load current and load voltage. The gate threshold voltage of IGBT is 2.5V.When Vge is less than the threshold voltage the IGBT will not turn on. Therefore collector current Ic is zero.
9. Slowly increase the gate voltage Vge simultaneously. Observe the load current (collector current Ic).
10. Further increasing of Vge at one particular voltage, the Ic will flow suddenly to a high value which is called threshold voltage $V_{GET.}$

\CIRCUIT DIAGRAM :(MOSFET)



CIRCUIT DIAGRAM :(IGBT)



TABULAR COLUMN (MOSFET):

Transfer Characteristics:

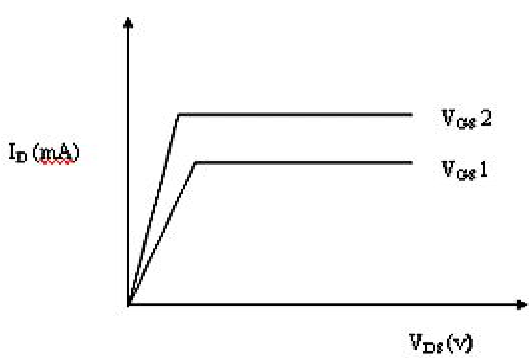
S. No.	V_{DS1}= -------------*V*	
	V_{GS} *mV*	I_D *mA*

Drain Characteristics:

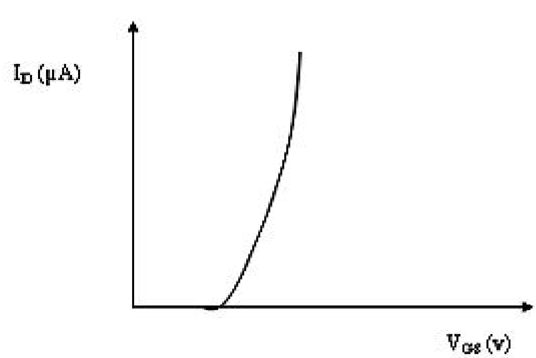
S. No	V_{GS1} = ------------*V*	
	V_{DS} *mV*	I_D *mA*

MODEL GRAPH (MOSFET):

Transfer Characteristics



Drain Characteristics



TABULAR COLUMN (IGBT)

Transfer Characteristics:

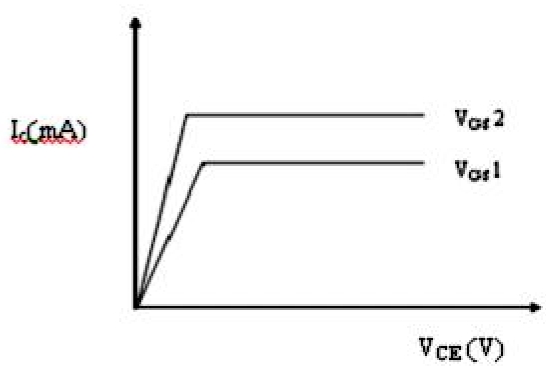
S. No.	V_{GE} = ------------- *V*		V_{GE} = ------------ *V*	
	V_{CE} *mV*	I_C *mA*	V_{CE} *mV*	I_C *mA*

Drain Characteristics:

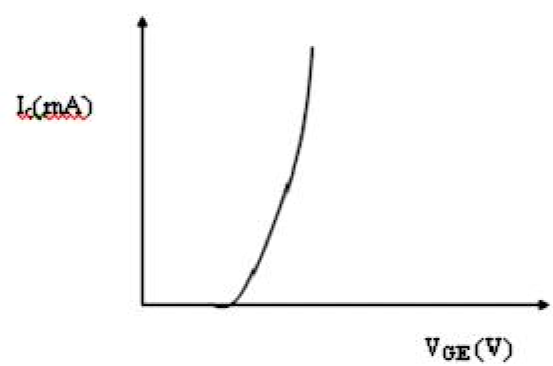
S. No	V_{CE} = -------------- *V*	
	V_{GE} *mV*	I_C *mA*

MODEL GRAPH (IGBT):

V-I Characteristics



Transfer Characteristics



V-I Characteristics (IGBT)

1. Make the connection as per circuit diagram.
2. Connect the external (0-10V) DC meter to measure the gate voltage.
3. Connect the external (0-300 mA) DC, (0-30V) DC meter to measure the load current and load voltage.
4. Keep the gate bias voltage and load voltage as minimum.
5. Switch on the trainer.
6. Set the gate bias voltage V_{GE} to threshold value.
7. Now slowly increase the collector emitter voltage V_{GE} (Load voltage).
8. For each increment of V_{CE} note down the collector current. At one particular value of V_{CE} I_C remains constant value further increasing of $V_{CE.}$
9. Decrease the load voltage V_{CE} to minimum value and set the (V_{GE}) gate bias to very small increment of threshold.
10. Repeat the above experiment note down the I_C and $V_{CE.}$
11. Plot the VI characteristics of given IGBT was placed at different $V_{GE.}$

RESULT:

Thus the Characteristics of MOSFET & IGBT were obtained.

Ex. No: 5	AC TO DC HALF CONTROLLED CONVERTER
DATE:	

AIM:

To construct a single phase half controlled Converter and plot its output response.

APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	Single Phase Half Controlled Bridge Rectifier Trainer Kit		LT-9021B	1
2	Digital Multimeter			1
3	CRO	30 MHZ		1
4	Patch Chords			10

FORMULA:

$$V_{O\,(avg)} = \frac{V_m}{\pi}(1+\cos\alpha),$$

$$V_m = \sqrt{2}\ V_s$$

Where,

Vs - RMS voltage *(V)*,

Vo $_{(avg)}$ - Average output voltage *(V)*,

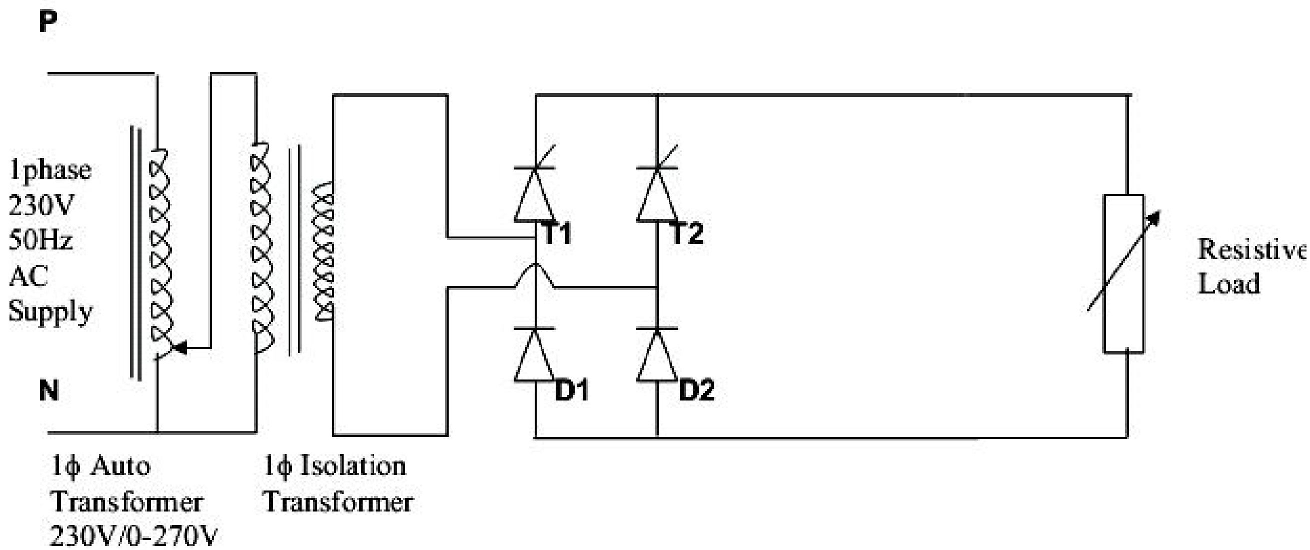
V m - Maximum peak voltage *(V)*,

α - Firing angle *(degree)*.

PROCEDURE:

1. Make the connections as per the circuit diagram.
2. Keep the multiplication factor of the CRO’s probe at the maximum position.
3. Switch on the thyristor kit.
4. Keep the firing circuit knob at the 180 °position.
5. Vary the firing angle in steps.
6. Note down the voltmeter r reading and waveform from the CRO.
7. Switch off the power supply and disconnect.

CIRCUIT DIAGRAM: (AC to DC Half Controlled Converter)



TABULATOR COLUMN: (AC to DC Half Controlled Converter)

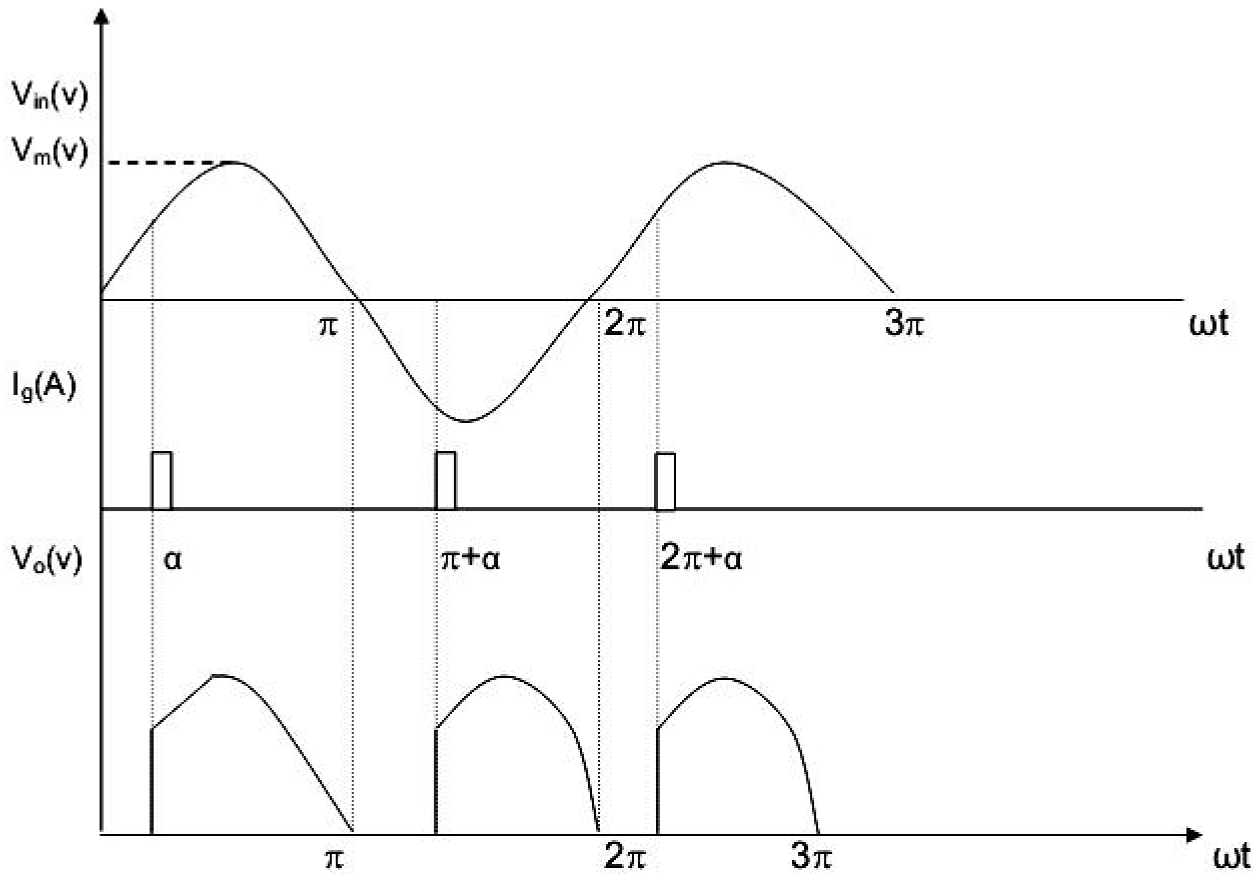
V_{in}=____________ *V*

S. No.	**Firing Angle** (α) *Degree*	**Time Period (T)** *ms*		**Output Voltage (Vo)** *V*	
		T_{ON}	**T_{OFF}**	**Practical**	**Theoretical**

$$T = T_{ON} + T_{OFF}$$

$$\alpha = 360^0 * T_{ON} / T$$

MODEL GRAPH: (AC to DC Half Controlled Converter)



RESULT:

Thus a single-phase half controlled converter was constructed and their Output waveforms were plotted.

Ex. No :6	AC TO DC FULLY CONTROLLED CONVERTER
DATE:	

AIM:

To construct a single phase fully controlled Converter and plot its response.

APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	Single Phase Fully Controlled Bridge Rectifier Trainer Kit		LT-9020B	1
2	Digital Multimeter			1
3	CRO	30 MHZ		1
4	Patch Chords			10

FORMULA :

$$V_{O\,(avg)} = \frac{2V_m}{\pi}(1+\cos\alpha),$$

Where,

V_s - Rms voltage (V),

$V_{o(avg)}$ - Average output voltage (V),

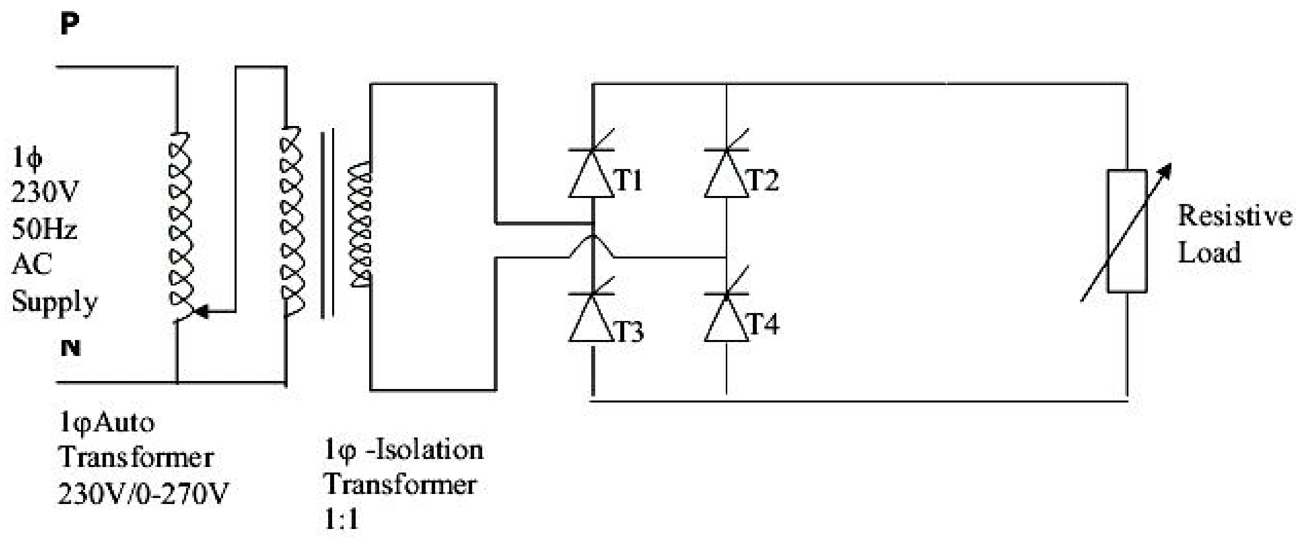
V_m - Maximum peak voltage (V),

α - Firing angle (degree).

PROCEDURE:

1. Make the connections as per the circuit diagram.
2. Keep the multiplication factor of the CRO's probe at the maximum position.
3. Switch on the thyristor kit and firing circuit kit.
4. Keep the firing circuit knob at the 180 ° position.
5. Vary the firing angle in steps.
6. Note down the voltmeter reading and waveform from the CRO.
7. Switch off the power supply and disconnect.

CIRCUIT DIAGRAM: (AC to DC Fully Controlled Converter)



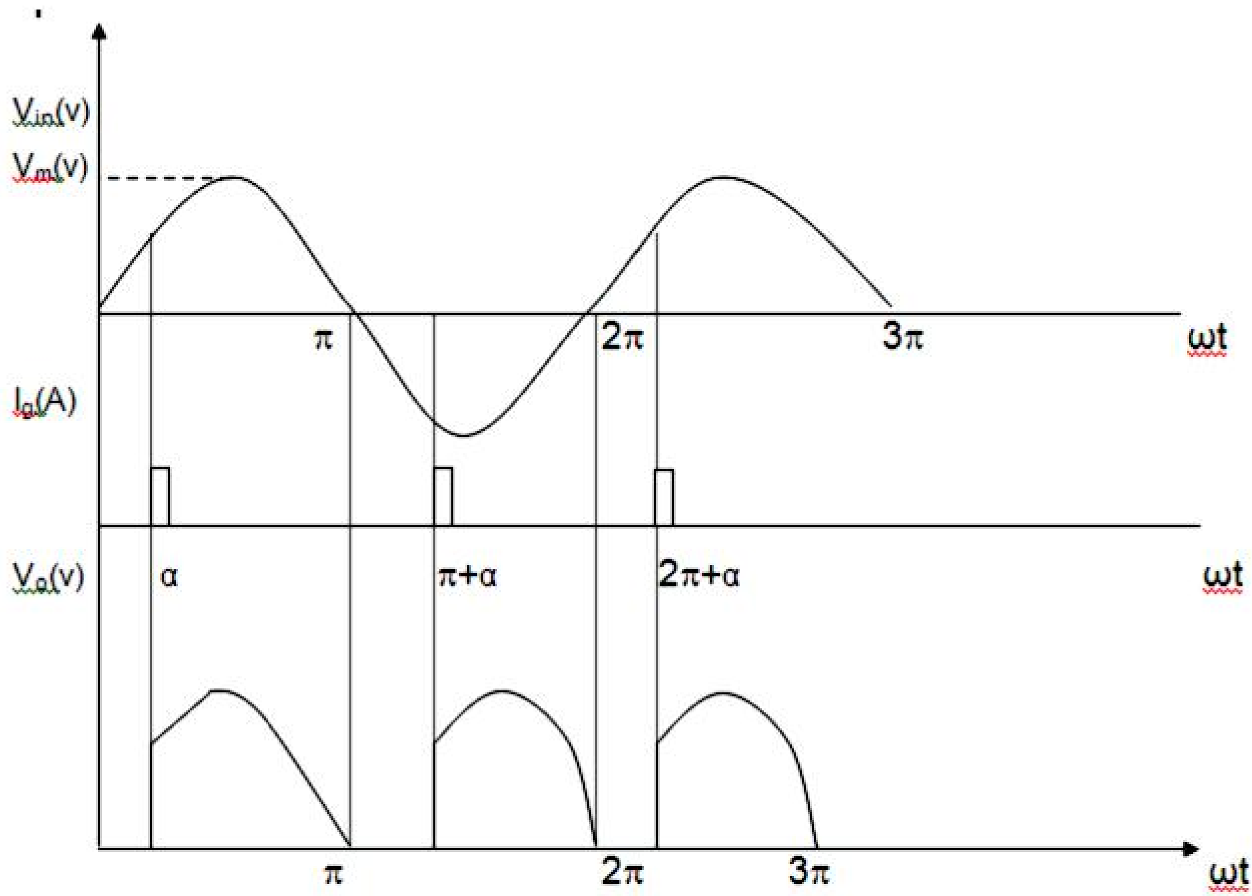
TABULAR COLUMN: (AC to DC Fully Controlled Converter)

V_{in}=____________ V

S. No.	**Firing Angle** (α) *Degree*	**Time Period (T)** *ms*		**Output Voltage (Vo)** *V*	
		T_{ON}	**T_{OFF}**	**Practical**	**Theoretical**

$$T = T_{ON} + T_{OFF}$$
$$\alpha = 360^0 * T_{ON} / T$$

MODEL GRAPH: (AC to DC Fully Controlled Converter)



RESULT:

Thus a single-phase fully controlled converter was constructed and their responses were plotted.

Ex. No : 7	STEP UP AND STEP DOWN MO SFET BASED CHOPPERS
DATE:	

AIM:

To construct Step down & Step up MOSFET based choppers and to draw its Output response.

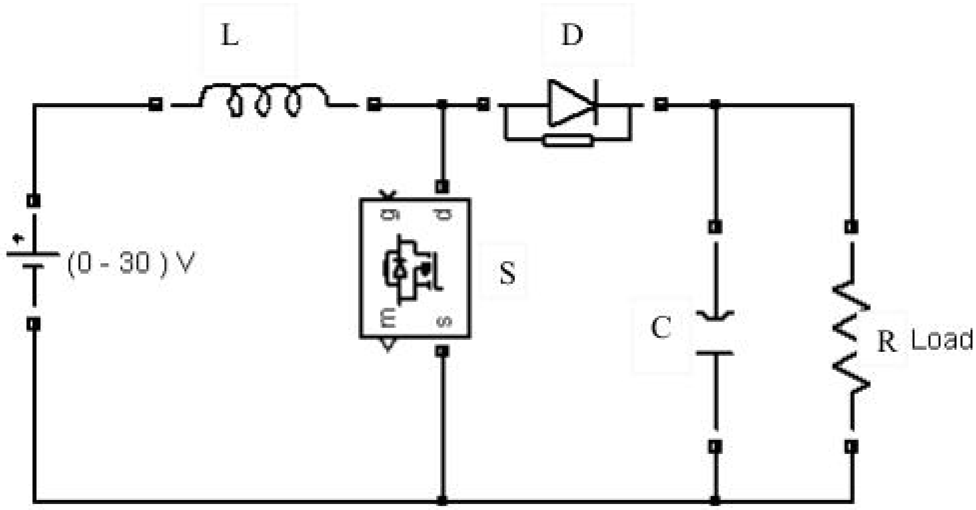
APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	Step up & Step down MOSFET based chopper kit		VSMPS-07A	1
2	Digital Multimeter			1
3	CRO	30 MHZ		1
4	Patch Chords			10

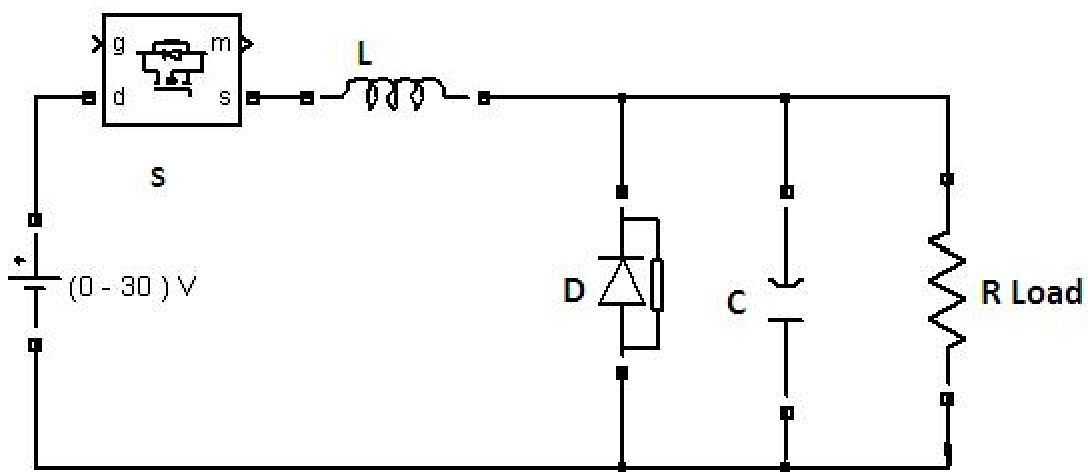
PROCEDURE (STEP UP CHOPPER & STEP DOWN CHOPPER) :

1. Initially keep all the switches in the OFF position
2. Initially keep duty cycle POT in minimum position
3. Connect banana connector 24V DC source to 24V DC input.
4. Connect the driver pulse [output to MOSFET input.
5. Switch on the main supply.
6. Check the test point wave forms with respect to ground.
7. Vary the duty cycle POT and tabulate the Ton, Toff & output voltage
8. Trace the waveforms of Vo Vs & Io.
9. Draw the graph for Vo Vs Duty cycle, K

CIRCUIT DIAGRAM: (Step Up Chopper)



CIRCUIT DIAGRAM: (Step Down Chopper)



TABULAR COLUMN: (Step up Chopper)

Vs = ____________ *V*

S.NO	T_{ON} *sec*	T_{OFF} *sec*	T *sec*	Duty Ratio, $k=T_{ON}/T$	Vo=Vs/(1-K) Theoretical *V*	Vo Practical *V*

$$T = T_{ON} + T_{OFF}$$

T_{ON} – On Time

T_{OFF} – Off Time

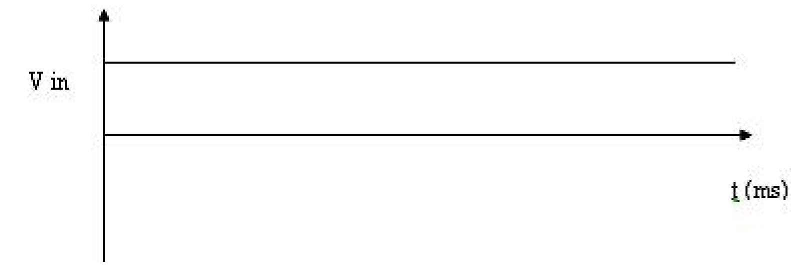
T – Total Time Peroid

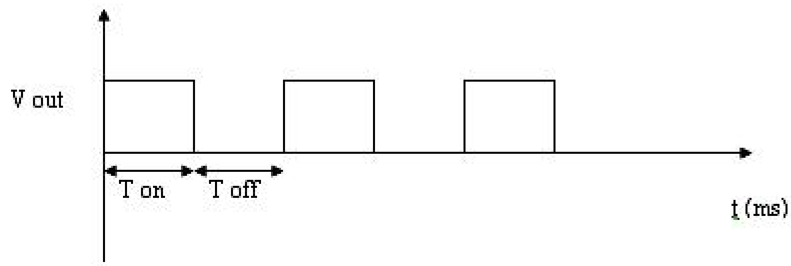
TABULAR COLUMN :(Step Down Chopper)

Vs = ____________ *V*

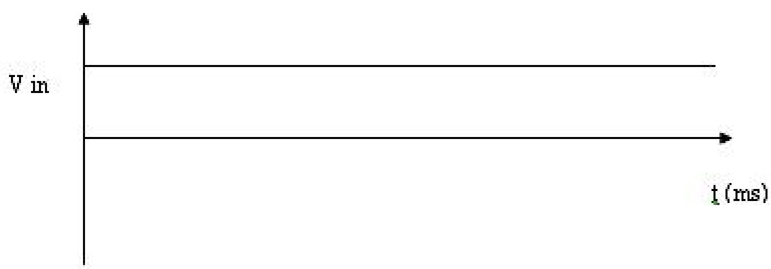
S.NO	T_{ON} *sec*	T_{OFF} *sec*	T *sec*	Duty Ratio, $k=T_{ON}/T$	Vo=KVs Theoretical *V*	Vo Practical *V*

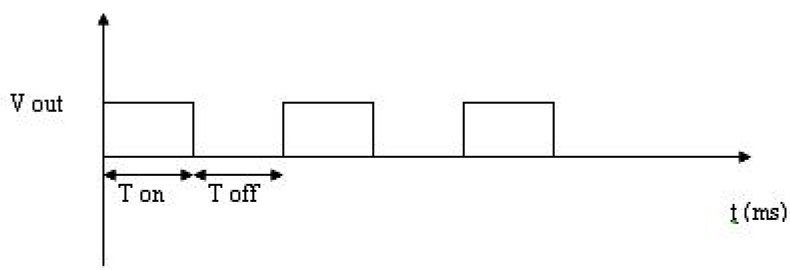
MODEL GRAPH :(Step Up Chopper)





MODEL GRAPH: (Step Down Chopper)





RESULT:

Thus the output response of Step down & Step up MOSFET based choppers were drawn.

CYCLE II

8. IGBT based single phase PWM inverter
9. IGBT based three phase PWM inverter
10. AC Voltage controller
11. Switched mode power converter.
12. Simulation of PE circuits (1 Φ&3Φ semi converter, 1 Φ&3Φfullconverter, dc-dc Converters, ac voltage controllers).

Ex. No : 8	**IGBT BASED SINGLE PHASE PWM INVERTER**
DATE:	

AIM:

To obtain Single phase output wave forms for IGBT based PWM inverter

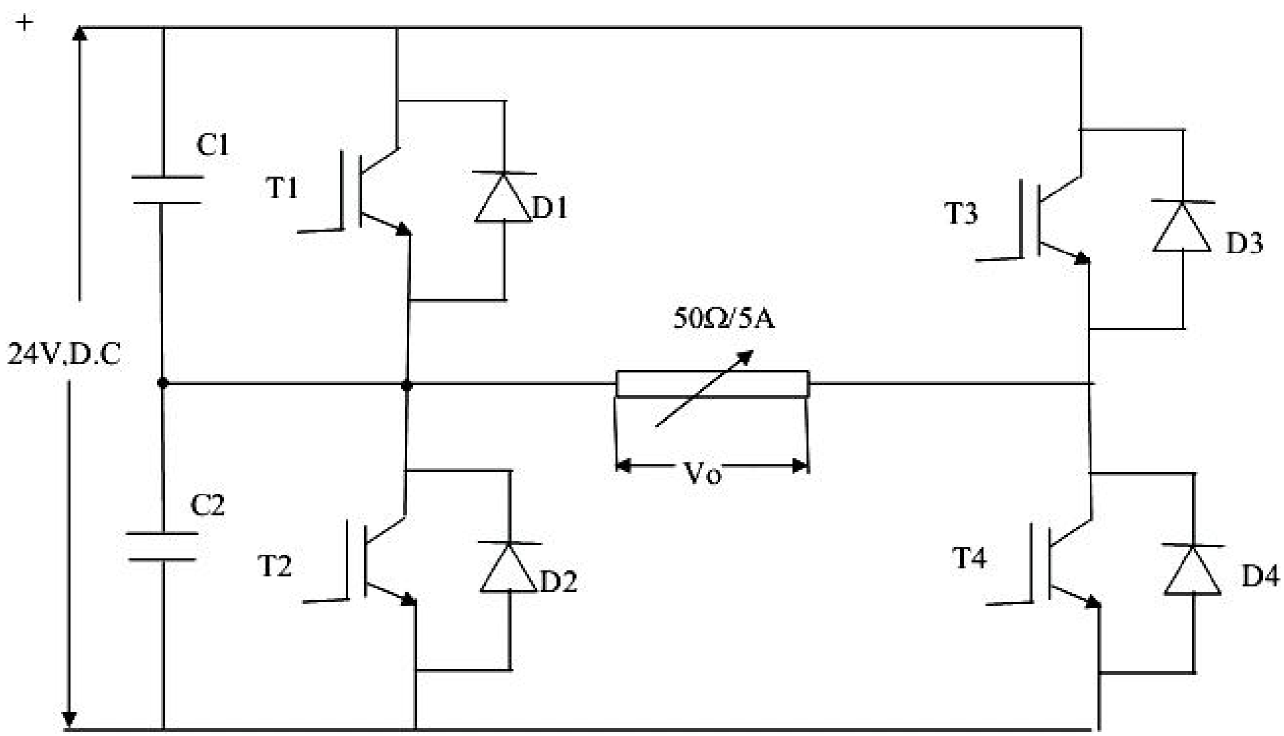
APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	IGBT Power Module Kit		PEC16M3	1
2	Single Phase PWM Inverter Control Module		PEC16M4#1	1
3	CRO	30 MHZ		1
4	Load Rheostat	100Ω/5A		1
5	Patch Chords			10

PROCEDURE:

1. Make the connection as per the circuit diagram.
2. Connect the gating signal from the inverter module.
3. Switch ON D.C 24 V.
4. Keep the frequency knob to particulars frequency.
5. Observe the rectangular and triangular carrier waveforms on the CRO.
6. Obtain the output waveform across the load Rheostat.

CIRCUIT DIAGRAM: (IGBT Based Single Phase PWM Inverter)



TABULAR COLUMN: (IGBT Based Single Phase PWM Inverter)

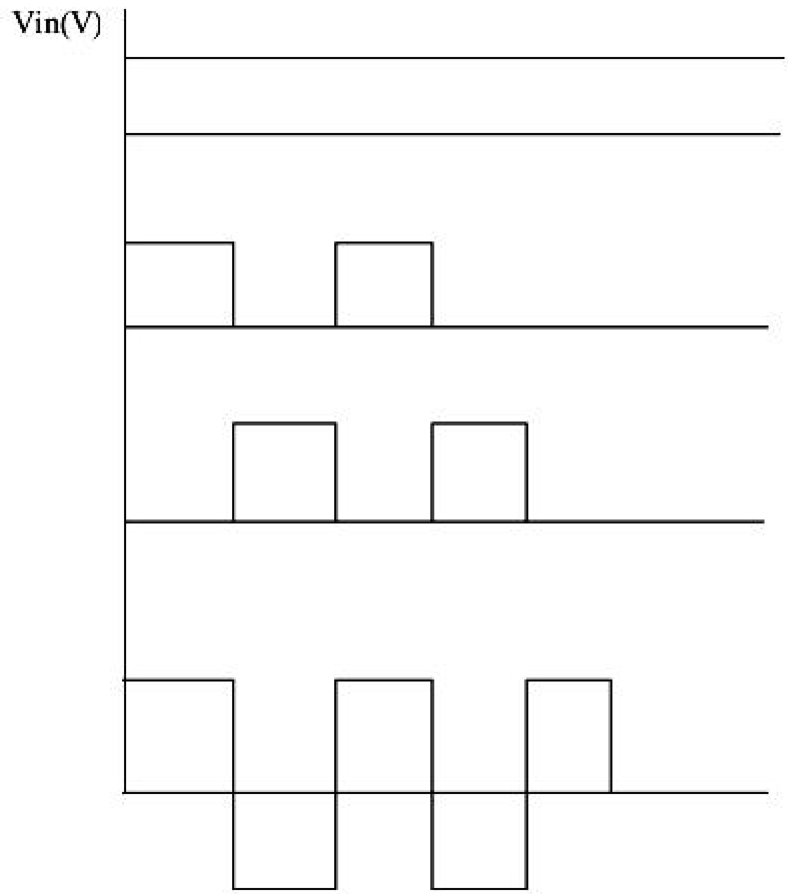
S.NO	Sine Wave Amplitude V	Carrier Wave Amplitude V	Modulation Index (MI)	Measured O/P Voltage V_O V	Calculated O/P Voltage V_O V

1) V_O =MI * V_{DC}

2) MI = ____________________

3) V_{DC} =Input DC Voltage

MODEL GRAPH: (IGBT Based Single Phase PWM Inverter)



RESULT:

Thus the output waveform for IGBT inverter (PWM) was obtained.

Ex. No: 9	**IGBT BASED THREE PHASE PWM INVERTER**
DATE:	

AIM:

To study the three phase inverter operation by using sine, trapezoidal square PWM.

APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	IGBT Power Module Kit		VPET-106A	1
2	Chopper/Inverter PWM Control Module		PEC16HV2B	1
3	CRO	30 MHZ		1
4	Patch Chords			10

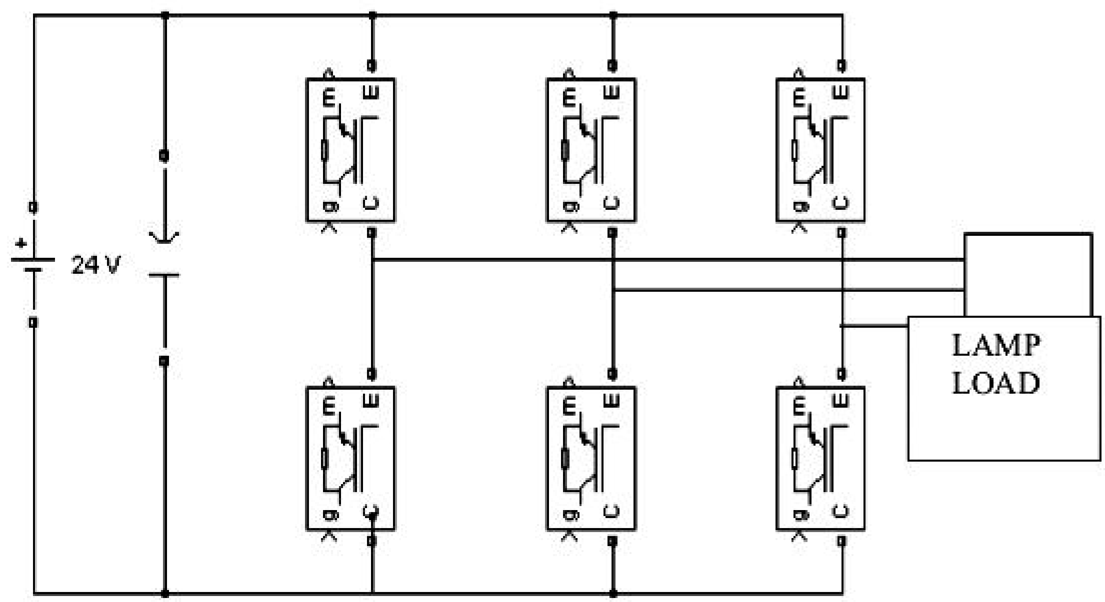
CONNECTION PROCEDURE:

1. Connect 1 Phase AC input supply to the power module.
2. Connect the power module and controller module to the supply mains.
3. Connect PWM output of the controller module to the PWM input of the power module using a 9 pin to 15 pin cable.
4. Connect the power module to R&L load.
5. Connect motor speed feedback cable to the motor feedback input of the controller module.

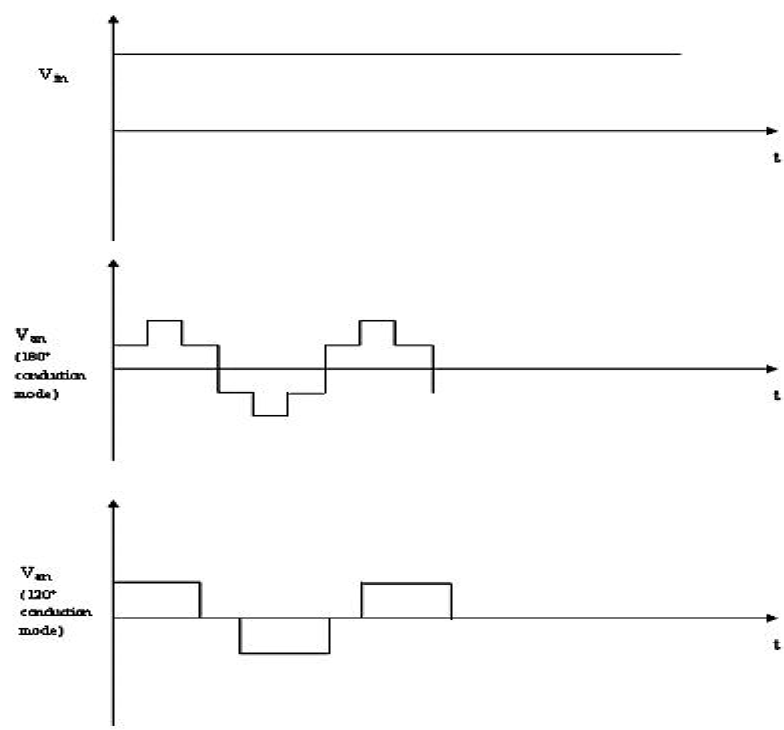
EXPERIMENTAL PROCEDURE:

1. Verify the connections as per the connection procedure.
2. Switch ON the power ON/OFF switch in both the IGBT based power module and the controller module.
3. Switch ON the MCB in the power module.
4. When the module is switched ON select 3 phase inverter by using decrement key.
5. Then select sine PWM by using increment switch.
6. Vary the frequency value by using increment and decrement key and vary the amplitude value by using enter key.
7. Repeat the above steps for trapezoidal PWM and square PWM.

<u>CIRCUIT DIAGRAM</u>: (IGBT Based Three Phase PWM Inverter)



<u>MODEL GRAPH:</u> (IGBT Based Three Phase PWM Inverter)



<u>RESULT:</u>

Thus the three phase inverter operation by using sine, trapezoidal and square wave is studied.

Ex. No:10	**SINGLE PHASE AC VOLTAGE CONTROLLER USING TRIAC**
DATE:	

AIM:

To study the Single phase AC voltage control using TRIAC with DIAC or UJT Firing Circuit.

APPARATUS REQUIRED:

S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	AC Regulator using SCR &TRIAC		LT-9025	1
2	CRO	30 MHZ		1
3	Patch Chords			10

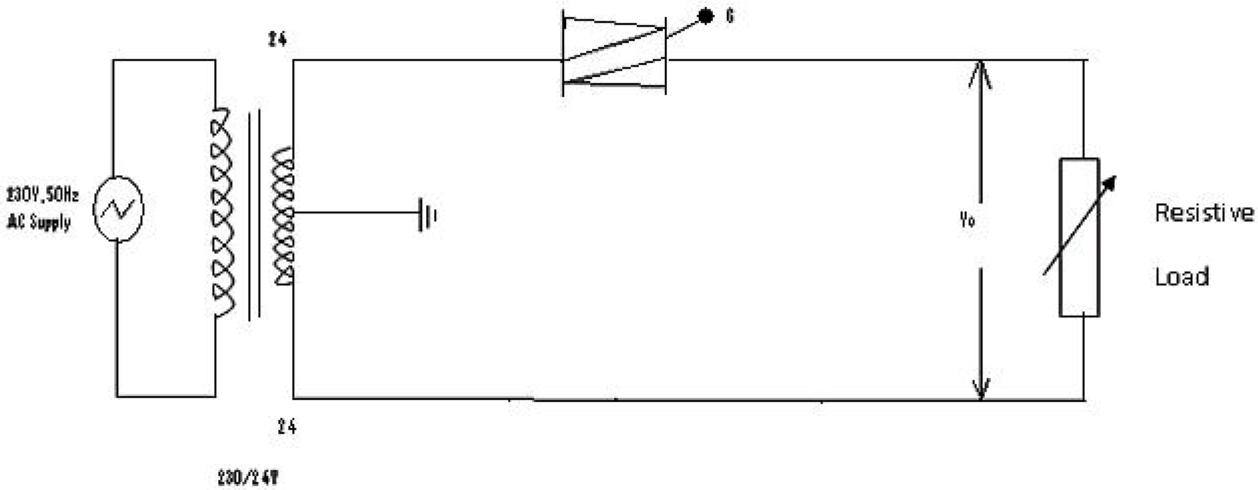
CIRCUIT OPERATION:

1. When potentiometer is in minimum position drop across potentiometer is zero and hence maximum voltage is available across capacitor. This Vc shorts the diac (Vc > Vbo) and triggers the triac turning triac to ON – state there lamp glows with Maximum intensity.
2. When the potentiometer is in maximum position voltage drop across Potentiometer is maximum. Hence minimum voltage is available across capacitor (Vc M Vbo) hence triac to is not triggered hence lamp does not glow.
3. When potentiometer is in medium position a small voltage is available across Capacitor hence lamp glows with minimum intensity.

PROCEDURE:

1. Connections are given as per the circuit diagram.
2. Keep ramp control potmeter in minimum position.
3. Switch ON the trainer.
4. Observe the variation in output voltage for different firing angles through voltmeter.
5. Calculate the output voltage theoretically.

CIRCUIT DIAGRAM: (Single Phase Ac Voltage Controller)



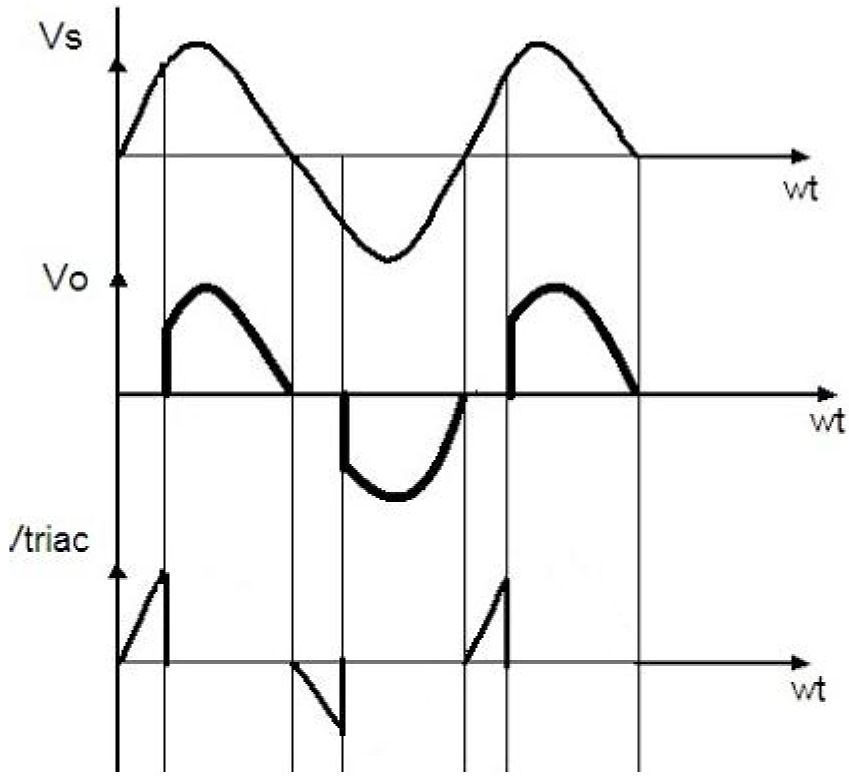
TABULAR COLUMN: (DIAC Firing Circuit)

S. No.	Firing Angle (α) *Degree*	Output Voltage (Theoretical) *V*	Output Voltage (Practical) *V*

Theoretical Output Voltage (V_O)

$$V_O = V_S\, [1/\pi\, (\pi - \alpha + (\sin 2\alpha)/2]^{1/2}$$

MODEL GRAPH: (_Single Phase Ac Voltage Controller)



RESULT:

Thus the operation and performance of t he single phase AC voltage control using TRIAC is done and output Verified

Ex. No:11	**SWITCHED MODE POWER CONVERTER**
DATE:	

AIM:

To study the switched mode power Converter and to plot its output waveforms.

APPARATUS REQUIRED:

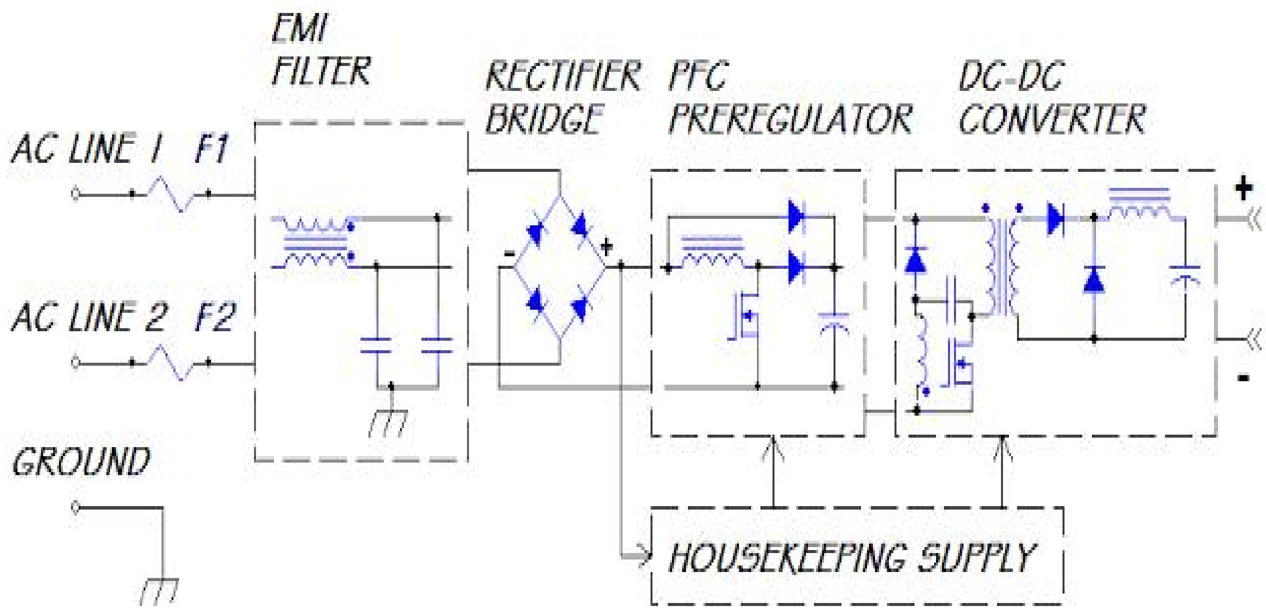
S. No.	APPARATUS	RANGE	TYPE	QUANTITY
1	Switched mode power converter kit			1
2	Lamp load			1
3	CRO	30 MHZ		1
4	Patch Chords			10

PROCEDURE:

1. Plug in the unit to AC mains 230V, 50Hz supply.
2. Switch ON the toggle switch. The neon lamp will glow indicating that the unit is ready.
3. LED in the AC source will be glowing indicating the availability of AC 20V.
4. Observe the trigger circuit waveforms.
5. Connect the AC source to the power circuit using patch chords.
6. Connect the lamp load with incandescent lamp of 36V.
7. Observe the load output for a chosen setting of duty cycle setting.
8. Output will be DC in the range of 0 to 40V.

.

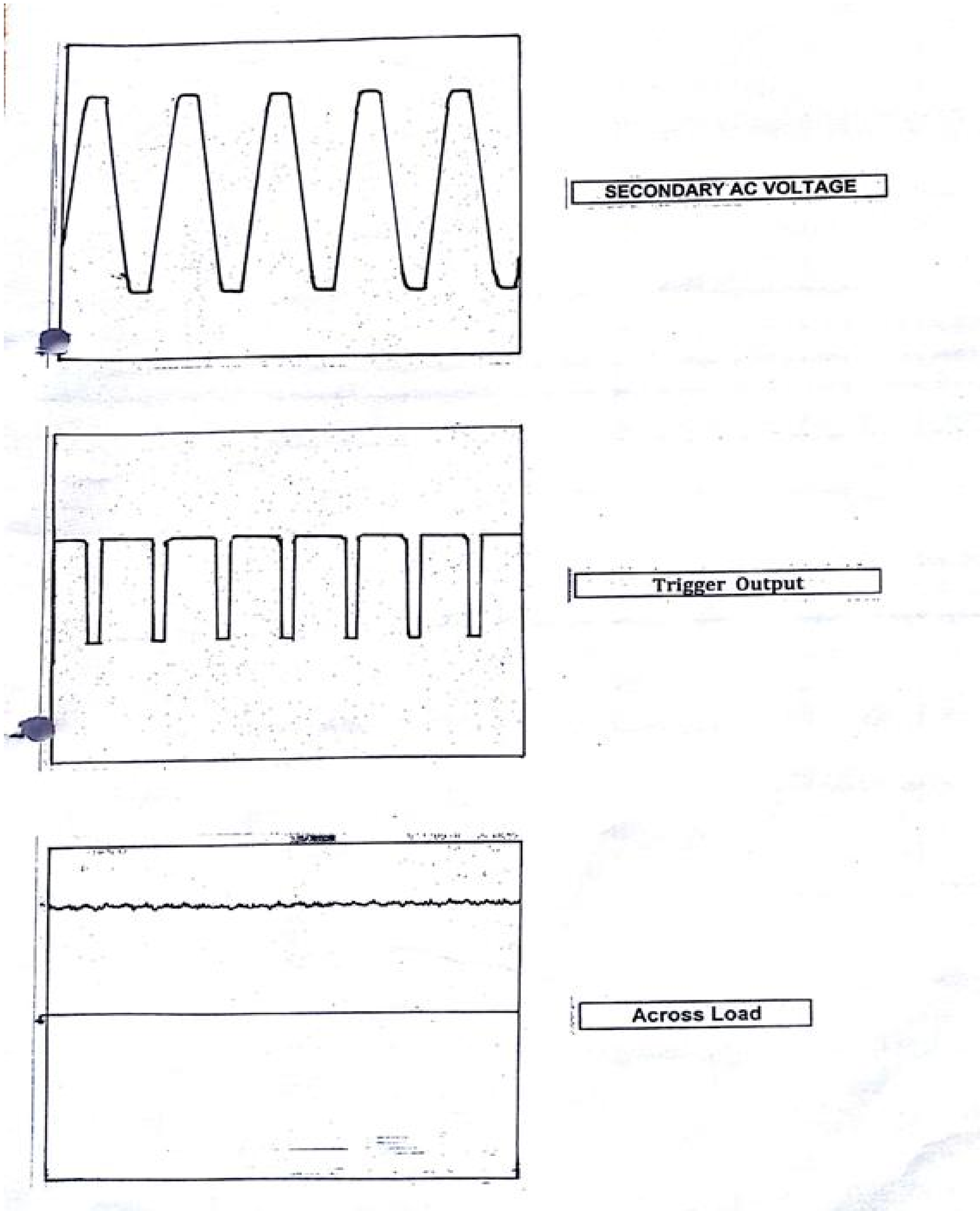
CIRCUIT DIAGRAM: (Switched Mode Power Converter)



TABULAR COLUMN: (Switched Mode Power Converter)

S. No.	Input Voltage (V_{in}) *V*	Output Voltage (V_{out}) *V*

SMPS Output Waveforms:



RESULT:

Thus a Switched mode power converter was studied and its output waveforms are plotted.

SIMULATION OF POWER ELECTRONICS CIRCUITS

STUDY OF BASIC MATLAB COMMANDS:

The name MATLAB stands for MATRIX LABORATORY. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation. It has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in MATHEMATICS, ENGINEERING AND SCIENCE. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include,

Math and computation

Algorithm development

Data acquisition Modeling, simulation, and prototyping

Data analysis, exploration, and visualization Scientific and engineering graphics

Application development, including graphical user interface building.

It is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN. It also features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

Ex. No:12	**SIMULATION OF SINGLE PHASE SEMI CONVERTER**
DATE:	

AIM:

To simulate single Phase Semi Converter circuit with R load in MATLAB - Simulink.

APPARATUS REQUIRED:

A PC with MATLAB package.

THEORY:

A semi converter uses two diodes and two thyristors and there is a limited control over the level of dc output voltage. A semi converter is one quadrant converter. A one-quadrant converter has same polarity of dc output voltage and current at its output terminals and it is always positive. It is also known as two - pulse converter. Figure shows half controlled rectifier with R load. This circuit consists of two SCRs T1 and T2, two diodes D1 and D2. During the positive half cycle of the ac supply, SCR T1 and diode D2 are forward biased when the SC R T1 is triggered at a firing angle $\omega t = \alpha$, the SCR T1 and diode D2 comes to the on state. Now the load current flows through the Path L - T1- R load –D2 - N. During this period, the output voltage and current are positive. At $\omega t = \pi$, the load voltage and load current reaches to zero, then SCR T1 and diode D2 comes to off state since supply voltage has been reversed. During the negative half cycle of the ac supply, SCR T2 and diode D1 are forward biased.

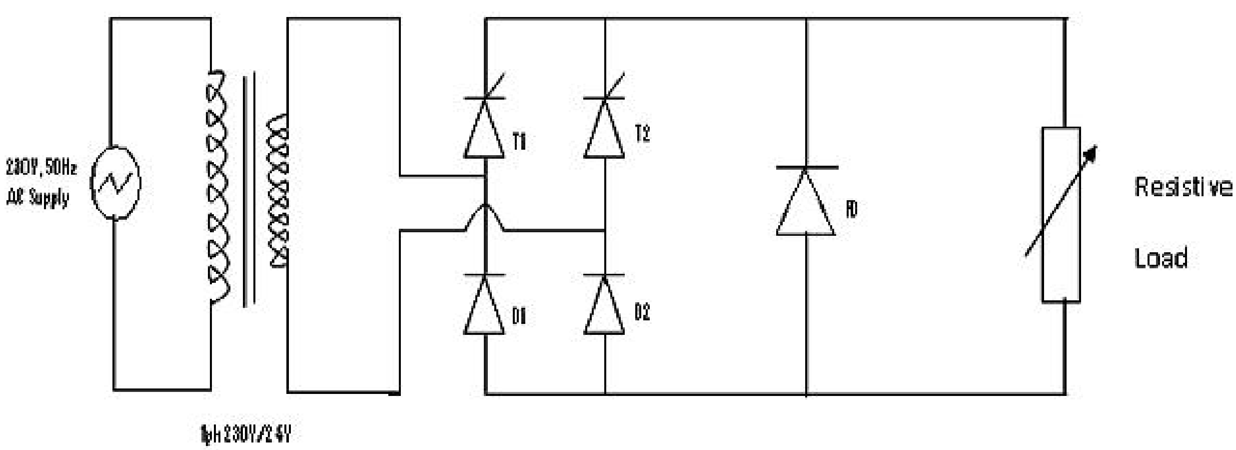
When SCR T2 is triggered at a firing angle $\omega t = \pi + \alpha$, the SCR T2 and diode D1 comes to on state. Now the load current flows through the path N - T2- R load –D1 -L. During this period, output voltage and output current will be positive. At $\omega t = 2\pi$,the load voltage and load current reaches to zero then S CR T2 and diode D1 comes to off state since the voltage has been reversed. During the period [($\pi + \alpha$) to 2π] SCR T2and diode D1 are conducting.

$$V_{OUT} = (\sqrt{2}V_S)\,(1+\cos\alpha)$$

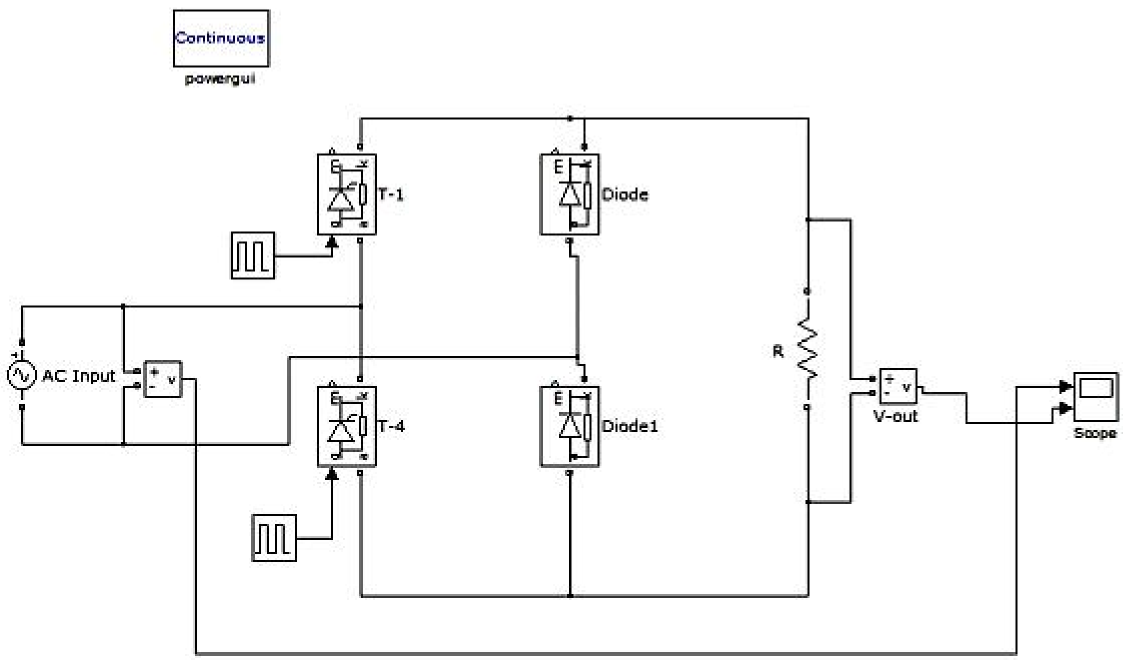
PROCEDURE:

1. In MATLAB software open a new model in File->New->model.
2. Start SIMULINK library browser by clicking the symbol in toolbar.
3. And Open the libraries that contain the blocks you will need. These usually will Include the sources, sinks, math and continuous function block and possibly other.
4. Drag the needed blocks from the library folders to that new untitled Simulink window. You must give it a name using the Save As menu command under the file menu heading. The assigned filename is automatically appended with an .mdl extension.
5. Arrange these blocks in orderly way corresponding by Matlab Model shown below.
6. Interconnect the blocks by dragging the cursor from the output of one block to the Input of another block.
7. Double click on any block having parameters that must be established and set these parameters.
8. It is necessary to specify a stop time for the simulation; this is done by clicking on the simulation parameters entry on the simulation-> parameters entry on the Simulation toolbar.
9. Now we are ready to simulate our block diagram. Press start icon to start the Simulation. After simulation is done, double click the scope block to display the Output. Click the auto scale icon in the display window to scale the axis as per variable range.
10. Finally Save the Output.

CIRCUIT DIAGRAM :(Single Phase Semi Converter)



MATLAB MODEL: (Single Phase Semi Converter)



OUTPUT WAVEFORMS:

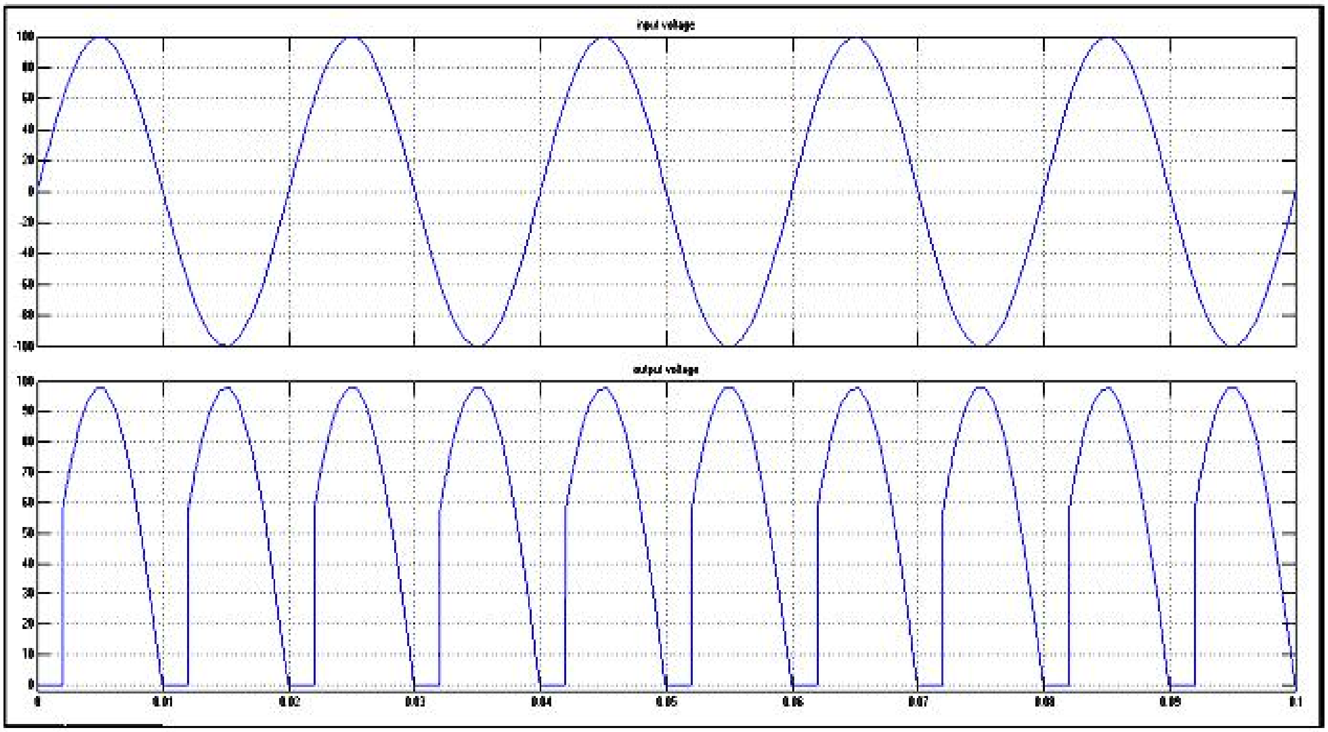
Set AC Input Parameter

(Peak amplitude =100 V, Phase=0 deg and Frequency=50 Hz)

Set Pulse generator Parameter

(First pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.002 sec)

(Second pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.012 sec)



RESULT:

Thus the simulation of single phase semi converter model is done and the output is verified using MATLAB Simulink.

Ex. No.13	SIMULATION OF SINGLE PHASE FULL CONVERTER
DATE:	

AIM:

To simulate single Phase Full Converter circuit with R load in MATLAB - Simulink.

APPARATUS REQUIRED:

A PC with MATLAB package.

THEORY:

SINGLE PHASE FULL CONVERTER

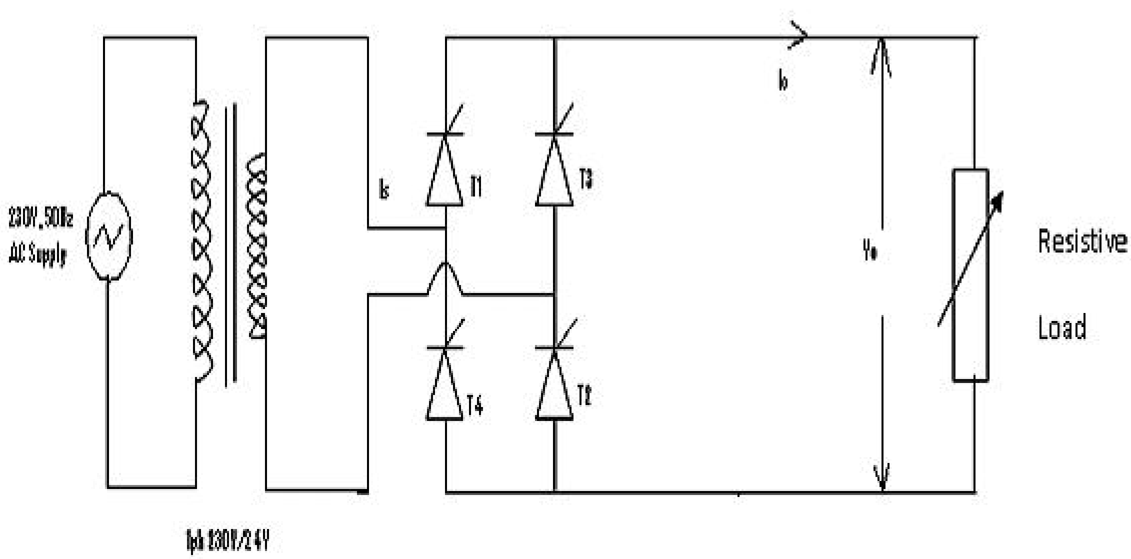
A fully controlled converter or full converter uses thyristors only and there is a wider control over the level of dc output voltage. With pure resistive load, it is single quadrant converter. Here, both the output voltage and output current are positive. With RL- load it becomes a two quadrant converter. Here, output voltage is either positive or negative but output current is always positive. Figure shows the quadrant operation of fully controlled bridge rectifier with R- load. Fig shows single phase fully controlled rectifier with resistive load. This type of full wave rectifier circuit consists of four SCRs. During the positive half cycle, SCRs T1 and T2 are forward biased. At $\omega t = \alpha$, SCRs T1 and T3 are triggered, and then the current flows through the L – T1- R load – T3 – N. At $\omega t = \pi$, supply voltage falls to zero and the current also goes to zero. Hence SCRs T1 and T3 turned off. During negative half cycle (π to 2π).SCRs T3 and T4 forward biased. At $\omega t = \pi + \alpha$, SCRs T2 and T4 are triggered, then current flows through the path N – T2 – R load- T4 – L. At $\omega t = 2\pi$, supply voltage and current goes to zero, SCRs T2 and T4 are turned off.

The Fig-3, shows the current and voltage waveforms for this circuit. For large power dc loads, 3-phase ac to dc converters are commonly used. The various types of three-phase phase-controlled converters are 3 phase half-wave converter, 3-phase semi converter, 3-phase full controlled and 3-phase dual converter. Three-phase half-wave converter is rarely used in industry because it introduces dc component in the supply current. Semi converters and full converters are quite common in industrial applications. A dual is used only when reversible dc drives with power ratings of several MW are required. The advantages of three phase converters over single-phase converters are as under: In 3-phase converters, the ripple frequency of the converter output voltage is higher than in single-phase converter.

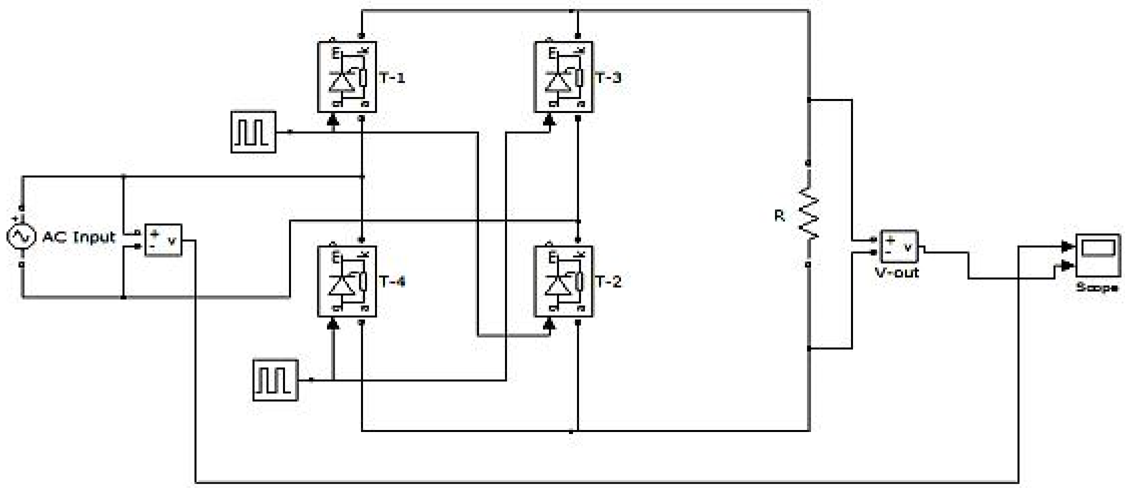
PROCEDURE:

1. In MATLAB software open a new model in File->New->model.
2. Start SIMULINK library browser by clicking the symbol in toolbar .
3. And Open the libraries that contain the blocks you will need . These usually will include the sources, sinks, math and continuous function block and possibly other.
4. Drag the needed blocks from the library folders to that new untitled Simulink Window. You must give it a name using the Save As menu command under the File menu heading. The assigned filename is automatically appended with an .mdl Extension.
5. Arrange these blocks in orderly way corresponding by Matlab Model Shown Below.
6. Interconnect the blocks by dragging the cursor from the output of one block to the Input of another block.
7. Double click on any block having parameters that must be established and set these parameters.
8. It is necessary to specify a stop time for the simulation; this is done by clicking on the simulation parameters entry on the simulation-> parameters entry on the Simulation toolbar.
9. Now we are ready to simulate our block diagram. Press start icon to start the Simulation. after simulation is done, double click the scope block to display the Output. Click the auto scale icon in the display window to scale the axis as per Variable range.
10. Finally Save the Output.

SINGLE PHASE FULL CONVERTER



MATLAB MODEL:



OUTPUT WAVEFORMS:

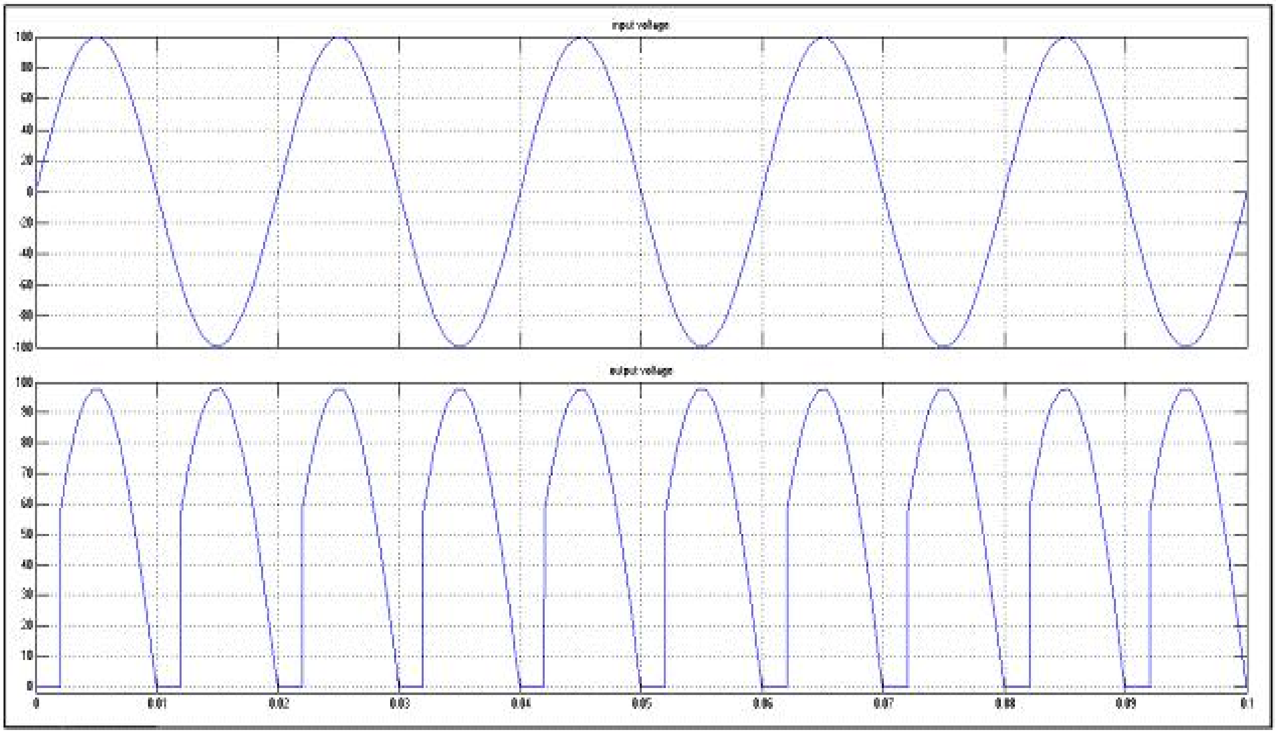
Set AC Input Parameter

(Peak amplitude =100 V, Phase=0 deg and Frequency=50 Hz)

Set Pulse generator Parameter

(First pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.002 sec)

(Second pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.012 sec)



RESULT:

Thus the simulation of single phase Full converter model is done and the output is verified using MATLAB Simulink.

Ex. No:14	SIMULATION OF SINGLE PHASE AC VOLTAGE CONTROL USING TRIAC
DATE:	

AIM:

To simulate single Phase AC Voltage Control Using TRIAC circuit with R load in MATLAB - Simulink.

APPARATUS REQUIRED:

A PC with MATLAB package.

THEORY:

SINGLE PHASE AC VOLTAGE CONTROL USING TRIAC

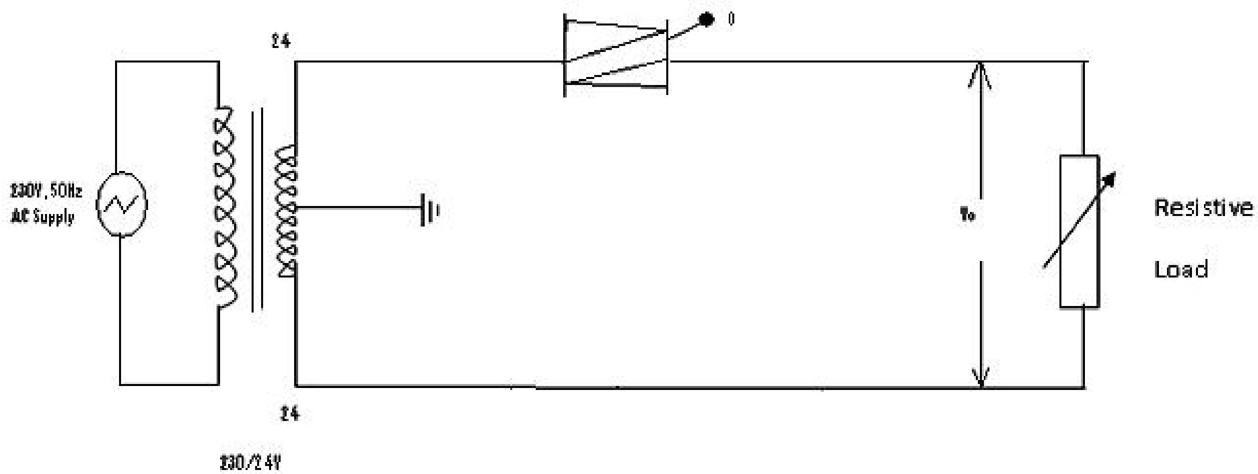
Triac is a bidirectional thyristor with three terminals. Triac is the word derived by Combining the capital letters from the words Triode and AC. In operation triac is equivalent to two SCRs connected in anti- parallel. It is used extensively for the control of power in ac circuit as it can conduct in both the direction. Its three terminals are MT1 (main terminal 1), MT2 (main terminal 2) and G (gate).

PROCEDURE:

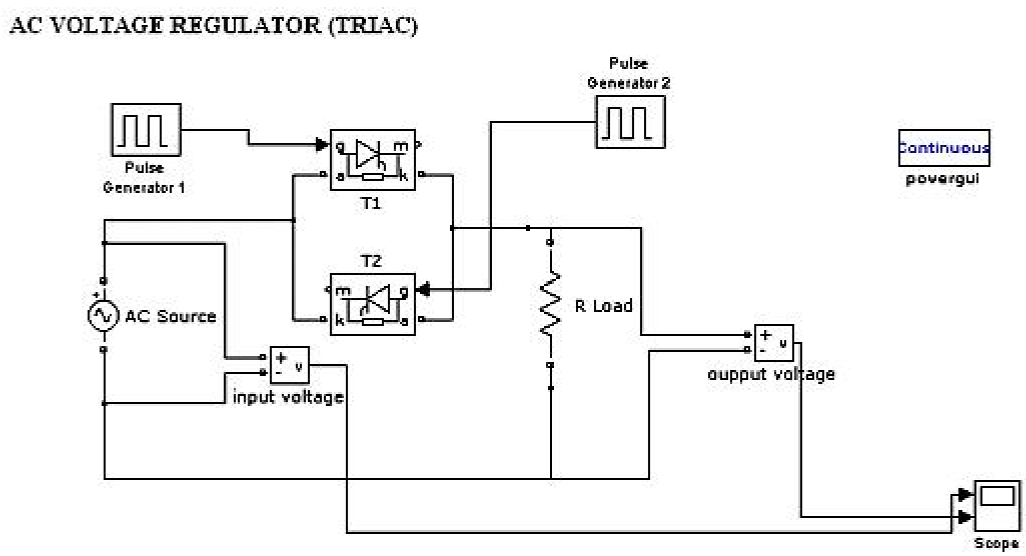
1. In MATLAB software open a new model in File->New->model.
2. Start SIMULINK library browser by clicking the symbol in toolbar .
3. And Open the libraries that contain the blocks you will need. These usually will include the sources, sinks, math and continuous function block and possibly other.
4. Drag the needed blocks from the library folders to that new untitled Simulink window. You must give it a name using the Save As menu command under the File menu heading. The assigned filename is automatically appended with an .mdl extension.
5. Arrange these blocks in orderly way corresponding by Matlab Model Shown Below.
6. Interconnect the blocks by dragging the cursor from the output of one block to the input of another block.
7. Double click on any block having parameters that must be established and set these parameters.

8. It is necessary to specify a stop time for the simulation; this is done by clicking on the simulation parameters entry on the simulation-> parameters entry on the Simulation toolbar.
9. Now we are ready to simulate our block diagram. Press start icon to start the Simulation. After simulation is done, double click the scope block to display the output. Click the auto scale icon in the display window to scale the axis as per variable range.
10. Finally Save the Output.

SINGLE PHASE AC VOLTAGE CONTROL USING TRIAC:



MATLAB MODEL:



OUTPUT WAVEFORMS:

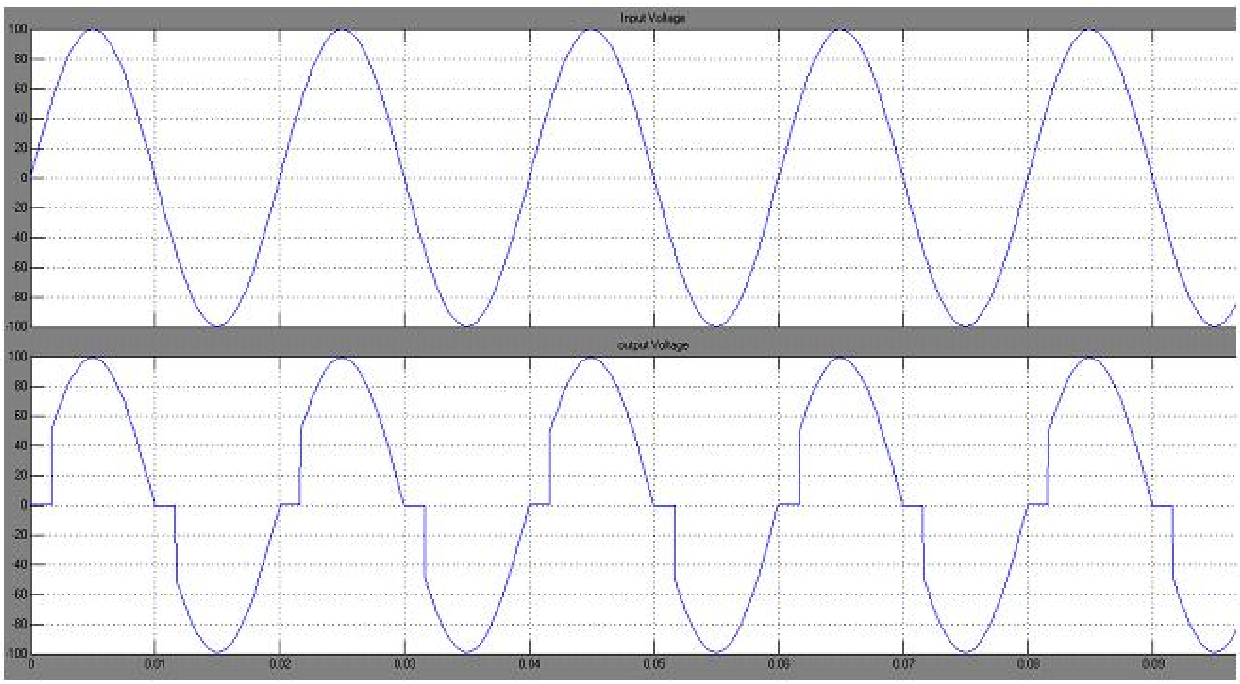
Set AC Input Parameter

(Peak amplitude =100 V, Phase=0 deg and Frequency=50 Hz)

Set Pulse generator Parameter

(First pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.003 sec)

(Second pulse generator period=0.02 sec, Pulse width=50% and Phase delay=0.013 sec)



RESULT:

Thus the simulation of single Phase AC Voltage Control Using TRIAC model is done and the output is verified using MATLAB Simulink.

Ex. No:15	SIMULATION OF DC-DC CONVERTERS
DATE:	

AIM:

To simulate DC-DC Converter circuit with R load in MATLAB - Simulink.

APPARATUS REQUIRED:

A PC with MATLAB package.

THEORY:

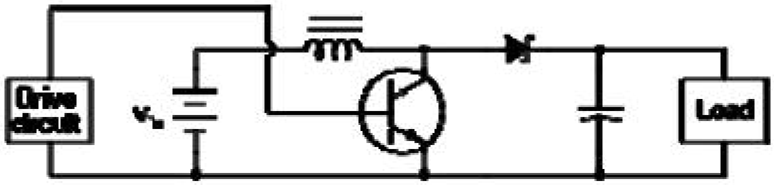
DC-DC BOOST CONVERTER

In this circuit, the transistor is either fully on or fully off; that is, driven between the extremes of saturation or cutoff. By avoiding the transistor' s active" mode (where it would drop substantial volta ge while conducting current), very low transistor power dissipations can be achieved. With little power wasted in the form of heat, Switching" power conversion circuits are typically very efficient. Trace all current directions during both states of the transistor. Also, mark the inductor's voltage polarity during both states of the transistor.

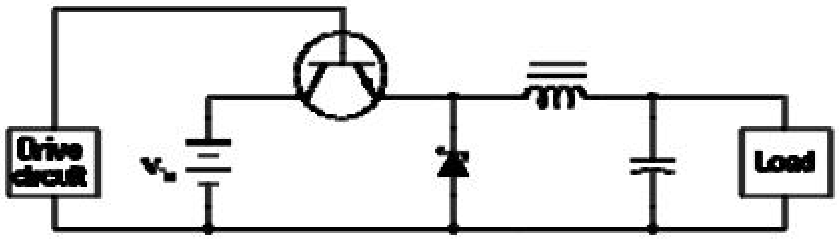
PROCEDURE:

1. In MATLAB software open a new model in File->New->model.
2. Start SIMULINK library browser by clicking the symbol in toolbar.
3. And Open the libraries that contain the blocks you will need. These usually will include the sources, sinks, math and continuous function block and possibly other.
4. Drag the needed blocks from the library folders to that new untitled simulink window. You must give it a name using the Save As menu command under the File menu heading. The assigned filename is automatically appended with an .mdl extension.
5. Arrange these blocks in orderly way corresponding by Matlab Model Shown Below.
6. Interconnect the blocks by dragging the cursor from the output of one block to the input of another block.
7. Double click on any block having parameters that must be established and set these parameters.
8. It is necessary to specify a stop time for the simulation; this is done by clicking on the simulation parameters entry on the simulation-> parameters entry on the Simulation toolbar.
9. Now we are ready to simulate our block diagram. Press start icon to start the Simulation. After simulation is done, double click the scope block to display the output. Click the auto scale icon in the display window to scale the axis as per variable range.
10. Finally Save the Output.

DC-DC BOOST CONVERTER

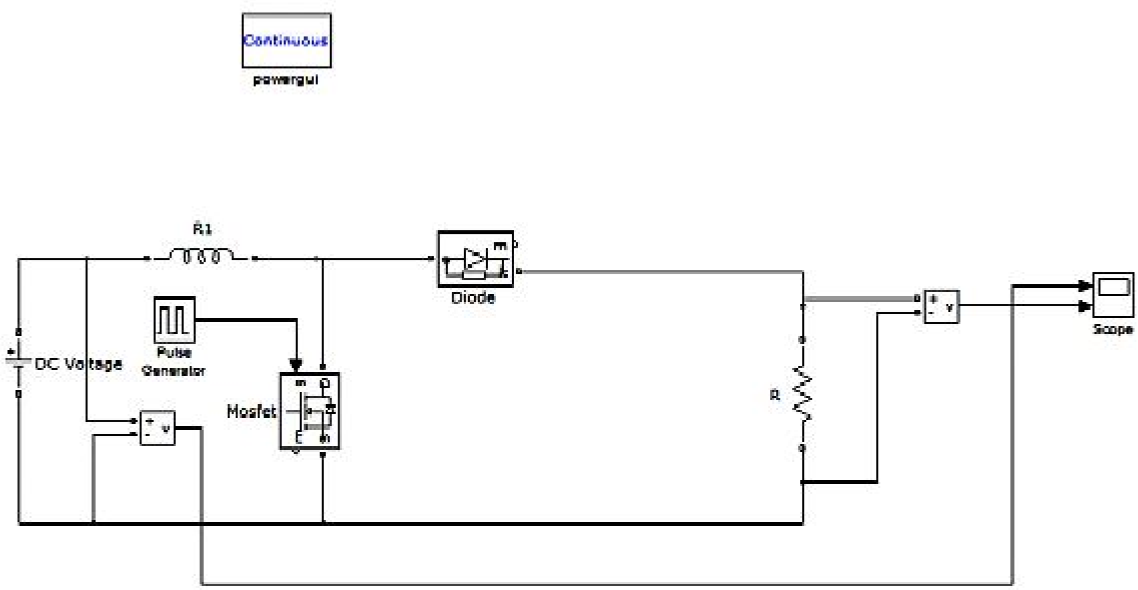


DC-DC BUCK CONVERTER

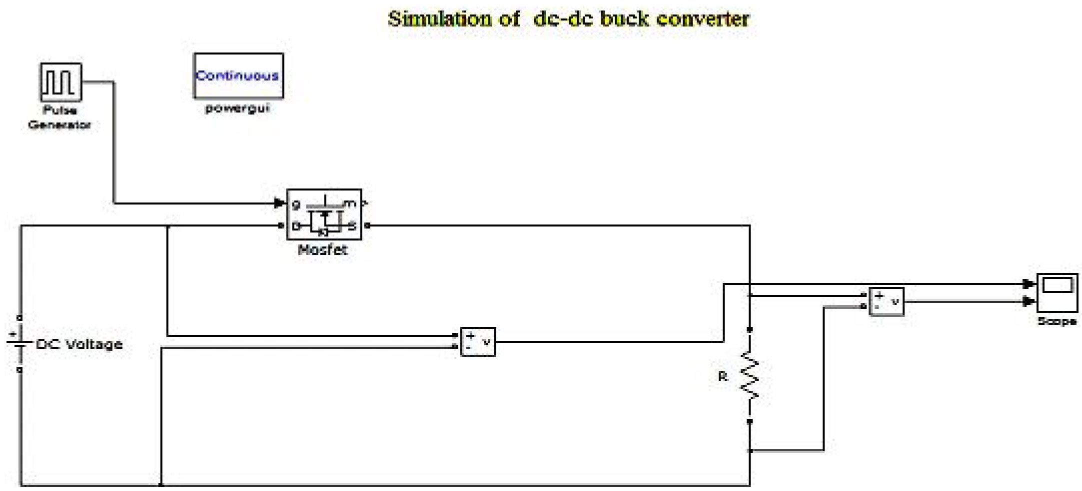


MATLAB MODEL:

DC-DC BOOST CONVERTER



DC-DC BUCK CONVERTER



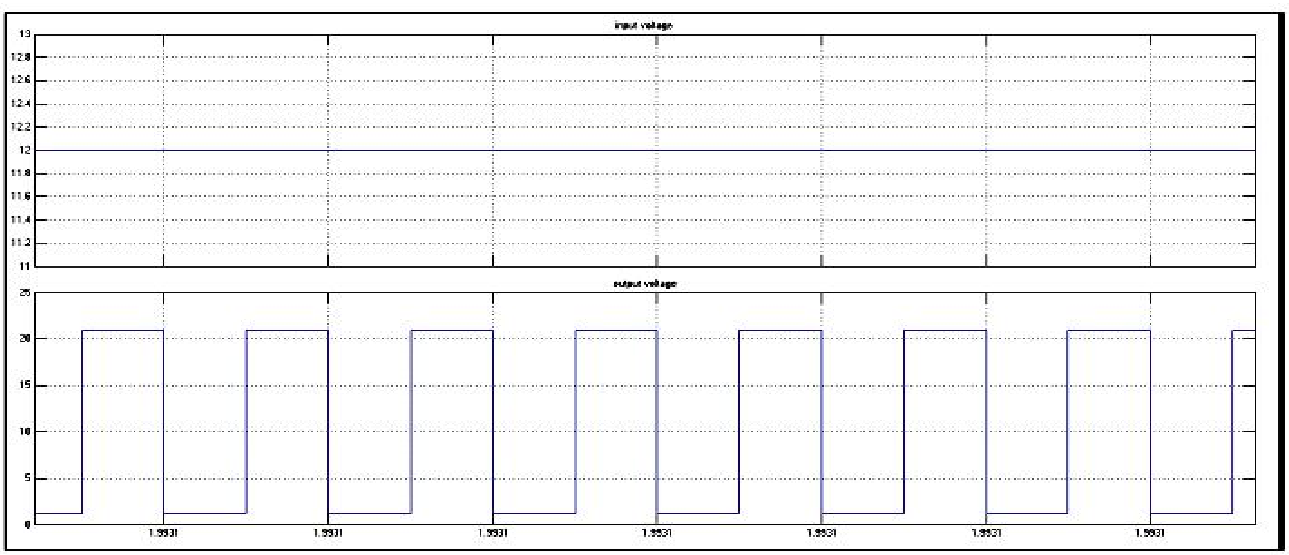
OUTPUT WAVEFORMS:

DC-DC Boost Converter

Set DC Input Parameter (Amplitude =12 V)

Set Inductor Parameter (Inductance=0.1 H)

Set Pulse generator Parameter (Period=10e-6 sec, Pulse width=50% and Phase Delay=0 sec)

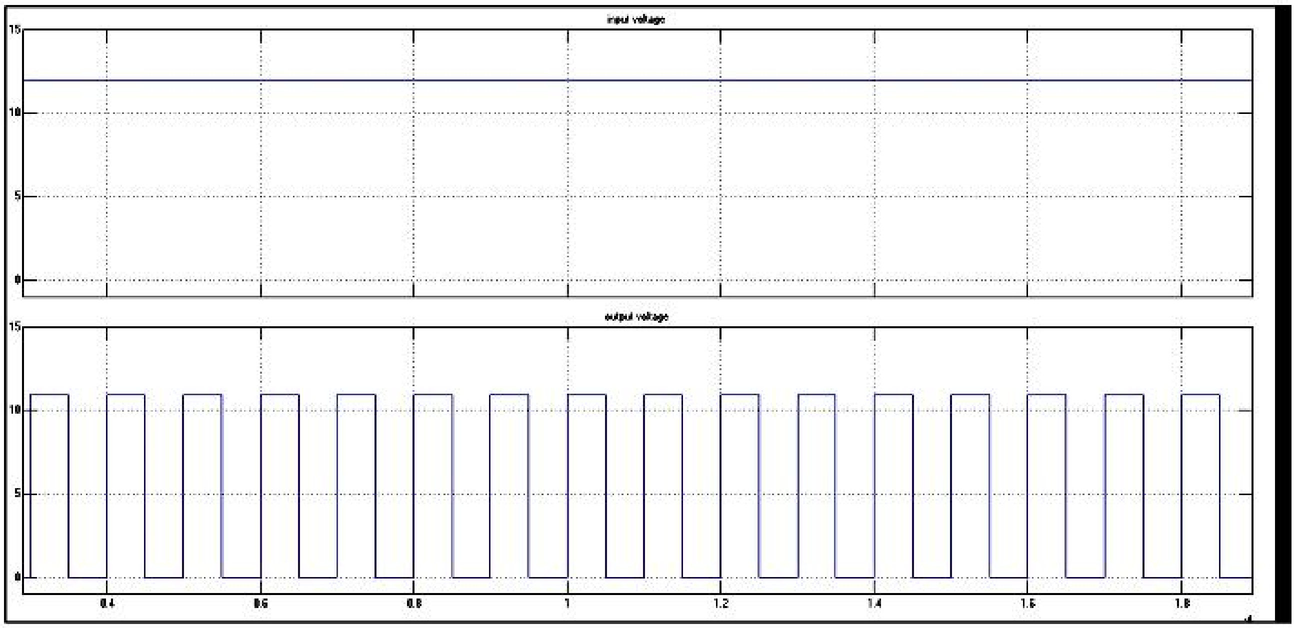


OUTPUT WAVEFORMS:

DC-DC Buck Converter

Set DC Input Parameter (Amplitude =12 V)

Set Pulse generator Parameter (Period=10e-6 sec, Pulse width=50% and Phase Delay=0 sec)



RESULT:

Thus the simulation of dc-dc converters (Buck and Boost Converter) model is done and the output is verified using MATLAB Simulink.

Ex. No:16	**SIMULATION OF THREE PHASE CONVERTER**
DATE:	

AIM:

To simulate three phase Converter circuit with RL load in MATLAB - Simulink.

APPARATUS REQUIRED:

A PC with MATLAB package.

THEORY:

Figure shows the circuit diagram of three Phase Bridge controlled rectifier. It consist of upper group (T1,T3,T5) and lower group (T2,T4,T5) of thyristors .Thyristor T1 is forward biased ad can be triggered for conduction only when Va is greater than both Vb and Vc. From figure this condition occurs at wt=300. Hence T1 can be triggered only at wt=300.If firing angle is α , then T1 starts conduction at wt=30 + α and conducts for 1200 where it get commutated by turning on of next thyristor ie,T3.Similarly triggering instant for T3 and T5 are determined when considering Vb and Vc respectively. For lower group T4, T6 and T2, negative voltages, ie,-Va,-Vb and -Vc respectively are considered.

AVERAGE VALUE OF OUTPUT VOLTAGE:

$$V_{avg} = \frac{3\sqrt{3}}{\pi} V_M \cos\alpha$$

Where

V_M – The maximum value of phase to neutral voltage

AVERAGE VALUE OF OUTPUT CURRENT:

$$I_{avg} = \frac{3\sqrt{3}}{\pi R} V_M \cos\alpha$$

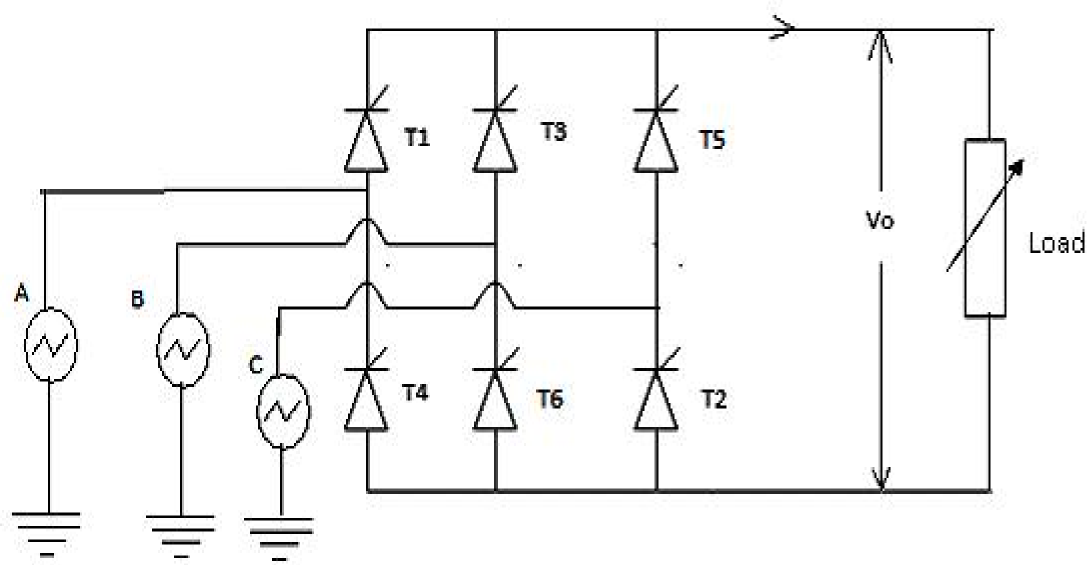
Where

R is the load resistance

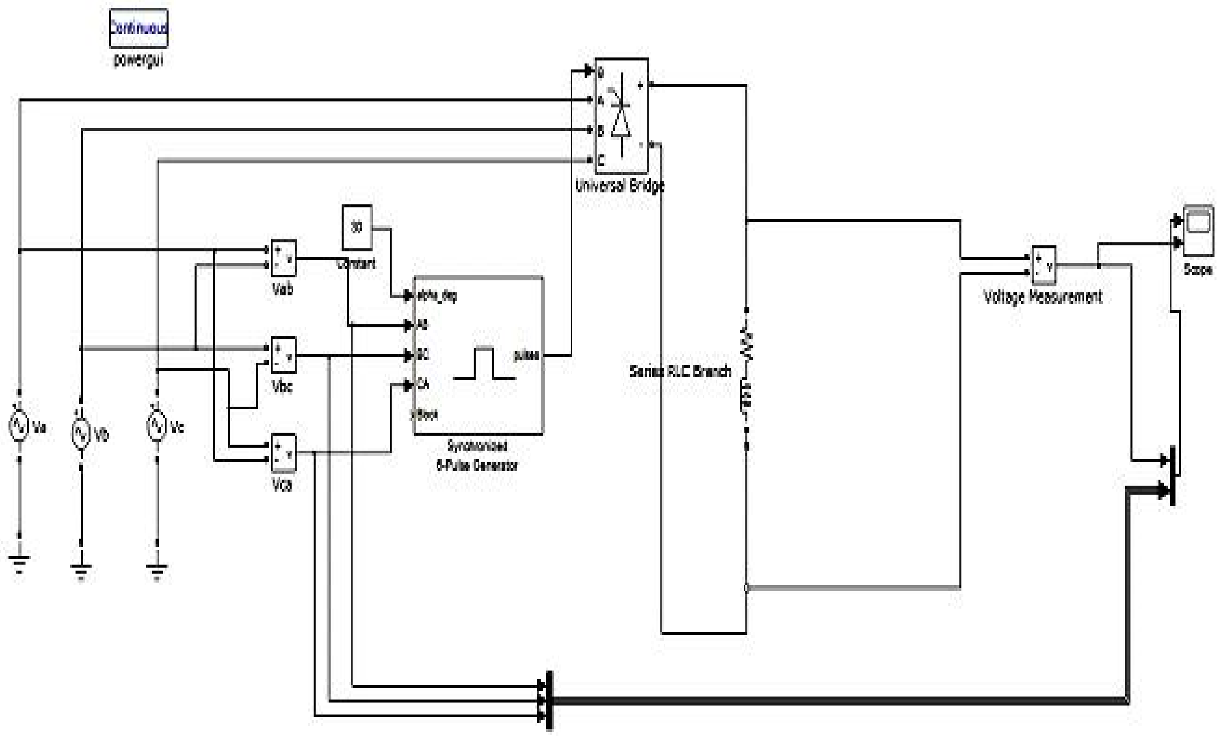
PROCEDURE:

1. In MATLAB software open a new model in File->New->model.
2. Start SIMULINK library browser by clicking the symbol in toolbar
3. And Open the libraries that contain the blocks you will need. These usually will include the Sources, sinks, math and continuous function block and possibly other.
4. Drag the needed blocks from the library folders to that new untitled simulink window. You must give it a name using the Save As menu command under the File menu heading. The assigned filename is automatically appended with an .mdl extension.
5. Arrange these blocks in orderly way corresponding by Mat lab Model Shown Below.
6. Interconnect the blocks by dragging the cursor from the output of one block to the input of another block.
7. Double click on any block having parameters that must be established and set these parameters.
8. It is necessary to specify a stop time for the simulation; this is done by clicking on the simulation parameters entry on the simulation-> parameters entry on the simulation toolbar.
9. Now we are ready to simulate our block diagram. Press start icon to start the simulation. After simulation is done, double click the scope block to display the output. Click the auto scale icon in the display window to scale the axis as per variable range.
10. Finally Save the Output.

THREE PHASE FULL CONVERTER:



MAT LAB MODEL:



OUTPUT WAVEFORMS:

DC-DC Boost Converter

Set AC Input Parameter

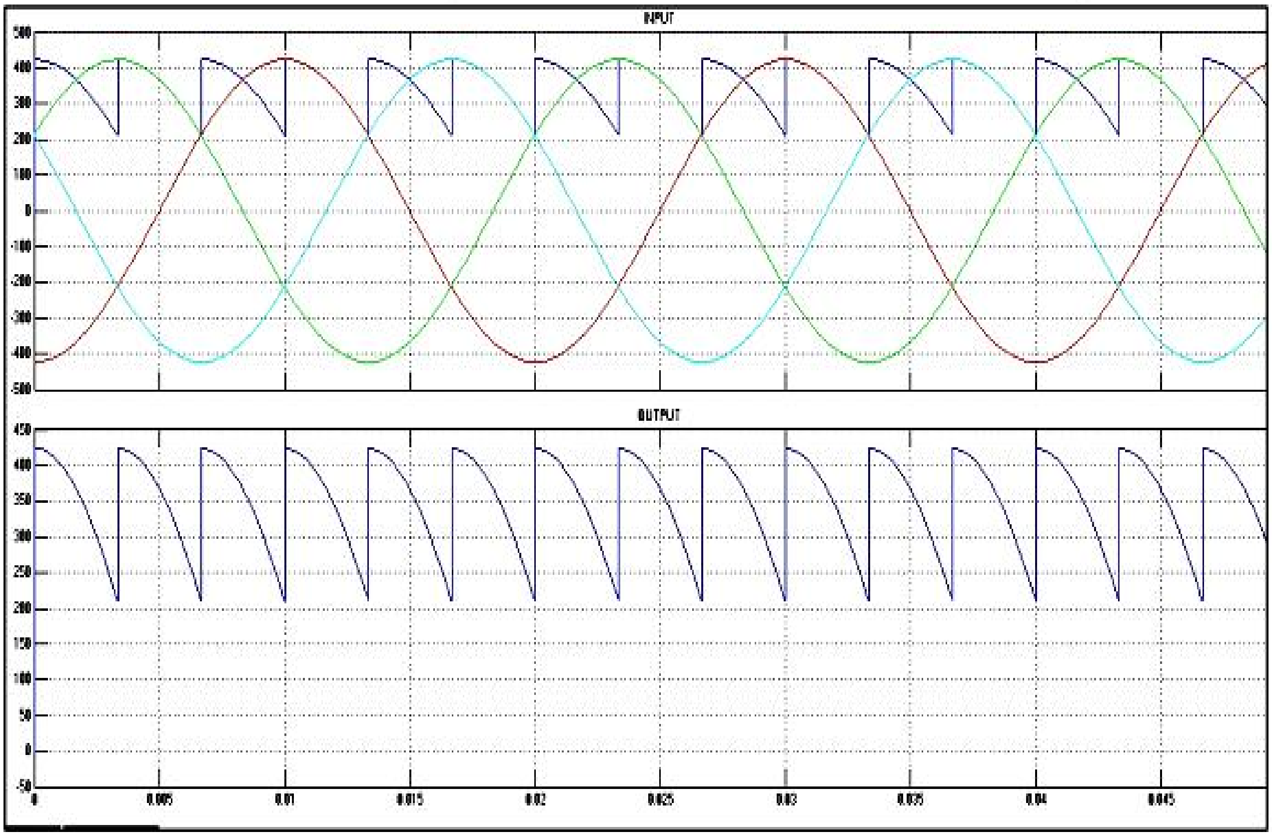
(For Va : Peak amplitude =245 V, Phase=0 deg and Frequency=50 Hz)

(For Vb : Peak amplitude =245 V, Phase= -120 deg and Frequency=50 Hz)

(For Vc: Peak amplitude =245 V, Phase=120 deg and Frequency=50 Hz)

Set Synchronized 6-Pulse Generator Parameter (Frequency=50 Hz, Pulse width=10 deg)

Set RL Branch Parameter (Resistance =1000 Ohms, Inductance =350e-3 H)



RESULT:

Thus the simulation of three phase converter model is done and the output is verified using MATLAB Simulink.