COURSE STRUCTURE FOR MINOR

IN

TRANSPORATION ELECTRIFICATION

Sl. No.	**Code**	**Subject**	**Hours per week**			**Credit**	**Semester**
			L	T	P		
1	EE 2T1	Introduction to Transportation Electrification	3	0	0	3	3rd
2	EE 2T2	Electric Motors for Transportation	3	0	0	3	4th
3	EE 3T1	Charging Infrastructure and Battery management System for Electric Vehicles	3	0	0	3	5th
4	EE 3T2	Propulsion Systems and Sensors for Electric Vehicles	3	0	0	3	6th
5	EE 4T1	Application of EV and its Effect on Grid Power Quality	3	0	0	3	7th
6	EE 4T2	Project	0	0	3	3	8th
Total Credit						18	

EE 2T1 **Introduction to Transportation Electrification**

L	T	P	C
3	0	0	3

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Module 1: Environment Impact and Review of Modern Transportation, Fundamental of Vehicle Propulsion and braking, Electrical System Components, System of Systems Concept, concept of regenerative braking,

Module 2: Traditional Plug in EV Charging, the plug-in chargers for electric vehicles, Inductive-Based Wireless Charging, Capacitive Wireless Charging, Charging coordination.

Module 3: Battery Management in Electric Vehicles, The Role of Battery Management in Electric Vehicles, The operation and function of lithium-ion batteries, Mathematical modelling of battery cells with a focus on empirical, equivalent circuit models.

Module 4: Basic Transportation Planning, Analysis and Optimization of Electrified Transportation Networks, Challenges in Transportation Electrification, Optimization of the Power Grid considering transportation electrification impact

Module 5: Life Cycle Assessment Applied to Electric Vehicles, Economic Aspects of EV technology, Pricing Strategies for Charging EVs, Accelerating EV Adoption Rates – An Economists Perspective, Role of Data Science in Electrified Transportation.

Course Outcomes (COs):

At the end of the course the students will be able to

1. Analyze the impact and review of modern transportation.
2. Optimize the size of electrical system component used in transportation electrification.
3. Design charging infrastructure for transportation electrification.
4. Assess the life cycle applied to Electric Vehicles

Text and Reference Books:

1. Ahmed A. Mohamed, Ahmad Arshan Khan, Ahmed T. Elsayed, and Mohamed A. Elshaer, *Transportation Electrification - Breakthroughs In Electrified Vehicles Aircraft Rolling Stock Watercraft*, ISBN: 978-1-119-81234-0, December 2022, Wiley-IEEE Press.
2. Mehrdad Ehsani, Stefano Longo, Kambiz Ebrahimi *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press.
3. Chris Mi, and M. Abul Masrur, *Hybrid Electric Vehicles - Principles and Applications with Practical Perspectives*, 2nd Edition, ISBN: 978-1-118-97054-6, Wiley.

EE 2T2	Electric Motors for Transportation	L	T	P	C
		3	0	0	3

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Module 1: Type of Electric Vehicles

BEV, HEV, PHEV, and FCEV. Electric motor configurations, characteristics, and applications: Single motor, Dual motor, Triple motor, and four motor configurations, characteristics, and applications.

Module 2: Type of EV Motors Based on Applications

2-wheeler, 3-wheeler, 4-wheeler, and heavy vehicle motors. Construction and working of different EV motors: BLDC, IM, PMSM, SRM, SynRM, and IPMSynRM.

Module 3: Mathematical Modeling of Different Electrical Vehicle Motors

Numerical and analytical method, mathematical modeling of BLDC, IM, PMSM, SRM, SynRM, and IPMSynRM. Torque speed characteristics of different EV motors: BLDC, IM, PMSM, SRM, SynRM, and IPMSynRM. Modeling tools: Introduction to EV motor modeling tools like ANSYS and MotorXP.

Module 4: Analysis of Various EV Motors

Electromagnetic analysis, Thermal analysis: Finite element analysis, and computational fluid dynamics. Analysis tools: Introduction to EV motor analysis tools like ANSYS Maxwell and COMSOL, Simcenter Motor solve.

Module 5: Design of EV motors

Design procedure, construction, and design of BLDC, IM, PMSM, SRM, SynRM, and IPMSynRM, and models/algorithms/methods used for EV motor design. Design optimization: Steps involved in design optimization. Design tools: Solidworks, MotorXP, JMAG, and Motor-CAD

Course Outcomes:

At the end of the course, students will be able to

1. Understand different motor configurations in EVs and their characteristics
2. Understand the working of various motors used in EVs
3. Model various motors used in EVs
4. Analyze various motors used in EVS
5. Design various motors used in EVs.

Reference Books:

1. Larminie, J. and Lowry, J., 2012. *Electric vehicle technology explained*. John Wiley & Sons.
2. Emadi, A. ed., 2014. *Advanced electric drive vehicles*. CRC Press.
3. Hughes, A. and Drury, B., 2019. *Electric motors and drives: fundamentals, types and applications*. Newnes.
4. Husain, I., 2021. *Electric and hybrid vehicles: design fundamentals*. CRC press.
5. Kim, S.H., 2017. *Electric motor control: DC, AC, and BLDC motors*. Elsevier.
6. Denton, T., 2020. *Electric and hybrid vehicles*. Routledge.
7. Krause, P.C. and Krause, T.C., 2022. *Introduction to Modern Analysis of Electric Machines and Drives*. John Wiley & Sons.

EE 3T1 Charging Infrastructure and Battery management System for Electric Vehicles

L	T	P	C
3	0	0	3

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Module 1: EV Fundamentals: Vehicle Basics, vehicle model, Vehicle Resistance: Rolling Resistance, Aerodynamic Drag, Grading Resistance, Dynamic Equation Tire–Ground Adhesion and Maximum Tractive Effort, Power Train Tractive Effort and Vehicle Speed, EV Powertrain Component Sizing. Hybridization of the Automobile: Basics of the EV, Basics of the HEV, Basics of Plug-In Hybrid Electric Vehicle (PHEV) and vehicle architectures: Series Hybrid Vehicle, Parallel Hybrid Vehicle, Basics of Fuel Cell Vehicles (FCVs).

Module 2: Power Electronics in EVs: Basic operation and modeling of power electronic devices applied in power transmission and distribution systems for electrical vehicles, various types of power electronics circuits used in energy processing; analysis and design of power converter circuits such as AC-DC, AC-AC, DC-DC and DC-AC converters; applications of power electronics circuit in electrical vehicles charging; methods of protection of power semiconductor devices and calculation of power device losses

Module 3: Batteries, Ultracapacitor, Fuel Cells, and Controls: Introduction, Different batteries for EV charging infrastructure, Battery Characterization, Comparison of Different Energy Storage Technologies for HEVs, Battery Charging Control, Charge Management of Storage Devices, and Battery Management System.

Module 4: EV Charging Technologies: Classification of different charging technology for EV charging station, introduction to Grid-to-Vehicle, Vehicle to Grid (V2G) or Vehicle to Buildings (V2B) or Vehicle to Home (V2H) operations, bi-directional EV charging systems, energy management strategies used in hybrid and electric vehicle, Wireless power transfer (WPT) technique for EV charging, Charging standards.

Textbooks/Reference Books:

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press , 2004
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press , 2003
3. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley , 2003
4. Chris Mi, M. Abul Masrur, David Wenzhong Gao, Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, John Wiley & Sons Ltd. , 2011

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

1. Understand the basics of electric and hybrid electric vehicles, their architecture, technologies and fundamentals.
2. Analyze the use of different power electronics converters and electrical machines in hybrid electric vehicles.
3. Select proper energy storage systems used for hybrid electric vehicles
4. Analyze different charging/discharging configurations of EV’s

EE3T2	Propulsion Systems and Sensors for EV	L	T	P	C
	Electrical engineering Branch	3	0	0	3

Prerequisites: Power Electronics, Batteries, Electrical Machines

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Module 1 : Introduction to EV: Introduction to Electric Vehicle technology , Past, Present & Future of EV, Current Major Issues, Recent Development Trends, Types of EVs, Components of EVs, Advantages and Disadvantages, State-of-the Art EVs, Comparison of EV Vs IC Engine, Challenges and Key Technologies of EVs – Challenges for EV Industry in India.

Module 2 : EV Propulsion System 1: Electrical Motors: Choice of electric propulsion system, block diagram of EV propulsion system, concept of EV Motors, single motor and multi-motor configurations, fixed & variable geared transmission, In-wheel motor configuration, classification of EV motors, Electric motors used in current vehicle applications, Recent EV Motors, Comparison of Electric Motors for EV applications.

Module 3 : EV Propulsion System 2: Require Power Electronics: Comparison of EV power devices, introduction to power electronics converter, four quadrant DC chopper, three-phase full bridge voltage-fed inverter, soft-switching EV converters, comparison of hard-switching and soft-switching converter, three-phase voltage-fed resonance dc link inverter

Module 4: Sensors: Automotive Sensors and Transducers: Temperature, Force, Oxygen Sensor, LAMBDA Sensor, Proximity Distance Sensors, Speed, Engine Knock Sensor, Resistive Potentiometer & Flow. Typical Sensors Specifications & Microcontroller Interfacing, Signal Processing circuit, Sensor Calibration.

Module 5: Control of electric propulsion system: Control system parameters: Importance of control system in Electrical vehicle, Study of control architecture in Electric vehicle, Systems models and their classifications, principles used in modelling of systems, Introduction, accuracy and mode of control, closed-loop control system, components of control system. Basics of Microcontroller & Control Strategies

Reference Books:

1. Modern Electric Vehicle Technology, C.C Chan, K.T Chau, Oxford University Press Inc., New York 2001
2. Electric Vehicle Technology Explained, James Larminie, John Lowry, Wiley-Blackwell, 2nd Edition, 2012
3. Modern Control Technology: Components and Systems, Christopher T. Kilian, West Pub
4. Control System Components, M. D. Desai, PHI
5. Design of Feedback Control Systems, R. T. Stefani, B. Shahian, C. J. Savant, Jr., and G. H. HostetterM, Oxford University Press, Fourth Edition 2002

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

1. Identify EV concepts, EV configurations and various EV parameters for better understanding of the EV technology
2. Analyse and Elaborate the EV propulsion system and electric motors for vehicular applications & power electronics converters required for their control
3. Analyse and describe different components of a control system
4. Explain different types of sensors

EE 4T1 Application of EV and its Effect on Grid Power Quality

	L	T	P	C
	3	0	0	3

Prerequisite: Knowledge of Basic Electrical Engineering

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid semester examination, surprise tests, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Module 1: Power Distribution Systems: Basic structure of power distribution systems, Balanced Distribution System, Unbalanced Distribution Systems, Distribution System components, Understanding of electrical loads

Module 2: Power Quality Analysis: Importance of power quality analysis, Power quality attributes, Sag, Swell, Harmonic analysis, Harmonics in balanced distribution systems, Harmonics in unbalanced distribution systems

Module 3: Residential Charging and Discharging of EVs: Residential demand curve, Home EV connectors, charging and discharging modelling of EV battery, TOU tariff system, Energy metering

Module 4: Impact of EV on Power Quality

Module 5: PQ Improvement Strategies: Residential demand curve, Short term load forecasting, Peak shading and valley filling, Demand side management with EVs, Ancillary services by EVs in power systems

Text and Reference Books

1. Influences of Electric Vehicles on Power System and Key Technologies of Vehicle-to-Gridby Canbing Li, Yijia Cao, Yonghong Kuang and Bin Zhou, Springer; 1st ed. 2016 edition
2. Power Quality Enhancement Using Custom Power Devices, Arindam Ghosh and Gerard Ledwich, Kluwer Academic Publishers Boston / Dordrecht / London.