Dr. D. Y. Patil Unitech Society's

Dr. D. Y. Patil Institute of Technology

Pimpri, Pune

Department of Electronics & Telecommunication Engineering

Vision of the Institute

Empowerment Through Knowledge

Mission of the Institute

Developing human potential to serve the nation by

- *Dedicated efforts for quality Education*
- *Yearning to promote research and development.*
- *Persistent endeavor to imbibe moral and professional ethics.*
- *Inculcating the concept of emotional intelligence.*
- *Emphasizing extension work to reach out to the society.*
- *Treading the path to meet the future challenges*

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Dr. D. Y. Patil Institute of Technology

Pimpri, Pune

Department of Electronics & Telecommunication Engineering

Vision of the Department

To be a distinct department building globally competent Electronics and Telecommunication professionals

Mission of the Department

- *Nurturing the spirit of innovation & creativity by providing conducive learning*
- *Enhancing potential of students to be globally competent by providing platform to build skills in advanced technologies and inculcate life-long learning*
- *Enabling students to imbibe social as well as ethical values as inner strength through educational experiences and collaborations*

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Pimpri, Pune

Department of Electronics & Telecommunication Engineering

Programme Educational Objectives (PEO)

PEO1:

Possess strong basics of science and engineering and inculcate efficient problem solving skills.

PEO2:

Acquire technical competency in Electronics & Telecommunication field to excel in their career or pursuit of higher studies.

PEO3:

Exhibit proficiency in interdisciplinary approach and conduct themselves in professional and ethical manner at all levels.

PEO4:

Demonstrate attributes for need based learning and utilize their engineering skills and spirit of team work in social context.

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Programme Specific Outcomes (PSO)

PSO1:

Ability to analyze, design and develop keys to challenges relevant to Electronics & Telecommunication Engineering

PSO2:

Act effectively to combat societal and environmental issues by using professional ethics.

PSO3:

Adaptability to be abreast of the latest trends and acceptance to advancement of the relevant technologies

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Department of Electronics & Telecommunication Engineering

Programme Outcomes (POs)

PO1	**Engineering Knowledge**	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem Analysis**	Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design & Development of Solutions**	Design solutions for complex engineering problems anddesign system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems**	Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern Tools Usage**	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society**	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment & Sustainability**	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**	Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual & Team work**	Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management & Finance**	Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments
PO12	**Lifelong Learning**	Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

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Department of Electronics & Telecommunication Engineering

Power Devices Circuit Lab

Course Objectives:

- To introduce different power devices viz. SCR, GTO, MOSFET and IGBT with construction, characteristics, repetitive and non repetitive ratings and typical triggering/driver circuits.
- To understand working, design and performance analysis and applications of various power converter circuits such as ac to dc converters, inverter and chopper
- To know various protection circuit requirements of power electronic devices

Course Outcomes:

- CO1: To differentiate based on the characteristic parameters among SCR, GTO, MOSFET & IGBT and identify suitability of the power device for certain applications and understand the significance of device ratings.
- CO2: To design triggering / driver circuits for various power devices.
- CO3: To evaluate and analyze various performance parameters of the different converters and its topologies.
- CO4: To understand significance and design of various protections circuits for power devices.
- CO5: To evaluate the performance of uninterruptible power supplies, switch mode power supplies and battery.
- CO6: To understand case studies of power electronics in applications like electric vehicles, solar systems etc.

Dr. D Y Patil Institute of Technology, Pimpri Pune
Department of Electronics & Telecommunication Engineering

Power Devices circuit Laboratory

List of Experiments

Expt. No.	Name of Experiment
	Group A: All Compulsory
1	VI Characteristics of SCR i) Plot output V-I characteristics to measure IH, IL and voltage before and after breakdown , ii) Observe the effect of gate current on forward break down iii) gate characteristics iv) compare with datasheet specifications 2
2	V-I Characteristics of Power MOSFET i) Plot output characteristics and calculate output resistance ii) Plot transfer characteristics and measure threshold voltage iii) compare with datasheet specifications
3	V-I Characteristics of IGBT i) Plot output characteristics and calculate output resistance ii) Plot transfer characteristics and measure threshold voltage iii) compare with datasheet specifications
	Group B: (Any 2)
4	Single phase Full Converter using IGBT / SCR with R & R-L load i) Observe load voltage waveform, ii) Measurement of average o/p voltage across loads, iii) Verification of theoretical values with practically measured values
5	Single-Phase PWM Power MOSFET / IGBT based bridge inverter for R and motor load i) Observe output voltage waveforms and measure set of rms output voltage for varying pulse width and variable input dc voltage for R and motor load, ii) compare measured output voltages with the theoretical findings
6	Step down / Step up chopper using power MOSFET / IGBT i) Measure duty cycle and observer effect on average load voltage for DC chopper
	Group C: (Any4)
7	SMPS /UPS Performance Evaluation i) find load & line regulation characteristics for no load condition and at 500 mA & 1A load ii) compare the performance with supplier specifications
8	Single phase AC voltage controller using IGBT/SCR for R and RL load i) Observe output rms voltage waveforms, ii) Measurement output voltage across load, iii) Verification of theoretical values with practically measured values. Or Simulation of the Single phase AC voltage controller using Powersim / any open source circuit simulation software
9	To study speed control of DC / single phase AC motor
10	To design and implement a solar cell operated emergency lighting system.
11	To study battery testing, safety and maintenance of batteries
	Group D : Content Beyond Syllabus
12	Energy conservation using power devices.

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Mapping with Cos, POs and PSOs

Expt. No.	Name of Experiment	COs	POs	PSOs
1	VI Characteristics of SCR	CO1	PO: 1,2,3,4,5,9	PSO: 1
2	V-I Characteristics of Power MOSFET	CO1	PO: 1,2,3,4,5,9	PSO: 1
3	V-I Characteristics of IGBT	CO1	PO: 1,2,3,4,5,9	PSO: 1
4	Single Phase Full Converter using IGBT / SCR with R & R-L load	CO3	PO: 1,2,3,4,5,9	PSO: 1
5	Single-Phase PWM Power MOSFET / IGBT based bridge inverter for R and motor load	CO3	PO: 1,2,3,4,5,9,	PSO: 1,2,3
6	Step down / Step up chopper using power MOSFET / IGBT	CO4	PO: 1,2,3,4,9,11	PSO: 1
7	SMPS /UPS Performance Evaluation	CO4	PO: 1,2,3,4,5,9	PSO: 1,3
8	Single phase AC voltage controller using IGBT/SCR for R and RL load	CO5	PO: 1,2,3,4,5,9	PSO: 1,3
9	To study speed control of DC / single phase AC motor	CO5	PO: 1,2,3,4,5,9	PSO: 1,3
10	To design and implement a solar cell operated emergency lighting system	CO6	PO:1,2, 3,4,5,9	PSO: 1,2,3
11	To study battery testing, safety and maintenance of batteries	CO6	PO: 1,2,3,4,5,9,11	PSO: 1,2,3
Content Beyond Syllabus				
12	Energy conservation using power devices.	-	PO: 1, 2,3,5	PSO: 1

Dr. D. Y. Patil Institute of Technology, Pimpri, Pune
Department of Electronics & telecommunication Engineering
Academic Year -2022-23
Subject : Power Devices Circuit Lab
Class : TE

Experiment No. 1

Aim : V-I Characteristics of SCR

- Plot output V-I characteristics to measure IH, IL and voltage before and after breakdown
- Observe the effect of gate current on forward break down
- gate characteristics

Apparatus required:

- SCR Kit
- Multimeter
- Patch cords

Theory:

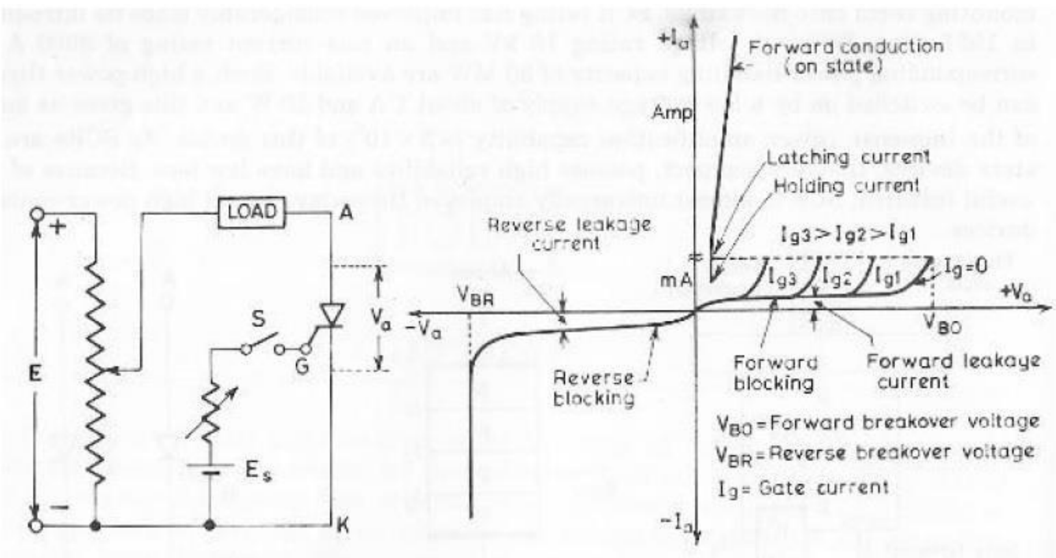

Fig.1. VI characteristics of SCR

An elementary circuit diagram for obtaining static V-I characteristics of a thyristor is shown in Fig 1. The anode and cathode are connected to main source through the load. The gate and cathode are fed from a source Es which provides positive gate current from gate to cathode.
Fig 1. shows static V-I characteristics of a thyristor. Here Va is the anode voltage across thyristor terminals A, K and Ia is the anode current. Typical SCR V-I characteristic shown in Fig2 reveals that a thyristor has three basic modes of operation; namely, reverse blocking mode, forward

blocking (off-state) mode and forward conduction (on-state) mode. These three modes of operation are now discussed below:

Reverse Blocking Mode:

When cathode is made positive with respect to anode with switch S open, thyristor is reverse biased. Junctions J1, J3 are seen to be reverse biased whereas junction J2 is forward biased. The device behaves as if two diodes are connected in series with reverse voltage applied across them. A small leakage current of the order of a few milliamperes (or a few microamperes depending upon the SCR rating) flows. This is reverse blocking mode, called the off-state, of the thyristor. If the reverse voltage is increased, then at a critical breakdown level, called reverse break-down voltage V_{BR}, an avalanche occurs at J1 and J3 and the reverse current increases rap- idly. A large current associated with V_{BR} gives rise to more losses in the SCR. This may lead to thyristor damage as the junction temperature may exceed its permissible tempera-ture rise. It should, therefore, be ensured that maximum working reverse voltage across a thyristor does not exceed V_{BR}. When reverse voltage applied across a thyristor is less than V_{BR}, the device offers a high impedance in the reverse direction. The SCR in the reverse blocking mode may therefore betreated as an open switch.

Note that V-I characteristic after avalanche breakdown during reverse blocking mode is applicable only when load resistance is zero. In case load resistance is present, a large anode current associated with avalanche breakdown at V_{BR} would cause substantial voltage drop across load and as a result, V-I characteristic in third quadrant would bend $V_{BR}$the right of vertical line drawn at VBR.

Forward Blocking Mode:

When anode is positive with respect to the cathode, with gate circuit open, thyristor is said to be forward biased as shown in Fig. It is seen from this figure that junctions J1, J3 are forward biased but junction J2 is reverse biased. In this mode, a small current, called forward leakage current, flows as shown in Fig. In case the forward voltage is increased, then the reverse biased junction J2 will have an avalanche breakdown at a voltage called forward break over voltage V_{BO}. When forward voltage is less than V_{BO}, SCR offers high impedance. Therefore, a thyristor can be treated as an open switch even in the forward blocking mode.

Forward Conduction Mode:

In this mode, thyristor conducts currents from anode to cathode with a very all voltage drop across it. A thyristor is brought from forward blocking mode to forward conduction mode by turning it on by exceeding the forward break over voltage or by applying a gate pulse between gate and cathode. In this mode, thyristor is in on-state and behaves like a closed switch. Voltage drop across thyristor in the on state is of the order of 1 to 2 V depending on the rating of SCR. It may be seen from Fig. 1 that this voltage drop increases slightly with an increase in anode current. In conduction mode, anode current is limited by load impedance alone as voltage drop across SCR is quite small. This small voltage drop vT across the device is due to ohmic drop in the four layers.

V-I CHARACTERISTICS OF SCR:-

V-I characteristics of SCR also called as static characteristics of SCR. The anode to cathode current Iak is plotted with respect to cathode to anode voltage. The voltage 'V_{bo}' is forward break over voltage. 'V_{br}' is the reverse break down voltage & I_{G1}, I_{G2}, I_{G3} is the gate currents applied to SCR. The important points on this characteristic are:

1-Latching Current IL

This is the minimum anode current required to maintain the thyristor in the on-state immediately after a thyristor has been turned on and the gate signal has been removed. If a gate current, greater than the threshold gate current is applied until the anode current is greater than the latching current IL then the thyristor will be turned on or triggered.

2-Holding Current IH

This is the minimum anode current required to maintain the thyristor in the on state. To turn off a thyristor, the forward anode current must be reduced below its holding current for a sufficient time for mobile charge carriers to vacate the junction. If the anode current is not maintained below IH for long enough, the thyristor will not have returned to the fully blocking state by the time the anode-to-cathode voltage rises again. It might then return to the conducting state without an externally applied gate current.

Circuit Diagram:-

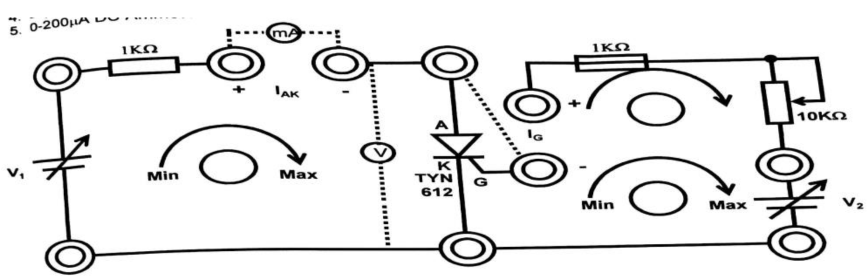

Fig - 7 : Basic Characteristics of SCR

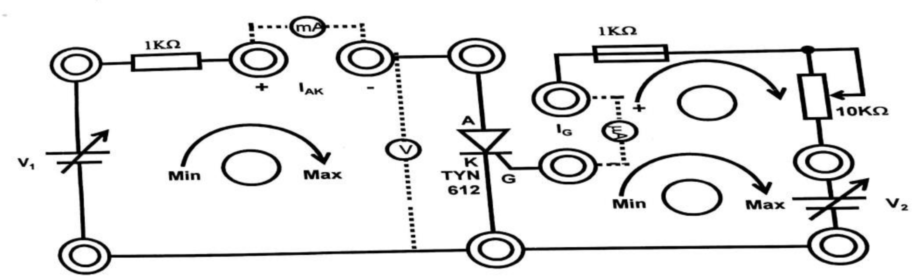

Fig - 8 : Gate Characteristics of SCR

OBSERVATION TABLE:

Ig= -------mA

Sr. No.	I_A(mA)	V_{AK}(V)

Ig -------mA

Sr. No.	I_A(mA)	V_{AK}(V)

Holding current =

Latching current =

PROCEDURE:

BASIC CHARACTERISTICS

- Connect the circuit as shown in Fig -7 adjust DC_1 to some voltage (say 4V) and connect a milli ammeter and a voltmeter in the anode circuit.
- Now short the gate terminal to the anode terminal.
- Then SCR fires and is indicated by the flowing of anode current in the anode circuit and voltage across SCR's anode to cathode falls.
- Now, open the gate terminal from anode terminal and observe whether the SCR is ON state (or) OFF state.
- If the SCR is on ON state, the anode current is sufficient enough to hold this SCR is in ON state. If the SCR is in OFF state, increases DC1 to some more value and repeat the same procedure until SCR holds in ON state.
- From the above procedure, find out the approximate value of the holding current I_1,

Gate Characteristics:-

- Set DC1=24V & find Ig(min) by varying pot and DC2.
- Reduce DC1 to minimum value, now vary DC1 and observe the readings for Vak and Iak.
- Increase Ig and repeat the above steps.
- Plot the Gragh across Vak and Iak.

Conclusion:

Experiment No :2

Aim : - To Study and Plot the characteristics of MOSFET.

- Plot output characteristics and calculate output resistance
- Plot transfer characteristics and measure threshold voltage
- compare with datasheet specifications

Apparatus : -

- MOSFET Kit, Voltmeter (0-50V)
- Ammeter (0-50mA)
- Patch Chord
- Ammeter (0- 500mA)
- Voltmeter (0-50V)

Theory :-

The MOSFET works by electronically varying the width of a channel along which charge carriers flow (electrons or holes). The charge carriers enter the channel at source and exit via the drain. The width of the channel is controlled by the voltage on an electrode is called gate which is located between source and drain. It is insulated from the channel near an extremely thin layer of metal oxide. The MOS capacity present in the device is the main part

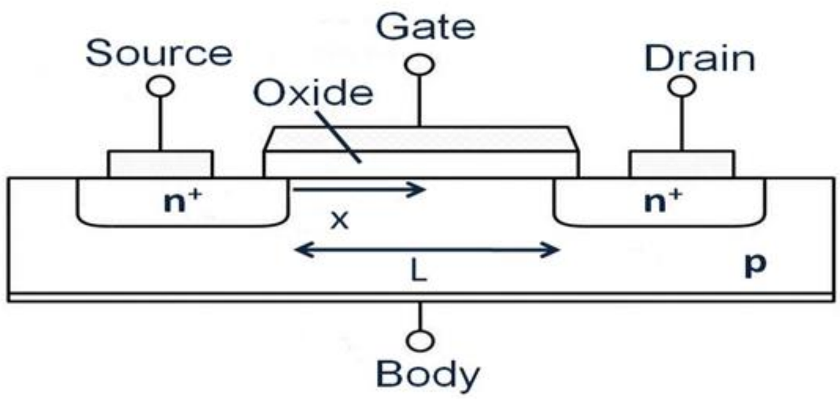

Fig 1: Internal structure of MOSFET

The MOSFET can be function in two ways

- Deflection Mode
- Enhancement Mode

Depletion Mode:

When there is no voltage on the gate, the channel shows its maximum conductance. As the voltage on the gate is either positive or negative, the channel conductivity decreases.

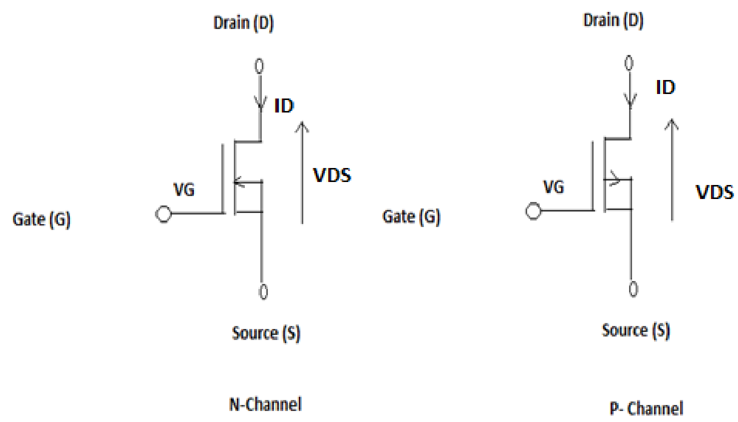

Fig 2: N & P Channel MOSFET in depletion mode

Enhancement mode:

When there is no voltage on the gate the device does not conduct. More is the voltage on the gate, the better the device can conduct.

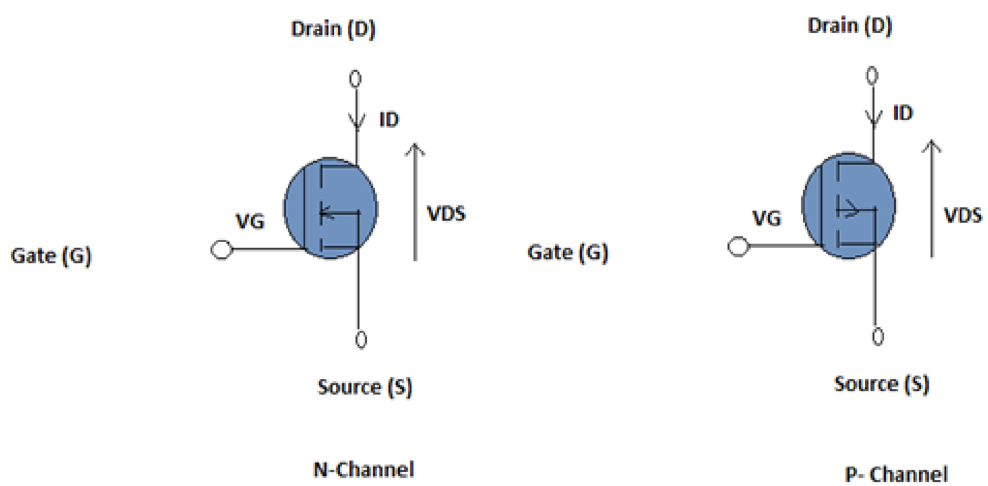

Fig 3: N & P Channel MOSFET in enhancemet mode

Working Principle of MOSFET:

The aim of the MOSTFET is to be able to control the voltage and current flow between the source and drain. It works almost as a switch. The working of MOSFET depends upon the MOS capacitor. The MOS capacitor is the main part of MOSFET. The semiconductor surface at the below oxide layer which is located between source and drain terminal. It can be inverted from p-type to n-type by applying a positive or negative gate voltages respectively. When we apply the positive gate voltage the holes present under the oxide layer with a repulsive force and holes are pushed downward with the substrate. The depltion region populated by the bound negative charges which are associated with the acceptor atoms. The electrons reach channel is formed. The positive voltage also attracts electrons from the n+ source and drain regions into the channel. Now, if a voltage is applied between the drain and source, the current flows freely between the source and drain and the gate voltage controls the electrons in the channel. Instead of positive voltage if we apply negative voltage , a hole channel will be formed under the oxide layer.

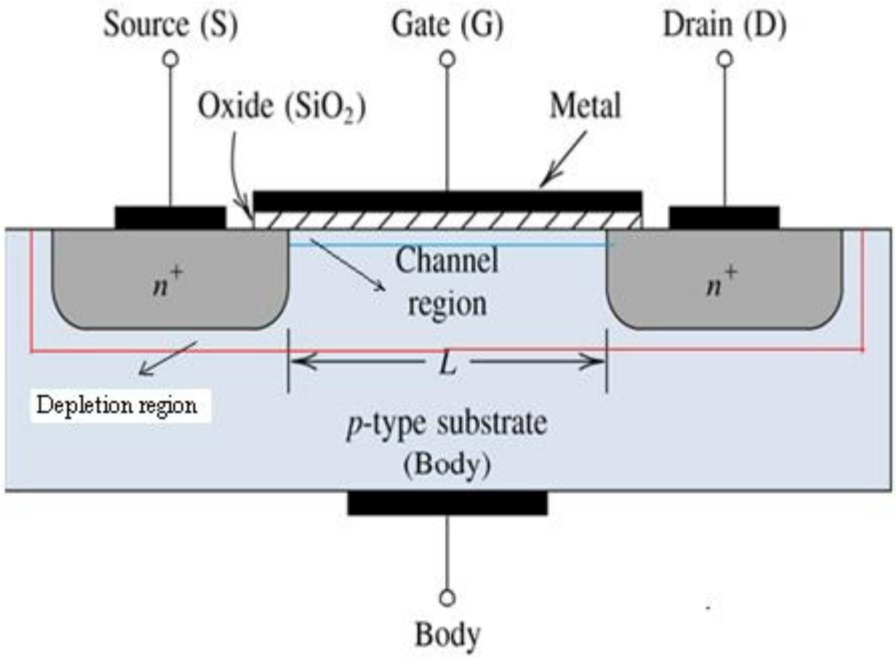

Fig 4 : MOSFET Block Diagram

P-Channel MOSFET:

The P- Channel MOSFET has a P- Channel region between source and drain. It is a four terminal device such as gate, drain, source, body. The drain and source are heavily doped p+ region and the body or substrate is n-type. The flow of current is positively charged holes. When we apply the negative gate voltage, the electrons present under the oxide layer with are pushed downward into the substrate with a repulsive force. The deflection region populated by the bound positive charges which are associated with the donor atoms. The negative gate voltage also attracts holes from p+ source and drain region into the channel region.

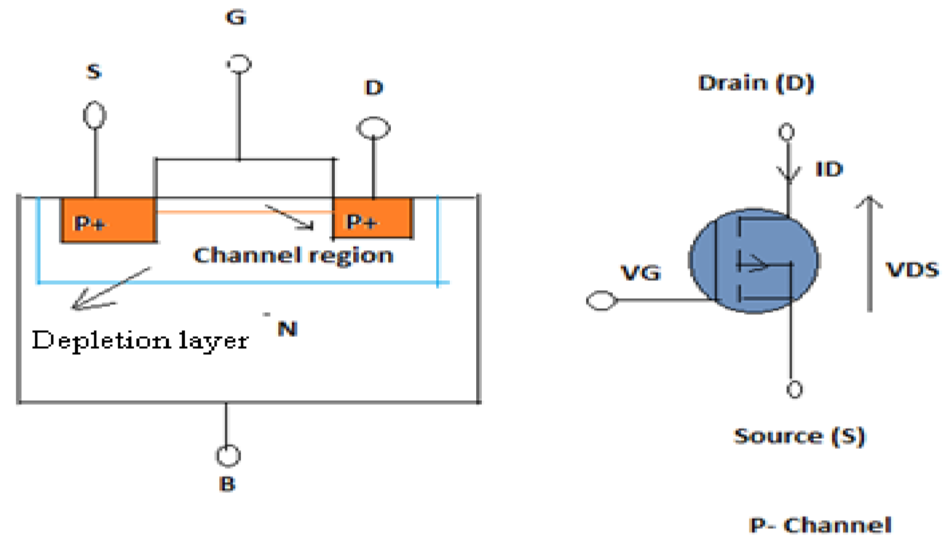

Fig 5 : Enhanced mode

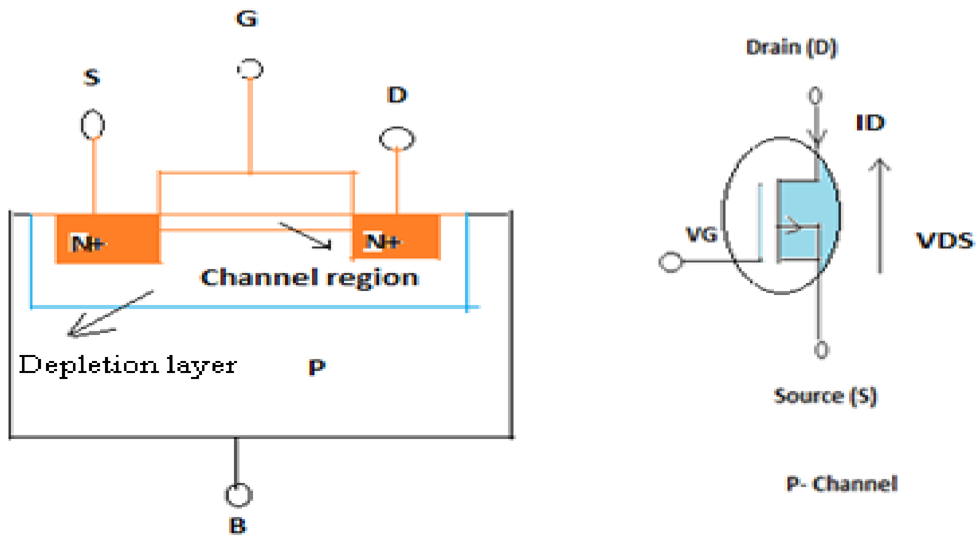

Fig 6 : Depletion Mode

N- Channel MOSFET:

The N-Channel MOSFET has a N- channel region between source and drain It is a four terminal device such as gate, drain , source , body. This type of MOSFET the drain and source are heavily doped n+ region and the substrate or body is P- type. The current flows due to the negatively charged electrons. When we apply the positive gate voltage the holes present under the oxide layer pushed downward into the substrate with a repulsive force. The depletion region is populated by the bound negative charges which are associated with the acceptor atoms. The electrons reach channel is formed. The positive voltage also attracts electrons from the n+ source and drain regions into the channel. Now, if a voltage is applied between the drain and source the current flows freely between the source and drain and the gate voltage controls the electrons in the channel. Instead of positive voltage if we apply negative voltage a hole channel will be formed under the oxide layer.

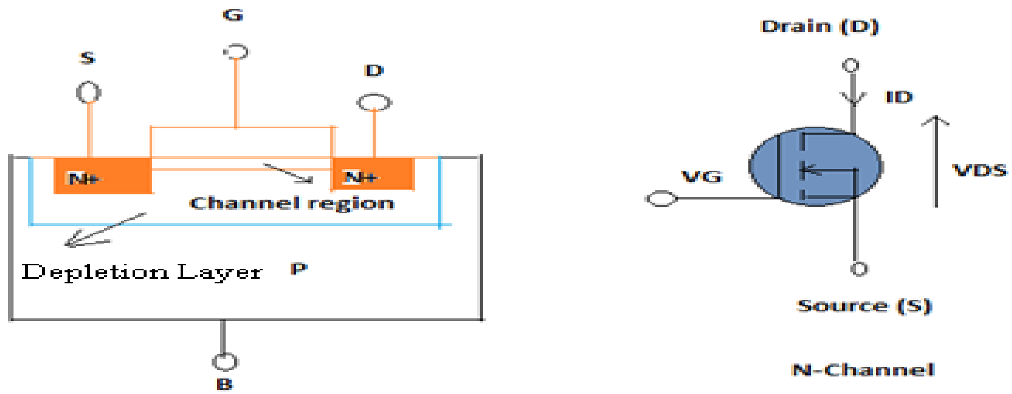

Fig 7: Depletion Mode

Circuit Diagram :

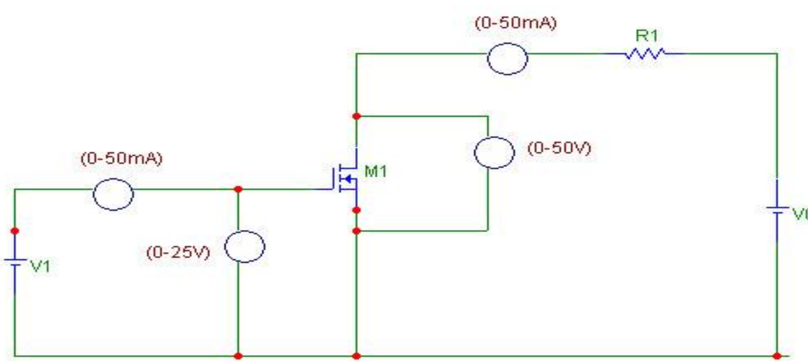

Fig 8: Crcuit Diagram

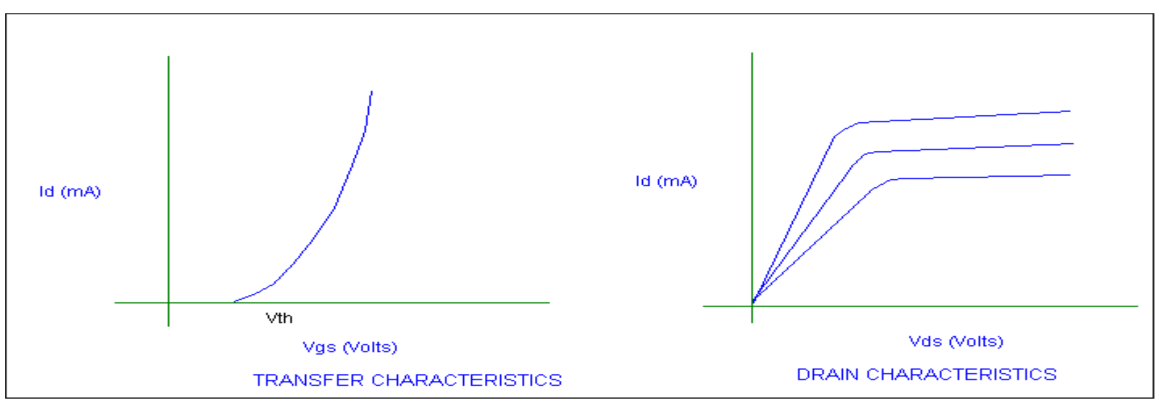

Fig 9: Standard characteristics of MOSFET

Procedure:

DRAIN CHARACTERISTICS:-

1) Keep Vgs say 3V & vary Vds in steps of 1V & note down corresponding value of drain current.
2) Increase Vgs in steps of 0.2 V and repeat the above procedure.
3) Plot the VI characteristics of MOSFET

TRANSFER CHARACTERISTICS:-

1) Keep Vds=10V and vary Vgs in steps.
2) Increase Vgs in steps and note the voltage at which the Id starts flowing (this is the Threshold Voltage).
3) Now increase the Vgs in steps of 0.5V, note Id.
4) Plot the transfer characteristics.

Result :-

Vgs=	
Vds(V)	**Id(mA)**

Vds=	
Vgs(V)	**Id(mA)**

CONCLUSION:-

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Department of Electronics and Telecommunication Engineering
Academic Year -2022-23
Subject : Power Devices Circuit Lab
Class : TE

Experiment No. 3

Aim : To plot V-I Characteristics of IGBT

i) Plot output characteristics

ii) Plot transfer characteristics

Apparatus:

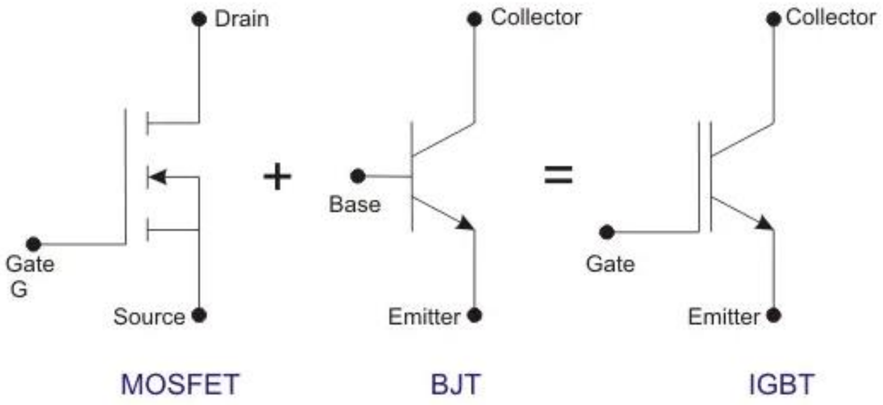
Sr. No.	Description	Specifications
1	IGBT	
2.	DC Power Supply	0-32V,2A
3.	Kit	
4.	DMM (as voltmeter)	0-20V
5	CRO	
6.	Connecting wires	---------

Theory :

IGBT is a relatively new device in power electronics and before the advent of IGBT, Power MOSFETs and Power BJT were common in use in power electronic applications. Both of these devices possessed some advantages and simultaneously some disadvantages. On one hand, we had bad switching performance, low input impedance, secondary breakdown and current controlled Power BJT and on the other we had excellent conduction characteristics of it. Similarly, we had excellent switching characteristics, high input impedance, voltage controlled PMOSFETs, which also had bad conduction characteristics and problematic parasitic diode at higher ratings. Though the unipolar nature of PMOSFETs leads to low switching times, it also leads to high ON-state resistance as the voltage rating increases.

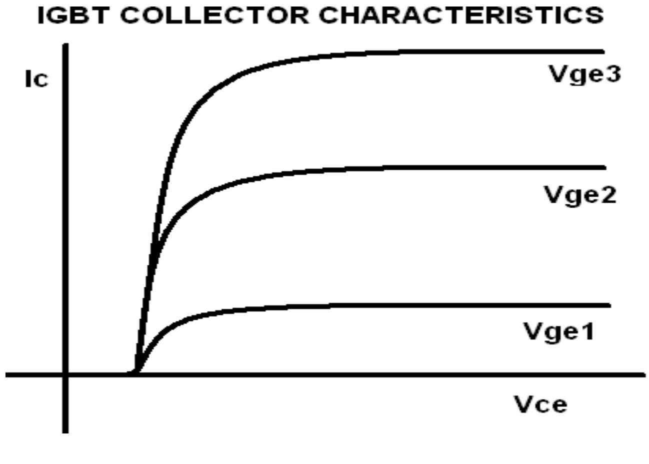
Thus the need was for such a device which had the goodness of both PMOSFETs and Power BJT and this was when IGBT was introduced in around the early 1980s and became very popular among power electronic engineers because of its superior characteristics. IGBT has PMOSFET like input characteristics and Power BJT like output characteristics and hence its symbol is also an amalgamation of the symbols of the two parent devices. The three terminals of IGBT are Gate, Collector and Emitter.

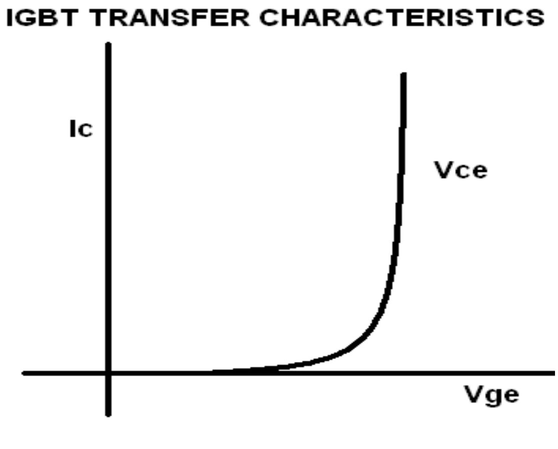
IGBT is known by various other names also, such as- Metal Oxide Insulated Gate Transistor (MOSIGT), Gain Modulated Field Effect Transistor (GEMFET), Conductively Modulated Field Effect Transistor (COMFET), Insulated Gate Transistor (IGT).



Device	Power capability	Switching speed
BJT	Medium	Medium
MOSFET	Low	Fast
GTO	High	Slow
IGBT	Medium	Medium
MCT	Medium	Medium

Graphs :





Procedure

IGBT: Transfer characteristics

1. Make the connections as shown in the circuit diagram with meters

2. Initially keep V1 and V2 zero. Set V1 = VCE1 = say 10v. Slowly vary V2 (VGE) and note down IC and VGE readings for every 0.5 volts and enter in the tabular column.

3. The minimum Gate voltage VGE which is required for conductionto start in the IGBT is called Threshold voltage VGE is less than VGE.

4. If VGE is less than VGE (Th) only very small leakage current flowsfrom collector to Emitter.

5. If VGE is greater than VGE (Th) the collector current depends on magnitude of the Gate voltage VGE varies from 5- to 6 volts.

6. Repeat the same for different values of VDS and draw the graph of ID/VGS.

Table :

Sr. No.	V1=VCE1=10V		V2=VCE2=30V	
	VGE (volts)	IC (mA)	VGE (volts)	IC (mA)

Collector characteristics:

1. Initially set V2 to VGE1 = 5 volts. Slowly vary V1 and note downIC and VGE.

2.For a particular value of VGE1 there is a pinch off voltage (Vp) between collector and Emitter as shown in figure.

3.If VGE is lower than VP the device works in the constant resistance region and IC is directly proportional to VGE if VGE is more than Vp. Constant IC flows from the device and this operating region is called constant current region.

4.Repeat the above for different values of VGE and note down IC v/s VGE

5.Draw the graph of IC v/s VGE for different values of VGE

Table :

S.No	VGE1=5 V		VGE2=5.4 V	
	VCE (volts)	IC (mA)	VCE (volts)	IC (mA)

Conclusion :

Dr. D. Y. Patil Institute of Technology, Pimpri, Pune
Department of Electronics & telecommunication Engineering
Academic Year -2022-23
Subject : Power Devices Circuit Lab
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Experiment No. 4 (A)

Aim:

To study the operation of single phase fully controlled converter with R load and to observe theoutput waveforms.

Apparatus Required:

1. Full converter trainer kit
2. CRO
3. Connection wires
4. Multimeter

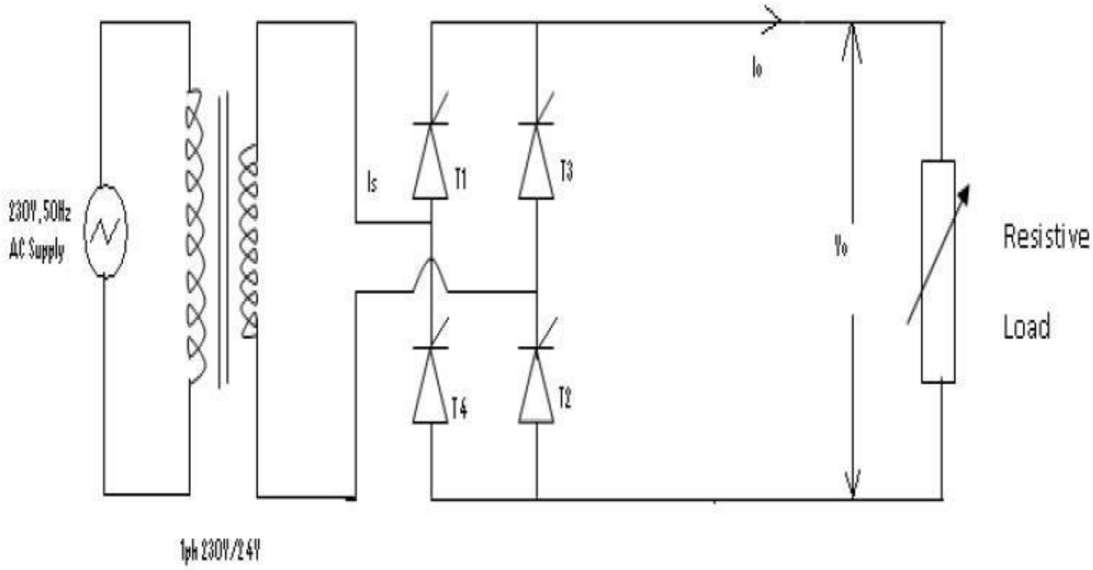
Theory:

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 R load it becomes a single quadrant converter. Here, output voltage is only positive and output current is also 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, 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. Consequently, the filtering requirements for smoothing out the load current are less. The load current is mostly continuous in 3-phase converters. The load performance, when 3-phase converters are used, is therefore superior as compared to when single-phase converters areused.

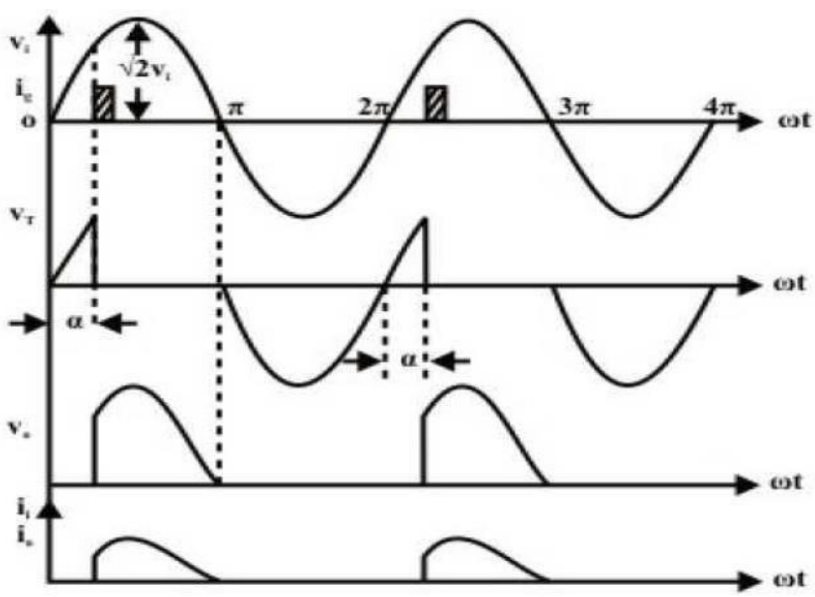
$$V_{out}=(2V_s)(\cos\alpha)/\pi$$

$$I_{avg}=V_{avg}/R$$



Circuit Diagram

Model Graph



Procedure:

1. Make the connections as per the circuit diagram.
2. Connect CRO and multimeter (in dc) across the load .
3. Keep the potentiometer (Ramp control) at the minimum position (maximum resistance).
4. Switch on the step down ac source.
5. Check the gate pulses at G1-K1, G2-K2,G3-K3,& G4-K4 respectively.
6. Observe the waveform on CRO and note the triggering angle 'α' and note the corresponding reading of the multimeter. Also note the value of maximum amplitude Vm from the waveform.
7. Set the potentiometer at different positions and follow the step given in (6) for every position.
8. Tabulate the readings in observation column.
9. Draw the waveforms observed on CRO.

Observation Table:

Serial No.	Triggering angle 'α' degree	Output voltage Voav (volt) (measured)	Time period(ms)
1			
2			
3			

Result:

Thus the operation of single phase fully controlled converter using R and RL load has been studied and the output waveforms has been observed.

Conclusion:

Experiment No. 4 (B)

SINGLE PHASE FULLY CONTROLLED CONVERTER WITH AND WITHOUTFREEWHEELING DIODE WITH RL LOAD

Aim: To study the operation of single phase fully controlled converter with and without freewheeling diode with RL load and to observe the output waveforms.

Apparatus required:

- Power thyristors
- Resistive Load
- CRO
- Transformer (1-phase)
- Connection wires
- Inductive Load
- Freewheeling Diode
- Gate Triggering
- Multimeter
- AC Supply

Theory:

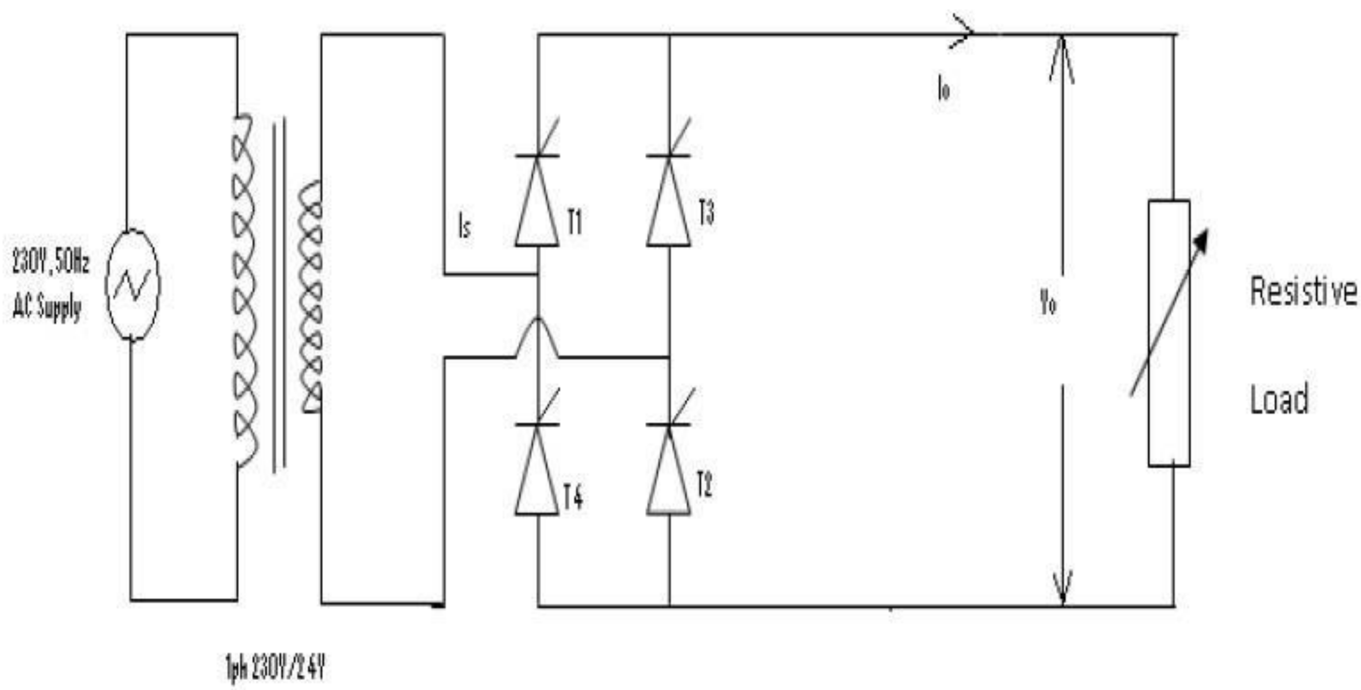
A fully controlled converter or full converter uses thyristors only and there is a wider control over the level of dc output voltage. With pure resistive load, it is single quadrant converter. Here, both the output voltage and output current are positive. With RL- load it becomes a two-quadrant converter. 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, then the current flows through the L – T1- R load – T3 – N. Inductor stores energy during this time period. 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. Energy stored gets dissipated and there are negative spikes in the waveform which is undesirable.Freewheeling diode is connected across load and energy gets dissipated through it and we get waveforms in positive region only.

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. Consequently, the filtering requirements for smoothing out the load current are less. The load current is mostly continuous in 3-phase converters. The load performance, when 3- phase converters are used, is therefore superior as compared to when single-phase converters are used.

$$V_{dc} = \frac{V_m}{\pi} (\cos a)$$



Circuit Diagram

Procedure:

10. Take the kit of Single Phase Fully Controlled Bridge Rectifier
11. Make the connections as per the circuit diagram.
12. Connect CRO and multimeter (in dc) across the load .
13. Keep the potentiometer (Ramp control) at the minimum position (maximum resistance).
14. Switch on the step down ac source.
15. Check the gate pulses at G1-K1, G2-K2,G3-K3,& G4-K4 respectively.
16. Observe the waveform on CRO and note the triggering angle 'α' and note the corresponding reading of the multimeter. Also note the value of maximum amplitude Vm from the waveform.
17. Set the potentiometer at different positions and follow the step given in (6) for every position.
18. Tabulate the readings in observation column.
19. Draw the waveforms observed on CRO.

Observation Table:

For R Load:

Sr. No.	Triggering angle (a)	T Off (ms)	O/ P voltage (Volts) (Measured)	O/P voltage (Volts) (Calculated)
1	36^0	2 ms		
2	54^0	3 ms		
3	72^0	4 ms		
4	90^0	5 ms		

For RL Load:

Sr. No.	Triggering angle (a)	T Off (ms)	O/ P voltage (Volts) (Measured)	O/P voltage (Volts) (Calculated)
1	36^0	2 ms		
2	54^0	3 ms		
3	72^0	4 ms		
4	90^0	5 ms		

Conclusion :

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Subject : Power Devices Circuit Lab
Class : TE

Experiment No.5

Aim : To study Single-Phase PWM bridge inverter for R load

Apparatus :

Sr. No.	Description	Specifications
1.	Power scope	
2.	DC Power Supply	0-32V,2A
3.	Trainer kit	--
4.	DMM	0-20V
5.	Function generator	--
6.	Connecting wires	--

Theory :

We have provided bridge inverter using MOSFET as shown in diagram. When MOSFET Q1 & Q4 conduct, load voltage will be positive. When MOSFETs Q2 & Q3 conduct, load voltage will Be negative. In this type of inverter, three power supplies are required. One supply for control action and DC supply for control action & DC power supply to bridge.

We have to drive MOSFET (1 3 2) with respect to their sources. For this purpose, we need Two separate power supplies for isolation purpose. Four opto-couplers are used to drive gate of MOSFET. For control action, we have to use IC 3524. This Ic is used for switching require transformer coupled dc-dc converters, transformer are less voltage doubles , dc to ac inverter ,highly efficient variable power supplies as well as other power control application.

For our application, we can change the pulse width by varying the voltage applied to pin 2 of IC 3524. As voltage at pin increases, pulse width increases frequency is set to 50 HZ by adjusting resistance at pin 6.we get require base drives for 1-4 and 3-2 at pin 12 and pin 13.

This control signal are connected to opto-isolator input ; at the output of opto-isolator, control

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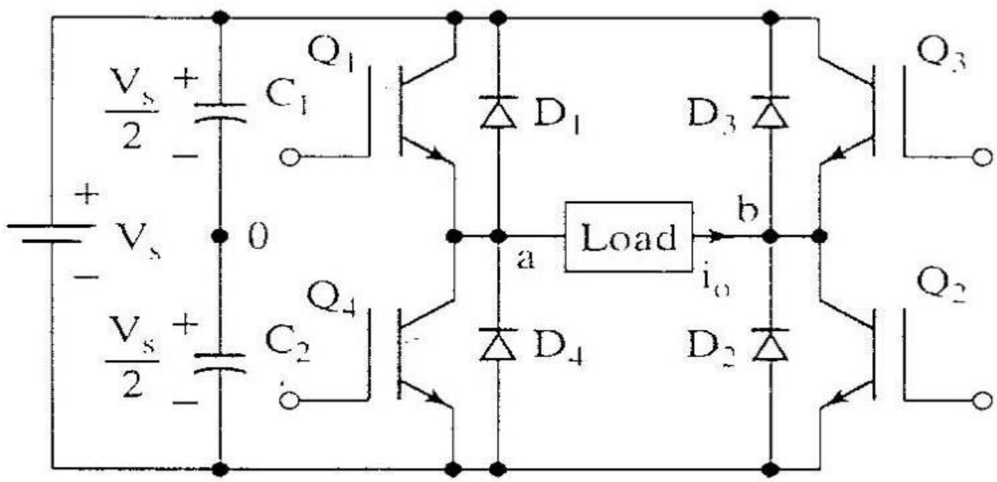
signal inverted, which are actually fed to gate of the MOSFET. Final output of inverter is given to step-up transformer .at the output of step-up transformer; a lamp load of 15w is connected.



Procedure :

Note: first keep switch near lamp to upper position.

1. Switch ON the power supply.

2. Observe point A & B on dual scope CRO.

3. Observe output of isolator 3 & 4 with respect to ground point(GND and bridge inverter) on dual scope CRO.

4. Observe output of isolator 1 with respect ground 1.

5. Observe output of isolator 2 with respect to ground 2.

6. Observe output across the load (for this, first ensure that, switch is at upper position).

7. Keep switch near lamp load to lower position, so that lamp will glow and observe its effect on output across load.

8. Vary pulse width and observe its effect on intensity of lamp. As pulse width increases, output voltage also increases and as pulse width decreases, output voltage decreases.

Observation :

Observe the waveforms

1. At socket B

Triangular waveform

Fmin= 1.262 kHz

Vpp= 2.88V

Fmax= 1.092MHz

2.At socket C

Digitized sine wave
Fmin= 329.70Hz

Vpp= 4.6V

Fmax= 1.52KHz

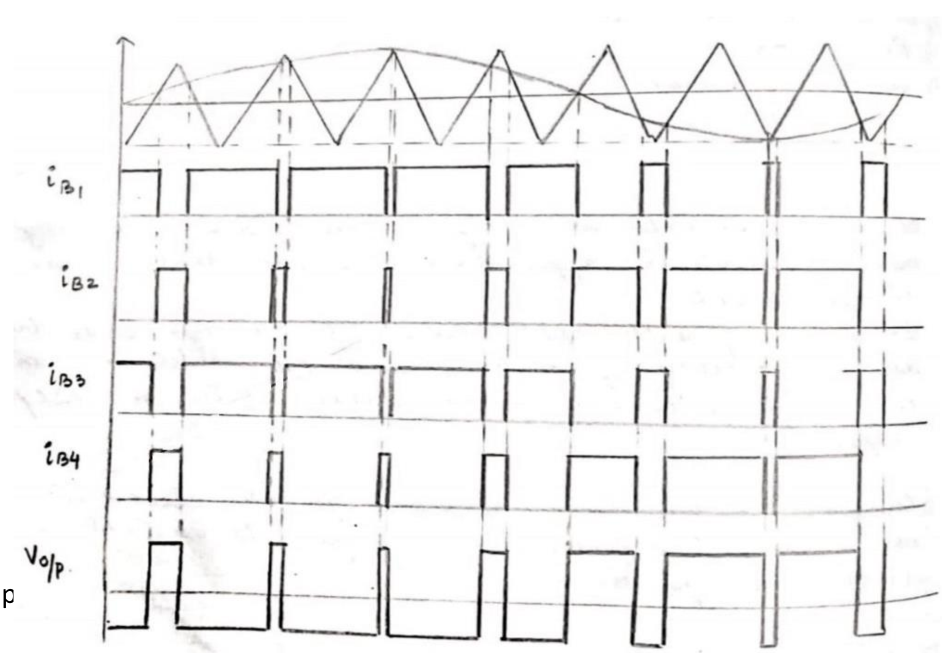
3. At socket D

PWM wave

Fmin=435.50Hz

Vpp=16.2V

Fmax=1.8KHz



Conclusion :

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Subject : Power Devices Circuit Lab
Class : TE

Experiment No 6

Aim: - To Study Chopper using MOSFET.

Apparatus:- Experimental kit,CRO, DMM, Connecting wires

Theory: - **DC to DC converter** is very much needed nowadays as many industrial applications are dependent upon DC voltage source. The performance of these applications will be improved if we use a variable DC supply. It will help to improve controllability of the equipments also. Examples of such applications are subway cars, trolley buses, battery operated vehicles etc. We can control and vary a constant DC voltage with the of a **chopper**.
Chopper is a basically static power electronics device which converts fixed DC voltage/power to variable DC voltage or power. It is nothing but a high speed switch which connects and disconnects the load from source at a high rate to get variable or chopped voltage at the output.

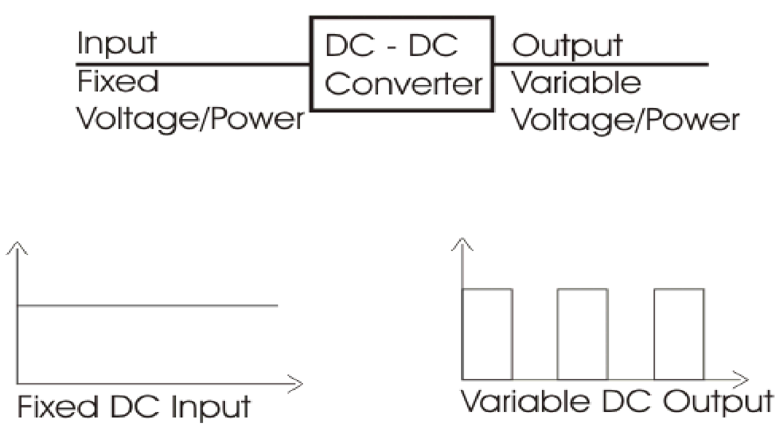


Fig 1 Chopper

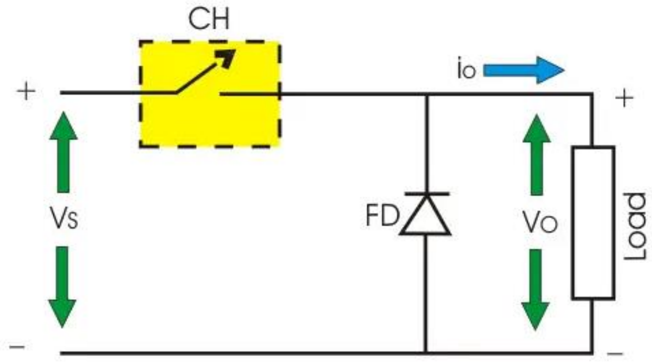
Chopper can increase or decrease the DC voltage level at its opposite side. So, chopper serves the same purpose in DC circuit transfers in case of ac circuit. So it is also known as DC transformer.

Devices used in Chopper

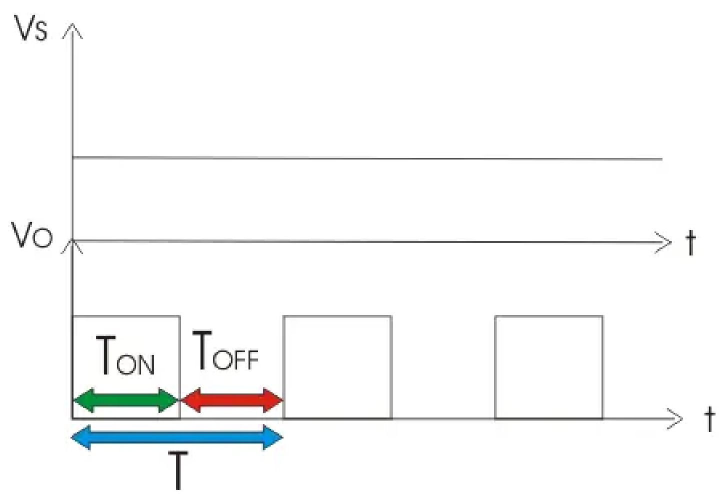
Low power application: GTO, IGBT, Power BJT, Power MOSFET etc.
High power application: Thyristor or SCR.
These devices are represented as a switch in a dotted box for simplicity. When it is closed current can flow in the direction of arrow only.

1) Step down Chopper :

Step down chopper as Buck converted is used to reduce the i/p voltage level at the output side. Circuit diagram of a step down chopper is shown in the adjacent figure.



When CH is turned ON, V_s directly appears across the load as shown in figure. So $V_o = V_S$. When CH is turned off, V_s is disconnected from the load. So output voltage $V_o = 0$.



Procedure:

1. Switch on the power supply.
2. Connect CRO GND to GND2 of control power supply.
3. Observe 555 o/p on CRO and measure its frequency
4. Connect o/p of 555 to i/p of Retriggerablemonoshot
5. Observe o/p of monoshot along with 555 o/p on dual trace CRO
6. Observe effect of nearby pot on the o/p of monoshot
7. Measure minimum duty cycle & maximum duty cycle of monoshot o/p
8. Measure supply voltage between GND1 & positive of upper power supply block
9. Connect GND2 to source of MOSFET i.e. ‘S’
10. Connect positive of upper power supply block to Drain of MOSFET i.e. ‘D’. 11. Connect o/p monoshot to Gate of MOSFET i.e. ‘G’
12. Connect point ‘S’ to load

13. Observe o/p across load. This time CRO gnd is connected to GND1. 14.
Connect source of MOSFET to common point of L1 & L2.
15. Connect other point of L1 to C1 and also to the load.
16. Observe o/p across the load on CRO
17. Measure DC Voltage across load using DMM
18. For minimum duty cycle & maximum duty cycle, measure load voltage (load is set to 200 ohm). Verify theoretical & practical results.
19. For L1 & C2 combination repeat above procedure. Also observe ripple at the load.
20. Now connect L2 & C1 combination along with Ioad (200 ohm).
21. For min. & max duty cycle measure load voltage & verify with the theoretical results. 22.
Repeat above for L2 & C2 combination.

Observation Table:

A) R load without filter

Sr. No.	Duty Cycle (%)	Output Voltage Practical (V)	Output Voltage Theoretical (V)

B) R load with filter (L1& C1)

Sr. No.	Duty Cycle (%)	Output Voltage Practical (V)	Output Voltage Theoretical (V)

Conclusion:-

Experiment No 7

Aim: Find load & line regulation of given SMPS

Apparatus :

Sr. No.	Description	Specifications
1.	SMPS Kit	
2.	Variac	
3.	DC Power Supply	0-32V,2A
4.	DMM (as voltmeter)	0-20V
5.	Connecting wires	---------

Theory

SMPS is an electronic power supply where to convert power in easy manner it uses switching regulator. SMPS can change the output voltage by switching lossless components like capacitors and inductors in between various electrical configurations. These switching components are known as transistors which managed outside the active mode, when it is "on" has no resistance and when it is "off" has no current. So it converts by this method with 100% efficiently. In short, the power transferred to the load so the power is not consumed to abandon the heat. There is no such method is exist in real; that's why the switching power supply is not 100% accomplished but it is still essential on linear regulator.

Applications of Switched Mode Power Supply

Switch Mode Power Supply (SMPS) applications, for the most part, include power connectors, desktop power, or server control. SMPS plan is isolated into essential and auxiliary areas due to segregation topology. The essential area includes EMI sifting, input correction, and control calculate redress (PFC) gadgets. The foremost critical plan concept is PFC to make strides proficiency. Great execution of a PFC rectifier enables the control supply to function productively beneath a light current stack. Ultra-fast recuperation time of the rectifier and low Qg of the exchanging MOSFET are the foremost critical variables related with PFC. No matter what kind of topology is included, PFC is the key not as it were to expanding effectiveness, but moreover to progressing warm execution, particularly for 80-plus SMPS. For EMI, film capacitors and ceramic plate capacitors are great for X-capacitor and Y-capacitor plan, individually. With respect to input rectifier gadgets, single-phase bridge rectifiers are the finest arrangement.

Types of SMPS (Switch Mode Power Supply)

- **DC-DC :**The power gotten from AC mains is amended and sifted as a high-voltage DC. This high DC voltage is at that point exchanged and nourished to the step-down transformer at the essential side. At the auxiliary side of the step-down transformer, the corrected and sifted yield is collected which is eventually sent as the yield to the control supply.
- **Forward**
  Independent of in the event that the transistor is conducting or not the choke carries the current within the forward converter. The diode interior the transistor carries the current amid the OFF period to back the vitality stream through the stack.
- **Flyback**
  In a Flyback converter, amid the On period of the switch attractive field of the inductor stores vitality. When the switch is within the open state the vitality is purged into the yield voltage circuit. The Duty cycle within the Flyback converter is decided by the yield voltage.
- **Self-oscillating:**
  It is based on the Flyback guideline. Amid conduction, a current through the transformer essential begins to slope up directly with the incline Vin/Lp. Due to the voltage initiated within the input winding and the auxiliary winding, the fast recovery rectifier begins to function in switch one-sided and hold the conducting transistor ON.

Advantages

- The switch mode power supply encompasses a smaller in size.
- The switch mode power supply has light weight.
- It includes a way better power effectiveness ordinarily 60 to 70 percent.
- It features a solid against interference.
- SMPS has wide yield range.

Disadvantages

- The switch mode power supply is complex.
- The SMPS has higher yield swell and its control is worse.

- It can be utilized as it were as a step down regulator.
- It has as it were one output voltage.
- SMPS moreover cause harmonic distortion.

Procedure

For Load Regulation:

Connect VARIAC to ac input terminals, ensuring at zeroposition switch ON it.
Now apply 230V ac from VARIAC, measure o/p at given terminals, it will be of 12V dc which is no load voltage i.e. VNL= 12V.
Connect a load or (rheostat) having 100 Ω to 220Ω at o/p,measure o/p across load.
Vary the load, from 220Ω to 2KΩ measure corresponding loadvoltages.
Tabulate the readings, find load regulation.

For Line Regulation:

Connect VARIAC to ac input terminals, ensuring at zeroposition switch ON it.

Now apply 250V ac from VARIAC, connect a load resistance of1KΩ, measure o/p at given terminals, it will be of 12V dc.

1. Decrease the ac i/p from VARIAC in step of 10V, measure o/p.
2. Repeat step 3 for various i/p voltages up to 150V.
3. Tabulate the result

Observation Table:

V_{NL} = 12V

(A) **For Load Regulation:**

Sr. No.	**RL**	**VFL (V)**	**Load Regulation (%)**
1	220Ω		
2	330Ω		
3	470Ω		
4	1KΩ		
5	2KΩ		

(B) **Line Regulation:**

Sr. No.	Variac voltage	Vo (V)	Line Regulation (%)
1	250V		
2	240V		
3	230V		
4	220V		
5	210V		
6	200V		

Calculations:

A) Load Regulation:

$$\%\text{Load Regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} * 100$$

B) Line Regulation:

$$\%\text{Line Regulation} = \frac{\Delta V_0}{\Delta V_{in}} * 100$$

Conclusion

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Subject : Power Devices Circuit Lab
Class : TE

Experiment No 8

Aim : Study and Design of single phase AC Voltage regulator using PSIM software.

Apparatus : 1. PSIM software
2. Computer

Theory :

AC voltage controllers (ac line voltage controllers) are employed to vary the RMS value of the alternating voltage applied to a load circuit by introducing Thyristors between the load and a constant voltage ac source. The RMS value of alternating voltage applied to a load circuit is controlled by controlling the triggering angle of the Thyristors in the ac voltage controller circuits.

In phase control the Thyristors are used as switches to connect the load circuit to the input ac supply, for a part of every input cycle. That is the ac supply voltage is chopped using Thyristors during a part of each input cycle. The thyristor switch is turned on for a part of every half cycle, so that input supply voltage appears across the load and then turned off during the remaining part of input half cycle to disconnect the ac supply from the load.

By controlling the phase angle or the trigger angle 'α' (delay angle), the output RMS voltage across the load can be controlled. The trigger delay angle 'α' is defined as the phase angle (the value of ωt) at which the thyristor turns on and the load current begins to flow.

A single-phase AC controller (voltage controller) is used to vary the value of the alternating voltage after it has been applied to a load circuit. A thyristor is also placed between the load and the constant source of AC voltage. The root mean square alternating voltage is regulated by changing the thyristor triggering angle. In the case of phase control, the thyristors are employed as switches to establish a connection from the AC input supply to the load circuit during each input cycle. For every positive input voltage, chopping occurs and voltage is reduced.

Circuit Diagram:

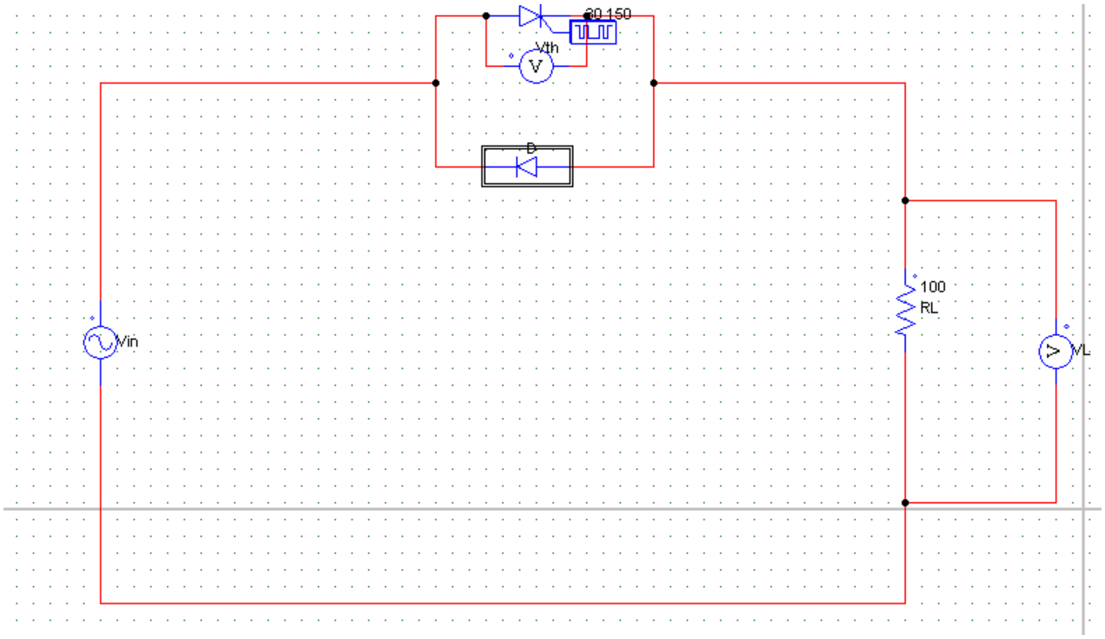

Fig.1. Single phase half wave controlled VSC with R load

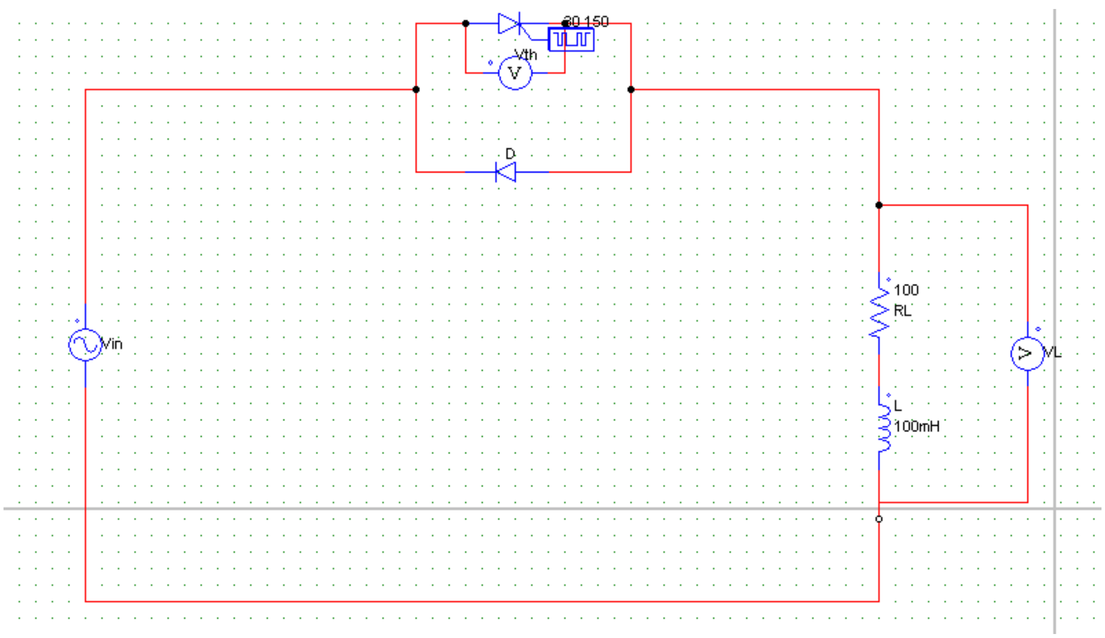

Fig.2. Single phase half wave controlled VSC with RL load

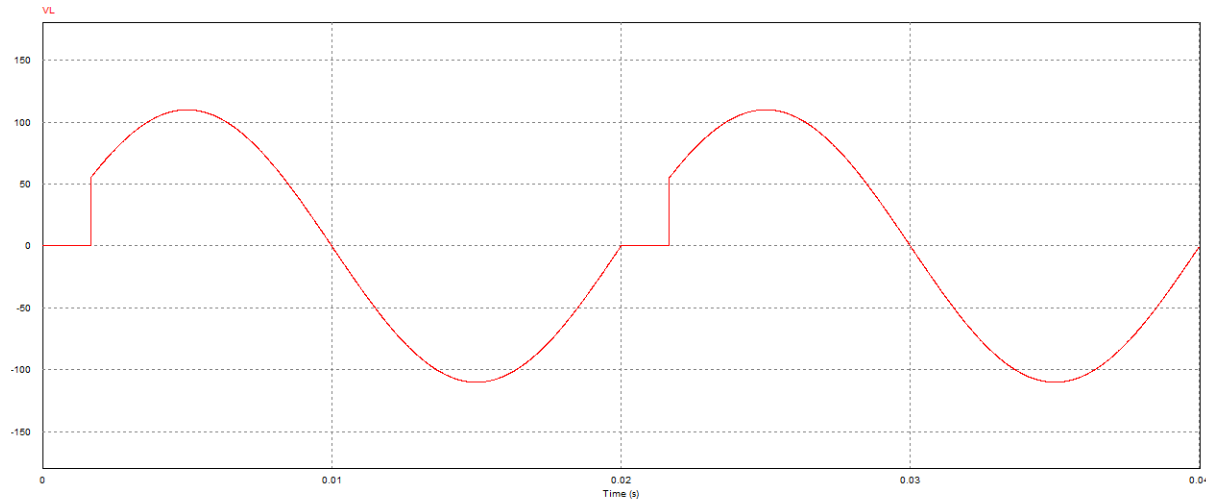

Fig.3. Output voltage of Single phase half wave controlled VSC with R load

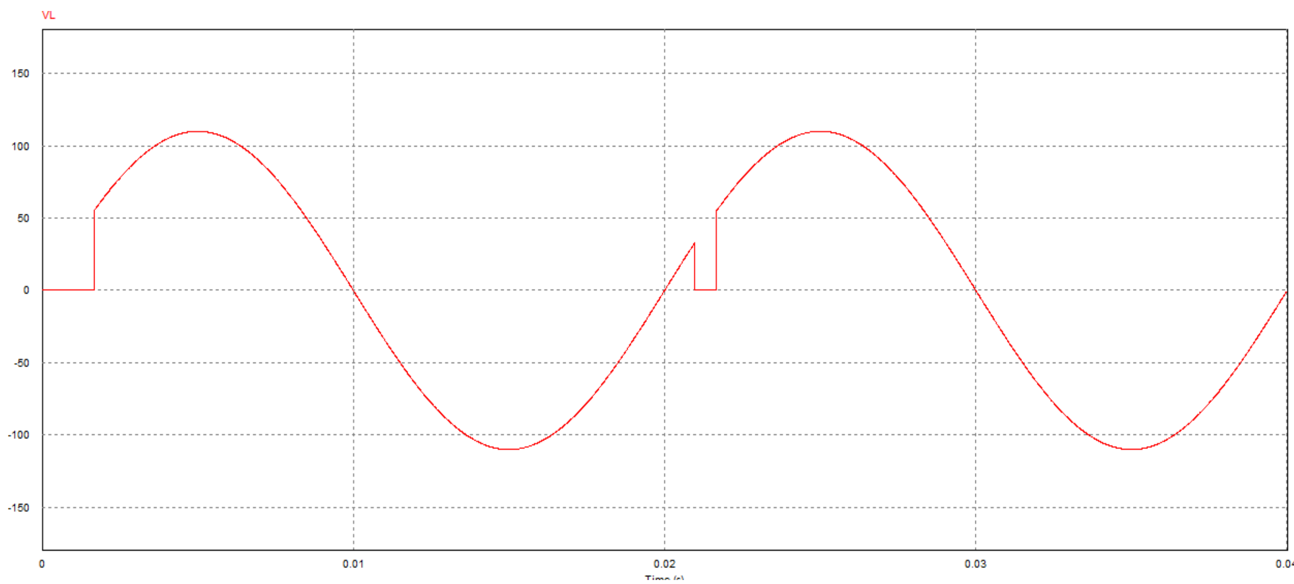

Fig.4. Output voltage of Single phase half wave controlled VSC with RL load

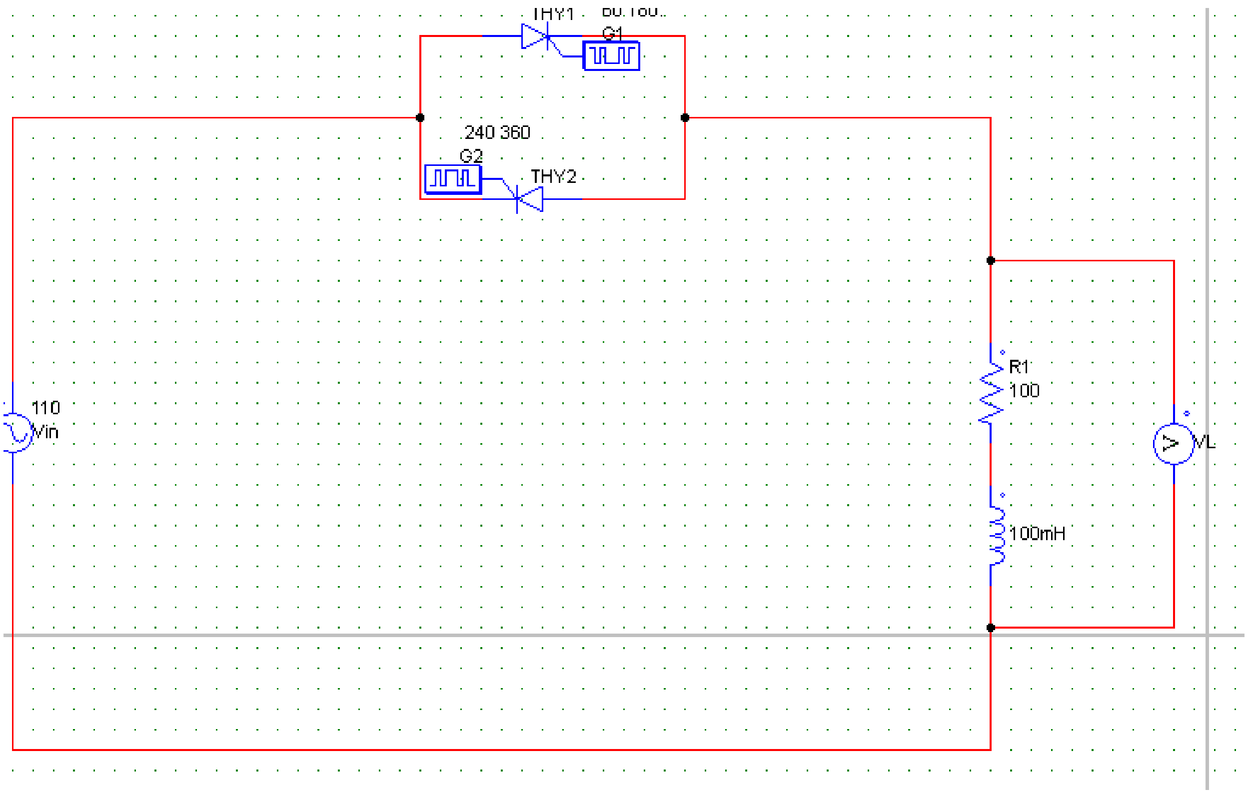

Fig.5. Single phase full wave controlled VSC with RL load

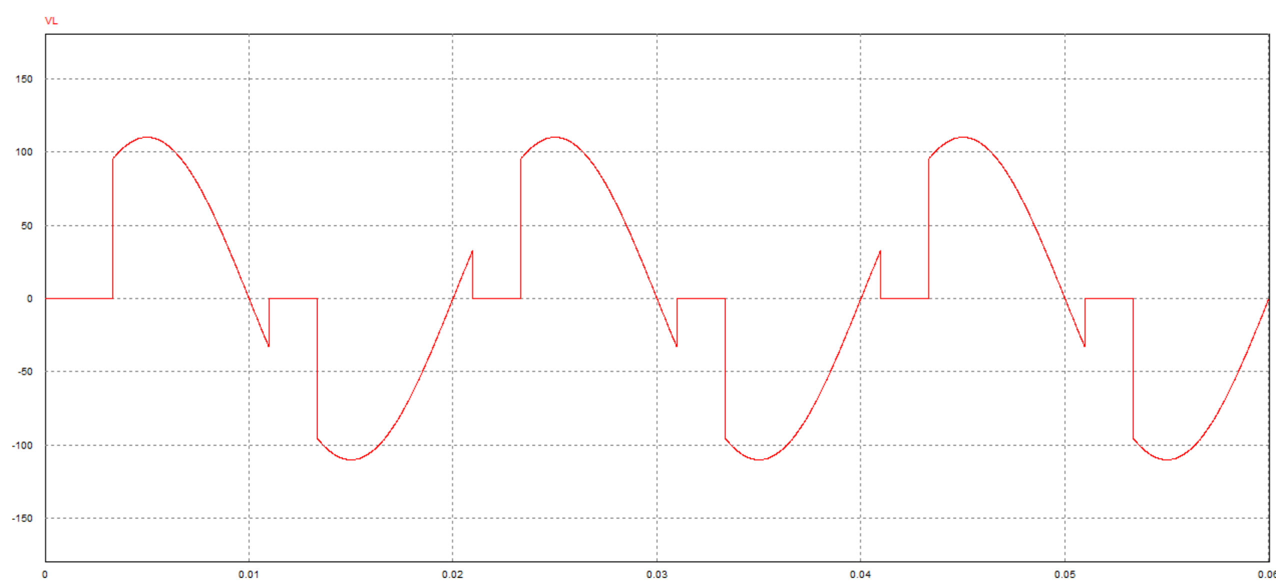

Fig.6. Output voltage of Single phase full wave controlled VSC with RL load

Procedure :

1. Open PSIM software.
2. Drag electronic elements from PSIM library.
3. Check for errors.
4. After removal of errors, RUN the circuit diagram and observe the waveforms.

Conclusion:

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Academic Year -2022-23
Subject : Power Devices Circuit Lab
Class : TE

Experiment No 9

Aim: To study speed control of DC motor / Stepper motor / AC motor

Apparatus :

Sr. No.	Description	Specifications
1.	Trainer Kit	
2.	DMM (as current meter)	0-10mA dc
3.	DMM (as voltmeter)	0-20V dc
4.	Connecting wires	---------

Theory :

We can control the motor speed by using the following two methods: Armature voltage control, Field flux control. When the first method is used the field is kept constant and when the second method is used the voltage is kept constant. First method is used for values below rated speed and the second is used for values above rated speed.

RATED SPEED - The speed which corresponds to the rated values of armature voltage, armature current and field current.

CONSTANT TORQUE REGION **-** The region below rated speed is the constant torque region and in this region we achieve speed control by varying the armature voltage. In this region the torque is constant while the power rises linearly with speed.

CONSTANT POWER REGION **-T**he region above the rated speed is the constant power region. In this region the speed is varied by varying the field flux. Here the torque gradually decreases but the power remains constant. By decreasing the field flux we are gradually increasing the speed hence this is known as Field Weakening.

The dc chopper is a high speed on and off switching devices. Therefore basic operation of dc chopper is to connect and disconnect the load from source at a great speed. Hence we obtained a chopped dc voltage from a constant dc voltage. In dc chopper operation we can observe two time period. They are ton and toff. During ton we get constant source voltage Vs} across load during toff we get zero voltage across load. Likewise we obtain dc voltage in the dc chopper load terminal.

Procedure :

1. Switch on the kit.
2. MOSFET based drive channelizes the current into the motor to control its speed.
3. The MOSFET Ton and Toff are controlled by the control signal (PWM).
4. Feedback is applied to the controller that maintains the speed at a particular decided speed.
5. To increase the speed further move the knob ahead to a new position to increase the speed.
6. Note the readings at different intervals and repeat the steps.

Conclusion :

Experiment No 10

Aim: To study battery testing, safety and maintenance of batteries.

Battery Testing

Battery testing should be considered an integral part of any periodic vehicle maintenance routine and should be performed whether or not a starting problem has occurred. Due to the increased electrical demands on the battery, little warning is given before failure. Pre-emptive battery replacement can help eliminate many of the costs and problems associated with a flat or end of life battery.Before testing a battery, it is important that the battery is fully charged. Even a slightly discharged battery can give a false reading and deem the battery faulty. There are many different types of testing equipment available. A digital battery tester is the preferred option as they are safe, easy to use and offer a quick diagnosis of the condition of the battery. Fixed and adjustable load testers, voltmeters, hydrometers and discharge testers can also be used, however correct training is required prior to using any of these testers to prevent personal injury or damage to the vehicle.

Hydrometer

The state-of-charge of a lead acid battery can be determined by the specific gravity (SG) of the electrolyte (its density compared to a reference such as water). The SG can be measured directly with a hydrometer or indirectly by the stabilised voltage with a voltmeter. Please note the temperature of the acid affects the result.

Digital Battery Testers

Microprocessor controlled digital battery testers are easy to use, very safe and can help determine early battery failure. The tester works by transmitting a small signal through the battery that uses measurements of conductance or resistance (impedance) to indicate battery condition.
Most models provide battery, starting and charging tests. Printer options enable results to be given to the customer.

Adjustable Load Testers

Adjustable load testers are a reliable method to determine the starting capacity of a battery as the test applies a real load similar to when cranking the engine. This load however does create a spark risk if leads are connected to corroded or loose terminals.

The standard test is to load the battery to 50% of its CCA rating (Cold Cranking Amperes) for 15 seconds. If the voltage reads above 9.6 volts the battery is ok. For example a battery that has a CCA rating of 600 should be tested at 300CCA for 15 seconds.

The standard interpretation of the result is that if, at the end of the 15 second test, the loaded voltage reading is between 9.6V and 10.6V then the battery is deemed to be good. If the result is under 9.6V the battery is not good and may not crank the engine. It is always recommended that you check the individual manufacturer's specifications.

Constant Rate Discharge Testers

Discharge testers are a simple method to check the capacity of a battery and are commonly carried out on Deep Cycle batteries.The tester works by discharging the battery at a pre-set current (Amps) until it drops to a pre- set disconnect voltage. The biggest concern with this type of tester is the time it takes to perform the test.As an example, if you were testing a 100 Ah (Ampere Hour) battery at 5 Amps, it could take up to 20 hours to complete the test.

Battery Charging

Charging a lead acid battery is the process of replacing the energy removed during discharge, plus EXTRA to compensate for any charging inefficiencies. The amount of energy necessary for complete recharge depends on the depth of discharge, rate of recharge and temperature. Typically 110% - 150% of the discharged ampere-hours depending on battery type must be returned to the battery to achieve full recharge.

Safety First

Before attempting to charge a battery with an external battery charger, it is important to be aware of the safety precautions when charging batteries and follow the instructions outlined by the charger manufacturer.

1. Turn the charger off before attaching, rocking or removing the terminal clamps.
2. Keep open flames and sparks away from the battery.
3. Keep vent caps in place.
4. Charge in well ventilated area.
5. Follow the battery charger manufacturer's instructions to avoid overheating.

Dangerous explosive gases are generated during the charging process that can be ignited by a variety of sources including, sparks, naked flames and static electricity. It is highly recommended to wear PPE (Personal Protection Equipment) including safety glasses, chemical resistant gloves and overalls.

Selecting the Correct Charger

Lead acid batteries should be charged in 3 stages; constant current (boost), constant voltage (absorption) and float charge.
When choosing a battery charger, it is important to select a charger that delivers the specified charging voltage and current to suit the battery type. Flooded, Absorbed Glass Mat (AGM) and Gel battery types require different charging specifications to provide optimum performance and service life.

Charging Voltage (for manual chargers)

Monitoring battery voltage during charging is extremely important to reduce the risk of overcharging and to check the progress of the battery during recharge. Always keep inside the parameters outlined in the below table. Failure to do so can result in permanent damage to the battery.

Auxiliary Charge Voltage by Battery Type

Type	Absorption Charging	Float Charging
Flooded (Maintainable / SMF)	14.4 to 14.8V	13.2 to 13.5V*
AGM (Absorbed Glass Mat)	14.6 to 14.8V	13.6 to 13.8V
Gel Electrolyte	14.2 to 14.4V	13.6 to 13.8V

The recommended temperature during charging is 25°C. Charging must be paused if the battery reaches 50°C. The above specifications are for 12 volt lead acid batteries. In addition to following the battery charging voltage guidelines, selecting the correct charging current (Amps) for the battery size is crucial to provide performance .

Charging Current (for manual chargers)

The recommended safe charging current is 10% of the battery's 20 hour (Ah) rating. For example if you want to charge a 100Ah battery, the recommended charger current for this battery would be 10 Amps. Slow charging is the best way to recharge a lead acid battery. Fast charging a lead acid battery by increasing the recommended amperes may cause undue stress and shorten battery life.

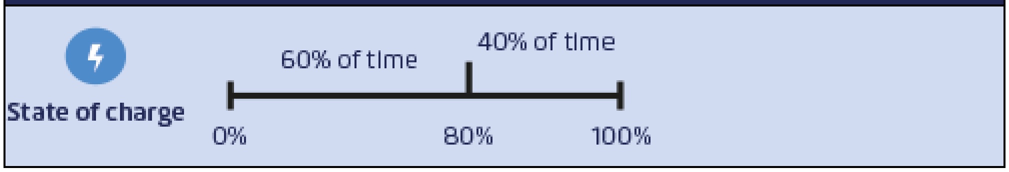
Current Charging Method (Amps x Hours)

Auxiliary Charging Chart		Product Rated Capacity							
		Rc (minutes)	< 65	65-80	81-105	106-120	121-150	151-170	171-185
		Ah @ 20hr	31-40	41-50	51-60	61-70	71-80	81-90	91-100
OCV	SOC %	Charging Current (10% of Ah)	4A	5A	6A	7A	8A	9A	10A
12.42~12.54	70~75%	Charging Time	3 Hours						
12.36~12.48	60~70%		5 Hours						
12.24~12.36	50~60%		6 Hours						
12.12~12.24	40~50%		8 Hours						
12.00~12.12	30~40%		9 Hours						
Below 11.99	<30%		12 Hours						

- Due to efficiency aspects, the charge amount must be more than the discharged amount. This coefficient factor can be between 110% to 150%.
- The deeper the discharge, the higher the coefficient factor.

Note: Charging must be paused when the temperature rises above 50°C

Charging Time



Typical Charging Time vs. 80% and 100% State of Charge

It will take about 60% of the total charging time to charge a lead acid battery to 80%, and the remaining 40% of the time to put the last 20% of charge back into the battery.

The recharging duration is difficult to determine due to variables such as:

- Depth of discharge
- Temperature
- Size and efficiency of the charger
- Age and condition of the battery
- For a guide, refer to the constant current charging method table

Connecting Batteries - Parallel Connection

- When connecting multiple 12 volt batteries in parallel, you are increasing the capacity of the battery bank while maintaining the voltage. E.g. 3 x 12 volt 60Ah batteries when parallel connected will create a 12 volt 180Ah bank.
- When connected to a battery charger, the charging current is divided between all the batteries in the bank. E.g. A 15 amp charger connected to 3 batteries will provide up to 5 amps current into each battery.

Connecting Batteries - Series Connection

- When connecting 12 volt batteries in series, you are increasing the voltage of the battery bank while maintaining the current. E.g. 3 x 12 volt 60Ah batteries when series connected will create a 36 volt 60Ah bank.

- When charging batteries in series, you must have the correct voltage charger for the number of batteries in the bank. E.g. If you have 3 x 12 volt batteries in series, you must use a 36 volt charger.

Factors Affecting Battery Life

As batteries age they gradually lose their capacity as their function is performed. The constant charge and discharge eventually leads to failure. Components corrode over time, electrical shorts occur and vibration causes damage; all eventually causing failure.

Battery Inspection

Check electrolyte level - fluid below the tops of the separators indicates overcharging or poor maintenance. Overcharge condition may be due to incorrect voltage setting, low voltage caused by heat or internal defects, or old age deterioration.

- Is there electrolyte on the top of the battery? This can indicate overcharging or overfilling.
- Is the battery loose in the carrier? This can cause failure from vibration.
- Does the battery have signs of damage or mistreatment? This can also cause failure.

Discharged (flat) Batteries

A flat battery should be checked with a hydrometer. A low Specific Gravity reading of 1.220 or less in all cells indicates a discharged battery and it must be charged before further examination and testing can occur. The discharged condition may be due to a problem in the electrical system (slipping alternator belt, faulty regulator or alternator, high resistance due to corrosion).

Early Warning Signs

Batteries often fail when least expected. The usual warning is a slower than normal battery ability to crank the engine. Other less noticeable factors, such as changed driving patterns and colder/hotter weather will all have an effect on the life of a battery. Encourage your customers to ask for a ‘FREE Battery Test’. It’s good public relations and if the battery is near failure, it may avoid the inconvenience of a roadside breakdown.

Technical Tips

Vibration can reduce a battery’s life. Always use an approved battery clamp to limit vibration. Century batteries are built tough, using robust internal components to resist damage through abrasion and puncture from vehicle vibration.

- Many alleged ‘dead batteries’ are merely flat batteries. Drivers simply leave lights on or can have faulty voltage regulators.
- Ensure your battery is properly tested before replacing a battery. It’s impossible to know exactly when a battery might fail. A slow starting engine is sometimes an indication.
- Old batteries can give trouble in colder weather.
- Equally, if an engine area becomes overheated in very hot weather and the battery is under strain from air conditioners it may fail. Regular battery checks are always advised.

Why do Batteries Fail?

Batteries have a finite life, determined by the application and the operating conditions. Battery failure can be attributed to various factors, however the causes of failure fall under two distinct categories: manufacturing..

Manufacturing Faults

Typically occur within the first 3 months.

Short Circuits/Dead Cells

Where one cell will show a dramatically lower Specific Gravity (SG) reading than the other cells.

Internal Break

Usually resulting from physical damage to a battery during transportation. Century’s stringent quality assurance and inspection processes demanded by leading vehicle manufacturers ensure genuine manufacturing faults in Century Batteries are negligible.

Non Manufacturing Faults

These fall outside of Century’s strict quality control systems and are more likely to occur the longer the battery is in service. They are often attributed to a problem with the vehicle’s electrical system, its operation or the battery application.

Wear and Tear

As a battery ages, grid metal corrodes and active material is lost from the plate. Over time this leads to a point where the battery will no longer be able to start a vehicle. High temperature will accelerate the degradation rates.

Physical Damage

Incorrect fitment, handling and storage often leads to external damage and subsequent battery failure.

Incorrect Application

Fitting a smaller, less powerful battery or a battery designed for another application can lead to early failure.

Negligence

Failure to maintain fluid levels exposes internal components and accelerates battery failure.

Sulphation

Occurs when the battery is allowed to stand in a discharged state for an extended period of time.

Over-Charging

Often caused if the alternator is incorrectly set or the alternator voltage control fails.

Under-Charging

Short journeys, stop start driving or faulty alternators will not fully recharge a battery.

Discharge

Lights or other accessories left on for extended periods.

Battery Maintenance :

Battery maintenance is well recognized as an important part of running an efficient and safe warehouse. However, the appropriate procedure for battery maintenance is often overlooked. Performing maintenance in the correct order is just as essential as the maintenance steps themselves when it comes to saving time, extending the lifespan of your battery and protecting your equipment.Follow the correct maintenance order for your batteries:

- **Charge battery once it is down to 20% capacity.**
  Do not allow battery to drop below 20% power before charging. Discharging the battery's banks too far will harm the battery, permanently impacting the performance and endurance of the battery. It may also overheat, damaging electric circuits to the forklift.Allow battery to charge to full power uninterrupted. A battery's lifespan is often proportional to the number of charges it receives. Undercharging, charging for short periods of time multiple times a day (this includes quick charging during a lunch break) or charging before battery has discharged more than 50% of its power can all lead to decreased performance rate and a shortened battery life.
- **Deliver equalizer charge when necessary.**
  This is a deliberate overcharge that many batteries require to function properly and efficiently. Chargers for batteries that need this will have button that must be manually pressed to turn on the equalizer charge. If you are uncertain about whether an equalizer charge is necessary, how often to deliver it or how to deliver an equalizer charge, consult your battery/charger manual for further instructions.During the process of receiving an equalizer charge, batteries will charge for a longer period of time. This extended charge time may lead to overheating, and batteries should be monitored during this process.
- **Turn power off and allow battery to cool before removing.**
  Do not turn power off until *after* battery has reached 100% power. The battery will run more efficiently throughout the day if it has reached full power. This practice will also decrease the number of times the battery needs to be charged, thus increasing the battery's lifespan.
  Battery must cool before being placed back into service or it may overheat, potentially damaging both the battery and electrical circuit.

- **When water/electrolytes are needed, be sure to water battery *after* charging and disconnecting.**
  It is not safe to water battery at any other point in time. Charge before watering as heat of charging can cause changes in water levels (both as evaporation and overflow). If water levels are quite low before charging, you may add a small amount of water to prevent battery overheating during the charging process.
- **If battery is overfilled, clean battery *immediately following* overflow.**
  Overflow during this process will leak battery acid across the surface of the battery and will cause corrosion if not immediately cleaned. Corrosion and residual acid can deteriorate battery life and cause battery to overheat during charging and use

- **Clean battery with a neutralizing detergent solution on a regular basis.**
  Surface cleaning will prevent grime build-up, corrosion and resulting problems.
  Clean battery *after* watering. This will save you from repeating a step in the event of an overflow, water drips, etc. Always clean batteries in the designated washing area with the appropriate equipment and specialized neutralizing detergent. The neutralizing agent may be a specified cleaner or a simple sprinkling of baking soda. Whatever is used, this is a vital step that will neutralize any battery acid that has accumulated on the surface and prevent corrosion of the battery and surrounding electrical circuits.

Conclusion :