M.Tech

ELECTRIC VEHICLE TECHNOLOGY

Programme Course Structure & Syllabus

Programme Structure

R25 M.Tech (ELECTRIC VEHICLE TECHNOLOGY) Structure

I Year MTech (ELECTRIC VEHICLE TECHNOLOGY) I – Semester

S. No.	Course Title	L	T	P	C
1	**Program Core – 1** Power Electronics for Electric Vehicles	3	1	0	4
2	**Program Core – 2** Electric and Hybrid Vehicles	3	1	0	4
3	**Program Core – 3** Automotive Engineering For Electric Vehicles	3	1	0	4
4	**Program Elective – I** Vehicular Communication Networks Sensor Systems for Electric Vehicles Renewable Energy Technologies	3	0	0	3
5	**Program Elective – II** Battery Management Systems Automotive Embedded Systems/~~Embedded control systems~~ Power Quality enhancement using Custom Power Devices	3	0	0	3
6	**Laboratory – 1** EV Simulation Laboratory	0	1	2	2
7	**Laboratory – 2** EV motors and controllers Lab	0	1	2	2
8	Seminar-I	0	0	2	1
	TOTAL	**15**	**5**	**6**	**23**

I Year M.Tech II – Semester

S. No.	Course Title	L	T	P	C
1	**Program Core – 4** EV Charging Technology and Policies	3	1	0	4
2	**Program Core – 5** Special machines for Autonomous Vehicles	3	1	0	4
3	**Program Core – 6** Design, Testing and certification of EV	3	1	0	4
4	**Program Elective – III** Machine Learning for Autonomous Vehicles Software Development for EVs IOT Applications in EVs	3	0	0	3
5	**Program Elective – IV** Smart Grid Interface of Electric Vehicles Energy Storage Systems for Electric Vehicle Energy Auditing Conservation & Management	3	0	0	3
6	**Laboratory – 3** Battery Management Systems Lab	0	1	2	2
7	**Laboratory – 4** Vehicular Communication Networks Lab	0	1	2	2
8	Seminar – II	0	0	2	1
	TOTAL	**15**	**5**	**6**	**23**

II Year MTech (Electric Vehicle Technology) I – Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1		Research Methodology and IPR / Swayam 12 week MOOC course – RM&IPR	3	0	0	3
2		Summer Internship/ Industrial Training (8-10 weeks)*	-	-	-	3
3		Comprehensive Viva#	-	-	-	2
4		Dissertation Part – A$	-	-	20	10
		TOTAL	**3**	**-**	**20**	**18**

* Student attended during summer / year break and assessment will be done in 3rd Sem.
# Comprehensive viva can be conducted courses completed upto second sem.
$ Dissertation – Part A, internal assessment

II Year MTech (Electric Vehicle Technology) II – Semester

Sl. No.	Course Code	Course Title	L	T	P	C
1		Dissertation Part – B%	-	-	32	16
		TOTAL	**-**	**-**	**32**	**16**

% External Assessment

I Semester	POWER ELECTRONICS FOR ELECTRIC VEHICLES (PROGRAM CORE – I)	L	T	P	C
		3	1	0	4

Pre-requisite: Basics of Power Electronics

Course Objectives: The primary objectives of this course are to

- Understand switching device characteristics and gate drive circuit design.
- Illustrate and compare the operation of multilevel inverter topologies.
- Analyze non-isolated switch-mode converter performance.
- Investigate and compare PWM techniques for single- and three-phase inverters.
- Evaluate PWM control strategies for CHB and diode-clamped multilevel inverters.

Course Outcomes: At the end of the course, student will be able to

- Illustrate the characteristics of Switching devices and use gate drive circuits. Illustrate the operation of multilevel inverters and compare their features.
- Analyze the performance of non-isolated switch mode converters.
- Investigate the PWM Control of single-phase and three-phase inverters and compare various PWM techniques.
- Investigate the PWM Control of CHB and diode clamped multilevel inverters.

UNIT– I

Overview of Switching Devices & AC-DC converters:

Power MOSFET, IGBT, GTO, GaN devices-static and dynamic characteristics, gate drive circuits for switching devices.

UNIT– II

Non-Isolated DC-DC Converters:

Control of DC-DC converters: Buck converters, Boost converters, Buck-Boost converter, CUK Converter, continuous and discontinuous operation, relation between input and output voltages, design of filter inductor and capacitors, Converter realization with non-ideal components.

UNIT– III

PWM Inverters: Voltage control of single-phase inverters employing phase displacement Control, Bipolar PWM, Unipolar PWM. Three-phase Voltage source inverters: Six stepped VSI operation-Voltage Control of Three-Phase Inverters employing Sinusoidal PWM, Third Harmonic PWM, Space Vector Modulation- Comparison of PWM Techniques- Three phase current source inverters.

UNIT– IV

Multilevel Inverters:

Introduction, Multilevel Concept, Types of Multilevel Inverters, Diode-Clamped Multilevel Inverter, Principle of Operation, Features of Diode-Clamped Inverter, Improved Diode Clamped Inverter, Cascaded H-bridge Multilevel Inverter, Principle of Operation, Features of Cascaded H-bridge Inverter, Comparison of DCMLI & CHB, Modular multilevel converters, principle of operation.

UNIT– V
PWM Multilevel Inverters:
CHB Multilevel Inverter: Stair case modulation-SHE PWM- Phase shifted Multicarrier modulation-Level shifted PWM- Diode clamped multilevel inverter: SHE PWM-Sinusoidal PWM- Space vector PWM-Capacitor voltage balancing.

Text Books
1. Power Electronics: Converters, Applications, and Design- Ned Mohan, .Tore M Undeland, .William P. Robbins, John Wiley& Sons, 2nd Edition, 2003
2. Power Electronics-Md.H.Rashid –Pearson Education Third Edition- First IndianReprint-2008.
3. High-power converters and AC drives -Wu, Bin, and Mehdi Narimani-John Wiley & Sons, 2017.

Reference Books:
1. Elements of Power Electronics – Philip T. Krein, Oxford University press, 2014.
2. Power Electronics Daniel W. Hart - McGraw-Hill,2011.

I Semester	ELECTRIC AND HYBRID VEHICLES (PROGRAM CORE – II)	L	T	P	C
		3	1	0	4

Pre-requisite: Electrical Circuits and Electrical Machines.

Course Objectives: The primary objectives of this course are to

- Understand the history, need, and impact of electric and hybrid vehicles.
- Explore various hybrid drive-train topologies and their power flow control.
- Learn the configuration and control of different electric motor drives used in EVs.
- Study energy storage technologies and their integration in EV systems.
- Examine energy management strategies and their implementation in EVs

Course Outcomes: At the end of the course, student will be able to

- Describe the evolution and significance of electric and hybrid vehicles.
- Compare different hybrid drive-train architectures and analyse their efficiency.
- Configure and control various electric motor drives for EV applications.
- Analyse and select suitable energy storage systems for hybrid and electric vehicles.
- Evaluate and implement appropriate energy management strategies in EV systems.

UNIT-I: Overview of Electric and Hybrid Vehicles

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.

UNIT-II: Drive Train Topologies

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

UNIT-III: Configuration and control of Motor drives

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 Switched Reluctance Motor drives, drive system efficiency.

UNIT-IV: Energy Storage

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, Ultra Capacitors, Hybridization of different energy storage devices.

UNIT-V: Energy Management Strategies

Introduction to energy management and their strategies used in hybrid and electric vehicles-Classification of different energy management strategies- Comparison of different energy management strategies- Implementation issues.

TEXT BOOKS:

1. C. C. Chan, K. T. Chau, "Modern Electric Vehicle Technology" published by Oxford University Press.
2. Chris Mi, M. AbulMasrur and David WenzhongGao, "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives" John Wiley Ltd. Publication.

3. Iqbal Husain "ELECTRIC and HYBRID VEHICLES Design Fundamentals" CRC PRESS Boca Raton
London New York Washington, D.C.

REFERENCES:

1. Rodrego 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.
3. NITI Aayog, Ministry of Power, Department of Science and Technology, Bureau of Energy Efficiency
"Handbook of Electric Vehicle Charging Infrastructure Implementation" WRI India, Ross Center.

I Semester	AUTOMOTIVE ENGINEERING FOR ELECTRIC VEHICLES (PROGRAM CORE – III)	L	T	P	C
		3	1	0	4

Pre-requisite: Engineering Physics, Basic Electrical and Electronics Engineering.
Course Objectives: The primary objectives of this course are to

- Understand the structure and function of conventional vehicle systems and configurations.
- Learn about vehicle modeling, propulsion loads, and various drive cycles.
- Study the types and functions of suspension, chassis, and body systems.
- Explore transmission, braking, and steering systems and their advancements.
- Understand electric motors, battery technologies, and battery management in vehicles.

Course Outcomes: At the end of the course, student will be able to

- Explain the fundamentals of vehicle systems and evaluate the forces acting on a moving vehicle.
- Analyze different vehicle configurations, drive cycles, and engine performance parameters.
- Classify various chassis, suspension, wheel, and tire systems and assess their advantages.
- Compare transmission types, braking systems, and steering mechanisms used in vehicles.
- Evaluate battery technologies, their thermal and performance management in electric vehicles.

UNIT – I
Conventional vehicle systems and configurations: Fundamentals of vehicle, modelling of vehicle-various forces acting on it, components of conventional vehicle and propulsion load; Drive cycles and drive trains; Engine components and systems, four stroke engines, engine performance, air pollution, emission norms.

UNIT – II
Chassis and Body: Frames – Conventional, Semi-Integral, Integral type, Chassis - Ladder frame, Backbone, Monocoque, Tubular chassis. Advantages and disadvantages.
Suspension system: Springs: coil springs, leaf springs & torsion bars.
Dampers: Hydraulic dampers, Nitrox dampers, Telescopic and USD suspensions, MR and ER dampers.
Types of suspension systems: rigid axle and independent suspensions, air suspension systems, electronic suspension systems, electromagnetic suspension, active and passive suspension systems.
Wheels and tires: Types of wheels, Front /rear wheel drive configurations - Four/All-wheel drive configurations.

UNIT – III

Transmission system: Power train configurations, components, features, advantages and disadvantages, hub motor direct drive configuration, centrally mounted configuration, differential- classification and types.

UNIT – IV

Braking systems: Drum brakes, disc brakes, hydraulic brakes, power-assisted brake, air brakes, electric brakes, anti-lock braking system (ABS), electronic brake force distribution system (EBD), regenerative braking, brake assist system. Supplementary restraint system, air bags, pyrotechnic inflator, air bag control unit.

UNIT – V

Steering system: Steering mechanism, steering geometry, steering gears, power-assisted steering hydraulic power steering (HPS), electric power hydraulic steering (EPHS), electric power steering (EPS).

Batteries: Types of batteries, constructional details, thermal management of batteries, vent management system, Battery life analysis, Battery performance Degradation.

Reference Books:

1.H. Heisler, Advanced Vehicle Technology, 2nd ed. Butterworth–Heinemann, 2002.
2.M Ehsani, Y Gao, L K Ebrahimi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, 3rd Edition,
Taylor and Francis, 2018.
3.Tom Denton, Electric and Hybrid Vehicles ,2nd ed., Routledge, 2020
4.W. H. Crouse and D. L. Anglin, Automotive Transmission and Power Trains construction, 10th ed. McGraw Hill, 2008.
5.W. H. Crouse and D. L. Anglin, Automotive mechanics, 10th ed. Tata McGraw-Hill, 2004.
6.K. Newton, W. Steeds, and T. K. Garret, Motor Vehicle, 13th ed. Butterworth-Heinemann, 2004.
7.M Matschinsky, Road Vehicle Suspensions, Wiley, ISBN: 978-1-860- 58202-8, 1997.
8.J Jiang, C Zhang, Fundamentals and Applications of Lithium-ion Batteries in Electric Drive Vehicles, Wiley, 2015
9. V. Sajith and S. Thomas, Internal Combustion Engines, 1st ed. Oxford University Press, 2017.

I Semester	VEHICULAR COMMUNICATION NETWORKS (PROGRAM ELECTIVE–I)	L	T	P	C
		3	0	0	3

Pre-requisite: Communication Networks, Wireless Communication Systems

Course Objectives: The primary objectives of this course are to

- Understand the fundamentals, architecture, and applications of VANET-based cooperative vehicular systems.
- Explore vehicular mobility and traffic modeling techniques across different levels.
- Analyze physical and MAC layer challenges specific to high-mobility vehicular communication.
- Study and evaluate various routing protocols used in VANETs.
- Understand the regulatory standards, layered architecture, and protocol stack for DSRC in VANETs.

Course Outcomes: At the end of the course, student will be able to

- Describe the core principles, challenges, and cooperative safety applications in VANETs.
- Apply and differentiate between various vehicular mobility and behavioral models.
- Analyze the wireless channel effects and MAC protocols for vehicular communications.
- Compare VANET routing techniques, including ad-hoc, geographic, and geocast routing.
- Interpret standards, protocols, and regulatory frameworks used in VANET communications.

UNIT-I: Introduction and Cooperative Vehicular Safety Applications:

Basic Principles and Challenges, Past and Ongoing VANET (Vehicular Ad-hoc network) Activities, Enabling Technologies, Cooperative System Architecture, VANET-enabled Active Safety Applications.

UNIT-II: Vehicular Mobility Modeling for VANET:

Random Models, Flow Models – Microscopic flow models, Macroscopic flow models, Mesoscopic flow models, Lane changing models; Traffic Models – Trip planning, Path planning, Influence of time; Behavioral Models, Trace or Survey-based Models.

UNIT-III: Physical Layer & MAC Layer Considerations for Vehicular Communications:

Wireless Propagation Theory – Deterministic multipath models, Statistical multipath models, Path loss modelling; Channel Metrics – Delay spread, Coherence bandwidth, Doppler spread, Coherence time, Impact on OFDM systems; A Survey on Proposed MAC Approaches for VANETs - Time-division, Space-division, Code-division; Communication based on IEEE 802.11p.

UNIT-IV: Routing Protocols:
Ad-hoc routing - Proactive routing protocols, Reactive routing protocols; Geographic routing - Geographic routing, Virtual-coordinate-based routing; Geocasting - ETSI GeoNetworking, Decentralized environmental notification messages, Topology-assisted geo-opportunistic routing.

UNIT-V: Standards and Regulations:
Layered Architecture for VANETs - General concepts and definitions, A protocol stack for DSRC; DSRC Regulations, DSRC Physical Layer Standard, DSRC Data Link Layer Standard (MAC and LLC).

TEXTBOOKS

1. H. Hartenstein and K. P. Laberteaux, VANET: Vehicular Applications and Inter-Networking Technologies, Wiley, 2010.
2. Chirstoph Sommer, Falko Dressler, Vehicular Networking, Cambridge University Press, 2015.

REFERENCE BOOKS:

1. H. Moustafa, Y. Zhang, Vehicular Networks: Techniques, Standards, and Applications, CRC Press, 2009.
2. Claudia Campolo, Antonella Molinaro and Riccardo Scopigno, Vehicular ad hoc Networks: Standards, Solutions, and Research, Springer, 2015.

I Semester	SENSOR SYSTEMS FOR ELECTRIC VEHICLES (PROGRAM ELECTIVE–I)	L	T	P	C
		3	0	0	3

Pre-requisite: Basic Electrical and Electronics Engineering, Digital Electronics, Signals and Systems, Microprocessors and Microcontrollers.
Course Objectives: The primary objectives of this course are to

- Understand the fundamentals and performance characteristics of sensors and actuators.
- Study the working principles and applications of temperature and optical sensors.
- Learn the functionality of electric, magnetic, and mechanical sensors.
- Explore chemical, MEMS, and smart sensor technologies and their integration.
- Analyze circuit-level interfacing and microcontroller-based integration of sensors and actuators.

Course Outcomes: At the end of the course, student will be able to

- Explain sensor and actuator types, classifications, and performance parameters.
- Analyze temperature and optical sensor types and their working principles.
- Evaluate electric, magnetic, and mechanical sensors for real-world applications.
- Distinguish between chemical, MEMS, and smart sensors and their usage in systems.
- Design basic interfacing circuits and apply microcontroller-based sensor integration.

Unit-I: Sensor fundamentals and characteristics
Definitions, Classification of sensors and actuators, General requirements for interfacing, Performance characteristics of sensors and actuators

Unit-II: Temperature & Optical sensors
Temperature sensors: Thermo-resistive 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.

Unit-III: Electric, magnetic and mechanical sensors
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.

Unit-IV: Chemical, MEMS and smart sensors

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.

Unit-V: Interfacing circuits and methods

Interfacing circuits: Amplifiers, Power amplifiers, Digital circuits.

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

Text Books:

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

I Semester	RENEWABLE ENERGY TECHNOLOGIES (PROGRAM ELECTIVE -II)	L	T	P	C
		3	0	0	3

Pre requisite: Power Electronics.

Course Objectives: The primary objectives of this course are to

- To understand the fundamental principles of renewable energy sources, distributed generation, and economic aspects including electricity generation cost and management options.
- To apply operational principles and mathematical models of induction generators including self-excitation, speed, and voltage control for renewable power systems.
- To analyze key factors in wind and photovoltaic power plant design, including site evaluation, turbine classification, PV cell characteristics, and maximum power point tracking techniques.
- To explore fuel cell technologies, their performance modeling, practical implementation challenges, and integration considerations for sustainable energy conversion and storage.

Course Outcomes: At the end of the course, student will be able to

- Understanding of renewable energy fundamentals, distributed generation concepts, and the economic/environmental impact of renewable power systems.
- Apply knowledge of induction generator operation and controls to model and control renewable energy conversion systems effectively.
- Analyze wind and solar energy system components, including turbine types, PV cell models, and MPPT algorithms, to optimize system performance.
- Explore fuel cell technologies, hydrogen storage issues, and system integration strategies for advancing renewable energy utilization.

UNIT– I: Introduction: Renewable Sources of Energy; Distributed Generation; Renewable Energy Economics - Calculation of Electricity Generation Costs; Demand-Side Management Options; Supply-Side Management Options; Control of renewable energy based power Systems

UNIT– II: Induction Generators: Principles of Operation; Representation of Steady-State Operation; Power and Losses Generated - Self-Excited Induction Generator; Magnetizing Curves and Self-Excitation - Mathematical Description of the Self-Excitation Process; Interconnected and Stand-alone operation - Speed and Voltage Control.

UNIT– III: Wind Power Plants: Site Selection; Evaluation of Wind Intensity; Topography; Purpose of the Energy Generation- General Classification of Wind Turbines; Rotor Turbines; Multiple-Blade Turbines; Drag Turbines; Lifting Turbines - Generators and Speed Control Used in Wind Power Energy; Analysis of Small wind energy conversion system.

UNIT– IV: Photovoltaic Power Plants: Solar Energy; Generation of Electricity by Photovoltaic Effect; Dependence of a PV Cell on Temperature and irradiance input-output Characteristics - Equivalent Models and Parameters for Photovoltaic Panels; MPPT schemes: P&O,INC, effect of partial shaded condition. Applications of Photovoltaic Solar Energy-Economical Analysis of Solar Energy

UNIT– V

Fuel Cells: The Fuel Cell; Low- and High-Temperature Fuel Cells; Commercial and Manufacturing Issues - Constructional Features of Proton Exchange-Membrane Fuel Cells; Reformers; Electrolyzer Systems; Advantages and Disadvantages of Fuel Cells - Fuel Cell Equivalent Circuit; Practical Determination of the Equivalent Model Parameters; Aspects of Hydrogen for storage

Text Books:

1. Felix A. Farret, M. Godoy Simo` es, Integration of Alternative Sources of Energy, John Wiley & Sons, 2006.
2. Remus Teodorescu, Marco Liserre, Pedro Rodríguez, Grid Converters for Photovoltaic and Wind Power Systems, John Wiley & Sons, 2011.

Reference Books:

1. Gilbert M. Masters, Renewable and Efficient Electric Power Systems, John Wiley & Sons, 2004

I Semester	BATTERY MANAGEMENT SYSTEMS (PROGRAM ELECTIVE–II)	L	T	P	C
		3	0	0	3

Pre-requisite: Basic knowledge of electrochemistry, circuit theory, and electrical energy systems.

Course Objectives: The primary objectives of this course are to

- Understand electrochemical principles and compare various battery and energy storage technologies.
- Learn equivalent circuit models to represent battery behavior under dynamic conditions.
- Develop simulation models of batteries and validate them through parameterization.
- Analyze battery selection, SOC estimation, and thermal and safety considerations for EV/HEV applications.
- Study optimal control strategies for battery management and degradation minimization.

Course Outcomes: At the end of the course, student will be able to

- Explain the working principles and characteristics of different battery chemistries and storage systems.
- Apply equivalent circuit models to analyze battery performance and impedance behaviour.
- Simulate rechargeable battery models (Li-ion and NiCd) and interpret their performance.
- Select appropriate batteries for electric vehicles and implement SOC estimation and thermal management techniques.
- Design optimal control strategies to improve battery life, manage charging, and ensure system safety.

UNIT-I: Introduction to Electrochemical batteries

Electrochemical reactions, Thermodynamic voltage, Specific Energy, Specific Power, Energy efficiency. Battery Specifications.

Batteries: construction and operation of Lead Acid Battery, Nickel based batteries, Sodium based batteries, Lithium based batteries– Li-ion & Li-poly, Metal Air Battery, Zinc Chloride battery; comparison of performance characteristics.

UNIT-II: Equivalent-Circuit Models

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.

UNIT-III: Modelling of Batteries

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.

UNIT-IV: Battery Selection

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.

UNIT-V: Optimal Control of Battery

Battery Optimal Controls, Minimizing degradation, Solid Electrolyte Interface (SEI) formation and growth, SEI Reduced Order Model (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.

TEXT BOOKS

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.
3. Gregory L. Plett, Battery Management Systems Volume II Equivalent-Circuit Methods, 2019.
4. T R Crompton, “Battery Reference Book-3 rd Edition”, Newnes- Reed Educational and Professional Publishing Ltd., 2000.
5. Chris Mi, Abul Masrur& David Wenzhong Gao, “Hybrid electric Vehicle- Principles & Applications with Practical Properties”, Wiley, 2021.
6. James Larminie, John Lowry, “Electric Vehicle Technology Explained”, John Wiley & Sons Ltd, 2019.

I Semester	AUTOMOTIVE EMBEDDED SYSTEMS (PROGRAM ELECTIVE–II)	L	T	P	C
		3	0	0	3

Pre-requisite: Basic understanding of embedded systems, microcontrollers.
Course Objectives: The primary objectives of this course are to

- Understand embedded system architecture and key functional components.
- Explore automotive communication protocols and embedded software reuse strategies.
- Study AUTOSAR architecture, layers, and software components.
- Learn the fundamentals of automotive functional safety and ISO26262 standards.
- Analyze testing and verification methods used in automotive embedded systems.

Course Outcomes: At the end of the course, student will be able to

- Describe the architecture, domains, and characteristics of embedded systems.
- Apply knowledge of automotive protocols (CAN, LIN, FlexRay) and model-based development.
- Explain the structure and operation of AUTOSAR layered architecture.
- Interpret automotive functional safety principles and ISO26262 standards.
- Evaluate testing methodologies including MIL, SIL, HIL, and Automotive SPICE compliance.

UNIT-I: Embedded Systems Overview:
Components of an Embedded System; Functional Domains, Standardized components and models, Typical Embedded System Architectures; Characteristics, Concepts and Challenges.

UNIT-II: Embedded Automotive Protocols and Embedded Software:
Embedded Automotive Protocols: Automotive Communication Systems – car domains, CAN, LIN, and FlexRay Protocols; V-model;
Embedded Software: Basic concepts of software product lines, Reuse of software, Requirements for the reuse of software in the automotive domain, Model based development – Role of MBD in automotive embedded systems and Potential benefits of MBD;

UNIT-III: AUTOSAR Architecture:
AUTOSAR Basics; Autosar Software Components & Application Layers. Basic Software Layer, MCAL Layer, Services Layer, Diagnostics, Memstack, AUTOSAR RTE, AUTOSAR OS & C Rules.

UNIT-IV: Safety and Reliability:
Automotive Functional Safety Concepts, Overview of ISO26262, Different safety standards & levels.

UNIT-V: Testing and Verification for Automotive Systems:
Automotive SPICE (ISO/IEC 15504); Testing in Virtual Environments; XiL Testing - Model in Loop, Hardware in Loop, Software in Loop;

TEXTBOOKS

1. Simonot-Lion, F., & Navet, N. (Eds.). (2009). Automotive Embedded Systems Handbook (1st ed.). CRC Press. https://doi.org/10.1201/9780849380273
2. AUTOSAR [on line]. Available on: www.autosar.org.

3. SPICE. Automotive SPICE® Process Reference and Assessment Model [on line]. RELEASE 3.1. 2017 [Consultation: 16/05/2018]. Available on:
http://www.automotivespice.com/download/.
https://www.automotivespice.com/fileadmin/software-download/Automotive_SPICE_PAM_30.pdf

REFERENCE BOOKS:

1. International Organization for Standardization. ISO/DIS 26262. Road Vehicles - Functional Safety [on line]. 2009 [Consultation: 16/05/2018]. Available on:
https://www.iso.org/obp/ui/#iso:std:iso:26262:-2:dis:ed-2:v1:en.
2. Koomen, Tim; Van der Aalst, Leo; Broekman, Bart; Vroon, Mitchiel. TMap Next, for result-driven testing. Tutein Nolthenius, Uitgeverij, 2007. ISBN 9789072194800.

I Semester	POWER QUALITY ENHANCEMENT USING CUSTOM POWER DEVICES (PROGRAM ELECTIVE–II)	L	T	P	C
		3	0	0	3

Pre requisite: Knowledge on electric circuit analysis, power systems, power electronics.

Course Educational Objectives: The primary objectives of this course are to

- To understand significance of power quality and power quality parameters.
- To analyze types of transient over voltages and protection of transient voltages.
- To examine harmonics, their effects, harmonic indices and harmonic minimization techniques.
- To know the importance of power devices and their applications.
- To understand different compensation techniques to minimize power quality disturbances.

Course Outcomes: At the end of the course, student will be able to

- Identify the issues related to power quality in power systems.
- Address the problems of transient and long duration voltage variations in power systems.
- Analyze the effects of harmonics and study of different mitigation techniques.
- Identify the importance of custom power devices and their applications.
- Acquire knowledge on different compensation techniques to minimize power quality disturbances.

UNIT– I

Introduction to power quality: Overview of Power Quality, Concern about the Power Quality, General Classes of Power Quality Problems, Voltage Unbalance, Waveform Distortion, Voltage fluctuation, Power Frequency Variations, Power Quality Terms, Voltage Sags, swells, flicker and Interruptions - Sources of voltage and current interruptions, Nonlinear loads.

UNIT– II

Transient and Long Duration Voltage Variations: Source of Transient Over Voltages - Principles of Over Voltage Protection, Devices for Over Voltage Protection, Utility Capacitor Switching Transients, Utility Lightning Protection, Load Switching Transient Problems.
Principles of Regulating the Voltage, Device for Voltage Regulation, Utility Voltage Regulator Application, Capacitor for Voltage Regulation, End-user Capacitor Application, Regulating Utility Voltage with Distributed generation

UNIT– III

Harmonic Distortion and solutions: Voltage vs. Current Distortion, Harmonics vs. Transients - Power System Quantities under Non-sinusoidal Conditions, Harmonic Indices, Sources of harmonics, Locating Sources of Harmonics, System Response Characteristics, Effects of

Harmonic Distortion, Inter harmonics, Harmonic Solutions Harmonic Distortion Evaluation, Devices for Controlling Harmonic Distortion, Harmonic Filter Design, Standards on Harmonics

UNIT– IV

Custom Power Devices: Custom power and custom power devices, voltage source inverters, reactive power and harmonic compensation devices, compensation of voltage interruptions and current interruptions, static series and shunt compensators, compensation in distribution systems, interaction with distribution equipment, installation considerations.

UNIT– V

Application of custom power devices in power systems: Static and hybrid Source Transfer Switches, Solid state current limiter - Solid state breaker. P-Q theory – Control of P and Q, Dynamic Voltage Restorer (DVR), Operation and control of Interline Power Flow Controller (IPFC), Operation and control of Unified Power Quality Conditioner (UPQC), Generalized power quality conditioner.

Text Books:

1. Electrical Power Systems Quality, Dugan R C, McGranaghan M F, Santoso S, and Beaty H W, Second Edition, McGraw-Hill, 2002.
2. Understanding Power Quality Problems: Voltage Sags and Interruptions, Bollen M H J, First Edition, IEEE Press; 2000.
3. Guidebook on Custom Power Devices, Technical Report, Published by EPRI, Nov 2000
4. Power Quality Enhancement Using Custom Power Devices – Power Electronics and Power Systems, Gerard Ledwich, ArindamGhosh, Kluwer Academic Publishers, 2002.

Reference Books:

1. Power Quality Primer, Kennedy B W, First Edition, McGraw-Hill, 2000.
2. Power System Harmonics, Arrillaga J and Watson N R, Second Edition, John Wiley & Sons, 2003.
3. Electric Power Quality control Techniques, W. E. Kazibwe and M. H. Sendaula, Van Nostrad Reinhold, New York.
4. Power Quality c.shankaran, CRC Press, 2001
5. Harmonics and Power Systems –Franciso C.DE LA Rosa-CRC Press (Taylor & Francis).
6. Power Quality in Power systems and Electrical Machines-EwaldF.fuchs, Mohammad A.S. Masoum-Elsevier
7. Power Quality, C. Shankaran, CRC Press, 2001
8. Instantaneous Power Theory and Application to Power Conditioning, H. Akagiet.al., IEEE Press, 2007.
9. Custom Power Devices - An Introduction, ArindamGhosh and Gerard Ledwich, Springer, 2002
10. A Review of Compensating Type Custom Power Devices for Power Quality Improvement, Yash Pal et.al., Joint International Conference on Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008.

I Semester	EV SIMULATION LABORATORY (LABORATORY – I)	L	T	P	C
		0	1	2	2

Pre-requisite: Basics of Electrical Machines and Drives, Control Systems, Power Electronics and Battery and Energy Systems.

Course Objectives: The primary objectives of this course are to

- Develop and analyze simulation models for EV systems.
- Understand effects of rolling resistance, mass, and drag on vehicle range.
- Simulate motor speed control for induction, PMDC, and BLDC motors.
- Analyze regenerative braking and battery management via simulation.
- Learn embedded system architecture and automotive protocols for EV control.

Course Outcomes: At the end of the course, student will be able to

- Describe architecture and domains of automotive embedded systems.
- Apply CAN, LIN, FlexRay protocols and model-based design in simulations.
- Explain AUTOSAR layered architecture for vehicle embedded systems.
- Interpret ISO 26262 safety standards and automotive functional safety.
- Evaluate MIL, SIL, HIL testing methodologies and Automotive SPICE compliance.

List of Experiments:

1. Develop a simulation model to analyse the effect of Rolling Resistance on vehicle range and Performance
2. Develop a simulation model to analyze the effect of vehicle mass 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. Simulation study and analyze the performance of speed control of Induction motor drives in EV.
5. Simulation study and analyze the performance of speed control of PMDC and BLDC motor drives in EV.
6. Simulation study of LV/High current electric motor drives with BLDC or PMSM drive.
7. Develop a simulation model to analyze Electric Motor Regenerative Braking Characteristics for different Driving Cycles.
8. Simulation study of Battery Management System in EV
9. Develop a simulation model for Series/parallel HEV to analyze the effect of changing of parameters on vehicle range and performance.
10. Simulation study of data acquisition system of EV

I Semester	EV MOTORS AND CONTROLLERS LAB (LABORATORY – II)	L	T	P	C
		0	1	2	2

Pre-requisite: Power Electronics fundamentals, Basics of Electrical Machines and Drives

Course Objectives: The primary objectives of this course are to

- Understand open and closed loop V/f control techniques for induction motors.
- Learn Field Oriented Control (FOC) and sensorless FOC with MRAS for induction motors.
- Analyze Direct Torque Control (DTC) methods for induction motor drives.
- Study speed control methods for synchronous, PMSM, BLDC, and switched reluctance motors.
- Develop simulation and practical skills for various motor drive control strategies using inverters.

Course Outcomes: At the end of the course, student will be able to

- Apply open and closed loop V/f control techniques for induction motors effectively.
- Implement and analyze FOC and sensorless FOC for three-phase induction motors.
- Demonstrate understanding of Direct Torque Control in induction motor drives.
- Control speed of PMSM and synchronous motors using sine-PWM and FOC methods.
- Design and simulate speed control for BLDC and switched reluctance motor drives.

List of Experiments:

1. Open loop V/f control of a three-phase induction motor.
2. Closed loop V/f control of a three-phase induction motor.
3. Field oriented control of three phase induction motor.
4. Sensorless Field oriented control of three-phase induction motor with MRAS based speed estimation.
5. Direct Torque control of three-phase induction motor.
6. Speed control of Synchronous Motor drive with three-phase inverter.
7. Speed control of PMSM drive with three-phase inverter by using Sine-PWM in open loop.
8. Speed control of PMSM drive with three-phase inverter by using Sine-PWM in closed loop.
9. Speed control of PMSM drive with three-phase inverter by using Field Oriented Control.
10. Speed control of BLDC drive with three-phase inverter in open loop.
11. Speed control of BLDC drive with three-phase inverter in closed loop.
12. Speed control of switched reluctance motor drive.

I Semester	SEMINAR - I	L	T	P	C
		0	0	2	1

II Semester	EV CHARGING TECHNOLOGY AND POLICIES (PROGRAM CORE – IV)	L	T	P	C
		3	1	0	4

Pre-requisite: Basic knowledge of electrical power systems, electric vehicles, and renewable energy integration.

Course Objectives: The primary objectives of this course are to

- Understand the criteria and design considerations for EV charging station location and infrastructure.
- Explore EV charging technologies, types of chargers, and charging methods.
- Analyze modes of EV charging, standards, connectors, and EVSE communication protocols.
- Examine communication interfaces, wireless charging, V2G, and battery swapping technologies.
- Understand national and international EV policies, incentives, and funding mechanisms for EVCI.

Course Outcomes: At the end of the course, student will be able to

- Identify location selection parameters and safety guidelines for EV charging infrastructure.
- Differentiate between slow, fast, AC, and DC charging systems and configurations.
- Evaluate EVSE types, charger standards, and smart charging limitations and protocols.
- Explain communication technologies like V2G, inductive charging, and battery swap systems.
- Analyze and interpret government policies and incentives supporting EV adoption and charging infrastructure.

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Unit-I: Overview of EV charging Location

EV Charging Location Selection-Location Selection criteria - Public charging stations-Guidelines on Charging Infrastructure-Design On-Grid solar charging stations for a parking lot-Electric Vehicle Charging Safety Guidelines.

Unit-II: Introduction to EV Charging Technology

Basic charging Block Diagram of Charger-Difference between Slow charger and fast Charger-On-board charging and Off-board charging-AC charging vs DC charging.

Unit-III: Modes of Charging

Levels of EV charging, AC charging - Type 1,2,3-DC charging - CHAdeMO, Tesla, CCS- Fast charging and its Limitations-Smart charging and applications.

Electric Vehicle Supply Equipment (EVSE): Different types of EV charger connectors-single-phase or three-phase socket-CHAdeMO standard - DC fast Charging-Selection of EVSE Communication Protocol (PLC / Ethernet / Modbus/ CAN Module)-National & International EV Standard Codes.

Unit-IV: Communication Interface

Introduction of Vehicle to grid (V2G) technology- Introduction to Wireless charging of EV-Inductive Charging Static and Dynamic-Battery swap Technology-Communication Interface between charger and Central Management System.

Unit-V: Policies for EV adoption

The nature and scope of policies to stimulate widespread EV adoption and support EVCI station implementation; policy formulation and implementation at various levels of government; examples of policies and incentives for EV adoption-replacement of the gasoline tax funding source in an increasingly electrified environment.

TEXTBOOKS

1. Charging the Future Challenges and Opportunities for Electric Vehicle Adoption, Henry Lee Harvard Kennedy School Alex Clark Climate Policy Initiative, September 2018 RWP18-026.
2. Electric Vehicle Charging Station Guidebook Planning for Installation and Operation, June 2014, CCRPC EV Charging Installation Guide.

REFERENCE BOOKS:

1. HANDBOOK of ELECTRIC VEHICLE CHARGING INFRASTRUCTURE IMPLEMENTATION Version 1, NITI AYOG, WRI INDIA.

II Semester	SPECIAL MACHINES FOR AUTONOMOUS VEHICLES (PROGRAM CORE – V)	L	T	P	C
		3	1	0	4

Pre-requisite: Basic knowledge of electrical machines, power electronics, and electric vehicle fundamentals.

Course Objectives: The primary objectives of this course are to

- Study the structure, modeling, and control of PM Brushless Motor Drives for EV applications.
- Understand the operation, control strategies, and design of Permanent Magnet Synchronous Motor (PMSM) drives.
- Explore Switched Reluctance Motor (SRM) structure, converters, and drive design for EVs.
- Learn advanced stator-PM motor drive configurations and their suitability for EVs.
- Analyze magnet-less motor drive technologies and their emerging applications in EVs.

Course Outcomes: At the end of the course, student will be able to

- Explain the principles, inverter configurations, and EV-specific design aspects of PM Brushless Motor Drives.
- Illustrate PMSM control techniques including vector and sensorless control with EV applications.
- Design and evaluate switched reluctance motor drive systems for electric vehicles.
- Differentiate stator-PM motor types and assess their performance in EV systems.
- Analyze the structure and performance of advanced magnet-less motor drives in modern EV applications.

UNIT-I: Permanent Magnet (PM) Brushless Motor Drives:

Structure of PM Brushless Machines, Principle of PM Brushless Machines Modeling 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.

UNIT-II: Permanent Magnet Synchronous Motor Drives:

Operation of PMSM, PMSM Block Diagram and Control, vector control of PMSM, sensor less control of PMSM, Design Criteria of PMSM Drives for EVs, Design Examples of PMSM Drives for EVs, Application, Advantages and Limitations for EVs .

UNIT-III: Switched Reluctance Motor drives:
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.

UNIT-IV: Stator-PM Motor Drives:
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.

UNIT-V: Advanced Magnet Less Motor Drives:
Introduction of Progressive Magnet less 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, Clarenden press, T.J.E. Miller, 1989, Oxford.

REFERENCE BOOKS:

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 Loury, Electric Vehicle Technology – Explained, John Wiley & Sons Ltd, 2003.
3. T. Kenjo and S. Nagamori, 'Permanent Magnet and Brushless DC Motors', Clarendon Press, London,1988.

II Semester	DESIGN, TESTING AND CERTIFICATION OF EV (PROGRAM CORE – VI)	L	T	P	C
		3	1	0	4

Pre-requisite: Basic understanding of electric vehicles, vehicle systems, and automotive regulations.

Course Objectives: The primary objectives of this course are to

- Understand EV construction, safety regulations, energy measurement methods, and type approval standards.
- Learn AC/DC charging standards and certification requirements for EV and HEV systems.
- Explore regulatory standards for hybrid and electric vehicle retrofitment and propulsion kits.
- Study the safety requirements and certification procedures for traction batteries.
- Analyze national EV policies and government schemes promoting electric mobility.

Course Outcomes: At the end of the course, student will be able to

- Explain EV type approval processes and functional safety requirements under CMVR and ISO 26262.
- Describe EV and HEV charging standards and their compliance requirements.
- Interpret retrofitment standards for hybrid and electric propulsion systems across vehicle categories.
- Evaluate safety standards and certification protocols for traction batteries and EV components.
- Analyze and summarize key national policies such as NEMMP, FAME, and NITI Aayog mobility frameworks.

UNIT-I: Introduction:
Electric power train vehicles-construction and functional safety requirements measurement of electrical energy consumption, Method of measuring the range, Measurement of net power and the maximum 30 minute power, CMVR type approval for electric power train vehicles, ISO 26262.

UNIT-II: Charger Standard:
Electric Vehicle Conductive AC Charging System, Electric Vehicle Conductive DC Charging System.
HEV Standard: CMVR Type Approval for Hybrid Electric Vehicles, CMVR Type Approval for Hybrid Electric Vehicles of M and N Category with GVW > 3500 kg

UNIT-III: Retro fitment Standards:
CMVR Type Approval of Hybrid Electric System Intended for Retro fitment on Vehicles of M and N Category having GVW <= 3500 kg and GVW > 3500 kg. CMVR Type Approval of Electric Propulsion Kit Intended for Conversion of Vehicles for Pure Electric Operation.

UNIT-IV: Safety Requirement of Traction Battery:
Introduction to Vehicle safety standards, Rules and Regulations, Environmental impurities and safety requirements, Battery Operated Vehicles -Safety Requirements of Traction Batteries, Automotive safety components certification by various organizations (ARAI, SIAM, SAE, ASME, FMVSS).

UNIT-V: Government Policies:
National Electric Mobility Mission Plan 2020 (NEMMP2020), Faster Adoption and Manufacture of (Hybrid and Electric Vehicles) – FAME, Niti Aayog Report on Transforming Mobility.

REFERENCE BOOKS:

1. **Automotive Industry Standards, India, 2015-2016**

Other References:

1. **https://araiindia.com**
2. **https://emobility.araiindia.com**
3. **https://dhi.nic.in/writereaddata/Content/NEMMP2020.pdf**
4. **https://niti.gov.in/content/national-mission-transformative-mobility-and-battery-storage**
5. **https://niti.gov.in/writereaddata/files/document_publication/NITI-RMI_India_Report_web-v2.pdf**

II Semester	**MACHINE LEARNING FOR AUTONOMOUS VEHICLES (PROGRAM ELECTIVE–III)**	**L**	**T**	**P**	**C**
		3	**1**	**0**	**4**

Pre-requisite: Fundamental knowledge of vehicle dynamics, sensors, and basic machine learning or AI concepts.

Course Objectives: The primary objectives of this course are to

- Understand the levels of vehicle autonomy and key subsystems enabling intelligent driving.
- Learn machine learning paradigms and their applications in autonomous vehicle perception.
- Apply supervised learning techniques for object detection, classification, and regression.
- Explore deep learning methods and sensor fusion techniques for perception in autonomous driving.
- Study decision-making strategies and trajectory planning algorithms used in self-driving cars.

Course Outcomes: At the end of the course, student will be able to

- Describe levels of autonomy and identify essential components for intelligent autonomous vehicles.
- Apply supervised and unsupervised learning to solve perception tasks in self-driving systems.
- Implement classification and regression algorithms for object recognition and motion prediction.
- Analyze perception using deep learning and multiple sensors like LiDAR, RADAR, and cameras.
- Evaluate decision-making and real-time trajectory planning methods for autonomous navigation.

UNIT-I: Introduction:
Levels of autonomy in automobiles - Levels 0 through 5. Subsystems required for embedding intelligence into automobiles such as sensors, feedback control, software and hardware architecture etc. Sensors, perception and visualization for decision making

UNIT-II: Automotive Machine Learning for Autonomous Vehicles:
Introduction – Types of Learning Paradigms: Supervised, and Unsupervised Learning, and their applications: object detection, object recognition, object classification, and object localization

UNIT-III: Supervised Learning:
Classification (Detection and Classification of Objects, K-Nearest-Neighbor, Bayesian Classification: Naive Bayes, Decision Trees, Overfitting, Random Forests, SVM, Multiclass & Ordinal Classification, Kernels. Dimensionality Reduction: Feature Extraction & Selection
Regression: Instance based learning: Linear Regression, Sensitivity Analysis, Multivariate Regression.: Linear Classification, Logistic Regression

UNIT-IV: Deep Learning for Self-Driving Cars:
Perception: Camera, LiDAR, RADAR, Sensor Fusion.
Applications: Lane Line Detection, Road Segmentation, Obstacle Detection, Traffic-Signs/Light Detection, Road Marking, Distance Estimation, Driver Monitoring, Multi-Object Tracking.

UNIT-V: Decision making and trajectory planning:
Principles of decision making- Heuristic approach and approximation approach; Trajectory planning: Graph based approach, Choice of best trajectory based on real-time data and tracking; various algorithms and their working principles for decision making and trajectory planning.

TEXTBOOKS:
1. Pattern Recognition and Machine Learning by Christopher Bishop
2. Machine Learning by Tom Mitchell
3. Autonomous Vehicle Driverless Self-Driving Cars and Artificial Intelligence: Practical Advances in AI and Machine Learning by Eliot et. al.
4. Applied Deep Learning and Computer Vision for Self-Driving Cars by Sumit Ranjan.
5. Machine Learning, Tom Mitchell, McGraw Hill, 1997.
6. Pattern Recognition and Machine Learning, Bishop, C. (2006), Berlin: Springer-Verla.

REFERENCES:
1. Introduction to Machine Learning, Ethem Alpaydin 2nd Edition.
2. Machine Learning for Hackers, Drew Conway & John Miles Wine.
3. Duda, Hart and Stork, Pattern Classification 2nd Edition Wiley Inter Science, 2000

II Semester	SOFTWARE DEVELOPMENT FOR EVS (PROGRAM ELECTIVE–III)	L	T	P	C
		3	0	0	3

Pre-requisite: Basic Electrical and Electronics Engineering, Digital Electronics, Signals and Systems, Microprocessors and Microcontrollers.

Course Objectives: The primary objectives of this course are to

- Understand the fundamentals and performance characteristics of sensors and actuators.
- Study the working principles and applications of temperature and optical sensors.
- Learn the functionality of electric, magnetic, and mechanical sensors.
- Explore chemical, MEMS, and smart sensor technologies and their integration.
- Analyze circuit-level interfacing and microcontroller-based integration of sensors and actuators.

Course Outcomes: At the end of the course, student will be able to

- Explain sensor and actuator types, classifications, and performance parameters.
- Analyze temperature and optical sensor types and their working principles.
- Evaluate electric, magnetic, and mechanical sensors for real-world applications.
- Distinguish between chemical, MEMS, and smart sensors and their usage in systems.
- Design basic interfacing circuits and apply microcontroller-based sensor integration.

Unit-I: Battery Management System (BMS) Software
Purpose: Manages the state, health, and safety of the battery pack.
Functions: State of Charge (SoC) estimation, State of Health (SoH) monitoring, thermal management, cell balancing, fault detection.
Examples: Altair Battery Designer, BatteryCAD

Unit-II: Powertrain Control Software
Purpose: Controls the electric motor and power electronics to optimize performance and efficiency.
Functions: Motor control algorithms (FOC, DTC), inverter management, regenerative braking control.
Examples: dSPACE Automotive Simulation Models (ASM), Simulink (MATLAB) for model-based design, etc.

Unit-III: Vehicle Control Unit (VCU) Software
Purpose: Integrates various subsystems (e.g., BMS, powertrain, HVAC) and coordinates their operation.
Functions: Supervisory control, energy management, diagnostics, and fault tolerance.
Examples: ETAS INCA, Vector CANoe for network simulation and testing.

Unit-IV: Energy Management Software
Purpose: Optimizes the use of energy within the vehicle to enhance efficiency and performance.
Functions: Energy distribution between battery and auxiliary systems, thermal management.
Examples: AVL CRUISE, Autonomie by Argonne National Laboratory

Unit-V: Advanced Driver Assistance Systems (ADAS) and Autonomous Driving Software
Purpose: Enhances driving safety and enables autonomous driving capabilities.
Functions: Perception (sensor data processing, object detection), decision making (path planning, obstacle avoidance), control (adaptive cruise control, lane keeping).
Examples: NVIDIA DRIVE, Apex.AI

References:
1. "Electric Vehicle Technology Explained" by James Larminie and John Lowry
2. "Battery Management Systems for Large Lithium Ion Battery Packs" by Davide Andrea
3. "Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives" by Chris Mi
4. "Advanced Electric Drive Vehicles" by Ali Emadi
5. "Autonomous Driving: Technical, Legal and Social Aspects" by Markus Maurer et al.

II Semester	IOT APPLICATIONS IN EVS (PROGRAM ELECTIVE–III)	L	T	P	C
		3	0	0	3

Pre-requisite: Basic understanding of electric vehicle systems, microcontrollers, and IoT communication protocols.

Course Objectives: The primary objectives of this course are to

- Introduce the fundamentals and architecture of IoT and its relevance in electric vehicles.
- Explore IoT-based solutions for battery management and real-time monitoring in EVs.
- Understand IoT applications in powertrain control, energy optimization, and predictive maintenance.
- Learn data security, encryption, and edge/cloud data management in IoT-enabled EV systems.
- Study IoT's role in autonomous driving, ADAS, perception systems, and V2X communication

Course Outcomes: At the end of the course, student will be able to

- Explain the structure and communication protocols of IoT systems in electric vehicle contexts.
- Implement IoT-enabled battery management systems for remote monitoring and diagnostics.
- Design IoT-based powertrain and energy management strategies for improved EV efficiency.
- Analyze IoT security challenges and apply techniques for secure and compliant data handling.
- Evaluate IoT-enabled control and communication systems for autonomous EV operation.

Unit-I: Introduction to IoT in EVs:
Definition, history, and evolution of Io, Key concepts and terminologies in IoT, Role and impo in electric vehicles, Applications of IoT in EV systems, Layers of IoT architecture (sensing, co processing, and application), Components of an IoT system (sensors, actuators, gateways Overview of communication protocols (Wi-Fi, Bluetooth, Zigbee, LoRa, NB-IoT, etc.), Prot to vehicular networks (V2V, V2I, V2X).

Unit-II: IoT for Battery Management and Monitoring:
Architecture and components of IoT-enabled BMS, Data acquisition from battery cells Techniques for real-time monitoring of battery parameters (voltage, current, temperature),Usin and gateways for data collection, Predictive Analytics, Remote Diagnostics.

Unit-III: IoT for Powertrain and Energy Management
Role of IoT in powertrain control and optimization, Key parameters monitored by IoT (motor efficiency), IoT-based energy management systems (EMS), Real-time data acquisition and energy optimization, Smart Charging, Predictive Maintenance

Unit-IV: IoT Security and Data Management in EVs
Common security threats in IoT-enabled EVs, Vulnerabilities in IoT components and commu Encryption techniques for secure data transmission, Intrusion detection and prevention acquisition, storage, and processing in IoT systems, Cloud and edge computing for IoT data Privacy and Compliance

Unit-V: IoT for Autonomous Driving and ADAS
IoT in Autonomous Vehicles, Role of IoT in enabling autonomous driving, Key IoT compon functions in autonomous vehicles, Perception Systems, IoT sensors for perception (LiDAR, ra ultrasonic sensors), Data fusion and processing for environment understanding, Vehicle Co Vehicle-to-Everything (V2X) communication using IoT, Protocols and standards for V2X co Control Systems, IoT-based control systems for autonomous driving, Real-time data processin making.

Reference Books:

1. **"Internet of Things: Principles and Paradigms"** by Rajkumar Buyya and Amir Vahid Dastjerdi
2. **"Building the Internet of Things"** by Maciej Kranz
3. **"IoT and Edge Computing for Architects"** by Perry Lea
4. **"Connected Vehicles: Intelligent Transportation Systems"** by Radovan Miucic
5. **"The Fourth Industrial Revolution"** by Klaus Schwab

II Semester	SMART GRID INTERFACE OF ELECTRIC VEHICLES (PROGRAM ELECTIVE–IV)	L	T	P	C
		3	0	0	3

Pre-requisite: Basic knowledge of electrochemistry, circuit theory, and electrical energy systems.

Course Objectives: The primary objectives of this course are to

- Understand electrochemical principles and compare various battery and energy storage technologies.
- Learn equivalent circuit models to represent battery behavior under dynamic conditions.
- Develop simulation models of batteries and validate them through parameterization.
- Analyze battery selection, SOC estimation, and thermal and safety considerations for EV/HEV applications.
- Study optimal control strategies for battery management and degradation minimization.

Course Outcomes: At the end of the course, student will be able to

- Explain the working principles and characteristics of different battery chemistries and storage systems.
- Apply equivalent circuit models to analyze battery performance and impedance behaviour.
- Simulate rechargeable battery models (Li-ion and NiCd) and interpret their performance.
- Select appropriate batteries for electric vehicles and implement SOC estimation and thermal management techniques.
- Design optimal control strategies to improve battery life, manage charging, and ensure system safety.

UNIT-I:

Introduction to the Smart Grid using EVs

The Smart Grid and Microgrid, Impact of EVs on Distributed Energy Resources in the Smart Grid, V2G Technology and PEVs Charging Infrastructures.

UNIT-II

Impact of EV and V2G on the Smart Grid and Renewable Energy Systems

Types of Electric Vehicles, Motor Vehicle Ownership and EV Migration, Impact of Estimated EVs on Electrical Network, Impact on Drivers and the Smart Grid

UNIT-III

Power Conversion Technology in the Smart Grid and EV

Dynamical Modeling of EV Connected to Single-Phase Smart Grid Node, Dynamical Modeling of EV Connected to Three-Phase Smart Grid Node, Power Conversion Problem Formulation in Smart Grids with EVs.

UNIT-IV

Power Control and Monitoring of the Smart Grid with Evs

Impacts of EV Penetration on Grid Power Profile and Requirements of Its Control and Monitoring Vehicle-to-Grid: Linking Electric Vehicles to the Smart Grid. Voltage and Frequency Regulation, Supporting and Balancing of Intermittent RES.

UNIT-V

EV Charging Technologies and V2G on Distributed Systems and Utility Interfaces

Vehicle-to-Grid Concept and EV Communication Requirements, Distributed Generation and the Smart Grid, Charging Diversity and Utility Interfaces, Local, Central and Distributed Generation, Current PEV Charging Standards, Socket Types, Contact-Based PEV Charging, Rectifier Topologies for G2V, Inverter Topologies for V2G, DC/DC Converters.

TEXT BOOKS

1. Hossain, Jahangir Lu, Junwei, "Vehicle-to-Grid Linking Electric Vehicles to the Smart Grid," Published by The Institution of Engineering and Technology, London, United Kingdom, 2015.

2. Qiuwei Wu, "Grid integration of Electric vehicles in Open electricity markets, " John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom, 2013.

3. Canbing Li, Yijia Cao, Yonghong Kuang Bin Zhou, "Influences of Electric Vehicles on Power System and Key Technologies of Vehicle-to-Grid," Jointly published with Science Press, Beijing and Springer-Verlag Berlin Heidelberg 2016.

II Semester	ENERGY STORAGE SYSTEMS FOR ELECTRIC VEHICLE (PROGRAM ELECTIVE–IV)	L	T	P	C
		3	0	0	3

Pre-requisite: Basic knowledge of electrical machines, electrochemistry, and electric vehicle fundamentals.

Course Objectives: The primary objectives of this course are to

- Understand different types of energy storage systems and their relevance to electric vehicles.
- Explore fuel cell technologies, modeling techniques, and system integration for EVs.
- Analyze battery selection criteria, parameters, and estimation techniques.
- Study battery installation, management strategies, safety, and hybrid storage combinations.
- Examine storage system design, testing, and control strategies in real-world EV applications.

Course Outcomes: At the end of the course, student will be able to

• Identify and differentiate energy storage technologies for electric vehicle applications.
• Evaluate fuel cell types, models, and integration with safety and lifecycle considerations.
• Select appropriate battery cells based on performance parameters and application needs.
• Apply battery management strategies considering SoH, DoD, SoC, and safety aspects.
• Design and test energy storage systems for EVs using case-based and simulation approaches.

UNIT – I: Overview of Energy Storage Technologies for EVs: Introduction to Energy Storage Requirements in Electric Vehicles - 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.

UNIT – II: Fuel Cell Technologies and System Integration:
Introduction and overview of fuel cells technology: 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 modeling-simulation and case studies, system integration, Safety issues and cost expectation and life cycle analysis of fuel cells, Placement of storage systems.

UNIT – III: Battery Selection and Performance Parameters:
Selection of battery cell and types, 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.

UNIT – IV: Battery Management Systems and Safety:
Battery mounting arrangement and installation methodology. State of health and charging efficiency and its effect on 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.

UNIT – V: Energy Storage System Design and Applications:
Design and Applications of Energy Storage - 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.

REFERENCES
1. D. A. J. Rand, R. Woods, and R. M. Dell, “Batteries for Electric Vehicles,” Society of Automotive Engineers,” Warrendale PA, 2003.
2. 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.
3. 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.
4. Mehrdad Ehsani, Yimin Gao, and Ali Emadi, "Modern Electric, Hybrid and Fuel Cell Vehicles: Fundamentals", CRC Press, 2010.
5. Electric Power Research Institute (USA), “Electricity Energy Storage Technology Options: A
White Paper Primer on Applications, Costs, and Benefits” (1020676), December 2010.
6. 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/ TP6A2-47187, January 2010.
7. Kim, Y., & Chang, N. (2014). Design and management of energy-efficient hybrid electrical energy storage systems. Cham, Switzerland: Springer International Publishing.
8. Rufer, Alfred. Energy storage: systems and components. CRC Press, 2017.
9. Viral, R., Tomar, A., Asija, D., Rao, U.M., & Sarwar, A. (Eds.). (2022). Smart Grids for Renewable Energy Systems, Electric Vehicles and Energy Storage Systems (1st ed.). CRC Press.

II Semester	ENERGY AUDIT CONSERVATION & MANAGEMENT (PROGRAM ELECTIVE–IV)	L	T	P	C
		3	0	0	3

Pre-requisite: Electrical power systems and measurements.

Course Objectives: The primary objectives of this course are to

- To understand the basics of energy audit and energy conservation schemes.
- To comprehend the principles of energy management and understand the need of energy efficient motors and lighting design practices.
- To study about power factor improvement techniques and energy instruments.
- To analyse the economic aspects of energy equipment.

Course Outcomes: At the end of the course, student will be able to

- Understand the principle of energy audit and their economic aspects.
- Recommend energy efficient motors and design good lighting system.
- Understand advantages to improve the power factor.
- Evaluate the depreciation of equipment.

UNIT– I: Basic Principles of Energy Audit

Energy audit- definitions, concept , types of audit, energy index, cost index ,pie charts, Sankey diagrams and load profiles, Energy conservation schemes- Energy audit of industries- energy saving potential, energy audit of process industry, thermal power station, building energy audit.

UNIT– II: Energy Management

Principles of energy management, organizing energy management program, initiating, planning, controlling, promoting, monitoring, reporting. Energy manager, qualities and functions, language, Questionnaire – check list for top management

UNIT– III: Energy Efficient Motors and Lighting

Energy efficient motors, factors affecting efficiency, loss distribution, constructional details, characteristics – variable speed , variable duty cycle systems, RMS - voltage variation-voltage unbalance-over motoring-motor energy audit. lighting system design and practice, lighting control, lighting energy audit

UNIT– IV: Power Factor Improvement and energy instruments

Power factor – methods of improvement, location of capacitors, Power factor with non-linear loads, effect of harmonics on p.f, p.f motor controllers – Energy Instruments- watt meter, data loggers, thermocouples, pyrometers, lux meters, tongue testers, application of PLC's

UNIT– V: Economic Aspects and their computation

Economics Analysis depreciation Methods, time value of money, rate of return, present worth method, replacement analysis, lifecycle costing analysis – Energy efficient motors. Calculation of simple payback method, net present value method- Power factor correction, lighting – Applications of life cycle costing analysis, return on investment.

Text Books:

1. Energy management by W.R.Murphy&G.Mckay Butter worth, Heinemann publications, 1982.
2. Energy management hand book by W.CTurner, John Wiley and sons, 1982.

Reference Books:

1. Energy efficient electric motors by John.C.Andreas, Marcel Dekker Inc Ltd-2nd edition,1995
2. Energy management by Paul o' Callaghan, Mc-graw Hill Book company-1st edition, 1998
3. Energy management and good lighting practice : fuel efficiency- booklet12-EEO

<table>
<tr><td rowspan="2">II Semester</td><td rowspan="2">BATTERY MANAGEMENT SYSTEMS LAB
(LABORATORY – III)</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>2</td></tr>
</table>

Pre-requisite: Basics of Electrical Machines and Power Electronics, Control Systems and Embedded Systems Fundamentals

Course Objectives: By the end of the course, students will be able to

- Model and simulate equivalent circuits of lead-acid and lithium-ion batteries.
- Measure and estimate battery parameters including SoC, DoD, SoH, and SoP through simulation.
- Design and simulate passive and active battery management systems (BMS).
- Simulate battery charging and discharging behaviors with various converter topologies.
- Implement and analyze CAN protocol for battery management systems.

Course Outcomes: Upon completion, students will

- Develop simulation models for various battery chemistries and equivalent circuits.
- Accurately estimate key battery parameters and states using simulation tools.
- Design and simulate both passive and active BMS for battery packs.
- Analyze battery charging/discharging characteristics using DC-DC and AC-DC converters.
- Implement and evaluate CAN communication protocols for battery management systems.

LIST OF EXPERIMENTS
(Any 10 experiments)

1. Simulation of 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 (Depth of Discharge, State of Health, State of Power).

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 Ni-MH Battery Model with the DC machine and show the charging and discharging process using DC machine.

8. Simulate Closed-loop Implementation of Bi-directional DC-DC Converter with two batteries.

9. Design the 2 Series, 4 Parallel Battery pack with passive BMS circuit.

10. Design 4 Series, 4Parallel Battery pack design with active BMS.

11. Implementation of CAN (Controller Area Network) protocol on active and Passive BMS.

12. Simulation of Battery Charging by using non isolated DC – DC converter

13. Simulation of Battery Charging by using AC – DC converter

14. Simulation of battery charging system to analyse its impact on power system.

II Semester	VEHICULAR COMMUNICATION NETWORKS LAB (LABORATORY – IV)	L	T	P	C
		0	1	2	2

Pre-requisite: Basics of Embedded Systems and Microcontrollers (e.g., Arduino), Fundamentals of Wireless Sensor Networks and IoT.

Course Objectives: By the end of the course, students will be able to

- Identify and configure hardware components of WSNs including Xbee modules and Arduino boards.
- Program Arduino for sensor data acquisition and transmission.
- Develop IoT applications to upload sensor data to the cloud via HTTP and MQTT.
- Test and analyze vehicular communication protocols including V2X and IEEE 802.11p.
- Perform CAN communication, ECU simulation, and vehicle diagnostic services (UDS) in EVs.

Course Outcomes: Upon completion, students will

- Configure and operate WSN hardware and interfaces using XCTU and related tools.
- Write embedded code for sensor data acquisition and wireless communication.
- Implement IoT network protocols and cloud data uploading for sensor networks.
- Evaluate performance of V2X and vehicular networking protocols.
- Simulate and validate automotive communication systems including CAN and ECU diagnostics.

Any 10 of the following experiments are to be conducted.
List of experiments

1. Familiarization of Hardware Components of Wireless Sensor Networks (WSNs) and Configuration of Xbee using XCTU Software. (Components: Arduino Boards, Xbee modules, Sensors, Xbee Explorer, IoT interface/bridge, WiGuy Routers, Switch, etc.)

2. Coding the Arduino Board for different Sensors.

3. Measurement and collection of sensor values

4. Development of program to upload sensor values to the cloud through HTTP.

5. IOT Network Protocol – MQTT (Message Queuing Telemetry Transport).

6. Collection of Measured Data at the Coordinator (Centralized node).

7. Development of IOT Network Application and Testing.

8. Performance Testing of V2X Interface.

9. Performance Testing of VCN (Vehicular Communications and Networking) Protocol – IEEE 802.11 P.

10. Conduct CAN (Controller Area Network) communication and ECU network in EV

11. Conduct UDS (Unified Diagnostic Services) - vehicle dynamics

12. Perform ECU (Electronic Control Unit) simulation, automotive V & V using CAN tools.

II Semester	SEMINAR - II	L	T	P	C
		0	0	2	1

<table>
<tr><td rowspan="2">III Semester</td><td rowspan="2">RESEARCH METHODOLOGY AND IPR / SWAYAM 12 WEEK MOOC COURSE – RM&IPR</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
</table>

III Semester	SUMMER INTERNSHIP/ INDUSTRIAL TRAINING (8-10 WEEKS)*	L	T	P	C
		0	0	0	3

III Semester	COMPREHENSIVE VIVA#	L	T	P	C
		0	0	0	2

III Semester	DISSERTATION PART – A$	L	T	P	C
		0	0	20	10

IV Semester	DISSERTATION PART – A$	L	T	P	C
		0	0	32	16