INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electrical Engineering

1. **Subject Code:** EEN-501 **Course Title:** Electric Vehicles: Power Train & Drives
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To familiarize students with the concept of electric vehicles, power train for electric vehicles and electric drives used in electric vehicles and their control.

10. **Details of Course:**

S.No.	Contents	Contact Hours
1.	**Introduction**: History and benefits of electric vehicles; fundamentals of EVs; tractive effort; vehicular dynamics; drive cycle and vehicle control unit	5
2.	**Components of Power Train**: Components of conventional vehicle and propulsion load; power train of HEV and EV; efficiency considerations for conventional vehicle, HEV and EV; multi-motor in-wheel EVs; impact and benefits of EV on utility grid	5
3.	**On-board Chargers**: Review of semiconductor devices; turn-on and turn-off characteristics; loss computation in semiconductor devices; basics of non-isolated/isolated DC-DC and grid connected converters; classification of EV chargers; modelling and control of bi-directional DC-DC converters; discussions on V2X applications	8
4.	**Induction Motor Drives**: Basics of induction motor; open-loop v/f control; basics of DC-AC power converters; basic pulse width modulation techniques; vector control of IM drives; advanced control techniques	8
5.	**SRM and PMSM Drives**: Basics of magnetic circuits and principle of reluctance; basics of switched reluctance motor; modelling and control of switched reluctance motor; modelling and control of PMSM drive; advanced control techniques for PMSM drive	8
6.	**High-power and High-speed EVs**: Applications of High-power induction motor drives; power converter design; special PWM techniques for high-power applications; field-oriented control of high-power IM drives; applications of high-speed PMSM drives; power converter design and PWM techniques; field-oriented control of high-speed PMSM drives	8
Total		**42**

11. List of Experiments: -

i) Vector control of PMSM and IM drives over complete drive cycle of EV
Objective: - To familiarize with the basic vector control of PMSM and IM drive with speed/torque control operation. Two-level DC-AC voltage source converter, fed from a DC power source, would be used for operating the motor.

ii) Characterization of power, torque and efficiency for EV over drive cycle
Objective: - Chassis of 4-wheeller EV would be operated in all possible modes for this experiment. Power, torque and efficiency would be plotted against speed of EV over the complete range of operation.

iii) Power flow in EV power train during charging, V2G feeding, motoring and braking
Objective: - To understand the flow of energy in the power train of EV during various modes of operation i.e. charging, V2G feeding, motoring and braking. EV would be operated in the aforementioned modes and power would be measured at different sections of EV.

iv) Forward & backward motoring and regenerative braking of EV consisting of multiple motor-drives
Objective: - EV must be capable of operating in all four quadrants *viz*. forward motoring, forward braking, reverse motoring and reverse braking. This experiment would consider operation of EV in all four quadrants with necessary PWM and control techniques.

v) Synchronized PWM techniques for high-power and high-speed IM drives
Objective: - Special PWM techniques would be implemented on IM drive in context with the high-power and/or high-speed applications. Field weakening would be demonstrated on the experimental setup.

12. Suggested Books:

S.No.	Name of Authors /Books / Publishers	Year of Publication/ Reprint
1.	Ali Emadi, "Advanced Electric Drive Vehicles", CRC Press	2015
2.	Iqbal Husain, "Electric and Hybrid Vehicles – Design Fundamentals", Second Edition, CRC Press.	2011
3.	W. Leonard, "Control of Electric Drives", Springer Press	2007
4.	R Krishnan, "Permanent Magnet Synchronous and Brushless DC Motor Drives", CRC Press	2010
5.	Berker B., James W. J. & A. Emadi, "Switched Reluctance Motor Drives", CRC Press	2019
6.	Bin Wu, "High-Power Converters and Ac Drives", IEEE WILEY Press	2017
7.	Bimal K. Bose, "Modern Power Electronics and AC Drives", Prentice Hall PTR	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electrical Engineering

1. **Subject Code:** EEN-503 **Course Title:** Energy Storage Techniques
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** Current and future trends in energy storage systems.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Energy Storage Technologies:** Classification of Storage Technologies by Energy type- Thermal Energy: Heat Storage; Chemical Energy: Organic and Non- Organic; Mechanical Energy: Kinetic and Potential Energy; Electrical Energy: Electrical Potential.	5
2.	**Energy Storage Systems in Modern Electrical Systems:** Lead-acid battery, Nickel-cadmium battery, Lithium-ion battery, Sodium-sulfur battery, Nickel metal hydride battery, Fuel cells, Capacitors and Super capacitors. Solid state Batteries. Differences amongst different ESS.	6
3.	**Typical ESS and Battery Chemistry:** Electrodes, Electrolytes, Collectors, Thermal management, Packaging of battery pack Lithium based batteries: Lithium manganese oxide, Lithium iron phosphate, Lithium nickel manganese cobalt oxide, Lithium nickel cobalt aluminum oxide and Lithium titanate; Silicon based Batteries, Sodium-sulfur Batteries, Proton Batteries, Graphite Dual-Ion Batteries, Salt-water Batteries and Potassium-Ion Batteries	10
4.	**Development cycle of Batteries:** ESS sizing**,** Electrical, Mechanical and Thermal Design, BMS Software and Hardware development, Prototype development, System Validation, Lab Testing, Safety test and Certification.	7
5.	**Battery Management Systems (BMS):** Introduction to BMS, Objectives of the BMS: Discharging control, Charging control, State-of-Charge Determination, State-of-Health Determination, Cell Balancing; BMS topologies: Distributed Topology, Modular Topology and Centralized Topology, Firmware development, Certification, Aging.	8
6.	**Batteries for the EV application:** Performance criterion for EV batteries- Energy density, Amp hour density, Energy efficiency, Cost, Operating temperature, number of life cycles, recharge and self-discharge rates and commercial availability, some reference batteries and extension to non-automotive sectors	6
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Books/Publishers	Year of Publication/Reprint
1.	Alfred Rufer, "Energy Storage systems and components", CRC Press	2017
2.	Tom Denton, "Automotive Electrical and Electronic Systems", 5th Edition, Routledge	2018
3.	Mehard Ehsani, Yiming Gao, Stefano longo and Kambiz Ebrahimi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", CRC Press, 3rd Edition.	2019
4.	Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press.	2021
5.	K. T. Chau, "Energy Systems for Electric and Hybrid Vehicles," IET Transportation Series 2	2016
6.	Jiuchun Jiang and Caiping Zhang, "Fundamentals and Applications of Lithium–Ion Batteries in Electric Drive Vehicles," John Wiley & Sons	2015

12. Suggested References:

1. E. Karden, S. Ploumen, B. Fricke, T. Miller and K. Snyder, "Energy storage devices for future hybrid electric vehicles," J. Power Sources, vol. 168, no. 1, pp. 2–11, 2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electrical Engineering

1. **Subject Code:** EEN-505 **Course Title:** Charging Infrastructure
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To impart the knowledge of EV battery chargers, electric vehicle supply equipment, their components, charging protocols.

10. **Details of Course:**

S.No.	Contents	Contact Hours
1.	**Introduction**: introduction to EV systems, EV benefits, battery charging modes, types of EV supply equipment (EVSE), components of EV battery chargers, charging infrastructure challenges	3
2.	**Charger Classification and standards:** classification based on charging levels (region-wise), modes, plug types, standards related to: connectors, communication, supply equipments, EMI/EMC	6
3.	**AC-DC Converter**: types of AC-DC converters; working principles, modulation, design, and closed loop control of power factor correction converters (PFC): Boost type PFC, Totem-pole PFC, active front-end converter, three-phase PFCs; working principles, modulation, design, and closed loop control of single-stage AC-DC converters; G2V, V2X operations	9
4.	**DC-DC Converter**: Types of DC-DC converter used for EV chargers; working principles, modulation, design, modelling and closed loop control of dual active bridge, LLC converter, high frequency magnetics, soft-switching criteria	9
5.	**Protocols and communication:** Open charge point protocol (OCPP), Open System Interconnection-Layer-Model (OSI), adapted PWM signal based low level communication, PLC based high level communication, CAN communication, testing methodology for EV battery chargers and EVSE	9
6.	**EMI/EMC considerations**: sources of EMI, differential mode noise, common mode noise, LISN, measuring of EMI/EMC spectrum, design of DM filters, CM filters	4
7.	**Case Study:** Case-studies on Delta, Hella on-board chargers, latest EV reports released by Government of India	2
	Total	**42**

11. List of Experiments: -

1) Generation of phase shift modulation for dual active bridge DC-DC converter using microcontroller
2) Working with the CAN communication
3) Measurement of EMI/EMC, design of CM and DM filters
4) Experiments on 3.3kW Totem-pole PFC
5) Experiments on Type-I onboard charger

12. Suggested Books:

S.No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	Tom Denton, "Automotive Electrical and Electronic Systems", 5th Edition, Routledge	2018
2.	Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press.	2021
3.	Robert W. Erickson, and Dragan Maksimovic "Fundamentals of Power Electronics", 3rd, Springer	2020
4.	L. Umanand, "Power Electronics: Essentials and Applications", Wiley India.	2012
5.	Mohan N., Underland T.M. and Robbins W.P., "Power Electronics – Converters, Applications and Design", 3rd Ed., Wiley India.	2008
6.	Christoph Marscholik and Peter Subke, "Road Vehicles - Diagnostic Communication" University Science Press	2009
7.	Wolfhard Lawrenz, "CAN System Engineering: From Theory to Practical Applications", Springer.	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electrical Engineering

1. **Subject Code:** EEN-507 **Course Title:** Control Systems for Electric Vehicle
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce advanced linear and state space methods for the control of electrified vehicles.

10. **Details of Course:**

S.No.	Contents	Contact Hours
1.	**Introduction to System modelling**: 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, Fundamental studies of Modelling of vehicle dynamics and control, Longitudinal Vehicle dynamics, Vertical Dynamics model and Lateral vehicle dynamics model, Integrated Vehicle Dynamics.	10
2.	**System simulation and validation:** System simulation, advantages and disadvantage, steps in simulation study, Simulation of Mechanical and Electrical Systems, Introduction to modelling and Simulation for Software in loop (SIL) and Hardware in loop (HIL), Study of control architecture.	4
3.	**Model based control approach for Electric Vehicle:** Introduction to P, PI & PID Controller, and Internal Model Control (IMC) Design, Introduction to Model based control system design for Electric Vehicle.	4
4.	**State Space Representation**: Introduction to State Space, State Space Representation, State Space Representation: Companion Form (Controllable Canonical Form), Extended Controllable Canonical Form Observable Canonical Form, Concept of Diagonalization, State transition matrix, Solution of state Equation, Steady State Error for State Space System. Controllability and Observability in State space, Pole Placement by State Feedback and State Observer design	13
5.	**Stability aspects of control systems:** Stability concept, Stability definition in the sense of Lyapunov, Stability of continuous time Linear systems, Lyapunov stability theorem, Vehicle stability analysis.	5
6.	**Applications**: Applications of control techniques in Traction control, Vehicle Control, Electric power steering control.	6
Total		**42**

11. List of Experiments: -

1. Familiarization of Electric Vehicle Control Modules
2. Modelling Studies of Electric Vehicles
3. Model Identification techniques for Electric Vehicle
4. Tuning Techniques for PI/PID Controller
5. PI/PID controller for Electric Vehicle
6. IMC based control techniques
7. Model based control techniques for Electric Vehicle
8. Modelling, Control in State space for Electric Vehicle
9. Study of Observer design for Electric Vehicle

12. Suggested Books:

S.No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1.	R. T. Stefani, B. Shahian, C. J. Savant, Jr., and G. H. Hostetter, Design of Feedback Control Systems, Oxford University Press, Fourth Edition	2002
2.	Katsuhiko Ogata, Modern Control Engineering, PHI, Twelfth Edition	2014
3.	Ashish Tewari, Modern Control Design: with MATLAB and SIMULINK, Wiley, First Edition	2002
4.	L.Umanand, "Power Electronics: Essentials and Applications", Wiley India	2009
5.	Rajesh Rajamani, Vehicle Dynamics and Control, Springer, Second Edition	2012
6.	Wuwei Chen, Hansong Xiao, Qidong Wang, Linfeng Zhao and Maofei Zhu, Integrated Vehicle Dynamics and Control, Wiley, First Edition	2016
7.	Hui Zhang and Dongpu Cao and Haiping Du, Modelling, Dynamics and Control of Electrified Vehicles, WP Publishing, Elsevier	2018

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electrical Engineering

1. **Subject Code:** EEN-509 **Course Title:** Automobile Engineering for Electric Vehicles
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide a fundamental understanding of the various mechanical systems of a typical electric vehicle.
10. **Details of Course:**

S.No.	Contents	Contact Hours
1.	**Vehicle Fundamentals**: Vehicle movement, Rolling Resistance, Aerodynamic Drag, Grading Resistance, Maximum tractive effort, Vehicle performance, Maximum speed, Gradeability, slip ratio, Calculation of normal tire forces, calculation of effective tyre radius, static forces, longitudinal forces cornering forces, Interaction between longitudinal and side forces.	5
2.	**Conventional Vehicle systems and configurations:** Engine Components, Operation of Four Stroke Engines, Engine Performance, Supercharging, Combustion in Spark Ignition Engines, Engine Emissions, Automotive Powertrain, Clutch, Transmission, Torque converter, Powertrain analysis, Rear-Wheel Drive Powertrains, Front-Wheel Drive (FWD) Powertrains, Multi-Wheel Drive Powertrains.	6
3	**Electrical vehicle system and configurations:** Power train configurations and components, Traction motor characteristics, Tractive effort, Drive cycles, Rear-Wheel Drive Powertrains, Front-Wheel Drive (FWD) Powertrains, Vehicle control unit, Vehicle Modelling Methodology, Range modelling of battery electric vehicle, Auxiliary system in electric vehicle, Powertrain Component Sizing, Auxiliary control functions (Anti-roll, start stop etc.)	6
4	**Chassis:** Vehicle and body Centre of gravity, Mass moments of inertia, Stiffness and strength, vibrational behavior, External loads, Chassis structure and components, Multi body models for vehicles, Ride comfort and NVH.	4
5.	**Steering System:** Introduction to Steering System, Manual Steering System, Steering column, Power Steering System	5
6.	**Brake System and ABS**: Introduction to Brake System, Components of Brake System, Hydraulic Brake, Air Brake, Antilock Brake System (ABS), Regenerative braking, Braking Analysis	6
7.	**Suspension:** Introduction to Suspension System, Components of Suspension System, Dependent and Independent Suspension	6
8.	**Controls for steering, braking, and suspension**: Steering control, braking control and electronic brake distributor, Vehicle stability control, Brake assist system, Antispin regulator, Suspension control, trim control, damping control, roll control.	4
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Books/Publishers	Year of Publication/ Reprint
1	Ehsani, Mehrdad, et al. Modern electric, hybrid electric, and fuel cell vehicles. CRC press	2018
2	Genta, G., and L. Morello. "The Automotive Chassis, Volume 1: Components Design, Springer Nature,	2009
3	Jazar, Reza N. Vehicle dynamics: theory and application. Springer	2017
4	Rajesh Rajamani, Vehicle Dynamics and Control, Springer	2012
5	Husain, Iqbal. Electric and hybrid vehicles: design fundamentals. CRC press	2010