PANIMALAR ENGINEERING COLLEGE

(An Autonomous Institution, Affiliated to Anna University, Chennai)
Bangalore Trunk Road, Varadharajapuram,
Poonamallee, Chennai – 600123

Minor Degree
ELECTRIC VEHICLE TECHNOLOGY
Curriculum & Syllabus

DEPARTMENT OF

ELECTRICAL AND ELECTRONICS ENGINEERING

REGULATION 2023

Department of Electrical and Electronics Engineering

MINOR DEGREE
on

ELECTRIC VEHICLE TECHNOLOGY

S. No	Course Code	Course Title	Category	L/T/P	Contact Hours	Credit	Ext / Int Weightage
1.	23EE4001	Electric Vehicle Architecture and Dynamics	PE	3/0/0	3	3	60/40
2.	23EE4002	Electrical Machines and Drives	PE	3/0/0	3	3	60/40
3.	23EE4003	Power Electronics for Electric Vehicles	PE	3/0/0	3	3	60/40
4.	23EE4004	Electric Vehicle Design, Modelling and Control	PE	3/0/0	3	3	60/40
5.	23EE4005	Design of Hybrid Electric Vehicles	PE	3/0/0	3	3	60/40
6.	23EE4006	Control System Design for EV Applications	PE	3/0/0	3	3	60/40
7.	23EE4007	Energy Storage Devices for Hybrid Electric Vehicles	PE	3/0/0	3	3	60/40
8.	23EE4008	Electric Vehicle Charging Systems	PE	3/0/0	3	3	60/40

23EE4001	ELECTRIC VEHICLE ARCHITECTURE AND DYNAMICS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

- To outline the history and evolution of EVs, HEVs, and PHEVs, and compare them with ICE vehicles.
- To introduce the architecture and key components of electric and hybrid vehicles.
- To explain basic vehicle dynamics and analyze EV/HEV performance.
- To analyze powertrain configurations and performance of electric vehicles.
- To describe the working and performance aspects of plug-in hybrid electric vehicles.

UNIT I — EV HISTORY AND ITS EVOLUTION — 9

Electric Vehicle History - IC Engines, BMEP and BSFC, Vehicle Fuel Economy, Emission Control Systems, Treatment of Diesel Exhaust Emissions, Evolution of Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs).

UNIT II — HEV ARCHITECTURE — 9

Architecture of HEVs - Series, Parallel and Series Parallel Architecture, Micro and Mild architectures. HEVs in Hilly terrains - Electric Cars and Heavy Duty EVs - Details and Specifications.

UNIT III — VEHICLE DYNAMICS — 9

Vehicle dynamics - Roadway fundamentals, Laws of motion - Drive Cycles - Dynamics of vehicle motion, - velocity and acceleration, Tire-Road mechanics - Tractive Force/Power / Energy - Tractive System

UNIT IV — POWER COMPONENTS AND BRAKES — 9

Power train Component sizing - Motors, Gears, Clutches, Differential, Transmission and Vehicle Brakes. EV power train sizing, HEV Powertrain sizing, Example.

UNIT V — PLUG-IN HYBRID ELECTRIC VEHICLE — 9

Introduction - History - Comparison with electric and hybrid electric Vehicle-Construction and working of PHEV-Block diagram and Components-Charging Mechanisms-Advantages of PHEVs.

SKILL DEVELOPMENT ACTIVITIES (Group Seminar/Mini Project/Assignment/Content Preparation / Quiz/ Surprise Test / etc)

Simulation of Electric Vehicle power components

- Simulation of drive cycles.
- Simulation of Power train components
- Simulation of Motors, Gears, Clutches
- Estimation of Torque/Power/Energy requirements for operation of EVs / HEVs

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Summarize the History and Evolution of EVs, Hybrid and Plug-In Hybrid EVs and compare the same with the performance of internal combustion engine vehicles.

CO2 Describe the various EV components and its architecture

CO3 Describe the concepts related to the dynamics of EVs / HEVs and analyse its performance

CO4 Analyse the performance of EVs with power train mechanism

CO5 Describe the concept and performance of Plug-in hybrid electric vehicle

TEXT BOOKS:

1. Iqbal Hussain, "Electric and Hybrid Vehicles: Design Fundamentals, Second Edition" CRC Press, Taylor & Francis Group, Third Edition 2021.
2. Mehrdad Ehsani, YiminGao, Sebastian E. Gay, Ali Emadi, "Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design", CRC Press, 2004.

REFERENCE BOOKS:

1. "Build Your Own Electric Vehicle", Seth Leitman, Bob Brant, McGraw Hill, Third Edition 2013.
2. "Advanced Electric Drive Vehicles", Ali Emadi, CRC Press, First edition 2017.
3. "The Electric Vehicle Conversion Handbook: How to Convert Cars, Trucks, Motorcycles, and Bicycles - Includes EV Components, Kits, and Project Vehicles", Mark Warner, HP Books, 2011.
4. "Heavy-duty Electric Vehicles from Concept to Reality", Shashank Arora, Alireza Tashakori Abkenar, Shantha Gamini Jayasinghe, Kari Tammi, Elsevier Science, 2021.
5. "Electric Vehicles Modern Technologies and Trends", Nil Patel, Akash Kumar Bhoi, Sanjeevikumar Padmanaban, Jens Bo Holm-Nielsen Springer, 2020.
6. "Hybrid Electric Vehicles: A Review of Existing Configurations and Thermodynamic Cycles", Rogelio León , Christian Montaleza , José Luis Maldonado , Marcos Tostado-Véliz and Francisco Jurado, Thermo, 2021.

CO-PO Mapping

CO / PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	–	–	–	2	–	–	–	–	3
CO2	3	3	–	–	–	2	–	–	–	–	2
CO3	3	3	–	–	–	1	–	–	–	–	2
CO4	3	3	–	–	3	2	–	–	–	–	2
CO5	3	3	2	2	2	2	–	–	–	–	2

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23EE4002	ELECTRICAL MACHINES AND DRIVES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

- Provide fundamental knowledge on the working principles and characteristics of DC machines and transformers.
- Introduce the operating principles and performance of AC machines, including induction and synchronous machines.
- Familiarize students with special machines such as BLDC, SRM, and PMSM along with their control principles.
- Develop the ability to model and control DC drives using classical control techniques.
- Explain the control strategies of AC drives using scalar and vector control methods.

UNIT I DC MACHINES AND TRANSFORMERS 9

DC Generator: Principle of operation -EMF equation - Characteristics DC- Motor working principle- Torque Equation-Characteristics - Starters - Speed Control-Applications of DC machines.

Transformer - Principle - Theory of ideal transformer - EMF equation - Construction -- Equivalent circuit –Performance

UNIT II AC MACHINES 9

Three phase Induction motor: -Types and principle of operation - toque-slip characteristics- Starting and speed control

Alternators: Principle of operation, Voltage regulation - Synchronous motor: Principle of operation-Starting.

UNIT III SPECIAL MACHINES 9

Doubly fed Induction Machine-Permanent magnet synchronous motor, Brushless DC motor, Switched reluctance motor Working principle-Governing equations and Control.

UNIT IV DC DRIVES 9

Modeling of drive elements – Equivalent circuit, transfer function of self, separately excited DC motors; Linear Transfer function model of power converters; Sensing and feeds back elements - Closed loop speed control – current and speed loops, P, PI and PID controllers

UNIT V AC DRIVES 9

Scalar Control of Induction motor, Characteristics. Reference frame theory: transformation of variables from stationary to arbitrary reference frame - variables observed from several frames of reference, Vector Control and Direct Torque control.

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Explain the construction, operation, and performance of DC machines and transformers.

CO2 Analyze the operation and characteristics of three-phase induction and synchronous machines.

CO3 Describe the working principles and control aspects of special machines such as BLDC, PMSM, and SRM.

CO4 Model and analyze DC drives with closed-loop control using controllers like P, PI, and PID.

CO5 Explain scalar and vector control strategies of AC drives using reference frame theory.

TEXT BOOKS:

1. Fitzgerald A.E., Kingsley C., Umans, S. and Umans S.D., "Electric Machinery", 6th Edition, McGraw-Hill, 2003.
2. Kothari. D.P, Nagrath. I.J., "Electric Machines" 5th edition, McGraw Hill Education, 2017.

REFERENCE BOOKS:

1. Paul C.Krause, Oleg Wasyzczuk, Scott S, Sudhoff, "Analysis of Electric Machinery and Drive Systems", John Wiley, Second Edition, 2010.
2. Stephen Chapman, "Electric Machinery Fundamentals", 4th edition, McGraw Hill Education. 2017.
3. Gopal K Dubey, "Power Semiconductor controlled Drives", Prentice Hall Inc., New Jersy, 1989.
4. R.Krishnan, "Electric Motor Drives – Modeling, Analysis and Control", Prentice-Hall of India Pvt. Ltd., New Delhi,2010.
5. Ashfaq Husain and Harroon Ashfaq., "Electric Machines", 3rd edition, Dhanpat Rai & Co., 2016.

CO-PO Mapping

CO / PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	–	–	2	–	–	–	–	–	3
CO2	3	3	3	–	2	–	–	–	–	–	3
CO3	3	3	3	–	2	–	–	–	–	–	3
CO4	3	2	3	–	3	–	–	–	–	–	3
CO5	2	2	2	–	3	–	–	–	–	–	3

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23EE4003	POWER ELECTRONICS FOR ELECTRIC VEHICLES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

- To provide knowledge on the operation, characteristics, and protection of various power semiconductor devices.
- To introduce the working and design aspects of controlled rectifiers for AC to DC conversion.
- To develop analytical and design skills for DC-DC converters.
- To enable understanding and design of different types of inverters for DC to AC conversion.
- To introduce the concepts and applications of soft switching techniques and resonant converters.

UNIT I POWER SEMICONDUCTOR DEVICES AND CHARACTERISTICS 9

Operating principle and switching Characteristics: Power diodes - Power BJT, Power MOSFET, IGBT, SCR, GTO, Power integrated circuits (PIC) – Drive and Protection circuits – SiC and GaN devices.

UNIT II CONTROLLED RECTIFIERS 9

Single phase – Three phase – Half controlled – Fully controlled rectifiers – Dual converters - Effect of source and load inductance, Performance parameters calculation.

UNIT III DC TO DC CONVERTERS 9

Step up and Step-down Chopper – Chopper classification - quadrant of operation – Switching mode Regulators – Buck, Boost, and Buck-Boost Regulators- Design of DC –DC Converters. Introduction to Dual Active Bridge Converters.

UNIT IV INVERTERS 9

Voltage source Inverters –1-PhaseHalf bridge and Full bridge –3-Phase Bridge Inverters – Voltage control –PWM Techniques – Current Source Inverters Multilevel Inverters- Types- Principle of Operation.

UNIT V RESONANT CONVERTERS 9

Review on Parallel and Series Resonant Switches-Soft Switching- Zero Current Switching – Zero Voltage Switching –Classification of Quasi resonant switches-Zero Current and Zero Voltage Switching of Quasi Resonant Buck converter- Zero Current and Zero Voltage Switching of Quasi Resonant Boost converter: Steady State analysis.

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Explain and analyse operations, characteristics and protection of power semiconductor devices

CO2 Classify, analyze and design, Controlled rectifier .

CO3 Classify, analyze and design of DC to DC converters

CO4 Design and analyze inverters.

CO5 Understand the principle of soft switching and resonant converters.

TEXT BOOKS:

1. Rashid, M.H., "Power Electronics – Circuits, Devices and Applications", PHI, Fourth edition, 2014.
2. Mohan, Undeland and Robbins., "Power Electronics", John Wiley and Sons, New York, 3rd edition 2006.
3. Bimbhra, P.S., "Power Electronics", Khanna Publishers, 5th edition, 2012.

REFERENCE BOOKS:

1. John G. Kassakian, Martin F. Schlecht, George C. Verghese, "Principles of Power Electronics", Pearson, India, New Delhi, 2010.
2. Philip T Krein, "Elements of Power Electronics", Oxford University Press, 1998.
3. Ned Mohan, "Power Electronics: A first course", John Wiley, 2011.
4. Issa Batarseh, Ahmad Harb, "Power Electronics- Circuit Analysis and Design, Second edition, 2018.
5. Dehong Xu, Rui Li, Ning He, Jinyi Deng, Yuying Wu, Soft-Switching Technology for Three-phase Power Electronics Converters, IEEE Press, 2022.
6. Fang Lin Luo, Hong Ye, Power Electronics Advanced Conversion Technologies, Second edition, CRC Press, 2018.
7. Deshang Sha, Guo Xu, High-Frequency Isolated Bidirectional Dual Active Bridge DC–DC Converters with Wide Voltage Gain, Springer 2019.

CO-PO Mapping

CO / PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	–	–	2	–	–	–	–	–	3
CO2	3	3	3	–	2	–	–	–	–	–	3
CO3	3	3	3	–	2	–	–	–	–	–	3
CO4	3	2	3	–	3	–	–	–	–	–	3
CO5	2	2	2	–	3	–	–	–	–	–	3

<table>
<tr><th colspan="4">Internal Assessment</th><th rowspan="2">End Semester Examinations</th></tr>
<tr><th colspan="2">Assessment I (100 Marks)</th><th colspan="2">Assessment II (100 Marks)</th></tr>
<tr><th>Individual Assignment / Case Study / Seminar / Mini Project</th><th>Written Test</th><th>Individual Assignment / Case Study / Seminar / Mini Project</th><th>Written Test</th><th>Written Examinations</th></tr>
<tr><td>40</td><td>60</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td colspan="4">40%</td><td>60 %</td></tr>
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23EE4004	ELECTRIC VEHICLE DESIGN, MODELLING AND CONTROL	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

- To introduce methods for estimating torque, power, and energy requirements in EVs and HEVs.
- To analyze the performance and suitability of different electric motors for EV/HEV applications.
- To estimate battery capacity and assess its performance in vehicle applications.
- To explain the fundamental concepts and key parameters of batteries used in EVs.
- To model batteries and explore current research and advancements in battery technology for electric mobility.

UNIT I ESTIMATION OF VEHICLE PARAMETERS 9

Dynamics of Electric Vehicles - Tractive force - Maximum grade - distance, time and terminal velocity of vehicles- Maximum speed, torque, power, energy requirements of EVs for acceleration and standard drive cycles.

UNIT II CHOICE OF MOTORS FOR EVs / HEVs 9

Speed and Torque control below and above rated speed of motors - Speed control of EVs / HEVs. - DC Motors, Induction Motor, Permanent Magnet Synchronous Motors (PMSM), Brushless DC Motors, Switched Reluctance Motors (SRMs). Synchronous Reluctance Machines - Speed and torque range for EVs and HEVs - Choice of electric motors for EVs / HEVs.

UNIT III ESTIMATION OF BATTERY CAPACITY FOR EV APPLICATIONS 9

Batteries in Electric and Hybrid Vehicles - Battery Basics -Battery Parameters - Types: Lead Acid Battery - Nickel-Cadmium Battery - Nickel-Metal-Hydride (NiMH) Battery - Li-Ion Battery - Li-Polymer Battery, Zinc-Air Battery, Sodium-Sulphur Battery, Sodium-Metal-Chloride - Battery Models - Battery Pack Management - SoC / SoD / DoD of Battery - Estimation of battery capacity for EVs / HEVs for standard drive cycles.

UNIT IV ELECTRIC VEHICLE CONTROL STRATEGY 9

Vehicle supervisory control, Mode selection strategy, Modal Control strategies, Autonomous vehicles and its control.

UNIT V DESIGN AND MODELING OF EVs / HEVs 9

Design and Modeling of architecture and dynamics of EVs / HEVs for standard drive cycles for level roads and hilly terrains.

SKILL DEVELOPMENT ACTIVITIES (Group Seminar/Mini Project/Assignment/Content Preparation / Quiz/ Surprise Test / etc)

- Estimation of Torque / Power / Energy requirements of EVs / HEVs
- Modeling and Simulation of motors for EV/HEV applications
- Design, model and analyse the performance of Batteries.
- Simulation of vehicle architecture and dynamics and control of EVs / HEVs.

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Estimate and analyse the torque / power / energy requirements of EVs / HEVs

CO2 Analyse the performance of motors for EV / HEV applications.

CO3 Estimate the capacity of battery and anayse its performance for EV / HEV applications.

CO4 Explain the concepts related with batteries and parameters of battery.

CO5 Module the battery and to study the research and development for batteries.

TEXT BOOKS:

1. Electric and Hybrid Vehicles, Design Fundamentals, Third Edition, Iqbal Husain, CRC Press, 2021.
2. Wie Liu, "Hybrid Electric Vehicle System Modeling and Control", Second Edition, John Wiley & Sons, 2017, 2nd Edition.

REFERENCE BOOKS:

1. Ali Emadi, Mehrdad Ehsani, John M.Miller, "Vehicular Electric Power Systems", Special Indian Edition, Marcel dekker, Inc 2003, 1st Edition.
2. C.C. Chan and K.T. Chau, 'Modern Electric Vehicle Technology', OXFORD University Press, 2001, 1st Edition.
3. Dynamic Simulation of Electric Machinery using MATLAB, Chee Mun Ong, Prentice Hall,1997, 1st Edition.
4. Electrical Machine Fundamentals with Numerical Simulation using MATLAB/ SIMULINK, Atif Iqbal, Shaikh Moinoddin, Bhimireddy Prathap Reddy, Wiley, 2021, 1st Edition.

CO-PO Mapping

CO / PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	3	–	–	–	–	–	–	–	–	3
CO2	3	3	–	–	3	–	–	–	–	–	3
CO3	3	3	–	–	3	–	–	–	–	–	3
CO4	3	3	–	3	3	–	–	–	–	–	3
CO5	3	3	–	–	3	–	–	–	–	–	3

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23EE4005	DESIGN OF HYBRID ELECTRIC VEHICLES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

- To provide an overview of the history, architecture, and technological challenges of hybrid electric vehicles.
- To explain the significance and application of power electronics in hybrid electric vehicle systems.
- To introduce the different energy sources used in HEVs, including batteries and fuel cells.
- To familiarize students with the selection and use of electric motors for hybrid vehicle applications.
- To study HEV modeling techniques and explore energy management strategies.

UNIT I INTRODUCTION TO HYBRID ELECTRIC VEHICLE 9

History of Hybrid Electric Vehicles, Architectures of HEVs, Interdisciplinary Nature of HEVs, State of the Art of HEVs, Challenges and Key Technology of HEVs. Basics of the EV, Basics of the HEV, Basics of Plug-In Hybrid Electric Vehicle (PHEV), Basics of Fuel Cell Vehicles (FCVs).

UNIT II POWER ELECTRONIC IN HYBRID ELECTRIC VEHICLE 9

Hybrid Vehicle Model, Vehicle Performance, EV Powertrain Component Sizing, Series Hybrid Vehicle, Parallel Hybrid Vehicle, Wheel Slip Dynamics. Plug-in HEVs Architectures, Fuel Economy of PHEVs, Power Management of PHEVs, Component Sizing of EREVs, Vehicle- to-Grid Technology.

Power electronics including switching, AC-DC, DC-AC conversion, electronic devices and circuits used for control and distribution of electric power, Thermal Management of HEV Power Electronics.

UNIT III BATTERIES, CAPACITORS, FUEL CELLS AND CONTROLS 9

Introduction to Batteries, capacitors, fuel cells and controls, Different types of batteries, Battery Characterization, Comparison of Different Energy Storage Technologies for HEVs, Battery Charging Control, Charge Management of Storage Devices, Flywheel Energy Storage System, Hydraulic Energy Storage System, Fuel Cells and Hybrid Fuel Cell Energy Storage System and Battery Management System.

UNIT IV ELECTRIC MACHINES AND DRIVES IN HEVs 9

Types of Motors- DC motors- AC motors, BLDC motors, Induction Motor Drives, Permanent Magnet Motor Drives, Switched Reluctance Motors, Doubly Salient Permanent Magnet Machines, Design and Sizing of Traction Motors, Thermal Analysis and Modelling of Traction Motors.

UNIT V MODELLING OF HEVs AND ENERGY MANAGEMENT STRATEGIES 9

Driving Cycles, Types of Driving Cycles, Range modeling for Battery Electric Vehicle, Hybrid (ICE & others), Fuel Cell EV, and Solar Powered Vehicles. Case study of 2 wheeler, 3 wheeler and 4 wheeler vehicles.

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

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Understand the history, architecture, challenges and key technologies of hybrid electric vehicles

CO2 Explain the role of power electronics in hybrid electric vehicles

CO3 Identify various energy source involved in HEVs like battery and fuel cell

CO4 Select suitable electric motor for applications in hybrid electric vehicles.

CO5 Explain the HEVs modeling and study the energy management strategies for hybrid electric vehicles.

TEXT BOOKS:

1. Iqbal Husain, "Electric and Hybrid Vehicles-Design Fundamentals", CRC Press,2003
2. Mehrdad Ehsani, " Modern Electric, Hybrid Electric and Fuel Cell Vehicles", CRC Press,2005

REFERENCE BOOKS:

1. James Larminie and John Lowry, "Electric Vehicle Technology Explained", John Wiley & Sons,2003
2. Lino Guzzella, "Vehicle Propulsion System" Springer Publications,2005
3. Ron HodKinson, "Light Weight Electric/ Hybrid Vehicle Design", Butterworth Heinemann Publication,2005

CO-PO Mapping

CO / PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
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CO4	3	–	–	–	3	–	–	–	–	–	3
CO5	–	3	–	3	–	–	–	–	–	–	3

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23EE4006	CONTROL SYSTEM DESIGN FOR EV APPLICATIONS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

- Introduce control system fundamentals and modeling of physical systems.
- Analyze control systems in time and frequency domains for stability.
- Design feedback controllers using compensators and PID techniques.
- Model dynamics of power electronic converters in EVs.
- Design controllers for DC-DC converters to meet performance goals.

UNIT I MODELING OF LINEAR TIME INVARIANT SYSTEM (LTIV) 9

Control system: Open loop and Closed loop – Feedback control system characteristics – First principle modeling: Mechanical, Electrical and Electromechanical systems – Transfer function representations: Block diagram

UNIT II TIME DOMAIN AND FREQUENCY DOMAIN ANALYSIS 9

TIME DOMAIN ANALYSIS: Standard test inputs – Time responses – Time domain specifications – Stability analysis: Concept of stability

FREQUENCY DOMAIN ANALYSIS Bode plot, – Frequency domain specifications Introduction to closed loop Frequency Response. Effect of adding lag and lead compensators.

UNIT III DESIGN OF FEED BACK CONTROL SYSTEM 9

Design specifications – Lead, Lag and Lag-lead compensators using Root locus and Bode plot techniques –PID controller. - PID control in State Feedback form.

UNIT IV CONVERTER DYNAMICS 9

AC equivalent circuit analysis – State space averaging – Circuit averaging – Averaged switch modeling – Transfer function model for buck, boost, buck-boost and cuk converters – Input filters.

UNIT V CONTROLLER DESIGN 9

Review of P, PI, and PID control concepts – gain margin and phase margin – Bode plot based analysis – Design of controller for buck, boost and buck-boost converters.

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Model mechanical, electrical, and electromechanical systems using transfer functions.

CO2 Analyze system responses and stability in time and frequency domains.

CO3 Design lead, lag, and PID controllers using root locus and Bode plots.

CO4 Model and analyze dynamics of DC-DC converters.

CO5 Design effective controllers for buck, boost, and buck-boost converters in EVs.

TEXT BOOKS:

1. Benjamin C Ku and Farid Golnaraghi, “Automatic Control Systems”, 10th edition McGraw-Hill Education,2017.
2. Nagrath,I.J. and Gopal,M, “Control Systems Engineering”, 6th edition New Age International Publishers 2017.
3. Graham C.Goodwin, Stefan F.Graebe, Mario E.Salgado, “Control System Design”, 2002.

REFERENCE BOOKS:

1. Hebertt Sira-Ramírez and Ramón Silva-Ortigoza, “Control Design Techniques in Power Electronics Devices”, Springer-Verlag London Limited 2006
2. Katsuhiko Ogata, “Modern Control Engineering”, PHI Learning Private Ltd, Pearson, 5th Edition, 2015.
3. Robert W. Erickson & Dragon Maksimovic, “Fundamentals of Power Electronics”, Second Edition, 2001 Springer science and Business media.
4. Ned Mohan, “Power Electronics: A first course”, John Wiley,2012.
5. Marian K. Kazimierczuk and Agasthya Ayachit, “Laboratory Manual for Pulse-Width Modulated DC–DC Power Converters”, Wiley 2016
6. Farzin Asadi and Kei Eguchi, Morgan & Claypool,” Dynamics and Control of DC-DC Converters”, 2018.
7. Andre Kislovski, “Dynamic Analysis of Switching-Mode DC/DC Converters” ,Springer 1991

CO-PO Mapping

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CO3	–	–	3	–	3	–	–	–	–	–	2
CO4	2	–	–	3	3	–	–	–	–	–	2
CO5	–	–	3	–	3	–	–	–	–	–	2

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23EE4007	ENERGY STORAGE DEVICES FOR HYBRID ELECTRIC VEHICLES	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

- To introduce the concept of energy storage and highlight its importance across various applications.
- To explain the working principles and applications of thermal energy storage systems.
- To provide knowledge on the characteristics and operation of different types of batteries.
- To understand the principles of fuel cells and hydrogen-based energy storage technologies.
- To enable students to select appropriate hybrid energy storage systems for specific applications.

UNIT I OVERVIEW OF ENERGY STORAGE TECHNOLOGIES 9

Introduction, Necessity for energy storage, Classification of energy storage systems, Overview of various energy storage technologies, Comparison of energy storage technologies

UNIT II THERMAL ENERGY STORAGE 9

Introduction, Types – Sensible, Latent and Thermochemical heat storage principle, Materials used in thermal energy storage systems – Organic, Inorganic and PCMs, Applications – Domestic, Industrial process heating and Solar thermal power plants, Advantages, and limitations.

UNIT III ELECTRICAL ENERGY STORAGE 9

Introduction, Types – Electrochemical and Capacitive systems, Working principle and characteristics of different batteries (lead-acid, lithium-ion and nickel-metal hydride) and capacitive storage systems (super capacitors and electric double-layer capacitors), Applications - renewable energy integration, electric vehicles, and grid-scale energy storage systems, energy recovery systems, and power quality improvement.

UNIT IV CHEMICAL ENERGY STORAGE 9

Introduction, Fuel cells – Proton exchange membrane and Solid oxide fuel cells – Working principles and electrochemical reactions – Materials – Advantages and limitations – Applications, Hydrogen storage – Compressed, liquid and metal hydride storage – Working principle and storage mechanism – Materials – Advantages and limitations – Applications.

UNIT V HYBRID ENERGY STORAGE SYSTEMS 9

Overview, Types – Combined electrochemical and capacitive storage, thermal and electrochemical, Working principle and integration of different storage technologies, Advantages and limitations, Applications – Micro grids, electric vehicles, renewable energy integration.

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Understand the concept of energy storage and its importance in various fields.

CO2 Discuss the working and potential applications of thermal energy storage systems in various fields.

CO3 Elaborate the working and study the characteristics of different batteries.

CO4 Understand the working principle of fuel cell and hydrogen storage technologies.

CO5 Choose appropriate hybrid energy technology for various applications.

TEXT BOOKS:

1. R. Pendse, “Energy Storage Science and Technology”, SBS Publishers & Distributors Pvt. Ltd., New Delhi, 2011.
2. Ibrahim Dincer and Mark A. Rosen, “Thermal Energy Storage Systems and Applications”, John Wiley & Sons, 3rd Edition, 2021.

REFERENCE BOOKS:

1. Ru-shi Liu, Lei Zhang and Xueliang sun, “Electrochemical technologies for energy storage and conversion”, Wiley publications, 2012.
2. Robert A. Huggins, “Energy Storage – Fundamentals, materials and applications”, Springer, 2nd Edition, 2016
3. A.G.Ter-Gazarian, “Energy Storage for Power Systems”, The Institution of Engineering and Technology (IET) Publication, UK, 2nd Edition, 2011.

CO-PO Mapping

CO / PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	–	–	–	–	–	–	–	–	2
CO2	2	2	–	–	–	3	–	–	–	–	2
CO3	3	–	–	–	2	–	–	–	–	–	2
CO4	3	–	–	–	–	2	–	–	–	–	2
CO5	2	2	2	–	2	3	–	–	–	–	2

Internal Assessment				**End Semester Examinations**
Assessment I (100 Marks)		**Assessment II (100 Marks)**		
Individual Assignment / Case Study / Seminar / Mini Project	**Written Test**	**Individual Assignment / Case Study / Seminar / Mini Project**	**Written Test**	**Written Examinations**
40	60	40	60	100
40%				**60 %**

23EE4008	ELECTRIC VEHICLE CHARGING SYSTEMS	L	T	P	C
		3	0	2	4

COURSE OBJECTIVE:

- To explain fundamental concepts of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV).
- To understand electric vehicle charging mechanisms and infrastructure.
- To introduce charging concepts using renewable energy and energy storage systems.
- To explain wireless charging technologies for electric vehicles.
- To apply power factor correction techniques in EV charging systems.

UNIT I ELECTRIC VEHICLES AND VEHICLE MECHANICS 9

Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Engine ratings- Comparisons of EV with internal combustion Engine vehicles- Fundamentals of vehicle mechanics.

UNIT II CHARGING STATIONS AND STANDARDS 9

Introduction-Charging technologies- Conductive charging, EV charging infrastructure, International standards and regulations - Inductive charging, need for inductive charging of EV, Modes and operating principle, Static and dynamic charging, Bidirectional power flow, Types of commercial chargers, International standards and regulations.

UNIT III EV CHARGING USING RENEWABLE AND STORAGE SYSTEMS 9

Introduction- - EV charger topologies , EV charging/discharging strategies - Integration of EV charging-home solar PV system(HSP), Operation modes of EVC-HSP system , Control strategy of EVC-HSP system - fast-charging infrastructure with solar PV and energy storage.

UNIT IV WIRELESS POWER TRANSFER 9

Introduction - Inductive, Magnetic Resonance, Capacitive types. Wireless Chargers for Electric Vehicles - Types of Electric Vehicles - Battery Technology in EVs -Charging Modes in EVs - Benefits of WPT. - WPT Operation Modes - Standards for EV Wireless Chargers, SAE J2954, IEC 61980. ISO 19363.

UNIT V POWER FACTOR CORRECTION IN CHARGING SYSTEM 9

Need for power factor correction- Boost Converter for Power Factor Correction, Sizing the Boost Inductor, Average Currents in the Rectifier and calculation of power losses.

TOTAL :45 PERIODS

COURSE OUTCOME

Upon completion of the course, students will be able to:

CO1 Describe the concepts related with EV, HEV.

CO2 Understand the electric vehicle charging mechanism. .

CO3 Learn the concepts of Charging using renewable energy storage systems. .

CO4 Explain the concepts related with wireless charging systems.

CO5 Perform power factor correction in charging system.

REFERENCE BOOKS:

1. Electric and Hybrid Vehicles, Design Fundamentals, Third Edition, Iqbal Husain, CRC Press, 2021.

2. Ali Emadi, Mehrdad Ehsani, John M.Miller, “Vehicular Electric Power Systems”, Special Indian Edition, Marcel dekker, Inc 2003, 1st Edition.
3. Wie Liu, “Hybrid Electric Vehicle System Modeling and Control”, Second Edition, John Wiley & Sons, 2017, 2nd Edition.
4. Mobile Electric Vehicles Online Charging and Discharging, Miao Wang Ran Zhang Xuemin (Sherman) Shen, Springer 2016, 1st Edition.
5. Alicia Triviño-Cabrera, José M. González-González, José A. Aguado, Wireless Power Transferor Electric Vehicles: Foundations and Design Approach, Springer Publisher 1st Edition. 2020.
6. Nil Patel, Akash Kumar Bhoi, Sanjeevikumar Padmanaban, Jens Bo Holm-Nielsen, Electric Vehicles Modern Technologies and Trends. Springer Publisher 1st Edition, 2021.
7. Cable Based and Wireless Charging Systems for Electric Vehicles, Technology and control, management and grid integration, Rajiv Singh, Sanjeevikumar Padmanaban, Sanjeet Dwivedi, Marta Molinas and Frede Blaabjerg, IET 2021, 1st Edition.

CO-PO Mapping

CO / PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	3	2	–	–	2	–	–	–	–	–	2
CO2	3	2	2	–	3	2	–	–	–	–	2
CO3	3	3	2	–	3	2	–	–	–	–	3
CO4	3	2	2	–	3	2	–	–	–	–	3
CO5	3	3	2	2	3	2	–	–	–	–	3

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<tr><th colspan="4">Internal Assessment</th><th rowspan="2">End Semester Examinations</th></tr>
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<tr><td>40</td><td>60</td><td>40</td><td>60</td><td>100</td></tr>
<tr><td colspan="4">40%</td><td>60 %</td></tr>
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