



OFFICE OF THE REGISTRAR MANIPUR TECHNICAL UNIVERSITY, IMPHAL

(A University established under the Manipur Technical University Act, 2016)
Recognised by UGC under Section 2(f) and Section 22 of UGC Act, 1956
www.mtu.ac.in

REGULATIONS (COURSES AND SYLLABI FOR MASTER OF TECHNOLOGY PROGRAMS IN ELECTRICAL ENGINEERING)

NOTIFICATION

Imphal, 7th September, 2026

AC-MTU-1/2/2026-MTU-MTU: It is notified to all that in exercise of the powers conferred by Section 45 of the Manipur Technical University Act, 2016, on recommendation of Board of Studies and as approved by the Academic Council of Manipur Technical University in its 9th meeting held on 30th May, 2026, hereby makes the following Regulations (Courses and Syllabi of Master of Technology program in Electrical Engineering), namely:-

1. Short title and commencement:

- (a) These Regulations may be called the Regulations (Courses and Syllabi for Master of Technology program in Electrical Engineering) 2026
- (b) They shall come into effect from the academic session 2026-27

2. Definitions:

- (1) In these Regulations, unless the context otherwise requires, -
 - (a) “Act” shall mean the Manipur Technical University Act, 2016
 - (b) “Board of Studies” means the board of studies of a Department
 - (c) “L”, “T”, “P”, “C”, shall mean respectively lecture hours per week, tutorial class hours per week, practical/ lab hours per week, credits per week.

(2) Words and expressions not defined in the Regulations but defined in the Statutes and Ordinances shall have the same meanings as assigned to them in the Statutes and Ordinances.

3. The Course Structure for the Master of Technology program in Electrical Engineering-

The Course Structure for the Master of Technology program in Electrical Engineering shall be as follows, with the detailed course for I semester, II semester, III semester and IV semester along with contents as given at Appendix.

Master of Technology

in

Electrical Engineering

with specialization in

ELECTRIC VEHICLE TECHNOLOGY



CURRICULUM Structure

2026 Admission onwards

DEPARTMENT OF ELECTRICAL ENGINEERING
Curriculum Structure
Master of Technology in Electrical Engineering
with specialization in
ELECTRIC VEHICLE TECHNOLOGY

**The Program Educational Objectives (PEOs) of M.Tech. in Electrical Engineering
with specialization in Electric Vehicle Technology**

Graduates are expected to

- PEO1 Administer enhanced knowledge and skills in the area of electric vehicle technology to excel in various sectors in the modern EV industry, entrepreneurial ventures or higher education and research.
- PEO2 Engage in the design of new products and strategic solutions to real-life problems in the areas of electric vehicle technology that are technically sound, economically feasible and socially acceptable.
- PEO3 Exhibit professionalism, maintain ethics in the profession and demonstrate effective communication skills, willingness to work in groups, and leadership qualities.

**Programme Outcomes (POs) of M.Tech. in Electrical Engineering with
specialization in Electric Vehicle Technology**

M. Tech. programme in Electrical Engineering with specialization in Electric Vehicle Technology under the Department of Electrical Engineering at Manipur Technical University has been designed to impart the following skills and abilities amongst the successful students, as stated under (1) through (5) below:

- PO1 Competence to demonstrate a degree of mastery over the area of electric vehicle technology, at a level higher than the requirements in the appropriate bachelor's program.
- PO2 Capacity to write and present a substantial technical report/document.
- PO3 Ability to independently carry out research/investigation and development work either solely or as a member of a team to solve related complex/practical problems.
- PO4 Competence to exhibit psychomotor and affective domain skills.
- PO5 Graduates are professional, ethical, and capable of lifelong learning.

Bloom's Taxonomy Levels	
L1	Remember
L2	Understand
L3	Apply
L4	Analyze
L5	Evaluate
L6	Create

Sl. No.	Program core	PO1	PO2	PO3	PO4	PO5
1.	Electric and Hybrid Vehicles	3	1	2	1	-
2.	EV Powertrain: Drives and Control	3	1	3	2	-
3.	Research Methodology and IPR	1	3	3	-	3
4.	Effective Technical Communication	1	3	2	-	1
5.	Modelling and Simulation of Electric Vehicles Laboratory	3	2	3	3	1
6.	EV Hardware Laboratory-I	2	2	3	3	1
7.	Vehicle Dynamics	3	1	2	1	-
8.	EV Charging Infrastructure and Analysis	2	1	3	2	-
9.	Battery Management Systems	3	1	3	2	-
10.	Indian Knowledge Systems in Electrical Engineering	2	1	2	1	3
11.	Seminar – I	2	3	2	1	1
12.	Battery Management Systems Laboratory	3	2	3	3	1
13.	EV Hardware Laboratory- II	3	2	3	3	1
14.	Internship	3	3	3	3	3
15.	Project Phase -I	3	3	3	3	3
16.	Project Phase -II	3	3	3	3	3

	PEO1	PEO2	PEO3	
PO1	3	2	1	6
PO2	2	2	3	7
PO3	3	3	1	7
PO4	2	3	2	7
PO5	2	2	3	7
	12	12	10	34

PROGRAMME STRUCTURE

SEMESTER -I							
Sl. No.	COURSE CATEGORY	COURSE CODE	NAME OF THE COURSE	L	T	P	C
1.	PCC	EE501	Electric and Hybrid Vehicles	3	0	0	3
2.	PCC	EE502	EV Powertrain: Drives and Control	3	0	0	3
3.	PCC	EE503	Research Methodology and IPR	4	0	0	4
4.	PEC	EE51X	Program Elective Course- I	3	0	0	3
5.	PEC	EE51Y	Program Elective Course- II	3	0	0	3
6.	OEC	XXxxx	Open Elective Course-I	0	2	0	2
PRACTICAL							
7.	PLC	EE504	Modeling and Simulation of Electric Vehicles Laboratory	0	0	2	1
8.	PLC	EE505	EV Hardware Laboratory-I	0	0	2	1
Total				16	2	4	20
SEMESTER-II							
1.	PCC	EE521	Vehicle Dynamics	3	0	0	3
2.	PCC	EE522	EV Charging Infrastructure and Analysis	3	0	0	3
3.	PCC	EE523	Battery Management Systems	3	0	0	3
4.	PEC	EE53X	Program Elective Course-III	3	0	0	3
5.	PEC	EE53Y	Program Elective Course-IV	3	0	0	3
6.	OEC	YYyyy	Open Elective Course-II	1	1	0	2
PRACTICAL							
7.	PCC	EE524	Seminar - I	0	0	2	1
8.	PLC	EE525	Battery Management Systems Laboratory	0	0	2	1
9.	PLC	EE526	EV Hardware Laboratory-II	0	0	2	1
Total				16	1	6	20
➤ Exit option to qualify for a PG Diploma in Electrical Engineering with a specialization in Electric Vehicle Technology: Students opting for the exit option must complete a six- to eight-week industrial training from a reputed industry. ➤ Continuation for M. Tech. in Electrical Engineering with a specialization in Electric Vehicle Technology: Students who continue in the program must also complete a four- to six-week industrial/academic training during the vacation.							
SEMESTER-III							
1.	SI	EE601	Summer Internship	0	0	0	2
2.	PRP	EE602	Project Phase -I	0	0	36	18
Total				0	0	36	20
SEMESTER- IV							
1.	PRP	EE603	Project Phase- II	0	0	40	20
Total				0	0	40	20
Total Credit is 80							

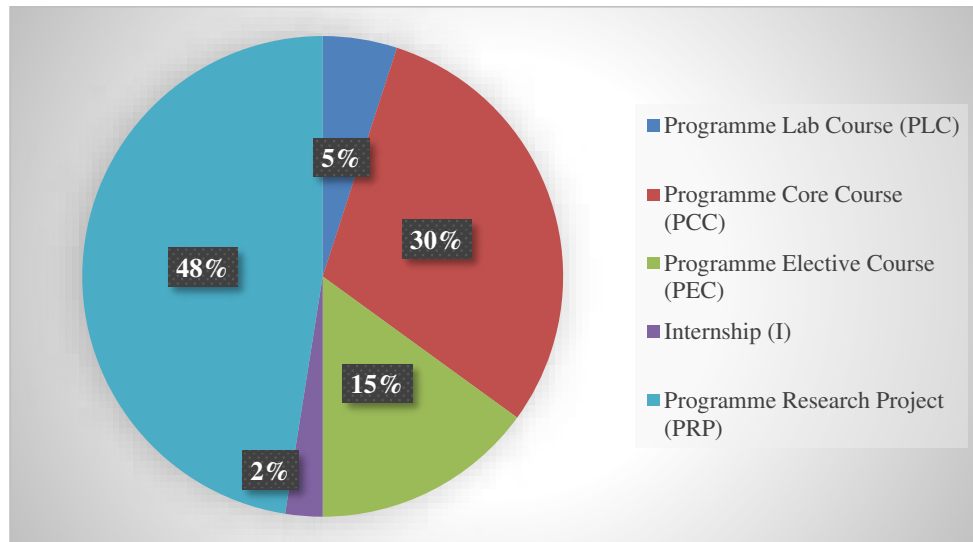
LIST OF PROGRAM ELECTIVES							
SL. NO	COURSE CATEGORY	COURSE CODE	NAME OF THE COURSE	L	T	P	C
Program Elective Course-I							
1.	PEC	EE511	Special Machines for Electric Vehicles	3	0	0	3
2.	PEC	EE512	Micro Electro Mechanical Systems	3	0	0	3
3.	PEC	EE513	Electric Vehicle System Engineering and Policy	3	0	0	3
Program Elective Course-II							
4.	PEC	EE514	Energy Storage Systems for Electric Vehicles	3	0	0	3
5.	PEC	EE515	Electric Vehicles in Smart Grid	3	0	0	3
6.	PEC	EE516	Artificial Neural Network and Fuzzy Logic Applications	3	0	0	3
Program Elective Course-III							
7.	PEC	EE531	Sensor Systems for Electric Vehicles	3	0	0	3
8.	PEC	EE532	Vehicular Networks in Communication	3	0	0	3
9.	PEC	EE533	Digital Control Systems	3	0	0	3
Program Elective Course-IV							
10.	PEC	EE534	Computer-Aided Design of Electric Machines	3	0	0	3
11.	PEC	EE535	Optimization Techniques	3	0	0	3
12.	PEC	EE536	Testing and Certification of Electric and Hybrid Vehicles	3	0	0	3

IOC to be offered:

Open Elective Course-I							
1.	OEC	EE541	Effective Technical Communication	0	2	0	2
Open Elective Course-II							
2.	OEC	EE542	Indian Knowledge Systems in Electrical Engineering	1	1	0	2

Notes:

1. Any course of 8/12 weeks offered by Swayam -NPTEL during the respective semester as electives with the prior approval from the Program Coordinator.
2. A list of electives offered in each semester will be announced by the Departments based on the requirements and availability of faculty.
3. The evaluation (Online elective courses) will be based on assignments and internal assessments conducted by the concerned course instructor and examinations as per the MTU P.G ordinance.
4. Internship Evaluation will be performed based on presentation within 1st month of 3rd semester.
5. Project Phase II is the continuation of Project Phase I.



SEMESTER-I

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: ELECTRIC AND HYBRID VEHICLES

Course Code: EE501

Semester: I

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to understand the fundamentals of electric and hybrid vehicles, drive-train topologies, energy storage systems, and energy management strategies.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the basic concept of electric and hybrid vehicles. (L4)

CO2: Evaluate the energy management strategies applied in electric and hybrid vehicles. (L5)

CO3: Analyze and compare various energy storage technologies and drive train configurations. (L4)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	1	1	-
CO2	3	1	2	1	-
CO3	3	1	2	1	-

Course Contents:

Module 1: Overview of Electric and Hybrid Vehicles **(8 Hours)**

History of hybrid and electric vehicles - Social and environmental importance of hybrid and electric vehicles - Impact of modern drive-trains on energy supplies - Basics of vehicle performance, vehicle power source characterization, Transmission characteristics.

Module 2: Drive Train Topologies **(7 Hours)**

Basic concept of hybrid traction, Introduction to various hybrid drive-train topologies, Power flow control in hybrid drive-train topologies -Fuel efficiency analysis.

Module 3: Configuration and control of Motor drives **(9 Hours)**

Introduction to electric components used in hybrid and electric vehicles, configuration and control of DC Motor drives, configuration and control of Introduction Motor drives configuration and control of Permanent Magnet Motor Drives Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Module 4: Energy Storage **(8 Hours)**

Matching the electric machine and the internal combustion engine (ICE) Sizing the propulsion motor, sizing the power electronics, battery-based energy storage and its analysis, Fuel cell-based energy storage and its analysis, hybridization of different energy storage devices.

Module 5: Energy Management Strategies **(8 Hours)**

Introduction to energy management and its strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, and implementation of energy strategies.

Textbooks

1. C. C. Chan, K. T. Chau, "Modern Electric Vehicle Technology" published by Oxford University Press, 2001.

2. Iqbal Husain “Electric and Hybrid Vehicles: Design Fundamentals” CRC PRESS
Boca Raton, London, New York, Washington, D.C., 2021.

References:

1. Rodrigo Garcia-Valle and J. A. P Lopes “Electric Vehicle Integration into Modern Power Networks” Springer.
2. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, “Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design”, CRC Press, 2004.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: EV POWER TRAIN: DRIVES AND CONTROL

Course Code: EE502

Semester: I

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to understand electric powertrain technology, drive control, power converters, and efficiency optimization in electric vehicle systems.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Evaluate various types of power trains and various converters utilized in EV drives. (L5)

CO2: Develop the capability to model drives and braking characteristics-involving load estimation, load cycle considerations, thermal aspects and motor-converter matching. (L6)

CO3: Analyze the performance of various controllers used in DC and AC drives. (L4)

CO4: Design and analyze various power converters used in Electrical Drives and their control. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	3	2	-
CO2	3	1	3	2	-
CO3	3	1	3	2	-
CO4	3	2	3	3	-

Course Contents:

Module 1: Review of Conventional Vehicle

(9 Hours)

Introduction to Electric Vehicles: Electric Drive-train, Tractive effort in normal driving, Energy consumption concept of Electric Drive Trains and its Architecture-Electric Propulsion unit. Si, SiC, GaN device-based power converters - Distribution of electric power in DCDC, AC-DC, DC-AC converters used in EV drives. Various Hybrid/EV architectures, various switched-mode DC/DC converters for EV drive. Construction and operation of speed control using the acceleration pedal.

Module 2: Role of power converters in Drives

(11 Hours)

DC-DC Converters, buck-boost, bidirectional DC-DC Converters, effect of parasitic elements, performance analysis, controllers design for DC-DC converters, Single Phase and Three Phase Inverter, VSI and CSI topologies, PWM Techniques- Space Vector PWM Hysteresis Control, Comparison of PWM techniques and closed loop control of drives. Transmission and Drive Train Characteristics-Regenerative Braking Characteristics-Driving Cycles Modelling and Analysis of Electric Vehicles Propulsion and Braking -Longitudinal Dynamics Equation of Motion.

Module 3: Drive efficiency

(10 Hours)

Drive efficiency: impact of altitude, ambient temperature, gradient and motors. Different types of motors used and their comparative study. Torque vs speed, calibration of the drive train based on vehicle parameters. EV design and components sizing. Electric Drive Train

Overview, Systems with Linear Motion and Rotating Systems, Types of loads, Four Quadrant Operation. Induction Motor for EV power train, Variable Voltage Variable Frequency Control - Steady State Analysis of Induction Drive, Direct & Indirect Vector Control, and Direct Torque Control.

Module 4: BLDC drives

(10 Hours)

BLDC drives-various speed control strategies – closed loop control – Autonomous control. Control strategies of regenerative braking in drives. Speed control of AC drives. Permanent magnet synchronous machine for EV power train, Non-Salient & Salient Drives, Generic Model, Steady State Analysis, Field Oriented Control. Switched Reluctance Machine for EV power train. Operating principles, Analysis of SRM drives and speed control. Multi-input EV drives concepts and their operation.

Textbooks:

1. Ali Emadi, “Handbook of Automotive Power Electronics and Drives”, Taylor & Francis Group, First Edition, USA, 2005.
2. R Krishnan, “Electric motor drives: Modeling, Analysis, and Control”, 2013.

References:

1. P.C. Sen, “Modern Power Electronics”, Wheeler Publishing Co, Third edition, New Delhi, 2008
2. Hybrid Electric Vehicle System Modelling and Control - Wei Liu, General Motors, USA, John Wiley & Sons, Inc., 2017.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: RESEARCH METHODOLOGY AND IPR

Course Code: EE503

Semester: I

Credits: L:T:PC::4:0:0:4

Course Objective: The course enables students to understand research problem formulation, literature review, research ethics, technical writing, and the fundamentals of intellectual property rights, including patents, copyrights, and technology transfer.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Formulate and analyze research problems, information, and ethics. (L6)

CO2: Construct a structured research proposal and technical article. (L6)

CO3: Evaluate the role of IPR in innovation and national development. (L5)

CO4: Apply the IPR as an incentive to inventors for further research work and investment in R & D. (L3)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	1	3	3	-	3
CO2	1	3	3	-	3
CO3	1	2	3	-	3
CO4	1	3	2	1	3

Course Contents:

Module 1: Research Problem

(9 Hours)

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentation.

Module 2: Literature Studies

(7 Hours)

Effective literature studies approaches, analysis Plagiarism, Research ethics.

Module 3: Technical Writing

(7 Hours)

Effective technical writing, how to write a report, Paper Developing a Research Proposal, Format of research proposal, presentation and assessment by a review committee.

Module 4: Nature of Intellectual Property

(8 Hours)

Patents, Designs, Trade, and Copyright. Process of Patenting and Development: technological research, innovation, patenting, and development. International Scenario: International Cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Module 5: Patent Rights

(8 Hours)

Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. Administration of Patent System. New developments

in IPR; IPR of Biological Systems, Computer Software, etc. Traditional knowledge Case Studies, IPR, and IITs.

Textbooks:

1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students.
2. Ayne Goddard and Stuart Melville, “Research Methodology: An Introduction”.

References:

1. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step-by-Step Guide for beginners”.
2. Asimov, “Introduction to Design”, Prentice Hall, 1962.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: MODELING AND SIMULATION OF ELECTRIC VEHICLES
LABORATORY

Course Code: EE504

Semester: I

Credits: L:T:P:C::0:0:2:1

Course Objective: The course enables students to develop practical skills in modelling, simulation, and performance analysis of electric vehicle components, including battery management systems, motor drives, and charging technologies.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Investigation on the performance analysis of EV by considering various forces acting on EV. (L4)
- CO2:** Design the skill to design a suitable power train for an electric vehicle. (L6)
- CO3:** Construct the simulation model to design and analyze the performance of power converters in EV applications. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	3	1
CO2	3	2	3	3	1
CO3	3	2	3	3	1

List of Experiments (Any 8 experiments):

1. Develop a simulation model to analyze Electric Motor Regenerative Braking Characteristics for different Driving Cycles.
2. Develop a simulation model to analyze the effect of Rolling Resistance on vehicle range and Performance.
3. Develop a simulation model to analyze the effect of Aerodynamic drag and Hill Climbing force on vehicle range and Performance.
4. Modelling of an electric vehicle using a BLDC Motor.
5. Modelling of an electric vehicle using SR Motor Drive.
6. Modelling of an electric vehicle using SynRM Drive.
7. To design an EV charging system using the grid.
8. To design an EV charging system using a renewable power source.
9. To design a V2G and G2V operation of the EV charging system.
10. To design a V2V charging system using a bidirectional converter.
11. To design an EV charging system using a DC microgrid.
12. To design an EV charging system using a Cuk converter.
13. To design an EV charging system using a Luo converter.
14. To design a wireless EV charging system for a static charging application.
15. To design a coil for wireless charging of electric vehicles.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: EV HARDWARE LABORATORY-I

Course Code: EE505

Semester: I

Credits: L:T:P:C::0:0:2:1

Course Objective: The course enables students to gain hands-on experience with EV components, understand their hardware implementation, and develop practical skills in testing, troubleshooting, and performance evaluation of EV systems.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Investigate the performance of a motor by measuring the real-time parameters of the electric vehicle. (L4)
- CO2:** Develop the skill to design and analyze the performance in motoring and braking operation of EVs. (L6)
- CO3:** Construct the hardware prototype to design and analyze the performance of machine drives in EV applications. (L6)
- CO4:** Investigate the speed tests and anti-theft detection systems. (L4)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	3	3	1
CO2	2	2	3	3	1
CO3	3	2	3	3	1
CO4	2	2	3	3	1

List of Experiments (Any 8 experiments):

1. Obtain the characteristics of speed control on the BLDC Motor.
2. Determine the performance characteristics of the load test on the BLDC Motor.
3. To perform the speed control (forward and reverse) of an Electric vehicle using the throttle and analyze the torque production using OPAL-RT.
4. Control of the electrical braking system (low brake and high brake).
5. Implementation of the anti-theft detection system.
6. Measure the accurate level of battery charging and its indication.
7. Study on thermal runaway of battery, motor, and power trains using OPAL-RT.
8. Sending the EV sensor data sets to the IoT cloud.
9. Obtain the characteristics of speed control on the PMSM Motor Drive.
10. Determine the performance characteristics of the load test on the PMSM Motor Drive.
11. Obtain the characteristics of speed control on the SynRM Drive.
12. Determine the performance characteristics of the load test on SynRM Drive.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: SPECIAL MACHINE FOR ELECTRIC VEHICLES

Course Code: EE511

Semester: I

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to understand the principles, modelling, control, and design of special machines used in electric vehicles, including PM brushless motors, switched reluctance motors, stator-PM motors, magnetic-gearless motors, and advanced magnet-less motor drives.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the operation of the PM Brushless Machine, Switched Reluctance Motor & Stator-PM Motor. (L4)

CO2: Develop simulation models of Magnetic-Gearless Motor Drives. (L6)

CO3: Analyze the Advanced Magnet Less Motor Drives. (L4)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	1	-
CO2	2	1	3	2	-
CO3	2	1	3	1	-

Course Contents:

Module 1: Permanent Magnet (PM) Brushless Motor Drives **(9 Hours)**

Structure of PM Brushless Machines, Principle of PM Brushless Machines, Modelling of PM Brushless Machines, Inverters for PM Brushless Motors, Motor Control, Design Criteria of PM Brushless Motor Drives for EVs, Design Examples of PM Brushless Motor Drives for EVs, Application, Advantages and Limitations for EVs.

Module 2: Switched Reluctance Motor drive **(7 Hours)**

Structure of SR Machines, Principle of SR Machines, SR Converters Topologies, SR Motor Control, Design Criteria of SR Motor Drives for EVs, Examples of SR Motor Drives for EVs, Application, Advantages and Limitations for EVs.

Module 3: Stator-PM Motor Drives **(8 Hours)**

Doubly-Salient PM Motor Drives, Flux-Reversal PM Motor Drives, Flux-Switching PM Motor Drives, Hybrid Excited PM Motor Drives, Flux-Mnemonic PM Motor Drives, Design Criteria of Stator-PM Motor Drives for EVs, Application, Advantages and Limitations for EVs.

Module 4: Magnetic-Gearless Motor Drives **(8 Hours)**

Principle of MG Machines, Modelling of MG Machines, Inverters for MG Motors, MG Motor Control, Design Criteria of MG Motor Drives for EVs, Application, Advantages and Limitations for EVs.

Module 5: Advanced Magnet Less Motor Drives **(8 Hours)**

Introduction of Progressive Magnetless technology, Synchronous Reluctance Motor Drives, Doubly-Salient DC Motor Drives, Flux-Switching DC Motor Drives, Design Criteria of Advanced Magnet Less Motor Drives for EVs, Application, Advantages and Limitations for EVs.

Textbooks:

1. K. T. Chau, Electric Vehicle Machines and Drives: Design, Analysis and Application, IEEE Press, Wiley, 2015.
2. Brushless Permanent magnet and reluctance motor drives, Clarendon Press, T.J.E. Miller, 1989, Oxford.

References:

1. Mehrdad Ehsani, Yimin Gao, Sebatien Gay and Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
2. James Larminie and John Lory, Electric Vehicle Technology – Explained, John Wiley & Sons Ltd, 2003.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: MICRO ELECTRO MECHANICAL SYSTEMS

Course Code: EE512

Semester: I

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to understand the fundamental knowledge of Micro Electro Mechanical Systems (MEMS), including their design, fabrication, materials, sensors, actuators, and packaging techniques, and analyze microsystems for engineering applications.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze the fundamentals, multidisciplinary nature, and applications of MEMS and microsystems for advanced engineering problems. (L4)
- CO2:** Evaluate the working principles and performance of microsensors and micro actuators for practical and research applications. (L5)
- CO3:** Select suitable materials and analyze microfabrication and micromachining techniques for MEMS device development. (L5)
- CO4:** Design and assess microsystem packaging techniques considering reliability, integration, and real-world constraints. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	-	-
CO2	2	1	2	1	-
CO3	2	2	2	1	-
CO4	2	2	2	2	-

Course Contents:

Module 1: Overview of MEMS and Microsystems (6 Hours)

MEMS and Microsystems- MEMS as micro sensors and micro actuators- MEMS and Microsystem products- Evolution of Microfabrication, Microsystems and Micro electronics Comparison of Microsystems and microelectronics-Multidisciplinary nature of Microsystems Microsystems and miniaturization- Applications of Microsystems in various industries.

Module 2: Micro Sensors and Actuators (9 Hours)

Microsensors- Bio sensors, Chemical sensors, Optical sensors, Pressure sensors, Thermal sensors – thermopiles, thermistors. Micro-actuator - Micro actuation principles-Micro gripper Micro Motors-Micro Valves-Micro pumps- Micro Accelerometers-Micro fluidics.

Module 3: Materials for MEMS and Microsystems (9 Hours)

Substrates and wafers – Silicon as a substrate material, ideal substrates for MEMS – single crystal Silicon and wafers crystal structure – mechanical properties of Si –Silicon compounds – Gallium arsenide- quartz – piezoelectric crystals – polymers.

Module 4: Micro-fabrication And Micro Machining (9 Hours)

Photolithography-Ion Implantation-Diffusion-Chemical vapour deposition (CVD)-Enhanced CVD- Physical vapours deposition (Sputtering)-Etching-chemical etching, plasma etching-Bulk Micro Machining -Surface Micro Machining -LIGA process.

Module 5: Micro-system Packaging (12 Hours)

General considerations in packaging - Levels of Micro-system packaging – die level, device level and system level – Essential packaging technologies – die preparation, surface bonding,

wire bonding and sealing - Three-dimensional packaging, assembly of Microsystems – selection of packaging materials.

Textbooks:

1. Tai-Ran Hsu, MEMS and Microsystems Design and Manufacture, Tata McGraw Hill, New Delhi, 2017.
2. Mahalik, N. P, MEMS, Tata McGraw Hill, New Delhi, 2007
3. Julian W. Gardner, Florin Udrea, Microsensors: Principles and Applications, Wiley, 2015.

References:

1. Michael Kraft and Neil M. White, MEMS for automotive and aerospace applications, Woodhead Publishing Limited, 2013.
2. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006
3. Marc F Madou, Fundamentals of Micro Fabrication, CRC Press, 2nd Edition, 2002

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: ELECTRIC VEHICLE SYSTEM ENGINEERING AND POLICY

Course Code: EE513

Semester: I

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to develop fundamental and applied knowledge of electric vehicle technologies, performance evaluation, modelling, and EV policy frameworks.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the concepts of electric vehicle system engineering. (L4)

CO2: Investigate and analyze testing methodologies of EV. (L4)

CO3: Develop and apply modeling and simulation techniques for electric vehicle systems. (L6)

CO4: Evaluate electric vehicle policies and their impact on adoption and development. (L5)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	1	1	3	-	1
CO2	2	1	3	1	1
CO3	2	2	3	1	1
CO4	1	2	2	1	2

Course Contents:

Module 1: Introduction to Electric Vehicle Technologies **(8 Hours)**

Introduction to EV technologies, Types of EV architecture, Electric vehicle and environment, Vehicle classification, Usage pattern of electric vehicles, Standardization in e-mobility, Government policies: standards and regulations

Module 2: EV Testing and Performance Evaluation **(9 Hours)**

Design aerodynamics, Chassis model for battery-operated vehicles, BMS design considerations, Electromagnetic compatibility testing, Efficiency and emissions testing, On-road EV testing, Battery safety and crash worthiness.

Module 3: EV Modelling and Simulation **(8 Hours)**

Range modelling of EV, Driving cycles, Acceleration performance parameters, Tractive effort calculation, Constant velocity range modelling, Dynamic and static testing, Charge and discharge testing, Battery, material, and cell performance modelling.

Module 4: Component Sizing and Energy Analysis **(8 Hours)**

Forward-looking vehicle model (driver perspective), Backward-looking vehicle model (drive cycle perspective), Modelling of driver and brake control unit, Vehicle control strategy modelling, Vehicle chassis modelling, Steady-state energy balance equation, Powertrain dimensioning (peak vs continuous performance), Performance, range, and consumption prediction.

Module 5: EV Policies, Standards, and Infrastructure **(9 Hours)**

Communication standards for EV systems, Communication architecture for DC fast charging, Communication protocols for EV-grid connectivity, Verification procedures for charging systems, AC Level 1 and Level 2 charging standards, Policies promoting EV adoption, EVCI station implementation strategies, Incentives and regulatory frameworks,

Safety and security aspects of EV.

Textbooks:

1. Iqbal Husain – Electric and Hybrid Vehicles: Design Fundamentals, Second Edition, CRC Press.
2. James Larminie, John Lowry – Electric Vehicle Technology Explained, Wiley.

References:

1. Godaiz Garzon, A. Hayes, Jung R, Wiley 2018 – Electric Powertrain: Energy Systems, Power Electronics & Drives for Hybrid, Electric & Fuel Cell Vehicles.
2. Wei Liu – Introduction to Hybrid Vehicle System Modelling and Control, Wiley.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: ENERGY STORAGE SYSTEMS FOR ELECTRIC VEHICLES

Course Code: EE514

Semester: I

Credits: L:T:P:C:: 3:0:0:3

Course Objective: The course enables students to develop comprehensive knowledge of energy storage systems for electric vehicles, including batteries, fuel cells, and hybrid storage technologies, and to apply concepts of modelling, performance evaluation, sizing, and power management for real-world EV applications.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyse the different types of energy storage systems and their performances to electric vehicles. (L4)
- CO2:** Investigate the depth analysis of fuel cell technology and its integration into electric vehicles. (L4)
- CO3:** Design and analysis of battery parameters and their performance measures for various types of batteries. (L6)
- CO4:** Evaluate the battery sizing for real-time driving patterns and investigate the battery testing and power management studies. (L5)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	-	-
CO2	2	1	3	1	-
CO3	2	2	3	1	-
CO4	2	2	3	2	-

Course Contents:

Module 1: Introduction to Energy Storage Requirements in Electric Vehicles **(10 Hours)**

Different types of energy storage: Mechanical: Flywheel-based energy storage; Chemical: Hydrogen production and storage; Electrical: Capacitors for EV, Super Capacitor, EDLC; Electrochemical: battery, fuel cell, biological, thermal; Magnetic Energy Storage, Superconducting Energy Storage systems, Hybridization of different energy storage devices. Modelling of various emerging storage systems – Simulation case studies.

Module 2: Introduction and overview of fuel cell technology **(10 Hours)**

low, medium and high temperature fuel cells - Types of fuel cells, liquid and methanol types, proton exchange membrane fuel cell, solid oxide, Microbial fuel cell, Thermodynamics of fuel cells, Fuel cell modelling-simulation and case studies, system integration, Safety issues and cost expectation and life cycle analysis of fuel cells, Placement of storage systems. Battery technology, Type of battery: Lead acid, Li-ion, Li-Polymer, Ni-MH, Ni-Cd and other advanced batteries for EV's. Battery modelling - simulation and case studies.

Module 3: Selection of battery cell and types **(10 Hours)**

Standardized sizes and shapes pertaining to both primary and secondary batteries, Selection of Key technical terms: End of life, Depth of Discharge (DoD), State of Charge (SoC), Cycling rate (C-rate), Study of Battery critical parameters selection (voltage of cell, Specific energy, Charge and Discharge rate, Cycle life, current density), Cell equalization problem. Thermal runaway, Battery series parallel connection and string size. Measurement, estimation and tracking of SoC. Battery mounting arrangement and installation methodology. State of health and charging efficiency and its effect on the life cycle for

various C-rates. Different battery management strategies, chemical properties, charge balancing, recyclability, salt - based batteries, solid state batteries, battery packaging, safety considerations. Combination of super capacitor and battery – the application perspective.

Module 4: Design and Applications of Energy Storage (10 Hours)

Battery sizing and stand-alone applications, Constant current and constant voltage charging methods, Hybrid Methods, Inductive chargers, Battery power testing for various vehicles, Battery testing for urban and highway driving cycles, Battery management systems and controls, control of charge discharge cycles. Case studies. Combination of super capacitor and battery – the application perspective.

Textbooks:

1. D. A. J. Rand, R. Woods, and R. M. Dell, “Batteries for Electric Vehicles,” Society of Automotive Engineers,” Warrendale PA, 2003.
2. A.G. Ter -Gazarian, “Energy Storage for Power Systems”, Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN – 978-1-84919-219-4), 2011.
3. Mehrdad Ehsani, Yimin Gao, and Ali Emadi, "Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals", CRC Press, 2010

References:

1. F. A. Silva and M. P. Kazmierkowski, "Energy Storage Systems for Electric Vehicles [Book News]," in IEEE Industrial Electronics Magazine, vol. 15, no. 4, pp. 93-94, Dec. 2021.
2. Electric Power Research Institute (USA), “Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits” (1020676), December 2010.
3. Paul Denholm, Erik Ela, Brendan Kirby, and Michael Milligan, “The Role of Energy Storage with Renewable Electricity Generation”, National Renewable Energy Laboratory (NREL) – A National Laboratory of the U.S. Department of Energy – Technical Report NREL/TP-6A2-47187, January 2010.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: ELECTRIC VEHICLES IN SMART GRID

Course Code: EE515

Semester: I

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to develop advanced knowledge of the integration of electric vehicles with smart grids, including charging strategies, grid impact analysis, ancillary services, ICT solutions, and planning of EV charging infrastructure for sustainable power systems.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze the impact of electric vehicle charging strategies and infrastructure on power grid performance and sustainability. (L4)
- CO2:** Evaluate the influence of EV penetration levels on power system demand under different charging scenarios. (L5)
- CO3:** Investigate the role of electric vehicles in providing ancillary services such as frequency control and voltage support. (L4)
- CO4:** Analyze ICT architectures and communication technologies enabling EV integration into smart grids. (L4)
- CO5:** Design EV charging facility planning strategies, including V2G systems and integration with renewable energy sources. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	-	-
CO2	2	1	3	1	-
CO3	2	1	3	1	-
CO4	2	2	3	1	-
CO5	2	2	3	2	-

Course Contents:

Module 1: Introduction

(9 Hours)

Introduction, Impact of charging strategies, EV charging options and infrastructure, energy, economic and environmental considerations, Impact of EV charging on power grid, effect of EV charging on generation and load profile, Smart charging technologies, Impact on investment.

Module 2: Influence of EVs on Power System

(9 Hours)

Introduction, identification of EV demand, EV penetration level for different scenarios, classification based on penetration level, EV impacts on system demand: dumb charging, multiple tariff charging, smart charging, case studies.

Module 3: Frequency Control Reserves & Voltage Support from EVs

(9 Hours)

Introduction, power system ancillary services, electric vehicles to support wind power integration, electric vehicles as frequency control reserves and tertiary reserves, voltage support and electric vehicle integration, properties of frequency regulation reserves, control strategies for EVs to support frequency regulation.

Module 4: ICT Solutions to Support EV Deployment

(9 Hours)

Introduction, Architecture and model for smart grid & EV, ICT players in smart grid, smart metering, information & communication models, functional and logical models, technology and solution for smart grid: interoperability, communication technologies.

Module 5: EV Charging Facility Planning

(9 Hours)

Energy generation scheduling, different power sources, fluctuant electricity, centralized charging schemes, decentralized charging schemes, energy storage integration into Microgrid, Design of V2G Aggregator.

Textbooks:

1. Crouse W.H, Anglin D.L, "Automotive Transmission and Power Train Construction", McGraw Hill, 1976.
2. Harald Naunheimer, Bernd Bertsche, Joachim Ryborz, Wolfgang Novak "Automotive Transmission: Fundamentals, Selection, Design and Application", 2nd Edition, Springer, 2011.

Reference:

1. Energy generation scheduling, different power sources, fluctuant electricity, centralized charging schemes, decentralized charging schemes, energy storage integration into Microgrid, Design of V2G Aggregator.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: ARTIFICIAL NEURAL NETWORK AND FUZZY LOGIC APPLICATIONS

Course Code: EE516

Semester: I

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to develop knowledge of artificial neural networks and fuzzy logic systems and to apply these intelligent techniques for modelling, control, and optimization of engineering systems, particularly in electrical and electric vehicle applications.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze fundamental concepts of artificial intelligence, neural networks, and fuzzy logic systems. (L4)
- CO2:** Design and implement artificial neural network models for engineering applications such as load forecasting, system identification, and control. (L6)
- CO3:** Develop fuzzy logic systems and controllers for solving nonlinear engineering problems. (L6)
- CO4:** Evaluate ANN and fuzzy logic techniques for modelling, control, and optimization of electrical and multidisciplinary systems. (L5)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	-
CO2	3	2	2	1	-
CO3	3	1	2	2	-
CO4	3	2	2	2	-

Course Contents:

Module 1: Introduction to Artificial Intelligence **(8 Hours)**

Introduction and motivation – Approaches to AI – Architectures of AI – Symbolic Reasoning System – Rule-based Systems – Knowledge Representation – Expert Systems.

Module 2: Artificial Neural Networks **(8 Hours)**

Basics of ANN - Comparison between Artificial and Biological Neural Networks – Basic Building Blocks of ANN – Artificial Neural Network Terminologies – McCulloch Pitts Neuron Model – Learning Rules – ADALINE and MADALINE Models – Perceptron Networks – Back Propagation Neural Networks – Associative Memories.

Module 3: ANN Applications to Electrical Systems **(8 Hours)**

ANN approach to: Electrical Load Forecasting Problem – System Identification –Control Systems – Pattern Recognition.

Module 4: Fuzzy Logic **(8 Hours)**

Classical Sets – Fuzzy Sets – Fuzzy Properties and Operations – Fuzzy Logic System– Fuzzification – Defuzzification – Membership Functions – Fuzzy Rule Base – Fuzzy Logic Controller Design.

Module 5: Fuzzy Logic Applications to Electrical Systems **(8 Hours)**

Fuzzy Logic Implementation for Induction Motor Control – Switched Reluctance Motor Control – Fuzzy Excitation Control Systems in Automatic Voltage Regulator – Fuzzy Logic Controller in an 18 Bus Bar System.

Textbooks:

1. S. N. Sivanandam, S. Sumathi and S. N. Deepa, “Introduction to Neural Networks using MATLAB”, McGraw Hill Edition, 2006
2. Timothy J. Ross, “Fuzzy Logic with Engineering Applications”, Third Edition, WILEY India Edition, 2012.

References:

1. S. N. Sivanandam, S. Sumathi and S. N. Deepa, “Introduction to Fuzzy Logic using MATLAB”, Springer International Edition, 2013.
2. Yung C. Shin and Chengying Xu, “Intelligent System – Modeling, Optimization & Control, CRC Press, 2009.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: EFFECTIVE TECHNICAL COMMUNICATION

Course Code: EE541

Semester: I

Credits: L:T:P:C::0:2:0:2

Course Objective: The course enables students to develop effective communication skills by enhancing their listening, speaking, reading, and writing abilities, with a focus on technical and professional contexts.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply effective communication techniques in technical and professional contexts. (L3)

CO2: Critically evaluate different principles of professional communication. (L5)

CO3: Analyze and interpret technical reports and research papers. (L4)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	1	3	1	-	1
CO2	-	3	2	-	1
CO3	1	3	2	-	1

Course Contents:

Module 1: Fundamentals of Communication **(9 Hours)**

7 Cs of communication, common errors in English, enriching vocabulary, styles, and registers.

Module 2: Aural-Oral Communication **(7 Hours)**

The art of listening, stress and intonation, group discussion, and oral presentation skills.

Module 3: Reading and Writing **(8 Hours)**

Types of reading, effective writing, business correspondence, interpretation of technical reports and research papers.

Textbooks:

1. Raman Sharma, "Technical Communication", Oxford University Press.
2. Thomas Huckin, Leslie Olsen, "Technical writing and Professional Communications for Non-native speakers of English", McGraw-Hill.

References:

1. Raymond Murphy "Essential English Grammar" (Elementary & Intermediate) Cambridge University Press.
2. Shirley Taylor, "Model Business Letters, Emails and Other Business Documents" (seventh edition), Prentise Hall

SEMESTER-II

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: VEHICLE DYNAMICS

Course Code: EE521

Semester: II

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to understand vehicle dynamics and acceleration, analyze braking performance, examine airflow mechanics around a vehicle, evaluate steady-state cornering behavior, and explore ride quality, suspension systems, and steering dynamics.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the vehicle dynamics and acceleration. (L4)

CO2: Evaluate the braking performance in vehicle deceleration. (L5)

CO3: Infer the mechanics of air flow around a vehicle. (L4)

CO4: Analyze the Steady State Cornering- low-speed and high-speed turning. (L4)

CO5: Evaluate suspension and steering systems affecting vehicle ride quality. (L5)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	1	-
CO2	3	1	2	1	-
CO3	3	1	2	2	-
CO4	3	2	3	2	-
CO5	3	1	2	2	-

Course Contents:

Module 1: Introduction to Vehicle Dynamics and Acceleration

(9 Hours)

Performance

Introduction to vehicle dynamics, Fundamental approach to modelling – Lumped mass, Vehicle fixed coordinate system, Motion variables, Earth fixed coordinate system, Euler angles, Forces, Newton's second law; Dynamic axle loads – Static loads on level ground, Low speed acceleration, Loads on grades; Power limited acceleration – Engines, Power train, Automatic transmissions; Traction limited acceleration – Transverse weight shift due to drive torque, Traction limits.

Module 2: Braking Performance

(7 Hours)

Basic equations – Constant deceleration, Deceleration with wind resistance, Energy, Power; Braking forces – Rolling resistance, Aerodynamic drag, Driveline drag, Grade; Brakes – Brake factor; Tire road friction – Velocity, Inflation pressure, vertical load.

Module 3: Road Loads

(8 Hours)

Mechanics of air flow around a vehicle, Pressure distribution on a vehicle, Aerodynamic forces, Drag components, Aerodynamic aids – Bumper spoilers, Air dams, Deck lid spoilers, Window and Pillar treatments, Optimization; Drag – Air density, Drag coefficient; Side force, Lift force, Pitching moment, Yawing moment, Rolling moment, Rolling resistance, Factors affecting rolling resistance, total road loads.

Module 4: Steady State Cornering

(8 Hours)

Introduction, Low speed turning, High-speed turning – Tire cornering forces, cornering equations, Understeer gradient, Characteristic speed, Critical speed, Lateral acceleration gain, Yaw velocity gain, Sideslip angle, Static margin; Suspension effects on cornering – Roll moment distribution, Camber change, Roll steer, Lateral force compliance steer, Aligning torque, Effect of tractive forces on cornering.

Module 5: Ride, Suspensions and Steering System

(8 Hours)

Frequency range of Ride and Noise, Excitation sources of Ride, Road roughness, Suspension isolation, Suspension stiffness, Suspension damping, Primary functions of suspension system, Four link, SLA front suspension, Multi link rear suspension, swing axle, Steering linkages, Steering geometry error, Front wheel geometry, Steering system forces and moments.

Textbooks:

1. Thomas D. Gillespie, Fundamentals of Vehicle Dynamics, Society of Automotive Engineers Inc, 1992.
2. Rajesh Rajamani, Vehicle Dynamics and Control, Springer, 2005.

References:

1. Reza N. Jazar, Vehicle Dynamics: Theory and Applications, Springer, 2008.
2. Hans B. Pacejka, Tyre and Vehicle Dynamics, Second Edition, Butterworth–Heinemann, 2006.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: EV CHARGING INFRASTRUCTURE AND ANALYSIS

Course Code: EE522

Semester: II

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to analyze the impact of EV charging on the power grid, design and evaluate various charging infrastructures, assess charging methodologies, and develop charger specifications along with communication protocol selection for different charging ports.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze the impact of EV charging on the power grid. (L4)

CO2: Design and analyze the various charging infrastructures and their selection and sizing. (L6)

CO3: Evaluate the various charging methodologies and analyze their performances. (L5)

CO4: Design charger specifications and select a communication protocol for various charging ports. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	2	-
CO2	3	1	3	2	-
CO3	2	1	3	2	-
CO4	2	1	3	2	-

Course Contents:

Module 1:

(10 Hours)

Introduction, EV charging options and infrastructure, energy, economic and environmental considerations, Impact of EV charging on power grid-distribution system, effect of EV charging on generation and load profile, Smart charging technologies, Identification of EV demand, EV penetration level for different scenarios, classification based on penetration level. General safety requirement for electric vehicle charging stations: IS/IEC 62305.

Module 2:

(9 Hours)

Types of charging stations and Charging Infrastructure, Battery Swapping Station, Move-and-charge zone. AC charging and DC charging - On board and off board charger specification - EVSE technical specification and charging time calculation - Selection and sizing of fast and slow charger (AC & DC) - AC Pile Charger, DC Pile Charger. Charging – Interoperability of chargers, impact of battery life due to chargers

Module 3:

(10 Hours)

Renewable Energy based Electric Vehicle Charging Station - Calculation and Selection - Components of Charging Station - Earth protection system for charging stations – Fire & safety aspects of charging stations, EV impacts on system demand: dumb charging, multiple tariff charging, smart charging, burp charging, negative pulse charging, random charging, high speed/fast charging, and different case studies of charging approach.

Module 4:

(11 Hours)

Selection of EVSE Communication Protocol (PLC / Ethernet / Modbus/ CAN Module) - Communication gateway - Specification of open charge point protocol (OCCP 1.6/2.0) - Bharat DC001 & AC001 Charger specification - Communication between AC charger and EV - Selection of DC charger connector GB/T, CHAdeMO, CCS-1 and CCS-2 - Communication methodology of DC fast chargers. IoT-based communication supporting systems for performance measures of EVs. Recent advancements in Vehicle to Grid (V2G) and Grid to Vehicle (G2V) technologies – Case Studies on EV charging. Reliability of charging stations – predictive approach and analysing for long-term maintenance-free operation. Significance of bathtub curve, reliability prediction based on working conditions.

Textbooks:

1. A. Khajepour, S. Fallah and A. Goodarzi, “Electric and Hybrid Vehicles Technologies, Modeling and Control: A Mechatronic Approach”, John Wiley & Sons Ltd, 2014.
2. Emadi, A. (Ed.), Miller, J., Ehsani, M., “Vehicular Electric Power Systems” Boca Raton, CRC Press, 2003

References:

1. Larminie, James, and John Lowry, “Electric Vehicle Technology Explained” John Wiley and Sons, 2012
2. Tariq Muneer and Irene IllescasGarcía, “The automobile, In Electric Vehicles: Prospects and Challenges”, Elsevier, 2017.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: BATTERY MANAGEMENT SYSTEMS

Course Code: EE523

Semester: II

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to understand and analyze various energy storage systems, battery characteristics, battery management systems, and battery recycling processes.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Evaluate performance parameters of EV batteries. (L5)

CO2: Compare various types of batteries used for EV applications. (L4)

CO3: Develop a battery charger for an EV. (L6)

CO4: Evaluate the application of various fuel cells in EVs. (L5)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	3	1	-
CO2	3	1	2	2	-
CO3	3	2	3	2	-
CO4	3	1	2	1	-

Course Contents:

Module 1:

(9 Hours)

Electrochemical reactions, Thermodynamic voltage, Specific Energy, Specific Power, Energy efficiency. Battery Specifications. Batteries: Lead Acid Battery, Nickel-based batteries, Sodium-based batteries, Lithium-based batteries– Li-ion & Li-poly, Metal Air Battery, Zinc Chloride battery; Ultra capacitors; Flywheel Energy Storage System; Hydraulic Energy Storage System; Comparison of different Energy Storage Systems.

Module 2:

(8 Hours)

Open-circuit voltage, State-of-charge dependence, Equivalent series resistance, Diffusion voltages, Rough parameter values, Warburg impedance, Hysteresis voltages, enhanced self-correcting cell model, Equipment for cell-data collection, tests to determine OCV relationship.

Module 3:

(7 Hours)

General approach to modelling batteries, simulation model of a rechargeable Li-ion battery, simulation model of a rechargeable NiCd battery, Parameterization of the NiCd battery model, Simulation examples.

Module 4:

(8 Hours)

Selection of battery for EVs & HEVs, Traction Battery Pack design, Requirement of Battery Monitoring, Battery State of Charge Estimation methods, Battery Cell equalization problem, thermal control, protection interface, SOC Estimation, Energy & Power estimation.

Module 5:

(8 Hours)

Battery Optimal Controls, Minimizing degradation, SEI formation and growth, SEI ROM results, Lithium plating on overcharging. Plating ROM results, Optimized power limits, Plug-in charging, Fast-charge example, Dynamic power calculation. Battery communication channel, Battery Pack Safety, Battery Standards & Tests.

Textbooks:

1. Mehrdad Ehsani, Yimin Gao, Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles_ Fundamentals, Theory, and Design, Second Edition”, CRC Press, 2010.
2. Gregory L. Plett, Battery Management Systems Volume I Battery Modeling, 2019.

References:

1. Gregory L. Plett, Battery Management Systems Volume II Equivalent-Circuit Methods, 2019
2. T R Crompton, “Battery Reference Book-3rd Edition”, Newnes- Reed Educational and Professional Publishing Ltd., 2000.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: SEMINAR-I

Course Code: EE524

Semester: II

Credits: L:T:P:C::0:0:2:1

Course Objective: The course enables students to develop report-writing and presentation skills by reviewing emerging technologies in Electric Vehicle Technology and effectively communicating their findings.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyze and identify emerging trends and promising directions in innovative technologies. (L4)

CO2: Develop structured technical reports on selected topics based on literature review. (L6)

CO3: Deliver effective oral presentations to communicate technical concepts clearly. (L3)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	3	-	1
CO2	2	3	2	-	1
CO3	2	3	2	2	1

Course contents:

Individual students will be asked to choose a current topic in any field of Electric Vehicle Technology in detail through a literature review. Prepare a detailed report- state of the art of the technology, methodology, applications, case studies, etc. and give a presentation of about thirty minutes. A committee (appointed by the HOD/Program coordinator) consisting of at least two faculty members specialized in the area will assess the report and presentation and award the marks to the students, and provide feedback for improvements, if necessary.

Evaluation:

Based on the report and oral presentation

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: BATTERY MANAGEMENT SYSTEMS LABORATORY

Course Code: EE525

Semester: II

Credits: L:T:P:C::0:0:2:1

Course Objective: The course aims to provide hands-on experience in simulating, designing, and analyzing battery management systems for electric vehicles, focusing on battery parameter estimation, charging/discharging characteristics, and system integration.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Investigate the impact on battery performance and its challenges. (L4)
- CO2:** Design a battery pack using different types of batteries for an EV application. (L6)
- CO3:** Construct the simulation model to design and analyze the performance of power converters in EV applications. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	3	1
CO2	3	2	3	3	1
CO3	3	2	3	3	1

List of Experiments (Any 8 experiments):

1. Simulation of the Equivalent circuit of a lead-acid and Lithium-Ion Battery.
2. Simulation of battery parameters measurement and estimation (Voltage, Current, SoC).
3. Simulation of battery parameters measurement and estimation (DoD, SoH, SoP).
4. Simulation of Passive battery management systems.
5. Simulate the Active battery management systems.
6. Simulate the Charging and discharging characteristics of a Battery.
7. Simulate the Ni-MH Battery Model with the DC machine and show the charging and discharging process using the DC machine
8. Simulate Closed-loop Implementation of a bidirectional DC-DC Converter with two batteries.
9. Design the 2S, 4P Battery pack with a passive BMS circuit.
10. Design a 4S, 4P Battery pack design with active BMS.
11. Implementation of CAN protocol on active and Passive BMS.
12. Simulation of Battery Charging by using a non-isolated DC – DC converter
13. Simulation of Battery Charging by using an AC–DC converter
14. Simulation of the battery charging system to analyze its impact on the power system.
15. Simulation of battery leakage current analysis.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: EV HARDWARE LABORATORY-II

Course Code: EE526

Semester: II

Credits: L:T:P:C::0:0:2:1

Course Objective: The course aims to provide hands-on experience in designing, implementing, and analyzing various power converters, charging systems, and control strategies for EV applications, including V2G, G2V, and wireless charging technologies.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Design different converters for EV charging applications. (L6)

CO2: Develop V2V, V2G, G2V charging system for EV. (L6)

CO3: Design PWM generation methods for power converters in EV applications. (L6)

CO4: Construct a hardware prototype for wireless EV charging. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	1
CO2	3	2	3	3	1
CO3	3	2	3	3	1
CO4	3	2	3	3	1

List of Experiments (Any 8 experiments):

1. To design an EV charging system using a buck converter.
2. To design an EV charging system using a boost converter.
3. To design a V2V EV charging system using a bidirectional buck-boost converter using OPAL-RT.
4. To design an EV charging system using a solar PV system.
5. To design a wireless EV charging system.
6. To design an EV charging system using a flyback converter.
7. To design an EV charging system from regenerative braking.
8. To study the PWM generation methods for power converters in EV charger applications.
9. To design a V2G and G2V operation of the EV charging system using OPAL-RT.
10. To design a V2H operation of the EV charging system using OPAL-RT.
11. To design and study the characteristics of a battery pack using a Li-ion battery.
12. To design the battery cooling system.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: SENSOR SYSTEMS FOR ELECTRIC VEHICLES

Course Code: EE531

Semester: II

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables the students to understand the principles of sensing and measurement, design and analyze measurement systems, and apply sensors for measuring physical parameters such as velocity, acceleration, strain, force, torque, and pressure.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze different types of sensors and actuators along with their performance characteristics. (L4)
- CO2:** Evaluate and select appropriate temperature and optical sensors based on standards and requirements. (L5)
- CO3:** Select the electric, magnetic and mechanical sensors for sensing the respective parameters in a multidisciplinary system. (L5)
- CO4:** Analyze and compare chemical, MEMS and smart sensors. (L4)
- CO5:** Design and implement interfacing circuits using microprocessors for sensors and actuators. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	-
CO2	2	1	2	1	-
CO3	2	1	2	1	-
CO4	2	1	2	-	-
CO5	2	2	2	2	-

Course Contents:

Module 1: Sensor fundamentals and characteristics **(8 Hours)**

Definitions, Classification of sensors and actuators, General requirements for interfacing, Performance characteristics of sensors and actuators

Module 2: Temperature & Optical sensors **(8 Hours)**

Temperature sensors: Thermoresistive sensors, Thermoelectric sensors, p-n junction temperature sensors.

Optical sensors: Quantum-based optical sensors, Photoelectric sensors, Charge coupled (CCD) sensors and detectors, Active far infrared (AFIR) sensors, Optical actuators

Module 3: Electric, magnetic and mechanical sensors **(9 Hours)**

Electric and magnetic sensors: Capacitive sensors - Capacitive position, proximity, and displacement sensors, Inductive sensor, eddy current sensor, Hall effect sensor, Voltage and current sensors.

Mechanical sensors: Force sensor, Acceleration sensor, Pressure sensor, Velocity sensor

Module 4: Chemical, MEMS and smart sensors **(8 Hours)**

Chemical sensors: Electrochemical sensors, Thermochemical sensors.

MEMS and smart sensors: MEMS sensors, Smart sensors, Wireless sensors and actuators and issues associated with their use, RFIDs and embedded sensors

Module 5: Interfacing methods and circuits & Interfacing to **(9 Hours)**

microprocessors

Interfacing methods and circuits: Amplifiers, Power amplifiers, Digital circuits.

Interfacing to microprocessors: The microprocessor as a general-purpose controller,
General requirements for interfacing sensors and actuators

Textbooks:

1. Nathan Ida, Sensors, Actuators and their interfaces, Second Edition, 2020, IET
2. Jacob Fraden, “Handbook of Modern Sensors: physics, Designs and Applications”, 2015, 3rd edition, Springer, New York.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: VEHICULAR NETWORKS AND COMMUNICATION

Course Code: EE532

Semester: II

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to develop advanced knowledge of vehicular communication networks, including in-vehicle bus systems, inter-vehicle communication protocols, and intelligent transportation systems, to analyze and design reliable and secure communication architectures for modern electric and connected vehicles.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze vehicular network architectures, bus systems, and their applications in modern automotive systems. (L4)
- CO2:** Evaluate vehicular communication technologies, including V2V, V2I, VANET, and wireless protocols for intelligent transportation systems. (L5)
- CO3:** Design and assess secure and efficient vehicular communication frameworks considering routing, medium access, and real-world constraints. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	-	-
CO2	2	1	2	1	-
CO3	2	2	2	2	-

Course Contents:

Module 1: Vehicular Networks

(12 Hours)

Vehicular Networks: Cross-System Functions, Requirements for Bus Systems, Classification of Bus Systems, Application In The Vehicle, Coupling of Networks, Examples of Networked Vehicles.

Module 2: Bus System

(12 Hours)

Bus Systems: CAN Bus, CAN-FD, LIN Bus, MOST Bus, Bluetooth, Flex Ray, Diagnostic Interfaces: Implementation of Body Electronics Functionalities Using Controllers.

Module 3: Vehicular Communication

(12 Hours)

Vehicular Communications: Intelligent Transportation Systems: IEEE 802.11p-ITS-IVC: Inter Vehicle Communications- Mobile Wireless Communications and Networks-Architecture Layers Communication Regime.V2V, V2I-VANET-WAVE; DSRC. Information In The Vehicle Network Routing-Physical Layer Technologies-Medium Access For Vehicular Communications- Security Applications and Case Studies.

Textbooks:

1. Dominique Paret, "Multiplexed Networks for Embedded Systems: CAN, LIN, FlexRay, Safe-by-Wire", Wiley, 2007.
2. Dominique Paret, "FlexRay and its Applications: Real Time Multiplexed Networks", Second Edition, Wiley, 2012.

References:

1. Xiang W, "Wireless Access in Vehicular Environments Technology", Springer, 2015.

2. Laun T.H, Shen X.(Sherman) and Bai F, “Enabling Content Distribution in Vehicular AdHoc Networks”, Springer, 2014.
3. Popescu-Zeletin R, Radusch I and Rigani M.A, “Vehicular-2-X Communication”, Springer,2010.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: DIGITAL CONTROL SYSTEMS

Course Code: EE533

Semester: II

Credits: L:T:P:C::3:0:0:3

Course Objective: The course should enable the students to develop a strong foundation in digital control systems, including modelling, analysis, and design of discrete-time control systems, and to apply digital control techniques and intelligent control strategies for real-world engineering and industrial automation problems.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Develop mathematical models for controlling system behavior. (L6)
- CO2:** Apply the z-transform to digital control systems for nonlinear behavior. (L3)
- CO3:** Analyze and apply digital control concepts for multidisciplinary engineering applications. (L4)
- CO4:** Evaluate intelligent and smart control strategies used in industrial automation systems. (L5)
- CO5:** Design digital control algorithms and compensators using root locus and z-plane techniques. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	-
CO2	2	1	2	1	-
CO3	2	1	2	1	-
CO4	2	1	2	2	-
CO5	2	2	2	2	-

Course Contents:

Module 1: Introduction

(8 Hours)

Control System Terminology, Computer-Based Control: History and Trends, An Overview of the Classical Approach to Analog Controller Design.

Module 2: Signal Processing in Digital Control

(9 Hours)

Configuration of the Basic Digital Control Scheme, Principles of Signal Conversion, Discrete Time Signals, Time-Domain Models for Discrete-Time Systems, The z-Transform, Transfer Function Models, Frequency Response, Stability on the z-Plane and the Jury Stability Criterion.

Module 3: Sample-And-Hold Systems

(8 Hours)

The Sampling operation, The Hold operation, Practical Sample-and-Hold Circuit, Sampled Spectra and Aliasing, Reconstruction of Analog Signals, Practical Aspects of the Choice of Sampling Rate, Principles of Discretization.

Module 4: Models of Digital Control Devices and Systems

(9 Hours)

z-Domain Description of Sampled Continuous-Time Plants, z-Domain Description of Systems with Dead-Time, Implementation of Digital Controllers, Tunable PID Controllers, Digital Temperature Control System, Digital Position Control System, Stepping Motors and Their Control, Programmable Logic Controllers.

Module 5: Design of Digital Control Algorithms

(9 Hours)

Z Plane Specifications of Control System Design, Digital Compensator Design using Frequency Response Plots, Digital Compensator Design using Root Locus Plots, z-Plane Synthesis

Textbooks:

1. M.Gopal, "Digital Control and State Variable Methods", McGraw-Hill Education.
2. Hemchandra Madhusudan Shertukde, "Digital Control Applications Illustrated with MATLAB" 2015, CRC Press

References:

1. B.C.Kuo, "Digital Control Systems", Oxford University Press, New Delhi
2. Ioan Doré Landau, Gianluca Zito, "Digital Control Systems: Design, Identification and Implementation", Springer-Verlag

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: COMPUTER AIDED DESIGN OF ELECTRIC MACHINES

Course Code: EE534

Semester: II

Credits:3:0:0:3

Course Objective: The course enables students to develop advanced knowledge of computer-aided design and optimization techniques for electrical machines, and to apply modelling, analysis, and finite element methods for the design and performance evaluation of various electric machines.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze design principles, constraints, and optimization techniques for electrical machines using computer-aided methods. (L4)
- CO2:** Apply fundamental design concepts, including magnetic circuits, thermal considerations, and material selection for electric machines. (L3)
- CO3:** Develop and implement computer-aided design models for DC machines using programming and FEM tools. (L6)
- CO4:** Design and analyze induction motors and special machines (BLDC, SRM, PMSM) using computer-aided and FEM-based approaches. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	1	-
CO2	2	1	3	1	-
CO3	2	2	3	2	-
CO4	2	2	3	2	-

Course Contents:

Module 1: Concept of Computer-Aided Design and Optimization **(9 Hours)**

Introduction; Computer Aided Design; Explanation of details of flow chart; Input data to be fed into the program; Applicable constraints Max or Minimum permissible limits; Output data to be printed after execution of program; Various objective parameters for optimization in an electrical machine; Selection of optimal design; Explanation of lowest cost and significance of "Kg/KVA"; Flowcharts.

Module 2: Basic Concepts of Design **(10 Hours)**

Introduction; Specification; Output coefficient; Importance of specific loadings; Electrical Materials: Conducting Materials, Insulating Materials and Magnetic Materials; Magnetic circuit calculations; General procedure for calculation of Amp-Turns; Heating and Cooling; Modes of heat dissipation; Standard ratings of Electrical machines; Ventilation in rotating machines; Quantity of cooling medium; Types of enclosures; General design procedure; Steps to get optimal design. Application of the finite element method in design.

Module 3: Computer-Aided Design of DC Machines **(8 Hours)**

Introduction: Flowcharts and programs for computer-aided design of DC machines. 2D FEM open source software-based DC machine part design.

Module 4: Computer-Aided Design of Induction Motor and Special **(9 Hours)**

Machines

COMPUTER AIDED DESIGN OF INDUCTION MOTOR: Introduction, Flowcharts and programs for computer-aided design of Induction motor, 2D FEM open source software-based Induction motor part design, COMPUTER AIDED DESIGN OF BLDC, SRM and PMSM motors.

Textbooks:

1. K M Vishnu Murthy, Computer-aided design of electrical machines. B S Publications.
2. Dr. M. Ramamoorthy. Computer- Aided Design of Electrical Equipment. Affiliated EastWest press Pvt. Ltd. New Delhi.

References:

1. S.K. Sen, Principles of Electrical Machine Design with Computer Programmes. Oxford & IBH Publishing Co.
2. R. Krishnan, Switched Reluctance Motor Drives: Modeling, Simulation, Analysis, Design, and applications, CRC Press.
3. Maurya, Jallan, Shukla, Computer-aided design of electrical machines. Kataria publication.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: OPTIMIZATION TECHNIQUES

Course Code: EE535

Semester: II

Credits: L:T:P:C::3:0:0:3

Course Objective: The course enables students to develop a strong foundation in classical and modern optimization techniques and to apply these methods for solving complex engineering problems, particularly in power systems and electric vehicle applications.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze and formulate optimization problems using classical techniques such as linear, nonlinear, and constrained optimization methods. (L6)
- CO2:** Apply linear programming and related methods to solve engineering optimization problems. (L3)
- CO3:** Evaluate and implement evolutionary optimization techniques such as Genetic Algorithms and Particle Swarm Optimization. (L5)
- CO4:** Develop and analyze advanced optimization algorithms, such as Differential Evolution and apply them to real-world power system problems. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	-
CO2	2	1	2	1	-
CO3	2	2	2	1	-
CO4	2	2	2	2	-

Course Contents:

Module 1: Fundamentals of optimization techniques **(10 Hours)**

Definition-Classification of optimization problems-Unconstrained and Constrained optimization Optimality conditions-Classical Optimization techniques (Lamda Iteration method, Linear programming, Quadratic programming). Brief introduction to lamda iteration method, formulate the Lagrange function, Lamda iteration method to solve Optimal dispatch problem. Introduction to quadratic programming, Working principle, sequential programming, Linear constrained optimization problem, Karush-Kuhn-Tucker conditions and its application to solve various problems, Interior point method, Lagrangian duality.

Module 2: Linear programming **(9 Hours)**

Examples of linear programming problems, The Simplex Method I, Fundamental theorem of linear programming, Weak and strong duality theorems, Integer programming, Network flow, develop a linear programming model from problem description.

Module 3: Genetic Algorithm **(9 Hours)**

Introduction to Genetic Algorithm, working principle, Principles of Genetic Algorithm-Evolutionary Strategy and Evolutionary Programming-Genetic Operators-Selection, Crossover and Mutation fitness function. GA operators; Similarities and differences between GA and traditional methods; Unconstrained and constrained optimization using Genetic Algorithm.

Module 4: Particle Swarm Optimization **(9 Hours)**

Fundamental principle-Velocity Updating-Advanced operators-Parameter selection- Hybrid approaches (Hybrid of GA and PSO, Hybrid of EP and PSO) -Binary, discrete and combinatorial.

Module 5: Differential Evolution

(9 Hours)

Fundamental principle, developing DE-based solution techniques for OPF problems with single and multiple objectives and comparing the performance and computational effectiveness of DE with other evolutionary and conventional techniques.

Application of population-based optimization techniques in power systems: Algorithms and flow chart of various optimization techniques for solving economic load dispatch and hydro-thermal scheduling problem.

Textbooks:

1. S.S.Rao, Engineering Optimization, 3rd Edition, New Age International (P) Ltd.
2. K. P. Chong, Stanislaw H. Zak, An Introduction to Optimization, 3rd Edition.

References:

1. Optimization on Power System Operation by Jizhong Zhu Wiley-IEEE Press.
2. Soft computing Technique and its application in electrical Engineering by Chaturvedi.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: TESTING AND CERTIFICATION OF ELECTRIC VEHICLES

Course Code: EE536

Semester: II

Credits: L:T:P:C:: 3:0:0:3

Course Objective: The course enables students to develop comprehensive knowledge of testing, certification, and regulatory standards for electric vehicles, and to analyze battery, motor, vehicle performance, and charging systems to ensure safety, reliability, and compliance for real-world applications.

Course Outcomes:

Upon successful completion of this course, students will be able to:

- CO1:** Analyze battery performance, safety, and lifecycle testing standards for electric vehicles. (L4)
- CO2:** Evaluate electric motor characteristics including performance, efficiency, thermal behavior, and regenerative braking. (L5)
- CO3:** Develop and analyze durability and vehicle performance testing under laboratory and real-world conditions. (L6)
- CO4:** Assess EV certification standards and charger testing procedures for compliance with national and international regulations. (L5)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	1
CO2	2	1	2	1	1
CO3	2	2	2	2	1
CO4	2	2	2	1	1

Course Contents:

Module 1: Battery performance safety test **(9 Hours)**

Evaluation testing of Battery as per AIS 048, ECE R100, USABC, etc., performance testing, life-cycle testing and safety/abusive testing, Material Characterization of battery electrodes and electrolytes.

Module 2: Electric Motor Characterization **(9 Hours)**

Net Power, Power & Efficiency as per AIS 041, ECE R85. Reliability, durability and overload capacity. Evaluation of torque, speed, motor characteristics Regenerative braking test. Thermal Characteristics.

Module 3: Durability Tests of Electric Vehicle **(8 Hours)**

Lab simulation of tracks. Simulations for environmental conditions like temperature and humidity

Module 4: Vehicle Performance **(9 Hours)**

Chassis Dynamometer and Test Tracks – Electric energy consumption as per AIS 039 and ECE R101. Electric range as per AIS 040 and ECE R101. Power at wheels as per AIS 041. Brakes, gradeability, noise.

Module 5: Charger Testing **(9 Hours)**

Certification – Testing as per AIS 138, Testing as per Bharat EV Charger specification AC001 and DC001.

Reference:

- Standards as per ARAI, Pune. <https://www.araiindia.com/>
- Standards as per the production of the e-motor company, <https://pureev.in/>

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle Technology

Course Title: INDIAN KNOWLEDGE SYSTEMS IN ELECTRICAL ENGINEERING

Course Code: EE542

Semester: II

Credits: L:T:P:C::1:1:0:2

Course Objective: The course integrates classical Indian scientific thought with modern Electrical Engineering domains such as power systems, signal processing, materials science, and sustainable energy. It promotes Multidisciplinary learning, Critical thinking, Ethical engineering practice, Indigenous knowledge integration, and Research orientation

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Analyse the epistemological foundations of Indian Knowledge Systems. (L4)

CO2: Analyse traditional Indian scientific contributions relevant to electrical engineering. (L4)

CO3: Evaluate historical claims using scientific methodology. (L5)

CO4: Integrate sustainability principles from IKS into modern electrical systems. (L6)

CO5: Develop research-oriented interdisciplinary perspectives. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	1	1	1	1	3
CO2	2	-	2	-	2
CO3	2	1	2	-	2
CO4	1	-	2	1	3
CO5	2	2	1	1	3

Course Contents:

Module 1: Foundations of Indian Knowledge Systems **(8 Hours)**

Overview of IKS framework, Pramana (means of knowledge), Nyaya logic and inference, Vaisheshika categories and physical realism, Systems thinking in Indian philosophy.

Module 2: Concept of Energy and Natural Philosophy **(7 Hours)**

Concept of Agni and energy transformation, Panchamahabhuta theory, Cyclical cosmology and conservation analogies, Thermodynamic interpretations.

Module 3: Ancient Indian Metallurgy & Electrical Materials **(7 Hours)**

Corrosion-resistant iron technologies, Zinc distillation at Zawar, Wootz steel, Implications for conductor and magnetic materials.

Module 4: Mathematical Foundations Relevant to EE **(7 Hours)**

Binary system of Pingala, Infinite series by Madhava of Sangamagrama, Geometry of Sulba Sutras, Links to digital systems & signal processing.

Module 5: Sustainable Systems and Decentralized Energy **(7 Hours)**

Water harvesting systems, Stepwell hydraulic engineering, Temple energy design principles, Microgrid analogies.

Textbooks:

1. Kapil Kapoor and R. S. Bhardwaj, "Indian Knowledge Systems", D. K. Printworld, New Delhi, 2005.
2. Sarvepalli Radhakrishnan, "Indian Philosophy Vol I&II", Oxford University Press, (rev. 1929).

References:

1. R. Balasubramaniam, “Delhi Iron Pillar, metallurgy, and Indian heritage”, Foundation Books / Cambridge University Press India, 2002.
2. A.K. Datta and A.N. Singh, “History of Hindu Mathematics Vol: I&II”, University of Lucknow, India, 1935–1938
3. Dr. Giridhar Boray(compiler) “The Bhagavad Gita (Based on HH Sri Raghavendra Teertha’s Gita Vivruti)” Sri A.V. Dharma Reddy, IDES Executive Officer, Tirumala Tirupati Devasthanams, Tirupati, 2023

SEMESTER-III

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: SUMMER INTERNSHIP

Course Code: EE601

Semester: III

Credits: L:T:P:C::0:0:0:2

Course Objective: The course aims to provide students with practical exposure to industrial environments, enhancing their technical skills, problem-solving abilities, and understanding of real-world applications in EV technology.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Apply industry practices and gain hands-on experience in electric vehicle technology. (L3)

CO2: Analyze and apply engineering knowledge to solve real-world industrial problems. (L4)

CO3: Develop technical report-writing and presentation skills based on industrial training. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	2
CO2	3	3	3	3	3
CO3	3	3	3	3	3

Industry/Institution Selection Process:

1. Students can choose a reputed industry/other institute for industrial training in the field of EV technology.
2. The selected industry/other institute must be evaluated and approved by a committee consisting of the HOD and two faculty members from the department.

Evaluation:

Exit Option for PG Diploma in Electrical Engineering with Specialization in Electric Vehicle Technology:

- Students opting for the exit option must complete a six- to eight-week industrial training from a reputed industry.
- They must submit a training completion certificate from the industry.
- A brief presentation summarizing the training experience and learning outcomes is required.

Continuation for M.Tech in Electrical Engineering with Specialization in Electric Vehicle Technology:

- Students who continue in the M.Tech program must complete a four- to six-week industrial/academic training during the vacation.
- They must submit a detailed technical report summarizing their learning and contributions.
- The evaluation will be conducted in the 3rd semester as per the assessment criteria.

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: PROJECT PHASE-I

Course Code: EE602

Semester: III

Credits: L:T:P:C::0:0:36:18

Course Objective: The course aims to equip students with research, analytical, and presentation skills by independently identifying, evaluating, and working on a dissertation topic in Electrical Engineering or interdisciplinary fields.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Identify key research and development topics in the field of the chosen dissertation area (Power Systems, Power electronics, Electrical machines, Energy systems, and any interdisciplinary area). (L4)

CO2: Identify, summarize, and critically evaluate relevant literature and write a literature review on the relevant topic. (L5)

CO3: Manage time effectively whilst working on independent research and prepare an action plan. (L6)

CO4: Show evidence of clarity of argument, understanding of the chosen topic area, and presentation of technical information. (L4)

CO5: Develop research presentations and reports. (L6)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	3	3
CO2	3	3	2	3	2
CO3	2	3	2	3	3
CO4	3	3	3	2	2
CO5	2	3	2	2	3

Course Contents:

The M. Tech. project is aimed at training the students to analyze independently any problem in the field of Electrical Engineering or interdisciplinary. The project may be analytical, computational, experimental or a combination of three. The project report is expected to show clarity of thoughts and expression, critical appreciation of the existing literature and analytical, experimental, and computational aptitude. The student's progress in the dissertation work will be evaluated by the departmental evaluation committee.

OR

The M. Tech project can be carried out at any reputed industry/other institute. Each student should identify a challenging topic in the area of EV Engineering, which can be done as a project with in one semester time span under the guidance of any faculty from the Institute. He/she shall have guides from both the institute and the industry/other institutes. The student has to study the topic and relevant literature to identify the problem based on challenges, objectives,

methodology, probable outcomes and work-time flow. Based on these, he/she shall submit a proposal. The problem shall be of sufficient size and challenging to come up with innovative solutions. A committee (appointed by the HOD/Programme coordinator) consisting of at least two faculty members specialized in the area, and the proposed guide will review the proposal, approve to continue, or suggest modifications. Students can utilize the laboratory setups, software available. In addition, they can take necessary data/information from industries/other technical institutions to improve the standard of the work. There will be review meetings to assess the progress of the work during the semester. If he/she is doing the project based on the industrial problem, as a part of the internship in a reputed industry, there will be a guide from the industry also. After the completion of the work, students have to give oral presentations with a hardware demonstration that would be evaluated by the committee. Once the committee approves the work, the student can submit a detailed report in the prescribed format and get it duly signed by the guide and attested by the HOD.

Evaluation:

The evaluation will be performed at the MTU. Based on technical contributions, hardware assembly and results, report, presentation and patent/publications. Appropriate weightages for interim and final evaluations.

References:

1. Various books, research papers, patents and IPRs on the topic selected for the dissertation.

SEMESTER-IV

Manipur Technical University

Master of Technology in Electrical Engineering with specialization in Electric Vehicle
Technology

Course Title: PROJECT PHASE-II

Course Code: EE603

Semester: IV

Credits: L:T:P:C::0:0:40:20

Course Objective: The course aims to equip students with research, analytical, and presentation skills by independently identifying, evaluating, and working on a dissertation topic in Electrical Engineering or interdisciplinary fields.

Course Outcomes:

Upon successful completion of this course, students will be able to:

CO1: Manage time and resources effectively whilst working on independent research. (L6)

CO2: Identify, analyze, and interpret suitable data to enable the research question to be answered. (L4)

CO3: Model, simulate/ develop innovative hardware/ develop new algorithms/ emulate/ HIL/ develop prototype for the selected topic. (L6)

CO4: Describe the process of carrying out independent research in written format and report your results and conclusions with reference to existing literature, and analyze and synthesize research findings. (L5)

CO5: Use and develop written and oral presentation skills and prepare good technical project reports for publication in journals and conferences. (L6)

CO6: Take up challenging issues in the industry and provide solutions. (L5)

CO-PO mapping matrix:

CO/PO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	3	3
CO2	3	3	3	2	2
CO3	3	3	3	2	3
CO4	3	3	3	2	2
CO5	2	3	2	2	3
CO6	3	3	3	3	3

Course Contents:

The M. Tech. project is aimed at training the students to analyze independently any problem in the field of Electrical Engineering or interdisciplinary. The project may be analytical, computational, experimental or a combination of three. The project report is expected to show clarity of thoughts and expression, critical appreciation of the existing literature and analytical, experimental, and computational aptitude. The student's progress in the dissertation work will be evaluated by the departmental evaluation committee.

OR

The M. Tech project can be carried out at any reputed industry/other institute. Each student should identify a challenging topic in the area of EV Engineering, which can be done as a project within a one-semester time span under the guidance of any faculty from the Institute.

He/she shall have guides from both the institute and the industry/other institutes. The student has to study the topic and relevant literature to identify a problem based on challenges, objectives, methodology, probable outcomes and work-time flow. Based on these, he/she shall submit a proposal. The problem shall be of sufficient size and challenging to come up with innovative solutions. A committee (appointed by the HOD/Programme coordinator) consisting of at least two faculty members specialized in the area, and the proposed guide will review the proposal, approve to continue or suggest modifications. Students can utilize the laboratory setups and the software available. In addition, they can take necessary data/information from industries/other technical institutions to improve the standard of the work. There will be review meetings to assess the progress of the work during the semester. If he/she is doing the project based on the industrial problem, as a part of the internship in a reputed industry, there will be a guide from the industry also. After the completion of the work, students have to give oral presentations with a hardware demonstration that would be evaluated by the committee. Once the committee approves the work, the student can submit a detailed report in the prescribed format and get it duly signed by the guide and attested by the HOD.

Evaluation:

The evaluation will be performed at the MTU. Based on technical contributions, hardware assembly and results, report, presentation and patent/publications. Appropriate weightages for interim and final evaluations.

References:

1. Various books, research papers, patents and IPRs on the topic selected for the dissertation.