lendi Institute of Engineering & Technology
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Department of Electrical and Electronics Engineering

LAB MANUAL

Name of the laboratory : **ELECTRIC VEHICLE TECHNOLOGY**

Regulation : **R 20**

Subject Code : **C331**

Branch : **EEE**

Year & Semester : **III B.Tech- II Semester**

INSTITUTE VISION, MISSION

DEPARTMENT VISION, MISSION PEO & PO/PSO

INSTITUTE

VISION

Produce globally competent and quality technocrats with human values for the holistic needs of industry and society.

MISSION

- Creating an outstanding infrastructure and platform for enhancement of skills, knowledge and behavior of students towards employment and higher studies.
- Providing a healthy environment for research, development and entrepreneurship, to meet the expectations of industry and society.
- Transforming the graduates to contribute to the socio-economic development and welfare of the society through value based education.

Department of Electrical & Electronics Engineering

VISION

To be a hub for imparting knowledge, skills, and behavior for exemplary Contributions in the field of Electrical and Electronics Engineering.

MISSION

- To impart Technical Education through the state-of-the-art infrastructure facilities, laboratories and instruction.
- To inculcate industry oriented learning through industrial visits, internships, projects at Industries, MOUs, to make students' technically skills oriented.
- Creating conducive environment for higher education, employment and entrepreneurship through quality education, professional skills and research.
- To promote societal commitment among students by inculcating moral and ethical values.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

- **PEO1:** Graduates shall have strong foundation in core and allied Electrical and Electronics Engineering, in sciences and mathematics, to become globally competent in designing, modeling and critical problem solving.
- **PEO2:** Graduates shall involve in research activities in the field of electrical and electronics engineering through lifelong learning and provide solutions to engineering problems for sustainable development of society.
- **PEO3:** Graduates shall have good communication skills and socio-ethical values for getting employment or higher studies by excelling in competitive examinations and be able to work in supportive and leadership roles.

PROGRAM SPECIFIC OUTCOMES (PSOs)

- **PSO1:** Capable of design, develop, test, verify and implement electrical and electronics engineering systems and products.
- **PSO2**: Succeed in national and international competitive examinations for successful higher studies and employment.

PROGRAM 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 and design 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 Tool Usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling 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 and 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 and 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 and 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	**Life-Long 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.

COURSE INFORMATION SHEET

PROGRAM: **Electrical And Electronics Engineering**	DEGREE: **B.TECH**
COURSE: **Electric Vehicle Technology Lab**	SEMESTER: **III-II** CREDITS: **2**
COURSE CODE: **C331** REGULATION:**R20**	COURSE TYPE: **SKILL COURSE** (LAB)
COURSE AREA/DOMAIN: **Power Electronics**	CONTACT HOURS: **3 HOURS/WEEK.**
CORRESPONDING LAB COURSE CODE (If Any):-	LAB COURSE NAME (IF ANY):

SYLLABUS:

UNIT	DETAILS	HOURS
I	Introduction to electric vehicle technology	6
II	Introduction to fundamentals, types of batteries and their design calculations for EV	3
III	Simulation of SPWM technique for electric vehicle converter using MATLAB/SIMULINK.	3
IV	Simulation of three – phase VSI for grid integration in EV using MATLAB/SIMULINK.	3
V	Design of bidirectional battery circuit using Buck / Boost converter using MATLAB/SIMULINK	3
VI	Battery controller based on SoC for charging and discharging of battery in EV using MATLAB/SIMULINK	3
VII	Modeling and Simulation of BMS for temperature control in EV using MATLAB/SIMULINK	3
VIII	SoC control of Lithium Ion battery in MATLAB/SIMULINK for EV	3
IX	Simulation of bidirectional operation in Electric Vehicle charger using single phase model	3
X	Modeling and Simulation to calculate electric vehicle speed from motor torque	3
XI	Speed control of electric vehicle using BLDC or PMSM in MATLAB/SIMULINK	3
XII	Simulation of electric vehicle using MATLAB/SIMULINK	3
	Additional Experiments	
XIII	Simulation of Dynamic wireless Charging electric vehicle using MATLAB/SIMULINK	3

	Repeat lab	3
	Internal lab	3
	TOTAL HOURS	48

TEXT/REFERENCE BOOKS:

T/R	BOOK TITLE/AUTHORS/PUBLICATION
T	Hybrid Electric Vehicle System Modeling and Control - Wei Liu, General Motors, USA, John Wiley & Sons, Inc., 2017.
R	Hybrid Electric Vehicles – Teresa Donateo, Published by ExLi4EvA, 2017
R	Electric and Hybrid Vehicles Power Sources, Models, Sustainability, Infrastructure and the Market Gianfranco Pistoia Consultant, Rome, Italy, Elsevier Publications, 2017.
R	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani Yimin Gao Stefano Longo Kambiz M. Ebrahimi, Taylor & Francis Group, LLC, 2018.

WEB SOURCE REFERENCES:

1	https://nptel.ac.in/courses/108106170
2	https://lms.pantechelearning.com/s/courses/62590b180cf2fc9e3475fcc9/take

COURSE PRE-REQUISITES:

C.CODE	COURSE NAME	DESCRIPTION	SEM
C305	Power electronics	Student should learn to study the operation of ac voltage controller, full converter , inverter, chopper	III-I

COURSE OBJECTIVES:

1	To study the working principle of electrical vehicles, fundamentals of batteries and their designing characteristics.
2	To design and analyze performance of power converters in electric vehicles.
3	To analyze the state of charge and battery management system of Battery in electric vehicle.
4	To analyze the speed control of motors used in electric vehicles.
5	To understand the bidirectional operation in electric vehicle charger.

COURSE OUTCOMES:

CO.NO	DESCRIPTION	PO(1..12) MAPPING	PSO(1,2) MAPPING
1	Explain the working principle of electrical vehicles, fundamentals of batteries and their designing characteristics(L2)	PO1,PO2,PO6,PO7,PO9,PO10, P012	PSO1,PSO2
2	Design power electronic converters using MATLAB/Simulink for electric vehicle applications.(L3)	PO1,PO2,PO3,PO5,PO6,PO7, PO9,PO10,PO11,P012	PSO1, PSO2
3	Analyze the state of charge and battery management system of Battery in electric vehicle.(L4)	PO1,PO2,PO3,PO5,PO6,PO7, PO9,PO10,PO11,P012	PSO1, PSO2

4	Analyze the speed control of motors used in electric vehicles.(L4)l	PO1,PO2,PO3,PO5,PO6,PO7, PO9,PO10,PO11,P012	PSO1, PSO2
5	Design a bidirectional charging circuit for an electric vehicle.(L4)	PO1,PO2,PO3,PO5,PO6,PO7, PO9,PO10,PO11,P012	PSO1, PSO2
COURSE OVERALL PO/PSO MAPPING: PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10, PO12, PSO1,PSO2			

COURSE OUTCOMES VS POs MAPPING (DETAILED; HIGH: 3; MEDIUM: 2; LOW: 1**):**

CO.NO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
C331.1	3	2	-	-	-	2	3	-	3	2	-	2	3	2
C331.2	3	2	3	-	3	2	3	-	3	2	1	2	3	2
C331.3	3	2	3	-	3	2	3	-	3	2	1	2	3	2
C331.4	3	2	3	-	3	2	3	-	3	2	1	2	3	2
C331.5	3	2	3	-	3	2	3	-	3	2	1	2	3	2
C331*	3	2	3	-	3	2	3	-	3	2	1	2	3	2

** For Entire Course, PO & PSO Mapping*

POs & PSO REFERENCE:

PO1	Engineering Knowledge	PO7	Environment & Sustainability	PSO1	Capable of design, develop, test, verify and implement electrical and electronics engineering systems and products
PO2	Problem Analysis	PO8	Ethics	PSO2	Succeed in national and international competitive examinations for successful higher studies and employment
PO3	Design & Development	PO9	Individual & Team Work		
PO4	Investigations	PO10	Communication Skills		
PO5	Modern Tools	PO11	Project Mgt. & Finance		
PO6	Engineer & Society	PO12	Life Long Learning		

COs VS POs MAPPING JUSTIFICATION:

SNO	**PO/PSO MAPPED**	**LEVEL OF MAPPING**	**JUSTIFICATION**
C331.1	PO1	3	Understanding of electric vehicles, their working principles, battery fundamentals, and design characteristics is essential for engineering specialization and the solution of complex engineering problems in that.
	PO2	2	Moderate analysis of challenges related to battery performance and electric vehicles is essential for applying engineering principles and developing effective solutions to complex problems.
	PO6	2	Students moderately explore the societal and environmental implications of electric vehicles to contribute to sustainability and energy conservation.

	PO7	3	Understanding the principles of electric vehicles and the fundamentals of batteries substantially emphasizes their importance in promoting sustainability and protecting the environment.
	PO9	3	Students are encouraged to engage in substantial collaboration to analyse and understand battery and vehicle systems, fostering teamwork, communication, and shared problem-solving skills
	PO10	2	The understanding of electric vehicles and battery systems requires a moderate level of communication skills to effectively convey technical concepts and analyses, ensuring clear documentation and presentation of engineering solutions.
	PO11	1	The design and analysis of battery systems incorporate a moderate level of project management, allowing students to develop planning, organization, and task management skills.
	PO12	2	Analysing the working principles of electric vehicles, battery fundamentals, and design characteristics fosters moderate lifelong learning by enabling students to adapt to advancements in sustainable engineering and emerging technologies.
	PSO1	3	Analysing the working principles of electric vehicles, battery fundamentals, and design characteristics provides students with substantial capability to design, develop, test, verify, and implement electrical and electronics engineering systems and products.
	PSO2	2	Analysing the working principles of electric vehicles, battery fundamentals, and design characteristics provides a moderate foundation for developing technical skills, helping students succeed in national and international competitive exams for higher studies and employment.
C331.2	PO1	3	Designing the power converter for electric vehicles involves a substantial foundation in engineering principles, ensuring efficient energy conversion and system performance.
	PO2	2	Designing the power converter for electric vehicles involves moderate problem-solving skills to evaluate system challenges, analyse requirements, and propose optimized solutions.
	PO3	3	Designing the power converter for electric vehicles substantially enables the development of efficient and reliable solutions that meet performance, safety, and sustainability standards

	PO5	3	Designing the power converter for electric vehicles substantially requires the use of modern simulation tools and software to enhance accuracy and efficiency.
	PO6	2	Designing the power converter for electric vehicles moderately helps engineers understand the societal impact of vehicle efficiency and emissions, contributing to sustainable transportation solutions.
	PO7	3	Designing the power converter for electric vehicles substantially supports sustainability by improving energy efficiency, reducing losses, and minimizing environmental impact.
	PO9	3	Designing and analysing the performance of power converters in electric vehicles requires substantial collaboration, fostering teamwork and effective communication in multidisciplinary engineering teams.
	PO10	2	Designing and analysing the performance of power converters in electric vehicles requires a moderate level of communication skills to convey technical concepts, document findings, and present analyses effectively.
	PO11	1	Designing and analysing the performance of power converters in electric vehicles slightly incorporates project management to plan, develop, and optimize designs within technical and financial constraints.
	PO12	2	Designing and analysing the performance of power converters in electric vehicles fosters moderate lifelong learning, enabling students to adapt to advancements in power converter technologies.
	PSO1	3	Designing and analysing the performance of power converters in electric vehicles substantially equips students with the necessary skills to design, develop, test, verify, and implement electrical and electronics engineering systems and products.
	PSO2	2	Designing the power converter for electric vehicles moderately enhances technical skills and problem-solving abilities, helping students succeed in national and international competitive exams for higher studies and employment.
C331.3	PO1	3	Analysing the state of charge and battery management system of a battery in an electric vehicle substantially relies on engineering principles for accurate assessment and efficient energy management.
	PO2	2	Analysing the state of charge and battery management system of a battery in an electric vehicle involves moderate problem-solving skills to evaluate battery

			performance challenges and propose effective management strategies
	PO3	3	Analysing the state of charge and battery management system of a battery in an electric vehicle substantially aids in developing efficient and reliable solutions that optimize performance and safety.
	PO5	3	Analysing the state of charge and battery management system of a battery in an electric vehicle substantially relies on modern simulation tools and software to assess performance and optimize battery management strategies.
	PO6	2	Analysing the state of charge and battery management system of a battery in an electric vehicle moderately helps engineers assess the societal impact of battery efficiency and longevity, supporting sustainable energy solutions
	PO7	3	Analysing the state of charge and battery management system of a battery in an electric vehicle substantially supports sustainability by improving energy efficiency, reducing waste, and enhancing battery lifespan
	PO9	3	Analysing the state of charge and battery management system of a battery in an electric vehicle requires substantial teamwork and collaboration to develop and implement effective battery management strategies
	PO10	2	Analysing the state of charge and battery management system of a battery in an electric vehicle involves moderate communication skills to effectively document, present, and explain technical findings
	PO11	1	Analysing the state of charge and battery management system of a battery in an electric vehicle slightly incorporates project management skills to optimize battery design and monitoring within technical and financial constraints
	PO12	2	Analysing the state of charge and battery management system of a battery in an electric vehicle fosters moderate lifelong learning by updating students on battery advancements and industry standards
	PSO1	2	Analysing the state of charge and battery management system of a battery in an electric vehicle substantially enhances the ability to design, develop, test, verify, and implement electrical and electronics engineering systems and products.
	PSO2	2	Analysing the state of charge and battery management system of a battery in an electric vehicle moderately enhances technical knowledge and problem-solving skills, helping students succeed in national and international

			competitive examinations for higher studies and employment.
C331.4	PO1	3	Analysing the speed control of motors used in electric vehicles substantially depends on engineering principles to ensure optimal efficiency and performance.
	PO2	2	Analysing the speed control of motors used in electric vehicles involves moderate problem-solving skills to assess control techniques, optimize motor efficiency, and address system limitations
	PO3	3	Analysing the speed control of motors used in electric vehicles substantially enables the development of efficient and reliable motor control strategies that enhance performance and vehicle safety
	PO5	3	Analysing the speed control of motors used in electric vehicles substantially utilizes modern simulation tools and software to model, analyse, and optimize motor performance.
	PO6	2	Analysing the speed control of motors used in electric vehicles helps engineers understand the societal impact of energy-efficient motor operation, contributing to sustainable transportation.
	PO7	3	Analysing the speed control of motors used in electric vehicles substantially supports sustainability by enhancing energy efficiency and reducing power losses.
	PO9	3	Analysing the speed control of motors in electric vehicles substantially involves teamwork to design, test, and optimize control strategies.
	PO10	2	Analysing the speed control of motors in electric vehicles requires moderate communication skills to effectively document, explain, and present technical findings.
	PO11	1	Analysing the speed control of motors used in electric vehicles slightly incorporates project management to plan, develop, and implement motor control strategies within technical and financial constraints.
	PO12	2	Analysing the speed control of motors used in electric vehicles fosters moderate lifelong learning by keeping students updated on advancements in motor control techniques, technologies, and industry standards.
	PSO1	3	Analysing the speed control of motors used in electric vehicles substantially enhances the ability to design, develop, test, verify, and implement electrical and electronics engineering systems and products.
	PSO2	2	Analyzing the speed control of motors used in electric vehicles moderately enhances technical knowledge and

			problem-solving skills, preparing students to succeed in national and international competitive examinations for higher studies and employment.
C331.5	PO1	3	Designing the bidirectional operation in electric vehicle chargers is substantially required to apply engineering principles for ensuring efficient energy transfer and grid integration.
	PO2	2	Designing the bidirectional charger in electric vehicle is substantially required to develop moderate problem-solving skills for analyzing energy flow, optimizing power conversion
	PO3	3	Understanding the bidirectional operation in electric vehicle chargers substantially enables the development of efficient and reliable charging systems that enhance performance, safety, and grid stability.
	PO5	3	Designing the bidirectional charger in electric vehicle chargers substantially utilizes modern simulation tools and software to model, analyses, and improve charging efficiency
	PO6	2	Designing the bidirectional charger in electric vehicle helps engineers understand the societal impact of vehicle-to-grid technology and renewable energy integration
	PO7	3	Designing the bidirectional charger in electric vehicle substantially supports sustainability by enabling energy reuse, reducing grid dependency, and promoting renewable energy adoption
	PO9	3	Designing the bidirectional charger in electric vehicle requires substantial teamwork and collaboration to develop, test, and implement efficient charging strategies
	PO10	2	Designing the bidirectional charger in electric vehicle involves moderate communication skills to document findings, convey technical concepts, and present analyses effectively.
	PO11	1	Designing the bidirectional charger for an electric vehicle c slightly incorporates project management to design and optimize charging strategies within technical and financial constraints.
	PO12	2	Designing the bidirectional charger in electric vehicle fosters moderate lifelong learning by keeping students updated on advancements in charging technology, grid interaction, and industry standards.
	PSO1	3	Designing the bidirectional charger in electric vehicle substantially enhances the ability to design, develop, test, verify, and implement electrical and electronics systems.

	PSO2	2	Designing the bidirectional charger in electric vehicle moderately enhances technical knowledge and problem-solving skills, helping students succeed in national and international competitive examinations for higher studies and employment.

DELIVERY/INSTRUCTIONAL METHODOLOGIES:

☑CHALK & TALK	☑ ICT TOOLS	☑ WEB REFERENCES	☐STUDENT SEMINARS
☐ INDUSTRIAL VISITS	☐ INTERNSHIPS	☑ EXPERIENTIAL LEARNING	☐ MODEL-BASED LEARNING
☐ GUEST LECTURES	☑ COLLABORATIVE LEARNING	☐ MINI/MAJOR PROJECTS	☑ CASE STUDIES/REAL LIFE EXAMPLES

ASSESSMENT METHODOLOGIES-DIRECT

☐ ASSIGNMENTS	☐ STUD. SEMINARS	☐ TESTS/MODEL EXAMS	☑ END SEMESTER
☑ STUD. LAB PRACTICES	☑ STUD. VIVA	☐ MINI/MAJOR PROJECTS	☐ CERTIFICATIONS
☐ ADD-ON COURSES	☐ OTHERS		

ASSESSMENT METHODOLOGIES-INDIRECT

☑ ASSESSMENT OF COURSE OUTCOMES (BY FEEDBACK, ONCE)	☐STUDENT FEEDBACK ON FACULTY (TWICE)
☐ ASSESSMENT OF MINI/MAJOR PROJECTS BY EXT. EXPERTS	☐ OTHERS

Prepared by

T.Sravya

Approved by **HOD, EEE**

PAC Member

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ELECTRIC VEHICLE TECHNOLOGY

Course objectives:

1. To study the working principle of electrical vehicles, fundamentals of batteries and their designing characteristics.
2. To analyze performance of power converters in electric vehicles.
3. To analyze the state of charge and battery management system of Battery in electric vehicle.
4. To analyze the speed control of motors used in electric vehicles.
5. To understand the bidirectional operation in electric vehicle charger.

Course outcomes: By the end of this course, student will be able to

1. Explain the working principle of electrical vehicles, fundamentals of batteries and their designing characteristics. **(L2)**
2. Design power electronic converters using MATLAB/Simulink for electric vehicle applications**.(L3)**
3. Analyze the state of charge and battery management system of Battery in electric vehicle. **(L4)**
4. Analyze the speed control of motors used in electric vehicles. **(L4)**
5. Design a bidirectional charging circuit for an electric vehicle**.(L4)**

List of Experiments

1. Introduction to electric vehicle technology.
2. Introduction to fundamentals, types of batteries and their design calculations for EV.
3. Simulation of SPWM technique for electric vehicle converter using MATLAB/SIMULINK.
4. Simulation of three – phase VSI for grid integration in EV using MATLAB/SIMULINK.
5. Design of bidirectional battery circuit using Buck / Boost converter using MATLAB/SIMULINK.
6. Battery controller based on SoC for charging and discharging of battery in EV using MATLAB/SIMULINK.
7. Modeling and Simulation of BMS for temperature control in EV using MATLAB/SIMULINK.
8. SoC control of Lithium Ion battery in MATLAB/SIMULINK for EV.
9. Simulation of bidirectional operation in Electric Vehicle charger using single phase model.
10. Modeling and Simulation to calculate electric vehicle speed from motor torque
11. Speed control of electric vehicle using BLDC or PMSM in MATLAB/SIMULINK.
12. Simulation of electric vehicle using MATLAB/SIMULINK.

Additional Experiments:

13. Simulation of Dynamic wireless Charging electric vehicle using MATLAB/SIMULINK

LAB INDEX SHEET

EXP. No	EXPERIMENT NAME	CO'S	PO'S & PSO'S
1	Introduction to electric vehicle technology.	CO1	PO1,PO2,PO6,PO7,PO9, PO10,P012, PSO1,PSO2
2	Introduction to fundamentals, types of batteries and their design calculations for EV.	CO1	PO1,PO2,PO6,PO7,PO9, PO10,P012, PSO1,PSO2
3	Simulation of SPWM technique for electric vehicle converter using MATLAB/SIMULINK.	CO2	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, P012,PSO1,PSO2
4	Simulation of three – phase VSI for grid integration in EV using MATLAB/SIMULINK	CO2	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, PO12,PSO1, PSO2
5	Design of bidirectional battery circuit using Buck / Boost converter using MATLAB/SIMULINK.	CO3, CO5	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, P012, PSO1,PSO2
6	Battery controller based on SoC for charging and discharging of battery in EV using MATLAB/SIMULINK.	CO3	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, PO12, PSO1,PSO2
7	Modeling and Simulation of BMS for temperature control in EV using MATLAB/SIMULINK.	CO3	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, PO12, PSO1,PSO2
8	SoC control of Lithium Ion battery in MATLAB/SIMULINK for EV.	CO3	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, PO12, PSO1,PSO2
9	Simulation of bidirectional operation in Electric Vehicle charger using single-phase model.	CO5	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, PO12, PSO1,PSO2
10	Modeling and Simulation to calculate electric vehicle speed from motor torque	CO4	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, PO12, PSO1, PSO2
11	Speed control of electric vehicle using BLDC or PMSM in MATLAB/SIMULINK.	CO4	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11, PO12, PSO1,PSO2
12	Simulation of electric vehicle using MATLAB/SIMULINK.	CO2,CO3, CO4,CO5	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11,P O12, PSO1,PSO2
Additional Experiments			
13	Simulation of Dynamic wireless Charging electric vehicle using MATLAB/SIMULINK	CO2,CO3, CO5	PO1,PO2,PO3,PO5,PO6, PO7,PO9,PO10,PO11,P O12, PSO1,PSO2

EXPERIMENT – 1

Introduction to electric vehicle technology

AIM: To study the introduction to electric vehicle technology

Electric Vehicle

A type of vehicle that uses one or more electric motor for propulsion is known as **electric vehicle (EV)**. In simple words, we can say the electric vehicles are the automobiles that are propelled by one or more electric motors using the energies stored in batteries.

Comparison between IC Engine Vehicle and Electric Vehicle

The following table highlights the points that differentiate an IC Engine Vehicle from an Electric Vehicle –

Point of Comparison	Internal Combustion Engine Vehicle	Electric Vehicle
Source of power	The source of power for ICEV is different types of fuels such as diesel or petrol.	Electricity obtained from charged batteries, ultra-capacitors, etc. is the source of power in electric vehicles.
Prime mover	Internal combustion engine (ICE) is the prime mover or powertrain.	Electric motor is the prime mover in the electric vehicles.
Specific energy	There is high specific energy of fuel.	In electric vehicles, low specific energy of battery.
Power density	Fuels used in ICEV have high power density.	In power density of power source is low.
Impact on Environment	ICEV emits green-house gases which have adverse effect on environment.	EV does not have adverse effect on environment.
Travelling distance	ICEV can travel more than around 300 miles per fill.	EV travels less than around 100 miles per charge.
Refilling time	ICEV requires less refilling time (approx. less than 5 min.).	EV has long charging time, about 0.5 to 8 hours.
Space & weight fuel tank	In ICEV, fuel tank takes less space and the weight of fuel is very less.	In EV, batter bank takes large. Also, the batteries are very heavy.
Maintenance & running costs	The maintenance and running costs of internal combustion	The electric vehicles require low running and maintenance costs.

Point of Comparison	Internal Combustion Engine Vehicle	Electric Vehicle
	engine vehicles are high.	
Efficiency	The efficiency of IC engines is about 30%.	The electric motors used in electric vehicles have approximately 80% efficiency.
Noise production	IC engine vehicles produces noise.	Electric vehicles have noise free operation.
Recovery of braking energy	In case of IC engine vehicles, the braking energy cannot be recovered.	In case of EVs, the braking energy can be recovered by using regenerative braking.
Time required for maximum torque	IC engine vehicles require to pick up some speed to deliver maximum torque.	Electric vehicles produce maximum torque instantly after starting of motor.
Capital cost	IC engine vehicles have average initial cost.	The initial cost of electric vehicles is high.
Power transmission	In IC engine vehicles, the system of power transmission from source to load is mechanical only.	Electric vehicles have both mechanical as well as electrical power transmission system.

Benefits of electric vehicles

- Lower running costs
- Low maintenance cost
- Zero Tailpipe Emissions
- Tax and financial benefits
- Electric Vehicles are easy to drive and quiet
- Convenience of charging at home
- No noise pollution

Challenges of electric vehicle

- EV and Battery cost
- Beta Version of vehicles
- Poor infrastructure and range anxiety
- Lack of standardization
- Temperature Issues
- Very few academic and local skill awareness
- Less performance
- Will increase the electricity demand at a national level
- Servicing is in danger

Components of Electric Vehicles (EVs)

The components of an Electric Vehicle (EV) include:

1. Battery Pack
2. Motor and Inverter
3. Charging Port
4. On-board Charger
5. Control Unit
6. Electric Drive Train
7. Power Management System
8. Battery Management System
9. High-Voltage Wiring
10. Battery Cooling System
11. Brake Energy Regeneration System
12. Power Steering Unit
13. Climate Control System

1. Battery Pack

The battery pack in an electric vehicle (EV) is a key component that stores energy and provides power to the electric motor. It typically consists of multiple battery cells that are connected together to form a single unit. The pack is typically made up of lithium-ion (Li-ion) batteries, which have a high energy density and can store a large amount of energy in a relatively small and lightweight package. The battery pack is also responsible for providing power to other systems in the vehicle, such as lights and entertainment systems. The performance and range of an EV are directly related to the capacity of its battery pack.

The battery pack is also responsible for providing power to the electric motor, which drives the wheels of the vehicle. The battery management system (BMS) in an EV is responsible for monitoring and managing the battery cells to ensure that they are functioning correctly and preventing damage. The BMS also regulates the charging and discharging of the battery cells, to ensure that the battery operates within a safe and optimal range.

The battery pack is typically the most expensive component of an EV, and the cost of the battery has been one of the main challenges facing the widespread adoption of EVs. However, with advances in battery technology, the cost of batteries has been decreasing, making EVs more affordable and accessible.

In terms of charging, BEVs can be charged using either a Level 1 (110V), Level 2 (220V), or Level 3 (fast-charging) station. Level 2 charging provides faster charging times compared to Level 1, while Level 3 charging can provide an 80% charge in 30-60 minutes.

Overall, the battery is a critical component of an EV, and it is important to choose a battery that meets the needs of the vehicle and its intended use.

2. Motor and Inverter

The electric motor and power inverter are two crucial components in an electric vehicle (EV). The electric motor converts electrical energy from the battery into mechanical energy to drive the wheels of the vehicle. The power inverter is responsible for controlling the flow of electrical energy from the battery to the motor, and vice versa during regenerative braking.

The electric motor used in an EV is typically an AC induction motor or a Permanent Magnet Synchronous Motor (PMSM). The type of motor used depends on the specific requirements of the vehicle and the desired performance characteristics.

3. Charging Port

The charging port of an electric vehicle (EV) is the interface between the vehicle and the charging station. It is where the vehicle is connected to the charging station to receive electrical energy, which is used to charge the battery.

4**. On-board Charger**

The on-board charger of an electric vehicle (EV) is a component that is responsible for converting the alternating current (AC) electrical energy received from the charging station into direct current (DC) electrical energy, which is used to charge the battery.

The on-board charger is located inside the vehicle, and it is connected to the charging port, which is used to connect the vehicle to the charging station.

5. Control Unit

The control unit of an electric vehicle (EV) is a central component that manages and coordinates the various systems in the vehicle. It is responsible for controlling the performance, efficiency, and safety of the vehicle.

The control unit includes a central processor, memory, and a number of sensors and inputs that monitor the vehicle’s systems and environment. These include sensors for the battery, motor, power inverter, charging system, and other critical components. The control unit uses the data from these sensors to control the operation of the vehicle and ensure optimal performance.

Some of the key functions of the control unit in an EV include:

1. Power management: The control unit manages the flow of electrical energy between the battery and the electric motor, and it ensures that the battery is charged and discharged within safe and optimal limits.
2. Performance optimization: The control unit optimizes the performance of the vehicle by controlling the speed and torque of the electric motor, and by adjusting the energy flow to the motor based on the vehicle’s load and conditions.
3. Safety: The control unit monitors the vehicle’s systems and environment to ensure that the vehicle is operating within safe and reliable limits, and it can take corrective actions if necessary to prevent damage or malfunctions.

4. Driver assistance: The control unit can provide driver assistance features, such as cruise control, traction control, and stability control, to improve the driving experience and safety of the vehicle.

6. Electric Drive Train

An electric drive train is a critical component in an electric vehicle (EV). It refers to the system responsible for delivering power from the vehicle's battery to the wheels, allowing the vehicle to move.

The electric drive train in an EV typically consists of several components:

- **Battery Pack:** This is the heart of the electric drive train, storing energy in the form of chemical energy and providing it to the drive motor as direct current (DC) power.
- **Electric Motor:** The electric motor is an AC or DC machine that converts the electrical energy from the battery into mechanical energy, driving the wheels of the vehicle.
- **Power Inverter:** A power inverter is an electronic device that converts DC power from the battery into AC power for the electric motor.
- **Drive Unit or Transmission:** This component transmits the power from the motor to the wheels, providing the necessary gear ratios and mechanical advantage to control the speed and torque of the vehicle.
- **Electronic Control Unit (ECU):** The ECU is responsible for controlling the different components of the drive train, ensuring that they work together efficiently and safely.

The electric drive train provides several benefits over traditional internal combustion engines, including better fuel efficiency, instant torque, and reduced emissions. With advances in battery technology and electric motors, the range and performance of EVs are continually improving, making them increasingly popular as a clean and efficient mode of transportation.

7. Power Management System

The power management system (PMS) in an electric vehicle (EV) is a critical component responsible for controlling and optimizing the energy flow between the vehicle's battery and its electrical components, such as the drive motor, climate control system, and lights.

The main functions of the PMS include:

- **Battery Management:** The PMS monitors the state of the battery and manages its charge level to ensure that it operates within a safe and efficient range.
- **Charging Control:** The PMS manages the charging process for the vehicle's battery, ensuring that it is charged safely and efficiently.
- **Energy Optimization:** The PMS optimizes the energy flow between the vehicle's battery and its electrical components, ensuring that the battery has enough energy to power the vehicle while also maximizing its range.
- **Thermal Management:** The PMS monitors and manages the temperature of the battery, ensuring that it operates within safe temperature ranges to avoid damage and reduce degradation.
- **Vehicle Power Management:** The PMS controls the distribution of power to the various electrical components of the vehicle, such as the drive motor, lights, and climate control system, to ensure that they operate efficiently and effectively.

Types of electric vehicles:

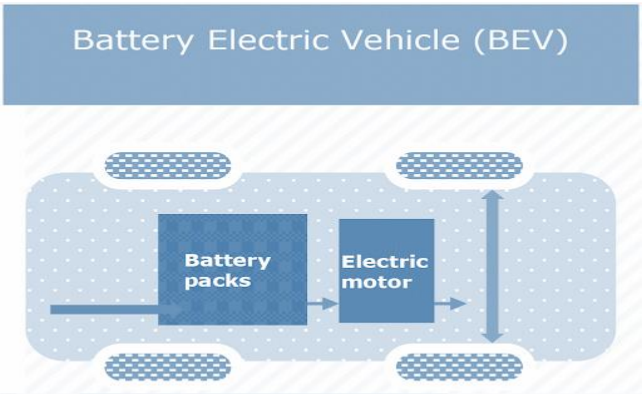
There are four types of electric vehicles available:

Battery Electric Vehicle (BEV): Fully powered by electricity. These are more efficient compared to hybrid and plug-in hybrids. BEVs are also known as All-Electric Vehicles (AEV). Electric Vehicles using BEV technology run entirely on a battery-powered electric drivetrain. The electricity used to drive the vehicle is stored in a large battery pack which can be charged by plugging into the electricity grid.

The charged battery pack then provides power to one or more electric motors to run the electric car. To find out more about BEVs, click below.

Main Components of BEV:

Electric motor, Inverter, Battery, Control Module, Drive train



Working Principles of BEV:

The power for the electric motor is converted from the DC Battery to AC. As the accelerator is pressed, a signal is sent to the controller. The controller adjusts the speed of the vehicle by changing the frequency of the AC power from the inverter to the motor. The motor then connects and leads to the turning of wheels through a cog. If the brakes are pressed, or the electric car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery

Examples of BEV:

MG ZS, TATA Nexon, TATA Tigor, Mahindra E20 plus, Hyundai Kona, Mahindra Verito

Hybrid Electric Vehicle (HEV):

HEVs are also known as series hybrid or parallel hybrid. HEVs have both engine and electric motor. The engine gets energy from fuel, and the motor gets electricity from batteries. The transmission is rotated simultaneously by both engine and electric motor. This then drives the wheels. To find out more about HEVs, click below.

Main Components of HEV:

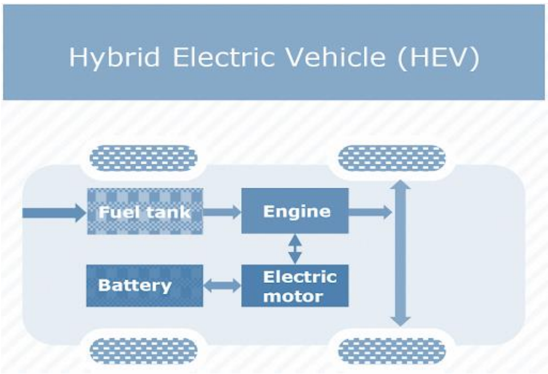
Engine, Electric motor, Battery pack with controller & inverter, Fuel tank, Control module

Working Principles of HEV:

The fuel tank supplies energy to the engine like a regular car. The batteries run on an electric motor. Both the engine and electric motor can turn the transmission at the same time.

Examples of HEV:

Engine, Electric motor, Battery pack with controller & inverter, Fuel tank, Control module



Plug-in Hybrid Electric Vehicle (PHEV):

The PHEVs are also known as series hybrids. They have both engine and a motor. You can choose among the fuels, conventional fuel (such as petrol) or alternative fuel (such as bio-diesel). It can also be powered by a rechargeable battery pack. The battery can be charged externally. To find out more about PHEVs, click below.

PHEVs can run in at least 2 modes:

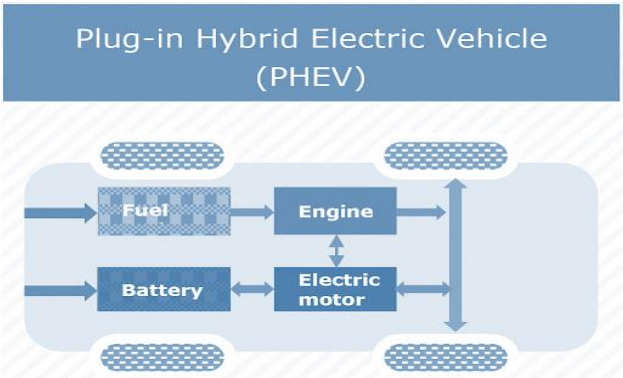
- All-electric Mode, in which the motor and battery provide all the car's energy
- Hybrid Mode, in which both electricity and petrol/diesel are employed.

Main Components of PHEV:

Electric motor, Engine, Inverter, Battery, Fuel tank, Control module, Battery Charger (if onboard model)

Working Principles of PHEV:

PHEVs start-up in all-electric mode and make use of electricity until their battery pack is depleted. Once the battery gets drained, the engine takes over, and the vehicle operates as a conventional, non-plug-in hybrid. PHEVs can be charged by plugging into an outside electric power source, engine, or regenerative braking. When brakes are applied, the electric motor acts as a generator, using the energy to charge the battery. The engine's power is supplemented by the electric motor; as a result, smaller engines can be used, increasing the car's fuel efficiency without compromising performance.



Examples of PHEV:

Porsche Cayenne S E-Hybrid, BMW 330e, Porsche Panamera S E-hybrid, Chevy Volt, Chrysler Pacifica, Ford C-Max Energi, Mercedes C350e, Mercedes S550e, Mercedes GLE550e, Mini Cooper SE Countryman, Ford Fusion Energi, Audi A3 E-Tron, BMW i8, BMW X5 xdrive40e, Fiat 500e, Hyundai Sonata, Kia Optima, Volvo XC90 T8.

Fuel Cell Electric Vehicle(FCEV):

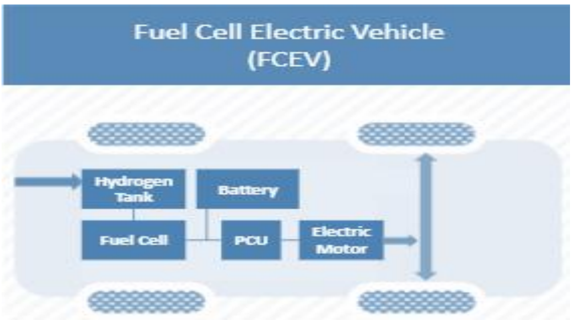
FCEVs are also known as Zero-Emission Vehicles. They employ 'fuel cell technology' to generate the electricity required to run the vehicle. The chemical energy of the fuel is converted directly into electric energy. To find out more about FCEVs, click below.

Main Components of FCEV:

Electric motor, Fuel-cell stack, Hydrogen storage tank, battery with converter and controller

Working Principles of FCEV:

The FCEV generates the electricity required to run this vehicle on the vehicle itself.



Examples of FCEV:

Toyota Mirai, Riversimple Rasa, Hyundai Tucson FCEV, Honda Clarity Fuel Cell, Hyundai Nexo.

RESULT: Hence, Introduction to electric vehicle technology is studied.

OUTCOMES:

By this experiment Course Outcomes CO1, Program Outcomes PO1, PO2, PO9, PO10, PO12, PSO1, PSO2 are attained.

Viva Questions:

1. What is an Electric Vehicle?
2. What are the different types of Electric vehicles?
3. What is PHEV?
4. What are the challenges of Electric Vehicle?
5. What is FCEV?

EXPERIMENT – 2

Fundamentals and types of Batteries

AIM: Introduction to fundamentals, types of batteries and their design calculations for EV.

Batteries are an essential component of electric vehicles (EVs) as they provide the energy required to power the vehicle's electric motor. A battery is an electrochemical device that converts chemical energy into electrical energy, and there are several different types of batteries that are used in electric vehicles, including:

1. **Lithium-ion (Li-ion) batteries:** These are the most common type of batteries used in electric vehicles due to their high energy density, long cycle life, and relatively low self-discharge rate.
2. **Nickel-metal hydride (NiMH) batteries:** These batteries have been used in electric vehicles in the past, but are now less common due to their lower energy density and shorter cycle life compared to Li-ion batteries.
3. **Lead-acid batteries:** These batteries are relatively cheap and have been used in some low-speed electric vehicles, but they have a low energy density and a short cycle life compared to Li-ion batteries.

Design parameters for an electric vehicle battery system involve several factors, including the required range of the vehicle, the power required to drive the vehicle, and the weight and size of the battery pack. The following are some key design parameters:

1. **Energy density:** The energy density of the battery pack is the amount of energy that can be stored per unit volume or weight. The higher the energy density, the lighter and more compact the battery pack can be for a given range.
2. **Range:** The range of the electric vehicle is determined by the energy stored in the battery pack and the energy required to drive the vehicle. The range can be calculated by dividing the energy stored in the battery pack by the energy required to drive the vehicle per unit distance.
3. **Power density:** The power density of the battery pack is the amount of power that can be delivered per unit volume or weight. The higher the power density, the faster the vehicle can accelerate and the more power it can deliver during high-load conditions.
4. **Battery capacity:** The capacity of the battery pack is the amount of energy it can store, and it is usually measured in kilowatt-hours (kWh). The battery capacity required for a given range can be calculated by dividing the energy required to drive the vehicle per unit distance by the efficiency of the vehicle.
5. **Battery weight:** The weight of the battery pack is an important factor as it affects the overall weight of the vehicle, which in turn affects its performance and range. The weight of the battery pack can be calculated by multiplying the battery capacity by the energy density of the battery.
6. **Cycle life:** Cycle life is the number of charge and discharge cycles a battery can undergo before its capacity starts to degrade. A battery with a longer cycle life will last longer and require fewer replacements over the lifetime of the vehicle.
7. **Charge time:** Charge time is the amount of time it takes to recharge the battery. A battery with a shorter charge time can be more convenient for users, especially for long-distance driving.
8. **Cost:** The cost of the battery is an important factor in the overall cost of the EV. The cost of the battery depends on its energy and power density, cycle life, and other factors.

9. **Safety**: Battery safety is an important consideration to prevent fires and explosions. Batteries with a higher safety rating are less likely to fail or catch fire, making them a better choice for EVs.
10. **Temperature range:** Batteries can perform differently at different temperatures, and extreme temperatures can damage the battery. Therefore, the battery should be able to operate within a temperature range that is suitable for the environment in which the EV will be used.
11. **The self-discharge rate** of a battery refers to the rate at which the battery loses its stored charge over time, even when it is not being used. This happens because of the chemical reactions that take place within the battery, which can gradually discharge the battery's energy. The self-discharge rate can vary depending on the type of battery and its age. Generally, rechargeable batteries such as nickel-cadmium (NiCad), nickel-metal hydride (NiMH), and lithium-ion (Li-ion) batteries have a higher self-discharge rate than non-rechargeable batteries like alkaline batteries.

Overall, the design of an electric vehicle battery system involves a trade-off between range, power, weight, and cost. Manufacturers of electric vehicles must carefully balance these factors to provide a battery system that meets the needs of their customers while remaining economically viable.

Comparison of different batteries

Specifications	Lead Acid	NiCd	NiMH	Li-ion Cobalt	Li-ion Manganese	Li-ion Phosphate
Specific energy density (Wh/kg)	30–50	45–80	60–120	150–190	100–135	90–120
Internal resistance[1] (mΩ)	<100 12V pack	100–200 6V pack	200–300 6V pack	150–300 7.2V	25–75[2] per cell	25–50[2] per cell
Cycle life[4] (80% discharge)	200–300	1000[3]	300–500[3]	500–1,000	500–1,000	1,000–2,000
Fast-charge time	8–16h	1h typical	2–4h	2–4h	1h or less	1h or less
Overcharge tolerance	High	Moderate	Low	Low. Cannot tolerate trickle charge		
Self-discharge/ month (room temp)	5%	20%[5]	30%[5]	<10%[6]		
Cell voltage (nominal)	2V	1.2V[7]	1.2V[7]	3.6V[8]	3.8V[8]	3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75	1.00		2.50 – 3.00		2.80
Peak load current Best result	5C[9] 0.2C	20C 1C	5C 0.5C	>3C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C	0 to 45°C		0 to 45°C[10]		
Discharge temperature	–20 to 50°C	–20 to 65°C		–20 to 60°C		
Maintenance requirement	3–6 months[11] (topping chg.)	30–60 days (discharge)	60–90 days (discharge)	Not required		
Safety requirements	Thermally stable	Thermally stable, fuse protection common		Protection circuit mandatory[12]		
In use since	Late 1800s	1950	1990	1991	1996	1999

RESULT: Hence, Introduction to Introduction to fundamentals, types of batteries and their design calculations for EV are studied.

OUTCOMES:
By this experiment Course Outcomes CO1, Program Outcomes PO1, PO2, PO9, PO10, PO12, PSO1, PSO2 are attained.

Viva Questions:

1. What is the difference between cell and battery?
2. What are the different batteries used in Electric vehicles?
3. What are the parameters to be considered while selecting a battery for Electric vehicle?
4. What is power density?
5. What is State of charge?

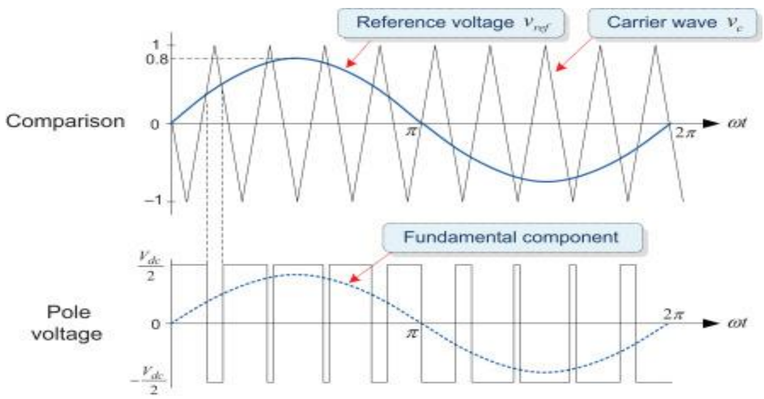
Experiment-3

AIM: To Simulate of SPWM technique for electric vehicle converter using MATLAB/SIMULINK.

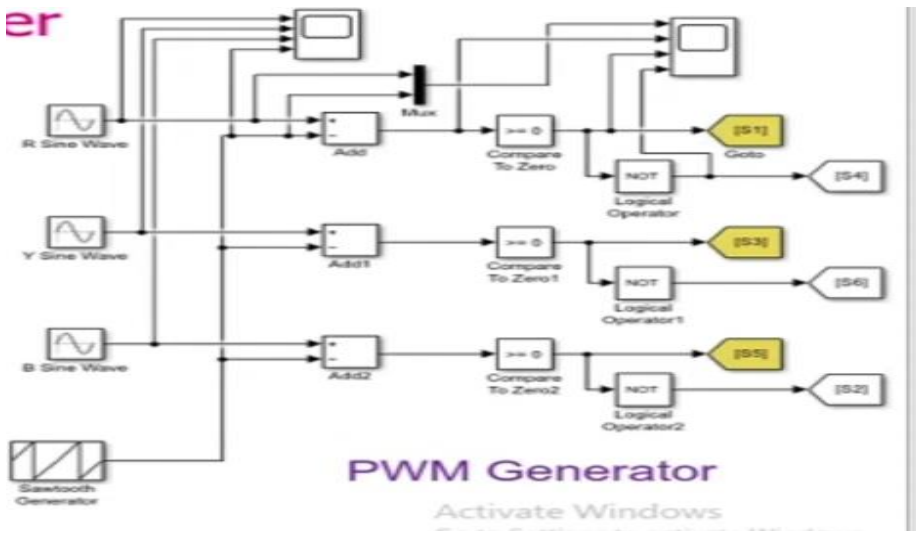
SOFTWARE USED: MATLAB/SIMULINK

THEORY:

Sinusoidal PWM is a typical PWM technique. In this PWM technique, the sinusoidal AC voltage reference v_{ref} is compared with the high-frequency triangular carrier wave v_c in real time to determine switching states for each pole in the inverter.



Simulink diagram:



PROCEDURE:

1 Open the MATLAB command window clicking on the MATLAB icon.

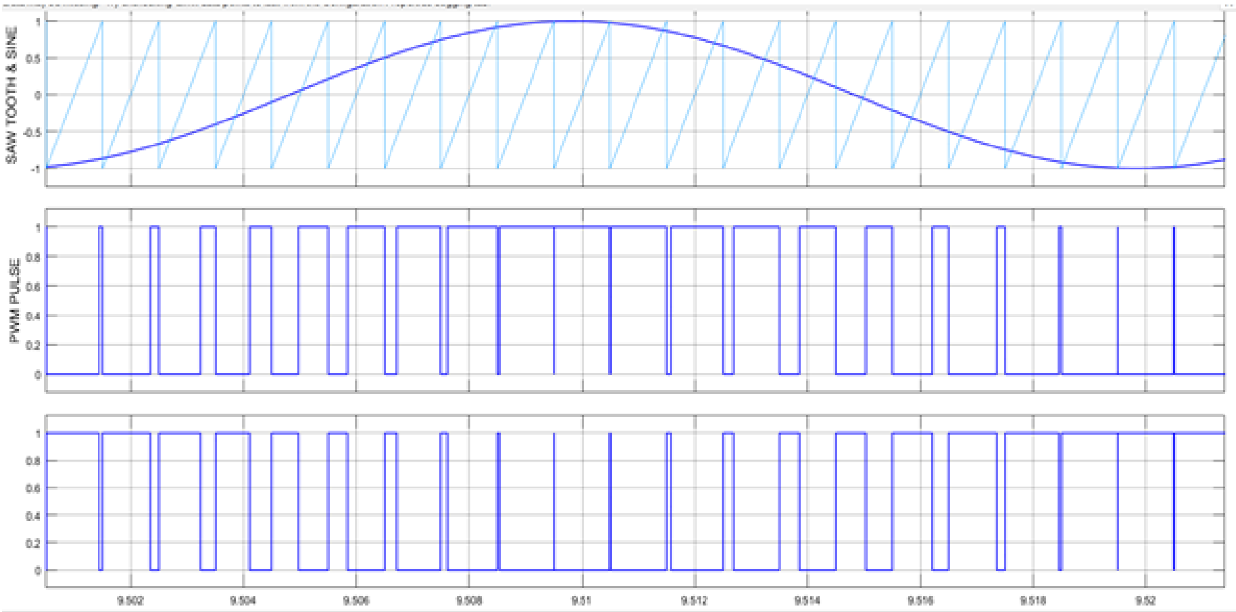
2 Click on file menu and open new Model file.

3 Draw the Circuit diagram in Model file by taking all necessary elements from Simulink library browser.

4 Click on the debug menu and run the Model.

5 Observe the output in scope and save the file.

SIMULATION RESULTS:



RESULT: Hence SPWM technique for electric vehicle converter has been designed by using MATLAB/SIMULINK.

OUTCOMES:
By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO7, PO9, PO10, P012, PSO1 & PSO2 are attained

Viva Questions:

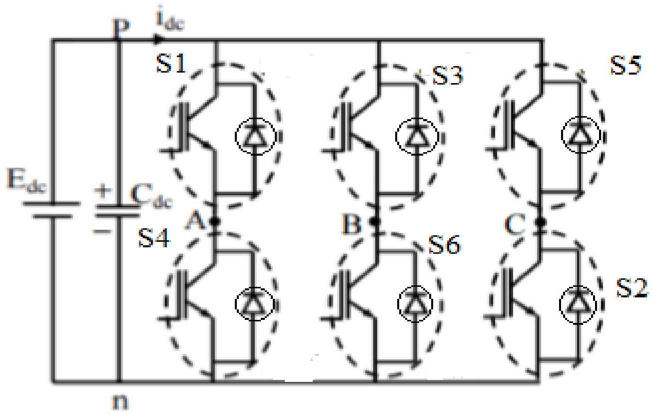
1. What is PWM technique?
2. What is SPWM technique?
3. What are the different types of PWM techniques?
4. What is Carrier signal?
5. What is reference signal?

Experiment-4

Aim: To Simulate of three – phase VSI for grid integration in EV using MATLAB/SIMULINK.

SOFTWARE USED: MATLAB/SIMULINK

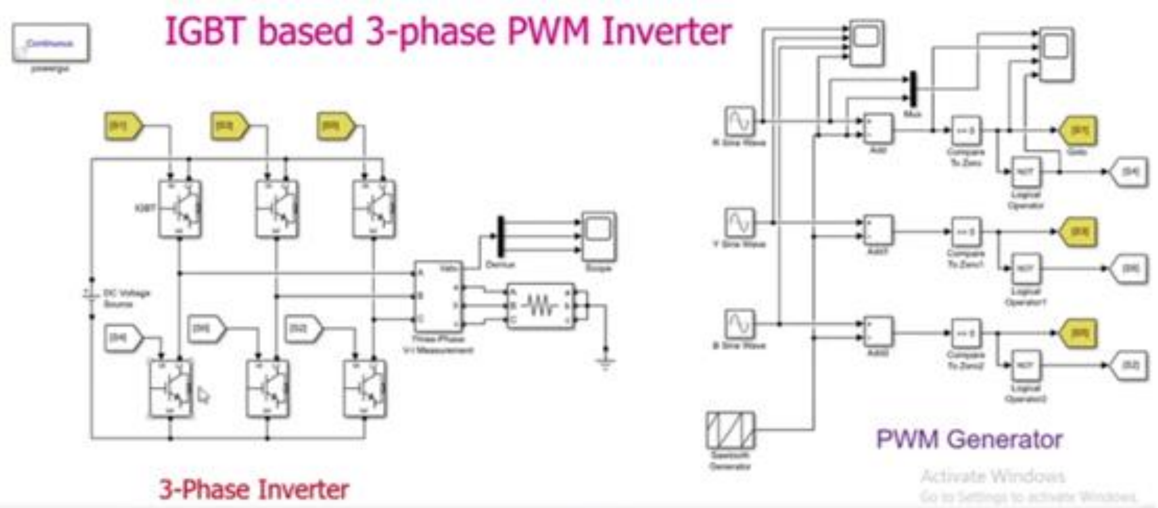
THEORY: A three-phase inverter is used to change the DC voltage to three-phase AC supply. The circuit diagram of a three-phase inverter is shown below. The main function of this kind of inverter is to change the input of DC to the output of three-phase AC. A basic 3 phase inverter includes 3 single phase inverter switches where each switch can be connected to one of the 3 load terminals.



Three Phase Inverter Circuit

Generally, the three arms of this inverter will be delayed with 120 degrees angle to generate a 3 -phase AC supply. The switches used in the inverter have 50% of ratio and switching can be occurred after every 60 degrees angle. The switches like S1, S2, S3, S4, S5, and S6 will complement each other. In this, three inverters with single-phase are placed across a similar DC source. The pole voltages within the three-phase inverter are equivalent to the pole voltages within the half-bridge inverter with a single phase.' The two types of inverters like the single-phase and three-phase include two conduction modes like 180 degrees conduction mode and 120 degrees conduction mode.

Simulink diagram:



PROCEDURE:

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2 Click on file menu and open new Model file.

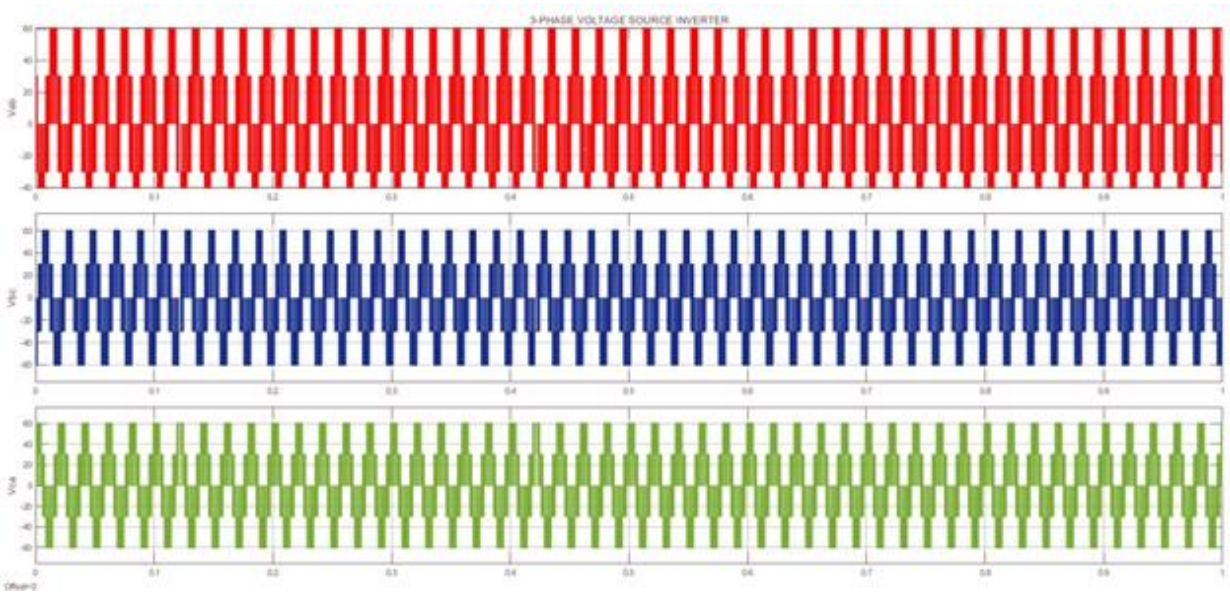
3 Draw the Circuit diagram in Model file by taking all necessary elements from

Simulink library browser.

4 Click on the debug menu and run the Model.

5 Observe the output in scope and save the file.

Simulation Results:



RESULT: Hence three – phase VSI for grid integration in EV has been designed and simulated using MATLAB/SIMULINK.

OUTCOMES:

By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. What is inverter?
2. What are the different types of inverters?
3. What is voltage source inverter?
4. What is the role of PWM in VSI?
5. What are the applications of VSI?

Experiment-5

Aim: To Design of bidirectional battery circuit using Buck / Boost converter using MATLAB/SIMULINK.

SOFTWARE USED: MATLAB/SIMULINK

THEORY: The bidirectional DC-DC converter is shown in fig.1. The presented topology has a single voltage source, LC filter circuit, battery, and two MOSFET switches.

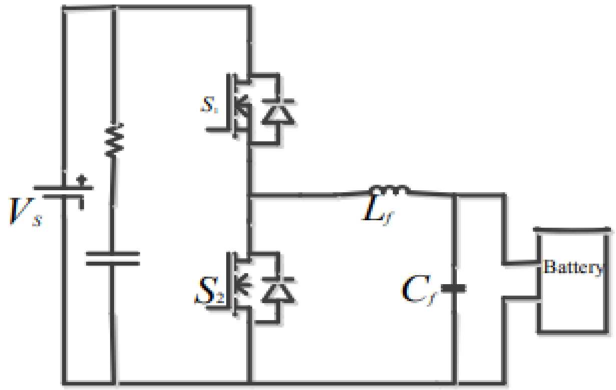
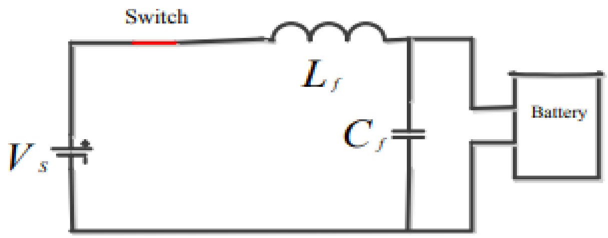


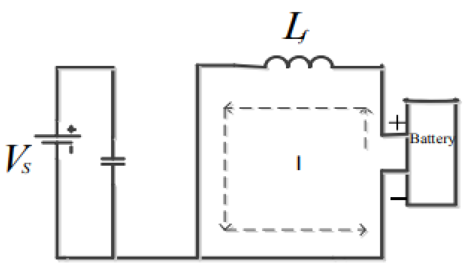
Fig.1 Bidirectional battery charger circuit

The converter functions as a boost converter when it is discharging and as a buck converter when it is charging. The closed-loop PI controller controls the bi-directional converter.

The buck converter's mode-I functioning is seen in Fig. 2. In this state, S1 is turned ON, S2 is turned OFF, and both diodes are turned off (battery charging mode).



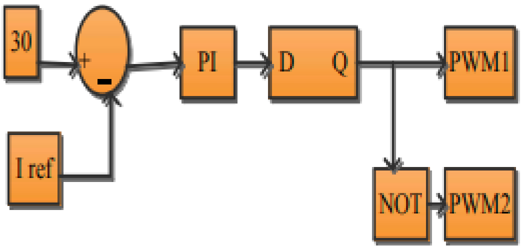
During discharging mode Switch S1 turn-off and S2 turn on. The diodes D1 and D2 turn off. This mode battery current is discharging through an inductor (boost mode).



Control scheme:

Proportional integral (PI) based PWM Generator implemented for controlling Bidirectional battery charger circuit using buck/boost converter. The comparator compared the Reference current and original current, the output of the comparator generator error signal. [16]- [19] The

PI controller input is connected to the comparator and the output is connected to the PWM generator. The PWM generator output generator two PWM pulses. Bidirectional battery charger circuits control these two pulses. The battery-charging mode PWM1 switch ON and PWM switch 2 OFF. The battery discharging modes are PWM2 ON and PWM1 OFF.



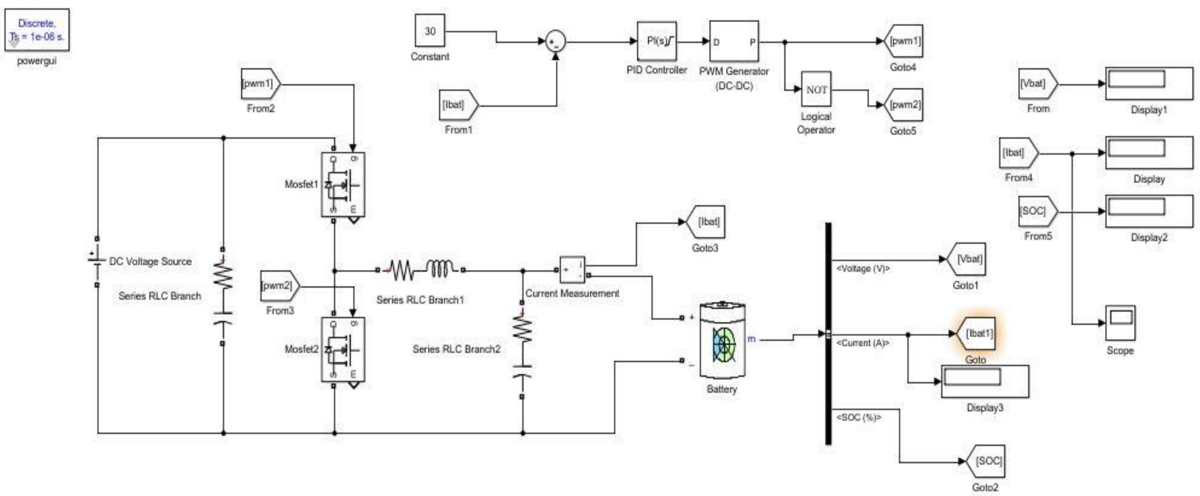
Converter Design Specifications:

$$L = (V_{out} * (V_{in} - V_{out}))/(I_{ripple} * F_{sw} * V_{in})$$
$$L = (360 * (800 - 360))/(3 * 5000 * 800)$$
$$L = 13mH$$

Vin = 800v
Vout = 360V
Fsw = 5Khz
Vripple = 0.36
Iripple = 3A

$$C = I_{ripple}/(8 * F_{sw} * V_{ripple})$$
$$C = 3/(8 * 5000 * 0.36)$$
$$C = 20uF$$

Simulink diagram:



PROCEDURE:

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2 Click on file menu and open new Model file.

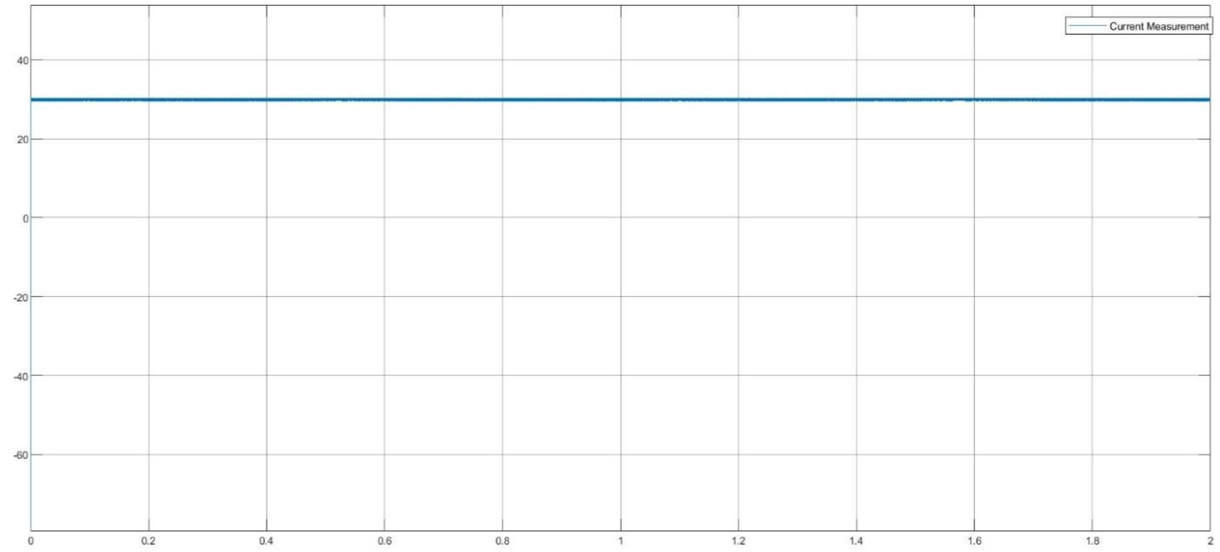
3 Draw the Circuit diagram in Model file by taking all necessary elements from Simulink library browser.

4 Click on the debug menu and run the Model.

5 Observe the output in scope and save the file.

Simulation Result:

Ibat



Time

RESULT: Hence bidirectional battery circuit using Buck / Boost converter has been designed and simulated using MATLAB/SIMULINK.

OUTCOMES:
By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. What is a Converter?
2. What are the different types of converter?
3. What is step down converter?
4. What is bidirectional converter?
5. What is duty cycle? How does it affect output voltage?

Experiment-6

Aim: To design Battery controller based on SoC for charging and discharging of battery in EV using MATLAB/SIMULINK.

SOFTWARE USED: MATLAB/SIMULINK

THEORY: This circuit is designed to control battery charging and discharging modes using constant current and constant voltage methods. When the voltage source is disabled, using switch1 battery supply the load. When the voltage source is enabled by closing switch 1 then battery will get charge and load will be supplied from the source.

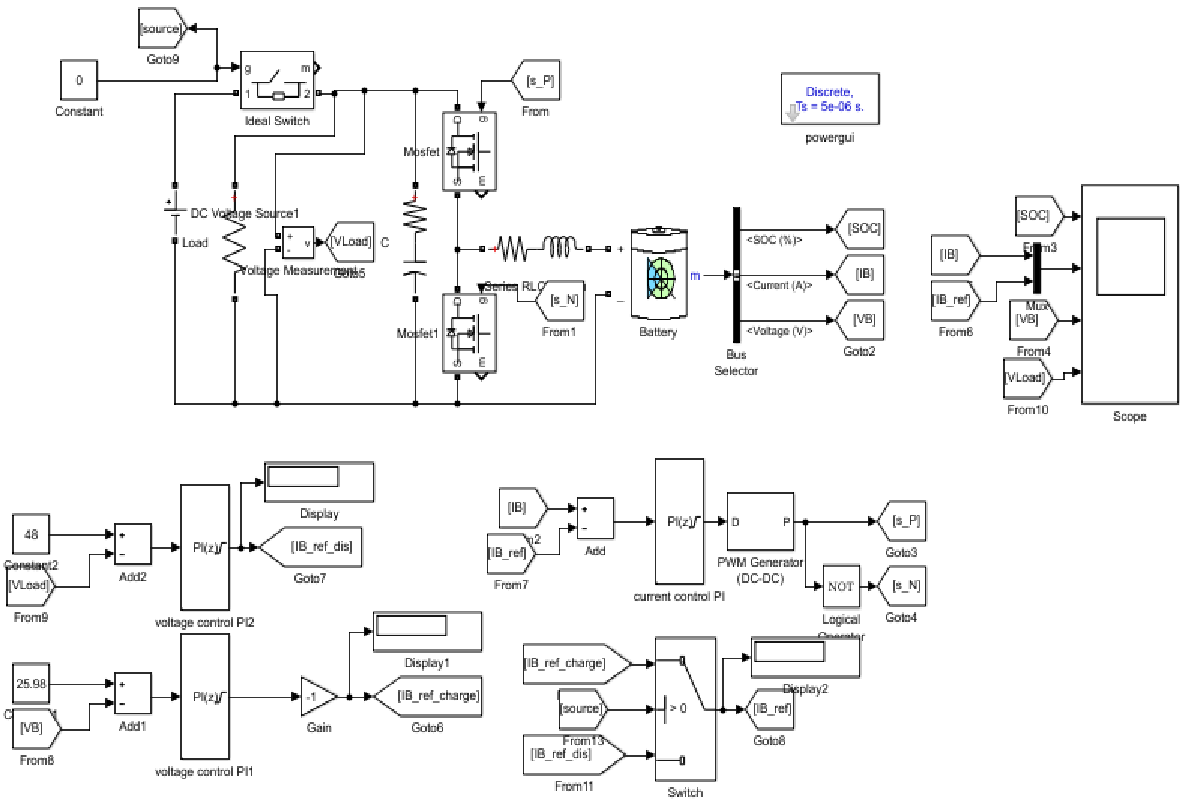
Batteries are charged in two modes:

1. Constant current (we should check whether maximum current is allowed.(22A))

2. Constant voltage.

Using PI controller these two modes were designed and implemented in this experiment.

Simulink diagram:

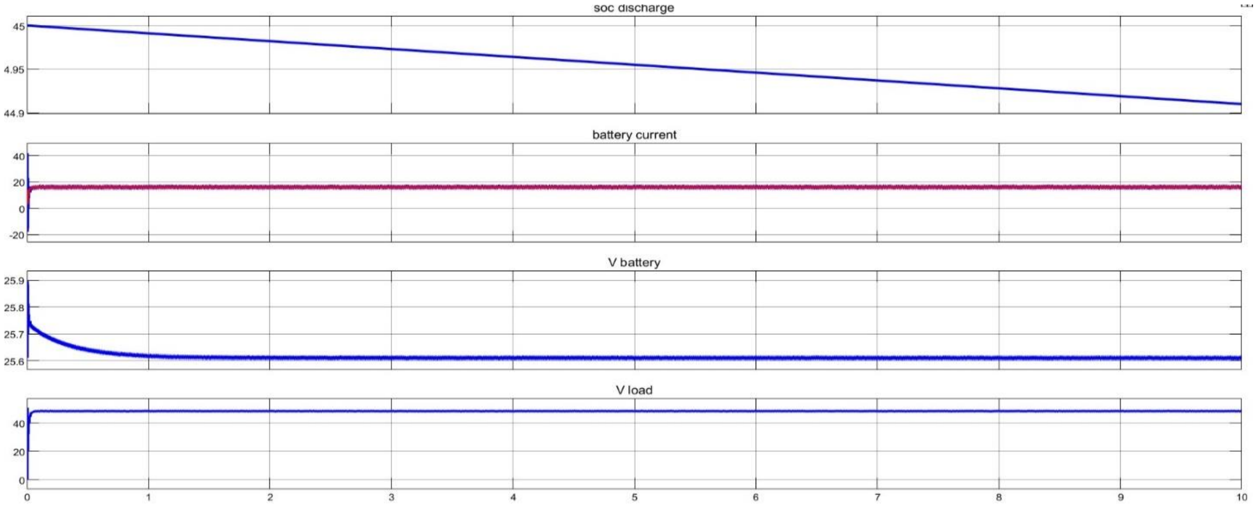


PROCEDURE:

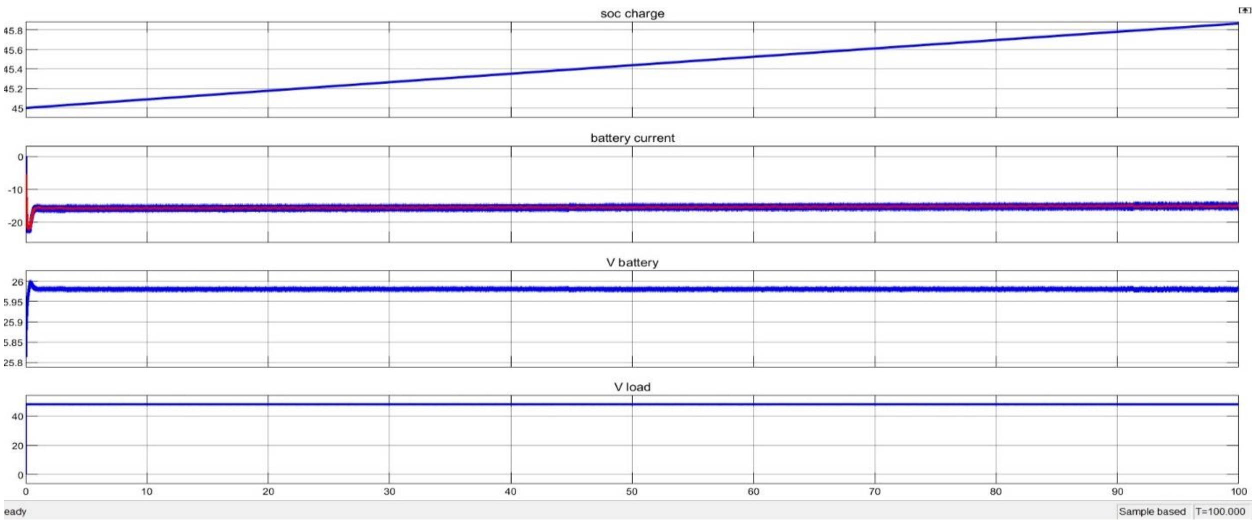
1. Open the MATLAB command window clicking on the MATLAB icon.
2. Click on file menu and open new Model file.
3. Draw the Circuit diagram in Model file by taking all necessary elements from Simulink library browser.
4. Click on the debug menu and run the Model.
5. Observe the output in scope and save the file.

Simulation Results:

Discharging Mode:



Charging Mode:



RESULT: Hence Battery controller based on SOC for charging and discharging of battery in EV has been designed and simulated using MATLAB/SIMULINK.

OUTCOMES:
By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. What is SoC (State of Charge) in a battery?
2. Why is SoC estimation important in Electric Vehicles (EVs)?
3. What is the role of a battery controller in an EV?
4. How does a battery management system (BMS) control charging and discharging?
5. What are the different battery charging methods in EVs?

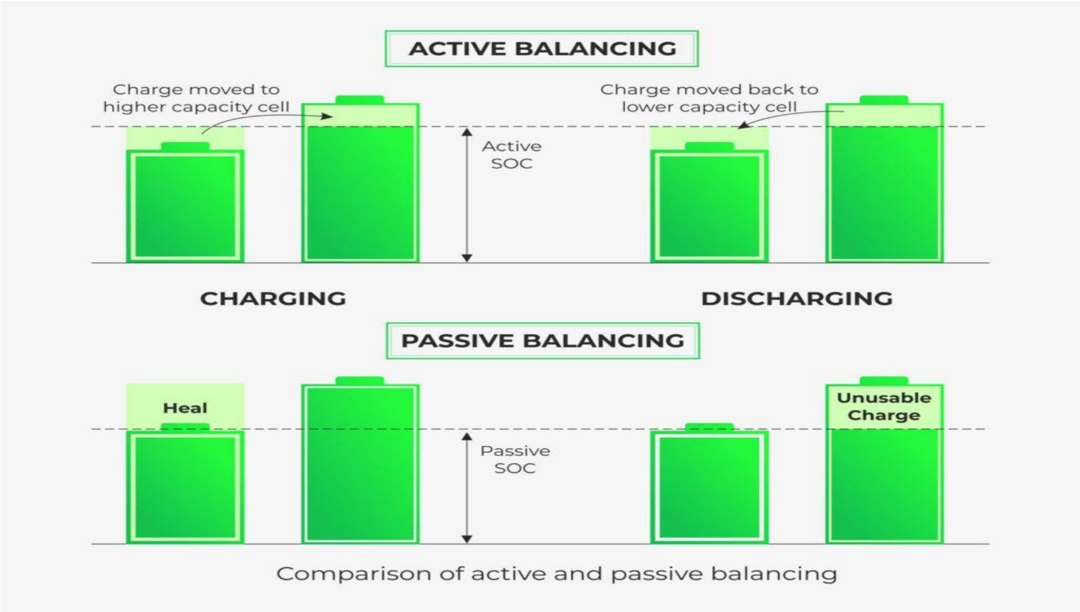
Experiment-7

Aim: To Model and Simulate the BMS for passive cell balancing in EV using MATLAB/SIMULINK.

SOFTWARE USED: MATLAB/SIMULINK

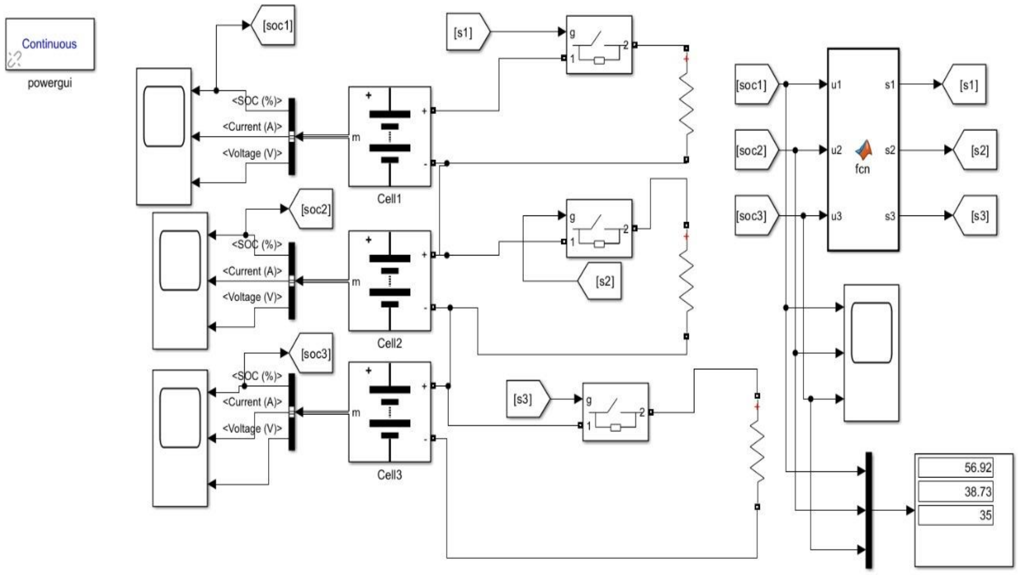
THEORY: Cell balancing is a technique that improves battery life by maximizing the capacity of a battery pack with multiple cells in series, ensuring that all of its energy is available for use. A cell balancer or regulator is a functionality in a battery management system that performs cell balancing often found in lithium-ion battery packs electric vehicles and ESS applications.

Typically, individual cells of a battery pack have different capacities and are at different SOC levels. Without redistribution, discharging must stop when the cell with the lowest capacity is empty, even though the other cells are still not empty. This limits the energy delivering capability of the battery pack.



A passive system potentially burns off excess energy from the high cells through a resistive element until the charge matches the lower energy cells in the pack. If you have cells packed in series and you notice that some of the cells have higher energy than the other lower energy cells, you can balance the cells in burning energy of the top cells simply by attaching a resistor to the cells which releases the energy into heat thereby equalizing the cell energy of the battery pack.

Simulink diagram:



Matlab Function code:

```
function [s1,s2,s3]  = fcn(u1,u2,u3)
u1=u1*1000
u2=u2*1000
u3=u3*1000

u1=int32(u1)
u2=int32(u2)
u3=int32(u3)

if((u1>u2) ||(u1>u3))
    s1=1;
else
    s1=0;
end

    if((u2>u1)||(u2>u3))
        s2=1;
    else
        s2=0;
    end
   if((u3>u1)||(u3>u2))
         s3=1;
     else
         s3=0;
   end
```

PROCEDURE:

1 Open the MATLAB command window clicking on the MATLAB icon.

2 Click on file menu and open new Model file.

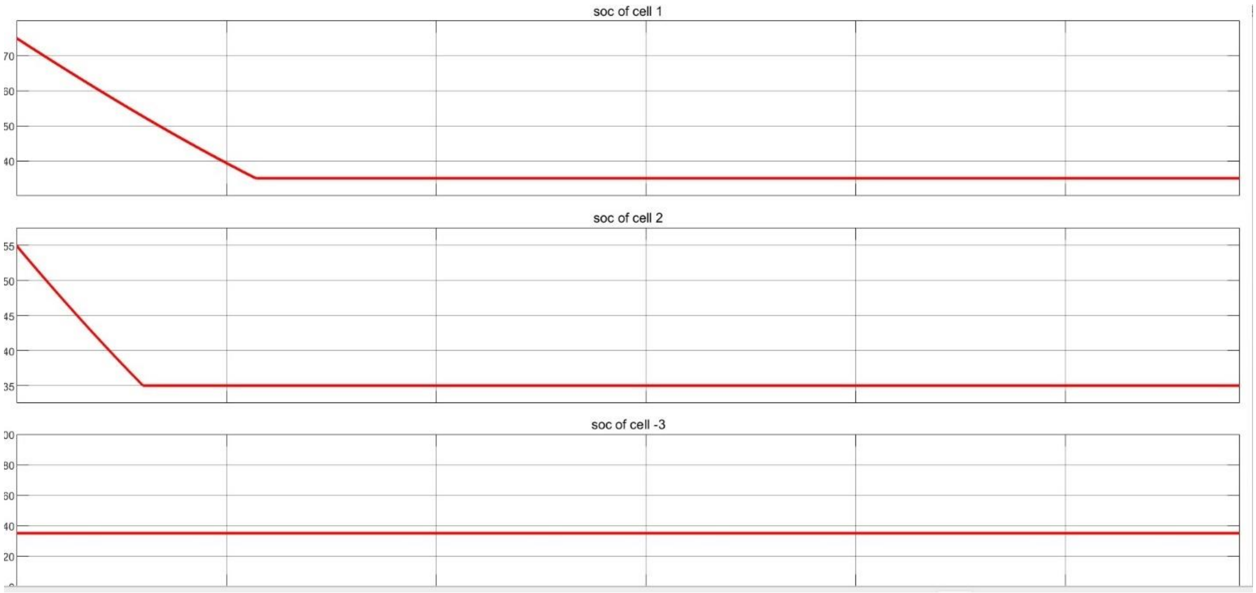
3 Draw the Circuit diagram in Model file by taking all necessary elements from

Simulink library browser.

4 Click on the debug menu and run the Model.

5 Observe the output in scope and save the file.

Simulation Results:



RESULT: Hence BMS for passive cell balancing in EV has been designed and simulated using MATLAB/SIMULINK

OUTCOMES:
By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. What is a Battery Management System (BMS)?
2. Why is cell balancing required in an EV battery pack?
3. What are the disadvantages of passive balancing?
4. What is Active cell balancing?
5. What is Passive cell balancing?

Experiment-8

Aim: To Design SoC control of Lithium Ion battery in MATLAB/SIMULINK for EV.

SOFTWARE USED: MATLAB/SIMULINK

THEORY:

The state of charge (SOC) is a measurement of the amount of energy available in a battery at a specific point in time expressed as a percentage. For example, the SOC reading for a computer might read 95% full or 10% full. The SOC provides the user with information of how much longer the battery can perform before it needs to be charged or replaced. Understanding the state of charge is important because understanding the remaining capacity of a batter can help make a control strategy.

Specifications:

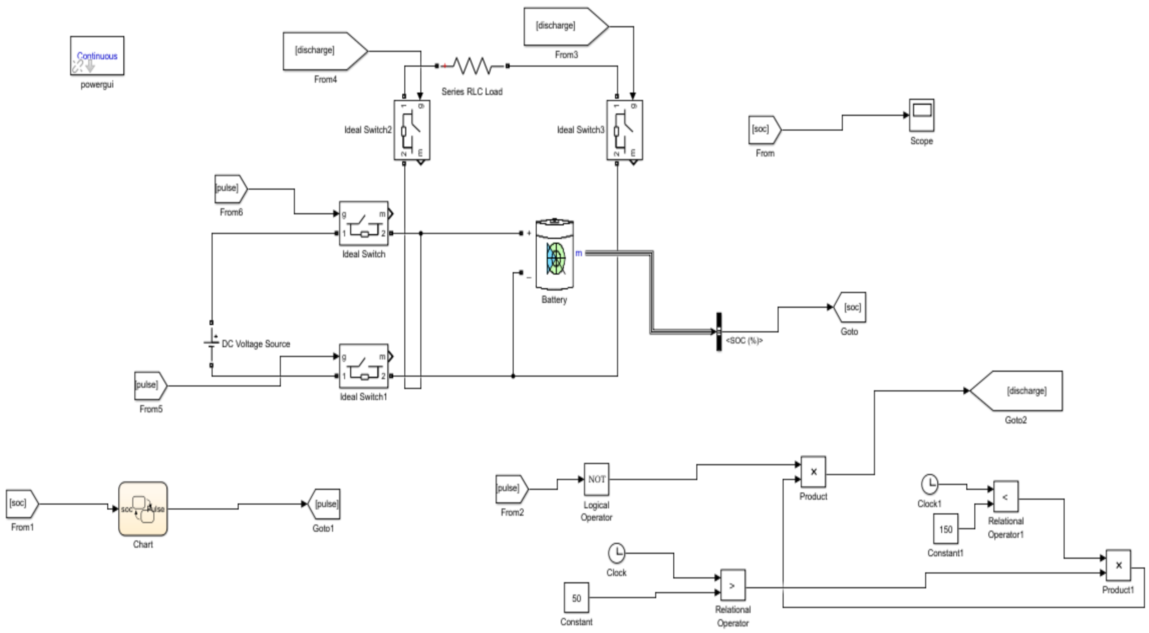
Battery nominal voltage=7.2V

Battery capacity=5.4Ah

Region of operation (Discharge) -40-80% of SOC resistive load – 1KW

Time t =50-150 seconds.

Simulink diagram:



PROCEDURE:

1 Open the MATLAB command window clicking on the MATLAB icon.

2 Click on file menu and open new Model file.

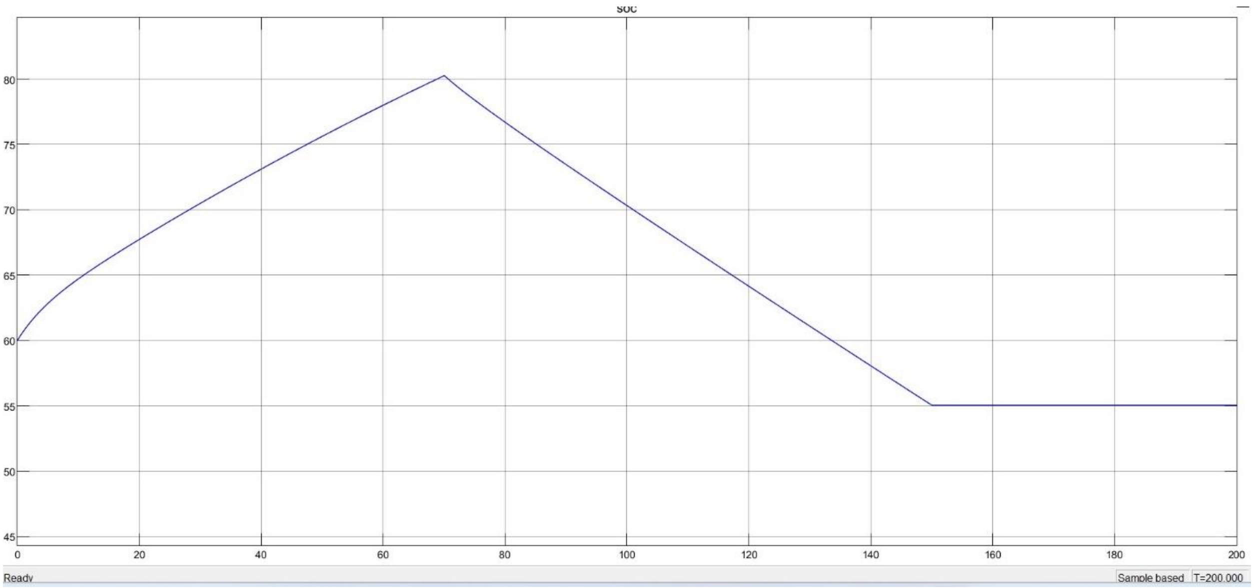
3 Draw the Circuit diagram in Model file by taking all necessary elements from

Simulink library browser.

4 Click on the debug menu and run the Model.

5 Observe the output in scope and save the file.

Simulation Results:



RESULT: Hence SOC control of Lithium Ion battery for EV has been designed and simulated using MATLAB/SIMULINK.

OUTCOMES:
By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. What happens if SoC is not properly controlled?
2. What is Depth of Discharge (DoD), and how is it related to SoC?
3. How do you implement a SoC control system in SIMULINK?
4. What is the typical charging voltage of a lithium-ion battery?
5. What is the safe SoC range for a lithium-ion battery?

Experiment-9

Aim: To Simulate the bidirectional operation in Electric Vehicle charger using single-phase model.

SOFTWARE USED: MATLAB/SIMULINK

THEORY: A bidirectional converter is the primary requirement for an EV charger with advanced charging modes like V2G. The commonly used building modules of such a Bidirectional charger comprises an AC/DC converter at the front end and DC/DC converter at the back end both bidirectional and a DC link capacitor in between. The topology of the AC/DC and DC/DC bidirectional converter used varies according to the purpose of converter design. In this experiment, we try to study a simple topology related to H bridge AC/DC converter and a Bidirectional non isolated buck-boost converter interface. The related control strategy is also presented. The AC/DC converter works as a sine PWM Inverter during V2G mode; and as a synchronous rectifier during G2V/Charging mode. The passive elements are designed for efficient converter operation during both V2G and G2V modes. A MATLAB/SIMULINK model has been constructed.

Plug in Electric vehicles can be seen as loads as well as energy sources connected to the grid. The load presented by PEV varies according to their charging behaviour, charging parameters and patterns. There are two different modes of operation namely V2G and G2V. During Grid to Vehicle operation (G2V) the vehicles act like normal loads while V2G is where energy is fed back to grid. Another mode of V2G is called V2H where the stored energy in vehicle batteries is used similar to home UPS systems.

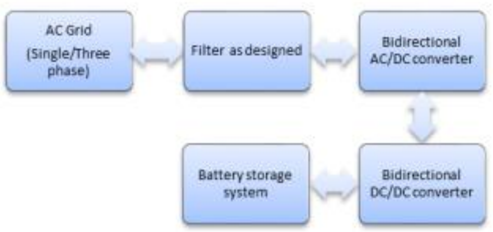
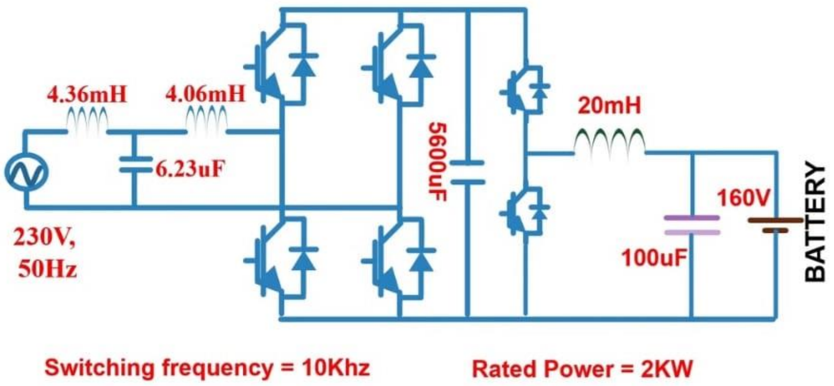
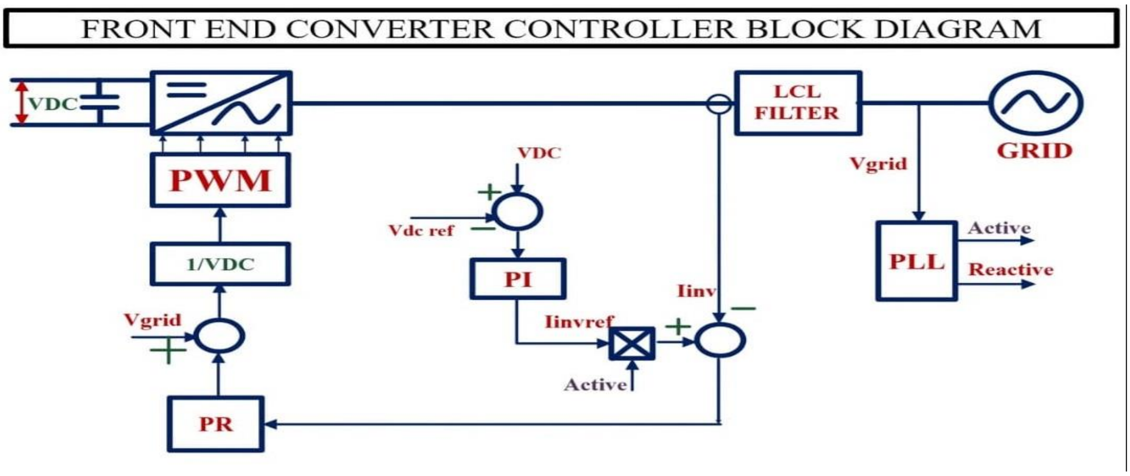


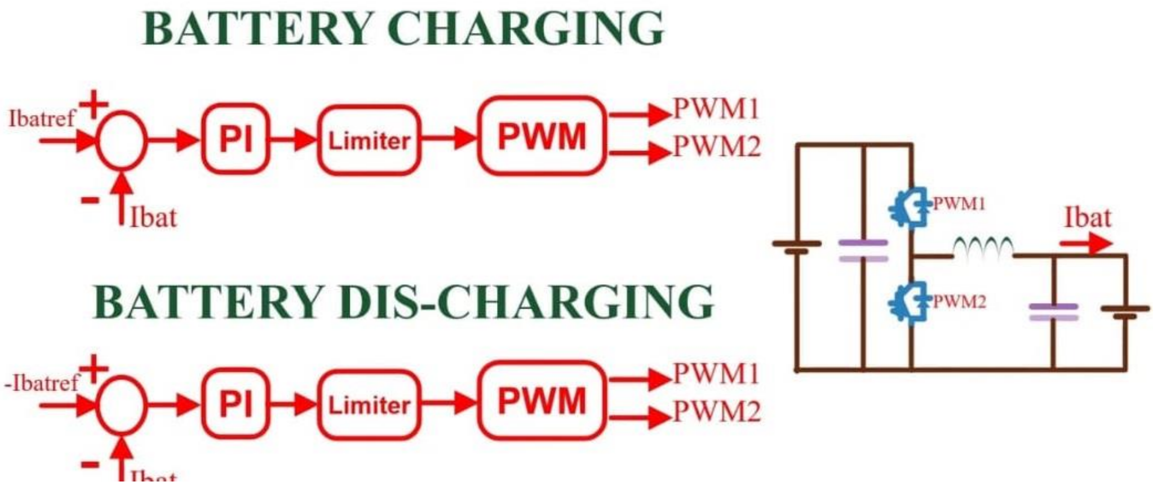
Fig.1 General Architecture of Bidirectional charging interface

Circuit Diagram:

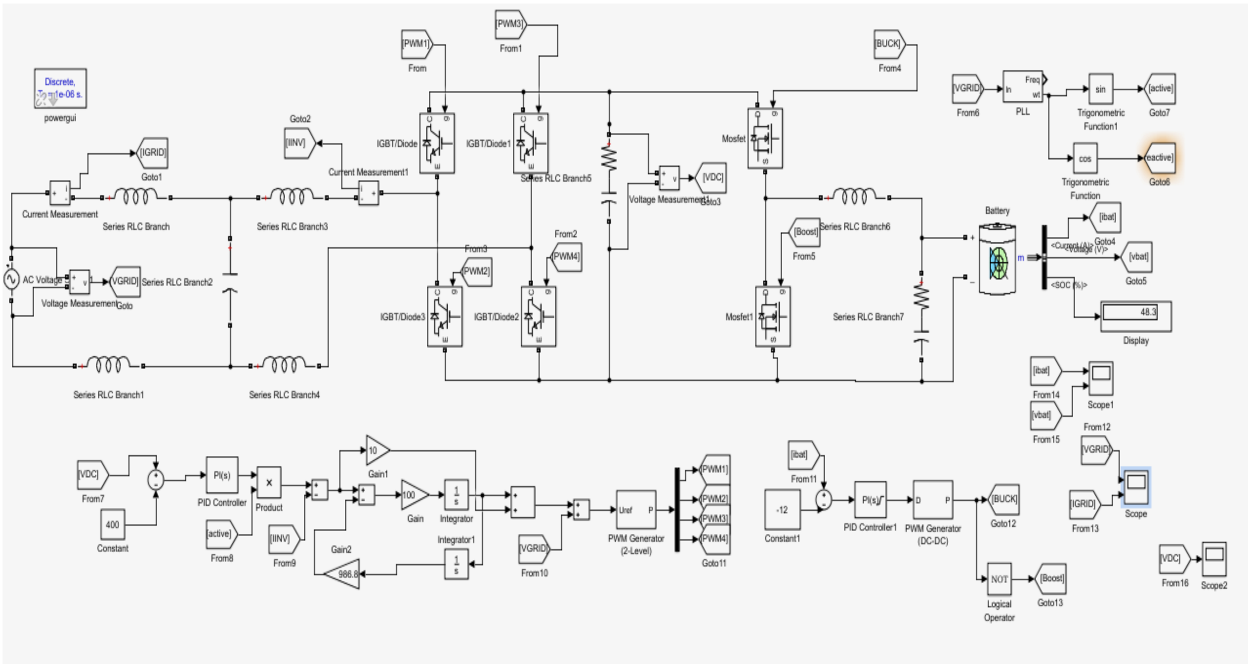


Control Scheme:





Simulink diagram:



PROCEDURE:

1 Open the MATLAB command window clicking on the MATLAB icon.

2 Click on file menu and open new Model file.

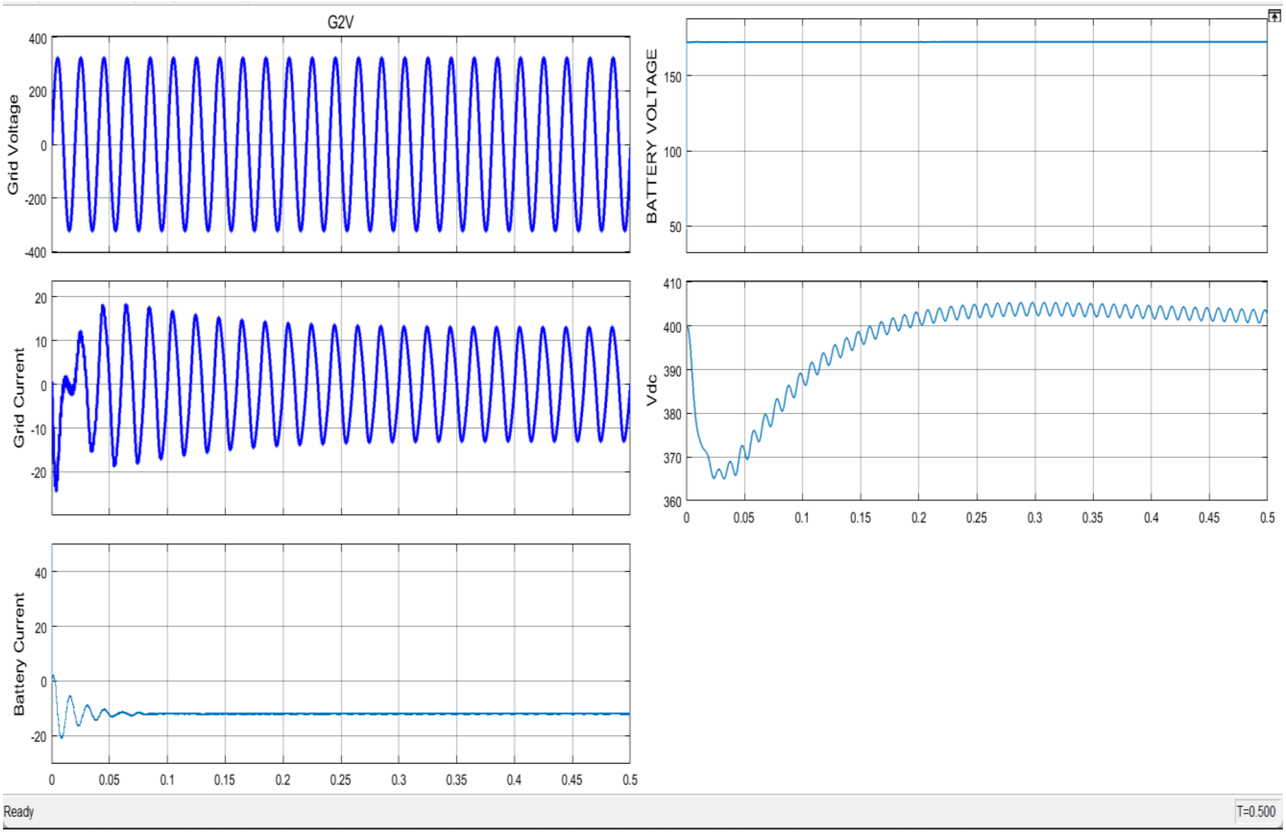
3 Draw the Circuit diagram in Model file by taking all necessary elements from Simulink library browser.

4 Click on the debug menu and run the Model.

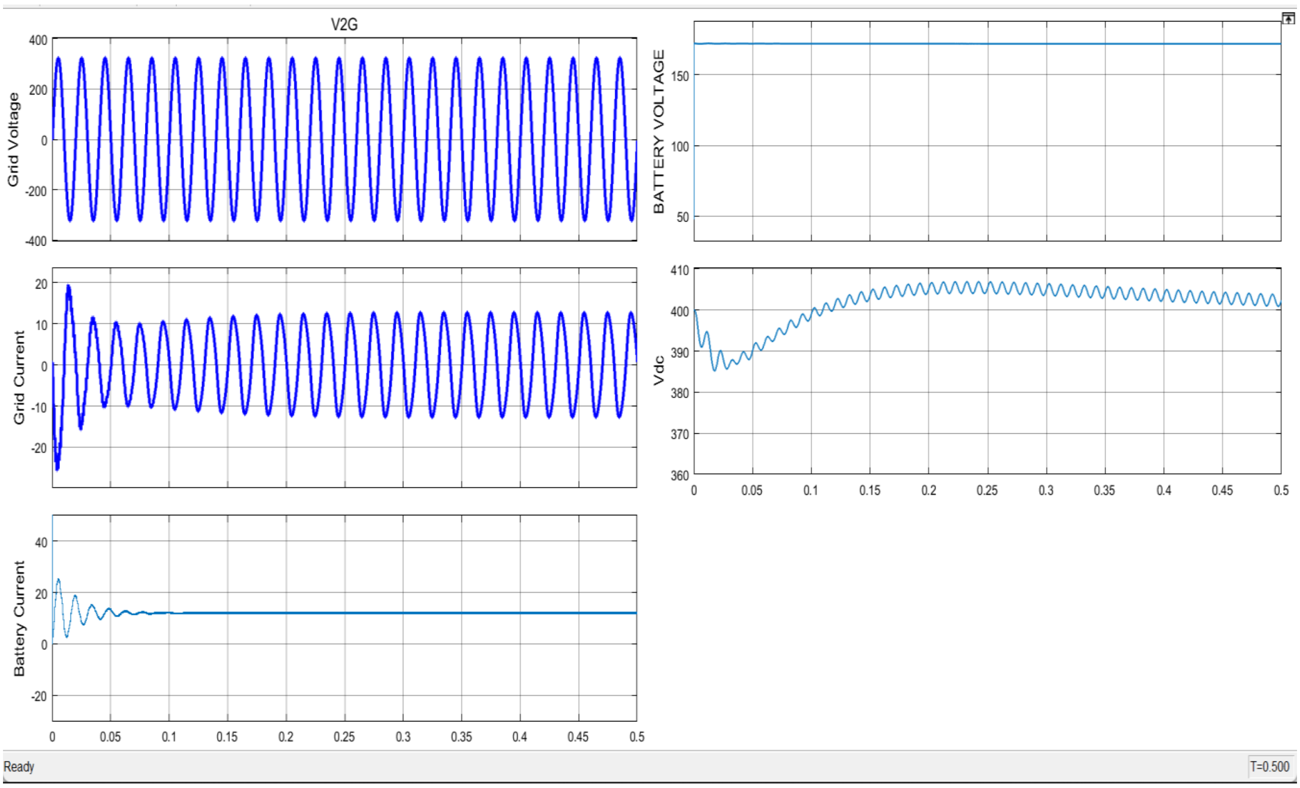
5 Observe the output in scope and save the file.

Simulation Results:

Vehicle to Grid Mode:



Grid to Vehicle Mode:



RESULT: Hence bidirectional operation in Electric Vehicle charger using single-phase model has been designed and simulated using MATLAB/SIMULINK.

OUTCOMES:
By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. What is a bidirectional EV charger?
2. What are the main modes of operation in a bidirectional EV charger?
3. What type of power converter is used in a bidirectional charger?
4. What is the difference between unidirectional and bidirectional chargers?
5. What is the role of a control system in bidirectional charging?

<u>Experiment-10</u>

Aim: To Design and Simulate the circuit to calculate electric vehicle speed from motor torque.

SOFTWARE USED: MATLAB/SIMULINK

THEORY: The total tractive force acting on a EV can be represented as below:

Ftrac = Faero + Fgrad + Facc + Froll

Rolling Resistance

Tire rolling resistance is the energy that your vehicle needs to send to your tires to maintain movement at a consistent speed over a surface. In other words, it is the effort required to keep a tire rolling.

$$F_{roll} = \text{force due to rolling resistance} = u_{rr} * m * g$$

where,

u_{rr}= Rolling resistance co-efficient (It depends on the tire material, tire structure, tire temperature, road roughness, road material etc.)

m= Total mass of the vehicle(Vehicle mass+ payload)

g = gravitational constant , that is 9.8 m/s^2

Aerodynamic Drag Force

Aerodynamic drag force is defined as the force which is faced by the vehicle as it moves through the air. This drag force depends mainly on the front area of the vehicle, side mirrors, ducts, and many other factors.

Faero = aerodynamic drag force = 0.5 * ρ * V^2 * A * Cd

where,

ρ = Air density, that is normally 1.25 kg/m^3.

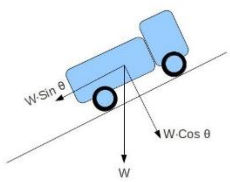
A = Frontal area of the vehicle in m^2

Cd = Air drag co-efficient of the vehicle (It depends on frontal area, shape, protrusions, ducts, air passage etc.)

V = Velocity of the vehicle in m/s

Gradient force:

When the vehicle travels uphill, a component of its weight works in a direction opposite to its motion. If some energy is not supplied to overcome this backward force, then the vehicle would slow down, stall and roll backwards.



Fgrad = force due to gradient = m * g * sinφ

where,

m = Total mass of the vehicle(vehicle mass + payload) in kg

g = Gravitational constant that is 9.8 m/s^2

φ = up gradient angle or inclination angle in radian In this case up gradient angle(φ) = 0, as there is no inclination.

Acceleration force:

The acceleration force refers to the vehicle's resistance to speed variations. This force holds you back when you increase your speed and also moves you forward when you slow down.

Facc = acceleration force = m * a

Where,

m = Total mass of the vehicle(vehicle mass + payload) in kg

a = vehicle acceleration in m/s^2

Torque & force relation

Torque, T = Ftrac * r

Where,

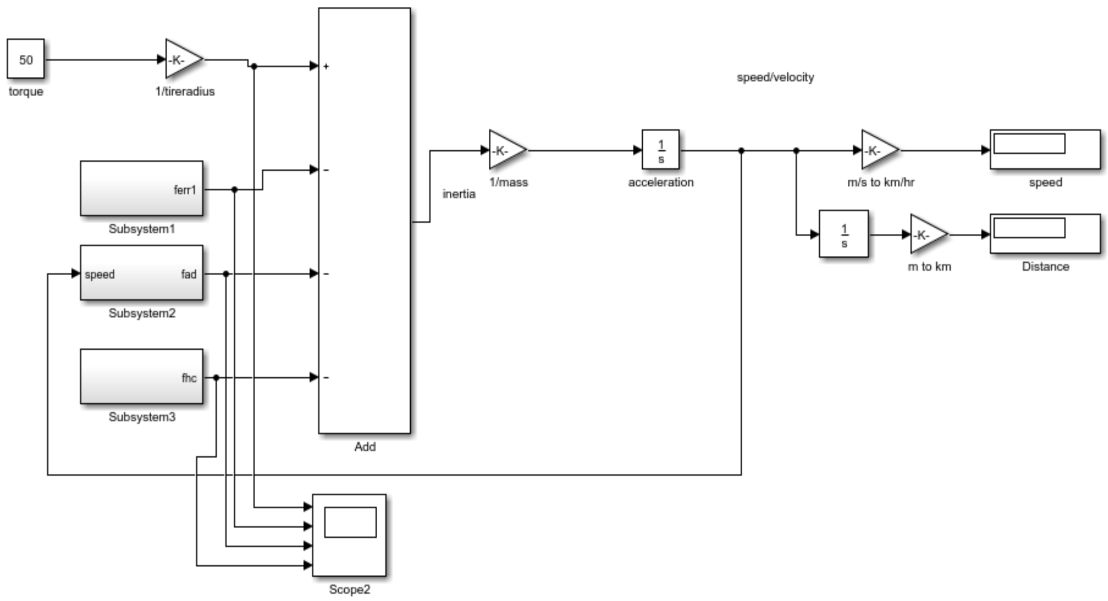
Ftrac = total tractive force

r = tyre radius

Parameters:

i. Mass=300
ii. Cd=0.5
iii. Frontal area=1.5
iv. μrr = 0.015 (Radial Ply Tyre)
v. Tyre radius = 0.3
vi. Gear ratio = 1
vii. Road Gradient = 0
viii. Motor Torque = 50 N-m

Simulink diagram:



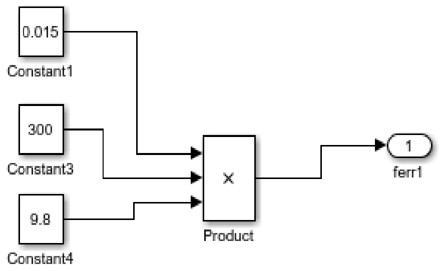


Fig: Subsystem-1

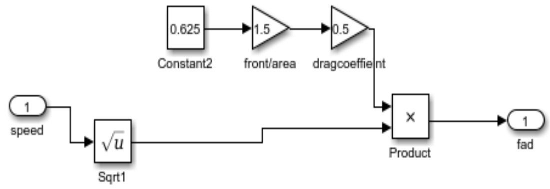


Fig: Subsytem-2

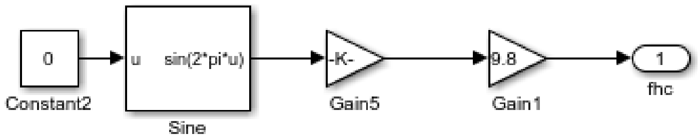


Fig: Subystem-3

PROCEDURE:

1 Open the MATLAB command window clicking on the MATLAB icon.

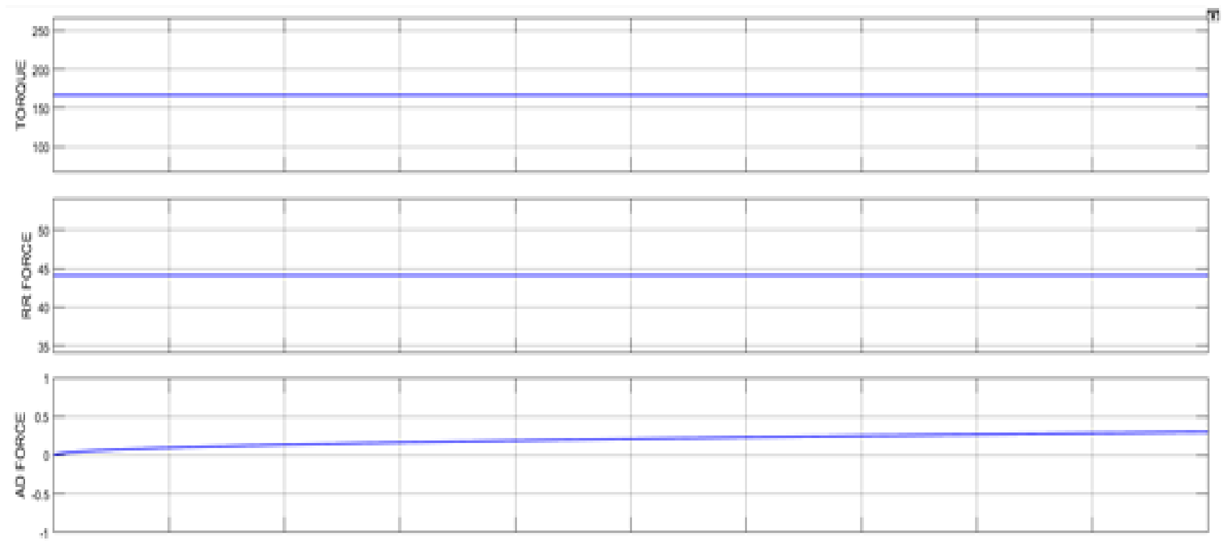
2 Click on file menu and open new Model file.

3 Draw the Circuit diagram in Model file by taking all necessary elements from Simulink library browser.

4 Click on the debug menu and run the Model.

5 Observe the output in scope and save the file.

Simulation Results:



RESULT: Hence electric vehicle speed from motor torque has been calculated and simulated in MATLAB/SIMULINK.

OUTCOMES: By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. Why is MATLAB/SIMULINK used for torque-speed simulation?
2. Which types of motors are used in electric vehicles?
3. Why is BLDC motor preferred in EVs?
4. What is Field-Oriented Control (FOC)?
5. What factors affect the speed of an electric vehicle?

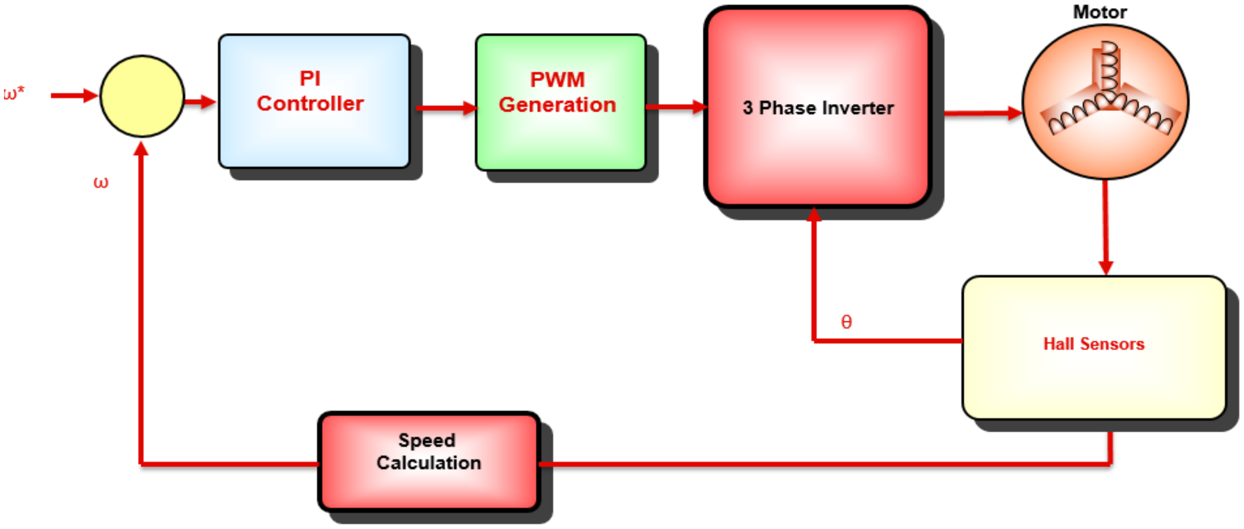
Experiment-11

Aim: To Design a circuit for the Speed control of electric vehicle using BLDC or PMSM in MATLAB/SIMULINK.

SOFTWARE USED: MATLAB/SIMULINK

THEORY:

BLDC motor works on the principle similar to that of a Brushed DC motor. The Lorentz force law, which states that whenever a current carrying conductor placed in a magnetic field it, experiences a force. Because of reaction force, the magnet will experience an equal and opposite force. It uses an electronic controller to switch DC currents to the motor windings producing magnetic fields which effectively rotate in space and which the permanent magnet rotor follows. The controller adjusts the phase and amplitude of the DC current pulses to control the speed and torque of the motor.

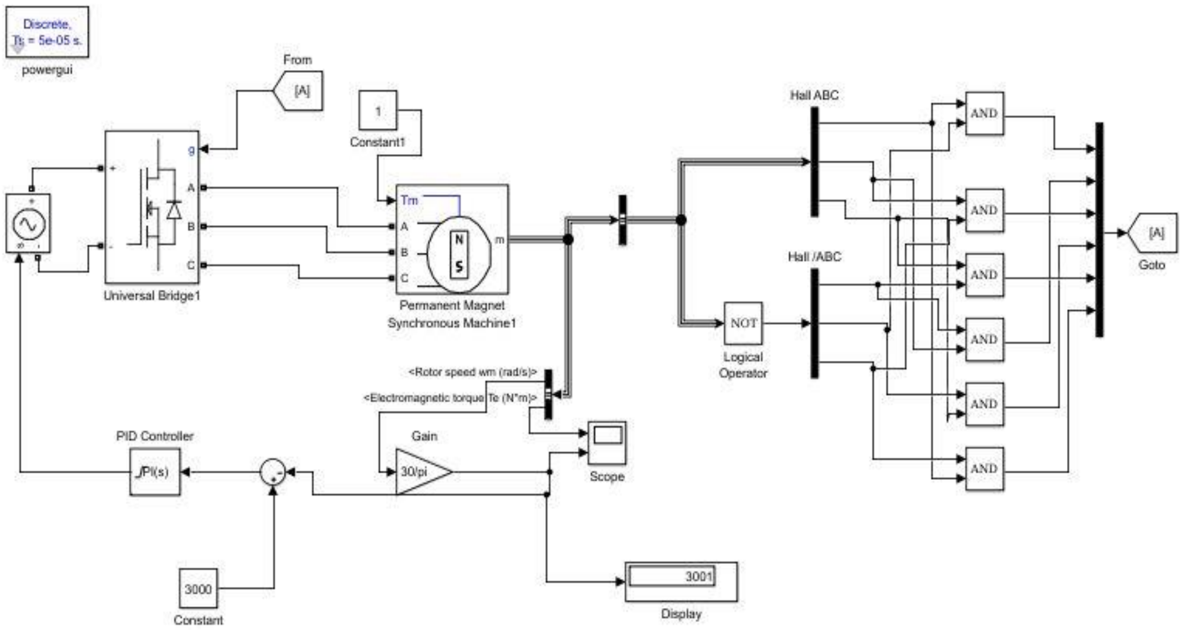


Block diagram

Hall Sensors

- Hall Sensors detect magnetic fields, and can be used to sense rotor angle.
- The output is a digital 1 or 0 for each sensor, depending on the magnetic field nearby.
- Each is mounted 120-degrees apart on the back of the motor.
- As the rotor turns, the Hall sensors output logic bits, which indicate the angle.
- The combination of all three sensors produce six unique logic combinations or steps
- PWM1 = Ha*Hb'
- PWM 2=Hb*Hc'
- PWM 3=Hc*Ha'
- PWM 4=Ha'*Hb
- PWM 5=Hb'*Hc
- PWM 6=Hc'*Ha

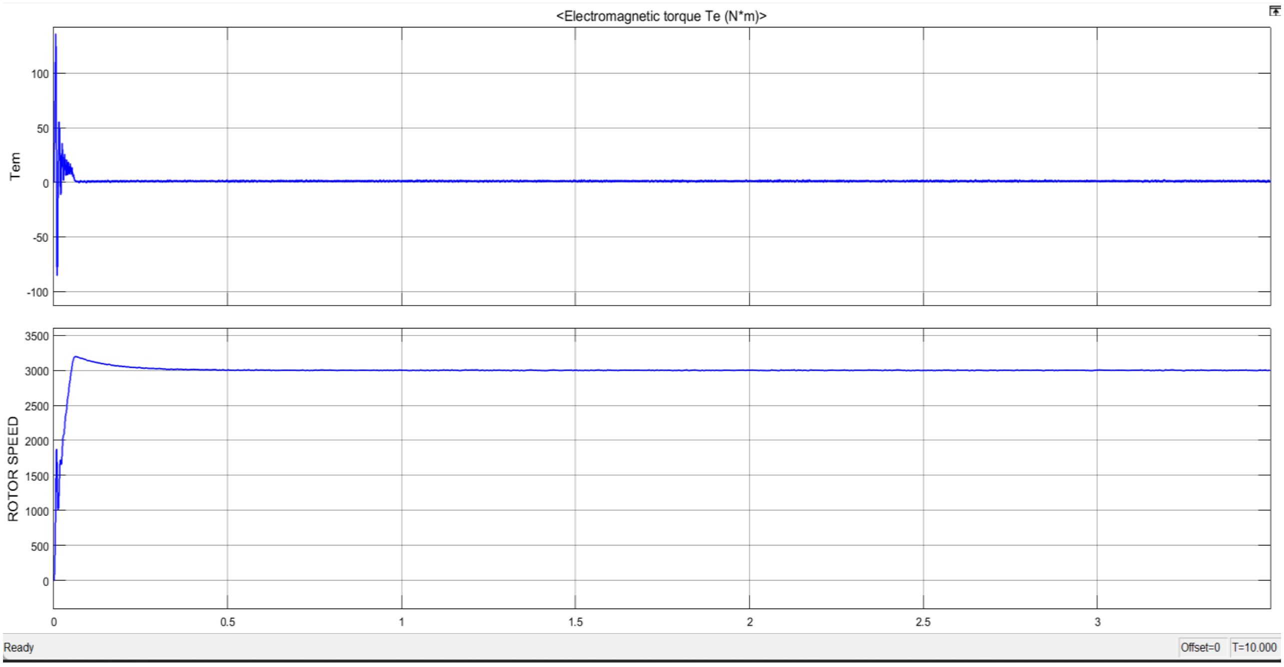
Simulink diagram:



PROCEDURE:

1 Open the MATLAB command window clicking on the MATLAB icon.
2 Click on file menu and open new Model file.
3 Draw the Circuit diagram in Model file by taking all necessary elements from Simulink library browser.
4 Click on the debug menu and run the Model.
5 Observe the output in scope and save the file.

Simulation Results



RESULT: Hence Speed control of electric vehicle using BLDC or PMSM has been designed and simulated Using MATLAB/SIMULINK.

OUTCOMES:
By Doing this Experiment Course Outcomes CO2, Program Outcomes PO1, PO2, PO3, PO5, PO6, PO7, PO9, PO10, PO11, PO12, PSO1 & PSO2 are attained.

Viva Questions:

1. Why are BLDC and PMSM motors used in EVs?
2. What are the common methods of speed control in BLDC/PMSM motors?
3. What is the difference between open-loop and closed-loop speed control?
4. What is back EMF in BLDC/PMSM motors?
5. What are the key components in a MATLAB/SIMULINK model for motor speed control?

Experiment-12

Aim: To Design and Simulate of electric vehicle using MATLAB/SIMULINK.

SOFTWARE USED: MATLAB/SIMULINK

THEORY:

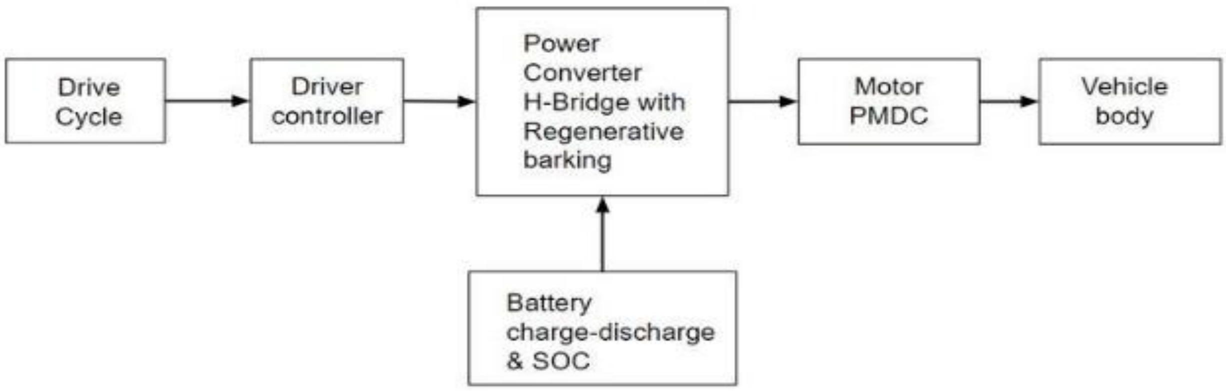
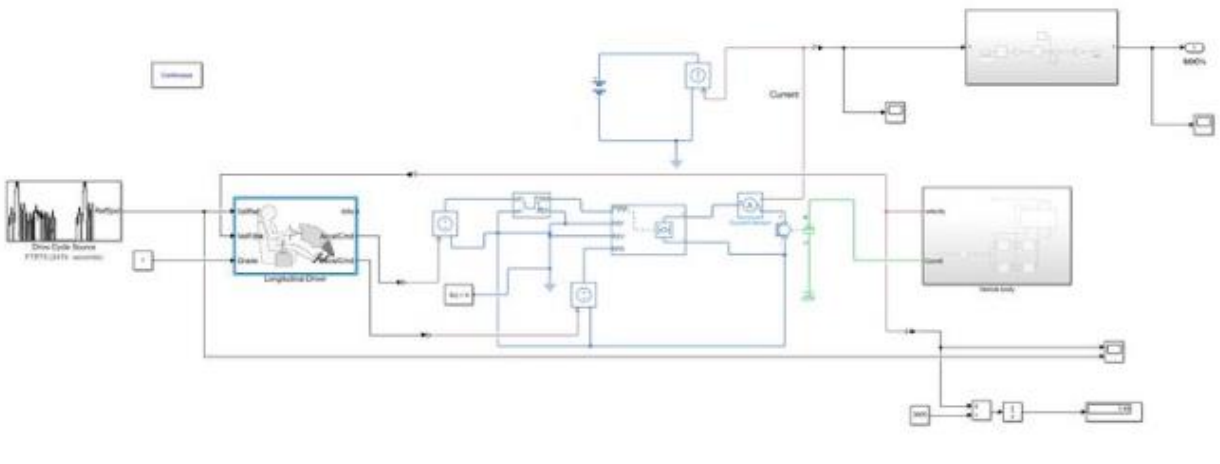


Figure: Basic block model of Electric Vehicle

Drive cycle: A drive cycle is typically represented by a series of data points which plots vehicle speed against time. Driving cycles are produced to assess the performance of vehicles in various ways, including fuel consumption and pollutant emissions.
Driver controller: The electric vehicle controller is the electronics package that operates between the batteries and the motor to control the electric vehicle's speed and acceleration much like a carburetor does in a gasoline-powered vehicle.
Power converter with regenerative braking: They are used to process and control the flow of electrical energy by supplying required voltages and current in a form that is optimally suited for the user loads.
Battery: This powerhouse which supplies the energy required to drive the vehicle.
Motor: It is the rotating device which converts the electrical energy in the form of current and voltage into the mechanical energy at the vehicle through a transmission system.
Vehicle body: This is where the output is achieved via the motor power is transferred to the wheel considering the different forces and resistance and compare with the input drive cycle.
Simulink diagram:



PROCEDURE:

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2 Click on file menu and open new Model file.

3 Draw the Circuit diagram in Model file by taking all necessary elements from

Simulink library browser.

4 Click on the debug menu and run the Model.

5 Observe the output in scope and save the file.

SIMULATION RESULT:

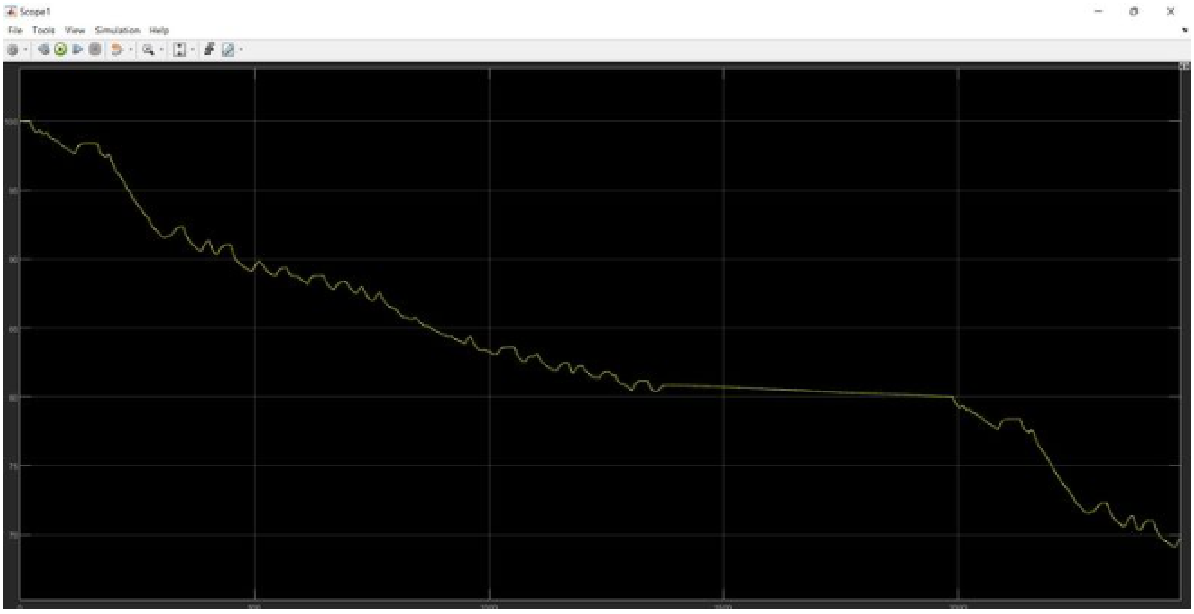


Figure: It is the state of charge of the battery which decreases when the vehicle accelerated and slightly increases when the vehicle decelerates.

RESULT: Hence electric vehicle has been designed and simulated using MATLAB/SIMULINK.

OUTCOMES:
By doing this experiment Course Outcomes CO2, CO3, CO4 & CO5, Program Outcomes PO1, PO2, PO3, PO5, PO7, PO9, PO10, PO12, PSO1 & PSO2are attained.

Viva Questions:

1. Which toolboxes are used in MATLAB/SIMULINK for EV simulation?
2. What are the key components in an EV MATLAB/SIMULINK model?
3. How is energy consumption analyzed in an EV simulation?
4. What is drive cycle?
5. What is drive controller?

EXPERIMENT –13

Aim: To design and simulate of Dynamic wireless Charging electric vehicle using MATLAB /SIMULINK

SOFTWARE USED: MATLAB/SIMULINK

THEORY:

Electrified transportation will help to reduce green-house gas emissions and increasing petrol prices. Electrified transportation demands that a wide variety of charging networks be set up, in a user-friendly environment, to encourage adoption. Wireless electric vehicle charging systems (WEVCS) can be a potential alternative technology to charge the electric vehicles (EVs) without any plug-in problems. The current available wireless power transfer technology for EVs. In addition, it also includes wireless transformer structures with a variety of ferrite shapes, which have been researched. WEVCS are associated with health and safety issues, which have been discussed with the current development in international standards. Two major applications, static and dynamic WEVCS, are explained, and up-to-date progress with features from research laboratories, universities, and industries are recorded. Moreover, future upcoming concepts-based WEVCS, such as "vehicle-to-grid (V2G)" and "in-wheel" wireless charging systems (WCS) are reviewed and examined, with qualitative comparisons with other existing technology.

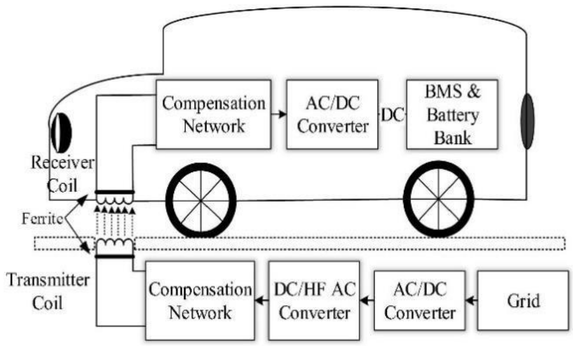


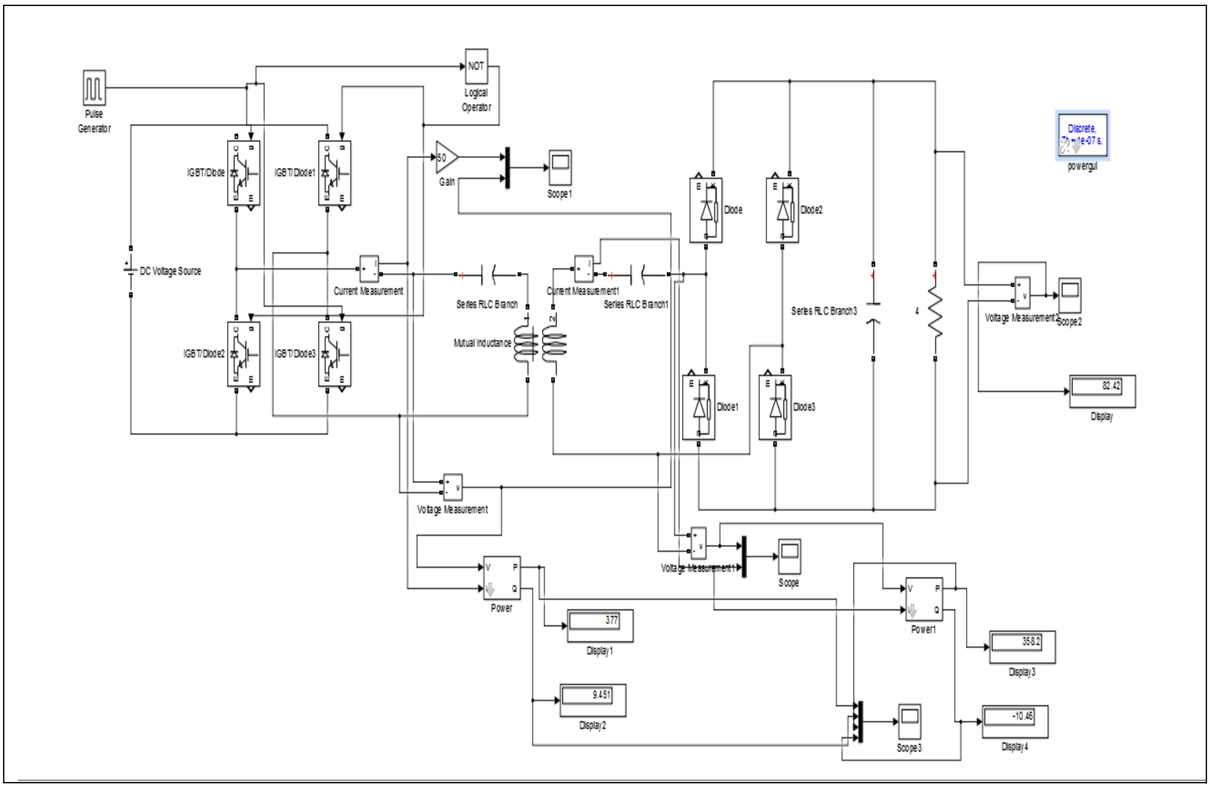
Figure: Basic block diagram of static wireless charging system for EVs.

To enable power transfer from the transmission coil to the receiving coil, AC mains from the grid is converted into high frequency (HF) AC through AC/DC and DC/AC converters. The receiving coil, typically mounted underneath the vehicle, converts the oscillating magnetic flux fields to HF AC. The HF AC is then converted to a stable DC supply, which is used by the on-board batteries. The power control, communications, and battery management system (BMS) are also included, to avoid any health and safety issues and to ensure stable operation. Magnetic planar ferrite plates are employed at both transmitter and receiver sides, to reduce any harmful leakage fluxes and to improve magnetic flux distribution.

It is a basic overview of the WEVCS for stationary and dynamic applications with current researched technology. In addition, a variety of core and ferrite shapes have been demonstrated, which have been utilized in current wireless charging pad design. Health and safety issues have been raised and current developments in international standards are tabled for WEVCS. State- of-the-art stationary- and dynamic- WEVCS have been studied and tabled, with current research and development from a variety of public and private organizations. Finally, upcoming future technologies are investigated and simulated with the utilization of FEM. Overall; the latest developments in the area of WEVCS are included in this.

Simulink diagram:

Dynamic wireless charging



PROCEDURE:

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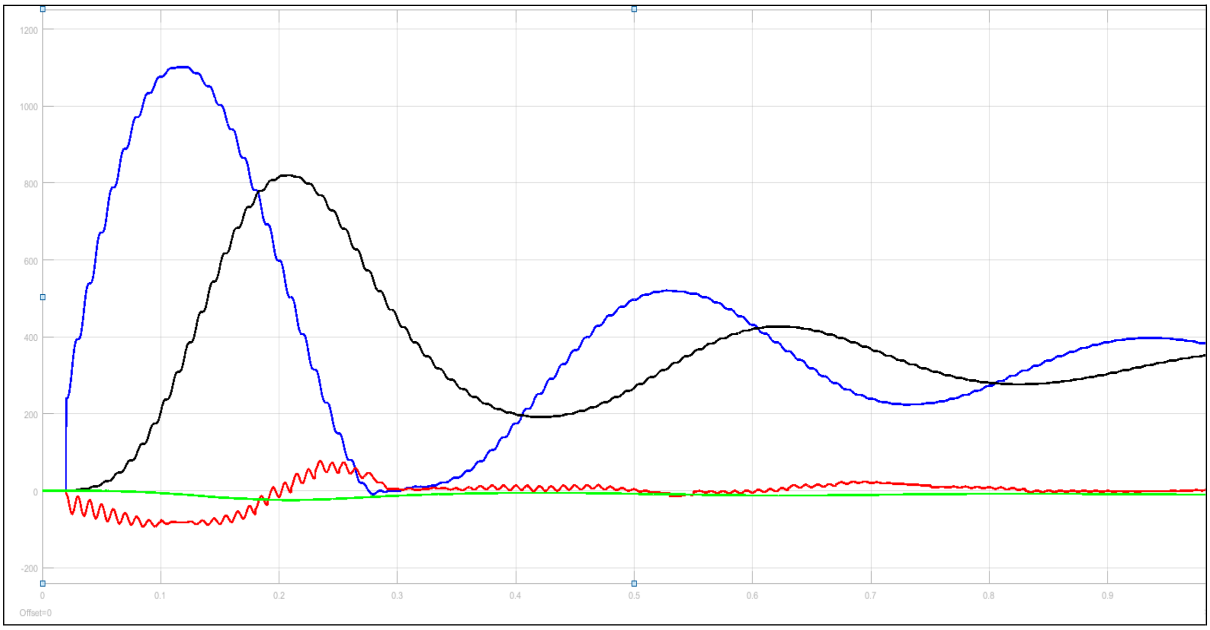
2. Click on file menu and open new Model file.
3. Draw the Circuit diagram in Model file by taking all necessary elements from Simulink library browser.
4. Click on the debug menu and run the Model.
5. Observe the output in scope and save the file.

Simulation Results:

Power of primary and secondary coils



RESULT: Hence the output waveforms of Dynamic wireless Charging electric vehicle using are observed by using MATLAB/SIMULINK.

OUTCOMES:

By doing this experiment Course Outcomes CO2, CO3, CO4 & CO5, Program Outcomes PO1, PO2, PO3, PO5, PO7, PO9, PO10, PO12, PSO1 & PSO2are attained.

Viva Questions:

1. What is dynamic wireless charging in electric vehicles?
2. What are the advantages of dynamic wireless charging over static charging?
3. What are the challenges in implementing dynamic wireless charging?
4. What factors affect the efficiency of wireless power transfer?
5. What type of converter is used in this experiment?