Shri Vile Parle Kelavani Mandal's

Dwarkadas J. Sanghvi College of Engineering

(Autonomous College Affiliated to the University of Mumbai)

Scheme and detailed Syllabus (DJS23)

of

Honours Degree Program

in

Electric Vehicle

Revision: 1 (2025)
With effect from the Academic Year: 2025-2026

Scheme for Honours in Electric Vehicle
(DJS23)

Sr. No.	Course Code	Course Title	Teaching Scheme (hrs.)				Semester End Examination (SEE) - A						Continuous Assessment (CA) - B						A+B	Total Credits
			Th. (Hrs)	P (Hrs)	T (Hrs)	Credits	Duration (Hrs)	Th	O	P	O&P	SEE Total (A)	TT1	TT2	TT3	TT Total	T/W	CA Total (B)		
Semester III																				
1	DJS23MH1201	Fundamentals of Electric Vehicles	4	--	--	4	4	60	--	--	--	60	15	15	10	40	--	40	100	4
Semester IV																				
2	DJS23MH1251L	Electric Vehicle Laboratory I	--	4	--	2	2	--	25	--	--	25	--	--	--	--	25	25	50	2
Semester V																				
3	DJS23MH1301	Electric Drives and Controls	3	--	--	3	3	60	--	--	--	60	15	15	10	40	--	40	100	3
4	DJS23MH1301L	Electric Vehicle Laboratory II	--	2	--	1	--	--	--	--	--	--	--	--	--	--	25	25	25	1
Semester VI																				
5	DJS23MH1351	Energy Source Management	3	--	--	3	3	60	--	--	--	60	15	15	10	40	--	40	100	3
6	DJS23MH1351L	Electric Vehicle Laboratory III	--	2	--	1	--	--	--	--	--	-	--	--	--	--	25	25	25	1
Semester VIII																				
7	DJS23MH1451	Electric Vehicle System Design and Safety	4	--	--	4	4	60	--	--	--	60	15	15	10	40	--	40	100	4
			14	8	--	18	16	240	25	--	--	265	60	60	40	160	75	235	**500**	18

Th: Theory; P: Practical; T: Tutorial; O: Oral; P: Practical; O&P: Oral and Practical; TT1: Term Test 1; TT2: Term Test 2; TT3: Term Test 3; TT: Term Test; T/W: Term Work

Prepared by Checked by Head of the Department Principal

Honors in Electric Vehicles	**S.Y. B.Tech**	**Semester: III**
Program: Mechanical Engineering		
Course: Fundamentals of Electric Vehicles (DJS23MH1201)		

Pre-requisite:

1. Fundamentals of mechanical, electronics, and electrical engineering.
2. Fundamentals of chemistry, physics, and engineering mechanics.

Objectives:

1. To study different automotive components and subsystems used in electric vehicles.
2. To develop a comprehensive understanding of vehicle dynamics and stability principles.
3. To provide a broad understanding of transmission systems used in electric vehicles.
4. To understand the principles of electrochemical reactions in batteries and analyze the parameters governing battery performance and efficiency.
5. To equip students with the knowledge and skills necessary for the selection and sizing of electric motors for diverse applications, covering criteria assessment, performance analysis, and matching to load requirements.

Outcomes: On completion of the course, the learner will be able to:

1. To explain the fundamentals of electric vehicles and their major parts.
2. Classify the chassis used in electric vehicles and select a suitable body type for the given requirements.
3. Apply vehicle dynamics and stability principles to analyze and optimize vehicle performance, including maximum speed, gradability, and acceleration.
4. Differentiate between different types of transmission systems, including manual, automatic, AMT, and CVT, and select a suitable transmission system for a vehicle to be designed.
5. Evaluate different types of batteries based on their electrochemical properties and determine their suitability for specific applications.
6. Evaluate vehicle requirements, motor criteria, and interpret performance characteristics to effectively select and size electric motors for various applications.

Fundamentals of Electric Vehicles (DJS23MH1201)		
Unit	**Description**	**Duration**
1	**Introduction to Electric Vehicles (EV)** Brief history of EV; Electric vehicle market; Need of EV; Types of EVs and their components: BEVs, PHEVs, HEV, FCEV; EV specifications; General layouts of the EVs; Comparison of EV with other types of vehicles; Overview of EV manufacturers; National Policy for adoption of EVs; Chassis and body used in EV: Classification of chassis; frame; Body types; Vehicle dimensions; Body and chassis materials; Government regulations.	10
2	**Vehicle Dynamics and Stability** Types of wheel rims, wheel dimension; Tyre: properties, specifications, types, construction, tread patterns; Study principles of rolling, pitch and yaw velocity and moments; Drag, lifts, resistance, body loads and load calculation; Vehicle resistance: rolling resistance, grading resistance, aerodynamic drag; Dynamic equation, Vehicle performance (Maximum speed, gradeability and acceleration); Calculation of acceleration force, maximum speed; Tractive effort, Torque required on the wheel;	10

	Torque speed characteristics of electric vehicle; Aesthetics and ergonomics consideration for stability and control.	
3	**Transmission Systems** Layout of transmission system and their components; Power Flows and Gear Ratios; Types of transmission: Manual, Automatic, Automated-Manual Transmissions, Continuously Variable Transmissions (CVT); Gear box design; Drive Layout - One/ Two/ Four /All-wheel drive layout, Transmission system Component design. Differential classification and Types: Open, Locked, Spool/ Welded, Limited Slip, Torsen, Active, Torque Vectoring. Clutch and its structure. Drivetrain and Differential.	8
4	**Steering, Suspension, and Braking System** **Steering System:** Geometry and classification; Layout and topology design: bicycle, tricycle, and Qudracycle; 4W configuration (2/3/4 Seater); Design of steering system. **Suspension System:** Classification; Components of the suspension system; Topology design; Design of Shock Absorbers, Coil Springs and linkages. **Wheels and Braking System:** Classification of wheels and tyres; Types of braking system; Topology design; Design of braking system; Integration of Wheel with traction motor, Braking system, Regenerative Braking.	10
5	**Power Unit: Batteries Technologies** Types of batteries: Lead acid battery, Nickel based batteries, Sodium based batteries, Lithium based batteries - Li-ion and Li-poly, Metal air battery, Zinc chloride battery, Graphene battery; Introduction to electrochemical battery; Electrochemical reactions; Battery parameters: Battery capacity, discharge rate, charging rate, SOC, SOD, SOH, DOD, thermodynamic voltage, specific energy, specific power, energy efficiency; Energy storage systems: Ultracapacitors; Flywheel energy storage system; Hydraulic energy storage system; Comparison of different energy storage system.	10
6	**EV Motors and Characteristics** Requirement of EV motors; Review of motor principles; Types of electric motors – construction and working; Motor load dynamics; Specifications of motors; Characteristic curves of motors; Motion profile: acceleration, steady operation and deceleration profiles; Starting, braking, speed and torque control of motors; Constant-torque mode, Constant-power mode; Efficiency map; Design variables of motors (introduction); Classification properties of PM material, Alnico, Ferrites, Rare-Earth PMs.	8
	Total	**56**

Books Recommended:

Textbooks:

- Behrooz Mashadi and David Crolla, Vehicle Powertrain Systems, Wiley, 2012.
- Joseph Katz, Automotive Aerodynamics, Wiley, 2016.
- David C. Barton and John D. Fieldhouse, Automotive Chassis Engineering, Springer, 2018.
- Yi Zhang and Chris Mi, Automotive Power Transmission Systems, Wiley, 2018
- Per Enge, Electric Vehicle Engineering (PB), McGraw-Hill Education, ISBN:9781265900526, 2023.
- Bruno Scrosati, Jürgen Garche, Werner Tillmetz, Advances in Battery Technologies for Electric Vehicles, Woodhead Publishing, ISBN:9781782423980, 2015.
- Ion Boldea, Linear Electric Machines, Drives, and MAGLEVs Handbook, CRC Press. 2017.

Reference Books:

- Zongxuan Sun and Guoming Zhu, Design and Control of Automotive Propulsion Systems, CRC Press, 2015.
- Robert Fischer, Ferit Küçükay, Gunter Jürgens, Rolf Najork, and Burkhard Pollak, The Automotive Transmission Book, Springer, 2015.
- Jian Pang, Noise and Vibration Control in Automotive Bodies, Wiley, 2019.
- Tariq Muneer, Mohan Kolhe, Aisling Doyle, Electric Vehicles: Prospects and Challenges, Elsevier, ISBN:9780128030400, 2017.

Web References:

- Electric Vehicles Part 1 (https://nptel.ac.in/courses/108102121)
- Introduction to Hybrid and Electric Vehicles (https://nptel.ac.in/courses/108103009)
- Electric vehicles and Renewable energy (https://nptel.ac.in/courses/108106182)

Honors in Electric Vehicles	**S.Y. B.Tech**	**Semester: IV**
Program: Mechanical Engineering		
Course: Electric Vehicle Laboratory I (DJS23MH1251L)		

Pre-requisite:

1. Fundamentals of electric vehicle;
2. Fundamentals of mechanical, electronics, and electrical engineering.
3. Fundamentals of chemistry, physics, and engineering mechanics.

Objectives:

1. To provide a comprehensive understanding of the different types of electric vehicles, and their configurations.
2. To study the various components like batteries, electric motors, controllers, inverters, and chargers, focusing on their roles, characteristics, and interactions within an electric vehicle system.
3. To investigate the different types of electric motors used in EVs and understand their working principles, characteristics, and suitability for different EV applications.
4. To explore different energy storage systems used in EVs, including Li-ion batteries, solid-state batteries, ultra-capacitors, and flywheel energy storage systems, and compare their specific energy, power, and efficiency.
5. To utilize numerical and simulation tools like Python, MATLAB, and Simulink to analyze various aspects of electric vehicles, such as acceleration performance, torque-speed characteristics, range prediction, and battery pack sizing.
6. To perform hands-on and simulation-based performance analysis of critical EV systems, including motor efficiency testing, regenerative braking efficiency, CVT efficiency, and structural analysis of the chassis.

Outcomes: On completion of the course, the learner will be able to:

1. Explain the architecture and working principles of various types of electric vehicles.
2. Identify and describe the key components and subsystems of an EV, understand their roles in the overall system, and evaluate their impact on vehicle performance.
3. Analyze and choose the appropriate electric motor and energy storage system for a given EV application based on technical specifications and requirements.
4. Demonstrate proficiency in using simulation tools like Python, MATLAB, and Simulink to model, simulate, and analyze various EV subsystems, such as batteries, motors, and powertrains, under different conditions.
5. Develop problem-solving skills by conducting numerical analysis and optimization of EV components, such as charging time estimation, battery life prediction, motor sizing, and energy consumption analysis.
6. Investigate the performance of EV components such as motor, CVT, etc., by testing them under various conditions.

Electric Vehicle Laboratory I (DJS23MH1251L)	
Sr. No.	**Experiment Title**
	Study-Type Experiments (Theoretical and Conceptual Learning)
1	Study of Electric Vehicle Types and Configurations
2	Study of EV Components and Subsystems
3	Study of Electric Motors Used in EVs

4	Study of EV Battery Technologies
5	Study of Powertrain Design in Electric Vehicles
6	Study of Vehicle Dynamics for Electric Vehicles
7	Comparison of Energy Storage Systems
8	Motor Sizing and Matching for EV Applications
	Numerical Analysis Experiments (Python/ MATLAB/ Simulink, etc.)
9	Numerical Analysis of EV Acceleration and Torque Curve
10	Simulation of Battery Charging and Discharging Cycles
11	Simulation of Electric Vehicle Range Using MATLAB
12	Numerical Analysis of Battery Pack Sizing
13	Analysis of Charging Time for Different EV Batteries
14	Simulation of Vehicle Dynamics Using Simulink
15	Monte Carlo Simulation for Battery Life Prediction
16	EV Range Prediction Using Machine Learning
	Performance-Based Experiments (Hands-on and Simulation Tools)
17	Performance Testing of an Electric Motor: Measure the efficiency, power output, and torque characteristics of an electric motor used in EVs.
18	Measurement of EV Battery Efficiency: Perform testing to measure the efficiency of a battery during charging and discharging cycles.
19	Testing of Regenerative Braking Efficiency
20	Simulation of Continuously Variable Transmission (CVT) Efficiency in EVs
21	Chassis Structural Analysis
22	Analysis of Drivetrain and Differential
23	Motor Efficiency Mapping and Optimization
24	Design and Simulation of Direct Drive Motors

List of Experiments (Any 16)

A minimum of sixteen experiments from the above-suggested list or any other experiment based on the syllabus will be included, which would help the learner to apply the concept.

Books Recommended:

Textbooks:

- Behrooz Mashadi and David Crolla, Vehicle Powertrain Systems, Wiley, 2012.
- Joseph Katz, Automotive Aerodynamics, Wiley, 2016.
- David C. Barton and John D. Fieldhouse, Automotive Chassis Engineering, Springer, 2018.
- Yi Zhang and Chris Mi, Automotive Power Transmission Systems, Wiley, 2018
- Per Enge, Electric Vehicle Engineering (PB), McGraw-Hill Education, ISBN:9781265900526, 2023.
- Bruno Scrosati, Jürgen Garche, Werner Tillmetz, Advances in Battery Technologies for Electric Vehicles, Woodhead Publishing, ISBN:9781782423980, 2015.
- Ion Boldea, Linear Electric Machines, Drives, and MAGLEVs Handbook, CRC Press. 2017.

Reference Books:

- Zongxuan Sun and Guoming Zhu, Design and Control of Automotive Propulsion Systems, CRC Press, 2015.
- Robert Fischer, Ferit Küçükay, Gunter Jürgens, Rolf Najork, and Burkhard Pollak, The Automotive

Transmission Book, Springer, 2015.
- Jian Pang, Noise and Vibration Control in Automotive Bodies, Wiley, 2019.
- Tariq Muneer, Mohan Kolhe, Aisling Doyle, Electric Vehicles: Prospects and Challenges, Elsevier, ISBN:9780128030400, 2017.

Web References:

- Fundamentals of Electric vehicles: Technology & Economics (https://nptel.ac.in/courses/108106170)

Honors in Electric Vehicles	**T.Y. B.Tech**	**Semester: V**
Program: Mechanical Engineering		
Course: Electric Drives and Controls (DJS23MH1301)		

Pre-requisite:

1. Fundamentals of electric vehicles.
2. Fundamentals of mechanical, electronics, and electrical engineering.

Objectives:

1. To provide fundamental knowledge of power devices and power conversion techniques used in electric drive systems and their application in electric vehicles.
2. To study various sensors, observers, and modulation schemes used in electric drives for feedback and control purposes to achieve high accuracy and efficiency.
3. To explore the types and control strategies of DC motors, including brushed and brushless DC motors, focusing on their dynamics, characteristic curves, control methods, and four-quadrant operations.
4. To understand the construction, characteristics, and control methods of various AC motors, such as induction motors and permanent magnet motors, and their role in electric vehicle applications.
5. To analyze advanced motor types, such as Switched Reluctance Motors (SRM) and BLDC motors, their control strategies, characteristic curves, and applications in electric vehicle systems.
6. To provide knowledge on selecting and sizing electric motors based on application requirements, motion profiles, and real-life case studies, focusing on their torque-speed characteristics and efficiency.

Outcomes: On completion of the course, the learner will be able to:

1. Explain the power devices, voltage source and current source inverters, and power conversion techniques applicable to electric vehicles.
2. Select and implement appropriate sensors, observers, and modulation schemes to optimize electric drive performance.
3. Design and control DC motors, utilizing different control strategies to achieve desired performance and understand four-quadrant operations.
4. Apply the knowledge of AC motor control methods such as Variable-Voltage Variable-Frequency Control (VVVF), Field-Oriented Control (FOC), and Direct Torque Control (DTC).
5. Develop proficiency in controlling advanced motor drive topologies like SRM and BLDC motors, focusing on reducing torque ripple and improving motor efficiency.
6. Select and size appropriate motors for different EV applications, evaluate motor performance characteristics, and understand their suitability for various types of electric vehicles.

Electric Drives and Controls (DJS23MH1301)		
Unit	**Description**	**Duration**
1	**Basics of Power Conversion:** **Power devices:** Silicon Controlled Rectifier (SCR), Triode for Alternating Current (TRIAC), Bipolar Junction Transistor (BJT), Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) and Insulated-Gate Bipolar Transistor (IGBT). **Power Conversion:** DC-DC converters, DC-AC Converters, and AC-DC Converters used in EV applications. Voltage source inverter, Current source inverter; High power and low power loops; Converter/ Inverter Loss calculation; Heat-sinking: passive and active cooling.	8

2	**Elements of Drives:** Encoders, Resolvers, R/D Converters, Hall current sensors and current sampling, Voltage Model Estimator, Current Model Estimator, Closed-loop MRAS observer, Sliding Mode Observer. **Modulation schemes:** Sinusoidal PWM, Injection of third order harmonics, Space Vector Modulation, Dead time & compensation, comparison of modulation techniques.	7
3	**EV Motors Drive Topologies - 1** Need and functions of Motor Controller; **DC motor:** Brushed and Brushless DC motors (BLDC); BLDC motor drive; Basics of brushed DC Motor, DC Motor dynamics, Characteristic Curves; PMSM drives and SRM (synchronous reluctance motor) based drive. **DC Motor Control:** Single-phase uncontrolled rectifiers, half and fully-controlled rectifiers, chopper control, open and closed loop control. Current Loop Control, Speed Control Loop. Feedback Linearization; Four quadrant operation;	7
4	**EV Motors Drive Topologies -2** **AC Motors:** Induction motors (IM), permanent-magnet ac synchronous motor-surface permanent-magnet (SPM) motors, and interior-permanent-magnet (IPM) motors; constructional details and Characteristic Curves; **Induction Motor Control:** Starting methods and speed control of single-phase induction motors, Variable-Voltage Variable-Frequency Control (VVVF), Field-Oriented Control (FOC), Direct Torque Control (DTC); Field Weakening Control;	7
5	**EV Motors Drive Topologies -3** Switched Reluctance Motor (SRM); Basic construction details and working principles of SRM machine, Types of SRM. Characteristic Curves; SRM motor control: Current chopping control (CCC), Torque-Ripple Minimization Control; **BLDC Motor:** Basic principles of BLDC Motor, motor construction, Types of BLDC motors. Characteristic Curves; BLDC Motor Control: Trapezoidal back EMF BLDC motor control, sensor control; PM Synchronous Motor Control: Field-Oriented Control of PMSM, Flux-Weakening Control of PMSM, Position Sensorless Control of PMSM;	7
6	**Selection/ Sizing of Electric Motor** Overview of electric drives and their applications; Comparison of various types of electric drives; Motion profile: acceleration, steady operation, and deceleration profiles; Traction force calculation; Criteria for selecting electric motors: torque, speed, power rating, efficiency, etc.; Understanding motor performance characteristics: torque-speed curve, efficiency map, etc.; Considerations for motor sizing and matching to load requirements; Suitability of electric motor in different domains for 2-, 3-, 4-wheeler and large-size vehicles; Selection of cooling system; Real-life examples/case studies.	6
	Total	**42**

Books Recommended:

Textbooks:

- Gopal K D, "Fundamentals of Electric Drives", Narosa Publishing House Pvt. Ltd., 2011.
- Ned Mohan, Siddharth Raju, Analysis and Control of Electric Drives: Simulations and Laboratory Implementation, Wiley, ISBN:9781119584551, 2020.
- Pillai S K, "A first course on Electrical Drives", Wiley Eastern Ltd, Bombay, 2011.

- Ali Elamadi, "Handbook of Automotive Power Electronics and Drives", CRC Press, 2012.
- Bimal K Bose, "Modern Power Electronics and Drives", Elsevier publishers, Butterworth-Heinemann, 2012.
- Krishnan R, "Permanent Magnet Synchronous and Brushless DC Motor Drives", CRC Publishers, 2010.
- Austin Hughes, Bill Drury, "Electric Motors and Drives Fundamentals, Types and Applications", Newnes, 5th Edition, 2019.
- Marian Kazmierkowski, Ramu Krishnan, Frede Blaabjerg," Control in Power Electronics", Academic Press, 1st Edition - August 20, 2002
- Rik W. De Doncker, Duco W.J. Pulle, André Veltman, Advanced Electrical Drives: Analysis, Modeling, Control, Springer International Publishing, ISBN:9783030489779, 2020.

Reference Books:

- Richard Crowder, Electric Drives and Electromechanical Systems: Applications and Control, Butterworth-Heinemann, ISBN: 9780081028858, 2019.
- Krishnan R, Switched Reluctance Motor Drives: Modelling, Simulation, Analysis, Design and Applications, CRC Publishers, 2012.
- Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
- James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
- K. Wang Hee, AC Motor Control & Electrical Vehicle Application, CR Press, Taylor & Francis Group, 2019.
- C. C. Chan, K. T. Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001.

Web References:

- Design of Electric Motors (https://nptel.ac.in/courses/108108191)
- Advanced Electric Drives (https://nptel.ac.in/courses/108104011)
- Fundamentals of Electric Drives (https://nptel.ac.in/courses/108104140)
- Industrial Drives: Power electronics (https://nptel.ac.in/courses/108108077)

Honors in Electric Vehicles	**T.Y. B.Tech**	**Semester: V**
Program: Mechanical Engineering		
Course: Electric Vehicle Laboratory II (DJS23MH1301L)		

Pre-requisite:

1. Fundamentals of electric vehicle;
2. Fundamentals of mechanical, electronics, and electrical engineering.
3. Fundamentals of chemistry, physics, and engineering mechanics.

Objectives:

1. To provide fundamental knowledge of power devices and power conversion techniques used in electric drive systems and their application in electric vehicles.
2. To study various sensors, observers, and modulation schemes used in electric drives for feedback and control purposes to achieve high accuracy and efficiency.
3. To explore the types and control strategies of DC motors, including brushed and brushless DC motors, focusing on their dynamics, characteristic curves, control methods, and four-quadrant operations.
4. To understand the construction, characteristics, and control methods of various AC motors, such as induction motors and permanent magnet motors, and their role in electric vehicle applications.
5. To analyze advanced motor types, such as Switched Reluctance Motors (SRM) and BLDC motors, their control strategies, characteristic curves, and applications in electric vehicle systems.
6. To provide knowledge on selecting and sizing electric motors based on application requirements, motion profiles, and real-life case studies, focusing on their torque-speed characteristics and efficiency.

Outcomes: On completion of the course, the learner will be able to:

1. Explain the power devices, voltage source and current source inverters, and power conversion techniques applicable to electric vehicles.
2. Select and implement appropriate sensors, observers, and modulation schemes to optimize electric drive performance.
3. Design and control DC motors, utilizing different control strategies to achieve desired performance and understand four-quadrant operations.
4. Apply the knowledge of AC motor control methods such as Variable-Voltage Variable-Frequency Control (VVVF), Field-Oriented Control (FOC), and Direct Torque Control (DTC).
5. Develop proficiency in controlling advanced motor drive topologies like SRM and BLDC motors, focusing on reducing torque ripple and improving motor efficiency.
6. Select and size appropriate motors for different EV applications, evaluate motor performance characteristics, and understand their suitability for various types of electric vehicles.

Electric Vehicle Laboratory I (DJS23MH1301L)	
Sr. No.	**Experiment Title**
	Study-Type Experiments (Theoretical and Conceptual Learning)
1	Study of Power Devices in Power Conversion Systems
2	Study the operation and applications of various converters used in electric vehicles and their effect on power efficiency.

3	Review different modulation schemes like Sinusoidal PWM, Space Vector Modulation (SVM), and third-order harmonic injection, and analyze their effectiveness.
4	Study of Motor Drive Topologies for Brushed and Brushless DC Motor:
5	Review the criteria for selecting and sizing electric motors for different vehicle categories, focusing on torque, speed, power ratings, and efficiency.
	Simulation-Based Experiments (Python/ MATLAB/ Simulink, etc.)
6	Simulation of Inverter and Converter Loss Calculation
7	Simulation of Motor Control Techniques for DC Motors
8	Simulation of Induction Motor Control Using Field-Oriented Control (FOC) and Direct Torque Control (DTC)
9	Simulation of BLDC Motor Control Using Trapezoidal Back EMF and Sensorless Control
10	Numerical Analysis of Motor Efficiency Map and Torque-Speed Characteristics
	Performance-Based Experiments (Hands-on)
11	Measure and analyze the efficiency, voltage, and current characteristics of a MOSFET-based DC-DC converter under different load conditions.
12	Performance Evaluation of a Brushed DC Motor under Different Load Conditions
13	Efficiency Measurement of Induction Motors with Variable Voltage and Frequency Control (VVVF)
14	Testing of Switched Reluctance Motor Control for Torque Ripple Minimization
15	Testing of BLDC Motor Drive with Sensored and Sensorless Control

List of Experiments (Any 8)
A minimum of eight experiments from the above-suggested list or any other experiment based on the syllabus will be included, which will help learners apply the concept.

Books Recommended:
Books Recommended:
Text books:

- Gopal K D, "Fundamentals of Electric Drives", Narosa Publishing House Pvt. Ltd., 2011.
- Ned Mohan, Siddharth Raju, Analysis and Control of Electric Drives: Simulations and Laboratory Implementation, Wiley, ISBN:9781119584551, 2020.
- Pillai S K, "A first course on Electrical Drives", Wiley Eastern Ltd, Bombay 2011.
- Ali Elamadi, "Handbook Automotive Power Electronics and Drives", CRC publishers, 2012.
- Bimal K Bose, "Modern Power Electronics and Drives", Elsevier publishers, Butterworth Hinnemann, 2012.
- Krishnan R, "Permanent Magnet synchronous and Brushless DC Motor Drives", CRC Publishers, 2010.
- Austin Hughes, Bill Drury, "Electric Motors and Drives Fundamentals, Types and Applications", Newnes, 5th Edition, 2019.
- Marian Kazmierkowski, Ramu Krishnan, Frede Blaabjerg," Control in Power Electronics", Academic Press, 1st Edition - August 20, 2002
- Rik W. De Doncker, Duco W.J. Pulle, André Veltman, Advanced Electrical Drives: Analysis, Modeling, Control, Springer International Publishing, ISBN:9783030489779, 2020.

Reference Books:

- Richard Crowder, Electric Drives and Electromechanical Systems: Applications and Control, Butterworth-Heinemann, ISBN: 9780081028858, 2019.

- Krishnan R, Switched Reluctance Motor Drives: Modelling, Simulation, Analysis, Design and Applications, CRC Publishers, 2012.
- Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
- James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003.
- K. Wang Hee, AC Motor Control & Electrical Vehicle Application, CR Press, Taylor & Francis Group, 2019.
- C. C. Chan, K. T. Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001.

Web References:

- Design of Electric Motors (https://nptel.ac.in/courses/108108191)
- Advanced Electric Drives (https://nptel.ac.in/courses/108104011)
- Fundamentals of Electric Drives (https://nptel.ac.in/courses/108104140)
- Industrial Drives: Power electronics (https://nptel.ac.in/courses/108108077)

Honors in Electric Vehicles	**T.Y. B.Tech**	**Semester: VI**
Program: Mechanical Engineering		
Course: Energy Source Management (DJS23MH1351)		

Pre-requisite:

1. Fundamentals of electric vehicles;
2. Electric drives and controls;
3. Basics of mechanical, electrical and electronics engineering.

Objectives:

1. To provide a comprehensive understanding of various energy sources and battery technologies.
2. To equip students with knowledge about the design and modeling of battery packs, including electrical and mechanical design aspects.
3. To explore thermal issues in battery packs, their impact on capacity and cycle life, and the design of cooling strategies and materials for efficient thermal management.
4. To familiarize students with different charging methods and infrastructure, charging standards, and protocols, including the impact of electric vehicles on the existing power grid.
5. To provide insights into energy storage plants, global and Indian energy scenarios, and policies related to energy conservation and sustainability, emphasizing the role of energy in economic development.
6. To impart knowledge on energy management strategies, optimization techniques, and in-vehicle communication networks.

Outcomes: On completion of the course, the learner will be able to:

1. To describe different types of batteries, including lithium-ion batteries, and explain their components, materials, and construction, as well as design considerations for battery packs.
2. To develop and simulate battery pack designs using equivalent circuit models, analyze electrical and mechanical design considerations, and evaluate the safety and reliability of battery structures.
3. To identify thermal issues in battery systems and implement suitable thermal management strategies, cooling methods, and materials for effective heat dissipation and safety.
4. To demonstrate the knowledge of AC and DC charging methods, battery chargers, and charging protocols, and will be able to assess the design and installation requirements for charging infrastructure.
5. To explain the role of energy storage systems in different load scenarios, the global and Indian energy scenarios, and the impact of energy policies on conservation and economic development.
6. To compare and classify different energy management strategies, apply optimization techniques, and address implementation challenges in energy management systems for electric vehicles.

Energy Source Management (DJS23MH1351)		
Unit	**Description**	**Duration**
1	**Energy Sources and Battery Technology:** Introduction to energy sources; Batteries: primary and secondary; Performance parameters; **Lithium-ion batteries:** Components; Materials: cathode and anode; Electrolytes: salts and solvents, separators; Battery cells: cylindrical, prismatic, and pouch cells.	7

	Battery pack design considerations: Requirements; Development process; Types and selection; Determination of power, voltage, and capacity of the battery pack; Trade-off between parallel and series cell connections, PCM, and SCM;	
2	**Battery Pack Design, Modelling, and Simulation - II** **Equivalent Circuit Modelling**: Modelling OCV and SOC; Voltage polarization, Warburg impedance; Estimation of Model parameter values: OCV, Columbic Efficiency, total capacity, temperature dependence of OCV, using the ECM to simulate constant voltage/ power charge/ discharge characteristics. **Electrical Design:** Design considerations; Conductor material selection; Busbar sizing; Short circuit; Conductor insulation; Contact resistance; Voltage drop and its significance; Current equalization in parallel path; Testing and standards. **Mechanical Design Aspects:** Design consideration; Forces acting; Noise and vibration; Material used; Layout-specific battery location selection; Battery pack structure; Compartment design for crashworthiness and cooling; Ashby Methodology, Battery Swelling.	8
3	**Thermal Design of Battery Pack** Thermal issues; Impact of temperature on capacity; Cycle life, and thermal runaway; Considerations for thermal design; Heat generation; Heat load determination; Energy flow in first principles; Modes of battery thermal management; **Cooling systems:** Forced air convection; Liquid cooling; Immersion cooling; Peltier cooling; Heat sink natural convection; Heat pipe cooling; **Cooling strategies:** Direct/ indirect cooling, Air cooling, liquid cooling, PCM-based cooling, advanced cooling methods; Materials: Thermal interface material; Phase change material; Thermal insulations; Temperature sensing and monitoring.	7
4	**Battery Charging Infrastructure** Introduction; AC and DC charging; CC-CV charging; Pulse charging; Battery Chargers: on-board and off-board; Standards and protocols; Types: Fast DC chargers; Home and public charging; Wireless Power Transfer (WPT) technologies; Move-and-charge technology; Selection and sizing of charging station; Single line diagram of charging station; Design considerations of AC and DC fast charger: vehicle interface and charging protocol. Charging Infrastructure-standardization and connectivity issues; SAE J1772, CHAdeMo, GB/T, CCS2 battery charging protocols. OCPP protocol Impact on existing power grid, G2V and V2X- Vehicle-to-home (V2H), vehicle-to-vehicle (V2V), and vehicle-to-grid (V2G) energy systems. Renewable Energy Based Charging infra. Connectivity and applicable charging standards, Installation guidelines, and grid requirements for charger installations. Battery Swapping Technology.	8
5	**Energy Storage and Distribution** Electrical energy route; Load curves; Energy Conversion Plants for Base Load, Intermediate Load, Peak Load, and Energy Displacement – Energy Storage Plants. Energy Scenario: Global and Indian, Impact of Energy on Economy; Development and Environment; Energy Policies; Energy Conservation Opportunities; Electrical ECOs Energy; Strategy for Future.	6

6	**Energy Management System** In-Vehicle Networks – CAN, Energy Management Strategies: Introduction to Energy Management Strategies with Optimization Techniques used in Hybrid and Electric Vehicles, Classification of Different Energy Management Strategies, Comparision of Different Energy Management Strategies and Implementation Issues of Energy Management Strategies,	6
	Total	**42**

Books Recommended:

Text books:

- Luis Romeral Martinez, Miguel Delgado Prieto, New Trends in Electrical Vehicle Powertrains, IntechOpen, 2019.
- Febin Daya J. L., Mohan Krishna S., Sheldon S. Williamson, Umashankar Subramaniam, Electric Vehicles and the Future of Energy Efficient Transportation, ISBN:978179987628,1 IGI Global, 2021.
- Kripal Singh Jogi, Encyclopaedia of Energy Resource Management (priorities for 21st Century), Institute of Environmental Development Studies, 2000.
- B. H. Khan, Non-conventional Energy Resources, McGraw-Hill Education (India) Pvt Limited, ISBN:9780070606548, 2006.
- Reinhart Job, Electrochemical Energy Storage Physics and Chemistry of Batteries, De Gruyter, ISBN:9783110484427, 2020.
- Batteries: Materials Principles and Characterization Methods, Chen Liao, Chemical Sciences and Engineering Division, Argonne National Laboratory, Lemont, USA.
- Batteries, Fuel Cells, and related Electrochemistry, U.S. Department of Energy, Washington, D.C. 20585.

Reference Books:

- Craig B. Smith, Kelly E. Parmenter, Energy Management Principles, Applications, Benefits, Savings, ISBN:9780128026441, 2015.
- Vladimir S. Bagotsky, Alexander M. Skundin, Yurij M. Volfkovich, Electrochemical Power Sources Batteries, Fuel Cells, and Supercapacitors, Wiley, ISBN:9781118460238, 2015.
- Amlan Chakrabarti, Energy Engineering and Management, Prentice Hall India Pvt., Limited, ISBN:9789387472891, 2019.
- V. Hacker, S. Mitsushima, Fuel Cells and Hydrogen: From Fundamentals to Applied Research, Elsevier, 2018.
- Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Practice, CRC Press, 2009.
- Amlan Chakrabarti, Energy Engineering and Management, Prentice Hall India Pvt., Limited, ISBN:9789387472891, 2019.

Honors in Electric Vehicles	T.Y. B.Tech	Semester: VI
Program: Mechanical Engineering		
Course: Electric Vehicle Laboratory III (DJS23MH1351L)		

Pre-requisite:

1. Fundamentals of electric vehicles
2. Electric drives and controls

Objectives:

1. To develop a thorough understanding of various energy sources and advanced battery technologies.
2. To equip students with the skills to design and model battery packs, addressing both electrical and mechanical design considerations.
3. To examine thermal challenges in battery systems, including their impact on capacity and cycle life, and to design efficient cooling strategies and select appropriate thermal management materials.
4. To familiarize students with diverse charging methods, infrastructure, standards, and protocols.
5. To provide insight into energy storage solutions, global and national energy scenarios, and policies that promote energy conservation, focusing on their influence on sustainable economic growth.
6. To impart knowledge on energy management strategies, optimization techniques, and in-vehicle network communication essential for efficient energy utilization in electric vehicles.

Outcomes: On completion of the course, the learner will be able to:

1. Describe various battery types, their components, materials, and construction.
2. Develop and simulate battery pack designs using equivalent circuit models, analyze key electrical and mechanical aspects.
3. Identify thermal challenges in battery systems and implement effective thermal management strategies, cooling methods, and materials for optimal heat dissipation and safety.
4. Demonstrate understanding of AC and DC charging methods, battery chargers, and charging protocols.
5. Discuss the role of energy storage systems in various load scenarios.
6. Compare and classify energy management strategies, apply optimization techniques, and address implementation challenges within energy management systems for electric vehicles.

Electric Vehicle Laboratory III (DJS23MH1351L)	
Sr. No.	**Experiment Title**
	Study-Type Experiments (Theoretical and Conceptual Learning)
1	Study of Lithium-ion Battery Components and Types
2	Analysis of Battery Pack Design and Development Process
3	Overview of Thermal Management Techniques in Battery Packs
4	Exploration of Battery Charging Infrastructure and Standards
5	Study of Energy Management Strategies in Hybrid and Electric Vehicles
	Numerical Analysis Experiments (Python/ MATLAB/ Simulink, etc.)
6	Simulation of Equivalent Circuit Models (ECM) for Battery Systems
7	Simulation of Thermal Analysis in Battery Packs
8	Simulation of Battery Charging Techniques and Control
9	Simulation of Energy Storage and Load Distribution
10	Simulation of Energy Management Strategy in Hybrid Vehicles
	Performance-Based Experiments (Hands-on and Simulation Tools)

11	Performance Evaluation of Lithium-Ion Battery under Different Discharge Rates
12	Efficiency and Loss Calculation in a DC-DC Converter for EV Applications
13	Performance Testing of Cooling Systems in Battery Packs
14	Performance Analysis of On-board and Off-board Battery Chargers
15	Testing of Energy Storage System for Peak Load Management

List of Experiments (Any 8)

A minimum of eight experiments from the above-suggested list or any other experiment based on the syllabus will be included, which would help the learner to apply the concept.

Books Recommended:

Textbooks:

- Luis Romeral Martinez, Miguel Delgado Prieto, New Trends in Electrical Vehicle Powertrains, IntechOpen, 2019.
- Febin Daya J. L., Mohan Krishna S., Sheldon S. Williamson, Umashankar Subramaniam, Electric Vehicles and the Future of Energy Efficient Transportation, ISBN:978179987628,1 IGI Global, 2021.
- Kripal Singh Jogi, Encyclopaedia of Energy Resource Management (priorities for 21st Century), Institute of Environmental Development Studies, 2000.
- B. H. Khan, Non-conventional Energy Resources, McGraw-Hill Education (India) Pvt Limited, ISBN:9780070606548, 2006.
- Reinhart Job, Electrochemical Energy Storage Physics and Chemistry of Batteries, De Gruyter, ISBN:9783110484427, 2020.
- Batteries: Materials Principles and Characterization Methods, Chen Liao, Chemical Sciences and Engineering Division, Argonne National Laboratory, Lemont, USA.
- Batteries, Fuel Cells, and related Electrochemistry, U.S. Department of Energy, Washington, D.C. 20585.

Reference Books:

- Craig B. Smith, Kelly E. Parmenter, Energy Management Principles, Applications, Benefits, Savings, ISBN:9780128026441, 2015.
- Vladimir S. Bagotsky, Alexander M. Skundin, Yurij M. Volfkovich, Electrochemical Power Sources Batteries, Fuel Cells, and Supercapacitors, Wiley, ISBN:9781118460238, 2015.
- Amlan Chakrabarti, Energy Engineering and Management, Prentice Hall India Pvt., Limited, ISBN:9789387472891, 2019.
- V. Hacker, S. Mitsushima, Fuel Cells and Hydrogen: From Fundamentals to Applied Research, Elsevier, 2018.
- Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Practice, CRC Press, 2009.
- Amlan Chakrabarti, Energy Engineering and Management, Prentice Hall India Pvt., Limited, ISBN:9789387472891, 2019.

Honors in Electric Vehicles	**Final Year B.Tech**	**Semester: VIII**
Program: Mechanical Engineering		
Course: Electric Vehicle System Design and Safety (DJS23MH1451)		

Pre-requisite:

1. Fundamentals of electric vehicles
2. Electric drives and control
3. Energy sources and management

Objectives:

1. To provide a comprehensive understanding of aesthetic design principles and their unique application to EVs.
2. To familiarize students with ergonomic principles for EV design, addressing user comfort, interface accessibility, and agronomical insights.
3. To introduce students to advanced safety, risk, hazard, and reliability analysis methods in EV systems.
4. To teach students about EV safety and testing standards.
5. To impart knowledge on fuel cell technology within EVs, exploring various types of fuel cells, materials, and safety concerns.
6. To analyze the economics of EVs, including life cycle cost analysis, incentives, and the impact of electricity pricing on charging patterns and grid support.

Outcomes: On completion of the course, the learner will be able to:

1. Explain and apply the principles of aesthetic design (both exterior and interior) in electric vehicles.
2. Apply ergonomic design principles to enhance the EV user experience, emphasizing comfort, accessibility, and user-centered control interfaces.
3. Perform safety and reliability analyses on EV components using techniques like FTA, FMEA, and RBD to predict and mitigate potential failures.
4. Demonstrate understanding of EV safety standards, conduct testing, and apply best practices for thermal, environmental, and crash safety.
5. Describe fuel cell operation in EVs, distinguishing between types of fuel cells, safety issues, and recent technological advancements.
6. Apply economic considerations to estimate the life cycle cost (LCC) of the electric vehicles.

Electric Vehicle System Design and Safety (DJS23MH1451)		
Unit	**Description**	**Duration**
1	**Aesthetic Design in EVs** Overview of aesthetic design in automotive industry; Principles of aesthetic design; Role of shape, proportions, and design lines; Colour psychology; Surface treatment and finish; Comparison of traditional vehicles and EVs; **Exterior design:** aerodynamics, styling, integration of sensors and cameras into exterior design; Material and color choices, Lighting design - headlamps, tail lamps, and ambient lighting; **Interior design:** customization, display and dashboard design, control units, seat design, material used for interiors and its selection methodology; **Design Technologies:** CAD and 3D modeling software, Role of AR and VR; Sustainable design.	10

2	**Design for Ergonomics** Basics of ergonomics and human-centered design principles; Goals of ergonomic design: Comfort, accessibility, and safety; Understanding user demographics and physiological needs; Driver and Passenger Comfort: seating design, ingress and egress, seat material; Control and Interface – simplified dashboard layout, steering wheel and pedal ergonomics; Cabin air quality and lighting: air quality systems, ambient lighting, NVH management; User interface and display design: Heads-Up Display (HUD), Multi-functional displays. **Integrating Agronomical Insights from Nature and Agriculture:** Drawing inspiration from agronomy such as energy efficiency, modularity, and adaptability, energy-efficient materials, modularity in design, biophilic design principles, regenerative systems.	10
3	**Safety, Hazard, and Risk Analysis of Electric Vehicle Systems** Life cycle phases of EV; Customer satisfaction; Reliability vs. durability in EVs; System analysis methods: Fault Tree Analysis (FTA); Failure Modes and Effects Analysis (FMEA); Reliability Block Diagrams (RBD); Reliability analysis of batteries and power electronics; Markov Chains and state-space models; Condition monitoring and predictive maintenance; Reliability allocation and optimization; Analysis of component failure modes, aging effects, and thermal degradation. Impact of reliability on EV range and performance.	10
4	**EV Safety and Testing Standards** Testing in EV Components: environmental, thermal cycling, vibration, and shock testing; Accelerated Life Testing (ALT); Software Reliability in EV Systems; **Safety in EV Design:** Thermal runaway in batteries, short circuit protection, fault diagnosis, and fire hazards in EV systems. **Safety Standards and Regulations:** ISO 26262 for functional safety, battery safety standards (IEC 62619, UL 2580), crashworthiness, and passenger safety. **Testing and Validation:** Battery testing (electrical, thermal, mechanical), powertrain testing, IP ratings for weather protection, and electromagnetic compatibility (EMC) testing. **Battery Recycling and Disposal:** End-of-life considerations, recycling processes, environmental impact, and regulations for safe disposal of battery packs.	10
5	**Fuel Cell and Electric Vehicles** Fuel cell technologies; Working mechanism of fuel cells; Types of fuel cells – PEMFC, SOFC, AFC, PAFC, DMFC, MCFC; Materials for electrodes, electrolytes, and other components; Hydrogen generation and storage - limitations, recent progress in fuel cells, safety issues and cost expectation; Life cycle analysis of fuel cells.	8
6	**Economics of Electric Vehicle** Product life cycle curve for EV; Life Cycle Cost (LCC) elements: acquisition cost, operating cost, maintenance cost, disposal cost/ net salvage value; Annualized life cycle costing; Grid supply side incentives; EV purchased incentives; Impact of electricity prices on charging and discharging pattern; Charging infrastructure incentives; Economic efficiency; Computation of electricity cost of charging of hybrid electric vehicle	8
	Total	**56**

Books Recommended:

Textbooks:

- Vivek D. Bhise, Ergonomics in the Automotive Design Process, CRC Press, ISBN:9781439842119, 2016.
- Richard Herriott, The Aesthetics of Industrial Design - Seeing, Designing and Making, Taylor & Francis, ISBN:9781000535242, 2021.
- Kailash C. Kapur, and Michael Pecht, 2014, Reliability Engineering, ISBN:9781118841792, Wiley, 2021.
- San Ping Jiang, and Qingfeng Li, Introduction to Fuel Cells - Electrochemistry and Materials, Springer Nature Singapore, ISBN:9789811076251, 2021.
- Cecilia Briceno-Garmendia, Wenxin Qiao, and Vivien Foster, The Economics of Electric Vehicles for Passenger Transportation, World Bank Publications, ISBN:9781464819490, 2022.

Reference Books:

- Boryann Liaw, and Gianfranco Pistoia, Behaviour of Lithium-Ion Batteries in Electric Vehicles Battery Health, Performance, Safety, and Cost, Springer International Publishing, ISBN:9783319699509, 2018.
- Kalpana Chauhan, and Rajeev Kumar Chauhan, , Distributed Energy Resources in Microgrids - Integration, Challenges and Optimization, Elsevier Science, ISBN:9780128177754, 2019.
- Shigenori Mitsushima, and Viktor Hacker, Fuel Cells and Hydrogen - From Fundamentals to Applied Research, Elsevier, ISBN:9780128115374, 2018,.
- David Beeton, and Gereon Meyer, Electric Vehicle Business Models - Global Perspectives, Springer International Publishing, ISBN:9783319122441, 2014.