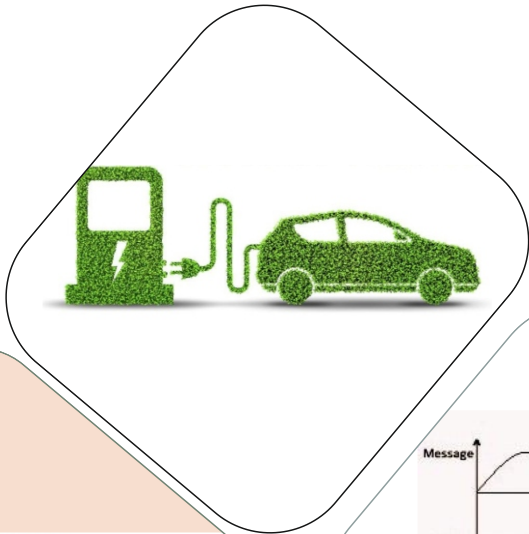
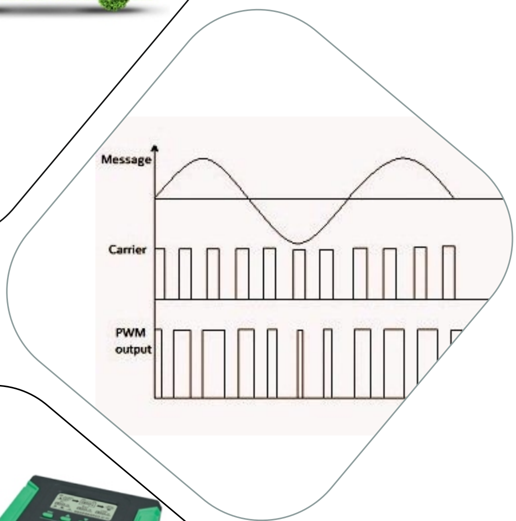
SCHEME :K

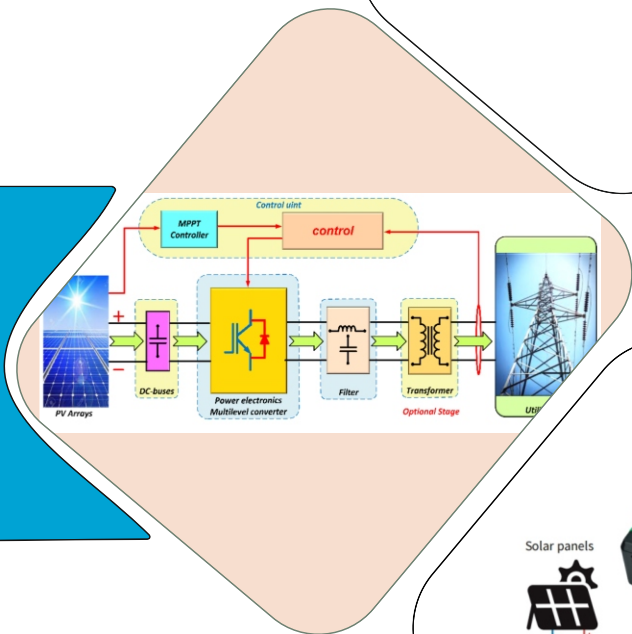
Name :______________________________
Roll No.:__________ Year : 20 ___ 20 __
Exam Seat No. :______________________

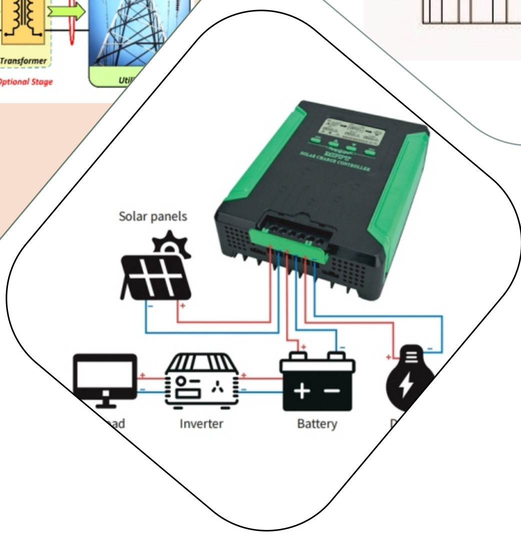
LABORATORY MANUAL FOR

ADVANCE POWER ELECTRONICS (315340)









ELECTRONICS ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)

VISION

To ensure that the Diploma Level Technical Education constantly matches the latest requirements of technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the changing technological and environmental challenges.

QUALITY POLICY

We, at MSBTE, are committed to offer the best-in-class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation evaluation and monitoring system along with adequate faculty development Programs.

CORE VALUES

MSBTE believes in the followings:

- Skill development in line with industry requirements.
- Industry readiness and improved employability of Diploma holders.
- Synergistic relationship with industry.
- Collective and Cooperative development of all stake holders.
- Technological interventions in societal development.
- Access to uniform quality technical education.

A Laboratory manual
for

Advance Power Electronics

(315340)

K-Scheme

Semester – V

(DE/EJ/ET/EX/IE/TE)

Maharashtra State
Board of Technical Education, Mumbai

(Autonomous) (ISO 21001:2018) (ISO/IEC 27001:2013)

Maharashtra State
Board of Technical Education, Mumbai
(Autonomous) (ISO 21001:2018) (ISO/IEC 27001:2013)
4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai – 400051.

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

Certificate

This is to certify that Mr./Ms. ………………………………………. Roll No. ………. Of fifth Semester of Diploma in ……………… of Institute ……………………………………………………….. (Code: ………) has attained pre-defined practical outcomes (PROs) satisfactorily in course **Advance Power Electronics (315340)** for the academic year 20…… to 20…… as prescribed In the curriculum.

Place: …………… Enrollment No.: ……………

Date: …………… Exam Seat No.: ……………

Course Teacher **Head of Department** **Principal**

Seal Of Institut

Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much-needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programs with outcome- based education as the focus and accordingly, a relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work, making each teacher, instructor and student realize that every minute of the laboratory time needs to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through 'chalk and duster' activity in the classroom situation. Accordingly, the 'K' scheme laboratory manual development team designed the practical's to ***focus*** on the ***outcomes***, rather than the traditional age-old practice of conducting practical's to 'verify the theory' (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the predetermined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through the procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student- centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The basic aim of the course Industrial Process Control (315352) is to facilitate the diploma students to acquire an understanding of the skills needed to handle process control system effectively, enhancing their ability to work in process industries.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

Program Outcomes (POs)

Following program outcomes are expected to be achieved through the practical of the course.

PO1: Basic and Discipline specific knowledge: Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the broad-based Electronics Engineering group program problems.

PO2: Problem analysis: Identify and analyze well-defined Electronics Engineering group program problems using codified standard methods.

PO3: Design/ development of solutions: Design solutions for well-defined technical problems and assist with the design of Electronics Engineering group program systems components or processes to meet specified needs.

PO4: Engineering Tools, Experimentation and Testing: Apply modern Electronics Engineering group program tools and appropriate technique to conduct standard tests and measurements.

PO5: Engineering practices for society, sustainability and environment: Apply appropriate Electronics Engineering group program technology in context of society, sustainability, environment and ethical practices.

PO6: Project Management: Use Electronics Engineering group program management principles individually, as a team member or a leader to manage projects and effectively communicate about well- defined engineering activities.

PO7: Life-long learning: Ability to analyze individual needs and engage in updating in the context of Electronics Engineering group program technological changes.

List of Industry Relevant Skills

The following industry relevant skills of the competency "Maintain converters, drives comprising of power electronic devices" are expected to be developed in the student by undertaking the practical of this laboratory manual

1. Select appropriate devices for power control applications based on switching and conduction properties.
2. Identifying faults and losses in converter circuits.
3. Design and testing of driver circuits for SIT, MCT and FCT Power devices.
4. Simulate sinusoidal pulse width modulation (PWM) using MATLAB Simulink / SCILAB/relevant software.
5. Proper handling of instruments.
6. Measure the voltage and current of a lithium-ion battery under various operating conditions.
7. Ability to evaluate converter output under various load conditions.
8. Adopt proper procedure while performing the experiment.

Practical- Course Outcome matrix

Course Level Learning Outcomes (COs)

CO1. Describe the operation of a given process control system

CO2. Apply the suitable process control action to the given unit operation

CO3. Use appropriate safety method in process automation industries

CO4. Describe the operation of a typical Distributed Control System

CO5. Select the relevant Distributed Control System for a given application

Sr. No.	Title of the Practical	CO 1	CO 2	CO 3	CO 4	CO 5
1.	Protection circuit for SCR based on dv/dt method					
2.	Simulation of Type-A chopper (Power MOSFET based) circuit using MATLAB Simulink/SCILAB /relevant software					
3.	Simulation of Type-E chopper (Power MOSFET based) circuit using MATLAB Simulink/SCILAB /relevant software					
4.	Simulation of input output voltage of Buck-Boost Converter Circuit by varying duty ratio using MATLAB Simulink/SCILAB/relevant software					
5.	Simulation of 180-degree mode and 120-degree mode of three Phase Voltage Source Inverter Circuit using MATLAB Simulink/SCILAB /relevant software					
6.	Simulation of sinusoidal PWM Waves using MATLAB Simulink/SCILAB/relevant software.					
7.	Measurement of voltages at different test points and verify specifications of UPS with the datasheet					
8.	Measurement of the output voltage for servo type voltage stabilizer for different values of ac input voltage					
9.	Test Performance of lithium-ion battery					
10.	Test the performance of Charge controller in PV System					

Guidelines to Teachers

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each practical.
3. Involve students in the performance of each experiment.
4. Teacher should ensure that the respective skills and competencies are developed in the students after the completion of the practical exercise.
5. Teachers should give opportunities to students for hands-on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected of the students by the industry.
8. Finally give practical assignments and assess the performance of students based on tasks assigned to check whether it is as per the instructions.
9. Teacher is expected to refer complete curriculum document and follow guidelines for implementation
10. At the beginning of the practical which is based on the simulation, teacher should make the students acquainted with any simulation software environment.

Instructions for Students

1. Listen carefully to the lecture given by the teacher about course, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and make a record of all programs.
3. Students shall develop maintenance skills as expected by industries.
4. Student shall attempt to develop related hand-on skills and gain confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual.
6. Student shall refer technical magazines.
7. Student should develop the habit to submit the practical on date and time.
8. Student should well prepare while submitting a write-up of exercise
9. Attach/paste separate papers wherever necessary.

Content Page

List of Practical's and Progressive Assessment Sheet

Sr. No.	Title of the practical	Page No.	Date of performance	Date of submission	Assessment marks (25)	Dated sign. Of teacher	Remarks (if any)
1.	Protection circuit for SCR based on dv/dt method	1					
2.	Simulation of Type-A chopper (Power MOSFET based) circuit using MATLAB Simulink/SCILAB /relevant software	7					
3.	Simulation of Type-E chopper (Power MOSFET based) circuit using MATLAB Simulink/SCILAB /relevant software	14					
4.	Simulation of input output voltage of Buck-Boost Converter Circuit by varying duty ratio using MATLAB Simulink/SCILAB/relevant software	22					
5.	Simulation of 180-degree mode and 120-degree mode of three Phase Voltage Source Inverter Circuit using MATLAB Simulink/SCILAB / relevant software	29					
6.	Simulation of sinusoidal PWM Waves using MATLAB Simulink/ SCILAB/relevant software.	37					
7.	Measurement of voltages at different test points and verify specifications of UPS with the datasheet	44					
8.	Measurement of the output voltage for servo type voltage stabilizer for different values of ac input voltage	50					
9.	Test Performance of lithium-ion battery	56					
10.	Test the performance of Charge controller in PV System	62					
Total							

Note: Out of above suggestive LLOs -

- '*' Marked Practical's (LLOs) are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

Practical No. 1: Protection circuit for SCR based on dv/dt method

I Practical Significance:

The dv/dt protection circuit for an SCR is essential for ensuring the reliable and safe operation of power electronic devices. SCRs are highly sensitive to rapid voltage changes, and excessive dv/dt (rate of voltage rise across the anode and cathode) can cause unintended triggering, even without a gate signal. This false triggering can lead to malfunctioning of circuits, damage to the SCR, or even failure of the entire system.

II Industry / Employer Expected outcome(s)

- Test the Performance of Power Electronic Devices and Circuits.

III Course Level Learning outcome(s)

- Modern Power Devices and Protection Circuits.

IV Laboratory Learning outcome(s)

- Test the protection scheme of SCR by dv /dt method.

V Relevant Affective Domain related outcome(s)

- Follow safety electrical rules for safe practices.

VI Relevant Theoretical Background.

A snubber circuit is used to protect the SCR from high voltage transients and to control the rate of rise of voltage (dv/dt) across the SCR during turn-off. It typically consists of a series combination of a resistor (R) and a capacitor (C) connected across the SCR:

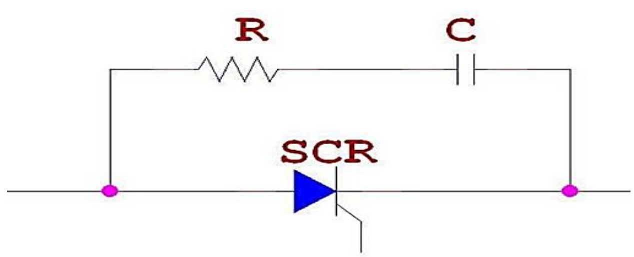


Figure 1.1: Snubber Circuit of SCR in Simplest Form

VII Actual Circuit diagram used in a laboratory with related equipment rating.

a. Sample Circuit:

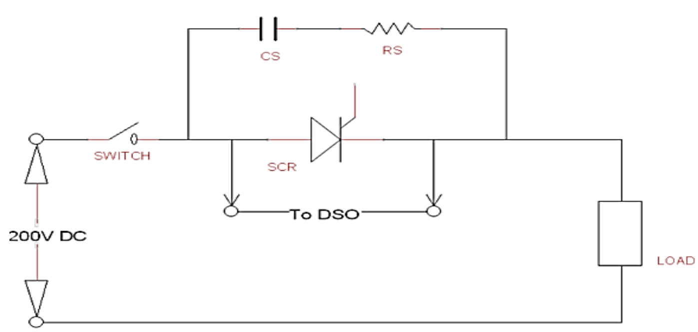


Figure 1.2: Circuit Diagram for Testing Snubber Circuit of SCR

b. Actual circuit diagram/Kit used in the laboratory:

VIII Required Resources/apparatus/equipment with specifications:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Regulated power supply	0-200 V DC	1
2	CRO/Digital Oscilloscope	20MHz, dual channel, sensitivity =1mV/div, Max Input = 400V, Power supply = 230VAC.	1
3	On-Off Switch	250V, 32A, Single Phase	1
4	Resistor	10 Ohm	1
5	Capacitor	0.5microfarad	1
6	Load (Resistive)	100 Ohm; 250V	1

IX Precautions to be followed (Safety instructions / Rules / Standards)

1 Ensure that the connections are correct and tight to avoid any loose contacts.
2 Make sure the oscilloscope probes are correctly placed and grounded.
3 Handle the SCR and other components carefully to avoid damage due to overheating.

X Procedure:

1 Assemble the circuit as per the circuit diagram.
2 Connect the snubber circuit (R-C network) across the SCR.
3 Connect the DC power supply, DSO, and load as shown in the circuit diagram.
4 Switch on the power supply without turning on the SCR.
5 Observe the variation in voltage across SCR using DSO.
6 Plot the observed graph of voltage Vs time
7 Calculate maximum dv/dt from the plotted graph.

XI Required Resources

Sr. No.	Name of Resource	Specifications	Quantity
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2			
3			
4			
5			

XII Actual Procedure

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XIII Observation table

a) Peak Voltage = ...;

b) Rise time = ...

XIV Result(s):

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XV Interpretation of Result(s):

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

Note: Below given are few sample questions. Teachers must design such questions to ensure achievement of identified CO.

1 State the types of protections required for SCR.

2 Illustrate the change in current and voltage across the snubber circuit during the turning on process of SCR with the help of diagram. (Assume the capacitor is charged before turning on the SCR.)

[Space for Answers]

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XVIII References/Suggestions for further reading: include websites/links.

1 Laboratory Manual for introductory electronics experiments, Maheshwari, L.K .; Anand M.M.S., New Age International Pvt. Ltd. New Delhi, ISBN:9780852265543
2 https://www.alldatasheet.com/
3 Power Electronics by P. S. Bimbhra; ISBN: 978-8174092793

XIX Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related (15 Marks)	**60%**
01	Handling of the components	10%
02	Identification of components	20%
03	Measuring value using suitable instrument	20%
04	Working in teams	10%
	Product Related (10 Marks)	**40%**
05	Calculated theoretical values of given component	10%
06	Interpretation of result	05%
07	Conclusion	05%
08	Practical related questions	15%
09	Submitting the journal in time	05%
	Total (25 Marks)	**100%**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 2: Simulation of Type-A Chopper (Power MOSFET Based) Circuit Using MATLAB Simulink/SCILAB/Relevant Software

I Practical Significance:

Type-A choppers (step-down DC-DC converters) are widely used in electric vehicles, battery charging, and motor control systems. Simulation of these circuits using software platforms helps students visualize switching behaviour, output voltage control, and waveform characteristics without the risks associated with hardware. This builds foundational skills required for power electronics design and control.

II Industry / Employer Expected outcome(s)

- Proficiency in simulating and analysing power electronic converters.
- Understanding of switching behaviour and waveform characteristics
- Ability to design, optimize, and troubleshoot chopper circuits
- Exposure to industry-standard tools like MATLAB and Simulink

III Course Level Learning outcome(s)

- Use DC-DC converters for different quadrant applications.

IV Laboratory Learning outcome(s)

- Simulate a Type-A chopper using MATLAB Simulink or SCILAB.
- Measure and analyse key performance parameters such as output voltage, ripple, and duty cycle effects.
- Observe the effect of switching frequency and load variations

V Relevant Affective Domain related outcome(s)

1. Demonstrate attention to detail in simulation settings and circuit configuration.
2. Develop patience and persistence during model debugging and result interpretation.
3. Exhibit curiosity and initiative in exploring different simulation scenarios.

VI Relevant Theoretical Background.

Type-A Chopper Overview:

A Type-A chopper, also known as a step-down chopper, is a DC-DC converter used to reduce the input DC voltage to a lower output voltage. Its basic construction consists of a single controlled switch, typically a power MOSFET or a thyristor, connected in series with a DC supply and a load, along with a freewheeling diode connected across the load to provide a path for the load current when the switch is off. During operation, the switch is turned ON and OFF at a high frequency using a control signal (PWM), controlling the average voltage delivered to the load by varying the duty cycle. When the switch is ON, the load is directly connected to the supply, allowing current to build up; when the switch turns OFF, the freewheeling diode conducts, maintaining the current flow through the load.

This chopper is widely used in electric drives and power supplies where an adjustable DC voltage is required

Average Output Voltage:

Vo=D X Vin …………………. 1.1

Duty cycle (D) = TON / (TON + TOF) ………..……..…. 1.2

VII Actual Circuit diagram used in a laboratory with related equipment rating.

a) Simple Circuit diagram:

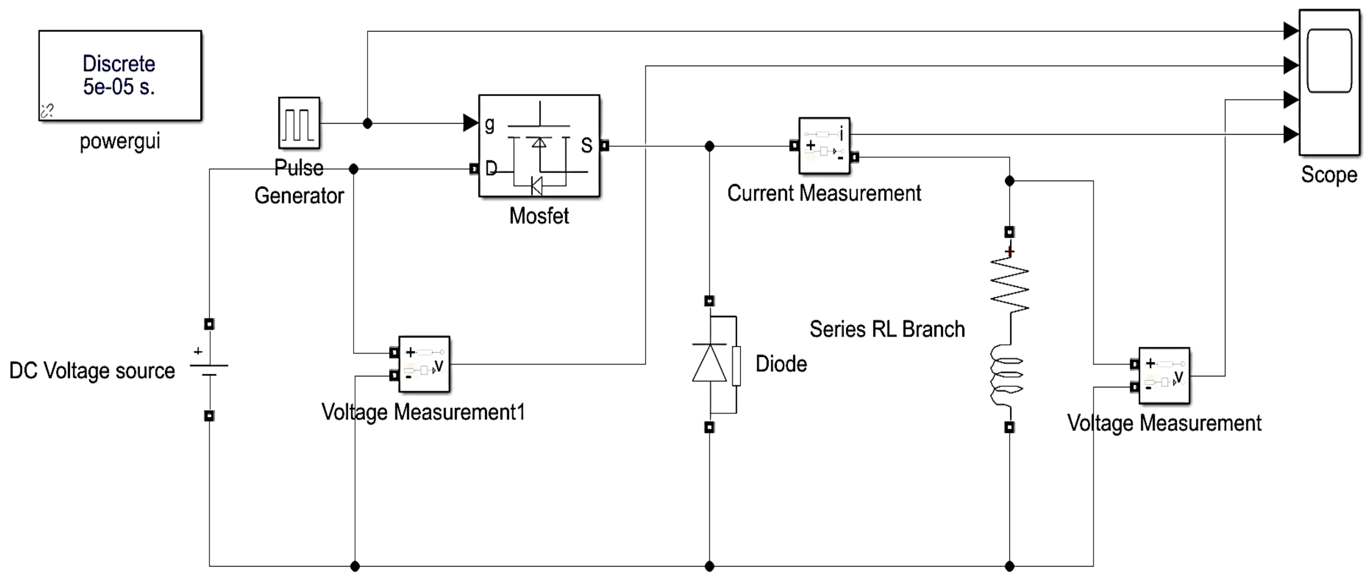

Figure 2.1: Simulink-Based Buck Converter Circuit.

b) Sample Simulation Waveform:

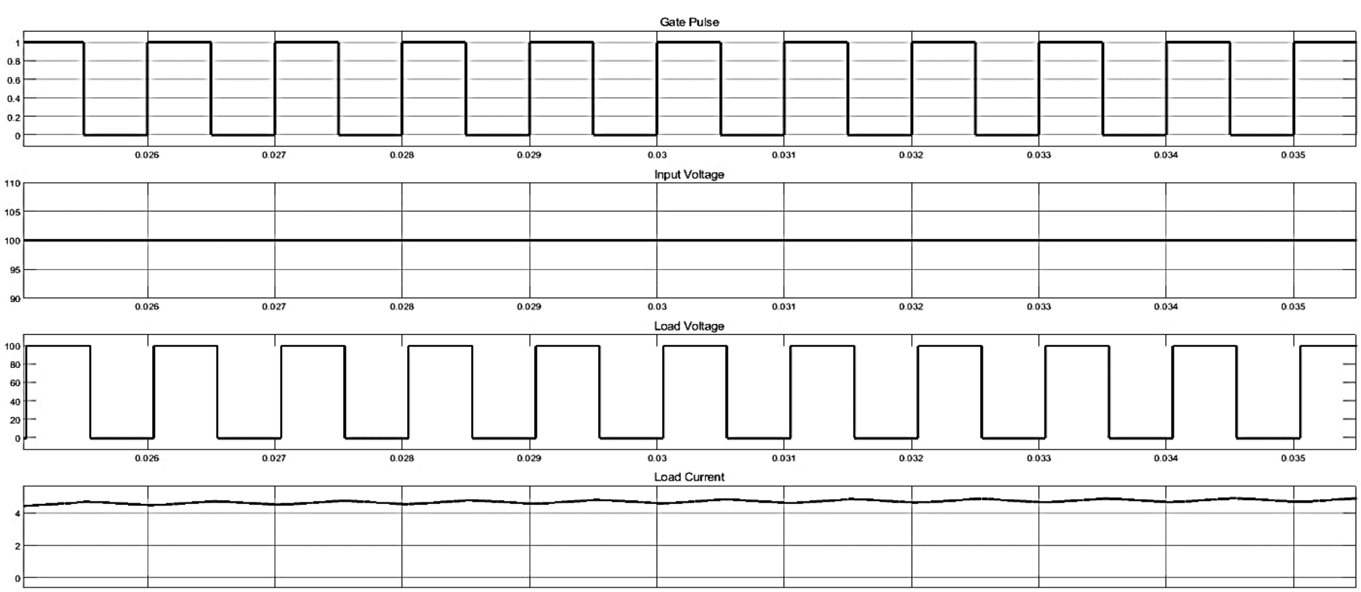

Figure 2.1: Simulink-Based Buck Converter waveform

c) Actual Circuit diagram/Kit used in the laboratory:

(Attach the simulated circuit diagram showing)

VIII Required Resources/apparatus/equipment with specifications:

Sr. No.	Name of Resource	Specification	Purpose
01	DC Voltage Source	100 V	Provides constant DC input to the chopper
02	Series RL Branch	10 Ω, 100e-3 H	Represents resistive-inductive load
03	MOSFET	Default	Acts as switching device to control power flow
04	Diode	Default	Provides freewheeling path for load current when MOSFET is off
05	PowerGUI	Sample time (s): 50e-6, Simulation type: Discrete	Required for running simulations with power electronics components
06	Pulse Generator	Amplitude=1, Period (secs): 1e-3, Pulse Width (% of period):50	Generates gate pulses for MOSFET switching
07	Scope	4 input channels (for pulse, input voltage, output voltage, load current)	Visualizes waveforms of signals in time domain
08	Current Measurement	Default Simulink block	Measures load current flowing through RL branch
09	Voltage Measurement	Default Simulink block	Measures voltage from DC source
10	MATLAB with Simulink	Version 2018 or above	–––
11	SCILAB with Xcos (optional)	Latest version	–––
12	Power Electronics Toolbox	Simscape Electrical preferred	–––

13	PC/Laptop	Minimum 4 GB RAM, i5 processor, Windows/Linux	–––

IX Precautions to be followed

1. Check all parameter settings before simulation (voltage levels, pulse timing).
2. Ensure the MOSFET block has appropriate Ron and threshold settings.
3. Avoid connecting output probes directly across power devices

X Procedure:

Steps to design a Type-A Chopper in MATLAB Simulink using the given parameters

1. Open Simulink and create a new blank model.
2. Add a DC Voltage Source from Simscape > Specialized Power Systems > Sources and set it to 100 V.
3. Add a Pulse Generator from Simulink > Sources and set the parameters: Amplitude = 1, Period = 1e-3 sec, Pulse Width = 50, Phase Delay = 0.
4. Add a MOSFET from Specialized Power Systems > Power Electronics > Switches, using the Ideal MOSFET and keeping the default values.
5. Add a Freewheeling Diode from Specialized Power Systems > Elements, use Ideal Diode with default parameters.
6. Add a Series RL Branch for the load and set Resistance = 10 Ω, Inductance = 100e-3 H.
7. Connect the drain of the MOSFET to the positive terminal of the DC source and its source to one side of the load.
8. Connect the other side of the load to the negative terminal of the DC source.
9. Place the freewheeling diode across the load, with anode to the MOSFET-source/load connection and cathode to the negative terminal of the DC source.
10. Connect the gate of the MOSFET to the output of the Pulse Generator.
11. Add a Voltage Measurement block across the input source and another across the load.
12. Add a Current Measurement block in series with the load.
13. Add a Scope block with four inputs and connect: pulse generator output, input voltage, load voltage, and load current to the scope using Simulink-PS and PS-Simulink converters as needed.
14. Add a PowerGUI block from Specialized Power Systems > Utilities and set it to Discrete, Sample Time = 50e-6.
15. Simulate for 01 second and observe switching pulses, input voltage, load voltage, and load current on the single scope.

XI Resources Used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
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5			
6			
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8			

XII Actual procedure followed

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XIII Observation Table

Sr. No	Pulse Width (% of period)	Input Voltage (V)	Load Voltage (V)	Load Current (A)
1				

XIV Result(s)

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

Note: Below given are few sample questions. Teachers must design such questions to ensure achievement of identified CO.

1. What is the effect of increasing the duty cycle in a Type-A chopper?
2. Why is a freewheeling diode necessary in this circuit?
3. How does the inductance value influence the output current waveform?
4. What simulation settings are critical for accurate results?
5. What are the real-world applications of Type-A chopper circuits?

[Space for Answers]

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XVIII References/Suggestions for further reading: include websites/links/Virtual lab Link

1 https://www.mathworks.com/help/sps/
2 https://scilab.org
3 Power Electronics: Converters, Applications, and Design by Mohan, Undeland, Robbins.
4 YouTube: MATLAB Simulink Power Electronics Tutorials by NPTEL and MathWorks

XIX Assessment Scheme:

Performance Indicators		Weightage
Process Related (15 Marks)		**60%**
01	Handling of the components	10%
02	Identification of components	20%
03	Measuring values (V, I, etc.) using probes/scope blocks	20%
04	Working in teams (collaboration & role clarity)	10%
Product Related (10 Marks)		**40%**
05	Calculated theoretical values of chopper parameters (Vout, Iout, duty cycle, etc.)	10%
06	Interpretation of result (waveform analysis, output matching, etc.)	05%
07	Conclusion (clarity and correctness)	05%
08	Practical related questions (concepts, applications)	15%
09	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 3: Simulation of Type-E chopper (Power MOSFET based) circuit using MATLAB Simulink/SCILAB /relevant software

I Practical Significance

The Type-E chopper is used for both step-up and step-down DC voltage conversion and can reverse the polarity of the load voltage. Simulating this chopper circuit helps students understand four-quadrant operation and control strategies using power electronics components such as MOSFETs. This knowledge is vital in designing electric drives and regenerative braking systems.

II Industry / Employer Expected outcome(s):

- Understanding of multi-quadrant DC-DC chopper operation.
- Familiarity with MOSFET-based switching for real-world applications.
- Proficiency in simulation tools like MATLAB, Simulink, or SCILAB.
- Ability to analyze and troubleshoot chopper circuits in EV, automation, and robotics domains.

III Course Level Learning outcome(s)

- Use DC-DC converters for different quadrant applications.

IV Laboratory Learning outcome(s)

- Simulate Type-E chopper using MATLAB Simulink.
- Measure and analyse voltage and current waveforms.
- Study the effect of duty cycle on output voltage and power flow direction

V Relevant Affective Domain related outcome(s)

- Demonstrate attention to detail and discipline while modelling power electronics circuits.
- Exhibit responsibility in handling simulation tools and components.
- Practice teamwork and communication in documenting and presenting results

VI Relevant Theoretical Background.

A Type-E chopper is a two-quadrant DC-DC converter that allows bidirectional current and voltage flow, enabling both motoring and regenerative braking modes in DC drives. It consists of two active switches (typically power MOSFETs or IGBTs) and two freewheeling diodes arranged to control current in both directions. This configuration supports operations in the first and third quadrants of the voltage-current (V-I) plane. When one switch conducts, it enables forward power flow, while the other switch allows reverse power flow when activated. The circuit is widely used in electric vehicles, reversible motor drives, and battery management systems. Pulse-width modulation (PWM) controls the switches, varying the output voltage by adjusting the duty cycle. The diodes ensure proper current path during switch-off periods. The Type-E chopper offers efficient energy conversion and regenerative braking capabilities. Its simulation using

MATLAB/Simulink helps analyse system behaviour without hardware. Understanding this topology is crucial for advanced power electronics applications.

Circuit Behaviour:

1 Forward Motoring: Positive voltage and current.
2 Reverse Regeneration: Negative voltage and current.

Key Equations:

Output Voltage:

Vo=D X Vin ………………… 1.1

Duty cycle (D) = TON / (TON + TOFF) ……….1.2

Where D is the duty cycle

VII Actual Circuit diagram used in a laboratory with related equipment rating.

a. Simple Circuit Diagram:

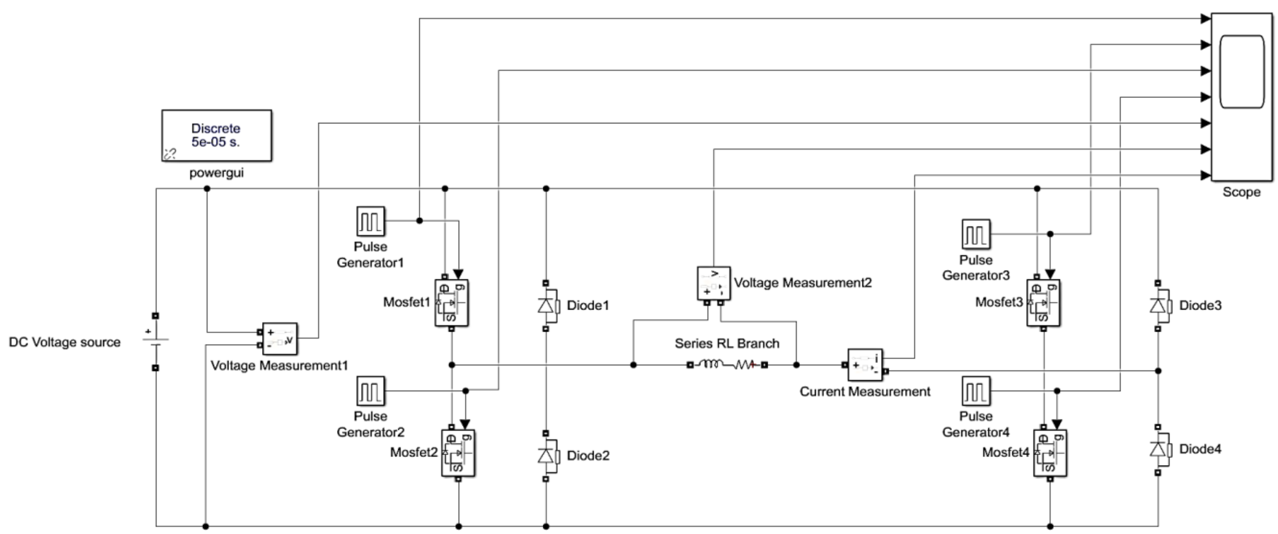

Figure 3.1:

b. Sample Waveform:

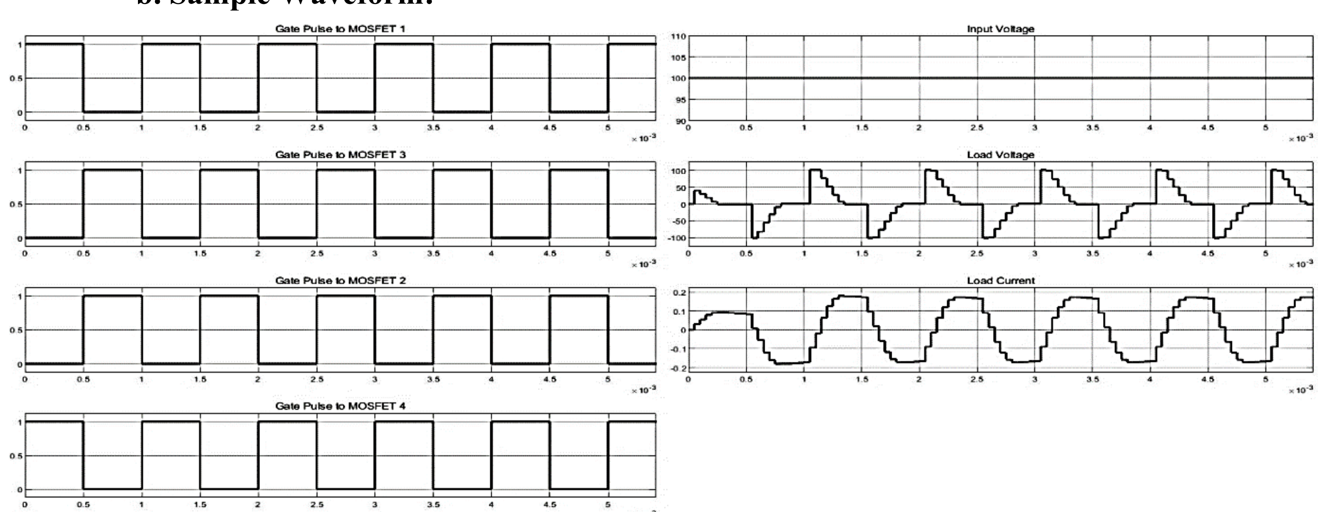

Figure 3.2:

c. Actual Circuit Diagram Used in Laboratory with Equipment Specifications

(Attach the simulated circuit diagram showing)

VIII Required Resources/apparatus/equipment with specifications:

Sr. No.	Resource/Software	Specification	Purpose
01	DC voltage Source	100V	Provides the constant DC input supply
02	Series RL Branch (Series RLBranch)	R=10 Ohm, L=50e-3H	Load representing practical application with resistive-inductive behavior
03	04 MOSFET	Default	Switching elements controlling power delivery
04	04 Diode	Default	Freewheeling path for each respective MOSFET branch
05	PowerGUI	Sample time (s): 50e-6, Simulation type: Discrete	Required for discrete simulation of power electronics systems
06	Pulse Generators 1 and 4	Amplitude=1, Period (secs): 1e-3, Pulse Width (% of period):50, Phase delay (secs)=0 Sec	Generates switching pulses for MOSFET 1 and 4
07	Pulse Generators 2 and 3	Amplitude=1, Period (secs): 1e-3, Pulse Width (% of period):50, Phase delay (secs)= 0.5e-3	Generates switching pulses for each MOSFET 2 and 3
08	Scope	At least 6-channel input (for 4 gate signals, voltage, current)	Displays waveforms of gate pulses, voltage, and current
09	Current Measurement	Default	For current monitoring
10	Voltage Measurement	Default	For voltage monitoring
11	MATLAB with Simulink	Version 2018 or above	——
12	SCILAB with Xcos (optional)	Latest version	——

13	Power Electronics Toolbox	Simscape Electrical preferred, Power GUI	----
14	PC/Laptop	Minimum 4 GB RAM, i5 processor, Windows/Linux	----

IX Precautions to be followed

1 Ensure proper grounding in simulation.
2 Set a suitable simulation time step to avoid instability.
3 Initialize PowerGUI block correctly.
4 Avoid unrealistic values for switching frequency or load.

X Procedure

Simulation Process of Type-E Chopper (Power MOSFET Based) in MATLAB Simulink – Pointwise Steps:-

1 Open MATLAB and launch Simulink using the Simulink command.

2 Create a new blank model from the Simulink Library Browser

3 Set the solver to Discrete with a fixed-step size of 50e-6

4 Add a PowerGUI block from Simscape > Electrical > Specialized Power Systems > Utilities and set it to Discrete with a sample time of 5e-5

5 Add a DC Voltage Source block from Specialized Power Systems > Sources and set its value to 100 V

6 Add four MOSFET blocks from Specialized Power Systems > Power Electronics and rename them as Mosfet1, Mosfet2, Mosfet3, and Mosfet4

7 Set the internal resistance (Ron) of each MOSFET to 0.01 ohm

8 Place the four MOSFETs in an H-bridge configuration with two on the left and two on the right.

9 Add four Diode blocks from the same library and place one across each MOSFET in anti-parallel configuration.

10 Add a Series RLC Branch block from Specialized Power Systems > Elements and configure it as an RL load with R = 10 ohms and L = 50 mH.

11 Connect the series RL branch across the midpoints of the MOSFET legs to act as the load.

12 Add four Pulse Generator blocks from Simulink > Sources and connect each to the gate terminal of one MOSFET.

13 Set Pulse Generator1 (for Mosfet1) with Period = 1e-3, Pulse Width = 50, Phase Delay = 0

14 Set Pulse Generator2 (for Mosfet2) with Period = 1e-3, Pulse Width = 50, Phase Delay = 0.5e-3.

15 Set Pulse Generator3 (for Mosfet3) with Period = 1e-3, Pulse Width = 50, Phase Delay = 0.5e-3

16 Set Pulse Generator4 (for Mosfet4) with Period = 1e-3, Pulse Width = 50, Phase Delay = 0

17 Add a Voltage Measurement block across the DC source and name it Voltage Measurement1

18 Add another Voltage Measurement block across the RL load and name it Voltage Measurement2

19 Add a Current Measurement block in series with the RL load.

20 Add a Scope block from Simulink > Sinks

21 Connect outputs from Voltage Measurement1, Voltage Measurement2, Current Measurement, and all Pulse Generators to the Scope using lines or a Mux.

22 Add a Ground block from Simscape > Foundation > Electrical > Electrical Elements and ground all required points.

23 Connect all components as per the H-bridge topology shown in the reference image.

24 Save the model and click Run to simulate the Class-E Chopper circuit.

25 Open the Scope to observe the input voltage, output voltage, output current, and gate pulses.

XI Required Resources:

Sr. No.	Name of Resource	Specifications
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XII Actual procedure followed

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XIII Observation Table

Sr. No	Pulse Width (% of period) of the Pulse Generator for switches 1 and 4	Pulse Width (% of period) of the Pulse Generator for switches 2 and 3	Input Voltage (V)	Load Voltage (V)	Load Current (A)
1					

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

Note: Below given are few sample questions. Teachers must design such questions to ensure achievement of identified CO.

1. What are the advantages of Type-E over Type-A or Type-B choppers?
2. How can bidirectional energy flow be achieved using choppers?
3. Explain the role of freewheeling diodes in this circuit?
4. Why is continuous conduction mode preferred?
5. How does the duty cycle affect output voltage?

[Space for Answers]

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XVIII References/Suggestions for further reading: include websites/links/Virtual lab Link

1. Muhammad H. Rashid, "Power Electronics: Circuits, Devices & Applications"
2. Ned Mohan, "Power Electronics: Converters, Applications, and Design"
3. NPTEL Lecture Series on Power Electronics
4. MATLAB Documentation: https://www.mathworks.com/help

XIX Assessment Scheme:

Performance Indicators		Weightage
Process Related (15 Marks)		**60%**
01	Circuit Construction Handling	10%
02	Component Identification	20%
03	Correct Pulse Generation	20%
04	Team Participation	10%
Product Related (10 Marks)		**40%**
05	Simulation Output Accuracy	10%
06	Graph/Scope Interpretation	05%
07	Conclusion (clarity and correctness)	05%
08	Practical related questions (concepts, applications)	15%
09	Submitting the manual in time (Proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 04: Simulation of input output voltage of Buck- Boost Converter Circuit by varying duty ratio using MATLAB Simulink / SCILAB/relevant software

I Practical Significance:

The Buck-Boost converter provides a regulated DC output voltage that can be either higher or lower than the input voltage, making it ideal for battery-powered systems, renewable energy sources, and embedded applications where input voltage may vary.

II Industry / Employer Expected outcome(s)

- Ability to model and simulate power electronic converters.
- Understanding of voltage regulation through duty cycle control.
- Competence in MATLAB/Simulink simulation tools.
- Readiness for roles in embedded systems, EVs, and renewable energy sectors.

III Course Level Learning outcome(s)

- Use DC-DC converters for different quadrant applications.

IV Laboratory Learning outcome(s)

- Simulate and interpret Buck-Boost converter behavior using MATLAB Simulink.
- Correlate duty cycle variation with output voltage.
- Analyze the efficiency and operating modes of the converter

V Relevant Affective Domain related outcome(s)

- Demonstrate discipline and focus during simulation tasks.
- Collaborate effectively in team-based simulation projects
- Show initiative in troubleshooting circuit configurations

VI Relevant Theoretical Background.

A Buck-Boost converter is a type of DC-DC converter that can step up or step down the input voltage depending on the requirement. It combines the functionality of both buck (step-down) and boost (step-up) converters. The converter uses a switching device such as a MOSFET, an inductor, a diode, and a capacitor to regulate the output. When the switch is ON, energy is stored in the inductor; when the switch is OFF, this energy is transferred to the load through the diode. The polarity of the output voltage is typically inverted in a basic Buck-Boost topology. It is widely used in battery-powered devices, renewable energy systems, and embedded circuits where input voltage fluctuates. The output voltage depends on the duty cycle of the switching signal. Buck-Boost converters offer a flexible solution for voltage regulation in compact electronic systems.

Key Equations:

Output Voltage

$$Vo = \frac{D}{1-D} X\ Vin \qquad \text{…………..……......... 1.1}$$

Duty cycle (D) = TON / (TON + TOFF) ………………….. 1.2

VII Actual Circuit diagram used in a laboratory with related equipment rating.

a. Sample diagram:

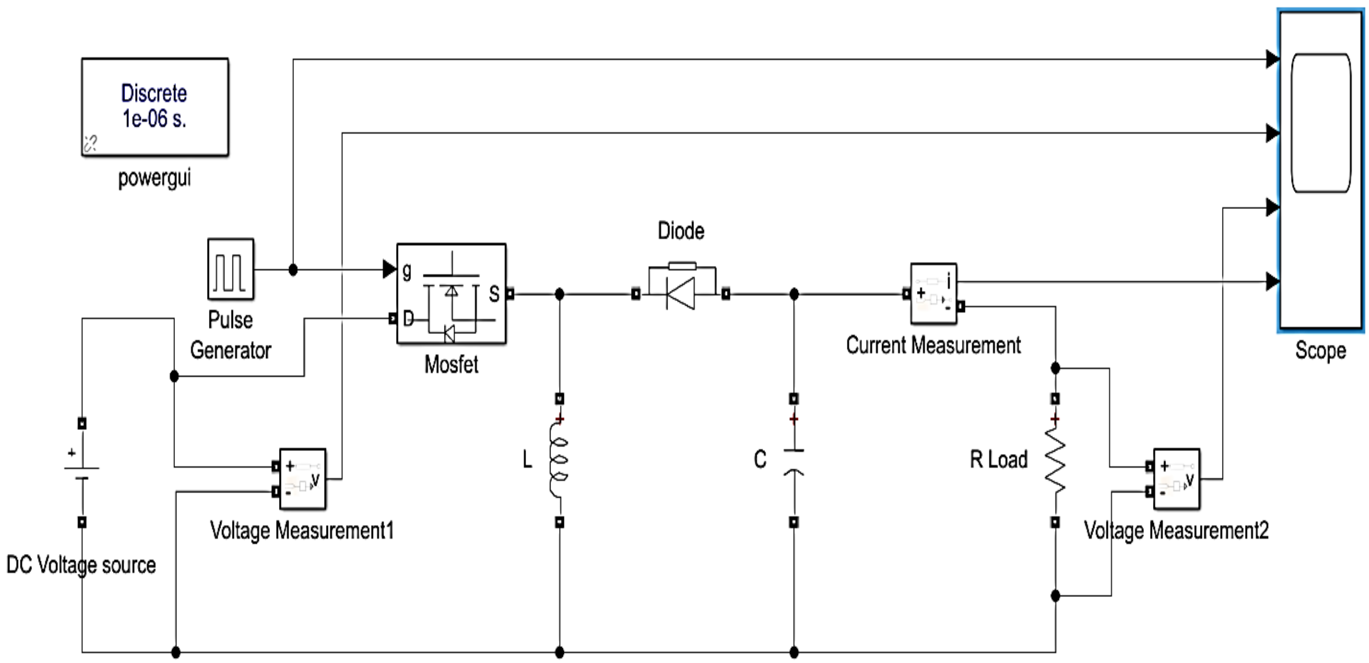

Figure 4.1:

b. Waveform of buck-boost converter

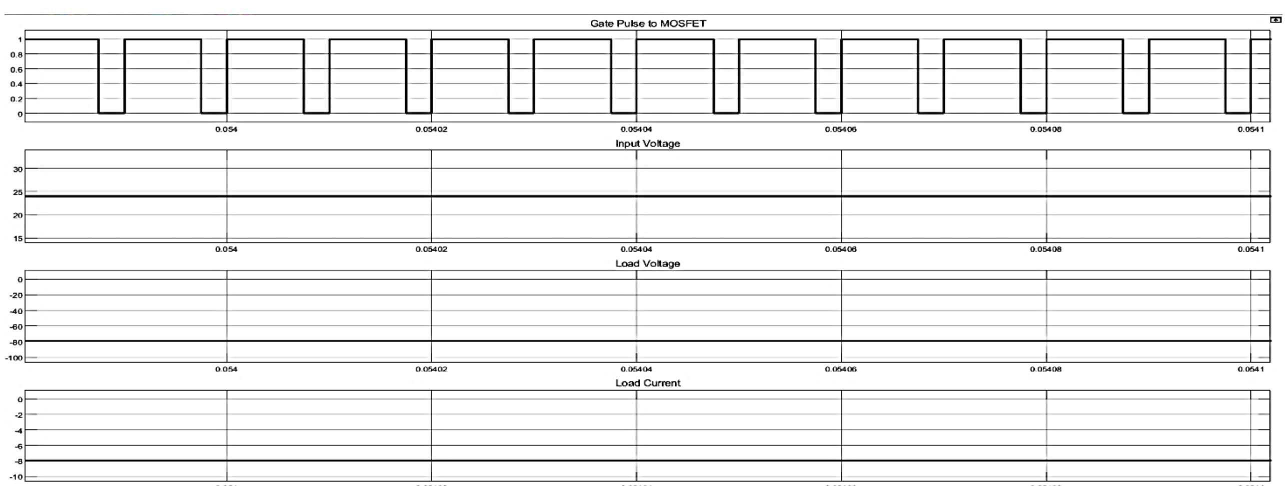

Figure 4.2:

c. Actual Practical Feedback Control in a Process using Simulator:

(Attach the simulated circuit diagram showing)

VIII Required Resources/apparatus/equipment with specifications:

Sr. No	Resource/Software	Specification	Purpose
1	DC Voltage Source	24 V	Provides the input DC power supply
2	Inductor	1 mH (1e-3)	Stores energy when the MOSFET is ON, and releases when OFF
3	Capacitor	470 µF (470e-6)	Filters the output voltage to reduce ripple
4	Load Resistance	10 Ω	Represents the practical load connected to output
5	MOSFET	Default	High-speed switch for energy storage in inductor during ON state
6	Diode	Default	Provides path for inductor current when switch is OFF
7	PowerGUI	Sample time (s): 1e-6, Simulation type: Discrete	Required for simulation of power electronics blocks
8	Pulse Generator	Amplitude=1, Period (secs): 10e-6, Pulse Width (% of period):25, 50,75	Generates gate signals to switch the MOSFET based on desired output
9	Scope	Minimum 3 input channels	Visualizes switching signal, input/output voltage, and output current
10	Voltage Measurement	Default	For monitoring voltage
11	Current Measurement	Default	Measures current flowing into the load
12	MATLAB with Simulink	Version 2020 or above	-
13	SCILAB with Xcos (optional)	Latest version	-
14	Power Electronics Toolbox	Simscape Electrical preferred, Power GUI	-
15	PC/Laptop	Minimum 4 GB RAM, i5 processor, Windows/Linux	-

IX Precautions to be followed

1. Ensure all components are correctly rated for voltage and current.
2. Use proper gate pulse signal and isolation in real hardware
3. Simulate under safe voltage and duty cycle ranges
4. Always simulate step-wise and validate each block

X Procedure:

Steps to Design a Buck-Boost Converter in MATLAB Simulink

1. Open a new blank model in Simulink.
2. Add a DC Voltage Source block and set its value to 24 V
3. Add a Pulse Generator block and set its parameters as follows: Period = 10e-6, Pulse Width = 25 (later change to 50 and 75 for observation), Amplitude = 1
4. Add an Ideal MOSFET block and connect its gate terminal to the output of the Pulse Generator
5. Add a Series RLC Branch block to act as the inductor, and set its parameters: Inductance L = 1e-3
6. Add an Ideal Diode block and connect its anode to the inductor output and cathode to the output node.
7. Add another Series RLC Branch block to act as the output capacitor, and set: C = 470e-6.
8. Add a third Series RLC Branch block to act as the load, and set: Resistance R = 10
9. Add a Current Measurement block between the capacitor and load to measure load current
10. Add a Voltage Measurement block across the DC Voltage Source to measure input voltage
11. Add another Voltage Measurement block across the output capacitor to measure load voltage
12. Add a Scope block and connect four signals to it: the output of Pulse Generator (gate pulse), the input voltage, the load voltage, and the load current
13. Add a PowerGUI block, set to Discrete, with sample time 1e-6
14. Simulate for 1 second for each Pulse Width: 25%, 50%, and 75%, and observe the waveforms in the Scope

XI Required Resources:

Sr. No	Resource/Software	Specification
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XII Actual procedure followed:

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XIII Observation:

Sr. No	Duty Cycle (%)	Input Voltage (V)	Load Voltage (V)	Load Current (A)
1				
2				
3				

XIV Result(s)

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XV Interpretation of Results

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XVI Conclusions and Recommendation

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XVII Practical Related Questions

Note: Below given are few sample questions. Teachers must design such questions to ensure achievement of identified CO.

1 What will happen if D = 0.5 in a Buck-Boost converter?
2 Why is a diode required in the Buck-Boost topology?
3 How does ripple in output voltage vary with component values?
4 What are the advantages of Buck-Boost over separate Buck or Boost converters?

[Space for Answers]

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XVIII References/Suggestions for further reading: include websites/ links

1 Muhammad H. Rashid, "Power Electronics: Circuits, Devices and Applications".
2 Ned Mohan, "Power Electronics"
3 IEEE Xplore: Articles on DC-DC converter design

XIX Assessment Scheme:

Performance Indicators		Weightage
Process Related (15 Marks)		**60%**
01	Circuit Construction Handling	10%
02	Understanding of Circuit Operation	20%
03	Accuracy of Simulation Configuration	20%
04	Team Collaboration and Clean Execution	10%
Product Related (10 Marks)		**40%**
05	Simulation Output Accuracy	10%
06	Graph/Scope Interpretation	05%
07	Conclusion (clarity and correctness)	05%
08	Practical related questions (concepts, applications)	15%
09	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 5: Simulation of 180-degree mode and 120-degree mode of three Phase Voltage Source Inverter Circuit using MATLAB Simulink/SCILAB /relevant software

I Practical Significance:

The three-phase VSI is widely used in motor drives and power systems. Understanding and simulating the 180° and 120° conduction modes helps students grasp inverter operation principles, waveform generation, and load behavior. It lays the groundwork for real-world applications like industrial drives, renewable energy interfaces, and UPS systems.

II Industry / Employer Expected outcome(s)

- Ability to design, simulate, and analyze three-phase inverter systems.
- Proficiency in MATLAB/Simulink or similar tools for power electronics simulation
- Understanding of motor control and inverter drive technologies
- Awareness of harmonic impact and switching strategies in power conversion

III Course Level Learning outcome(s)

- Use DC-DC converters for different quadrant applications.

IV Laboratory Learning outcome(s)

- Ability to simulate 180° and 120° conduction modes using MATLAB Simulink.
- Understand the impact of conduction mode on output waveforms.
- Learn the difference in output voltage patterns and harmonics.
- Interpret simulation results for academic or industrial insights

V Relevant Affective Domain related outcome(s)

- Develop interest and confidence in simulation-based design
- Foster responsibility in conducting simulations ethically and precisely.
- Enhance teamwork and communication during group simulation tasks

VI Relevant Theoretical Background.

In a three-phase Voltage Source Inverter (VSI), 180° and 120° conduction modes refer to the duration each switch conducts in an electrical cycle. In 180° mode, each switch remains ON for 180 electrical degrees, and at any time, three switches conduct (two from one group and one from the other), producing a quasi-square line voltage waveform with higher harmonic content. In 120° mode, each switch conducts for 120°, and at any instant only two switches are ON (one upper and one lower), resulting in a line voltage with more intervals of zero voltage and reduced harmonic distortion. Both modes generate six-step output waveforms, but 180° mode offers higher average output voltage, while 120° mode provides better waveform quality. The choice between these modes affects power quality, efficiency, and torque ripple in motor applications. The line-to-line voltage remains the same peak-wise, but its harmonic profile differs significantly. Gate pulse generation is synchronized with a 60° phase shift in both modes. These conduction modes form the basis for advanced inverter control like PWM. Simulation and analysis help in selecting appropriate conduction mode for industrial drives

VII Actual Circuit diagram used in a laboratory with related equipment rating.

a. Sample Diagram:

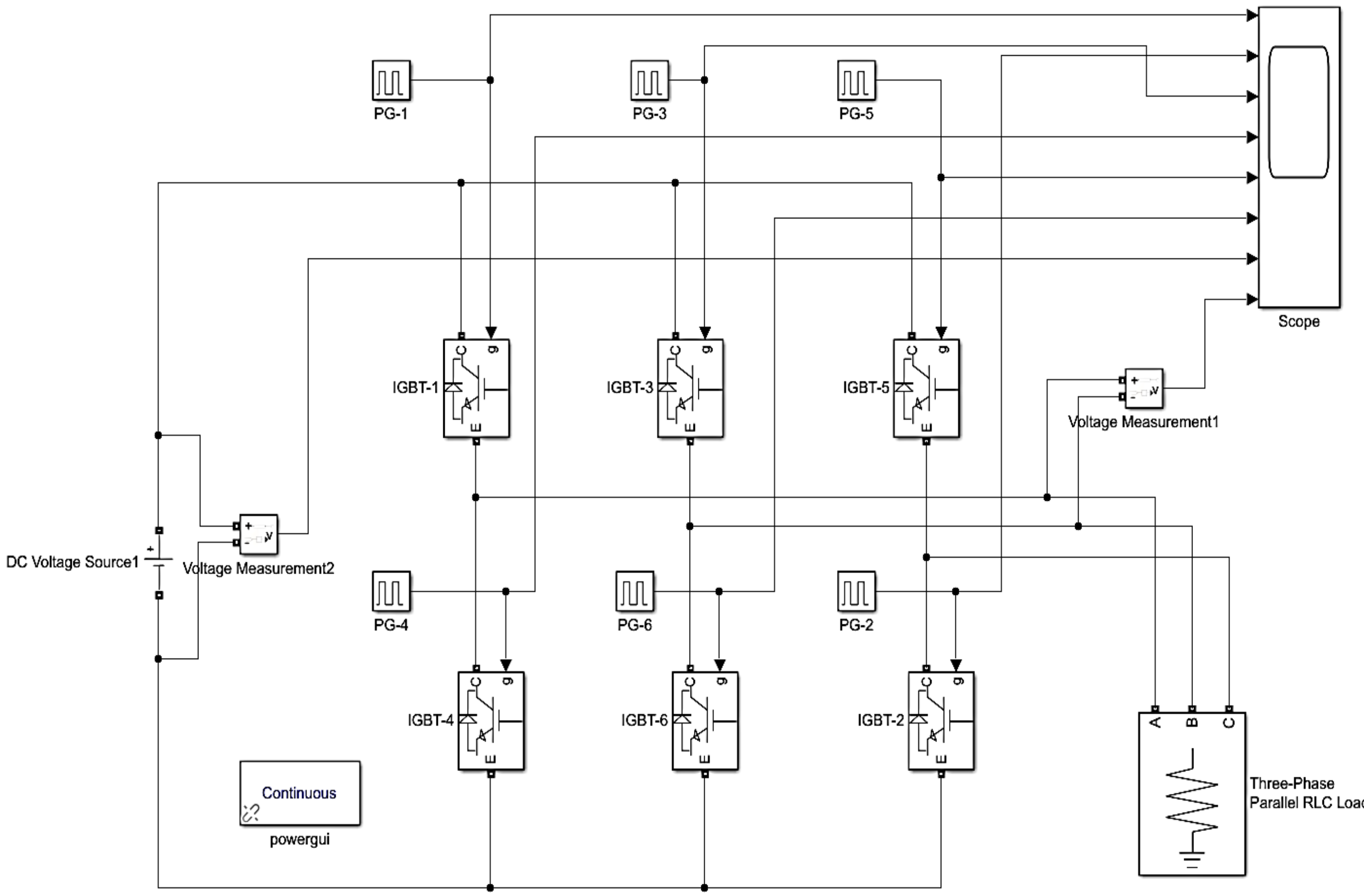

Figure 5.1:

b. Waveform for 120-degree mode operation:

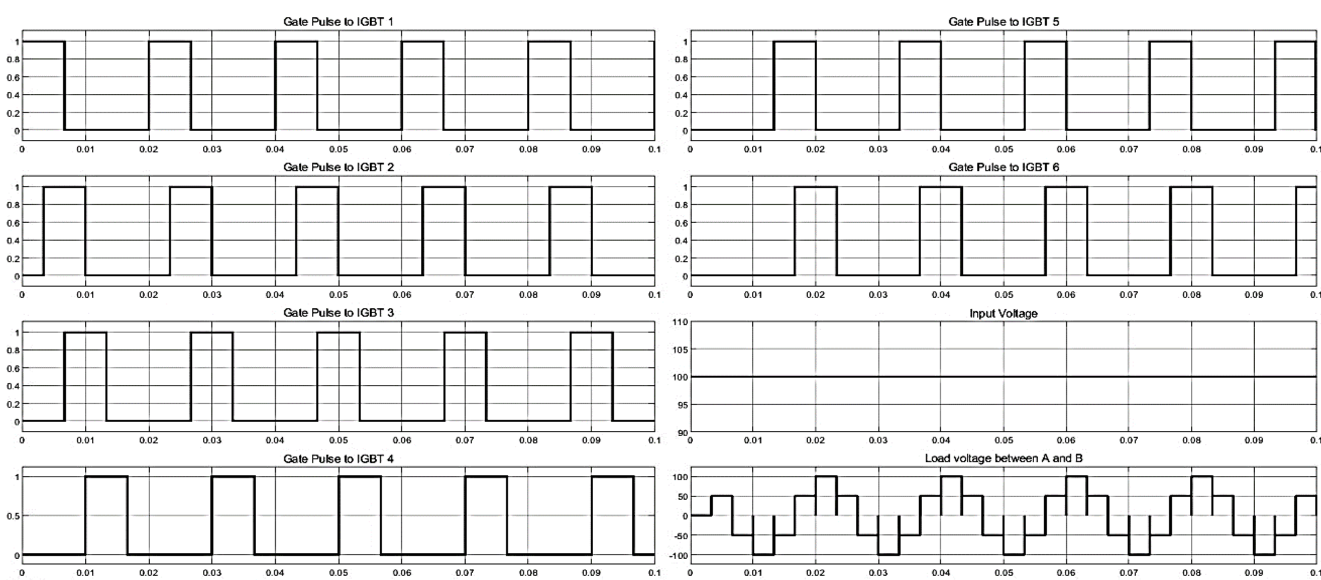

Figure 5.2:

c. Waveform for 180-degree mode operation

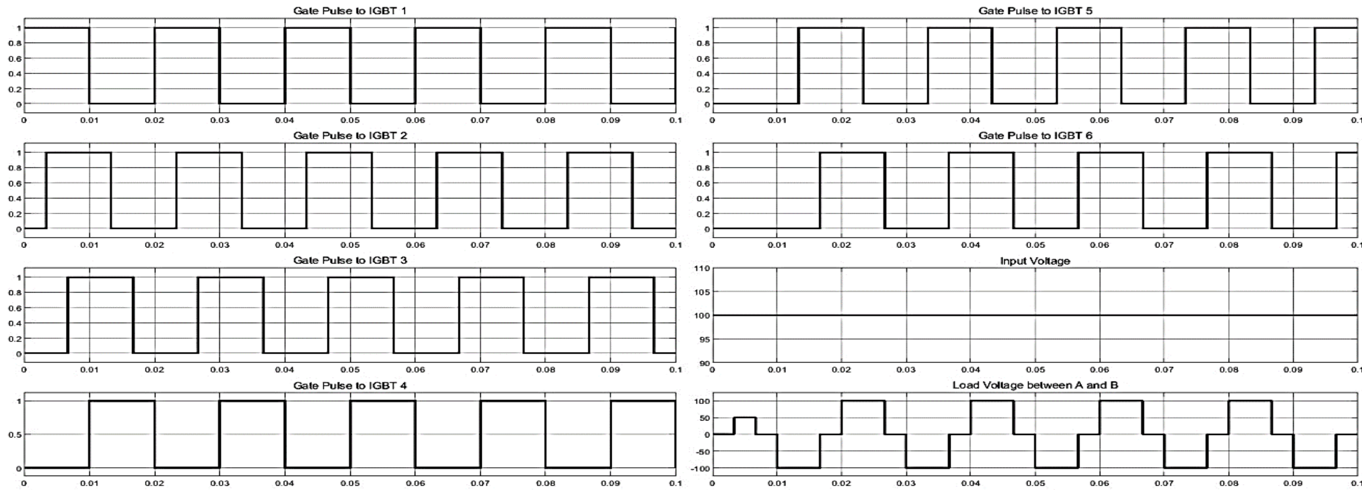

Figure 5.3:

d. Actual Circuit Diagram Used in Laboratory with Equipment Specifications

(Attach the simulated circuit diagram showing)

VIII Required Resources/apparatus/equipment with specifications:

Sr. No	Resource/Software	Specification	Purpose
1	DC Voltage Source	100 V	Provides the DC input to the inverter
2	Three-Phase Parallel RLC Load	Configuration (Y grounded Nominal frequency fn (Hz):50Hz, Active power P (W):10e3, Inductive reactive Power QL:00, Capacitive reactive power Qc:00.	Simulates an inductive-resistive-capacitive load on the inverter output

3	Power GUI	Simulation type: Continuous	Enables the simulation of power electronics circuits with continuous-time solvers.
4	06 Pulse Generator	Specification details given in procedure	Controls ON/OFF switching in 180°/120° conduction mode
5	06 IGBT	Default	Acts as controllable switches for each leg of the inverter
6	Scope	At least 6–8 channel input	Monitors gate signals, phase voltages, and line voltages
7	Voltage measurement	Default	Measures the voltage values at different points in the inverter
8	MATLAB with Simulink	Version 2018 or above	-
9	SCILAB with Xcos (optional)	Latest version	-
10	Power Electronics Toolbox	Simscape Electrical preferred, Power GUI	-
11	PC/Laptop	Minimum 4 GB RAM, i5 processor, Windows/Linux	-

IX Precautions to be followed

1. Follow the safety norms.
2. Confirm RL load values for comparative study
3. Use appropriate simulation step size for waveform accuracy
4. Save simulation files with clear names and backup regularly

X Procedure:

Steps for MATLAB Simulink Simulation

1. Set up a DC Voltage Source of 100 V. Location in MATLAB Library: Simscape > Electrical > Specialized Power Systems > Sources > DC Voltage Source.
2. Use 6 IGBT switches to form a three-phase inverter. Location in MATLAB Library: Simscape > Electrical > Specialized Power Systems > Power Electronics > IGBT (Ideal) Connect them as:
   - Phase A: IGBT-1 (top), IGBT-4 (bottom)
   - Phase B: IGBT-3 (top), IGBT-6 (bottom)
   - Phase C: IGBT-5 (top), IGBT-2 (bottom)
3. Use Pulse Generator blocks to generate gate signals for each IGBT. Location in MATLAB Library: Simulink > Sources > Pulse Generator.
4. Connect each Pulse Generator output to the corresponding IGBT gate
5. Use a Three-Phase Parallel RLC Load at the inverter output Location in MATLAB Library: Simscape > Electrical > Specialized Power Systems > Elements > Three-Phase Parallel RLC Load
6. Use Voltage Measurement blocks to monitor voltages. Location in MATLAB Library: Simscape > Electrical > Specialized Power Systems > Measurements > Voltage Measurement
   - Connect one across the DC input
   - Connect one at the three-phase load (line voltages)

7. Use a Scope block to visualize signals. Location in MATLAB Library:Simulink > Sinks > Scope
    - Connect signals from all pulse generators
    - Connect input voltage signal
    - Connect output phase voltages (A, B, C)
8. Set the simulation time to at least 0.10 s in Simulation Settings
9. Choose Continuous solver in the solver configuration. Location in MATLAB Library: Simulink > Solver Configuration
10. Run the simulation and observe:
    - Gate pulse waveform of 120-degree and 180-degree mode of operation
    - 6-step quasi-square three-phase AC output voltage
    - Input DC voltage across inverter

For 120-degree mode operation

Configure Pulse Generator parameters as follows:

Pulse Generator	Connected IGBT	Amplitude	Period (s)	Pulse Width (%)	Phase Delay (s)	Phase Delay (s)
PG-1	IGBT-1	1	0.02	33.33	0	0
PG-2	IGBT-2	1	0.02	33.33	(60/360) ×0.02	0.0033
PG-3	IGBT-3	1	0.02	33.33	(120/360) ×0.02	0.0067
PG-4	IGBT-4	1	0.02	33.33	(180/360) ×0.02	0.0100
PG-5	IGBT-5	1	0.02	33.33	(240/360) ×0.02	0.0133
PG-6	IGBT-6	1	0.02	33.33	(300/360) ×0.02	0.0167

For 180-degree mode operation

Pulse Generator	Connected IGBT	Amplitude	Period (s)	Pulse Width (%)	Phase Delay (s)	Phase Delay (s)
PG-1	IGBT-1	1	0.02	50	0	0
PG-2	IGBT-2	1	0.02	50	(60/360) ×0.02	0.0033
PG-3	IGBT-3	1	0.02	50	(120/360) ×0.02	0.0067
PG-4	IGBT-4	1	0.02	50	(180/360) ×0.02	0.0100
PG-5	IGBT-5	1	0.02	50	(240/360) ×0.02	0.0133
PG-6	IGBT-6	1	0.02	50	(300/360) ×0.02	0.0167

XI Resources used

Sr. No.	Name of Resources	Specifications	Quantity
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2			
3			

XII Actual procedure followed

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XIII Observation:

Sr. No	Mode	Input Voltage	Output Line Voltage (V_{AB} peak)	Output Line Voltage Shape
1	180°			
2	120°			

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:
Note: Below given are few sample questions for reference. Teachers must design such questions to ensure achievement of identified CO.

1. What are the major differences between 180° and 120° conduction modes?
2. Why are only two switches ON at a time in 120° conduction?
3. How does the harmonic content differ in both modes?

4. Can this inverter feed an inductive motor load? Why?
5. What happens if gate pulses overlap incorrectly?

[Space for Answers]

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XVIII References/Suggestions for further reading:

1 Rashid, M. H., Power Electronics: Circuits, Devices and Applications

2 Bimbhra, P. S., Power Electronics

3 MATLAB Documentation – Three-Phase VSI Simulation

4 IEEE Transactions on Industrial Electronics

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**60%**
01	Circuit Construction Handling	10%
02	Understanding of Circuit Operation	20%
03	Accuracy of Simulation Configuration	20%
04	Team Collaboration and Clean Execution	10%
Product Related (10 Marks)		**40%**
05	Simulation Output Accuracy	10%
06	Graph/Scope Interpretation	05%
07	Conclusion (clarity and correctness)	05%
08	Practical related questions (concepts, applications)	15%
09	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 6: Simulation of sinusoidal PWM Waves using MATLAB Simulink / SCILAB / relevant software

I Practical Significance:

Sinusoidal Pulse Width Modulation (SPWM) is a crucial technique in power electronics for generating AC waveforms from DC sources, typically used in inverters. This simulation helps students understand how modulated gate signals are synthesized and applied to power electronic switches in real-world systems, such as inverters, motor drives, and UPS systems.

II Industry / Employer Expected outcome(s)

- Ability to simulate and analyze SPWM techniques.
- Understanding of inverter operation and switching control.
- Familiarity with MATLAB/SCILAB for power electronics applications.
- Readiness to design and troubleshoot inverter gate drive circuits

III Course Level Learning outcome(s)

- Use DC-DC converters for different quadrant applications.

IV Laboratory Learning outcome(s)

- Develop skills in simulating SPWM signals.
- Interpret simulation results concerning modulation index and waveform quality
- Use MATLAB Simulink/SCILAB blocks efficiently for waveform generation

V Relevant Affective Domain related outcome(s)

- Exhibit precision and patience during simulation setup.
- Demonstrate professional ethics while interpreting simulation results.
- Collaborate effectively in simulation-based lab assignments

VI Relevant Theoretical Background:

Sinusoidal Pulse Width Modulation (SPWM) is a widely used technique in power electronics for generating AC waveforms from a DC source using inverters. It involves comparing a high-frequency triangular carrier wave with a low-frequency sinusoidal reference signal. The result of this comparison is a series of pulses whose widths vary in proportion to the amplitude of the sine wave—hence, pulse width modulation. These pulses are used to switch power semiconductor devices such as MOSFETs or IGBTs in an inverter circuit. The output is a PWM waveform that, when passed through an LC filter, yields a sinusoidal voltage with the same frequency as the reference sine wave. SPWM provides efficient control of output voltage and frequency, reduces harmonic distortion, and improves the dynamic response of the system. It is extensively used in applications like motor drives, UPS systems, and renewable energy converters due to its simplicity and effectiveness

VII Actual Circuit diagram used in a laboratory with related equipment rating.

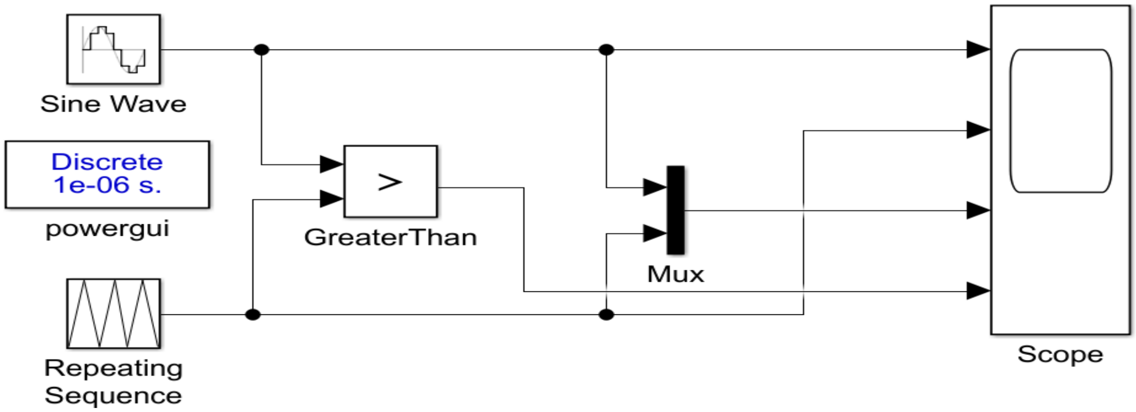

Figure 6.1:

a) Waveform:

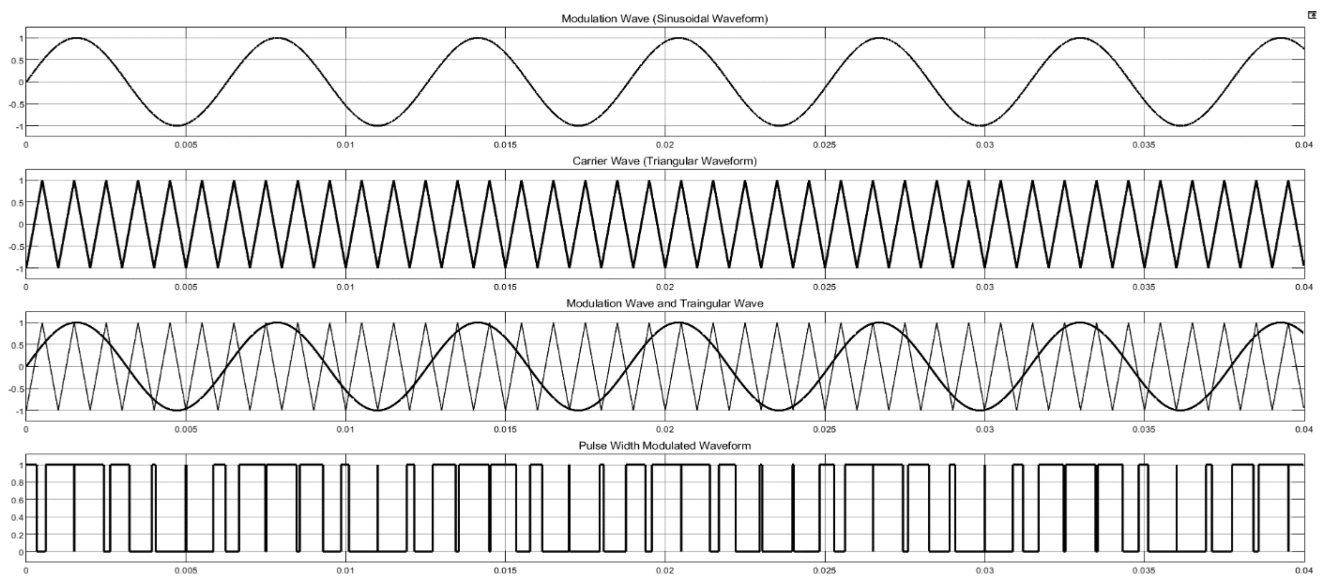

Figure 6.2:

b) Actual Circuit Diagram Used in Laboratory with Equipment Specifications:

(Attach the simulated circuit diagram showing)

VIII Required Resources/apparatus/equipment with specifications:

Sr. No	Resource/Software	Specification	Purpose
1	MATLAB with Simulink	Version 2018 or above	
2	SCILAB with Xcos (optional)	Latest version	
3	Power Electronics Toolbox	Simscape Electrical preferred, Power GUI	
4	PC/Laptop	Minimum 4 GB RAM, i5 processor, Windows/Linux	
5	Sine Wave (Source Block)	Amplitude:1 Bias:0 Frequency (rad/sec):500HZ, 1000Hz, 1500Hz Phase (rad):0 Sample time:1e-5	Acts as the modulating/reference waveform representing the desired output
6	Repeating Sequence	Time values = [0 1/2000, 1/1000], Output values = [-1 1 1] (This gives a carrier frequency of 1 kHz).	Acts as the carrier wave for PWM generation
7	Relational Operator (> or GreaerThan)	(> or GreaterThan)	Compares sine wave with triangular wave to generate SPWM output
8	Mux	3-input Mux	Combines the three signals: sine wave, triangular wave, and SPWM
9	Scope	Minimum 3 inputs	Displays SPWM pulses, sine wave, and triangular wave
10	PowerGUI (Discrete mode)	Manages simulation configuration (discrete solver, e.g., 1e-6s)	Required for signal processing and waveform synchronization

IX Precautions to be followed

1. Ensure correct time step and simulation parameters.
2. Avoid frequency overlap between reference and carrier signals.
3. Validate block parameter settings before running the simulation.

X Procedure:

Steps to Design in MATLAB Simulink

1) Open MATLAB and create a new Simulink model for simulating sinusoidal pulse width modulation (SPWM).
2) Set the simulation type to discrete with a fixed step size of 1e-6 seconds.
3) Add a Sine Wave block from *Simulink* > *Sources* and set the parameters: Amplitude = 1, Frequency = 500Hz for 1st reading, Frequency = 1000Hz for 2nd reading, Frequency = 1500Hz for 3rd reading, Sample time = 1e-5 s.
4) Add a Repeating Sequence block from *Simulink* > *Sources* to generate a triangular carrier waveform with Time values = [0 1/2000, 1/1000], Output values = [-1 1 1], and Sample

time = 1e-6 s (this gives a carrier frequency of 1 kHz).

5) Add a Relational Operator block from *Simulink > Logic and Bit Operations*, set the operator to '>', and compare the sine wave with the triangle wave to generate the SPWM signal.
6) Add a Mux block from *Simulink > Signal Routing* and set the number of inputs = 2 to combine the sine wave and the triangular wave.
7) Add a Scope block from *Simulink > Sinks* and connect the output of the Mux block, sine wave, and repeating sequence (triangular waveform) to it to display all three waveforms on the same scope.
8) Connect all blocks as per the required signal flow: sine and triangle waves into the comparator, all three signals into the Mux, and the Mux output into the Scope.
9) Simulate for a simulation time = 0.04 seconds.
10) Observe the output in the Scope block, where the SPWM signal's pulse width varies according to the amplitude of the sine wave, confirming successful SPWM generation

XI Required Resources

Sr. No.	Resource/Software	Specifications
1		
2		
3		
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7		
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10		

XII Actual procedure followed

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XIII Observation Table:

Sr. No	Carrier Frequency (Hz)	Modulation Wave Frequency (Hz)	Output Pulse Shape
1			**Narrow pulses/Wider pulses**
2			**Narrow pulses/Wider pulses**
3			**Narrow pulses/Wider pulses**

XIV Result(s):

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XV Interpretation of Results:

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XVI Conclusions and Recommendations:

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XVII Practical Related Questions:

Note: Below given are few sample questions for references. Teachers must design such questions to ensure achievement of identified CO.

1. What is the significance of the modulation index in SPWM?
2. What happens during overmodulation?
3. Why is a triangular waveform preferred as a carrier?
4. What are typical applications of SPWM?
5. How does carrier frequency affect output?

[Space for Answers]

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XVIII References/Suggestions for further reading: include websites/links/Virtual lab Link

1 Rashid, M. H., Power Electronics: Circuits, Devices and Applications, Pearson.

2 Bimbra, P. S., Power Electronics, Khanna Publishers.

3 MATLAB Documentation: https://www.mathworks.com/help/simulink

4 SPWM Concept: https://www.electronics-tutorials.ws/pwm/pwm_2.html

5 SCILAB XCos Resources: https://help.scilab.org/docs/6.1.1/en_US/Xcos.html

XIX Assessment Scheme

Performance Indicators		Weightage
Process Related (15 Marks)		**60%**
01	Circuit Construction Handling	10%
02	Understanding of Circuit Operation	20%
03	Accuracy of Simulation Configuration	20%
04	Team Collaboration and Clean Execution	10%
Product Related (10 Marks)		**40%**
05	Simulation Output Accuracy	10%
06	Graph/Scope Interpretation	05%
07	Conclusion (clarity and correctness)	05%
08	Practical related questions (concepts, applications)	15%
09	Submitting the manual in time (proper documentation)	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.7: Measurement of voltages at different test points and verify specification of UPS with data sheet

I. Practical Significance

This practical provides hands-on experience in understanding and analyzing the internal operation of a UPS by measuring voltages at various test points. It enhances students' troubleshooting skills, promotes safe working practices, and builds familiarity with key power electronics subsystems such as rectifiers, inverters, and batteries. Comparing observed values with datasheet specifications develops critical thinking and quality verification skills, essential for real-world industrial applications. Overall, it prepares learners for roles in maintenance, power systems, and UPS servicing while laying a strong foundation for advanced projects in smart and renewable energy-based UPS systems.

II. Industry/Employer Expected Outcome(s)

- Understand and diagnose UPS systems by measuring voltages at key test points and identifying faults in rectifier, inverter, and battery circuits.

III. Course Level Learning Outcome(s)

- AC voltage stabilizer and Uninterruptable Power supply

IV. Laboratory Learning Outcome(s)

- Set up the UPS in a test environment, ensuring correct connections to input and output loads, and configuring any necessary settings.

V. Relevant Affective Domain related outcome(s)

- Develop a responsible and professional attitude by actively participating in UPS testing, valuing accuracy, safety, and the importance of verifying specifications with industry standards

VI. Relevant Theoretical Background

An Uninterrupted Power Supply (UPS) is an electrical device that provides emergency backup power to a load when the input power source, typically the mains supply, fails. It also protects sensitive electronic equipment from voltage fluctuations, surges, and spikes.

The key components of a UPS include:

1. **Rectifier/Charger** – Converts AC input to DC to charge the battery and power the inverter simultaneously.
2. **Battery** – Stores DC energy for backup operation.
3. **Inverter** – Converts DC back to AC to supply uninterrupted power to the load during mains failure.
4. **Static Switch/Controller** – Automatically switches between mains and battery power without interrupting the load.

To ensure proper functioning and reliability, various test points are provided in the UPS circuitry (e.g., input, output, rectifier output, battery voltage, and inverter output). Measuring voltages at these points helps verify whether each stage of the UPS is operating within the specifications defined by the manufacturer's datasheet.

The datasheet is a technical document provided by the UPS manufacturer that includes standard operating parameters like:

- Input voltage and frequency
- Output voltage, waveform type, and frequency
- Backup time
- Battery charging voltage and current
- Inverter switching characteristics

By comparing the measured voltages with the datasheet values, users can identify faults, validate performance, and confirm compliance with design specifications. This process is essential in service, testing, and commissioning of UPS systems, especially in critical applications like hospitals, data centers, and industrial control systems.

VII. Actual Circuit diagram used in laboratory with related equipment rating.

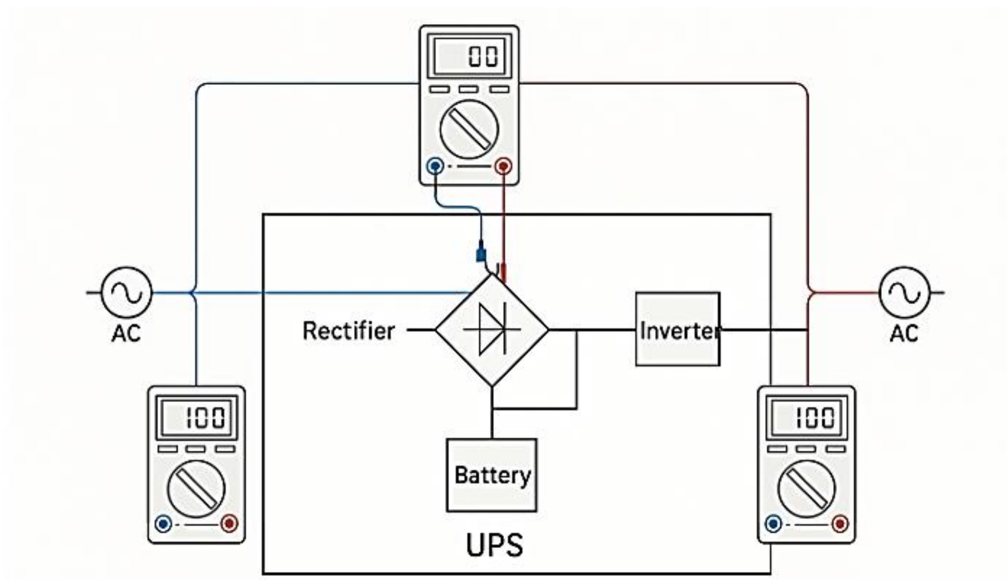

Figure 7.1: Basic block diagram of UPS

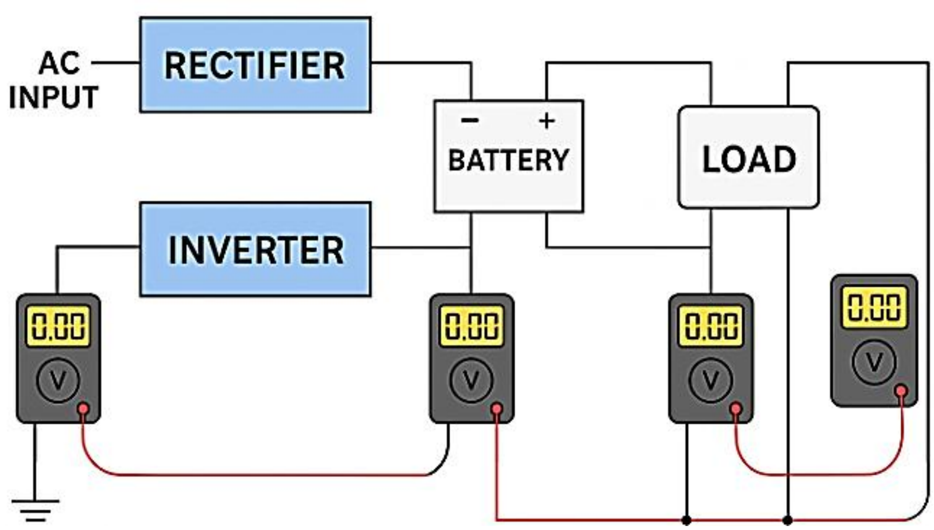

Fig.7.2, UPS internal testing kit circuit

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	UPS trainer kit	DC Input : 12V, DC Output : 230V, AC Battery : 12V, 6AH	1
2	Regulated power supply	0-230 V AC	
3	CRO/Digital Oscilloscope	20MHz, dual channel, sensitivity =1mV/div, Max Input = 400V, Power supply = 230VAC.	1
4	Digital multimeter	(0-230V)AC, (0-15V) DC	1
5	Safety gloves	-	1

IX. Precautions to be followed

1. Ensure that the connections are correct and tight to avoid any loose contacts.
2. Make sure the oscilloscope probes are correctly placed and grounded.
3. Remove the power cord from the AC mains supply before starting this task

X. Procedure

1. Open the UPS trainer kit
2. Identify the major components/devices and sections on the assembled circuit board of UPS
3. Draw the sketch of layout of the sections and mark the major/important test points in each section
4. Connect the power cord to mains supply and switch ON the UPS
5. Measure the AC input voltage in the wall socket as shown in Fig
6. Select the DC voltage function on multimeter and measure the rectifier voltage
7. Measure the battery voltage by referring the Fig

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			
5			

XII. Actual procedure followed

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XIII. Observations and Calculations

Observation table

Sr. No	Name of test point	Voltage	Remarks
1	AC input supply		
2	Rectifier output		
3	Battery Voltage		
4	UPS output		

XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teachers must design such questions to ensure achievement of identified CO.

1. State how does the output voltage of the inverter compared with the mains supply during battery operation?
2. State the importance of comparing the measured test point voltages with the values provided in the datasheet
3. State the impact of an overloaded UPS on the output voltage, and how can it be detected?

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. Laboratory Manual for introductory electronics experiments, Maheshwari, L.K.; Anand, M.M.S., New Age International Pvt. Ltd. New Delhi, ISBN:9780852265543
2. https://www.alldatasheet.com/
3. Power Electronics by P. S. Bimbhra; ISBN: 978-8174092793

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.8: Measurement of the output voltage for servo type voltage stabilizer for different values of ac input voltage

I. Practical Significance

A servo-type voltage stabilizer maintains a constant output voltage despite fluctuations in the input supply. This technology plays a vital role in electrical diagnostics, instrumentation, and system protection, aligning with industry expectations for roles in maintenance, testing, and control systems.

II. Industry/Employer Expected Outcome(s)

Understand and test voltage regulation systems like servo stabilizers, apply electrical safety and measurement skills, and demonstrate the ability to troubleshoot and protect sensitive equipment across industrial applications.

III. Course Level Learning Outcome(s)

AC voltage stabilizer and Uninterruptable Power supply

IV. Laboratory Learning Outcome(s)

Measure and record the output voltage of the servo-type voltage stabilizer for a range of AC input voltages

V. Relevant Affective Domain related outcome(s)

Follow electrical safety rules diligently, demonstrate a responsible attitude while working with live voltage equipment, and appreciate the importance of voltage regulation in safeguarding sensitive devices in both industrial and domestic settings.

VI. Relevant Theoretical Background

Servo Voltage Stabilizer save the life of costly appliances, CNC machines, electrical equipment, medical equipment's, motors, lab equipment etc. by correcting the voltage fluctuations in the incoming AC voltage and bringing and keeping it at the desired voltage levels. The principal of operation of servo stabilizer. The control circuit controls the servo motor. The motor is mechanically attached to the arm of a continuously variable auto transformer which feeds to the primary of a series control buck boost transformer. The stabilizer output voltage is compared with the reference voltage & resultant error signal controls the servo motor which corrects the voltage by bringing it to the preset voltage

VII. Actual Circuit diagram used in laboratory with related equipment rating.

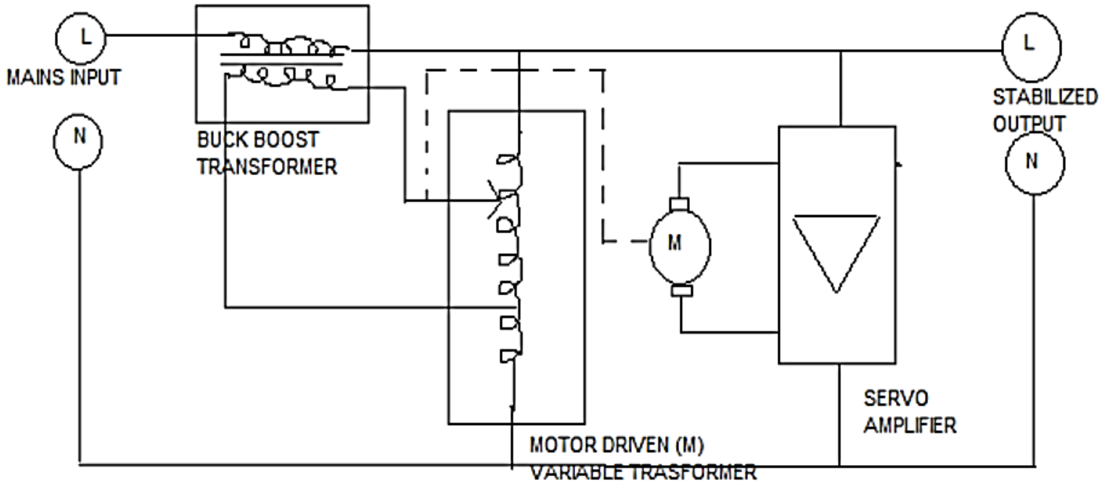

Figure 8.1: Variable Transformer

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Servo Voltage Stabilizer	2 kVA , Output Voltage: 230 V, Load current: 8.5 A, Input Voltage:170-290V, Input frequency: 50-60 Hertz	1
2	Regulated power supply	230V, 50Hz	1
3	CRO/Digital Oscilloscope	20MHz, dual channel, sensitivity =1mV/div, Max Input = 400V, Power supply = 230VAC.	1
4	Lamp Load bulbs each 200 W	2 kVA	10
5	Digital Multimeter	(0-230V)AC, (0-15V) DC	1
6	Ammeter	(0-10)A	1

IX. Precautions to be followed

1. Ensure that the connections are correct and tight to avoid any loose contacts.
2. Make sure the oscilloscope probes are correctly placed and grounded.
3. While studying the load characteristics the maximum current should not exceed the current rating specified
4. The output socket of the transformer must never get short circuited even momentarily

X. Procedure

1. Assemble the circuit as per the circuit diagram.
2. Connect the variable load with ammeter to the output of servo stabilize
3. Connect the input of servo stabilizer to the mains 220-volt, 50 hertz and adjust the output voltage at 220 volts.
4. Now vary the load at steps to maximum load and record the output voltage and current and find out the percentage load regulation.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			
5			

XII. Actual procedure followed

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XIII. Observations and Calculations

1. **Observation table**

Output Voltage at No load ……….

Sr.No.	Load(W)	Output Voltage(V)	Current (A)	Regulation(%)	Remark
1					
2					
3					
4					
5					

2. **Formula**

$$\%\text{Load Regulation} = \left(\frac{\text{No Load Output Voltage} - \text{Output Voltage on Load}}{\text{Output}}\right) \times 100$$

3. **Calculation**

XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teachers must design such questions to ensure achievement of identified CO.

1. What happens to the output voltage of a servo-type stabilizer when the input AC voltage fluctuates beyond its rated range?
2. How does the servo motor and control circuit work together to maintain a constant output voltage in a servo stabilizer?
3. State why is it important to measure the output voltage under different input conditions, and how does it help in evaluating the stabilizer's performance?

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. Laboratory Manual for introductory electronics experiments, Maheshwari, L.K .; Anand, M.M.S., New Age International Pvt. Ltd. New Delhi, ISBN:9780852265543
2. https://www.alldatasheet.com/
3. Power Electronics by P. S. Bimbhra; ISBN: 978-8174092793

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related : 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.9: Test the performance of lithium-ion battery

I. Practical Significance

Lithium-ion batteries are widely used in portable electronics, electric vehicles, and renewable energy storage systems due to their high energy density, low self-discharge rate, and long cycle life. Testing the performance of lithium-ion batteries is essential to ensure safety, efficiency, and optimal usage. These practical enables learners to analyze charge/discharge characteristics, monitor voltage and current profiles, and determine state-of-charge (SOC) and internal resistance.

II. Industry/Employer Expected Outcome(s)

- Test the performance and safety of lithium-ion battery systems under standard operating conditions.

III. Course Level Learning Outcome(s)

- Evaluate the performance parameters of voltage stabilizer and uninterrupted power supply.

IV. Laboratory Learning Outcome(s)

- Measure the voltage and current of a lithium-ion battery under various operating conditions, such as during charging, discharging, and at rest.

V. Relevant Affective Domain related outcome(s)

- Follow standard safety protocols while handling lithium-ion battery systems.

VI. Relevant Theoretical Background

Lithium-ion batteries are rechargeable energy storage devices widely used in smartphones, laptops, electric vehicles, and solar power systems due to their high energy density, lightweight, and long cycle life.

Battery performance is evaluated based on:

1. **Open Circuit Voltage (OCV)** – Voltage when no load is connected.
2. **Load Voltage** – Voltage across battery when a load is applied.
3. **Discharge Current** – Current drawn under load.
4. **Capacity** – Total charge a battery can deliver (measured in Ah).
5. **State of Charge (SOC)** – Estimated percentage of charge remaining.
6. **Efficiency** – Ratio of output energy to input energy during charging/discharging cycles.

VII. Actual Circuit diagram used in laboratory with related equipment rating.

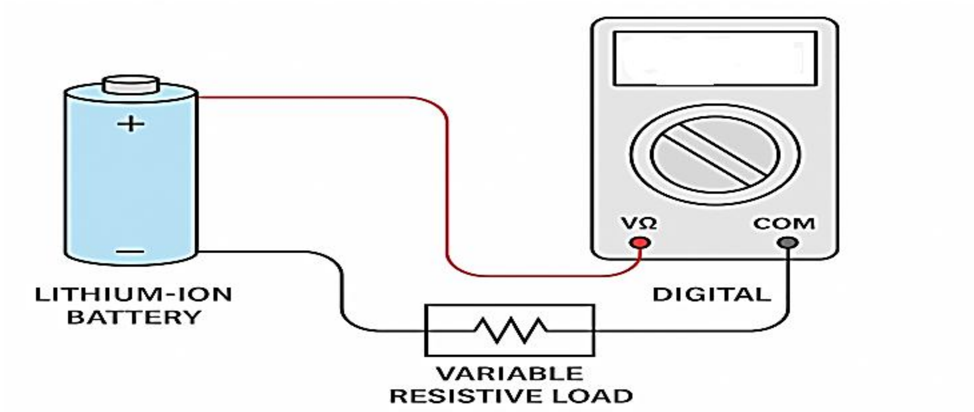

Figure 9.1: Circuit diagrams of lithium battery connected with variable resistive load

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Lithium-ion battery	3.7V, 2200mAh (or similar)	1
2	Digital Multimeter	0–20V DC, 0–10A DC	1
3	Variable resisitive Load	1W to 10W	1
4	Battery Analyzer (optional)	For advanced monitoring	1
5	Stopwatch / Timer	For discharge time measurement	1
6	Charger for Li-ion Battery	Compatible constant current/voltage	1
7	Wires, Connectors, Safety Tools	-	As required

IX. Precautions to be followed

1. Never short-circuit the battery terminals.
2. Do not discharge below the recommended cut-off voltage.
3. Use appropriate resistor loads to avoid overheating.
4. Always handle lithium-ion batteries with care to prevent fire or explosion.
5. Perform the test in a ventilated, supervised environment.

X. Procedure

A. Measuring Open Circuit Voltage (OCV)

1. Ensure the battery is fully charged.
2. Disconnect any load and let the battery rest for 10–15 minutes.
3. Measure the open circuit voltage using a multimeter.

B. Discharge Test Under Load

1. Connect a known load to the battery.
2. Start the timer and measure:
3. Initial voltage (load voltage)

4. Current using a multimeter
5. Continue discharging the battery until it reaches the minimum cut-off voltage (usually ~3.0V).
6. Note the total discharge time.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
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XII. Actual Procedure

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XIII. Observations and Calculations

1. Observation Table

Sr.No	Parameter	Measured Value	Reamak if any required
1	Open Circuit Voltage (V)		
2	Load Voltage (V)		
3	Discharge Current (A)		
4	Discharge Time (min)		
5	Final Voltage (cut-off)		
6	Calculated Capacity (Ah)		

2. Calculation

Battery capacity (Ah) = Discharge current(A)*Discharge time(hours)

XIV. Result(s)

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XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more suchquestions so as to ensure the achievement of identifies CO.

1. State how battery capacity is calculated?
2. State the difference between open-circuit voltage and load voltage in terms of lithium-ion battery
3. Why are lithium-ion batteries widely used in Electric Vehicles and portable electronics?

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. Laboratory Manual for introductory electronics experiments, Maheshwari, L.K .; Anand, M.M.S., New Age International Pvt. Ltd. New Delhi, ISBN:9780852265543
2. https://www.alldatasheet.com/
3. Power Electronics by P. S. Bimbhra; ISBN: 978-8174092793

XIX. Assessment Scheme

Performance Indicators		Weightage
Process Related: 15 Marks		**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
Product Related: 10 Marks		**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No.10: Test the performance of charge controller in PV System

I. Practical Significance

A charge controller is essential in renewable energy systems, particularly in solar and wind energy setups, for regulating the voltage and current going into batteries. It prevents overcharging, which can damage batteries and reduce their lifespan. By controlling the flow of energy, it also helps avoid excessive discharging, ensuring efficient battery usage. Some charge controllers also provide protection against power surges and short circuits. In advanced systems, they offer features like tracking maximum power points (MPPT) to optimize energy capture.

II. Industry/Employer Expected Outcome(s)

- Test the performance of Power Electronic Devices and Circuits

III. Course Level Learning Outcome(s)

- Maintain electric drives used in various industrial applications

IV. Laboratory Learning Outcome(s)

- Measure and record key electrical parameters of the PV system, including voltage, current, and power output from the PV panels.

V. Relevant Affective Domain related outcome(s)

- Follow safety electrical rules for safe practices.

VI. Relevant Theoretical Background

A charge controller is a crucial component in PV systems, designed to regulate the voltage and current from the PV panels to the battery. It prevents overcharging and over-discharging of the battery, thereby extending its life. Charge controllers typically operate in two modes:

1) PWM (Pulse Width Modulation) Charge Controller: Regulates the voltage by gradually reducing the charging current as the battery reaches its full charge.
2) MPPT (Maximum Power Point Tracking) Charge Controller: Optimizes the PV panel output by adjusting the voltage to ensure the maximum power output

VII. Actual Circuit diagram used in laboratory with related equipment rating.

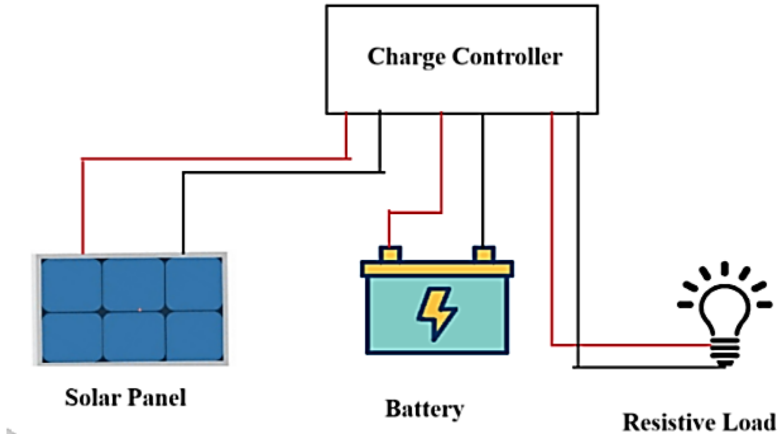

Figure 10.1: Circuit diagram of solar panel connected with resistive load.

VIII. Required Resources/apparatus/equipment with specifications

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	PV Panel	50W or higher	1
2	Charge Controller	PWM or MPPT	1
3	Battery	12V or 24V, depending on the charge controller specification	1
4	Variable resistive load	30W to 100W	1
5	Voltmeter	0-30 V DC	1
6	Ammeter	0-10 A DC	1

IX. Precautions to be followed

1) Ensure Correct Polarity: Always connect the PV panel, battery, and load to the charge controller with the correct polarity (positive to positive and negative to negative). Incorrect connections can damage the charge controller, battery, or other components.
2) Avoid Short Circuits: When connecting and disconnecting the PV panel, battery, and load, ensure that there are no short circuits. Use insulated tools and avoid touching exposed wires or terminals to prevent electrical hazards or damage to equipment.

X. Procedure

Step 1: Circuit Setup

1. PV Connection: Connect the PV panel to the input terminals of the charge controller.
2. Battery Connection: Connect the battery to the charge controller's battery terminals. Ensure correct polarity (positive to positive and negative to negative).
3. Load Connection: Connect a resistive load or an inverter to the load terminals of the charge controller.
4. Measurement Setup: Connect meters at the input (PV panel), battery, and output (load)

terminals to measure voltage and current.

Step 2: Test Under No-Load Condition

1. Ensure the load is disconnected.
2. Record the following parameters:
   - PV Voltage (Voc): Open circuit voltage from the PV panel.
   - PV Current (Isc): Short circuit current from the PV panel.
   - Battery and Current (Vbat, Ibat): Measure the voltage and current across the battery terminals.
3. Check if the charge controller properly charges the battery without the load.

Step 3: Test Under Load Condition

1. Connect a load (e.g., resistive load or inverter) to the output terminals.

2. Record the following parameters:

- PV Voltage and Current (Vpv, Ipv): Measure the voltage and current at the input side from the PV panel.
- Battery Voltage and Current (Vbat, Ibat): Measure the battery voltage and current to verify charging status.
- Load Voltage and Current (Vload, Iload): Measure the output voltage and current delivered to the load.

XI. Resources used

Sr. No.	Name of Resource	Specifications	Quantity
1			
2			
3			
4			
5			

XII. Actual Procedure

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XIII. Observations and Calculations

1. **No-Load Condition:**
   - PV Open Circuit Voltage (Voc) =
   - PV Short Circuit Current (Isc) =
   - Battery Voltage (Vbat) =
   - Battery Current (Ibat) =
2. **Under Load Condition:**
   - PV Input Voltage (Vpv) =

- PV Input Current (Ipv) =
- Battery Voltage (Vbat) =
- Battery Current (Ibat) =
- Load Voltage (Vload) =
- Load Current (Iload) =

XIV. Result(s)

1. Power loss in charge controller when load is not connected = ...
2. Power loss in charge controller when load is connected = ...……………………………………………………………………………

XV. Interpretation of results

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XVI. Conclusion and recommendation

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XVII. Practical related questions

Note: Below given are few sample questions for reference. Teacher must design more suchquestions so as to ensure the achievement of identifies CO.

1. State the function of charge controller.
2. Explain how a charge controller prevents battery overcharging

[Space for Answers]

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XVIII. References/Suggestions for further reading

1. Laboratory Manual for introductory electronics experiments, Maheshwari, L.K .; Anand, M.M.S., New Age International Pvt. Ltd. New Delhi, ISBN:9780852265543
2. https://www.alldatasheet.com/

XIX. Assessment Scheme

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Marks Obtained			**Dated signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	