RAMDEOBABA UNIVERSITY, NAGPUR– 440013

(Formerly, Shri Ramdeobaba College of Engineering and Management, Nagpur 440013)

School of Electrical and Electronics Engineering

Department of Electrical Engineering

Teaching and Evaluation Scheme and Syllabi

(as per National Education Policy-2020)

M. Tech. in Electrical Engineering
(Electrical Vehicle Technology)

(With effect from Academic Year 2024-25)

Electric Vehicle deals with the vehicular systems that are electrically powered. The transition to electric vehicle is a promising global strategy for decarbonizing the transport sector. India is among a few countries that support the global EV30@30 campaign, which targets to have at least 30% new vehicle sales be electric by 2030. This has led to the growing demand for graduates and post graduates in B. Tech and M. Tech in Electric Vehicle Technology.

This post graduate program is focused on the design, development, and implementation of electric vehicle technology. The course will help the students in exploring and addressing the opportunities along with the challenges in implementing this automotive technology.

Primary goal of this programme in Electric vehicles is to provide students with engineering skills and foundational knowledge needed to excel as leaders in the modern-day mobility industry as well as take up the research challenges.

Program Features and Scope:

The specialized courses in areas such as electric vehicle design, energy storage system, EV communication, Motor control are also included in the programme.

The programme provides flexibility through wide range of electives and allows students to specialize in the area of electric vehicles, charging infrastructure and develop programming skills. Students can acquire skill sets of designing the microcontroller system, power electronics converter and EV battery system etc. The topics like EV policies and regulation, Internet of Things (IoT) applications in EV sector has also been covered.

This course may also offer opportunities for hands-on experience through internships, minor and major project work. Students may work on projects such as designing and analyzing various systems for electric vehicles, charging infrastructure and battery performance estimation. Program has provision for internship/ on-job training at IV semester level, in which student can work in the industry or other reputed Institutes for one complete semester.

After course completion, students have a plethora of career options, including roles in automotive companies, electric vehicle manufacturers, research and development organizations, and government agencies. They may work as design engineers, systems engineers, research scientists, or project managers, among other roles. Additionally, this excellent specialization can serve as a foundation for further education. Students can also make career as an entrepreneur in Energy sector/ E-Mobility and as consultants in allied fields.

Program Educational Objectives

PEO1. To mould the students to improve their technical and intellectual capability in Electric Vehicle applications and to develop interest for life-long learning.

PEO2. To prepare the students to acquire the knowledge, skills, qualities and values necessary for employment in areas related with Electric Vehicles.

PEO3. To prepare and inspire the students to become future researcher/good teacher/technocrat/ with innovative idea for sustainable development.

Program Outcomes

After completion of the program, the students shall have,

PO1. An ability to carry out independent research/investigation and development work to solve practical problems.

PO2. An ability to write and present a substantial technical report/document.

PO3. An ability to demonstrate a degree of mastery over the area in Electric Vehicle applications.

Program Specific Outcomes

After completion of the program, the students shall have,

PSO1. An ability to understand, analyse and design the electrical devices, power converters and control circuit for electric vehicle applications.

PSO2. An ability to learn, utilize and develop modern tools for modelling, analysing and solving various engineering problems related to electric vehicle applications.

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School of Electrical and Electronics Engineering
Department of Electrical Engineering
M. Tech in Electrical Engineering (Electric Vehicle Technology)
To be implemented from Session: 2024-2025

Semester I

Sr. No.	Course Type	Course Code	Course	L	P	C	Continuous Assessment	End Semester/Internal Evaluation	Total	Duration of End Semester
1	PCC	24EE52TH1175	Advanced Power Electronics	4	0	4	50	50	100	3 Hrs.
2	PCC	24EE52PR1175	Advanced Power Electronics Lab	0	2	1	25	25	50	---
3	PCC	24EE52TH1176	Fundamentals of Electric Vehicles	4	0	4	50	50	100	3 Hrs.
4	PCC	24EE52TH1177	Microcontroller: Programming and System Design	4	0	4	50	50	100	3 Hrs.
5	PCC	24EE52PR1177	Microcontroller: Programming and System Design Lab	0	2	1	25	25	50	---
6	PCC	24EE52TH1178	EV Instrumentation and Communication	3	0	3	50	50	100	3 Hrs.
7	PCC	24EE52PR1178	EV Instrumentation and Communication Lab	0	2	1	25	25	50	---
8	PEC	*	Program Elective-I	3	0	3	50	50	100	3 Hrs.
9	SEC	24EE52PR1180	Simulation Tools Lab-I	0	2	1	25	25	50	---
10	SEC	24H02PR1176	Professional Communication and Employability Skills	0	2	1	25	25	50	---
11	MLC	24EE52TH1181	Research Methodology and IPR	2	0	2	50	50	100	2 Hrs.
			TOTAL	**20**	**10**	**25**			**900**	

Program Elective-I	
Course Code*	**Course**
24EE52TH1179-1	Optimization Techniques in Artificial Intelligence
24EE52TH1179-2	Digital Signal Processing
24EE52TH1179-3	IoT and It's Application in EV Sector
24EE52TH1179-4	Industry Offered Elective-I
24EE52TH1179-5	Equivalent SWAYAM NPTEL/MOOC course approved by the Department

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Semester II

Sr. No.	Course Type	Course Code	Course	L	P	C	Continuous Assessment	End Semester/Internal Evaluation	Total	Duration of End Semester
1	PCC	24EE52TH1275	EV Drives and Control	4	0	4	50	50	100	3 Hrs.
2	PCC	24EE52PR1275	EV Drives and Control Lab	0	2	1	25	25	50	---
3	PCC	24EE52TH1276	Energy Storage Systems	4	0	4	50	50	100	3Hrs.
4	PCC	24EE52PR1276	Energy Storage Systems Lab	0	2	1	25	25	50	-
5	PCC	24EE52TH1277	Microcontroller Applications in Power Converter	4	0	4	50	50	100	3Hrs.
6	PEC	*	Program Elective-II	3	0	3	50	50	100	3 Hrs.
7	PEC	**	Program Elective-III	3	0	3	50	50	100	3 Hrs.
8	OE	***	Open Elective	3	0	3	50	50	100	3Hrs.
9	Project/ VSEC	24EE52PR1281	Participative Learning	0	4	2	25	25	50	--
			TOTAL	**21**	**06**	**25**			**750**	

Course Code*	Program Elective - II
24EE52TH1278-1	EV Chargers and Charging Infrastructures
24EE52TH1278-2	Design of Battery Management System
24EE52TH1278-3	Power Quality
24EE52TH1278-4	Industry Offered Elective-II
24EE52TH1278-5	Equivalent SWAYAM NPTEL/MOOC course approved by the Department

Course Code**	Program Elective -III
24EE52TH1279-1	EV Policies and regulations
24EE52TH1279-2	Energy Management Strategies in EV
24EE52TH1279-3	Industry Offered Elective-III
24EE52TH1279-4	Equivalent SWAYAM NPTEL/MOOC course approved by the Department

Open Elective*	
Course Code	Course
24EE52TH1280-1	Hydrogen and Fuel Cell Technology
24EE52TH1280-2	Equivalent SWAYAM NPTEL/MOOC course approved by the Department
24EE52TH1280-3	Industry Offered Elective-IV

Exit option: Award of PG Diploma in Electrical Engineering (Electric Vehicle Technology) after the completion of 50 credits and an additional 8 credits.

Sr. No.	Course Code	Course Title	Lecture	Tutorial	Practical	Credits
1		EV Components and Design	3	0	0	3
2		Power Converter for EV Applications	3	0	0	3
3		Internship	Four weeks			2
OR						
1		Project/ Internship/On-Job Training (OJT)	Eight Weeks			8

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Semester III

Sr. No.	Course Type	Course Code	Course	L	P	C	Continuous Assessment	End Semester/Internal Evaluation	Total	Duration of End Semester
1.	PEC	*	Program Elective-IV	3	0	3	50	50	100	3 Hrs.
2.	PEC	**	Program Elective-V	3	0	3	50	50	100	3 Hrs.
3.	SEC	24EE52PR1377	Simulation Tools Lab-II	0	4	2	25	25	50	--
4.	AEC	24EE52PR1378	Hardware Implementation Lab	0	4	2	25	25	50	--
5.	Project/ VSEC	24EE52PR1379	Project Phase-I	0	8	4	100	100	200	--
			TOTAL	**6**	**12**	**14**			**500**	

OR

Sr. no.	Course Type	Course Code	Course Name	L	P	C	Continuous Assessment	End Semester/Internal Evaluation	Total	Duration of End Semester
1.	#PEC	*	Program Elective-IV	-	-	3	-	-	100	-
2.	#PEC	**	Program Elective -V	-	-	3	-	-	100	-.
3.	Project/ VSEC	24EE52PR1380	Industry Project / Research Internship	-	-	8	-	-	300	
			Total			**14**			**500**	

Program Elective – IV*	
24EE52TH1375-1	EV Components and Design
24EE52TH1375-2	AI Techniques for Power Converters
24EE52TH1375-3	Industry Offered Elective-V
24EE52TH1375-4	# Equivalent SWAYAM NPTEL/MOOC course approved by the Department

Program Elective –V**	
24EE52TH1376-1	Digital and Optimal Control Systems
24EE52TH1376-2	Power Converter for EV Applications
24EE52TH1376-3	Entrepreneurship in Electric Mobility
24EE52TH1376-4	Industry Offered Elective-VI
24EE52TH1376-5	# Equivalent SWAYAM NPTEL/MOOC course approved by the Department

Semester IV

Sr. No.	Course Type	Course Code	Course	L	P	C	Continuous Assessment	End Semester/Internal Evaluation	Total	Duration of End Semester
1.	Project /VSEC	24EE52PR1475	Project Phase – II	0	8	16	200	200	400	-
			TOTAL	**0**	**8**	**16**			**400**	

OR										
1.	Project /VSEC	24EE52PR1476	Industry Internship/ On Job Training	-	-	16	--	--	400	-
			TOTAL	**0**	**6**	**16**			**400**	

Semester I	
Course Code: 24EE52TH1175	**Course:** Advanced Power Electronics
L: 4Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 04
Compulsory	**Course Type: PCC**

Course Objectives:	
1	To understand the characteristics, capabilities, ratings, limitations and testing of various power semiconductor switches used for various Power Electronic applications.
2	To understand the performance and design of low frequency switched and high frequency switched AC to DC, AC to AC, DC to DC and DC to AC power electronic converters for various applications.
3	To understand the analysis of high frequency switched converters.
4	To expose the students to various types of power electronic devices and converter circuits including brief analysis and design concepts.

Course Outcomes: After completion of the course, students will be able to	
CO1	Understanding various power switching devices and their control.
CO 2	Applying various power electronic circuits for realization of AC-DC, AC-AC, DC-AC, DC-DC conversion.
CO 3	Analyzing the principle operation of pulse-width modulation and pulse frequency control of power electronic converters.
CO 4	Design of gate driver circuit, protection circuit & magnetic components required in power electronics converters.

Syllabus
Review of power semiconductor switching devices :- SCR, Triac, BJT, IGBT, MOSFET, GTO and modern devices, characteristics, , their turn-on and turn-off methods and applications.
Introduction to Turn-ON/Turn-OFF mechanism of switching devices:- Gate-drive circuits, Switching-aid circuits, protection, Heat sink design.

AC to AC Voltage converters : Dual converters, Multiphase converters ,single phase and three phase Cycloconverters, their applications, configurations, performance analysis, harmonics, introduction to Matrix converters and their applications.
DC-DC Converters: - pulse width modulation, Non-isolated and isolated Topologies, continuous and discontinuous modes of operations, steady-state analysis, energy storage elements design, higher-order topologies. Full-bridge dc-dc converters high power factor converter and their applications.
Inverters: - single and three-phase inverter configurations, voltage and current source inverters and their operating modes, voltage control inverters and harmonic reduction using PWM strategies. Harmonic reduction.
Multilevel Inverter: principles, topologies, control and applications

Textbooks:	
1	Fundamental of Power Electronics: Robert Erickson, D. Maksimovic
2	Power Electronics, Circuits, Devices and Applications: Muhammad H. Rashi

Reference Books:	
1	Power Electronics converters, Application and Design: Mohan N. Underland TM, Robbins WP., John Wiley & Sons.
2	Modern Power Electronics: P. C. Sen
3	Power Electronics and AC Drives: B. K. Bose, Prentice Hall, NJ, (1985).
4	Related IEEE papers/ NPTEL lectures.
5	Power Electronic, Devices, Applications, and Passive Components: Barry W. Williams
6	Power Electronics converters, Applications, and Design: Ned Mohan, Tore. M. Undeland, William P. Robbins
7	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52PR1175	**Course:** Advanced Power Electronics Lab
L: 0Hrs, **T**:0Hrs, **P**:2 Hrs per Week	**Total Credits:** 01
Compulsory	**Course Type: PCC**

Course Objectives:	
1	To make students conversant with characteristics of various power semiconductor switches e.g. Power MOSFET, IGBT, SCR, Triac etc.
2	To make student capable of using state of the arts test equipment's e.g. Digital Storage Oscilloscope, Power Quality Analyzer, Hall Effect Transducer etc.
3	To understand the various conversion techniques of AC to DC converter using phase angle & PWM control methods & its effect on power quality & power factor.
4	To understand the conversion of fixed AC to variable AC voltage & frequency.

Course Outcomes: After completion of the course, students will be able to	
CO1	Test power semiconductors switches & converters and select suitable switch for particular applications.
CO 2	Handle and use important test equipment's e.g. Power Quality Analyzer& DSO etc.
CO 3	Analyze input supply parameters while using different types of converters
CO 4	Use particular configuration of converter and inverters depending upon the availability of power supply & load requirement.

Experiments based on,
• Characteristics of semiconductor switches.
• Various types of AC & DC converters & their wave forms.
• Performance parameters of AC to AC, DC- DC and DC- AC converters

Textbooks:	
1	Power Electronics, circuit, Devices and applications: Rashid M.H., Prentice Hall of India.
2	Power Electronics Principles and Applications: Joseph Vithyathil, Tata Mc Graw Hill.

Reference Books:

1	Power Electronics converters, Application and Design: Mohan N. Underland TM, Robbins WP., John Wiley & Sons.
2	Modern Power Electronics: P. C. Sen
3	Power Electronics and AC Drives: B. K. Bose, Prentice Hall, NJ, (1985).
4	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52TH1176	**Course:** Fundamentals of Electric Vehicles
L: 4Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 04
Compulsory	**Course Type: PCC**

Course Objectives:
The objective of this course is to make the students familiar with architecture of electric and hybrid electric vehicles, various topologies, electric motor drives, energy storage devices, energy management strategies and charging systems used in EV and HEV.

Course Outcomes: After completion of the course, students will be able to	
CO1	Compare the conventional, hybrid and electric vehicles and need of EV.
CO 2	Understand the various aspects of electric and hybrid drive train topologies.
CO 3	Understand the working of advanced electric motors and their application in electric vehicles.
CO 4	Understand the various energy storage device, charging systems, converter used in electric and hybrid electric vehicles.

<u>Syllabus</u>
Environmental impact and history of modern transportation: Air Pollution, Global Warming, Petroleum resources etc., Comparison of internal combustion engine and electric vehicles. Electric vehicle Market.
Vehicle Dynamics: Tractive efforts, forces acting when a vehicle move-aerodynamic drag, rolling resistance and uphill resistance, Power and torque to accelerate, Drive cycle and Energy used per km.
Drive train of HEVs and EVs: Basic concept of HEV and EVs, classification of hybrid electric vehicles, Introduction to electric drive-train topologies, power flow control in electric drive-train topologies, Configurations and performance of EVs. Social and environmental importance of EV and HEV.

Energy Storage Devices: Battery, introduction to BMS, Fuel Cell, Super Capacitor and Flywheel
Advanced Motor Drives for Vehicular Applications: Induction Motor, Brushless dc motor drives, and switched reluctance motor drives.
Automotive power electronic converter: DC-DC converter, rectifier, Inverter**,** Case Study on HEV, BEV

Textbooks:	
1	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles - Fundamentals, Theory, and Design: M.Ehsani, Y. Gao, S. E. Gay and A. Emadi, CRC Press, 2004.
2	AC Motor Control & Electric Vehicle Applications by Kwang Hee Nam, CRC Press, Special Indian Edn, (Yes Dee Publishing Pvt. Ltd, Chennai) 2013.
3	Electric Vehicle Battery Systems by Sandeep Dhameja, Elsevier India Pvt. Ltd, 2013.
4	Electric and Hybrid Vehicles: T. Denton, Routledge, 2016
5	Electric and Hybrid Vehicles Design Fundamentals by Iqbal Husain, CRC Press

Reference Books:	
1	Recent IEEE papers
2	NPTEL Courses
3	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52TH1177	**Course:** Microcontroller Programming and System Design
L: 4Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 04
Compulsory	**Course Type: PCC**

Course Objectives:
The objective of this course is to make the students familiar with microcontroller, its programming and microcontroller-based system designing.

Course Outcomes: After completion of the course, students will be able to	
CO1	Understand the architecture and organization of microcontroller.
CO 2	Use assembly language and Embedded C for microcontroller programming.
CO 3	Understand the use of various peripherals for system designing.
CO 4	Design simple applications using microcontroller.

Syllabus
Introduction: Review of microcontrollers, architecture, memory organization, CPU details, Interrupt structure, addressing modes, peripheral Modules. Introduction to Instruction set.
Microcontroller Programming: Introduction, C Compiler, Integrated development environment, Introduction to GPIO, Timer, ADC, DAC, Memories; Serial Communication: Operation and Programming, Peripheral programming, Interrupt programming using C
Microcontroller based system design: Introduction to system design approach, Hardware development, firmware development. Microcontroller based application development.

Textbooks:	
1	The AVR microcontroller and Embedded systems using assembly and C, Muhammad Ali Mazdi, Sarmad Naimi and Sepher Naimi 2011, Prentice Hall.
2	Embedded C Programming and the Atmel AVR, Second Edition Richard Barnett, Larry O'Cull and Sarah Cox, Delmar, Cengage Learning
3	Go Embedded, Second Edition Asang Dani, Yeshwant Kanetkar, B.P.B. Publication.

Reference Books:	
1	Programming And Customizing the AVR Microcontroller by Dhananjay Gadre, Tata McGraw-Hill Education
2	Product Datasheets
3	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52PR1177	**Course:** Microcontroller Programming and System Design Lab
L: 0Hrs, **T**:0Hrs, **P**:2 Hrs per Week	**Total Credits:** 01
Compulsory	**Course Type: PCC**

Course Objectives:
The objectives of this laboratory course are to prepare students for Microcontroller programming, introduce the open source/proprietary development environment and make them acquainted with microcontroller development board.

Course Outcomes:
After completion of the course, students will be able to

CO1	Use open source or proprietary development environment and microcontroller development board for Microcontroller programming.
CO 2	Implement control algorithm using suitable programming language.
CO 3	Set up the circuit on microcontroller development board for testing of program.
CO 4	Debug the program to make it working.
CO 5	Design a small application based on microcontroller

Reference Books:

1	Product Datasheets
2	Laboratory manual
3	Open-source development tool guide
4	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52TH1178	**Course:** EV Instrumentation and Communication
L: 3Hrs, **T**:0Hrs, **P**:2Hrs per Week	**Total Credits:** 03
Compulsory	**Course Type: PCC**

Course Objectives:
To make the students familiar with the instrumentation and communication systems used in electric vehicle

Course Outcomes: After completion of the course, students will be able to	
CO1	Differentiate the different sensors in EV
CO 2	Describe about in –vehicle networking
CO 3	Explain the different network and communication protocol.

Syllabus
Module I – Sensors And Instrumentation Introduction, Architecture of Electronic Control Units, Voltage and Current Measurement, Temperature, Acceleration, Pressure, Velocity, Position, and Displacement Other Sensors, Reliability Constraints in Automotive Environment
Module II - Basics Of In-Vehicle Networking Overview of Data communication and networking –need for In-Vehicle networking – layers of OSI reference model –multiplexing and de-multiplexing concepts –vehicle buses.
Module III– Networks And Protocols Overview of general-purpose networks and protocols -Ethernet, TCP, UDP, IP, ARP, RARP - LIN standard overview –workflow concept-applications –LIN protocol specification –signals - Frame transfer –Frame types –Schedule tables –Task behaviour model –Network management –status management - overview of CAN –fundamentals –Message transfer – frame types-Error handling –fault confinement-Bit time requirements.
Module IV– Higher Layer Protocol

Introduction to CAN open –TTCAN –Device net -SAE J1939 - overview of data channels – Control channel-synchronous channel – asynchronous channel –Logical device model – functions-methods-properties-protocol basics- Network section-data transport –Blocks – frames –Preamble-boundary descriptor
Module V– Latest Trends Car networking protocols – Networking future trends –Roadmaps –Competitive advantage

Reference Books:	
1	J.Gabrielleen,"Automotive In-Vehicle Networks", John Wiley & Sons, Limited, 2008
2	Robert Bosch," Bosch Automotive Networking", Bentley publishers, 2007
3	Society of Automotive Engineers, "In-Vehicle Networks", 2002
4	Ronald K Jurgen, "Automotive Electronics Handbook", McGraw-Hill Inc. 1999
5	Indra Widjaja, Alberto Leon-Garcia, "Communication Networks: Fundamental Concepts and Key Architectures", McGraw-Hill College; 1st edition, 2000
6	Konrad Etschberger, "Controller Area Network, IXXAT Automation", August 22, 2001
7	Olaf Pfeiffer, Andrew Ayre, Christian Keydel, "Embedded Networking with CAN and CANopen", Annabooks/Rtc Books, 2003
8	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52PR1178	**Course:** EV Instrumentation and Communication Lab
L: 0Hrs, **T**:0Hrs, **P**:2Hrs per Week	**Total Credits:** 03
Compulsory	**Course Type: PCC**

Course Objectives:

To make the students familiar with the instrumentation and communication systems used in electric vehicle

Course Outcomes:

After completion of the course, students will be able to

CO1	Differentiate the different sensors in EV
CO 2	Describe about in –vehicle networking
CO 3	Differentiate the different communication protocol.

<u>List of Practical</u>

1. To study various types of sensors
2. To study dspace Microlab Box for sensing the voltage and current
3. To study voltage sensor CV3-500
4. To study RS 232 and RS 485 protocol
5. To study CAN protocol
6. To study LIN protocol
7. To study TCP-IP protocol
8. To study one wire protocol
9. To study MOST, Flex Ray and Bluetooth protocol
10. To study synchronous communication protocol (I2C, SPI and USB)

Reference Books:

1	J.Gabrielleen,"Automotive In-Vehicle Networks", John Wiley & Sons, Limited, 2008
2	Robert Bosch," Bosch Automotive Networking", Bentley publishers, 2007
3	Society of Automotive Engineers, "In-Vehicle Networks", 2002
4	Ronald K Jurgen, "Automotive Electronics Handbook", McGraw-Hill Inc. 1999
5	Indra Widjaja, Alberto Leon-Garcia, "Communication Networks: Fundamental Concepts and Key Architectures", McGraw-Hill College; 1st edition, 2000
6	Konrad Etschberger, "Controller Area Network, IXXAT Automation", August 22, 2001
7	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52TH1179-1	**Course:** Optimization Techniques in Artificial Intelligence
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Elective	**Course Type: PEC**

Course Outcomes: After completion of the course, students will be able to	
CO1	Learn how biological systems exploit natural processes.
CO 2	Analyze how complex and functional high-level phenomena can emerge from low-level interactions.
CO 3	Solve optimization problem by using evolutionary & Natural computation.
CO 4	Design and implement simple bio-inspired algorithms.

Syllabus
Introduction What is Life? Life and Information, The Logical Mechanisms of Life, what is Computation? Universal Computation and Computability, Computational Beauty of Nature (fractals-systems, Chaos) Bio- inspired computing, Natural computing, Biology through lens of computer science.
Complex Systems and Fuzzy Systems - Complex Systems and Artificial Life, Complex Networks Self Organization and Emergent Complex Behavior, Cellular Automata, Boolean Networks, Development and Morphogenesis, Open ended evolution, Introduction to Fuzzy Set Theory, Uncertainty and Fuzzy, Hedges and Alpha Cuts,Fuzzification Models, Methods of Defuzzification
Natural Computation and Neural Networks-Biological Neural Networks, Artificial Neural Nets and Learning, pattern classification & linear separability, single and multilayer perceptrons, back propagation, associative memory, Hebbian learning, Hop field networks, Stochastic Networks, Unsupervised learning.
Evolutionary Systems and Algorithms - Evolutionary Programming: biological adaptation &evolution, Autonomous Agents and Self-Organization: termites, ants, nest building, flocks,

herds, and schools. Genetic algorithms: Schema theorem, Reproduction, Crossover, Mutation operators.
Competition, Cooperation and Swarm Intelligence - Collective Behavior and Swarm Intelligence,SocialInsects,StigmergyandSwarmIntelligence;CompetitionandCooperation,zero-andnonzero, sum games, iterated prisoner's dilemma, table strategies, ecological & spatial models, Communication and Multi-Agent simulation–Immuno computing.

Text and Reference Books:	
1	Leandro Nunes De Castro, Fernando Jose Von Zuben, “Recent Developments in Biologically Inspired Computing”, Idea Group Publishing, 2005.
2	Leandro Nunes De Castro, “Fundamentals of Natural Computing: Basic concepts, Algorithms and Applications”, Chapman & Hall/CRC Computer & Information Science Series, 2006.
3	Dario Floreano, Claudio Mattiussi, “Bio-Inspired Artificial Intelligence: Theories, Methods and Technologies”, MIT Press, 2008.
4	George J. Klir & Bo Yuan, Fuzzy Sets and Fuzzy Logic: Theory & Applications, Prentice Hall, 2005
	Related IEEE papers/ NPTEL lectures.

Websites and External Links:	
1	http://informatics.indiana.edu/rocha/i-bic/
2	http://web.eecs.utk.edu/~mclennan/Classes/420/
3	http://www.cs.stir.ac.uk/courses/31YB/

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Semester I	
Course Code: 24EE52TH1179-2	**Course:** Digital Signal Processing
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Elective:	**Course Type: PEC**

Course Objectives:	
1	To understand the concept of discrete time signals and systems with their properties.
2	To understand the use of different transforms for discrete LTI systems
3	To understand the representation and designing of the FIR and IIR filters.
4	To understand the different applications of DSP.

Course Outcomes: After completion of the course, students will be able to	
CO1	Differentiate between different types of signals and systems.
CO 2	Evaluate the discrete Fourier transform (DFT) and Fast Fourier transform (FFT) of a sequence
CO 3	Compute the z-transform and inverse z transform of a sequence, & identify its region of convergence.
CO 4	Represent and design the FIR and IIR filter
CO 5	Describe the application of DSP in A/D and D/A conversion and speech recognition etc.

Syllabus
Introduction: Signals, systems and signal processing, classification of signal concept of discrete time signals, sampling of analog signal and sampling theorem, anatomy of digital filter.
Discrete Time Signals & Systems: Classification, analysis of discrete time signals and systems, implementation of discrete time systems, correlation of discrete time signals, z transform and its application to the analysis of linear time invariant systems.
Discrete and Fast Fourier Transforms: Frequency domain sampling, proportion of DFT, efficient computation of DFT: FFT algorithms, Quantization effects in the computation of

the DFT.
Digital Filters: Structures of FIR and IIR filters, design of FIR filters using windows; Optimum approximations of FIR filters using Parks- McClellan algorithm, Design of IIR filters from analog filters by bilinear transformations; impulse invariance method. Applications of DSP: Applications of DSP to power system/power electronics/Instrumentation.

Textbooks:	
1	Theory & application of digital signal processing: Rabiner-Gold, PHI, 1992.
2	Digital signal processing: 3rd ed., Sanjit Mitra, McGraw-Hill Science / Engineering / Math; 2005.

Reference Books:	
1	Digital signal Processing: 3rd ed., Proakis-Manolakis, PHI, 2000.
2	Discrete time signal processing: 2nd ed., Oppenheim-Schetor, Prectice Hall, 1997.
3	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52TH1179-3	**Course:** IoT and It's Applications in EV Sector
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Elective:	**Course Type: PEC**

Course Objectives:
The objective of this course is providing an integrated picture of how IoT can come to transform our energy infrastructure.

Course Outcomes: After completion of the course, students will be able to	
CO1	Understand the basic blocks and applications of IoT.
CO 2	Understand different communication protocols used in IoT systems.
CO 3	Understand the necessity of IoT in energy sector
CO 4	Understand the architecture of IoT system used for energy infrastructure.
CO 5	Appreciate the use of IoT in various energy related applications

Syllabus

Introduction to IoT and Electric Vehicles
Overview of Internet of Things (IoT) technology and its applications, Introduction to electric vehicles (EVs) and their significance in the automotive industry, Intersection of IoT and EVs: opportunities and challenges.

IoT Fundamentals
Basics of IoT architecture: sensors, actuators, connectivity, and cloud computing, Communication protocols for IoT devices: MQTT, CoAP, HTTP, etc., IoT platforms and frameworks for data collection, processing, and analysis.

Sensors and Data Acquisition in EVs
Types of sensors used in electric vehicles: temperature sensors, current sensors, voltage sensors, etc. Sensor fusion techniques for accurate data acquisition, Data acquisition systems in EVs: onboard diagnostics (OBD), CAN bus, LIN bus, etc.

IoT-enabled Vehicle Monitoring and Diagnostics

Remote monitoring of EV components: battery health, motor performance, charging status, etc. Predictive maintenance using IoT data: early fault detection, condition monitoring, prognostics Real-time diagnostics and troubleshooting for EV systems.
Smart Charging and Energy Management IoT-enabled charging infrastructure: smart charging stations, EVSE communication protocols, Dynamic load management and demand response in electric vehicle charging, Energy management strategies for optimizing charging schedules and grid integration.

Test Books:	
1	Internet of Things by Rajkamak, McGraw Hills Publications
2	eIoT- The Development of the Energy Internet of Things in Energy Infrastructure, by Steffi O. Muhanji, Alison E. Flint, Amro M. Farid Infrastructure, Springer Open access publication

Reference material:	
1	Related IEEE papers/ NPTEL lectures.

Semester I	
Course Code: 24EE52PR1180	**Course:** Simulation Tools Lab.-I
L: 0Hrs, **T**:0Hrs, **P**:2 Hrs per Week	**Total Credits:** 01
Compulsory	**Course Type: SEC**

Course Objectives:	
1	The course will prepare students to develop electrical systems for simulation using MATLAB, PSim & ETAP Softwares.
2	The course will prepare the students to develop electrical applications programming using Python.
3	The course will give the insight of the use of Python for Power Electronics
4	The course will prepare the students to compare the simulation results with theoretical results

Course Outcomes: After completion of the course, students will be able to	
CO1	Simulate the power system/power electronics circuit using MATLAB / Simulink / PSim / ETAP Software / Open Source Software.
CO 2	Programme the power electronics circuit using Python.
CO 3	Analyze results of simulated circuit/system.

References:	
1	Hadi Saadat, "Power System Stability", TMH, New Delhi, 2010.
2	MATLAB Manual from MATHWORKS Inc
3	Manual, ETAP Software
4	Fundamentals of Python: First Programs Author: Kenneth Lambert Publisher
5	Technology, Cengage Learning, 2012 ISBN-13: 978-1-111-82270-5
6	Open source development tool guide.

Semester I	
Course Code: 24H02PR1176	**Course:** Professional Communication and Employability Skills
L: 0Hrs, **T**:0Hrs, **P**:2Hrs per Week	**Total Credits:** 01
Compulsory	**Course Type: SEC**

Course Objectives:
The course aims to develop professional spoken, written and employability skills of students; and enable them to face professional situations with enhanced confidence.

Course Outcomes: After completion of the course, students will be able to	
CO1	Students learn public speaking and presentation skills
CO 2	Students learn to practice effective strategies for group discussion and personal interviews
CO 3	Students acquire proficiency in professional writing
CO 4	Students will be able to take apt decisions and perform as better professionals

List of Practical
Practical sessions -1: Professional Communication
1. Speaking Skills: Orientation & Practice in Public Speaking- I
2. Speaking Skills: Practice in Public Speaking – II
3. Presentation Skills: Orientation & Practice (Verbal and Non-verbal Communication)
4. Presentation Skills: Orientation & Practice (Visual Aids)
Practical sessions -2: Employability Skills
5.Group Discussion: Orientation & Practice
6.Group Discussion: Mock Sessions

7.Personal Interviews: Orientation(SWOT Analysis, Creating dynamic resume & LinkedIn profile, effective usage of portals like www.indeed.com and www.glassdoor.co.infor job purposes)
8.Personal Interviews: Mock Session
Practical sessions -3: Interpersonal Communication & Generic Skills (Post-employability)
The following practical's will involve case studies, projects and MCQ-based assessments
9. Professional Writing: Orientation (ethics and gender neutrality in writing, letters, emails, memos, etc.)
10. Professional Writing: Practice
11. Time Management (Covey's Matrix, Prioritizing, Goal Setting, Tracking Progress)
12. Self-responsibility & Adaptability

Assessment will be based on:	
1	Teacher's Continuous Assessment – 30 Marks
2	Peer Evaluation – 10 Marks (Practical 2, Practical 4 and Practical 6)
3	Self-analysis and report writing – 10 Marks (at the end of each practical session). Students won't be asked to submit a journal on each practical but on each of the practical sessions.

Semester I	
Course Code: 24EE52TH1181	**Course:** Research Methodology and IPR
L: 2Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 02
Compulsory	**Course Type: MLC**

Course Objectives:	
1	To introduce the concept of engineering research including selection of problem, literature review, hypothesis, research methodology, professional ethics and criteria for good research.
2	To introduce various aspects of technical paper writing, report writing and presentation skills.
3	To introduce the importance of intellectual property rights.

Course Outcomes: After completion of the course, students will be able to	
CO1	Understand research problem formulation and developing of research proposal.
CO 2	Conduct literature survey and analyze research related information.
CO 3	Recognize the importance of AI methods, and simulation studies in engineering research
CO 4	Understand research ethics and journal ranking.
CO 5	Understand various aspects of intellectual property rights.

<u>Syllabus</u>
General Aspects of Research Meaning, motivation, characteristics, general objectives and types of research, difference between research technique, research method and research methodology, criteria for good research.
Research Problem Meaning of research problem, selection of research problem, research process, setting objectives of research, developing a research proposal, format of research synopsis.
Literature review

Significance and procedure of literature review, types of literature, current areas of research in electrical engineering, standard national and international journals on electrical engineering, environmental and societal aspects in engineering research.
Hypothesis Construction, functions, types of hypothesis, errors in testing of hypothesis.
Technical Paper Writing, Report Writing and Power Point Presentation Necessities of good technical paper, paper format, approach towards writing different components of technical paper, do's and don'ts in paper writing, writing references, technical report writing, and effective power point presentation skills. Data Presentation Skills: Histogram, bar charts, pie charts, 2D & 3D plots, interpolation, extrapolation, curve fitting, FFT.
Basics of AI Methods Basics of expert system, basics of fuzzy logic, basics of ANN, sample examples using MATLAB software.
Research Ethics & Journal Ranking Plagiarism, IEEE levels of plagiarism, methods to avoid plagiarism, journal impact factor, eigen factor score, h- index, citation, indexing.
Intellectual Property Rights Patents, design, trade mark and copyright, benefits of IPR, inventions which cannot be patented in India, procedure for application and grant of patents, Patent Cooperation Treaty (PCT).

Books/References:	
1	Ranjit Kumar, "Research Methodology: A step by step guide for beginners," Pearson, 2nd Ed. 2005, New Delhi.
2	C. R. Kothari, "Research Methodology: Methods & Techniques," Wishwa Prakashan, 2nd Ed. 2001, New Delhi.
3	B. K. Bose, "Modern Power Electronics & AC Drives," Pearson Ed. Asia, 2003, Delhi.
4	B. K. Bose, "Global Warming: Energy, Environmental Pollution and the Impact of Power Electronics," IEEE Magazine, Ind. Electronics, Vol. 4, No. 1, 2010, pp. 6-17.
5	B. K. Bose, "How to get paper accepted in transactions," IEEE Newsletter, Ind. Electronics, Vol. 53, No. 4, 2006.
6	Standard Format for Preparing the Synopsis of PhD/MS Thesis, Dept. of Electrical Engg., IIT Madras (Available at: www.ee.iitm.ac.in/sites/default/files/eedownload/synopsis_Format.pdf)
7	IEEE Publication Services and Products Board Operations Manual, Section 8.2, 2013.
8	Intellectual Property India: The Patent Act 1970.
9	Intellectual Property India, Indian Patent Office, Comprehensive e-filing services for

	Patents, User Manual 2012.
10	Manual of Patent Office Practice & Procedure, Office of Controller General of Patents, Designs & Trademarks, Mumbai.
11	Related NPTEL course
12	T. Ramappa, "Intellectual Property Rights under WTO," S. Chand & Co., New Delhi, 2008*.
13	Stuart Melville, Wayne Goddard, "Research Methodology: An introduction for science & engineering students" Juta & Company, 1996*

Semester II	
Course Code: 24EE52TH1275	**Course:** EV Drives and Control
L: 4Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 04
Compulsory/Elective: Compulsory	**Course Type: PCC**

Course Objectives:	
1.	To understand various types of mechanical loads, flywheels used and the equivalent torque and inertia reflected on driving system.
2.	To understand the conventional AC and DC drives.
3.	To understand control methods for high performance applications and modern drives.

Course Outcomes: After completion of the course, students will be able to	
CO1	Select an electric motor of appropriate ratings for given application with due consideration to the nature of load, load cycle and stability considerations.
CO 2	Calculate the firing angle/duty cycle for required torque/ speed and vice-versa for an AC-DC converter fed/ DC-DC chopper fed DC motor drive and discuss its operation.
CO 3	Compare and discuss the operations of Scalar controlled/ Vector controlled/ Direct torque controlled 3-phase induction motor drives.
CO 4	Compare and discuss the construction and operation of PMSM drive, BLDC motor drive and SRM drive.

Syllabus
Dynamics of Electric Drive Basic elements of electric drive, classification of electric drive, types of load torque, components of load torque, selection of motor torque and power rating, stability considerations of electric drive.
DC Motor Drive Steady state characteristics, speed control, Phase Controlled DC motor drive, Chopper Controlled DC Motor Drive, four quadrant operations.
Three Phase Induction Motor Drive Stator voltage control, frequency control, VVVF control, energy conservation by using VFD, slip-energy recovery scheme. abc to d-q transformation and vice-versa, dynamic modelling of induction machine, Vector control (FOC): a qualitative examination, direct and indirect vector

control, concept of voltage space vector, direct torque control (DTC), concept of speed-sensor less control, Model Reference Adaptive System (MRAS) for speed-sensor less control.
Special Motor Drives Switched reluctance motor (SRM): construction, variation of phase inductance with rotor position, torque and control; Synchronous machine with PMs: different topologies of rotor, development of sinusoidal and trapezoidal emfs, hall effect sensor, BLDC motor drive, control strategies.

Text books:	
1	Dubey G. K. "Fundamentals of Electric Drives," Narosa Pub. House (2013).
2	Bose B. K. "Power Electronics & AC Drives," PHI Learning Pvt. Ltd. (2013).
3	Krishnan R. "Electric Motor Drives, Modelling, Analysis & Control," Pearson Edn. (2003).

Reference Books:	
1	Krause P.C. "Analysis of Electrical Machinery," McGraw (1987)
2	Vas P. "Vector Control of AC Machines," Clarendon Press (1990).
3	Leonhard W. "Control of Electric Drives," Narosa Pub. House, (1984).
4	Teller T. J. E. "Brushless Permanent Magnet & Reluctance Motor Drives," Clarendom Press (1989).
5	Bridges &, Nasar S. A., "Electric Machine Dynamics," Macmilan Pub. Co. (1986)
6	Related IEEE Transaction papers

Semester II	
Course Code: 24EE52PR1275	**Course:** EV Drives and Control Lab
L: 0Hrs, **T**:0Hrs, **P**:2Hrs per Week	**Total Credits:** 01
Compulsory/Elective:	**Course Type: PCC**

Course Objectives:	
1.	To understand various types of mechanical loads, flywheels used and the equivalent torque and inertia reflected on driving system.
2.	To understand the conventional AC and DC drives.
3.	To understand control methods for high performance applications and modern drives.

Course Outcomes: After completion of the course, students will be able to	
CO1	Select an electric motor of appropriate ratings for given application with due consideration to the nature of load, load cycle and stability considerations.
CO 2	Calculate the firing angle/duty cycle for required torque/ speed and vice-versa for an AC-DC converter fed/ DC-DC chopper fed DC motor drive and discuss its operation.
CO 3	Compare and discuss the operations of Scalar controlled/ Vector controlled/ Direct torque controlled 3-phase induction motor drives.
CO 4	Compare and discuss the construction and operation of PMSM drive, BLDC motor drive and SRM drive.

Contents: Experiments based on,
• Power semiconductor-controlled AC & DC drive.
• Study of performance of these drives with different loads.
• Measurement of input power quality including p.f., harmonics & ripples generated by converter used in these drives.
• Study of controller circuits for these drives

Reference Books:	
1	Fundamentals of Electrical Drives: Dubey G.K. CRC Press, (2002).
2	Power Electronics and AC Drives: Bose B.K., Printice Hall, NJ, (1985).
3	Electric Machine Dynamics: Bridges I. & Nasar S.A., Macmilan Publishing Company, NY, (1986).

4	Electric Motor Drives, Modelling, Analysis and Control: Krishnan, R., Prentice Hall India, (2003).
5	Control of Electrical Drives: Leonhard W., Narosa Publishing House, India (1984).
6	Analysis of Electrical Machinery: Krause P.C., McGraw Hill (1987).
7	Brushless permanent Magnet & Reluctance Motor Drives: Teller T.J.E, Clarendom press, (1989).
8	Data sheets.

Semester II	
Course Code: 24EE52TH1276	**Course:** Energy Storage Systems
L: 4Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 04
Compulsory/Elective: C	**Course Type: PCC**

Course Objectives:
To discuss the theory and applications of different energy storage devices

Course Outcomes: After completion of the course, students will be able to
CO1: Understand different aspects and parameters of energy storage systems.
CO2: Analyze various battery technologies and their components, focusing on performance and key characteristics
CO3: Analyze battery parameters and performance measures for various Lithium-ion battery types.
CO4: Evaluate the principles, materials, and applications of super capacitors, comparing them with batteries and identifying challenges and future directions
CO5: Apply the knowledge gained for energy storage integration and hybrid energy storage systems

Syllabus
Introduction: Needs and opportunities in energy storage, Energy storage in the power and transportation sectors. Types of energy storage, Compressed Air storage, Pumped Hydro Storage system, Advanced Flywheel: Construction and working principle, advantages and disadvantages, economic considerations, comparison of energy storage technologies
Electrochemical storage system: Battery technologies: Electrochemical energy storage mechanisms, Battery terminology, classifications, types Based on electrode materials and electrolytes, Basic operation and key characteristics) of batteries (Lead-Acid, Nickel Cadmium, Nickel Hydrogen, Nickel Metal Hydride) and applications.
Lithium ion battery: Classifications based on cathode and anode materials, Components, functions, Charge/discharge cycles, Safety, Lifetime, comparison, Battery pack design, Battery modelling, battery management systems, cell balancing techniques, SoC and SoH estimation techniques, applications in EV, overview on research activities.

Super capacitor: Energy Storage Mechanisms: Electrostatic vs. pseudo capacitive, Comparison with Batteries, electric charge, electric field, capacitance, charging/discharging, Materials for Super capacitors: Electrolytes: Aqueous, organic, ionic liquids. Electrode materials: Carbon materials (activated carbon, CNTs, graphene), metal oxides/sulfides conducting polymers. **Fuel cells:** Working principle and types, applications in Electric vehicle. **Hybrid Energy storage systems:** configurations and applications,

Text books:	
1	A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN – 13:9789380090122), 2011.
2	Rahn C. D. and Wang C., Battery Systems Engineering, First Edition, Wiley (2013)
3	Narayan R. and Viswanathan B., Chemical and Electrochemical Energy System, Universities Press (1998)
4	Lithium-Ion Batteries Basics and Applications by Reiner Korthauer, Springer.
5	Lithium-ion Batteries Fundamentals and Applications. by Wu, Yuping, CRC Press, Taylor and Francis.
6	Vladimir S. Bagotsky, Alexander M. Skundin, Yurij M. Volfkovich, Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors, Wiley, 2015.
7	O'hayre, S.W. Cha, W.G. Colella, F.B. Prinz, Fuel Cell Fundamentals, 3rd edition, Wiley publisher.
8	R. P. Deshpande, Ultracapacitors: Future of Energy Storage, McGraw-Hill Education, 2014
9	Genta, G, Kinetic Energy Storage: Theory and Practice of Advanced Flywheel System eBook
10	Related IEEE papers/ NPTEL lectures.

Ramdeobaba University, Nagpur
School of Electrical and Electronics Engineering
Department of Electrical Engineering
M. Tech in Electrical Engineering (Electric Vehicle Technology)
To be implemented from Session: 2024-2025

Semester II	
Course Code: 24EE52PR1276	**Course:** Energy Storage Systems Lab
L: 0Hrs, **T**:0Hrs, **P**:2Hrs per Week	**Total Credits:** 01
Compulsory/Elective:	**Course Type:**

Course Outcomes: After completion of the course, students will be able to	
CO1	Understand the charge/discharge characteristics and performance parameters of different energy storage devices like Lead-Acid, Li-ion batteries, and super capacitors.
CO 2	Analyze battery behavior under different C-rates
CO 3	Evaluate the thermal performance and heat dissipation in battery packs, and understand the impact of temperature on battery life and safety.
CO 4	Estimate the State of Charge (SoC) using techniques like voltage method and Coulomb counting, and assess their accuracy and limitations.

List of Experiments:
1. Determine charge/discharge characteristics of Lead-Acid, Li-ion batteries
2. Determine charge/discharge characteristics of Super capacitor.
3. To test batteries under various charge/discharge cycles and C-rates
4. To study heat generation and cooling in battery packs
5. To estimate SoC using voltage and Coulomb counting methods.
6. Analyze super capacitor behaviour under load.
7. To study Hybrid Energy system analysis using Li-ion battery and Super capacitor.
8. To create an off-grid solar system with battery storage.
9. Study battery failure modes (overcharge, short circuit).
10. Modelling of Li-ion battery using MATLAB/SIMULINK.

Semester II	
Course Code: 24EE52TH1277	**Course:** Microcontroller Applications in Power Converter
L: 4Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 04
Compulsory/Elective:	**Course Type: PCC**

Course Objectives:
The objective of this course introduces the use of microcontroller for development of various applications in power converters and power systems.

Course Outcomes: After completion of the course, students will be able to	
CO1	Design signal conditioning circuit required in microcontroller-based control.
CO 2	Design hardware for microcontroller-based power converters.
CO 3	Implement control scheme used in microcontroller-based controllers.
CO 4	Discuss the use of Microcontroller in basic numeric protective relays.

Syllabus
Signal conditioning circuits: Clipper, clampers, zero crossing detectors, level shifters, Filters, Compensators, Sensor interfacing for measurement of electrical quantities,
Control applications: PWM control, Implementation of hysteresis control, PI, PID control
Application in Power supplies: Control of DC-DC converters, Inverter control, SPWM Technique,
Applications in electric motor drives: DC motor control, Induction motor control, BLDC motor control
Applications in Power system: Introduction to schemes for basic Numerical Protective relays, flow charts- programming.

Text books:	
1	The AVR microcontroller and Embedded systems using assembly and C, Muhammad Ali Mazdi, Sarmad Naimi and Sepher Naimi 2011, Prentice Hall.
2	PIC Microcontroller and Embedded Systems: Using Assembly and C: for MC18 by Muhammad Ali Mazidi, Sarmad Naimi and Sepehr Naimi. Pearson Custom Electronics Technology
3	Modern Power Electronics and AC Drives: B. K. Bose, Prentice Hall; First edition.
4	Digital Power System Protection, S. R. Bhide, PHI Learning

Reference Books:	
1	Data sheets of hardware components
2	Related IEEE papers/ NPTEL lectures.

Semester II	
Course Code: 24EE52TH1278-1	**Course:** EV Chargers and Charging Infrastructures
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type: PEC**

Course Outcomes:
After completion of the course, students will be able to

CO1	Explain EV charging standards and protocols.
CO 2	Identify various EV charger types such as Level 1, Level 2, and DC fast chargers.
CO 3	Explain AC and DC charging technology.
CO 4	Describe the charging station components and its operations.
CO 5	Describe the grid impact and load management strategies for large-scale charging deployments.

Syllabus

Introduction to Electric Vehicle Chargers and Charging Infrastructures: Overview of electric vehicle (EV) charging technologies and infrastructure, importance of charging infrastructure in the adoption of electric vehicles, evolution of EV charging standards and protocols.

Types of Electric Vehicle Chargers: Classification of EV chargers: AC chargers, DC chargers, wireless chargers, charging power levels: Level 1, Level 2, Level 3 (DC fast charging), charging connector types: SAE J1772, CCS Combo, CHAdeMO, Tesla Supercharger, etc.

AC and DC Charging Infrastructure: Principles of AC and DC charging technology, Types of AC and DC chargers, High-power charging (HPC) and ultra-fast charging (UFC) technologies.

Charging Station Components and Operation: Components of EV charging stations: power modules, connectors, communication interfaces, Charging station architecture: AC/DC conversion, power distribution, safety features, Operation of charging stations: user authentication, payment systems, remote monitoring and management.

Charging Station Installation and Grid Integration: Site selection and planning for EV charging station deployment, Electrical infrastructure requirements for charging station installation, Grid impact and load management strategies for large-scale charging deployments.

Text books:	
1	Modern Electric, Hybrid Electric, and Fuel Cell Vehicles - Fundamentals, Theory, and Design: M.Ehsani, Y. Gao, S. E. Gay and A. Emadi, CRC Press, 2004.
2	AC Motor Control & Electric Vehicle Applications by Kwang Hee Nam, CRC Press, Special Indian Edn, (Yes Dee Publishing Pvt. Ltd, Chennai) 2013.
3	Electric Vehicle Battery Systems by Sandeep Dhameja, Elsevier India Pvt. Ltd, 2013.
4	Electric and Hybrid Vehicles: T. Denton, Routledge, 2016
5	Electric and Hybrid Vehicles Design Fundamentals by Iqbal Husain, CRC Press

Reference Books:	
1	Recent IEEE papers
2	NPTEL Courses

Semester II	
Course Code: 24EE52TH1278-2	**Course:** Design of Battery Management System
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type: PEC**

Course Objectives:
The objective of this course is to make the students familiar batteries used in EV applications and designing of Battery system.

Course Outcomes: After completion of the course, students will be able to	
CO1	Discuss about the different types of energy storage system.
CO 2	Describe about the battery characteristic & parameters.
CO 3	Familiar with Analyze different types of batteries.
CO 4	Apply the concepts of battery management system and design the battery pack.
CO 5	Explain about the battery testing, disposal and recycling.

<u>Syllabus</u>
Battery Characteristics and Parameters: Cells and Batteries- conversion of chemical energy to electrical energy- Battery Specifications: Variables to characterize battery operating conditions and Specifications to characterize battery nominal and maximum characteristics; Efficiency of batteries; Electrical parameters Heat generation- Battery design- Performance criteria for Electric vehicles batteries- Vehicle propulsion factors- Power and energy requirements of batteries- Meeting battery performance criteria- setting new targets for battery performance.
Battery modelling: 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.
Battery Pack and Battery Management system: Selection of battery for EVs, Traction Battery Pack design, Requirement of Battery Monitoring,

Battery State of Charge Estimation methods, Battery Cell equalization problem, thermal control, protection interface, SOC and SOH Estimation, Energy & Power estimation, Battery thermal management system, Battery Management System: Definition, Parts: Power Module, Battery, DC/DC Converter, load, communication channel, Battery Pack Safety, Battery Standards & Tests.
Battery Testing, Disposal and Recycling: Chemical & structure material properties for cell safety and battery design, battery testing, limitations for transport and storage of cells and batteries, Recycling, disposal and second use of batteries. Battery Leakage: gas generation in batteries, leakage path, leakage rates. Ruptures: Mechanical stress and pressure tolerance of cells, safety vents, Explosions: Causes of battery explosions, explosive process, Thermal Runway: High discharge rates, short circuits, charging and discharging. Environment and Human Health impact assessments of batteries, General recycling issues and drivers, methods of recycling of EV batteries.

Text books:	
1	James Larminie, John Lowry, “Electric Vehicle Technology Explained”, John Wiley & Sons Ltd, 2003.
2	Chris Mi, Abul Masrur& David Wenzhong Gao, “Hybrid electric Vehicle- Principles & Applications with Practical Properties”, Wiley, 2011.
3	T R Crompton, “Battery Reference Book-3 rd Edition”, Newnes- Reed Educational and Professional Publishing Ltd., 2000.
4	Ibrahim Dinçer, Halil S. Hamut and Nader Javani, “Thermal Management of Electric Vehicle Battery Systems”, JohnWiley& Sons Ltd., 2016.
5	Guangjin Zhao, “Reuse and Recycling of Lithium-Ion Power Batteries”, John Wiley & Sons. 2017. (ISBN: 978-1-1193-2185-9)
6	Related IEEE papers/ NPTEL lectures.

Semester II	
Course Code: 24EE52TH1278-3	**Course:** Power Quality
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type: PEC**

Course Objectives:	
1	To introduce various power quality events.
2	To introduce indices used for the analysis of power quality events.
3	To introduce mitigation techniques for the improvement of power quality.
4	To introduce the application of switching controller for power quality improvement.

Course Outcomes: After completion of the course, students will be able to	
CO1	Identify the various power quality events like short and long duration variations, Waveform distortion, Unbalance, Transients, Power factor etc.
CO 2	Analyze the power quality issues using the Power quality indices
CO 3	Suggest suitable mitigation strategies for some of the power quality issues.
CO 4	Provide solution for the mitigation of power quality issues like waveform distortion, unbalance, and poor power factor.

<u>Syllabus</u>
Origin of power quality variation & events, power quality indices, causes and effects of power quality disturbances, Characterization of power quality events & event classification. Power quality measuring instruments, Analysis of Power outages, unbalance, distortions, voltage sag, flickers & load balancing.
Reactive Power Compensation under non sinusoidal conditions, Effect of Harmonics on Transformers, Power quality problems created by drives and its impact on drives, Power factor improvement techniques, Passive Compensation, Harmonic Filters, DSTATCOM, DVR and UPQC: Structure & control of power converters, load compensation using DSTATCOM, Generation of reference currents, DVR/UPQC structures & control.

Text books:	
1	Power quality enhancement using Custom Power Devices: Ghosh A., Ledwich G., Kluwer academic publication-Boston, (2002)
2	Power Quality: C. Sankaran, CRC Press,
3	Signal Processing of Power Quality Disturbances: Bollen Math H.J., GU Irene Y.H., Wilely Interscience Publication, IEEE Press, (2006).

Reference Books:	
1	Understanding Power quality Problems Voltage Sags and Interruptions: Bollen Math H.J, IEEE Press, Standard Publishers Distributors, (2001).
2	Power Quality in Power Systems and Electrical Machines: Fuchs E.F., Masoum Mohammad A.S, Elsevier Academic Press, (2008).
3	Related IEEE papers/ NPTEL lectures.

Semester II	
Course Code: 24EE52TH1279-1	**Course:** EV Policies and regulations
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type: PEC**

Course Objectives:
The objectives of EV policies and regulations are to incentivize the widespread adoption of electric vehicles through financial incentives, taxation policies, and regulatory mandates while ensuring the development of supportive infrastructure and grid integration measures to facilitate their seamless integration into transportation systems.

Course Outcomes: After completion of the course, students will be able to	
CO1	Understand policies and regulations for electric vehicles.
CO 2	Implement infrastructure policies and market incentives for electric vehicles.
CO 3	Understand the process for certification and regulations for compliances.
CO 4	Understand charging infrastructure in low-income areas and work force development in employment.
CO 5	Overview of emerging trends in EV policies, regulations and innovations for sustainable mobility.

Syllabus
Environmental and Emission Regulations Emission Standards for Vehicles: Euro Standards, US EPA Standards, China VI Emission Standards. Impact of EVs on Emission Reduction, Policies for Environmental Sustainability
National and International EV Policies

National Policies for EV Promotion: Incentives and Subsidies, Taxation Policies, Mandates and Regulations. Regional and Local Policies: Urban Mobility Plans, Local Incentives and Restrictions, Case Studies of Successful Regional Policies Overview of International EV Policy Frameworks, Key Policies from Leading EV Markets: US, EU, China, Japan, International Standards and Regulations for EVs: UNECE Regulations, ISO Standards, IEC Standards.
Energy and Infrastructure Policies Charging Infrastructure Policies: Public and Private Charging Infrastructure, Standards for Charging Stations (CCS, CHAdeMO, GB/T), Grid Integration and Smart Charging Policies. Renewable Energy Integration with EVs, Energy Storage and Grid Stability Policies.
Economic and Market Incentives Financial Incentives for EV Adoption: Purchase Subsidies and Tax Credits, Research and Development Grants, Loan and Lease Programs. Market-Based Mechanisms: Cap-and-Trade Programs, Carbon Credits and Trading, Fleet Purchase Mandates
Safety and Compliance Regulations Safety Standards for EV Components and Systems: Battery Safety Standards, Crashworthiness and Vehicle Safety Regulations. Compliance and Certification Processes, Recall and Warranty Policies.
Social and Equity Considerations Policies for Equitable EV Adoption: Access to Charging Infrastructure in Low-Income Areas, Subsidies and Incentives for Low-Income Households. Impact of EV Policies on Employment and Workforce Development. Community Engagement and Public Awareness Campaigns.
Future Trends and Policy Innovations Emerging Trends in EV Policies and Regulations: Autonomous Vehicles and Policy Implications, Shared Mobility and EV Integration, Blockchain and Smart Contracts in EV Ecosystems. Policy Innovations for Sustainable Mobility: Green New Deals, Zero Emission Zones (ZEZs), Future Mobility Scenarios.

Text books:	
1	The Electric Vehicle Conversion Handbook by Mark Warner.
2	Transportation Electrification: Policy and Planning" by Nikolaos E. Bekiaris and Yannis M. Martakos.
3	Government Reports and White Papers on EV Policies.
4	Academic Journals and Conference Papers on EV Regulations.
5	Related IEEE papers/ NPTEL lectures.

Semester II	
Course Code: 24EE52TH1279-2	**Course:** Energy Management Strategies in EV
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type: PEC**

Course Objectives:	
1	To impart the knowledge of different energy sources for Electric Vehicle and their energy management strategies.
2	To introduce hybrid electric vehicle and its energy management system.

Course Outcomes: After completion of the course, students will be able to	
CO1	Understand the construction, working and characteristics of energy sources for electric vehicle (EV)
CO 2	Understand the necessity of hybridization of the energy sources and its impact of the performance for vehicle.
CO 3	Describe the energy management strategy for hybrid energy storage systems and hybrid electric vehicle.
CO 4	Design the vehicle with required specifications.

Syllabus
Energy Sources for Electric Vehicle Battery**:** Types, structure, working, characteristics and properties. Comparative study and application in Electric Vehicle. Super capacitor: Features, construction, working, types, modelling equation and performance. Comparative study with electrolytic capacitor and battery (Ragone plot analysis), super capacitor technologies and applications. Fuel cell: Features, construction, working, types and characteristics.
Hybrid Energy Storage Systems for Electric Vehicle: Reason for hybridization, its impact on vehicle performance, merits and limitations.

Battery and Super capacitor as hybrid energy storage system (HESS): selection of battery rating for selected motor, selection of the super capacitor rating, topologies, modelling equations Fuel cell and super capacitor as HESS: rating for selected motor load, topologies, modelling equations.
Energy Management Strategies (EMS): EMS, Functions of EMS, role of EMS in electric vehicle, types of EMS (rule based and optimization based), Problem formulation.
Design of Hybrid Energy Storage Systems for Electric Vehicle Design of an electric vehicle (e-rickshaw) by considering battery and super capacitor/Fuel Cell as HESS, suitable topology, EMS and motor for selected speed and load conditions.
Energy Management strategy for Hybrid Electric Vehicle (HEV) Introduction, Modelling of HEV, Energy Management problem in HEV and case study.

Text books:	
1	Ehsani M, et.al. “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles,” CRC Press (2019)
2	Rizzoni G., et.al . “Hybrid Electric Vehicles: Energy Management Strategies”, Springer (2015).
3	Dubey G. K. "Fundamentals of Electric Drives," Narosa Pub. House (2013)
4	Bose B. K. "Power Electronics & AC Drives," PHI Learning Pvt. Ltd. (2013).
5	Krishnan R. "Electric Motor Drives, Modelling, Analysis & Control," Pearson Edn. (2003).

Reference Papers:	
1	R. Ostadian, J. Ramoul, A. Biswas, and A. Emadi, “Intelligent Energy Management Systems for Electrified Vehicles: Current Status, Challenges, and Emerging Trends,” *IEEE Open J. Veh. Technol.*, vol. 1, pp. 279–295, 2020, doi: 10.1109/ojvt.2020.3018146.
2	A. Berrueta, A. Ursua, I. S. Martin, A. Eftekhari, and P. Sanchis, “Supercapacitors: Electrical Characteristics, Modeling, Applications, and Future Trends,” IEEE Access, vol. 7, pp. 50869–50896, 2019, doi: 10.1109/ACCESS.2019.2908558.
3	I.-S. Sorlei et al., “Fuel Cell Electric Vehicles—A Brief Review of Current Topologies and Energy Management Strategies,” Energies, vol. 14, no. 1, p. 252, 2021, doi: 10.3390/en14010252.

4	C. Yang, M. Zha, W. Wang, K. Liu, and C. Xiang, “Efficient energy management strategy for hybrid electric vehicles/plug-in hybrid electric vehicles: Review and recent advances under intelligent transportation system,” IET Intell. Transp. Syst., vol. 14, no. 7, pp. 702–711, 2020, doi: 10.1049/iet-its.2019.0606.
5	I. Aharon and A. Kuperman, “Topological overview of powertrains for battery-powered vehicles with range extenders,” IEEE Trans. Power Electron., vol. 26, no. 3, pp. 868–876, 2011, doi: 10.1109/TPEL.2011.2107037.
6	A. Burk, “Ultracapacitors: why, how, and where is the technology,” J. Power Sources, vol. 91, no. 1, pp. 37–50, 2000, [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0378775300004857%5Cnpapers3://publication/livfe/id/55939.
7	C. C. Chan, A. Bouscayrol, and K. Chen, “Electric, hybrid, and fuel-cell vehicles: Architectures and modeling,” IEEE Trans. Veh. Technol., vol. 59, no. 2, pp. 589–598, 2010, doi: 10.1109/TVT.2009.2033605.
8	M. A. Hannan, M. M. Hoque, A. Hussain, Y. Yusof, and P. J. Ker, “State-of-the-Art and Energy Management System of Lithium-Ion Batteries in Electric Vehicle Applications: Issues and Recommendations,” IEEE Access, vol. 6, pp. 19362–19378, 2018, doi: 10.1109/ACCESS.2018.2817655.
9	A. Poullikkas, “Sustainable options for electric vehicle technologies,” Renewable and Sustainable Energy Reviews. 2015, doi: 10.1016/j.rser.2014.09.016.
10	B. Zakeri and S. Syri, “Electrical energy storage systems : A comparative life cycle cost analysis,” Renew. Sustain. Energy Rev., vol. 42, pp. 569–596, 2015, doi: 10.1016/j.rser.2014.10.011.
11	Poonam, K. Sharma, A. Arora, and S. K. Tripathi, “Review of supercapacitors: Materials and devices,” Journal of Energy Storage, vol. 21. Elsevier Ltd, pp. 801–825, Feb. 01, 2019, doi: 10.1016/j.est.2019.01.010.
12	G. Udhaya Sankar, C. Ganesa Moorthy, and G. RajKumar, “Smart Storage Systems for Electric Vehicles–A Review,” Smart Sci., vol. 7, no. 1, pp. 1–15, 2019, doi: 10.1080/23080477.2018.1531612.
13	J. A. Sanguesa, V. Torres-Sanz, P. Garrido, F. J. Martinez, and J. M. Marquez-Barja, “A Review on Electric Vehicles: Technologies and Challenges,” Smart Cities, vol. 4, no. 1, pp. 372–404, 2021, doi: 10.3390/smartcities4010022.

Semester II	
Course Code: 24EE52TH1280-1	**Course:** Hydrogen and Fuel Cell Technology
L: 3Hrs, **T**:0Hrs, **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type: OE**

Course Objectives:
The course is designed to provide the fundamental knowledge of Hydrogen Energy and Fuel Cell Technology and its relevant applications.

Course Outcomes:

After completion of the course, students will be able to

CO1	Discuss the use of Hydrogen as a Fuel, its production methods and related issues.
CO 2	Understand the working and operation of Fuel Cell
CO 3	Analyse the performance hydrogen fuel cell under different operating condition
CO 4	Discuss the use of Hydrogen Fuel Cell for different applications.

<u>Syllabus</u>
Hydrogen Energy Fundamentals: Hydrogen as a source of energy, physical and chemical properties, properties of hydrogen as fuel, hydrogen production, storage, transportation and safety aspects.
Introduction to Fuel Cell: Principle, working, thermodynamics and kinetics of fuel cell process, types of Fuel Cell – Merits and Demerits, Nernst equation.
Fuel Cell Performance: Performance characteristics and efficiency of fuel cells, and factors affecting them. Fuel cell modelling and polarization curve.
Application of Fuel Cell and Economics: Fuel Cell usage for domestic power systems, large scale power generation, automobile, Economic and environmental analysis on usage of Hydrogen and Fuel cell, future trends of Fuel Cell.

Text books:	
1	Vishwanathan,B and M Aulice Scibioh, Fuel Cells – Principles and Applications, Universities Press.
2	Bent Sorensen,Hydrogen and Fuel cell: Emerging Technologies and Applications; Elsevier Academic Press (UK)
3	James Larminie and Andrew Dicks; Fuel Cell Systems Explained by, John Wiley and Sons.
4	Frano Barbir, PEM Fuel Cells : Theory and Practice , Elsevier Academic Press (UK)
5	Related IEEE papers/ NPTEL lectures.

Semester III	
Course Code: 24EE52TH1375-1	**Course:** Entrepreneurship in Electric Mobility
L: 3 Hrs,T:02 **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type:** PEC

Course Outcomes:
After completion of the course, students will be able to

CO1	Apply market research techniques to gather strategic insights for EV start-ups.
CO2	Create digital marketing strategies and brand positioning to enhance EV adoption.
CO3	Develop financial models and investment strategies to drive sustainable growth in EV startups.
CO4	Evaluate case studies of successful EV start-ups by identify latest industry trends, challenges and opportunities.
CO5	Understand key business models and operational aspects of Entrepreneurship in EV

Syllabus

MODULE I: Market Analysis and Business Development (08 Hours)
EV market analysis, Market research methodologies for EV startups, Business model canvas for EV companies, Identifying potential customer segments and market needs, pricing strategies for EV products and services.

MODULE II: Marketing and Branding for EVs (08 hours)
Digital marketing strategies for EVs, Brand positioning and communication for EV companies, Consumer perception and adoption of EVs, and Sustainability marketing and messaging.

MODULE III: Financial Management and Investment (08 Hours)
Financial analysis for EV start-ups, Investment strategies and funding options, Cost of ownership and total cost of operation for EVs, Financial modelling for EV ventures

MODULE IV: **Case Studies and Industry Insights (07 Hours)**
Case studies of successful EV start-ups, Industry trends and future developments, Challenges and opportunities in the EV market, and Emerging technologies in electric mobility.

MODULE V: Scope of Entrepreneurship in EV (05 Hours)
EV Charging Station, Battery Assembly, EV accessories, Battery swapping business

Text Books:	
1	Electric Vehicle Business Models: Global Perspectives, David A. Hensher, Corinne Mulley
2	Electric Vehicles: Prospects and Challenges, Tariq Muneer, Mohammad Asif, and Arunav Das
3	*EV Everything: Electric Vehicles and Future of Business, Ravi Kempaiah*
4	The Electric Vehicle Revolution: The Past, Present, and Future of EVs, Kevin R. Nilsson
5	Related IEEE papers/ NPTEL lectures.

Semester III	
Course Code: 24EE52TH1375-2	**Course:** AI Techniques for Power Converter
L: 3 Hrs,T:02 **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type:** PEC

Course Outcomes:
After completion of the course, students will be able to

CO1	Solve the problems related to the fundamental concepts in machine learning.
CO2	Compare the strengths and weaknesses of various machine learning approaches.
CO3	Apply machine learning algorithms to solve classification, and regression problems.
CO4	Implement various machine learning models to solve problems related to power converter design/control /analysis.

Syllabus

Foundations for ML: ML Techniques overview, Validation Techniques (Cross-Validations), Over-fitting and under-fitting, Data Normalization, Hypothesis Evaluation, Feature Reduction/Dimensionality reduction, Linear and Logistic regression

Discriminative Methods: K-nearest neighbour, Linear Discriminant Functions, Decision Tree, Random Forest algorithm, Bagging and Boosting
Feature extraction, Feature selection techniques: Filter Method, Wrapper Method, Curse of Dimensionality, Dimensionality Reduction techniques: Introduction to PCA, LDA.

Foundations for ML: ML Techniques overview, Validation Techniques (Cross-Validations), Over-fitting and under-fitting, Data Normalization, Hypothesis Evaluation, Feature Reduction/Dimensionality reduction, Linear and Logistic regression

Introduction to applications of Machine learning techniques in
- Power converter control
- Battery management system,

- Vehicle efficiency improvement,
- Predictive Maintenance of electric vehicle,
- Charging Infrastructure,
- Energy Management for EVs

Text Books:	
1	Tom Mitchell; Machine Learning- an Artificial Intelligence Approach, Volume-II; Morgan Kaufmann, 1986.
2	Christopher Bishop, Pattern Recognition and machine learning; Springer Verlag, 2006.
Reference Books:	
1	Soumen Chakrabarti; Mining the Web: Discovering Knowledge from Hypertext Data, Morgan Kaufmann, 2003
2	A. K. Jain and R. C. Dubes; Algorithms for Clustering Data; Prentice Hall PTR, 1988.
3	Ethem Alpaydin, Introduction to Machine Learning, PHI.
4	Related IEEE papers/ NPTEL lectures.

Semester III	
Course Code: 24EE52TH1376-1	**Course:** Digital and Optimal Control System
L: 3 Hrs,T:02 **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type:** PEC

Course Outcomes:
After completion of the course, students will be able to

CO1	Analyze the discrete time control systems with MATLAB programming and simulation.
CO2	Design the state feedback controllers.
CO3	Apply different stability analysis techniques to analog and digital systems.
CO4	Optimize the system to achieve desired performance.

Syllabus

Digital Control System: Representation of SDCS. Sample & Hold Circuit. Z- Transform. Inverse Z-transform & solution of difference equation. Z & S domain relationship. Comparison of timeresponse of continuous and digital control systems, Effect of sampling period on transient responsecharacteristic Discretization of continuous time state equation. Solution of Discrete time state equations. Controllability & Obervability of discrete time systems

State Feedback Control Design: State Feedback Control - Pole Placement Design, State Feedback with Integral Control, Observer-based State Feedback Control, Digital Control Design using State Feedback.

Stability Analysis : Stability by bilinear transformation & Jury's test, Stability of Equilibrium State in the Sense of Liapunov; Liapunov's Stability Test, Second Method of Liapunov; Liapunov Function Basedon Aizerman's Method,

Optimal Control System: Calculus of Variation, the Lagrangian and Hamilton Functions.

Text Books:

1	Digital control and State variable Methods, Fourth Edition, Mc Graw Hills, M Gopal
2	Modern Control system theory, Third Edition, New Age International Publishers, M. Gopal

3	Modern Control Engineering, Fourth Edition, Prentice Hall, 2001 - Katsuhiko Ogata.
4	Automatic Control Systems, High Education Press, 2003 - B. C. Kuo
5	Control Systems Engineering, Fifth Edition, New Age International Publishers, 2007 J. Nagrath &M Gopal
6	Related IEEE papers/ NPTEL lectures.

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Ramdeobaba University, Nagpur
School of Electrical and Electronics Engineering
Department of Electrical Engineering
M. Tech in Electrical Engineering (Electric Vehicle Technology)
To be implemented from Session: 2024-2025

Semester III	
Course Code: 24EE52TH1376-2	**Course:** Power Converter for EV Applications
L: 3 Hrs,T:02 **P**:0Hrs per Week	**Total Credits:** 03
Compulsory/Elective: Elective	**Course Type:** PEC

Course Outcomes: After completion of the course, students will be able to	
CO1	Design power converters for EV battery charging applications.
CO2	Select the topologies used for controlling the different types of motors used in EV.
CO3	Appreciate the control characteristics requirement of different EV motors.
CO4	Implement the control strategies for power converters in EV Motors.

<u>Syllabus</u>

Module 1: AC-DC Converters for EV Charging

Design considerations for EV chargers. Power Electronic Converter for Battery Charging: Charging methods for battery, Termination methods, charging from grid, High-frequency transformer based isolated charger topology, Transformer less topology. Overview of Power conversion techniques, Converters for wired charging, Converters for wireless charging.

Module 2: Bidirectional Converter Topology for plug in Electric vehicle
Bidirectional AC/DC Converters for plug-in EV with reduced conduction losses, Plug in charging mode, propulsion mode. Bidirectional converter for HEV applications.

Module 3: DC-AC converter for BLDC drives.

BLDC drives-various speed control strategies – closed loop control – Control strategies of regenerative braking in drives.

Module 4:- DC-AC converter for PMSM drives.

Permanent magnet synchronous machine for EV powertrain, Field Oriented Control. Various speed control strategies – closed loop control – Control strategies of regenerative braking in drives.
Module 5:- DC-AC converter for SRM drives. Switched Reluctance Machine for EV powertrain, Various speed control strategies – closed loop control – Control strategies of regenerative braking in drives.

Text Books:	
1	Ned Mohan, Tore Undeland and Willima Robbins, "Power Electronics - Converters, Applications and Design", John Wiley & Sons, Inc.
2	L. Ashok Kumar, S. Albert Alexander ,"Power Converter for electric vehicle" ,Taylor and Francis group
3	Fundamental of Power Electronics: Robert Erickson, D. Maksimovic
Reference Books	
1	Power Electronics, Circuits, Devices and Applications: Muhammad H. Rashi
2	Modern Power Electronics: P. C. Sen
3	Power Electronics and AC Drives: B. K. Bose, Prentice Hall, NJ, (1985).
4	Related IEEE papers/ NPTEL lectures

Semester III	
Course Code: 24EE52PR1377	**Course:** Simulation Tools Lab.-II
L: 0Hrs, **T**:0Hrs, **P**:4 Hrs per Week	**Total Credits:** 02
Compulsory	**Course Type: SEC**

Course Outcomes: After completion of the course, students will be able to	
CO1	Simulate the Electric Vehicle model using MATLAB/other electrical software.
CO 2	Analyze the results of simulated circuit.

Experiments are based on Simulation of
1. Charging circuit
2. Battery and Energy Management
3. Electric Motor Control (BLDC/PMSM/DC)
4. Vehicle Dynamics & Performance
5. Vehicle-to-Grid (V2G) Integration

References:	
1	MATLAB Manual from MATHWORKS Inc
2	Open source development tool guide.
3	IEEE papers

Semester III	
Course Code: 24EE52PR1379	**Course:** Project Phase-I
L: 0 Hrs,T:00 **P**: 4 Hrs per Week	**Total Credits:** 04
Compulsory/Elective: Compulsory	**Course Type:** VSEC

Course Outcomes:
After completion of the course, students will be able to

CO1	Communicate effectively by using power point presentation
CO2	Take initiative and conduct self-study with commitment to improve own knowledge &competence.
CO3	Conduct literature survey effectively

Assessment by

Project Supervisor and Project Review Committee Members

Semester IV	
Course Code: 24EE52PR1475	**Course:** Project Phase-II
L: 0 Hrs,T:00 **P**: 8 Hrs per Week	**Total Credits:** 16
Compulsory/Elective: Compulsory	**Course Type:** VSEC

Course Outcomes: After completion of the course, students will be able to	
CO1	Conduct literature survey effectively
CO2	Analyze critically
CO3	Learn and apply simulation tools/ hardware tools/IE rules etc for the purpose of study/ simulation / design/ fabrication to execute the project
CO4	Take initiative and conduct self-study with commitment to improve own knowledge and competence
CO5	Analyze the outcome of one's own efforts, learn from mistakes and take corrective measures without depending on external feedback.
CO6	Communicate effectively by using power point presentation
CO7	Demonstrate the knowledge of project management principles with due consideration of economical and financial factors
CO8	Understand professional and ethical responsibility
CO9	Perform multidisciplinary research
CO10	Write effective project report/ dissertation

Evaluation

Dissertation / Viva-Voce on project work

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