Syllabi
Third Year
Electric Vehicle

Course Type	Course Code	Course Name	Credits
HMC	HMCEV501	ELECTRICAL AND HYBRID ELECTRIC VEHICLE	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. ESC102: Basic Electrical Engineering
2. ESL102: Basic Electrical Engineering Laboratory
3. ESC203: Basic Electronics Engineering
4. ESL206: Basic Electronics Engineering Laboratory

Program Outcomes addressed :

1. PO2: Problem analysis
2. PO3: Design/Development of Solutions
3. PO6: The Engineer and The World
4. PO11: Life-long learning

Course Objectives :

1. To learn the history of electric hybrid electric vehicles (EV & HEV) and emphasize the need and importance of EV-HEV for sustainable future.
2. To study the fundamental concepts and principles of electric and hybrid electric vehicles drive train topologies
3. To develop a thorough understanding of the key elements of EV/HEV: Electric Motors and Energy Sources
4. To understand various energy management strategies adopted in EVs/ HEVs

Module	Details	Hrs
0	**Course Introduction:** Every country in the world is facing environmental challenges with excessive usage of fossil fuels. With zero tailpipe emissions, EVs are a direct cure for air pollution. There has been a significant rise in the production and sales of electric vehicles in recent years. Many major automobile manufacturers are launching a wide range of EV models to cater to the growing demand. This increased availability and diversity of electric vehicles contribute to the notion that the era of EVs is indeed underway. Advancements in battery technology and infrastructure have played a crucial role in accelerating the adoption of EVs. Additionally, the expansion of charging infrastructure, including public charging stations and home charging solutions, has improved the convenience and accessibility of EVs for drivers.	1
1	**Introduction:**	6
	Learning Objectives: *1. To gain the knowledge of both historical development and state of the art of automotive domain.*	

	2. *To get acquainted with Indian and global scenario in EV/HEV and general trend in automotive industry.*	
	Contents: History of Vehicle Development, General Configuration of Automobile, Automotive Powertrain, Transmission Systems; Internal Combustion Engine (ICE) performance characteristics, Power and Torque generation, specific fuel consumption, fuel conversion efficiency. History of electric vehicles (EV) and hybrid electric vehicles (HEV), need and importance of EV and HEV, Power/Energy supplies requirements for EV/HEV applications. State of the art and Indian and global scenario in EV/HEV Comparison of ICE vehicle with HEVs and EVs, National Policy for adoption of EVs	
	Learning Outcome: *The learner would be able to:* *LO1.1: Correlate the history of vehicle development and state of the art technology in automotive industry. (P.I.-3.1.3, P.I.-6.1.1)* *LO1.2: Sketch the general configuration of Automobile, Automotive Powertrain and Transmission Systems. (P.I.-3.1.3 & P.I.-6.1.1)* *LO1.3: State and compare the ICE and EV/ HEV performance. (P.I.-2.2.4)*	
2	**Drive-train Topologies:**	8
	Learning Objectives: *To gain knowledge about different types of EV/ HEV drive-train topologies and the basics of the power flow control in such drivetrains*	
	Content: Various electric drive-train topologies, basics of hybrid traction system, hybrid drive-train topologies: Series HEVs, Parallel HEVs, Series–Parallel HEVs, Complex HEVs, Operating Modes, Degree of Hybridization, Comparison of HEVs, Plug-in Hybrid Electric Vehicles (PHEVs), power flow control in drive-train topologies, Real Life examples of HEVs.	
	Learning Outcome: *The learner would be able to* *LO2.1: Identify different types of EV/ HEV drive-train topologies and the sketch the power flow control in such drivetrains. (P.I.-3.1.3, P.I.-6.1.1)* *LO2.2: Compare the performance of such drive trains and correlate the same in commercially available EVs/HEVs. (P.I.-3.1.3, P.I.-6.1.1 & P.I.-11.3.2)*	
3	**Electric Motors for Propulsion Applications**	8
	Learning Objectives: *To gain knowledge about various electric motors and their performance in EV/ HEV applications*	
	Contents: Electric System components for EV/HEV, suitability of DC and AC machines for EV/HEV applications, AC and DC Motor drives: with Induction Motor, BLDC Motor, PMSM and SRM. Comparison and applications. State of the art in EV Motor Technology.	

	Learning Outcome: *The learner would be able to* *LO3.1: Compare the performance of various electric motors for EV/HEV applications and access the same with real life examples of EVs/HEVs (P.I.-2.2.4, P.I.-3.1.3 & P.I.-11.3.2)* *LO3.1: Select / recommend the specific electric motors for given EV/HEV application. (P.I.-2.2.4, P.I.-3.1.3 & P.I.-11.3.2)*	
4	**Energy Sources for EV/HEV:**	8
	Learning Objectives: *To gain knowledge about various energy sources used in EV/ HEV, their characteristics, performance and suitability.*	
	Contents: Requirements of energy sources in EV/HEV: batteries, fuel cells, flywheels and ultra-capacitors as energy sources for EV/HEV, characteristics and comparison of energy sources for EV/HEV, hybridization of different energy sources.	
	Learning Outcome: *The learner would be able to* *LO4.1: Recognize the requirements of energy sources for EV/HEV applications (P.I.-3.1.3, P.I.-6.1.1)* *LO4.2: Compare the characteristics, performance and suitability of various energy sources for EV/ HEV applications. (P.I.-2.2.4, P.I.-6.1.1)* *LO4.3: State the need and impact of hybridization of different energy sources. (P.I.-6.1.1)*	
5	**EV Battery Chargers and EV/ HEV Ecosystem**	8
	Learning Objectives: *To know the basics and state of the art technologies in EV battery charging and its impact on exiting electric grid*	
	Contents: EV battery chargers: Basics of On-board & Off-board Chargers, AC and DC Chargers, Fast chargers and related standards for charging (ARAI/ IS), Wireless Power Transfer (WPT) technology for EV charging. EV Electric grid challenges with EV charging, Charging ecosystem: State of the art, G2V and V2G concept.	
	Learning Outcome: *The learner would be able to* *LO5.1: Identify and describe the basics of different types of EV battery chargers. (P.I.-2.2.4, & P.I.-11.3.2)* *LO5.2: the norms and specifications of various EV charging infrastructure regulatory standards. (P.I.-6.1.1)* *LO5.3: State the impact of EV charging infra on the exiting electric grid and means to mitigate the impact. (P.I.-6.1.1 & P.I.- 11.3.2)*	
6	**Energy Management Strategies in EV/HEVs**	5
	Learning Objectives: *Use the fundamentals knowledge of EV/ HEV energy sources and power flow to examine the energy management strategies to optimize the performance.*	
	Contents: EV/HEV energy management strategies, classification and comparison of various energy management strategies.	

	Learning Outcome: *The learner would be able to* *LO6.1 Illustrate the classification and working of various EV/HEV energy management strategies and compare their performance. (P.I.-2.2.4, P.I.-3.1.3, P.I.-6.1.1 & P.I.-11.3.2)*	
7	***Course Conclusion***	1
	TOTAL	45

Performance Indicators:

P.I. No.	**P.I. Statement**
2.2.4	Compare and contrast alternative solution processes to select the best process
3.1.3	Synthesize engineering requirements from a review of the state-of-the-art
6.1.1	Identify and describe various engineering roles; particularly as pertains to protection of the public and public interest at global, regional and local level
7.1.2	Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability
11.3.2	Analyze sourced technical and popular information for feasibility, viability, sustainability, etc.

Course Outcome:

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

CO1: Identify and correlate the historical evolvement of electric & hybrid electric vehicles to the current state of the art. (*LO1.1, LO1.2, LO1.3*)

CO2: Identify and illustrate the various hybrid electric powertrains and their different modes of operations. *(LO2.1, LO2.2*)

CO3: Select electric propulsion system components for EV/HEV drives for the desirable performance and control**.** *(LO3.1, LO3.2*)

CO4: Compare and evaluate various energy sources and energy storage components for EV/HEV. *(LO4.1, LO4.2, LO4.3*)

CO5: Summarize different types, features and current state-of-the-art of the various battery charging mechanisms and energy management strategies. (*LO5.1, LO5.2, LO5.3, LO6.1*)

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCEV501.1		2	3			3					
HMCEV501.2			3			3					2
HMCEV501.3		3	3								3
HMCEV501.4		2	2			3					
HMCEV501.5		3				3					3
Average		**3**	**3**			**3**					**3**

Text Books:

1. I. Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.
2. M. Ehsani, Y. Gao, S.E. Gay and Ali Emadi, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*, CRC Press. 2005
3. Sheldon Williamsom, *Energy Management Strategies for Electric and Plug-in Hybrid Vehicles*, Springer 2013

4. J. Larminie and J. Lowry, *Electric Vehicle Technology Explained*, Wiley, 2003
5. C. MI, M. Abul and D. W. Gao, *Hybrid Electrical Vehicle Principles and Application with Practical Perspectives,* Wiley 2011

Reference Books:

1. N.Mohan, T.M.Undeland, and W.P Robbins, *Power Electronics, Converters, Applications & Design,* Wiley India Pvt. Ltd., 2003
2. B. K Bose*, Modern Power Electronics and AC Drives*, Pearson Education 2002
3. Robert A. Huggins, *Energy Storage*, Springer 2010
4. Vehicle Powertrain Systems by Behrooz Mashadi and David Crolla, Wiley, 2012
5. Automotive Aerodynamics by Joseph Katz, Wiley, 2016
6. Automotive Chassis Engineering, by David C. Barton and John D. Fieldhouse, Springer, 2018
7. Automotive Engineering Powertrain, Chassis System and Vehicle Body Edited by David A. Crolla, Elsevier, 2009
8. Automotive Power Transmission Systems by Yi Zhang and Chris Mi, Wiley, 2018

NPTEL/ Swayam Course:

1. Fundamentals of Automotive Systems, by Prof. C.S. Shankar Ram, IIT Madras, https://nptel.ac.in/courses/107/106/107106088/
2. Intro. to Hybrid and Electric Vehicles - Prof. Praveen Kumar & Prof. S. Majhi (IIT Guwahati): Weblink: https://nptel.ac.in/courses/108/103/108103009/
3. Electric Vehicles - Part 1 By Prof. Amit Kumar Jain (IIT Delhi) Weblink: https://nptel.ac.in/courses/108/102/108102121/

IN-SEMESTER ASSESSMENT (50 MARKS)

Suggested breakup of distribution

1. Continuous Assessment (20 Marks)
   Case Study assignment: 10 Marks
   Open book test: 05 marks
   Regularity and Active Participation: 05 marks
2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
HMC	HMCEV602	Energy Storage System in EV Application	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :	
1.	EEPCC : Basic Electrical Engineering
2.	EEPCC304 : Renewable Sources and Energy Storage
3.	EEPE5013 : Electrical Vehicle Technology
Program Outcomes addressed :	
1.	PO1 : Engineering knowledge
2.	PO2 : Problem analysis
3.	PO3 : Design/Development of Solutions
4.	PO4 : Conduct investigations of complex problems
5.	PO5: Engineering tool usage
6.	PO6 : The Engineer and The World
7.	PO8: Individual and Collaborative Team work
Course Objectives :	
1.	To impart knowledge on energy storage requirements for EVs across different energy storage technologies.
2.	To familiarize the key design requirements for battery pack formation in EV applications, with a focus on thermal management and safety.
3.	To impart knowledge on the designs and architectures of Hybrid Energy Storage Systems (HESS).
4.	To familiarize with safety and thermal management requirements for BMS from relevant codes and standards, focusing on performance.
5.	To impart knowledge on charging infrastructures and explore techniques for managing EV energy systems sustainably.
6.	To introduce tools and techniques for detecting faults, monitoring performance, and assessing the lifecycle of energy storage systems.

Module	Details	Hrs
	Course Introduction This course provides an in-depth exploration of energy storage systems (ESS) used in electric vehicles (EVs). Students will learn about the role of energy storage in enhancing the performance, efficiency, and sustainability of EVs. Key topics will include different types of energy storage technologies such as batteries, super-capacitors, and fuel cells, as well as hybrid energy storage systems (HESS). The course will also	**01**

	cover essential aspects such as battery management systems (BMS), thermal management, charging infrastructure, and the latest trends in the EV energy storage market. By the end of the course, students will have a solid understanding of the fundamental principles, design requirements, and real-world applications of energy storage systems in electric vehicles.	
01.	**Introduction to Energy Storage Systems for Electric Vehicles**	**06**
	Learning Objective/s: *To identify energy storage systems used in electric vehicles.*	
	Contents: Overview of Electric Vehicles (EVs)- EV components and powertrain, Role of energy storage systems in EVs, Energy Storage Requirements for EVs-Power density, energy density, efficiency, and cycle life, Types of Energy Storage Systems-Batteries, super-capacitors, and fuel cells, Comparison of technologies for EV applications, Current Trends and Market Overview-Global energy storage market for EVs, Prominent energy storage solutions and manufacturers.	
	Self-Learning Topics: Nil	
	Learning Outcomes :	
	A learner will be able to *LO1.1: Apply fundamental engineering concepts to explore Electric Vehicle (EV) Components and Powertrain. (PI-1.3.1)* *LO1.2: Apply engineering concepts to comprehend the role of Energy Storage Systems in EVs. (PI-1.4.1)* *LO1.3: Identify and evaluate energy storage requirements for EVs.(PI-2.2.2)* *LO1.4: Identify energy storage technologies and market dynamics for EV applications. (PI-2.2.3)*	
02.	**Battery Technologies**	**09**
	Learning Objective/s: *To explore EV batteries, focusing on their operation, features, types, design, methods to manage degradation and performance criteria.*	
	Contents: Battery Fundamentals-Electrochemical principles and energy storage mechanisms, battery parameters-voltage, capacity, energy density, and power density; Battery Chemistries for EVs- Lead-acid battery, Nickel-based batteries, Sodium based batteries, lithium batteries Metal/air batteries; Battery parameters, Battery pack formation and testing, SoC & SoH, Battery cell balancing, Thermal and safety considerations in battery pack design; Voltage and AHr/ kWhr ratings of battery for EV applications: Major design considerations	
	Self-Learning Topics: *Electrochemical principles*	
	Learning Outcomes : *A learner will be able to*	

	LO2.1: Apply fundamental engineering concepts to explore Battery technologies. (PI-1.3.1) *LO2.2: Apply electrical engineering concepts to comprehend battery chemistries for EVs. (PI-1.4.1)* *LO2.3: Identify battery parameters for EV applications (PI-2.1.2)* *LO2.4: Identify the mathematical, engineering and other relevant knowledge that applies for battery pack formation and cell balancing (PI-2.1.3)* *LO2.5: Explore and synthesize engineering requirements considering thermal management and safety in battery pack design. (PI-3.1.5)* *LO2.6: Determine major design objectives, functional requirements and arrive at specifications of battery for EV applications.(PI-3.1.6)* *LO2.7: Collaboratively design battery pack using a suitable simulation tool, demonstrating effective leadership skill and problem-solving strategies. (PI-5.1.1, PI-8.2.1)* *LO2.8: Adapt the simulation tool to model the given battery pack , present the result as a group, combining everyone's work into a clear and well-organized presentation. (PI-5.1.2, PI-8.3.1)*	
03.	**Hybrid Energy Storage System in EV** ***Learning Objective/s:*** *To identify hybrid energy storage system in EV and explore its design and architecture.* **Contents:** Concept of HESS, Energy and power density trade-offs in hybrid systems, Design and Architecture-Parallel and series configurations of HESS, Power electronics for HESS management, Comparative Analysis of Different HESS Architectures in EVs, Case Studies: HESS in Commercial EV Models ***Self-Learning Topics: Nil*** ***Learning Outcomes :*** *A learner will be able to* *LO3.1: Apply fundamental engineering concepts to explore Hybrid Energy Storage System. (PI-1.3.1)* *LO3.2: Apply electrical engineering concepts to comprehend hybrid energy storage systems for EVs. (PI-1.4.1)* *LO3.3: Identify engineering systems, variables, and parameters involved in Hybrid Energy Storage System. (PI-2.1.2)* *LO3.4: Extract desired understanding and conclusions in terms of HESS designs and architectures (P.I.-2.4.4)*	**06**
04.	**Battery Management Systems (BMS)** ***Learning Objective/s:*** *Explore the components and functions of battery management systems, along with thermal management strategies for battery packs.* **Contents:** Functions of a BMS-Monitoring, balancing, and protection of battery cells; Communication protocols and real-time data monitoring; State Estimation-State of Charge (SOC) and State of Health (SOH) estimation techniques ; Thermal Management-Cooling strategies for battery packs, Impact of thermal management on safety and performance; Safety	**06**

	Features-Overcharge, over-discharge, and thermal runaway prevention, Safety standards and certifications (ISO, IEC).	
	Self-Learning Topics: Nil	
	Learning Outcomes : ***A learner will be able to*** *LO4.1: Identify, assemble and evaluate information and resources for Battery management systems (PI-2.2.2)* *LO4.2: Identify existing protocols and state estimation techniques used in battery management systems.(PI-2.2.3)* *LO4.3: Extract engineering requirements for safety in terms of thermal management in BMS from relevant engineering Codes and Standards such as ISO and IEC.(PI-3.1.4)* *LO4.4: Explore and synthesize engineering requirements for thermal management in BMS considering safety risks and performance..(PI-3.1.5)* *LO4.5: Submits a report or delivers a presentation analyzing at least one Battery management system including its impact on engineering and society. (PI-11.3.1)* *LO4.6: Review at least one technical paper to support the preparation of a report on thermal management of battery with a focus on sustainability. (PI-11.3.2)*	
05.	**Charging Infrastructure**	**08**
	Learning Objective/s: *To gain an understanding of EV charging infrastructure and energy management systems.*	
	Charging Infrastructure: Types of chargers- Level 1, Level 2, and DC fast chargers; Standards and protocols- CCS, CHAdeMO, GB/T, and wireless charging; Energy Management in EVs-Energy flow: charging, discharging, and regenerative braking; Vehicle-to-Grid (V2G) and Vehicle-to-Home (V2H) applications; Emerging Trends-Smart charging systems and integration with renewable energy, Battery swapping stations: concepts and challenges.	
	Self-Learning Topics: Nil	
	Learning Outcomes :	
	A learner will be able to *LO5.1: Identify, assemble and evaluate information and resources for charging infrastructures.(PI-2.2.2)* *LO5.2: Identify existing charging protocols and standards. (PI-2.2.3)* *LO5.3: Explore the connection between technical, socio-economic, and environmental dimensions of sustainability for energy management in EVs.(PI-6.3.2)* *LO5.4: Identify techniques for effectively managing energy systems in EVs to promote sustainable development. (PI-6.3.3)*	
06.	**Performance, Safety, and Maintenance of Energy Storage Systems**	**08**
	Learning Objective/s: *To acquire an understanding of the performance, safety, maintenance, and sustainability considerations of energy storage systems.*	
	Contents:	

	Energy storage system performance indicators-capacity, efficiency, and lifecycle analysis; Factors affecting performance- temperature, aging, and usage patterns; Safety Considerations-Thermal runaway: causes and mitigation strategies; Battery safety standards (ISO 26262, IEC 62660); Maintenance and Diagnostics-Regular maintenance practices for energy storage systems; Diagnostic tools and techniques for fault detection; Recycling and Disposal; Environmental impact and regulatory compliance.	
	Self-Learning Topics: Nil	
	Learning Outcomes :	
	A learner will be able to *LO6.1: Identify performance indicators for Energy storage system.(PI-2.1.2)* *LO6.2: Identify, assemble and evaluate information and resources related to energy storage performance.(PI-2.2.2)* *LO6.3: Extract engineering requirements from relevant engineering Battery Standards such as ISO and IEC .(PI-3.1.4)* *LO6.4: Explore and synthesize engineering requirements considering safety risks for energy storage system. (PI-3.1.5)* *LO6.5: Use appropriate diagnostic tools and techniques to conduct experiments and collect data for fault detection of energy storage systems (PI-4.3.1)* *LO6.6: Synthesize information and knowledge about the diagnostic tools for monitoring energy storage system performance. (PI-4.3.4)* *LO6.7: Identify risks/impacts in the life-cycle of energy storage system.(PI-6.3.1)* *LO6.8: Understand the environmental dimensions of sustainability for energy storage system.(PI-6.3.2)*	
	Course Conclusion In conclusion, this course has provided a comprehensive understanding of energy storage systems (ESS) used in electric vehicles (EVs). Students are equipped with the knowledge to assess, design, and manage energy storage systems in EV applications, considering performance, safety, and sustainability factors.	**01**
Total		**45**

P.I. No.	P.I. Statement
1.3.1	Apply laws of natural science to an engineering problem
1.4.1	Apply Electrical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.2.2	Identify, assemble and evaluate information and resources.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
2.4.4	Extract desired understanding and conclusions consistent with objectives and limitations of the analysis
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards such as ASME, ASTM, BIS, ISO and ASHRAE
3.1.5	Explore and synthesize engineering requirements considering health, safety risks, environmental, cultural and societal issues

3.1.6	Determine design objectives, functional requirements and arrive at specifications
4.3.1	Use appropriate procedures, tools and techniques to conduct experiments and collect data
4.3.4	Synthesize information and knowledge about the problem from the raw data to reach appropriate conclusions
5.1.1	Identify modern engineering tools such as computer aided drafting, modeling and analysis; techniques and resources for engineering activities
5.1.2	Create/adapt/modify/extend tools and techniques to solve engineering problems
6.3.1	Identify risks/impacts in the life-cycle of an engineering product or activity
6.3.2	Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability
6.3.3	Describe management techniques for sustainable development
8.2.1	Demonstrate effective communication, problem solving, conflict resolution and leadership skills
8.3.1	Present results as a team, with smooth integration of contributions from all individual efforts
11.3.1	Source and comprehend technical literature and other credible sources of information
11.3.2	Analyze sourced technical and popular information for feasibility, viability, sustainability, etc
Course Outcomes: Learner will be able to	
1.	Develop a foundational understanding of electric vehicle (EV) components and powertrains, applying engineering principles to analyze energy storage systems, assess storage requirements, and explore emerging technologies and market trends in EV applications. *(LO1.1, LO1.2, LO1.3, LO1.4)*
2.	Apply engineering concepts to explore EV battery technologies and HESS, analyze design needs, and develop safe, efficient battery solutions using simulations. *(LO2.1,LO2.2,LO2.3,LO2.4,LO2.5,LO2.6,LO3.1, LO3.2, LO3.3, LO3.4)*
3.	Assess battery management systems with respect to safety standards and thermal management. *(LO4.1, LO4.2, LO4.3, LO4.4, LO4.5, LO4.6)*
4.	Explore EV charging infrastructure, protocols, and standards while assessing energy management strategies. *(LO5.1, LO5.2, LO5.3, LO5.4)*
5.	Assess the performance of energy storage systems with a focus on safety, maintenance, and sustainability, while adhering to relevant codes and standards. *(LO6.1, LO6.2, LO6.3, LO6.4, LO6.5, LO6.6, LO6.7, LO6.8)*

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCEV602.1	3	3									
HMCEV602.2	3	3	3		3			3			
HMCEV602.3		3	3								3
HMCEV602.4		3				3					
HMCEV602.5		3	3	3		3					
Average	3	3	3	3	3	3		3			3

Textbooks :	
1.	Energy Systems for Electric and Hybrid Vehicles by K.T.Chau, IET,2016.

2.	Electric Vehicle Battery Systems by Sandeep Dhameja, Newens,2002.
3.	Battery Management Systems for Large Lithium-Ion Battery Packs , by Davide Andrea, Artech House Publication, 2010.
4.	Electric and Hybrid Vehicles Power Sources, Models, Sustainability, Infrastructure and The Market by Gianfranco Pistoia, Elsevier, 2013.
Reference Books :	
1.	Fundamentals And Applications Of Lithium-Ion Batteries In Electric Drive Vehicles by Jiuchun Jiang and Caiping Zhang, Wiley, 2015
2.	Fundamentals And Applications Of Lithium-Ion Batteries In Electric by Jiuchun Jiang and Caiping Zhang, Wiley, 2015
3.	Optimal Charging Control of Electric Vehicles in Smart Grids by Wanrong Tang and Ying Jun Zhang, Springer, 2017Rajakaruna, Farhad Shahnia and Arindam Ghosh, Springer 2015
4.	Plug In Electric Vehicles in Smart Grids Charging Strategies Edited by Sumedha Rajakaruna, Farhad Shahnia and Arindam Ghosh, Springer 2015
5.	Younghyun Kim and Naehyuck Chang, Design and Management of Energy-Efficient Hybrid Electrical Energy Storage Systems, Springer, 2014
Other Resources :	
1.	NPTEL Web Course: Electric Vehicles – Part 1 by PROF.AMIT KUMAR JAIN Department of Electrical Engineering IIT Delhi; https://npte;.ac.in/courses/108/102/108102121/
2.	NPTEL Web Course: Fundamentals of Electric vehicles: Technology & Economics: by Prof. Ashok Jhunjhunwala, Prof. Prabhjot Kaur, Prof. Kaushal Kumar Jha and Prof. L Kannan, IIT Madras, https://nptel.ac.in/courses/108/106/108106170/
3.	NPTEL Web Course: Introduction to Hybrid and Electric Vehicles by Dr. Praveen Kumar and Prof. S. Majhi, IIT Guwahati, https://nptel.ac.in/courses/108/103/108103009/

IN-SEMESTER ASSESSMENT (50 MARKS)

Suggested breakup of distribution

1. Continuous Assessment (20 Marks)
   - Assignment on live problems/case studies: 10 Marks
   - Think-pair-share: 05 marks
   - Regularity and Active Participation: 05 marks
2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

CIA		MSE	ESE
Tool-1	Tool-2		
Assignment on live problems/ Case Study	Think-pair-share	CO-1: LO 1.1-1.4 CO-2: LO 2.1 to 2.6 , LO 3.1-3.2	CO1:LO 1.1-1.4 (20%) CO2: LO 2.1 -2.6,LO 3.1 to 3.4 (20%) CO3: LO 4.1-4.4 CO4:LO 5.1-5.2 CO5: LO 6.1-6.6
CO2: LO 2.7-2.8 CO3: LO 4.5-4.6 CO4: LO 5.3-5.4 CO5:LO 6.7-6.8	CO-1: LO 1.1-1.4 CO2: LO 2.1 to 2.6, LO 3.3 – 3.4 CO3: LO 4.1 – 4.4 CO4: LO 5.1- 5.2 CO5: LO 6.1- 6.6		

Syllabi
Third Year
Renewable Energy

Course Type	Course Code	Course Name	Credits
HMC	HMCRE501	SOLAR ENERGY SYSTEMS	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. BSC102- Engineering Physics-I
2. ESC102- Basic Electrical Engineering
3. ESC203- Basic Electronics Engineering

Program Outcomes addressed :

1. PO1: Engineering knowledge
2. PO2: Problem Analysis
3. PO3: Design/Development of Solutions
4. PO5: Engineering tool usage
5. PO6: Engineer and the world
6. PO8: Individual and teamwork
6. PO11: Life-long learning

Course Objectives:

1. To impart the knowledge of solar radiation and measurement techniques.
2. To impart fundamental knowledge of solar thermal and solar PV system.
3. To design solar thermal system and solar photovoltaic system for various applications.

Module	Details	Hrs
	Course Introduction Overview of course, application of course in Industry/real life problem. This is a foundation course which deals with fundamental knowledge of solar and energy systems, basic elements of solar system design of system. The fundamental concepts of this subject are essential for understanding the renewable energy based system.	**01**
01.	**Solar radiation and measurement**	**06-08**
	Learning Objective/s:	
	To learn the characteristics and the methods of measuring the solar insolation data later to be used in the design and optimization of solar energy systems	
	Contents:	
	Global and diffuse solar radiation on the earth surface, angle of incidence on horizontal and inclined planes - Terrestrial and extra-terrestrial radiation	

	characteristics, solar insolation. Measurement of solar radiation – Pyranometer, Pyrheliometer, Sunshine recorder, Analyzing shading and calculating insolation: Determining the impact of shadows on solar panels to optimize their placement and orientation, Uses of tools like sun path diagrams and solar pathfinders to estimate the amount of solar energy available at a specific location, environment effects on standard test conditions	
	Learning Outcomes: *A learner will be able to* *LO 1.1: Apply the fundamental knowledge of natural science to calculate the solar insolation at a particular location. (PI-1.2.1).* *LO 1.2: Apply the basic knowledge of solar insolation measurement techniques to determine the solar energy available. (PI- 1.3.1).* *LO 1.3: Analyze the impact of shading for optimal placement of solar panel.(PI- 2.1.2).*	
02.	**Solar Thermal System**	**05-07**
	Learning Objective/s: *To learn the process and components of power generation through solar thermal system.*	
	Contents: Solar collectors: Flat plate collectors, materials for flat plate collectors, efficiency of flat plate collectors, flat plate air heating collectors, solar concentrating collectors- compound parabolic collector, materials for solar concentrators, tubular solar energy collectors, solar water heaters, hybrid solar-gas power plants, central tower receiver power plant. Solar ponds for electricity generation. Efficiency and useful energy gain of a solar collector. Solar thermal system design for Residential water heating, Industrial process heat, Solar thermal power plants.	
	Learning Outcomes: *A learner will be able to* *LO 2.1: Apply fundamental basics and types of solar collectors to identify the process of conversion of solar radiation into usable thermal energy. (PI 1.2.1).* *LO 2.2: Apply the basic knowledge of solar collectors to identify how Solar thermal energy systems convert sunlight into thermal energy, later into electrical energy. (PI:1.3.1).* *LO 2.3: Identify the parameters and analyse the factors to be considered for the design of solar thermal system (PI: 2.1.2).* *LO 2.4: Design of solar thermal system for different applications. (PI 3.3.1).*	
03.	**Solar Photovoltaic System(SPV)**	**07-09**
	Learning Objective/s: *To acquire the knowledge on components and process of power generation in solar photovoltaic systems*	
	Contents:	

<table>
<tr><td rowspan="2"></td><td>Features of monofacial, bifacial panels, flexible, roof top panel. Wattage and ratings of PV module, effect of solar irradiation and temperature on power output of PV module, effect of stacking solar panel in series and parallel on I-V, P-V & maximum power point tracking characteristics of PV modules, cell efficiency, fill factor.
PV System components - PV arrays, solar trackers, power inverters, batteries, charge controllers, system metering, earthing of components.
Types of SPV systems: standalone and grid connected PV system, distributed PV System, hybrid system and small system for consumer applications.</td><td rowspan="2"></td></tr>
<tr><td>Learning Outcomes:
A learner will be able to
LO 3.1: Apply Fundamental knowledge of different types of solar panels to identify their features and how they can be used effectively in various applications. (PI 1.2.1)
LO 3.2 Apply electrical engineering concepts to identify the process of power generation in solar photovoltaic system (PI 1.3.1)
LO 3.3. Identify and select appropriate components of solar photovoltaic system based on system requirements and site condition. (PI 2.1.2)
LO3.4 Identify types of solar PV system and select the best PV system suitable for different applications. (PI 2.2.4)</td></tr>
<tr><td rowspan="5">04.</td><td>Design consideration of Solar PV System.</td><td rowspan="5">08-10</td></tr>
<tr><td>Learning Objective/s:
To learn the design considerations and power management for a standalone solar PV off grid system.</td></tr>
<tr><td>Contents:</td></tr>
<tr><td>Design of photovoltaic off-grid standalone system: calculation of energy demand array sizing and module selection, series and parallel connection of cells, mismatch in cell/module, inverter sizing and selection, String sizing for the inverter, battery sizing, Solar photovoltaic energy conversion and utilization, power control and management in hybrid PV system. Introduction to multiport converters</td></tr>
<tr><td>Learning Outcomes:
A learner will be able to
LO 4.1: Identify and analyse the components of efficient and sustainable solar voltaic system. (PI 2.3.1, PI 6.3.1, 6.3.2)
LO 4.2: Design efficient and sustainable solar standalone photovoltaic systems. (PI 3.3.1, PI 6.3.1, 6.3.2)</td></tr>
<tr><td rowspan="3">05.</td><td>Solar thermal and PV system applications</td><td rowspan="3">06-08</td></tr>
<tr><td>Learning Objective/s:
To learn the applications of solar thermal and solar photovoltaic systems</td></tr>
<tr><td>Contents:
Solar thermal: Solar energy for industrial process heat, active and passive solar heating system for building, solar refrigeration and air conditioning.
Solar PV: Standalone and grid-interacting central power stations, standalone devices for distributed power supply in remote and rural areas, power in space, solar farms, solar powered vehicles.</td></tr>
</table>

	Learning Outcomes: *A learner will be able to* *LO 5.1: Identify and analyse the applications of solar thermal system in various fields (PI-2.2.3)* *LO 5.2: Identify and analyse the applications of solar photovoltaic system in various fields (PI-2.2.3)*	
06.	**Software tools and Case study**	**05-07**
	Learning Objective/s: *To acquire the knowledge to simulate the solar energy systems for electrical design validation*	
	Contents: Overview of effective tools for solar energy systems - Sizing, simulation and analysis of photovoltaic systems, solar thermal systems. **Case studies**	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Design solar energy system and validate by simulating the design using domain specific modern tools. (PI-3.3.1, 5.2.2)* *LO 6.2: To model efficient solar PV and thermal system and analyze the performance of the systems under various conditions with a focus on sustainability. (PI-3.3.1, 11.3.1, 11.3.2)* *LO 6.3: Apply fundamental concepts of photovoltaic, including selection of energy efficient PV system for specific application and work as a team demonstrating effective communication, problem-solving, conflict resolution and leadership skills making use of case studies. (PI.-8.2.1, 8.3.1)*	
	Course Conclusion	**01**
Total		**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.2.1	Apply laws of natural science to an engineering problem
1.3.1	Apply fundamental engineering concepts to solve engineering problems
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
2.2.4	Compare and contrast alternative solution processes to select the best process.
2.3.1	Combine scientific principles and electrical engineering concepts to formulate model of a system that is appropriate in terms of applicability and required accuracy.
3.3.1	Apply formal decision making tools to select optimal engineering design solutions for further development
5.2.2	Demonstrate proficiency in using discipline specific tools
6.3.1	Describe management techniques for sustainable development
6.3.2	Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline
8.2.1	Demonstrate effective communication, problem-solving, conflict resolution and leadership skills.

8.3.1 Present results as a team, with smooth integration of contributions from all individual efforts.

11.3.1 Source and comprehend technical literature and other credible sources of information

11.3.2 Analyze sourced technical and popular information for feasibility, viability, sustainability, etc.

Course Outcomes:

1. To apply fundamental knowledge of solar insolation to identify the process of collection and measurement of solar energy.(*LO 1.1, LO 1.2*)
2. Apply the fundamental knowledge of solar collectors to identify how Solar thermal energy systems convert sunlight into thermal energy and later into electrical energy. *(LO 2.1, LO 2.2).*
3. Apply the fundamental knowledge of solar collectors to identify how Solar photovoltaic systems convert sunlight into electrical energy. (*LO 3.1, LO 3.2*).
4. Develop the ability to design and analyse efficient solar energy systems for various application and use IT tools to model and simulate the system.(*LO1.3, LO2.3, LO2.4, LO3.3, LO3.4, LO 4.1, LO 4.2, LO 6.1, LO 6.2*)
5. Identify the applications of solar thermal and solar photovoltaic system in various fields. (*LO 5.1, LO 5.2, LO 6.3*)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCRE501.1		3									
HMCRE501.2		3									
HMCRE501.3			3								
HMCRE501.4					3	2					
HMCRE501.5								3			3
Average		3	3		3	2		3			

Text Books :

1. Dincer I., and Rosen M. A. (2011); Thermal Energy Storage: Systems and Applications, Wiley.
2. Ahmed Faheem Zobaa, Energy storage – Technologies and Applications, InTech Publication 2013.
3. K.T. Chau, Energy Systems for Electric and Hybrid Vehicles, IET, UK, 2016
4. Foster .R, Ghassemi M., Cota A., "Solar Energy", CRC Press, 2010
5. Artur V.Kilian, "Solar Collectors: Energy Conservation, Design and Applications",Nova Science Publishers Incorporated, 2009

Reference Books :

1. Chetan Singh Solanki, Solar Photo Voltaics , PHI Learning Pvt Ltd., New Delhi,2009 Hashem
2. Green M.A "Solar Cells": Operating Principles, technology and System Applications, Prentice Hall Inc, Englewood Cliffs N.J, U.S.A, 1982.
3. S. Chakraborty, M. G. Simões and W. E. Kramer, Power Electronics for Renewable and Distributed Energy System, Springer 2013.
4. N. Femia, G. Petrone, G. Spagnuolo and M. Vitelli, Power Electronics and Control Techniques for Maximum Energy Harvesting in Photovoltaic Systems, CRC Press, 2013

5. Garg .H.P, Prakash .J, “Solar Energy Fundamentals and Applications”, TataMcGraw-Hill, 2005
6. Tiwari .G.N, “Solar energy: Fundamentals, Design, Modeling & Applications”,CRC Press Inc., 2002.

Other Resources :

1. NPTEL/ Swayam Course: Solar Energy EngineeringBasic Electric Circuits By Prof. Pankaj Kalita, IIT Guwahati :- Web link - https://onlinecourses.nptel.ac.in/noc20_ph14/preview
2. NPTEL Course: Renewable Energy Engineering: Solar, Wind and Biomass Energy Systems b Prof. R. Anandalakshmi, Prof. Vaibhav Vasant Goud , Guwahati:- Web link - https://onlinecourses.nptel.ac.in/noc22_ch27/preview

IN-SEMESTER ASSESSMENT (50 MARKS)

Suggested breakup of distribution

1. Continuous Assessment (20 Marks)
   - Case Study assignment: 10 Marks
   - Open book test: 05 marks
   - Regularity and Active Participation: 05 marks
2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Course Type	Course Code	Course Name	Credits
HMC	HMCRE602	WIND ENERGY SYSTEM	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)	MSE	ESE	
Continuous Assessment	Mid-Semester Exam (MSE)				
20	30	50	1.5	2	100

Pre-requisite :	
1.	ESC102-Basic Electrical Engineering
2.	EEPCC304-Renewable sources and energy storage
Program Outcomes addressed :	
1.	PO1: Engineering knowledge
2.	PO2: Problem analysis
3.	PO3: Design/Development of Solutions
4.	PO6: The engineer and the World
5.	PO11: Life-long learning
Course Objectives :	
1.	To impart knowledge on the current status of wind energy systems and the underlying physics of wind energy.
2.	To familiarize with components and design considerations of wind energy system
3.	To impart knowledge on grid integration, power quality and economic factors of wind energy system.

Module	Details	Hrs
	Course Introduction Wind energy systems harness the power of the wind to generate electricity, offering a sustainable and renewable alternative to traditional fossil fuels. These systems consist of sophisticated turbines designed to capture the kinetic energy of wind and convert it into electrical power. As the world seeks cleaner energy solutions to combat climate change, wind energy has emerged as a key player in the transition to a more sustainable future. This course explores the principles, components, design considerations, and economics of wind energy systems, highlighting their crucial role in global efforts to reduce carbon emissions and secure energy independence.	**01**
01.	**Introduction to Wind Energy System & Wind flow**	**06**
	Learning Objective/s: *To explore the current advancements in wind energy systems, identify different wind sources, and analyze their influence on wind flow dynamics.*	
	Contents Status, Advantages & disadvantages of Wind energy systems, Different types of wind energy converters-an overview; Wind-Origin and Global Availability, Different Wind Flows; Local Effects on Wind Flow- Roughness Length and Wind Shear, Wind Speed Variability, Turbulence, Obstacles to Wind Flow, The Wind Wake and Park Effect, The Tunnel Effect and Hill Effect; Selecting a Turbine Site	

	Self-Learning Topics: *History of Wind Energy, General Characteristics of the Wind Resource*	
	Learning Outcomes: *A learner will be able to* *LO1.1: Apply laws of natural science to explore different wind flows. (PI-1.2.1)* *LO1.2: Apply basic principles to explore effects on wind flow. (PI-1.4.1)* *LO1.3: Identify, assemble information about wind energy systems and sources of wind. (PI-2.2.2)* *LO1.4: Extract key insights and conclusions about wind flow dynamics from the review of wind energy systems and wind flow patterns essential for turbine site selection.(PI-2.4.4)*	
02.	**Physics of Wind Energy**	**06**
	Learning Objective: *To examine the underlying physics of wind energy.*	
	Contents: Energy Content in Wind, Energy Conversion at the Blade; Power Coefficients and Principles of Design-Coefficient of Power and Betz' Law, Tip Speed Ratio, Power Efficiency, Principles of Design; Wind Variations - Wind Shear with Height, Influence of Weibull Distribution.	
	Self-Learning Topics: Airfoils	
	Learning Outcomes: *A learner will be able to* *LO2.1: Apply laws of natural science to assess energy content in wind (PI-1.2.1)* *LO2.2: Apply fundamental engineering concepts to determine energy conversion at the turbine blade (PI-1.3.1)* *LO2.3: Identify variables, parameters and principles required for analyzing wind energy(PI-2.1.2)* *LO2.4: Identify the mathematical, engineering and other relevant knowledge that applies to understand influence of Weibull distribution (PI-2.1.3)*	
03.	**Wind Energy Converter**	**07**
	Learning Objective: *To identify and analyze the components, operation, and control of a wind energy converter.*	
	Contents: Components of Wind Energy Converter - Rotor blades, Gearbox, Generator, Tower, Miscellaneous parts; Operation and Control of Wind Energy Converters- Power Curve and Capacity Factor, Power Control of Wind Turbines (Pitch Control, Stall Control, Yaw Control), Connection to the Grid (Applications of Wind Energy Converters, Voltage Requirement, Special Aspects of the Connection of Offshore Wind Parks)	
	Learning Outcomes: *A learner will be able to* *LO3.1: Identify components of Wind Energy Converter to analyze wind energy conversion system. (PI-2.1.2)* *LO3.2: Investigate operation and control of wind energy converter for improving performance of the system. (PI-2.2.3)* *LO3.3: Synthesize engineering requirements for grid application. (PI-3.1.3)* *LO3.4: Determine design objectives, functional requirements of wind energy converter and arrive at specifications (PI-3.1.6)*	

04.	**Design Considerations**	**08**
	Learning Objective: *To analyze design considerations in order to finalize the specifications of wind turbines for installation.*	
	Contents: Rotor Area of Turbines, Number of Blades, Horizontal or Vertical Axis Turbine, Upwind or Downwind Turbine, Load Considerations for Turbine Selection, Wind Turbines: With or Without Gearbox, Requirement of Grid, Synchronous or Asynchronous Generators, Issue of Noise and its Control	
	Learning Outcomes: *A learner will be able to* *LO4.1: Apply fundamental engineering concepts to finalize wind energy system design.(PI-1.3.1)* *LO4.2: Apply mechanical, electrical engineering concepts to finalize wind turbine design. (PI-1.4.1)* *LO4.3: Explore and synthesize engineering requirements for wind turbines considering safety risks and environmental issues(PI-3.1.5)* *LO4.4: Determine functional criteria and arrive at specifications of wind energy system (PI-3.1.6)* *LO4.5: Identify risks/impacts of noise in the life-cycle of wind turbine.(PI-6.3.1)* *LO4.6: Explore the relationship between wind turbine design considerations and the technical and environmental aspects of sustainability.(PI-6.3.2)* *LO4.7: Submits a report or delivers a presentation analyzing at least one turbine design consideration including its impact on engineering and society. (PI-11.3.1)* *LO4.8: Review at least one technical paper to support the preparation of a report on turbine design with a focus on sustainability. (PI-11.3.2)*	
05.	**Grid Integration and Power Quality**	**10**
	Learning Objective: *To investigate the concepts of grid integration and power quality, and to extract the essential standard requirements for connecting wind energy system to the grid.*	
	Contents: Basics of Grid Connection-General introduction, Permissible Power Ratings for Grid Connection, Power Variation and Grid Reaction; Standard Requirements- Safety-Relevant Set Values, Reactive Power Compensation, Lightning Protection; System Operator Regulations-General introduction, Active Power and Frequency, Reactive Power and Voltage, Short-Circuit and Fault Ride-Through; Power Quality- Harmonics, Voltage Deviations and Flicker, Audio Frequency Transmission Compatibility; Noise Emission-General introduction, Sound Emission by WES.	
	Learning Outcomes:	

	A learner will be able to *LO5.1: Apply fundamental engineering concepts in formulating basic requirements for grid connection (PI-1.3.1)* *LO5.2: Apply electrical engineering concepts to identify basic wind turbine characteristics (PI-1.4.1)* *LO5.3: Extract engineering requirements from relevant engineering Codes and Standards for standard requirements of grid integration (PI-3.1.4)* *LO5.4: Explore and synthesize engineering requirements considering safety relevant set values for wind energy systems (PI-3.1.5)* *LO5.5: Identify and describe various engineering roles pertaining to grid integration and power quality. (PI-6.1.1)* *LO5.6: Interpret permissible power ratings , system operator regulations and standards applicable to grid connection of wind energy systems.(PI-6.2.1)* *LO5.7: Identify risks/impacts of sound emission by wind energy system. (PI-6.3.1)* *LO5.8: Explore the connection between the technical and environmental aspects of wind energy system sustainability in relation to grid integration and power quality.(PI-6.3.2)*	
06.	**Wind Energy System Economics**	**07**
	Learning Objective/s: *To explore methods of economic analysis and case studies for financing wind parks.*	
	Contents: Introduction, Overview of Economic Assessment of Wind Energy Systems, Capital Costs of Wind Energy Systems, Operation and Maintenance Costs, Value of Wind Energy, Economic Analysis Methods, Wind Energy Market Considerations, Wind Energy Economics- Financing of Wind Park (A Case Study for India)	
	Learning Outcomes: *A learner will be able to* *LO6.1: Identify information related to economics of wind energy systems (PI-2.2.2)* *LO6.2: Identify and compare economic analysis methods to select the best method for examining cost effectiveness of the system. (PI-2.2.4)* *LO6.3: Extract Wind energy market considerations from worldwide technical publications (PI-3.1.4)* *LO6.4: Explore and synthesize engineering requirements for financing Wind park. (PI-3.1.5)* *LO6.5: Identify risks/impacts related to wind energy system economics. (PI-6.3.1)* *LO6.6: Explore the connection between the technical and socio-economic dimensions of sustainability in relation to wind energy systems. (PI-6.3.2)*	
	Course Conclusion This course has covered the components of wind energy systems and the underlying physics of wind energy. Additionally, it has highlighted design considerations and global economic policies relevant to wind energy systems..	**01**
	Total	**45**

Performance Indicators:

P.I. No.	P.I. Statement
1.2.1	Apply laws of natural science to an engineering problem
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply electrical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
2.2.2	Identify, assemble and evaluate information and resources
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
2.2.4	Compare and contrast alternative solution processes to select the best process.
3.1.3	Synthesize engineering requirements from a review of the state-of-the-art
3.1.4	Extract engineering requirements from relevant engineering Codes and Standards such as ASME, ASTM, BIS, ISO and ASHRAE.
3.1.5	Explore and synthesize engineering requirements considering health, safety risks,environmental, cultural and societal issues.
3.1.6	Determine design objectives, functional requirements and arrive at specifications.
6.1.1	Identify and describe various engineering roles; particularly as pertains to protection of the public and public interest at the global, regional and local level.
6.2.1	Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.
6.3.1	Identify risks/impacts in the life-cycle of an engineering product or activity.
6.3.2	Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability.
11.3.1	Source and comprehend technical literature and other credible sources of information
11.3.2	Analyze sourced technical and popular information for feasibility, viability, sustainability, etc

Course Outcomes:
Learner will be able to

1.	Analyze wind flow, assess energy potential, and evaluate turbine performance using scientific principles for effective turbine site selection. *(LO1.1, LO1.2, LO1.3, LO1.4, LO2.1, LO2.2, LO2.4)*
2.	Identify components of wind energy converters, analyze performance, explore control methods, define grid application requirements and determine design specifications. *(LO3.1, LO3.2, LO3.3, LO3.4)*
3.	Apply engineering concepts to design wind energy systems and turbines, considering safety, environmental factors, noise risks, and sustainability. *(LO4.1, LO4.2, LO4.3, LO4.4, LO4.5, LO4.6)*
4.	Extract grid integration requirements, explore safety values, interpret power ratings, identify sound risks, and examine the connection between sustainability, grid integration, and power quality. *(LO5.3, LO5.4, LO5.5, LO5.6, LO5.7, LO5.8)*

5.	Analyze the economics of wind energy systems, compare cost methods, explore market, financing, risk factors, and examine the link between technical and socio-economic sustainability in wind energy. *(LO6.1, LO6.2, LO6.3, LO6.4, LO6.5, LO6.6)*

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCRE602.1	3	3									
HMCRE602.2		3	3								
HMCRE602.3	3		3			3					3
HMCRE602.4	3		3			3					
HMCRE602.5		3	3			3					
Average	3	3	3			3					3

Text Books :	
1.	Hermann-Josef Wagner, Jyotirmay Mathur, "Introduction to Wind energy systems-Basics, Technology & Operation", Springer International Publishing AG 2018
2.	Manfred Steibler, "Wind Energy Systems for Electric Power Generation", Springer-Verlag Berlin Heidelberg 2008
3.	J.F. Manwell, J.G. McGowan, A. L. Rogers, "Wind Energy Explained-theory design and applications", John Wiley & Sons Ltd., 2009
Reference Books :	
1.	Tony Burton et al, "Wind Energy Handbook", John Wiley & Sons Ltd., New York, USA.
2.	Ahmad Hemami, "Wind Turbine Technology", Cengage Learning, Clifton Park, New York, USA.
3.	Thomas Ackermann, "Wind Power in Power Systems", John Wiley & Sons, Ltd
4.	Sathyajith Mathew, "Wind Energy Fundamentals, Resource Analysis and Economics", Springer.
5.	Siegfried Heier, "Grid integration of wind energy conversion systems", John Wiley and Sons Ltd., 2006.
Other Resources :	
1.	NPTEL Course: Renewable Energy Engineering by Prof. Vaibhav Vasant Goud, Prof. R. Anandalakshmi, IIT Guwahati :-Web link- https://nptel.ac.in/courses/103103206
2.	NPTEL Course: Non-Conventional Energy Systems by Prof. L. Umanand, IISc-Bangalore :-Web link- https://nptel.ac.in/courses/108108078

IN-SEMESTER ASSESSMENT (50 MARKS)

Suggested breakup of distribution

1. Continuous Assessment (20 Marks)
   - Case Study assignment: 10 Marks
   - Open book test: 05 marks
   - Regularity and Active Participation: 05 marks
2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.
END SEMESTER EXAMINATION (50 MARKS)
End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.

Syllabi
Third Year
Power Electronics and Drives

Course Type	Course Code	Course Name	Credits
EEHEPD501	EEHEEV501	SPECIAL ELECTRICAL MACHINES AND DRIVES	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Exam (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. ESC102 - Basic Electrical Engineering

Program Outcomes addressed :

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO6: The Engineer and The World
4. PO9: Communication

Course Objectives:

1. Comprehend the constructional details of special electrical machines.
2. Study the performance characteristics of special electrical machines.
3. State applications of different special electrical machines.
4. Selection and sizing BLDC motors/PMSM motors for EV applications.

Module	Details	Hrs
	Course Introduction This course provides an in-depth understanding of special electrical machines, focusing on their unique constructions, operating principles, and applications. It covers various types of special electrical machines, including Switched Reluctance Motors (SRM), Stepper Motors, and Synchronous Reluctance Motors (SyRM), among others. The course aims to equip students with the knowledge required to analyze, control, and apply these machines effectively in various industrial contexts.	**01**
01.	**Brushless Permanent Magnet DC Motors (BLDC Motors)**	**09-10**
	Learning Objective: *Apply fundamental concepts of BLDC motors and identify its applications for specific engineering problems.*	

<table>
<tr><td></td><td>Content:
Classification of BLDC motors, Construction, Working principle, Electronic commutation, types, Control of BLDC motors, Microprocessor based control of BLDC motor, DSP based control of BLDC motor, Sensor less control of BLDC motor, Comparison of DC motor and BLDC motor, selection and sizing of BLDC motor for EV applications.</td><td></td></tr>
<tr><td></td><td>Learning Outcomes:
A learner will be able to
LO1.1: Apply fundamental concepts of DC and AC motor to understand construction of BLDC motors. (P.I.1.3.1)
LO 1.2: Apply fundamental concepts of microcontroller in control techniques of BLDC motors. (P.I. 1.4.1)
LO1.3: Identify suitable rating of BLDC motor in EV applications. (P.I.2.1.2)
LO1.4: Identify existing BLDC motors used in different applications and their ratings. (P.I.2.2.3)
LO 1.5: Demonstrate legislation, regulations, codes, and safety standards followed by the industry to manufacture BLDC motors. (P.I. 6.1.1) (P.I.6.2.1)
LO 1.6: Comprehend and integrate practical insights from BLDC motor observations in the manufacturing industry and produce a clear, well-structured, and well-supported report. (P.I.9.1.2) (P.I.9.2.1)</td><td></td></tr>
<tr><td>02.</td><td>Permanent Magnet Synchronous Motor (PMSM)</td><td>09-10</td></tr>
<tr><td></td><td>Learning Objective:
Analyze performance of PMSM motors and identify its applications for specific engineering problems.</td><td></td></tr>
<tr><td></td><td>Content:
Construction, principle of operation, EMF equation, torque equation, Phasor diagram, circle diagram, comparison of conventional and PM synchronous motor, Control of PMSM motors: Vector control of PMSM, self-control, sensor less control of PMSM, DSP based control of PMSM, Selection and sizing for EV applications.</td><td></td></tr>
<tr><td></td><td>Learning Outcomes:
A learner will be able to
LO 2.1: Apply basic mathematical techniques to drive EMF and torque equation of PMSM motors. (P.I.1.1.1)
LO 2.2: Apply fundamental concepts phasors to draw phasor diagram of PMSM motors. (P.I. 1.4.1)
LO 2.3: Identify different parameters and determine their ratings in EV applications. (P.I.2.1.2)
LO 2.4: Compare control techniques of PMSM motors and select best technique for specific application. (P.I. 2.2.4)</td><td></td></tr>
<tr><td>03</td><td>Switched Reluctance Motors (SRM)</td><td>07-08</td></tr>
<tr><td></td><td>Learning Objective:
Use characteristics of Switched reluctance motors to select in different industrial applications.</td><td></td></tr>
<tr><td></td><td>Content:</td><td></td></tr>
</table>

	Construction, principle of working, Basics of SRM analysis, Torque equation and characteristics, Power converter circuits, control of SRM, Rotor position sensors, Microprocessor based control of SRM, DSP based control of SRM, Applications.	
	Learning Outcomes: *Learner will be able to* *LO 3.1: Apply basic mathematical techniques to drive EMF and torque equation of SRM motors. (P.I.1.1.1)* *LO3.2: Apply fundamental concepts phasors to draw phasor diagram of SRM motors. (P.I. 1.4.1)* *LO3.3: Identify objective of Rotor position sensors and analyze different schemes (P.I.2.1.1)* *LO 3.4: Compare different power converter circuits and select suitable one for engineering applications. (P.I. 2.2.4)*	
04.	**Stepper Motors**	**06-07**
	Learning Objective: *Compare different types of Stepper motors and select suitable one for industrial applications.*	
	Content: Variable reluctance stepper motor, Permanent magnet stepper motor, Hybrid stepper motors, Windings in stepper motors, torque equation, characteristics of stepper motor, open loop and closed loop control, microprocessor based control of stepper control, comparison of different types of stepper motor, applications.	
	Learning Outcomes: *LO 4.1: Apply basic mathematical techniques to drive torque equation of Stepper motors. (P.I.1.1.1)* *LO 4.2: Apply fundamental concepts electrical engineering to analyze characteristics of stepper motors. (P.I. 1.4.1)* *LO 4.3: Compare different types of Stepper motors and their characteristics to select suitable motor for given application. (P.I. 2.2.4)* *LO 4.4: Extract desired understanding and conclusions consistent with objectives and limitations of open loop and closed loop control of Stepper motors. (P.I.2.4.4)*	
05.	**Synchronous Reluctance Motors (SyRM)**	**04-05**
	Learning Objective: *Analyze performance of SyRM and select in suitable engineering applications.*	
	Content: Construction, working principle, phasor diagram, torque equation, Introduction to control of SyRM, advantages of SyRM, applications	

	Learning Outcomes: *Learner will be able to* *LO 5.1: Apply basic mathematical techniques to drive torque equation of SyRM.. (P.I.1.1.1)* *LO 5.2: Apply fundamental concepts of phasors and draw phasor diagram of SyRM. (P.I. 1.4.1)* *LO 5.3: Identify engineering systems in which SyRM motors are used and find their ratings. (P.I. 2.1.2)* *LO 5.4: Extract desired understanding and conclusions consistent with objective of control technique used in SyRM. (P.I.2.4.4)*	
06.	**Linear Induction Motors**	**04-05**
	Learning Objective/s: *Analyze basic working principle of Linear Induction motors and identify its applications.*	
	Content: Construction, Thrust equation of Linear Induction motors, Goodness factor, equivalent circuit of LIM, characteristics of LIM, design aspects, applications.	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Apply basic mathematical techniques to drive thrust equation and Goodness factor of Linear Induction motors. (P.I.1.1.1)* *LO 6.2: Apply fundamental knowledge of Linear Induction motors to draw its equivalent circuit. (P.I. 1.4.1)* *LO 6.3: Select Linear Induction Motor and apply design concepts to get different parameters. (P.I. 2.1.1)* *LO 6.4: Identify engineering systems in which LIM motors are used and find their ratings. (P.I. 2.1.2)*	
	Course Conclusion: This course will provide students with comprehensive knowledge of special electrical machines, preparing them for advanced studies or careers in electrical engineering and related fields. By understanding the unique characteristics and applications of these machines, students will be well-equipped to contribute to technological advancements and industrial applications.	**01**
Total		**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.1.1	Apply mathematical techniques such as calculus, linear algebra, and statistics to solve problems
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply electrical engineering concepts to solve engineering problems.
2.1.1	Articulate problem statements and identify objectives.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.

2.2.3 Identify, assemble and evaluate information and resources.

2.2.4 Compare and contrast alternative solution processes to select the best process.

2.4.4 Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
6.1.1 Identify and describe various engineering roles; particularly as pertains to protection of the public and public interest at the global, regional and local level.
6.2.1 Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public.
9.1.2 Produce clear, well-constructed, and well-supported written engineering Document.

9.2.1 Listen to and comprehend information, instructions, and viewpoints of others

Course Outcomes: Learner will be able to

1. Identify the suitability of BLDC motors for various industrial applications and produce a technical report based on observations and technical insights gained during an industrial visit. (LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO1.5, LO 1.6)
2. Analyze performance of Permanent Magnet Synchronous Motors and determine its size for automotive applications. (LO 2.1, LO 2.2, LO 2.3, LO 2.4)
3. Identify industrial and automotive applications suitable for Switched Reluctance Motor technology. (LO 3.1, LO 3.2, LO 3.3, LO 3.4)
4. Compare different types of Stepper motors and their characteristics to select suitable one in industrial applications. (LO 4.1, LO 4.2, LO 4.3, LO 4.4)
5. Analyze performance of Synchronous Reluctance Motors and state the applications. (LO 5.1, LO 5.2, LO 5.3, LO 5.4)
6. Identify the benefits of LIM technology in high-speed transportation systems, material handling, and other specialized fields. (LO 6.1, LO 6.2, LO 6.3, LO 6.4)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
EEPC509.1	3	3				3			3		
EEPC509.2	3	3									
EEPC509.3	3	3									
EEPC509.4	3	3									
EEPC509.5	3	3									
EEPC509.6	3	3									
Average	3	3				3			3		

Text Books :

1. Special Electrical Machine, E. G. Janardanan, PHI publication
2. Special Electric Machines, K. Venkataratnam-, Universities Press, Apr-2009
3. Electric Machines, Ashfaq Husain, Dhanpat Rai and co. publications

Reference Books :

1. Permanent Magnet Synchronous and Brushless DC Motor Drives, R.Krishnan, CRC Press.

2. Switched Reluctance Motor Drives Modeling, Simulation, Analysis, Design, and Applications By R. Krishnan, CRC Press.
3. Stepper Motors : Fundamentals, Applications and Design, V.V. Athani, New Age International Publishers.

Other Resources :

1. NPTEL Course: Fundamentals of Electrical Drives by Prof.S. P. Das IIT Kanpur
   Web link: https://archive.nptel.ac.in/courses/108/104/108104140/#
2. NPTEL Course: Electrical Machines By Prof. G. Bhuvaneshwari, Dept. of Electrical Engineering ,IIT-Delhi. Weblink:- https://nptel.ac.in/courses/108/102/10810214

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Two Class test: 05 marks each
Seminar: 05 Marks
Regularity and active participation: 05 Marks

2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination(MSE) carrying 20% weightage, and the syllabus covered from MSE to ESE carrying 80% weightage

Course Type	Course Code	Course Name	Credits
HMC	HMCPD602	INDUSTRIAL DRIVES	03

Examination Scheme					
Distribution of Marks			Exam Duration (Hrs.)		Total Marks
In-semester Assessment		End Semester Examination (ESE)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. HMCPD501: Special Electric Machines and Drives

Program Outcomes addressed :

1. PO1: Engineering knowledge.
2. PO2: Problem analysis.
3. PO3: Design/Development of solutions
4. PO6: The Engineer and the World
5. PO8: Individual and Collaborative Team Work
6. PO11: Lifelong learning

Course Objectives :

1. Understand the basic principles and concepts of electrical drives.
2. Explore the application of power electronics in drives.
3. Impart knowledge on thermal model of motor and selection of motor rating for different load profiles.
4. Comprehend the performance and control of various types of industrial drives.
5. Learn energy-efficient and dynamic control strategies for industrial applications.

Module	Details	Hrs.
	Course Introduction Industrial drives are systems used to control the speed, torque, and direction of electric motors in industrial applications. They play a crucial role in ensuring efficient operation, precise control, and energy optimization in various processes. An industrial drive consists of three primary components: an electric motor, a power converter, and a control system. These systems are essential for achieving productivity and sustainability in industrial environments.	**01**
01.	**Introduction** ***Learning Objective:*** *To comprehend basic concepts of electrical drives in particular application.*	**4-6**
	Contents: Basics of electric drives and components: Motor, Power Converter, Controller, Load. Types of loads and their characteristics. Selection criteria for drives based	

	on torque-speed requirements. Dynamics of electrical drives: Steady-state and transient performance. *Self-Learning Topics:* ***Advantages and applications of Electrical Drives*** ***Learning Outcomes:*** *A learner will be able to* *LO 1.1: Apply fundamental concepts of electrical drives in industrial applications to solve engineering problems. (PI-1.3.1)* *LO 1.2: Apply Electrical Engineering concepts such as electric drive system, including motors, power converters, controllers, and loads to a given problem. (PI-1.4.1)* *LO 1.3: Identify type of drive suitable for Engineering application. (PI-2.1.2)* *LO 1.4: Identify the torque-speed requirements for different electrical drive applications. (PI-2.1.3)*	
02.	**Power Electronics in Drives** ***Learning Objective:*** *To impart knowledge on role of Power Electronics in Industrial Drives.* **Contents:** Role of power electronic converters in drives. DC-DC converters, rectifiers, and inverters. PWM techniques for motor control, protection of power converters. ***Self-Learning Topics:*** *Applications of power electronic converters in Industrial drive systems.* ***Learning Outcomes:*** *A learner will be able to* *LO 2.1: Apply fundamental concepts of Power Electronic converters in Industrial drive applications to solve Engineering problems. (PI-1.3.1)* *LO 2.2: Apply Electrical Engineering concepts to analyze operation of different power electronic converters for given engineering problem. (PI-1.4.1)* *LO 2.3: Identify suitable Power Electronic Converter for specific application. (PI-2.1.2)* *LO 2.4: Identify and select the best PWM technique or protection circuit for power electronic devices and systems for given engineering problem. (PI-2.2.4)*	**06-08**
03.	**Selection of Motor Power Rating** ***Learning Objective:*** *To gain understanding on choosing the appropriate motor power rating for applications with different duty cycles.* **Contents:** Thermal model of motor for heating and cooling, Classes of motor duty, Determination of Motor Rating: Continuous duty; Equivalent current, Torque and Power Methods for Fluctuating and Intermittent Loads; Short Time Duty; Intermittent Duty. ***Self-Learning Topics:*** ***Criteria for motor rating selection.*** ***Learning Outcomes:*** *A learner will be able to* *LO 3.1: Derive the thermal model equations and heating and cooling curves of motor (PI 2.3.1)* *LO 3.2: List out the classes of motor duty available in the manufacturer's website, relate with sample applications. (PI 2.1.3, 11.3.1, 11.3.2)*	**05-07**

	LO 3.3: Select the motor power rating of a motor for applications intended for various duty cycles considering the overload factor and constraints like maximum allowable current and breakdown torque. (PI 2.2.3) *LO 3.4: Determine key design objectives and functional requirements for motor applications. (PI-3.1.6)* *LO 3.5: Identify suitable evaluation criteria for comparing different motor designs.(PI-3.2.3)*	
04.	**DC/AC Drives** ***Learning Objectives:*** *To impart knowledge on basic concepts of DC/AC motor drives and their applications in Industry.*	**09-11**
	Contents: **DC Motor Drives:** Characteristics of DC motors, Speed Control methods, Closed-loop control of DC drives, applications of DC drives in industry, regenerative braking and energy recovery systems in DC motor drives. **Induction motor drives:** Speed-torque characteristics, speed control methods, Scalar and vector control methods, Applications of AC drives in industrial systems, regenerative braking and energy recovery systems in AC motor drives.	
	Self-Learning Topics: ***Regenerative braking and energy recovery systems.***	
	Learning Outcomes: *A learner will be able to* *LO 4.1: Apply fundamental concepts of DC/AC motor and drives to solve engineering problems. (PI-1.3.1).* *LO 4.2: Apply Electrical Engineering concepts to analyze operation of different drive systems for given engineering problem. (PI-1.4.1)* *LO 4.3: To identify control method for DC/AC drive application. (PI-2.2.3)* *LO 4.4: Identify and select the best control technique in DC/AC drives for given engineering problem. (PI-2.2.4)*	
05.	**Special Purpose Drives** ***Learning Objective/s:*** *To impart knowledge on basic concepts of special motor drives and their applications in Industry.*	**07-09**
	Contents: Stepper motor, Servo motor, BLDC motor, Linear motor, Synchronous motor: Drive schemes and their working. Introduction to electric and hybrid electric vehicle drives.	
	Self-Learning Topics: ***Electric and Hybrid Electric Vehicles.***	
	Learning Outcomes :	
	A learner will be able to *LO 5.1: Apply fundamental concepts of special purpose drives to solve engineering problems. (PI-1.3.1)* *LO 5.2: Apply Electrical Engineering concepts to analyze operation of different special purpose drive systems for given engineering problem. (PI-1.4.1)* *LO 5.3: Identify suitable special purpose motor drive for particular application. (PI-2.1.2)* *LO 5.4: Identify and select suitable special purpose drives for given engineering problem. (PI-2.2.4)*	

06.	**Energy Efficiency and Drive Applications** *Learning Objective/s:* ***To impart knowledge on energy efficient practices in Industrial drive applications.***	**06-08**
	Contents: **Energy-efficie**nt drive systems and techniques. **Case studies of industrial applications: Conveyor** systems, rolling mills, electric traction, electric vehicles, **robotics. Drive selection for energy-saving applications.**	
	Self-Learning Topics: ***Case Studies on Industrial Applications.***	
	Learning Outcomes: *A learner will be able to* *LO 6.1: Apply fundamental concepts of energy efficient drive systems and techniques to solve engineering problems. (PI-1.3.1)* *LO 6.2: Apply Electrical Engineering concepts to analyze energy efficient technologies in drives for given engineering problem. (PI-1.4.1)* *LO 6.3: Identify energy efficient solution for a specific Industrial Drive application. (PI-2.1.2)* *LO 6.4: Identify and select the suitable energy efficient technique in electrical drives for given engineering problem. (PI-2.2.4)* *LO 6.5: Describe energy efficient techniques and their management in Industrial Drive applications. (PI-6.3.3)* *LO 6.6: Apply principles of preventive engineering and sustainable development to an electrical engineering product/system design. (PI. -6.3.4)* *LO 6.7: Apply fundamental concepts of electrical drives, including motor, power converter, controller, and load to select energy-efficient electrical drive system for industrial application and work as a team demonstrating effective communication, problem-solving, conflict resolution and leadership skills making use of case studies. (PI.-8.2.1, 8.3.1)*	
	Course Conclusion The course on Industrial Drives provides a comprehensive understanding of the principles, components, and control strategies of electric drive systems used in industrial applications. Students gain theoretical knowledge in selecting drive systems, focusing on energy efficiency, reliability, and performance optimization.	**01**
	Total	**45**

Performance Indicators:

P.I. No.	**P.I. Statement**
1.3.1	Apply fundamental engineering concepts to solve engineering problems.
1.4.1	Apply Electrical engineering concepts to solve engineering problems.
2.1.2	Identify engineering systems, variables, and parameters to solve the problems.
2.1.3	Identify the mathematical, engineering and other relevant knowledge that applies to a given problem.
2.2.3	Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions.
2.2.4	Compare and contrast alternative solution processes to select the best process.
3.1.6	Determine design objectives, functional requirements and arrive at specifications.
3.2.3	Identify suitable criteria for the evaluation of alternate design solutions.

6.3.3 Describe management techniques for sustainable development.
6.3.4 Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline.
8.2.1 Demonstrate effective communication, problem-solving, conflict resolution and leadership skills.
8.3.1 Present results as a team, with smooth integration of contributions from all individual efforts.

Course Outcomes: A learner will be able to -

1. Apply fundamental concepts of electrical drives, including motor, power converter, controller, and load, to solve engineering problems in industrial applications. *(LO 1.1, LO 1.2, LO 2.1, LO 2.2, LO 3.1, LO 3.2, LO 4.1, LO 4.2, LO 5.1, LO 5.2, LO 6.1, LO 6.2)*
2. Identify and apply power electronic converters such as DC-DC converters, rectifiers, and inverters in motor control systems to address industrial applications. *(LO 2.3, LO 2.4)*
3. Calculate the appropriate motor power ratings considering thermal models, duty cycles, and constraints like overload factors, allowable current, and torque for industrial applications. *(LO 3.1, LO 3.2, LO 3.3, LO 3.4, LO 3.5)*
4. Utilize the characteristics, control methods, and regenerative braking principles of DC, AC, and special motor drives to solve engineering problems in industrial systems. *(LO 4.3, LO 4.4, LO 5.3, LO 5.4)*
5. Apply principles of preventive engineering and sustainable development in the selection of energy-efficient and eco-friendly electrical drive systems using case studies and working in a team. *(LO 6.3, LO 6.4, LO 6.5, LO 6.6, LO 6.7)*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
EEHEPD602.1	3	3									3
EEHEPD602.2		3									
EEHEPD602.3		3	3								3
EEHEPD602.4		3									
EEHEPD602.5		3				3		3			
Average	3	3	3			3		3			3

Text Books :

1. "Electric Drives: Concepts and Applications" by Vedam Subrahmanyam.
2. "Power Electronics: Circuits, Devices, and Applications" by Muhammad H. Rashid.
3. "Fundamentals of Electric Drives" by G.K. Dubey.

Reference Books :

1. "Modern Power Electronics and AC Drives" by Bimal K. Bose.
2. "Control of Electrical Drives" by Werner Leonhard.
3. "Electrical Machines, Drives, and Power Systems" by Theodore Wildi.

Other Resources :

NPTEL Course on "Industrial Drives": https://nptel.ac.in/courses/108108077

IN-SEMESTER ASSESSMENT (50 MARKS)

Suggested breakup of distribution

1. Continuous Assessment (20 Marks)
   - Case Study assignment: 10 Marks
   - Flip Classroom: 05 marks
   - Regularity and Active Participation: 05 marks
2. Mid Semester Exam (30 Marks)

Mid semester examination will be based on 40% to 50% syllabus.

END SEMESTER EXAMINATION (50 MARKS)

End Semester Examination will be based on syllabus coverage up to the Mid Semester Examination (MSE) carrying 20%-30% weightage, and the syllabus covered from MSE to ESE carrying 70%-80% weightage.