

Agnel Charities

Fr. C. Rodrigues Institute of Technology

Sector 9A, Vashi, Navi Mumbai, 400703, Maharashtra, India

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An Autonomous Institute Affiliated to the University of Mumbai



Department of Electrical Engineering

Curriculum Structure for

Honours/Minor

Degree Programs in B. Tech.

&

Honours/Minor Syllabi

Prepared by: Board of Studies for Electrical Engineering

Approved by: Academic Council of Fr. C. Rodrigues Institute of Technology

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PREAMBLE-DEAN ACADEMICS

Accelerating Towards Excellence: Unveiling a New Era in Education

Dear Students, Faculty, and Stakeholders,

It is with great pleasure and anticipation that we introduce the newly designed curriculum for autonomy at Agnel Charities' Fr. C. Rodrigues Institute of Technology. This pioneering initiative aims to revolutionize engineering education, ensuring our graduates are equipped with not only technical prowess but also the holistic skills necessary for thriving in today's dynamic professional landscape.

1. **Purpose of Autonomy:** Our commitment to autonomy is rooted in the imperative to bridge the gap between academia and industry. We envision education as a catalyst for individual growth, fostering self-sustainability and enhancing employability. Through our curriculum, we strive to nurture engineers who not only excel in their fields but also contribute meaningfully to society.
2. **Curriculum Design: A Top-to-Down Approach:** Our curriculum is meticulously crafted with a top-to-down approach, encompassing all 12 attributes of Program Outcomes mandated by regulatory bodies. Emphasizing a blend of theoretical knowledge and practical application, it is designed to cultivate well-rounded professionals capable of tackling real-world challenges with confidence and competence.
3. **Alignment with National Education Policy-2020:** In adherence to the guidelines laid out in the National Education Policy-2020, our curriculum embodies a multidisciplinary approach, offering a diverse array of core and elective courses. It integrates hands-on learning experiences such as mini and major projects, skill-based labs, and one-semester internships to nurture innovation and problem-solving skills. Additionally, the inclusion of value-added courses, honours, and minors ensures a comprehensive educational journey tailored to individual interests and aspirations.
4. **Opportunities for Teachers in Innovation:** We recognize the pivotal role of our faculty in shaping the educational experience. Our curriculum provides ample opportunities for teachers to innovate in teaching-learning methodologies and evaluation techniques. Through continuous professional development programs and collaborative platforms, we empower our educators to experiment with innovative pedagogies, leverage technology for enhanced learning outcomes, and implement novel assessment strategies. By fostering a culture of innovation among our faculty, we aim to enrich the learning experience and inspire a passion for lifelong learning among our students.

As we embark on this transformative journey, we invite all stakeholders to join us in shaping the future of engineering education. Together, let us strive towards excellence, innovation, and societal impact.

Sincerely,

Dean of Academics Agnel Charities Fr. C. Rodrigues Institute of Technology, Vashi

PREAMBLE- BOS CHAIRPERSON

Established in 1994, the Electrical Engineering department, provides comprehensive programs spanning undergraduate, postgraduate, and Ph. D levels. Comprising a team of highly qualified and experienced faculty, the department distinguishes itself through its cutting-edge facilities such as the Renewable Laboratory, Protection Laboratory, Power Electronics, Drives and Control System Laboratory. Additionally, the program has received accreditation thrice in 2005, 2012, and 2018, maintaining its validity to date. Furthermore, the institute is scheduled to transition to autonomy from the academic year 2024-25.

The scheme and syllabus of the Department of Electrical Engineering under autonomy are centred entirely on fostering the development of learners and cultivating the essential attributes that graduates should possess. When crafting the curriculum, two primary considerations are taken into account: the essential domain knowledge, skill sets, and tools required for the diverse career paths available to contemporary Electrical engineers and the 12 attributes of Program Outcomes mandated by regulatory bodies. The NBA-SAR January 2016 serves as a benchmark for shaping the learning outcomes within each module of the syllabus. Electrical engineering curriculum is structured to cover a range of core areas and specialized topics, ensuring that graduates are well-equipped to tackle the challenges of the modern world.

National Educational Policy-2020 guidelines are considered as reference while designing the curriculum. It incorporates practical learning opportunities like mini projects and major projects, skills-based labs, and internships to foster creativity and problem-solving abilities. Furthermore, offering value-added courses, honours programs, and minors ensures a well-rounded educational experience that caters to students' unique interests and goals.

The curriculum offers abundant chances for educators to pioneer teaching methods and assessment approaches, with the goal of enriching students' learning experiences and cultivating a lifelong passion for learning.

With a strong foundation in electrical engineering principles and specialized knowledge in key areas, graduates of our program are well-prepared to make significant contributions to the field and drive innovation in technology.

As we embark on this transformative journey, we invite all stakeholders to join us in shaping the future of Electrical Engineering education.

**BOS Chairperson,
Department of Electrical Engineering.**

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Honours, Minor, and Honours in Research Degree Program

The Honours, Minor, and Honours in Research degree programs aim to empower students by offering specialized courses/research internships or projects in emerging fields of their interest, thus enhancing their proficiency in those areas. Students who achieve a CGPI of 7.5 or higher by the end of the fourth semester are eligible to pursue an additional 18 credits from the fifth to eighth semesters to qualify for a B. Tech degree with Honours, Minor, or Honours in Research designation.

Students need to refer to the Institute level Handbook for Honours/Minor/Honours in Research Degree Programs for further details.

Syllabi

Honours/Minor:

Electric Vehicle-Track

Curriculum Structure – Honours/Minor: Electric Vehicle-Track

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		L	P	T	L	P	T	Total
HMCEV501	Electric and Hybrid Electric vehicle	3	--	--	3	--	-	3
HMCEV602	Energy Storage System in EV Application	3	--	--	3	--	--	3
HMCEV703	Drives In Electric Vehicle	4	--	--	4	--	--	4
HMLEV701	Electric Vehicle Laboratory	--	4	--	--	2	--	2
HMCEV804	Electric Vehicle System Design	4	--	--	4	--	--	4
HMPEV801	Mini Project	--	6	--	--	2	--	2
Total		14	10	--	14	4	--	18

Examination Scheme – Honours/Minor

Course Code	Course Name	Examination Scheme					Total
		In-Semester Assessment		End Sem Exam (ESE)	Exam Duration for Theory (in Hrs)		
		Continuous Assessment	Mid-Sem Exam		Mid-Sem	End-Sem	
HMCEV501	Electric and Hybrid Electric vehicle	20	30	50	1.5	2	100
HMCEV602	Energy Storage System in EV Application	20	30	50	1.5	2	100
HMCEV703	Drives In Electric Vehicle	20	30	50	1.5	2	100
HMLEV701	Electric Vehicle Laboratory	50	--	--	--	--	50
HMCEV804	Electric Vehicle System Design	20	30	50	1.5	2	100
HMPEV801	Mini Project	50	--	50	--	--	100
Total		180	120	250	--	--	550

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. PO7: Environment and sustainability
5. 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: <i>Learning Objectives:</i> 1. To gain the knowledge of both historical development and state of the art of automotive domain.	6

	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 <i>Learning Outcome:</i> <i>The learner would be able to:</i> 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 & P.I.-7.1.2) 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 & P.I.-7.1.2)	
2	Drive-train Topologies: <i>Learning Objectives:</i> <i>To gain knowledge about different types of EV/ HEV drive-train topologies and the basics of the power flow control in such drivetrains</i> 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. <i>Learning Outcome:</i> <i>The learner would be able to</i> 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)	8
3	Electric Motors for Propulsion Applications <i>Learning Objectives:</i> <i>To gain knowledge about various electric motors and their performance in EV/ HEV applications</i> 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.	8

	<i>Learning Outcome:</i> <i>The learner would be able to</i> <i>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)</i> <i>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)</i>	
4	Energy Sources for EV/HEV:	8
	<i>Learning Objectives:</i> <i>To gain knowledge about various energy sources used in EV/ HEV, their characteristics, performance and suitability.</i>	
	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.	
	<i>Learning Outcome:</i> <i>The learner would be able to</i> <i>LO4.1: Recognize the requirements of energy sources for EV/HEV applications (P.I.-3.1.3, P.I.-6.1.1)</i> <i>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)</i> <i>LO4.3: State the need and impact of hybridization of different energy sources. (P.I.-6.1.1)</i>	
5	EV Battery Chargers and EV/ HEV Ecosystem	8
	<i>Learning Objectives:</i> <i>To know the basics and state of the art technologies in EV battery charging and its impact on exiting electric grid</i>	
	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.	
	<i>Learning Outcome:</i> <i>The learner would be able to</i> <i>LO5.1: Identify and describe the basics of different types of EV battery chargers. (P.I.-2.2.4, & P.I.-11.3.2)</i> <i>LO5.2: the norms and specifications of various EV charging infrastructure regulatory standards. (P.I.-6.1.1)</i> <i>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)</i>	
6	Energy Management Strategies in EV/HEVs	5
	<i>Learning Objectives:</i> <i>Use the fundamentals knowledge of EV/ HEV energy sources and power flow to examine the energy management strategies to optimize the performance.</i>	
	Contents: EV/HEV energy management strategies, classification and comparison of various energy management strategies.	

	<i>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)</i>	
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		2.5	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. ESC102 : Basic Electrical Engineering
2. HMCEV501: Electrical and Hybrid Electric Vehicle

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 teamwork

Course Objectives :

1. To understand the energy storage requirements for EVs across different energy storage technologies.
2. To learn key design requirements for battery pack formation in EV applications, with a focus on thermal management and safety.
3. To develop the essential understanding and conclusions related to the designs and architectures of Hybrid Energy Storage Systems (HESS).
4. To extract safety and thermal management requirements for BMS from relevant codes and standards, focusing on performance.
5. To identify charging infrastructures and explore techniques for managing EV energy systems sustainably.
6. To identify 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 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	01

	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: <i>To identify energy storage systems used in electric vehicles.</i>	
	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.	
	Learning Outcomes : <i>A learner will be able to</i> <i>LO1.1: Apply fundamental engineering concepts to explore Electric Vehicle (EV) Components and Powertrain. (PI-1.3.1)</i> <i>LO1.2: Apply engineering concepts to comprehend the role of Energy Storage Systems in EVs. (PI-1.4.1)</i> <i>LO1.3: Identify and evaluate energy storage requirements for EVs.(PI-2.2.2)</i> <i>LO1.4: Identify energy storage technologies and market dynamics for EV applications. (PI-2.2.3)</i>	
02.	Battery Technologies	09
	Learning Objective/s: <i>To explore EV batteries, focusing on their operation, features, types, design, methods to manage degradation and performance criteria.</i>	
	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/ kWh ratings of battery for EV applications: Major design considerations	
	Self-Learning Topics: <i>Electrochemical principles</i>	
	Learning Outcomes : <i>A learner will be able to</i> <i>LO2.1: Apply fundamental engineering concepts to explore Battery technologies. (PI-1.3.1)</i> <i>LO2.2: Apply electrical engineering concepts to comprehend battery chemistries for EVs. (PI-1.4.1)</i> <i>LO2.3: Identify battery parameters for EV applications (PI-2.1.2)</i> <i>LO2.4: Identify the mathematical, engineering and other relevant knowledge that applies for battery pack formation and cell balancing (PI-2.1.3)</i>	

	<i>LO2.5: Explore and synthesize engineering requirements considering thermal management and safety in battery pack design. (PI-3.1.5)</i> <i>LO2.6: Determine major design objectives, functional requirements and arrive at specifications of battery for EV applications.(PI-3.1.6)</i> <i>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)</i> <i>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)</i>	
03.	Hybrid Energy Storage System in EV	06
	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	
	Learning Outcomes : <i>A learner will be able to</i> <i>LO3.1: Apply fundamental engineering concepts to explore Hybrid Energy Storage System. (PI-1.3.1)</i> <i>LO3.2: Apply electrical engineering concepts to comprehend hybrid energy storage systems for EVs. (PI-1.4.1)</i> <i>LO3.3: Identify engineering systems, variables, and parameters involved in Hybrid Energy Storage System. (PI-2.1.2)</i> <i>LO3.4: Extract desired understanding and conclusions in terms of HESS designs and architectures (P.I.-2.4.4)</i>	
04.	Battery Management Systems (BMS)	06
	Learning Objective/s:	
	<i>Explore the components and functions of battery management systems, along with thermal management strategies for battery packs.</i>	
	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 Features-Overcharge, over-discharge, and thermal runaway prevention, Safety standards and certifications (ISO, IEC).	
	Learning Outcomes : <i>A learner will be able to</i> <i>LO4.1: Identify, assemble and evaluate information and resources for Battery management systems (PI-2.2.2)</i> <i>LO4.2: Identify existing protocols and state estimation techniques used in battery management systems.(PI-2.2.3)</i> <i>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)</i>	

	<i>LO4.4: Explore and synthesize engineering requirements for thermal management in BMS considering safety risks and performance..(PI-3.1.5)</i> <i>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)</i> <i>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)</i>	
05.	Charging Infrastructure Learning Objective/s: <i>To gain an understanding of EV charging infrastructure and energy management systems.</i> 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. Learning Outcomes : <i>A learner will be able to</i> <i>LO5.1: Identify, assemble and evaluate information and resources for charging infrastructures.(PI-2.2.2)</i> <i>LO5.2: Identify existing charging protocols and standards. (PI-2.2.3)</i> <i>LO5.3: Explore the connection between technical, socio-economic, and environmental dimensions of sustainability for energy management in EVs.(PI-6.3.2)</i> <i>LO5.4: Identify techniques for effectively managing energy systems in EVs to promote sustainable development. (PI-6.3.3)</i>	08
06.	Performance, Safety, and Maintenance of Energy Storage Systems Learning Objective/s: <i>To acquire an understanding of the performance, safety, maintenance, and sustainability considerations of energy storage systems.</i> 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. Learning Outcomes : <i>A learner will be able to</i> <i>LO6.1: Identify performance indicators for Energy storage system.(PI-2.1.2)</i> <i>LO6.2: Identify, assemble and evaluate information and resources related to energy storage performance.(PI-2.2.2)</i> <i>LO6.3: Extract engineering requirements from relevant engineering Battery Standards such as ISO and IEC .(PI-3.1.4)</i> <i>LO6.4: Explore and synthesize engineering requirements considering safety risks for energy storage system. (PI-3.1.5)</i>	08

	<i>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)</i> <i>LO6.6: Synthesize information and knowledge about the diagnostic tools for monitoring energy storage system performance. (PI-4.3.4)</i> <i>LO6.7: Identify risks/impacts in the life-cycle of energy storage system.(PI-6.3.1)</i> <i>LO6.8: Understand the environmental dimensions of sustainability for energy storage system.(PI-6.3.2)</i>	
	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

- 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*)
- 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

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, 2017 Rajakaruna, 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://nptel.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.

Course Type	Course Code	Course Name	Credits
HMC	HMCEV703	DRIVES IN 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. HMCEV501: Electrical and hybrid electric vehicle
2. HMCEV602 Energy Storage System in EV Application

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis
3. PO5: Engineering tool usage
4. PO9: Communication
5. PO11: Lifelong learning

Course Objectives: To impart knowledge on

1. The primary components of electric vehicle propulsion system.
2. The suitability of IM, PMSM, BLDCM, SRM and SynRM drives for EV applications.
3. Simulation and analysis of major components of EV power train.

Module	Details	Hrs
	Course Introduction Drives in electric vehicles (EVs) are crucial components that convert electrical energy into mechanical energy, propelling the vehicle. Unlike traditional internal combustion engines, EV drives rely on electric motors, which offer several advantages including higher efficiency, reduced emissions, and quieter operation. These drives typically include an inverter, motor, and transmission system, working together seamlessly to provide smooth and responsive performance. As technology advances, the drives in EVs continue to evolve, enhancing range, power, and overall vehicle efficiency, making them a key factor in the growing popularity and adoption of electric vehicles worldwide.	01
01.	Electric Vehicle Propulsion System	05-07
	Learning Objective/s: <i>To acquire knowledge on electric vehicle propulsion system.</i>	
	Contents: Block diagram of an EV propulsion system and its primary components, Tractive effort and the power rating calculation for the primary components for a typical drive cycle, Power/Energy supply requirements for EV applications, Tractive effort vs speed characteristics, EV traction power & torque characteristics, Factors affecting the choice of electric propulsion systems for EVs, Requirements of the EV motor drive, Speed torque characteristics of the EV drive, Motors used in EV application.	
	Self-Learning Topics: <i>List out the components and specifications of any one real life EV propulsion system.</i>	

	Learning Outcomes: A learner will be able to LO1.1: Apply fundamental engineering concepts to calculate the tractive effort and the power rating of the primary components for a typical drive cycle. (PI 1.3.1) LO1.2: Plot the EV traction power & torque characteristics for the entire speed range. (PI 1.4.1) LO1.3: Obtain power/energy supply requirements of EV application for a given drive cycle. (PI 2.2.3) LO1.4: Choose the electrical motors required in various EV applications. (PI 2.2.2)	
02.	Induction Motor Drive for EV Application Learning Objective: To analyze the feasibility of an induction motor drive for EV applications. Contents: Construction and Working principle, Advantages of IM in EV applications, motor dynamics, Slip and its significance, Specifications, Components of Induction Motor Drive Systems, Power modulators, Pulse width modulation techniques and Control Strategies for Induction Motors, Sensors and feedback mechanisms, Scalar control (V/f control), Speed torque characteristics in Constant torque, constant power and constant slip region. Vector control (field-oriented control), Direct torque control (DTC), Performance Characteristics and Optimization, Efficiency Map; Suitability of IM in Electric vehicle domain for 2W, 3W, 4 wheeler and large size vehicles, Thermal management, Noise and vibration reduction, Battery management and power distribution, Regenerative braking systems, Case studies of EVs using induction motors. Learning Outcomes: A learner will be able to LO2.1: Analyze the speed torque characteristics of IM in constant torque, constant power and constant slip region. (PI 2.1.3, 9.1.3) LO2.2: Analyze the power modulators and various control schemes of induction motor (PI 2.2.4, 9.2.2) LO2.3: Analyze the suitability of induction motor drive for EV applications. (PI, 2.1.3, 9.2.2)	09-11
03.	Brushless DC Motor Drive for EV Application Learning Objective: To analyze the feasibility of a brushless DC motor drive for EV applications. Contents: Construction and Working principle, Comparison with brushed DC motors, Advantages in EV applications, Fundamental Operation of BLDC Motors, Construction and Working principle, Role of Hall effect sensors, Components of BLDC Motor Drive Systems, Power modulators and Control Strategies for BLDC Motors, Commutation methods (sensor-based, sensorless), Speed and torque control, Case studies of EVs using BLDC motors Learning Outcomes: A learner will be able to LO3.1: Identify the components of BLDC motor drive systems. (PI 2.1.2) LO3.2: Analyze the power modulators and various control schemes of BLDC motor. (PI 2.2.4, 9.1.3) LO3.3: Analyze the suitability of BLDC motor drive for EV applications. (PI 2.1.3, 9.2.2)	06-08

04.	Permanent Magnet Synchronous Motor Drive for EV Application	06-08
	Learning Objective: <i>To analyze the feasibility of a permanent magnet synchronous motor drive for EV applications.</i>	
	Contents: Construction and Working principle, Role of permanent magnets, Advantages in EV applications, Components of PMSM Drive Systems, Power modulators and Control Strategies for PMSM, Field-oriented control (FOC), Direct torque control (DTC), Sensorless control methods, Case studies of EVs using PMSM.	
	Learning Outcomes: <i>A learner will be able to</i> LO4.1: Identify the components of PMSM drive systems. (PI 2.1.2, 9.1.3) LO4.2: Analyze the power modulators and various control schemes of PMSM drive (PI 2.2.4) LO4.3: Analyze the suitability of PMSM drive for EV applications. (PI 2.1.3, 9.2.2)	
05.	Switched Reluctance Motor (SRM) Drive and Synchronous Reluctance Motor (SynRM) Drive for EV Application	05-07
	Learning Objective: <i>To analyze the feasibility of a switched reluctance motor drive and Synchronous Reluctance Motor Drive for EV applications.</i>	
	Contents: SRM Drive: Construction and Working principle, Magnetic reluctance and torque production, Advantages and disadvantages in EV applications, Components of SRM Drive Systems, Power modulators and Control Strategies for SRM, Current control methods, Position sensing and sensorless control techniques, Torque ripple reduction techniques. SynRM Drive: Construction and Working principle, Advantages and disadvantages in EV applications, Components of SynRM Drive Systems, Power modulators and Control Strategies for SynRM, Field-oriented control, Torque ripple reduction.	
	Learning Outcomes: <i>A learner will be able to</i> LO5.1: Identify the components of SRM and SynRM drive systems. (PI 2.1.2) LO5.2: Analyze the power modulators and various control schemes of SRM and SynRM. (PI 2.2.4) LO5.3: Analyze the suitability of SRM and SynRM drive for EV applications. (PI 2.1.3) LO5.4: Compare the techniques which can be adapted for the torque ripple reduction in SRM. (PI 2.2.4)	
06.	Simulation and Analysis of Major Components of EV Power Train	06-08
	Learning Objective/s: <i>To gain knowledge on the simulation and analysis of major components of the EV power train.</i>	
	Contents: Introduction to simulation tools, Modelling and analysis of electrical machines used in EV applications, Simulation and analysis of speed and torque control methods of EV motors.	
	Learning Outcomes: <i>A learner will be able to</i>	

	<i>LO6.1: Create the Simulink model of the electrical machines used in EV applications. (PI-1.3.1, 5.2.1)</i> <i>LO6.2: Analyze the performance of the electrical machines used in EV applications. (PI-2.4.2, 11.2.2)</i> <i>LO6.3: Simulate and analyze the speed / torque control methods of EV motors. (PI- 1.4.1, 5.2.2)</i> <i>LO6.4: Extract desired understanding and valid conclusions about the speed and torque control methods of EV motors. (PI-2.4.4, 11.3.1)</i>	
	Course Conclusion In conclusion, drives in electric vehicles are essential for converting electrical energy from the battery into mechanical energy for propulsion. These systems, comprising electric motors and power electronics, offer higher efficiency, lower emissions, and reduced maintenance compared to traditional internal combustion engines. Ongoing advancements in drive technology are enhancing EV performance, range, and reliability, making them a cornerstone in the shift towards sustainable transportation.	01
Total		45

Course Outcomes:

Learner will be able to

1. Decide the power and energy supply requirements for an EV application for a specified driving cycle (LO1.1, LO1.2, LO1.3).
2. Identify and assess various traction motors along with their suitability in various EV segments (LO1.4, LO2.1, LO2.3, LO3.1, LO3.3, LO4.1, LO4.3, LO5.1, LO5.3).
3. Describe and differentiate various power converters and their control which are suitable for EV drives (LO2.2, LO3.2, LO4.2, LO5.2, LO5.4).
4. Determine the suitability of a PMSM drive for electric vehicle applications in comparison to an IM drive (LO2.1, LO2.3, LO4.1, LO4.3).
5. Simulate and analyse the major components of EV power train (LO6.1, LO6.2, LO6.3, LO6.4).

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
- 2.2.2 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.
- 5.2.1 Identify the strengths and limitations of tools for (i) acquiring information, (ii) modelling and simulating, (iii) monitoring system performance, and (iv) creating engineering designs.
- 5.2.2 Demonstrate proficiency in using discipline specific tools
- 9.1.3 Create flow in a document or presentation - a logical progression of ideas so that the main point is clear
- 9.2.2 Deliver effective oral presentations to technical and non-technical audiences
- 11.1.2 Identify deficiencies or gaps in knowledge and demonstrate an ability to source information to close this gap
- 11.3.1 Source and comprehend technical literature and other credible sources of information

CO-PO mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCEV703.1	3	3	--	--	--	--	--	--	--	--	--
HMCEV703.2	3	3	--	--	--	--	--	--	3	--	--
HMCEV703.3	3	3	--	--	--	--	--	--	3	--	--
HMCEV703.4	3	3	--	--	--	--	--	--	3	--	--
HMCEV703.5	3	3	--	--	3	--	--	--	--	--	3
Average	3	3	--	--	3	--	--	--	3	--	3

Text Books:

1. Handbook of Automotive Power Electronics and Motor Drive Edited by Ali Emadi, CRC Press, 2005
2. Modern Power Electronics and AC Drives by B. K. Bose, Prentice Hall PTR
3. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles_ Fundamentals, Theory, and Design by Mehrdad Ehsani et. al., Second Edition, CRC Press.
4. Electric Vehicle Technology Explained by James Larminie et.al. Second Edition, Wiley

Reference Books:

1. Electric Motor Drives: Modelling, Analysis and Control by Krishnan R, PHI
2. Power electronics by Muhammad H. Rashid, Pearson
3. High Performance AC Drives Modelling Analysis and Control by Mukhtar Ahmad, Springer.

Other Resources:

1. NPTEL Web Course: Electric Vehicles - Part 1 by Prof. Amit Kumar Jain, Dept. of Electrical Engineering, IIT Delhi
<https://nptel.ac.in/courses/108/102/108102121/>
2. NPTEL Web Course: Fundamentals of Electric vehicles: Technology & Economics: by Prof. Ashok Jhunjunwala, 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 (Web)
Co-ordinated by IIT, Guwahati.
<https://archive.nptel.ac.in/courses/108/103/108103009/>

IN-SEMESTER ASSESSMENT (50 MARKS)*Suggested breakup of distribution*

1. Continuous Assessment (20 Marks)
 - Case Study assignment: 10 Marks
 - Technical report writing and presentation: 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
HML	HMLEV701	Electric Vehicle Laboratory	2

Examination Scheme		
Continuous Assessment	Practical /Oral	Total
50	-	50

Pre-requisite:

1. HMCEV501- Electrical and Hybrid Electric Vehicle
2. HMCEV602 - Energy Storage System in EV Application

Program Outcomes addressed:

1. PO2: Problem analysis
2. PO5: Modern Tool Usage
3. PO6: The Engineer and The World:
4. PO8: Individual and team work
5. PO9: Communication
6. PO11: Life-long learning

Course Objectives:

1. To impart the knowledge on various components /sub-systems of Electric Vehicles (EV) and EV powertrain with their functionalities.
2. To impart the knowledge to characterize, evaluate and select/size various energy sources for EV applications and their charging systems
3. To impart the knowledge on the analysis and implementation of speed/torque control schemes for various types of EV motors.

Module	Details	Hrs
	Course Introduction This lab course in Electric Vehicles offers insight and hands-on in different EV powertrains, components, and various subsystems. It also includes exploration of EV powertrain components characterization and control implementation.	
01.	EV Powertrain And Auxiliary Systems Learning Objective: <i>To acquire the knowledge of various components /sub-systems of Electric Vehicles (EV) and EV powertrain with their functionalities.</i> Theme for conducting experiment: 1. To identify various components / sub-systems of EV powertrain and their functionalities. Learning Outcomes: <i>A learner will be able to</i> <i>LO 1.1: Identify, assemble and analyse the functionalities of various components/sub-systems of EV powertrain. (PI-2.2.2, 2.2.3, 11.3.1)</i> Theme for conducting simulation: 2. Modeling, Simulation, and Performance Analysis of EV powertrain with different kind of EV Motors (BLDC/Induction Motor /PMSM) using suitable simulation /emulation platform. Learning Outcomes: <i>A learner will be able to</i> <i>LO 1.2: Use any simulation tool to model EV Powertrain based on various kinds of EV motors, analyze the performance, and assess operation of EV powertrain (PI 2.1.2, 2.2.2, 5.2.1, 5.2.2)</i> Theme for conducting experiments/ simulation: 3. Experimental / Simulation based verification of EV auxiliary systems like-steering system, Braking system, HVAC system, Safety system, Thermal management system etc. Learning Outcomes: <i>A learner will be able to</i>	08

	LO 1.3: verify and evaluate the operation of the various EV subsystems with suitable experimental setups or simulation tool (PI 2.1.2, 2.2.2, 5.2.1, 5.2.2, 11.3.1)	
02.	Energy Sources for Electric Vehicles Learning Objective: To acquire skill to characterize, evaluate and select/size various energy sources for EV applications Theme for conducting experiment: 4. To test and characterize battery cells/modules/pack of different chemistry and types Learning Outcomes: A learner will be able to LO 2.1: Test, characterize and assess the suitability of various types battery cell/modules/pack EV applications. (P.I.-2.2.2, 2.2.3, 4.3.1, 11.2.2, 11.3.1) Theme for conducting experiment: 5. To test and characterize ultra-capacitor cells/modules. Learning Outcomes: A learner will be able to LO 2.2: Test, characterize and assess the suitability of ultra-capacitor as energy source for EV applications. Also to compare the performance with respect to battery as energy source for EV applications (P.I.-2.2.2, 2.2.3, 4.3.1, 11.2.2, 11.3.1) Theme for conducting experiment/simulation: 6. To test the Hybrid Energy Storage (HES) source using battery and ultra-capacitor. Learning Outcomes: A learner will be able to LO 2.3: evaluate the performance of HES source for EV applications. (P.I.-2.2.2, 2.2.3, 4.3.1, 5.2.1, 5.2.2, 11.2.2, 11.3.1)	12
03.	EV Motors Learning Objective: To acquire knowledge on simulation, analysis and implementation of speed/torque control schemes of BLDC/Induction Motor/PMSM motor. Theme for conducting experiment/simulation: 7. Experimental / Simulation based of speed/torque control schemes of BLDC/Induction Motor/PMSM motor. Learning Outcomes: A learner will be able to LO 3.1: Analyze the operation and performance of speed/torque control schemes of permanent magnet synchronous motor by simulations/experiments. (PI 2.2.2, 2.2.3, 4.3.1, 5.2.1, 5.2.2, 11.3.1)	08
04.	EV Chargers Learning Objective: To acquire knowledge of use, test and analyze the different EV charging infrastructural components / systems and protocols. Theme for conducting experiment: 8. Test and analyze the operation of AC /DC (slow/fast chargers) EV chargers. Learning Outcomes: A learner will be able to LO 4.1: Identify, use, test and analyze performance of the different EV charging infrastructural components / systems /protocols and relate to the safety while charging through EV infrastructural facility. (P.I.-2.2.2, 2.2.3, 4.3.1, 6.1.1, 6.2.1, 11.2.2, 11.3.1) Theme for visit EV manufacturing / EV charging infra facility: 9. Visit to a facility / industry / research institute carrying out work in the domain of EV or EV-charging infrastructure (report based on actual field Visit)	08

	Learning Outcomes: <i>A learner will be able to</i> <i>LO 4.2: Demonstrate effective communication as individual and present reports as a team for an Industrial visit (PI. 8.2.1,.8.3.1)</i>	
5	Electric Vehicle Lab Course Project- Learning Objective: To acquire hands-on experience of design, development and testing of EV subsystems with the help of software tools / hardware or emulation platforms to realize the real world practices of design & testing of such systems Theme for conducting experiment: 10. Design, develop and test of a EV subsystems with the help of software tools / hardware or emulation platforms to realize the real world practices. Learning Outcomes: <i>A learner will be able to</i> <i>LO 5.1: Demonstrate the skill to realize the real world practices for design and development of subsystem in EV domain, to effectively communicate the work carried out as an individual and present report as a team for the course project (PI. 8.2.1,.8.3.1)</i>	08
	Minimum 1 experiments/simulations from Modules 1 to 4 , one Industrial visit and a Course Project based on Module 5	

Performance Indicators:

P.I. No.	P.I. Statement
2.1.2	Identify engineering systems, variables, and parameters to solve the problems
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
4.1.1	Define a problem, its scope and importance for purposes of investigation
4.3.1	Use appropriate procedures, tools and techniques to conduct experiments and collect data
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
5.2.1	Identify the strengths and limitations of tools for modeling and simulating engineering designs.
5.2.2	Demonstrate proficiency in using discipline-specific tools
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
6.2.1	Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public
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
11.2.2	Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field
11.3.1	Source and comprehend technical literature and other credible sources of information

Course Outcomes:

Learner will be able to

1. Identify and analyse the functioning of various EV components/ sub-systems (*LO1.1, LO1.2, LO1.3, LO2.1, LO2.2, LO2.3, LO3.1, LO4.1, LO4.2*).
2. Test, characterize and evaluate the performance of the major components of EV powertrain (*LO1.1, LO1.2, LO1.3, LO2.1, LO2.2, LO2.3, LO3.1, LO4.1, LO4.2*)
3. Identify and analyse EV motor control schemes using experimental setups and using modern engineering tools (*LO 3.1, LO 3.2*).
4. Test, characterize and evaluate the performance EV energy sources and charging infrastructure (*LO2.1, LO2.2, LO2.3, LO3.1, LO4.1*).

CO-PO mapping table with correlation level:

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMLEV701.1		3		3	3						3
HMLEV701.2		3		3	3						3
HMLEV701.3		3		3	3						3
HMLEV701.4		3		3		3		3			3
Average		3		3	3	3		3			3

Other Resources: Virtual Lab Website

1. <https://www.vlab.co.in/broad-area-mechanical-engineering> - Energy Storage Labs, Solar Energy lab, Wind Energy Lab
2. <http://vlab.co.in/broad-area-electrical-engineering>

CONTINUOUS ASSESSMENT (50 Marks)

Suggested breakup of distribution

- Laboratory Exercises: **20 Marks**
- Course Project: **20 Marks**
As a part of Internal Assessment, students will do course mini project as a team to inculcate teamwork.
Students will be tasked with design /develop a small-scale EV sub-system using suitable H/W, Software, Simulation or Emulation platform. This project-based assessment will require students to apply their knowledge and skills gained throughout the course to design and implement a functional system.
Course Project Rules:
 1. Group Size: Groups of 2 to 4 members allowed.
 2. Project Proposal: Detailed proposal with scope, objectives.
 3. Presentation:
 - Present project features, challenges faced, and solutions.
 - Q&A session for evaluation.
 4. Evaluation Criteria:
 - Adherence to requirements and objectives.
 - Effective presentation and Q&A skills.
- Industrial Visit: Students' visit to be arranged to the nearby facility industry involved in design/ manufacturing/ processing. in the EV domain All students shall submit visit report in appropriate format as a part of the submission: **05 Marks**
- Regularity and active participation: **05 Marks**

Course Type	Course Code	Course Name	Credits
HMC	HMCEV804	ELECTRIC VEHICLE SYSTEM DESIGN	04

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. HMCEV501: Electrical and Hybrid Electric Vehicle
2. HMCEV602: Energy Storage System in EV Application

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. PO8: Individual and Collaborative Team work
7. PO11: Life-long learning

Course Objectives:

1. To comprehend the design philosophies applied in electric vehicles (EVs).
2. To select and analyze the selection and configuration of power and control architectures in EV drives.
3. To study the design and sizing principles of EV battery packs and other energy sources.
4. To explore the design aspects of EV subsystems, charging systems, and functional safety considerations.

Module	Details	Hrs.
	Course Introduction Electric vehicle (EV) design focuses on efficiency, safety and integration by optimizing the subsystems such as battery, motor, power electronics, control and charging systems. Power and control architectures ensure efficient energy conversion, regenerative braking, and precise torque management through inverters and DC–DC converters. Battery pack design emphasizes proper cell selection, thermal management and protection via a Battery Management System (BMS). Supporting subsystems like thermal control, communication, and charging are designed for reliability and compliance with safety standards. Overall, EV design unites electrical, mechanical, and software elements to deliver sustainable and high-performance transportation.	01

01.	Electric Vehicle Motor Selection and Sizing for Traction Applications Learning Objective: • Calculate tractive force, torque, power, and speed requirements for different EV types • Analyze vehicle dynamics to determine acceleration, gradeability, and traction limits • Evaluate and select appropriate electric motors for EV applications Contents: determination of acceleration limits, gradeability, and traction constraints, analysis of vehicle power demand over standard driving cycles, motor selection criteria including torque-speed characteristics, continuous and peak ratings, efficiency, and thermal limits, types of motors such as BLDC, PMSM, induction, and switched reluctance motor sizing and matching motor performance to vehicle dynamics. Self-Learning Topics: Principle and method for sizing electric motors for EVs, EV types including 2-wheelers, 3-wheelers and 4-wheelers, and HEVs based on vehicle dynamics such as rolling resistance, aerodynamic drag, gradient effects, and inertial forces, calculation of tractive force, torque, power, and speed requirements Learning Outcomes: A learner will be able to LO 1.1: Applying fundamental engineering concepts, determine maximum acceleration, gradeability, traction limits etc. as parameter of vehicle dynamics. (PI 1.3.1) LO 1.2: By identification of vehicle dynamics, analyze electric vehicle performance. (PI 2.1.2) LO 1.3: Apply electric motor parameters, to solve electric motor selection criterion for EV application. (PI, 1.4.1, 8.2.1) LO 1.4: Identify the relevant practical constraints and solve the electric motor sizing and its performance parameters. (PI, 2.2.3, 8.2.1)	07
02.	Selection and Sizing of Energy Storage for EVs Learning Objective: • Evaluate and select appropriate battery types for 2W, 3W and 4W EVs • Size battery packs, fuel cells, and hybrid energy storage systems for defined EV performance • Assess energy storage system performance under real-world operating conditions Contents: Battery pack sizing, design considerations including range per charge, EV motor power requirements, impact of road, environmental and traffic conditions, selection and sizing of fuel cells for FCEVs. Self-Learning Topics: Selection of battery pack types for 2-wheelers and 4-wheelers Learning Outcomes: A learner will be able to LO 2.1: Compare and contrast different types of energy storage systems for EVs and FCEV. (PI 2.2.4) LO 2.2: Extract desired understanding for design consideration different types of energy storage systems. (PI 2.2.4, 11.2.2) LO 2.3: Using appropriate procedures calculate battery or hybrid storage capacity based on range and power requirements (PI 1.3.1) LO 2.4: Apply impact of road, environmental and traffic conditions to determine energy storage sizing. (PI 1.2.1) LO 2.5: Select appropriate technique and analyze sizing of EV energy storage. (PI 4.3.1) LO 2.6: Design and analyze battery and fuel cell design stating possible limitations. (PI 4.3.2, 11.2.2)	10
03.	Automotive Subsystem Design Learning Objective: • Design and configure ECUs for EV subsystems	10

	• Design acceleration, braking, and steering control strategies • Design HVAC control for passenger comfort and system efficiency Contents: Electronic Control Unit (ECU) functions and control features, communication protocols between ECUs, acceleration and braking control, regenerative braking, automotive steering systems, design considerations for HVAC controllers. Self-Learning Topics: - Learning Outcomes: A learner will be able to LO 3.1: Comprehend ECU functions and communication for automotive systems investigation. (PI 4.1.1, 11.3.2) LO 3.2: Define and analyze vehicle control systems for acceleration, braking, and steering using articulation of problem statements (PI 4.1.1) LO 3.3: Extract engineering requirements from relevant engineering standards and define automotive subsystem parameters. (PI 3.1.4) LO 3.4: Identify criteria for the evaluation of alternate design solutions for HVAC controllers (PI 3.2.3) LO 3.5: Apply decision-making tools to design solution for HVAC and other subsystems for EV applications (PI 3.3.1, 11.3.2)	
04.	EV System Integration Learning Objectives: To understand and apply electromagnetic compatibility (EMC) design principles at ECU, system, and subsystem levels in electric vehicles. Contents: EMI Electromagnetic compatibility (EMC) design at ECU and system levels, radiated and conducted emissions, EMI/EMC measurement techniques, EMC design for special subsystems. Learning Outcomes: A learner will be able to LO 4.1: Applying the sources of radiated and conducted emissions to identify EMI/EMC issues. (PI 1.3.1) LO 4.2: Apply basic concepts to mitigate EMI/EMC issues in EV subsystem using tool. (PI 1.4.1) LO 4.3: Identify engineering systems parameters to solve the problems in EMI/EMC measurement. (PI 2.1.2, 5.1.1) LO 4.4: Analyze EMC challenges in ECUs and EV subsystems and propose appropriate design solutions to minimize interference using computer aided tool. (PI 2.3.1, 5.1.1) LO 4.5: Identify and evaluate EMI/EMC measurement results to ensure compliance with international EMC standards. (PI 2.2.2)	08
05.	Design of electric vehicle chargers Learning Objective/s: To understand and apply the design principles and standards for AC, On-Board charger and DC fast EV chargers. Contents: AC charger design considerations, vehicle interface design, selection of charging protocols, compliance with applicable international charging standards, On-Board Charger (OBC) design, selection of power topology, control strategies, power capacity considerations, DC fast charger design considerations Learning Outcomes : A learner will be able to LO 5.1: Apply transportation engineering concepts to give solution to electric vehicle charging. (PI 1. 4.1) LO 5.2: Apply to an engineering problem to international charging standards to electric vehicle charging system. (PI 1.2.1)	08

	<i>LO 5.3: Identify the scope and importance for purposes of design considerations in power topologies and control strategies for AC, OBC, and DC fast chargers. (PI 2.1.2)</i> <i>LO 5.4: Identify trends and correlations, stating possible limitations for vehicle interface to ensure compatibility and safety. (PI 2.3.2,11.2.2)</i> <i>LO 5.5: Validate charger designs against applicable standards and propose improvements for efficiency, compliance, and connectivity l.(PI 2.4.2,11.2.2)</i>	
06.	Functional Safety of Automotive Electronics	07
	Learning Objective/s: <i>To apply functional safety principles for automotive electronic systems to ensure reliability, risk mitigation, and compliance with safety standards.</i>	
	Contents: Functional Safety requirements of Automotive Electronics; ASIL identification and safety goal finalization, ISO 26262. Energy Storage integrity / protection: rupture and toxic gas management; low energy stranding, Unintended vehicle movement, shock protection, and Elimination of potential thermal/explosive event.	
	Self-Learning Topics: <i>Safety standard ISO 26262</i>	
	Learning Outcomes: <i>A learner will be able to</i> <i>LO 6.1: Elucidate key concepts, standards e.g., ISO 26262, and design principles of functional safety in automotive electronics. (PI 1.3.1, 11.2.2)</i> <i>LO 6.2: Apply automotive electronic system designs to identify potential hazards, failure modes, and safety risks.(PI 1.4.1, 11.3.2)</i> <i>LO 6.3: Apply decision-making tools to design solution for functional safety for EV application (PI 3.3.1,11.3.2)</i>	
	Course Conclusion The study of electric vehicle (EV) design culminates in the ability to integrate electrical, mechanical, and control subsystems into a unified, efficient, and safe transportation system. By mastering converter control, motor drive design, battery management, and charging infrastructure, learners develop the skills to analyze, model, and optimize vehicle performance under diverse operating conditions. The course equips students to apply system-level thinking and sustainable design principles for developing reliable, energy-efficient, and technologically advanced electric mobility solutions that meet modern safety and environmental standards.	01
Total		52

Performance Indicators:

P.I. No.P.I. Statement

- 1.1.2 Apply advanced mathematical techniques to model and solve electrical engineering problems
- 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 Mechanical 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 engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
- 2.3.2 Identify assumptions (mathematical and physical) necessary to allow modeling of a system at the level of accuracy required.
- 2.4.1 Apply engineering mathematics and computations to solve mathematical models

- 3.1.1 Recognize that need analysis is key to good problem definition
- 3.1.4 Extract engineering requirements from relevant engineering Codes and Standards
- 3.3.1 Apply formal decision-making tools to select optimal engineering design solutions for further development
- 3.3.1 Apply formal decision-making tools to select optimal engineering design solutions for further development
- 3.4.1 Refine a conceptual design into a detailed design within the existing constraints (of the resources)
- 5.2.1 Identify the strengths and limitations of tools for (i) acquiring information, (ii) modeling and simulating, (iii) monitoring system performance, and (iv) creating engineering designs.
- 8.2.1 Demonstrate effective communication, problem-solving, conflict resolution and leadership skills
- 11.3.1 Source and comprehend technical literature and other credible sources of information
- 11.2.2 Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field
- 11.3.2 Analyze sourced technical and popular information for feasibility, viability, sustainability, etc.

Course Outcomes: A learner will be able to -

1. Analyze vehicle dynamics and performance parameters to define tractive effort, torque, and power needs for various EV/HEV configurations. (LO1.1, LO1.2, LO1.3, LO1.4)
2. Comprehend energy storage systems, calculate battery/hybrid capacity, and analyze environmental impacts on EV performance. Design, select, and size electric motors, converters, and energy storage systems (battery, hybrid, or fuel cell) to meet defined range and performance targets. (LO2.1, LO2.2, LO2.3, LO2.4)
3. Develop and integrate control algorithms and ECUs for propulsion, braking, steering, and auxiliary subsystems ensuring effective communication and coordination. (LO3.1, LO3.2, LO3.3)
4. Design and evaluate AC, on-board, and DC fast charging systems with appropriate control topologies, protocols, and standard compliance. (LO5.1, LO5.2, LO5.3)
5. Apply functional safety and EMC design principles to ensure reliability, risk mitigation, and compliance with international automotive standards. (LO4.1, LO4.2, LO4.3, LO6.1, LO6.2)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCEV804.1	3	3						3			
HMCEV804.2	3	3		3							3
HMCEV804.3			3	3							3
HMCEV804.4	3	3									
HMCEV804.5	3	3	3		3						3
Average	3	3	3	3	2			2			3

NOTE: CO can be mapped to PO at level 3 if at least two PIs are associated with that CO; otherwise, it can be mapped at level 2.

Text Books :

1. Design and Control of Automotive Propulsion Systems by Zongxuan Sun and Guoming Zhu, CRC Press, 2015

2. Electric Vehicle Machines and Drives Design, Analysis and Application by K. T. Chau, IEEE Press and Wiley, 2015
3. I. Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
4. 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

Reference Books :

1. Sheldon Williamsom, Energy Management Strategies for Electric and Plug-in Hybrid Vehicles, Springer 2013.
2. J. Larminie and J. Lowry, Electric Vehicle Technology Explained, Wiley, 2003
3. EMC and Functional Safety of Automotive Electronics by Kai Borgeest, IET, 2018

Other Resources :

1. NPTEL Web Course: Electric Vehicles - Part 1 by Prof. Amit Kumar Jain D IIT Delhi
2. NPTEL Web Course: Fundamentals of Electric vehicles: Technology & Economics, by Prof. Asho

IN-SEMESTER ASSESSMENT (75 MARKS)

1. Continuous Assessment - Theory-(20 Marks)

Suggested breakup of distribution

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
HMP	HMPXX801	Honours/Minor Mini Project	02

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: Modern Tool Usage
6. PO6: The Engineer & World
7. PO7: Ethics
8. PO8: Individual & team work
9. PO9: Communication
10. PO10: Project Management & Finance
11. PO11: Life-long learning

Course Objectives

1. To guide students in identifying specialization-domain problems
- 2.. To explore advanced solutions using emerging technologies and specialized tools.
3. To develop research aptitude, innovation mindset, entrepreneurship potential, and lifelong learning skills.
- 4.. To foster self-directed learning, domain-specific competency, and collaboration.

Course Outcomes

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

CO1: Identify and articulate a domain-relevant societal, industrial, or research problem using literature review and analysis.

CO2: Apply engineering principles and specialized tools to design innovative and feasible technical solutions.

CO3: Conduct investigations, simulations, or experiments to validate the proposed solution using appropriate methods.

CO4: Evaluate the solution considering sustainability, ethics, feasibility, and potential for commercialization or IP.

CO5: Demonstrate teamwork, project management, and professional technical communication through reports and presentations.

CO6: Engage in self-directed learning and continuous improvement to enhance domain expertise and professional growth.

Guidelines for the Mini Project

- Projects should align with the Honors/Minor specialization domain
- Mini project may be carried out in one or more form of following:

Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc. • Students must form groups of 3 to 4 members. • Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty. • An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted. • Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor. • Faculty input should emphasize guiding by faculty and self-learning by group members. • Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model. • The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report. • With the focus on self-learning, innovation, research orientation, addressing societal and industry challenges, and developing entrepreneurship qualities among students, the Mini Project should reflect appropriate depth, technical sophistication, specialization-domain relevance, and quality. Students are encouraged to adopt an innovative approach, explore emerging technologies, and demonstrate prototype development, domain-specific research outputs, or commercialization potential, rather than limiting to basic model implementation.
In-Semester Continuous Assessment and End-Semester Examination Guidelines • The coordinating Head of the Department will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations in a semester. • Assessment will be based on individual contributions, understanding, and responses to questions asked. • Continuous Assessment marks distribution (50 marks): ○ 20 marks for the Topic Approval Presentation in front of the progress monitoring committee ○ 20 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee ○ 10 marks for regularity & active participation The review/progress monitoring committee will assess projects based on the following criteria. • Theoretical solution completion, including component/system selection/design of software solution and cost analysis. • Two reviews will occur: ○ The first review will focus on finalizing the problem statement (topic approval). ○ Second review will assess the progress of building a working prototype. (Mid Semester Presentation)

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. Quality of survey and need identification aligned with specialization or societal/industry relevance.
2. Clarity and innovativeness in problem definition and solution Clarity, originality, and innovativeness in problem definition, solution approach, and use of advanced tools/techniques.
3. Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.
4. Completeness and full functioning of the working model.
5. Effective use of skill sets and engineering norms.
6. Verification & validation of the solutions/test cases.
7. Individual contributions to the group.
8. Clarity in written and oral communication.
9. Participation in research paper presentation, domain-specific competitions, hackathons, demonstrations, start-up pitching, or innovation challenges.

End-Semester Examination (50 marks):

1. Presentation and demonstration to internal and external examiners: 20 marks.
2. Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.

Syllabi

Honours/Minor:

Renewable Energy-Track

Curriculum Structure – Honours/Minor: Renewable Energy-Track

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		L	P	T	L	P	T	Total
HMCRE501	Solar Energy System	3	--	--	3	--	-	3
HMCRE602	Wind Energy System	3	--	--	3	--	--	3
HMCRE703	Design Of Renewable Energy System	4	--	--	4	--	--	4
HMLRE701	Renewable Energy Laboratory	--	4	--	--	2	--	2
HMCRE804	Grid Integration of Renewable system	4	--	--	4	--	--	4
HMPRE801	Mini Project	--	6	--	--	2	--	2
Total		14	10	--	14	4	--	18

Examination Scheme – Honour/Minor

Course Code	Course Name	Examination Scheme					Total
		In-Semester Assessment		End Sem Exam (ESE)	Exam Duration for Theory (in Hrs)		
		Continuous Assessment	Mid-Sem Exam		Mid-Sem	End-Sem	
HMCRE501	Solar Energy System	20	30	50	1.5	2	100
HMCRE602	Wind Energy System	20	30	50	1.5	2	100
HMCRE703	Design Of Renewable Energy System	20	30	50	1.5	2	100
HMLRE701	Renewable Energy Laboratory	50	--	--	--	--	50
HMCRE804	Grid Integration of Renewable system	20	30	50	1.5	2	100
HMPRE801	Mini Project	50	--	50	--	--	100
Total		180	120	250	--	--	550

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

Program Outcomes addressed :

1. PO1: Engineering knowledge
2. PO 3: Design/Development of Solutions
3. PO5: Modern tool usage
4. PO8: Individual and teamwork
5. 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 inculcate the fundamental knowledge of design of solar thermal system.

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 Learning Objective/s: <i>To identify the characteristics and the methods of measuring the solar insolation data later to be used in the design and optimization of solar energy systems</i> 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, environment effects on standard test conditions	07
	Learning Outcomes:	

	<i>A learner will be able to</i> <i>LO 1.1: Identify the methods used for measurement of solar insolation (PI- 2.3.1)</i> <i>LO 1.2: Identify the basics of solar energy. (PI-2.2.3)</i>	
02.	Solar Thermal System Learning Objective/s: To identify 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 different applications Learning Outcomes: <i>A learner will be able to</i> <i>LO 2.1: Identify the process of power generation in solar thermal energy system. (PI 2.3.1)</i> <i>LO 2.2: Identify the parameters and factors to be considered for the design of solar thermal system (PI: 2.1.3)</i> <i>LO 2.3: Design of solar thermal system for different applications. (PI 3.3.1)</i>	06
03.	Solar Photovoltaic System (SPV) Learning Objective/s: To identify the process and components of power generation of solar photovoltaic system Contents: 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. Types of SPV systems: standalone and grid connected PV system, distributed PV System, hybrid system and small system for consumer applications. PV System components - PV arrays, solar trackers, power inverters, batteries, charge controllers, system metering, earthing of components. Learning Outcomes: <i>A learner will be able to</i> <i>LO 3.1: Identify the process of power generation in solar photovoltaic energy system. (PI 2.3.1)</i> <i>LO 3.2: Identify and select the appropriate components of solar photovoltaic system based on system requirements and site condition. (PI 2..3.1)</i>	08
04.	Design consideration of Solar PV System. Learning Objective/s: To analyze design considerations and power management for a standalone solar PV off grid system. Contents:	09

	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 Learning Outcomes: A learner will be able to LO 4.1: Identify the components of solar photovoltaic system. (PI 2.3.1) LO 4.2: Design of solar photovoltaic standalone system. (PI 3.3.1)	
05.	Solar thermal and PV system applications Learning Objective/s: To identify the applications of solar thermal and solar photovoltaic systems 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. Learning Outcomes: A learner will be able to LO 5.1: Identify the applications of solar thermal ad solar photovoltaic system in various fields (PI-2.2.3)	07
06.	Software tools and Case study Learning Objective/s: 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: Use domain specific modern tools to simulate solar PV and thermal system. (PI-5.2.2) LO 6.2: To model efficient solar PV and thermal system and analyze the performance of the systems under various conditions. (PI-3.3.1) 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) LO 6.4: Review at least one technical paper on solar PV system design to support the preparation of a report on solar PV design with a focus on sustainability. (PI-11.3.1, 11.3.2)	06
	Course Conclusion	01
Total		45

Performance Indicators:**P.I. No. P.I. Statement**

- 2.2.3 Identify existing processes/solution methods for solving the problem, including forming justified approximations and assumptions
- 2.1.3 Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
- 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
- 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. Identify and analyze the process of collection and utilization of solar thermal energy.(*LO 1.1, LO 1.2, LO 2.1, LO 2.2*)
2. Identify and analyze the process of collection and utilization of solar photovoltaic energy.(*LO 3.1, LO 3.2, LO 4.1*)
3. Develop the ability to design efficient solar energy systems for various applications.(*LO 2.3, LO 4.2*)
4. Use IT tools to model and simulate solar energy systems.(*LO 6.1, LO 6.2*)
5. Identify the applications of solar thermal and solar photovoltaic system in various fields. (*LO 5.1, LO6.3, LO6.4*)

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						
HMCRE501.5								3			3
Average		3	3		3			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 :

Curriculum Structure & Syllabi (R-2024) B.Tech. in Electrical Engineering

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)			
Continuous Assessment	Mid-Semester Exam (MSE)		MSE	ESE	
20	30	50	1.5	2	100

Pre-requisite :

1. ESC102-Basic Electrical Engineering
2. HMCRE501- Solar Energy System

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 gain knowledge on the current status of wind energy systems and the underlying physics of wind energy.
2. To analyze components and design considerations of wind energy system
3. To gain insights 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 <i>Learning Objective/s:</i> 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 <i>Self-Learning Topics: History of Wind Energy, General Characteristics of the Wind Resource</i>	06

	Learning Outcomes: <i>A learner will be able to</i> <i>LO1.1: Apply laws of natural science to explore different wind flows. (PI-1.2.1)</i> <i>LO1.2: Apply basic principles to explore effects on wind flow. (PI-1.4.1)</i> <i>LO1.3: Identify, assemble information about wind energy systems and sources of wind. (PI-2.2.2)</i> <i>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)</i>	
02.	Physics of Wind Energy Learning Objective: <i>To examine the underlying physics of wind energy.</i> 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: <i>A learner will be able to</i> <i>LO2.1: Apply laws of natural science to assess energy content in wind (PI-1.2.1)</i> <i>LO2.2: Apply fundamental engineering concepts to determine energy conversion at the turbine blade (PI-1.3.1)</i> <i>LO2.3: Identify variables, parameters and principles required for analyzing wind energy (PI-2.1.2)</i> <i>LO2.4: Identify the mathematical, engineering and other relevant knowledge that applies to understand influence of Weibull distribution (PI-2.1.3)</i>	06
03.	Wind Energy Converter Learning Objective: <i>To identify and analyze the components, operation, and control of a wind energy converter.</i> 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: <i>A learner will be able to</i> <i>LO3.1: Identify components of Wind Energy Converter to analyze wind energy conversion system. (PI-2.1.2)</i> <i>LO3.2: Investigate operation and control of wind energy converter for improving performance of the system. (PI-2.2.3)</i> <i>LO3.3: Synthesize engineering requirements for grid application. (PI-3.1.3)</i> <i>LO3.4: Determine design objectives, functional requirements of wind energy converter and arrive at specifications (PI-3.1.6)</i>	07
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 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)	10

	<i>LO5.3: Extract engineering requirements from relevant engineering Codes and Standards for standard requirements of grid integration (PI-3.1.4)</i> <i>LO5.4: Explore and synthesize engineering requirements considering safety relevant set values for wind energy systems (PI-3.1.5)</i> <i>LO5.5: Identify and describe various engineering roles pertaining to grid integration and power quality. (PI-6.1.1)</i> <i>LO5.6: Interpret permissible power ratings , system operator regulations and standards applicable to grid connection of wind energy systems.(PI-6.2.1)</i> <i>LO5.7: Identify risks/impacts of sound emission by wind energy system. (PI-6.3.1)</i> <i>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)</i>	
06.	Wind Energy System Economics 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 <i>LO6.1: Identify information related to economics of wind energy systems (PI-2.2.2)</i> <i>LO6.2: Identify and compare economic analysis methods to select the best method for examining cost effectiveness of the system. (PI-2.2.4)</i> <i>LO6.3: Extract Wind energy market considerations from worldwide technical publications (PI-3.1.4)</i> <i>LO6.4: Explore and synthesize engineering requirements for financing Wind park. (PI-3.1.5)</i> <i>LO6.5: Identify risks/impacts related to wind energy system economics. (PI-6.3.1)</i> <i>LO6.6: Explore the connection between the technical and socio-economic dimensions of sustainability in relation to wind energy systems. (PI-6.3.2)</i>	07
	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.

Course Type	Course Code	Course Name	Credits
HMC	HMCRE703	DESIGN OF RENEWABLE ENERGY SYSTEMS	4

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. HMCRE501: Solar Energy Systems
2. HMCRE602: Wind Energy System

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. PO6: The Engineer and The World
6. PO11: Life-long learning

Course Objectives:

1. To provide learners with conceptual and analytical foundation in renewable energy resources, load estimation, and site-specific system planning using real-world datasets.
2. To guide learners in designing Solar PV, Solar Thermal, Wind, Hydro, and other renewable energy systems by applying core engineering fundamentals.
3. To develop learners proficiency in sizing power electronic converters and energy storage systems for renewable energy applications.
4. To enable learners to incorporate sustainability principles by assessing the environmental, social, and economic impacts associated with renewable energy system design.
5. To strengthen learners capability to size and integrate energy storage systems.
6. To facilitate learner's competency in designing, optimizing, and managing hybrid renewable energy systems.

Module	Details	Hrs.
	Course Introduction This course provides a comprehensive foundation in the design, analysis, and integration of renewable energy systems, enabling learners to understand the technical, economic, environmental, and sustainability-driven aspects of modern energy solutions. Beginning with resource assessment and system sizing fundamentals, the syllabus progresses	01

	through the design of Solar PV, Solar Thermal, Wind, Hydro, and advanced emerging renewable technologies. Learner's will gain exposure to power electronics, energy storage, system optimization, and hybrid renewable architectures. The course also integrates AI-based forecasting, smart control strategies, advanced battery technologies, and next-generation renewable energy systems. Overall, the course equips learners with the analytical, design, and decision-making skills needed to develop efficient, reliable renewable energy solutions for future energy systems and microgrid applications.	
01.	Fundamentals of Renewable Energy System Design and Resource Analysis <i>Learning Objective: To enable learners to identify renewable energy resources, perform accurate load estimation, and analyse site-specific data using standard engineering tools and validated datasets.</i> Contents: Load estimation and site survey; Data-driven resource analysis: solar irradiation, wind profiles, biomass potential and small hydro power plants, design constraints, use of datasets available on: NREL, NIWE, MNRE; Development of design specifications and load–resource matching using real datasets. <i>Self-Learning Topics: Statistical Resource Modeling</i> <i>Learning Outcomes:</i> A learner will be able to LO 1.1 Apply fundamental engineering concepts using concepts like energy conversion, power estimation, and efficiency to calculate load requirements and match them with resource potential (load-resource matching) (PI 1.3.1) LO 1.2 Apply mathematical/ computational modelling techniques to understand the performance of solar panels, wind turbines, or power output based on real datasets. (PI 1.1.2) LO 1.3 Identify the key engineering systems (e.g., solar, wind, hydro) and the variables/parameters (e.g., solar irradiation, wind profiles, load demand) necessary for renewable energy system design and resource analysis. (PI 2.1.2) LO 1.4 Analyse site-specific resource data (solar, wind, biomass, hydro) and extract valid conclusions regarding resource availability and suitability for the engineering design. (PI 2.4.4)	7
02.	Design of Solar Photovoltaic & Solar Thermal Systems <i>Learning Objective: To guide learners in designing PV and solar thermal systems by enabling them to perform module sizing, converter design, MPPT implementation, inverter selection, and thermal performance analysis.</i> Content: PV System Design: PV module selection using datasheet parameters, Array sizing (Voltage window, current, number of modules Series/Parallel), Design of DC–DC converter (Buck/Boost/SEPIC) based on PV voltage range, MPPT algorithm selection and hardware design constraints, Inverter sizing & design considerations (DC-link voltage, filters), Protection design (AC/DC disconnects, fuses, surge protection). Solar Thermal System Design: Collector sizing, heat transfer calculation, efficiency analysis, Thermal storage tank sizing and loss estimation.	10

	Self-Learning Topics: PV Modeling, Advanced MPPT/Control, Solar Thermal Dynamics, Smart Inverter Functions (Grid-Forming/Grid-Following) Learning Outcomes: A learner will be able to LO2.1 Apply mathematical techniques to model PV modules, converters/ other sub-components, for analysing thermal performance and power output by sourcing and comprehending relevant technical literature. (PI 1.1.2, PI 11.3.1) LO2.2 Apply fundamental electrical, thermal engineering concepts (e.g., heat transfer, power electronics, and circuit theory), preventive engineering and sustainable development to the design process, ensuring system longevity, minimal material waste, and optimization for net-zero carbon operation. (PI 1.3.1, PI 6.3.4) LO2.3 Combine scientific principles and engineering concepts to formulate mathematical models for PV module current-voltage characteristics, DC-DC converter operation, and solar thermal collector efficiency. (PI 2.3.1) LO2.4 Identify the design limitations and potential sources of error in the selected PV and thermal system designs, related to component datasheets/protection limits and explain why keeping updated information on new component developments is important for mitigating these limitations. (PI 2.4.3, PI 11.2.2) LO2.5 Determine detailed design specifications for all major components including array sizing, converter design (Buck/Boost/Buck-Boost), and thermal storage capacity. (PI 3.1.6) LO2.6 Refine the conceptual design of the PV/Thermal system into a detailed design incorporating protection schemes (fuses, surge protection) and specific component selections based on given parameters. (PI 3.4.1) LO2.7 Apply appropriate instrumentation (e.g. solar meters, multi meters) and/or software tools to measure physical quantities such as current, voltage, and irradiance during the “PV panel testing”. (PI 4.1.3) LO2.8 Synthesize the collected data and operational information from “On campus 100 kW plant visit” to reach conclusions about the overall performance of the solar PV system, and analyse sourced information for the long-term viability and sustainability of the plant. (PI 4.3.4, PI 6.3.4)	
03.	Design of Wind Energy Conversion Systems Learning Objective: To train learners to model, size, and evaluate wind turbine aerodynamics, key components, and control strategies to ensure efficient and reliable energy extraction. Contents: Aerodynamic modeling: Characteristics, torque & power curves; Turbine rotor sizing (diameter, rated wind speed); Generator selection (PMSG/DFIG) based on speed-torque profile; Mechanical design: shaft, gearbox, braking system basics, pitch control, MPPT control, cut-in/cut-out strategy; Grid-tied wind system inverter/converter design; Tower design basics (height selection, thrust load) Self-Learning Topics: Aerodynamic Control, Structural Load Analysis, Offshore Wind Systems. Learning Outcomes: A learner will be able to LO3.1 Apply advanced mathematical techniques for aerodynamic modelling (e.g., torque and power curves) and for sizing electrical and mechanical components of the wind system. (PI 1.1.2)	8

	LO3.2 Apply fundamental engineering concepts from fluid mechanics, power electronics, and electrical machines for evaluating component characteristics and system efficiency. (PI 1.3.1) LO3.3 Formulate mathematical models for wind turbine aerodynamics, generator (PMSG/DFIG) speed-torque profiles, and control strategies (e.g., MPPT, pitch control). (PI 2.3.1) LO3.4 Analyse the results of aerodynamic and component modelling to extract conclusions regarding the optimal rotor diameter, rated wind speed, and cut-in/cut-out strategy for efficient energy extraction. (PI 2.4.4) LO3.5 Develop detailed design specifications for the wind system, including rotor diameter, generator type (PMSG/DFIG), and control system requirements (MPPT, pitch control). (PI 3.1.6) LO3.6 Refine the conceptual design into a detailed system design, incorporating the basics of the grid-tied inverter/converter, tower height selection, and thrust load analysis. (PI 3.4.1) LO3.7 Examine and apply the methodology for experiment design and system calibration necessary to perform reliable hardware testing and real-time data acquisition on the wind turbine setup. (PI 4.1.2) LO3.8 Use appropriate hardware testing procedures to systematically evaluate system behaviour (e.g., MPPT efficiency) under varying operational situations and collect real-time data for performance analysis. (PI 4.3.1)	
04.	Design considerations for Hydro, Biomass, and Geothermal Systems Learning Objectives: To enable learners to understand design considerations of micro-hydro, biomass, geothermal and other emerging renewable energy technologies. Contents: Small Hydropower Design Considerations: Resource Assessment, Hydraulic Design, Turbine Selection, Electrical Design. Biomass Conversion System Design Considerations: Feedstock Handling, Thermo-chemical Design, Biochemical Design (Biogas) Geothermal Power Plant Design Considerations: Cycle Selection, Plant Design, etc. Self-Learning Topics: Micro-Hydro Hydraulics, Biomass Conversion Prep, Geothermal Resource Basics Learning Outcomes: A learner will be able to LO4.1 Apply fundamental engineering concepts (e.g., fluid dynamics, mass and energy balance, and thermodynamics) to the design and sizing of small hydropower, biomass conversion, and geothermal systems. (PI 1.3.1) LO4.2 Apply mechanical engineering concepts in hydraulic design, turbine selection, feedstock handling, and thermo-chemical conversion for biomass systems. (PI 1.4.1) LO4.3 Determine the functional requirements and preliminary specifications for key system choices, including micro-hydro turbine type, biomass reactor design, and geothermal power cycle selection. (PI 3.1.6) LO4.4 Evaluate and determine the functional requirements and preliminary specifications for micro-hydro, biomass, and geothermal systems by analysing the socio-economic and environmental impacts of alternative technological solutions to ensure sustainable development. (PI 3.1.6, PI 6.3.2) LO4.5 Apply principles of sustainable development to design decisions, focusing on long-term resource reliability (water, feedstock) and waste management in all three energy domains. (PI 6.3.4)	7
05.	Design of Energy Storage Systems	6

	Learning Objective/s: To equip learners with the ability to size energy storage technologies.	
	Contents: Battery sizing (capacity, DoD, C-rate, autonomy days, round-trip efficiency), Series/parallel configuration design, Super capacitor bank sizing for transient support, Design of bidirectional DC-DC converter for battery, Charging/discharging control and protection threshold design, Integration with PV/wind: DC-link design and balancing, Thermal design and BMS configuration (cell monitoring, safety).	
	Self-Learning Topics: Safety and Standards	
	Learning Outcomes: A learner will be able to LO5.1 Apply mathematical techniques to models for battery sizing, including parameters like capacity, DoD, C-rate, autonomy days, and efficiency for system sizing. (PI 1.1.2) LO5.2 Apply fundamental engineering concepts of power electronics and electrical circuits to design the series/ parallel configuration, and bidirectional DC-DC converter for battery integration. (PI 1.3.1) LO5.3 Combine scientific principles and engineering concepts to Formulate mathematical models for super capacitor bank sizing to provide transient support and for the charging/discharging behaviour of the storage system. (PI 2.3.1) LO5.4 Analyse the system requirements from the PV/wind source to extract conclusions regarding the optimal DC-link voltage and balancing strategies required for integration. (PI 2.4.4) LO5.5 Determine design specifications for the energy storage system, including battery sizing, converter topology, protection and BMS configuration. (PI 3.1.6) LO5.6 Justify the selection of the optimal Battery Management System (BMS) configuration (e.g., cell monitoring topology) and thermal management strategy by comparing alternatives against design, safety, and performance criteria. (PI 3.3.1)	
06.	Design Considerations for Hybrid Renewable Energy Systems & AI-Based Optimization	6
	Learning Objective/s: To guide learners in designing hybrid multi-source energy architectures and in applying appropriate energy optimization strategies for efficient system performance.	
	Contents: Architecture selection: (PV-Wind, PV-Hydro, PV-Biomass, PV-Wind-Battery); Power electronics coordination and DC-link voltage coordination in multi-source systems; Energy management strategies (priority-based, rule-based, AI-based); Sizing methodology for multi-source systems; Microgrid operation: steady-state & transient design considerations.	
	Self-Learning Topics: Advanced EMS, Techno-Economic Analysis, Microgrid Stability (Black Start procedure and intelligent, priority-based load shedding techniques.)	
	Learning Outcomes:	
	A learner will be able to LO6.1 Identify the critical coordination variables and parameters (e.g., resource availability, load demand, component state-of-charge) necessary for	

	<i>modelling hybrid multi-source energy systems (PV-Wind-Battery, etc.). (PI 2.1.2)</i> <i>LO6.2 Combine scientific principles and engineering concepts to formulate energy management models to implement different strategies for coordinating power flow among multiple sources (PV, Wind, Battery, etc.). (PI 2.3.1)</i> <i>LO6.3 Determine comprehensive design specifications for hybrid system architectures, including component-sizing methodology for multi-source systems. (PI 3.1.6)</i> <i>LO6.4 Evaluate and justify alternative hybrid architecture selections (e.g., PV-Wind vs. PV-Biomass) and energy management strategies (rule-based vs. AI-based) based on resource and load characteristics. (PI 3.2.1)</i> <i>LO6.5 Recognize the need and be able to clearly explain the importance of AI-based (new and emerging technologies) optimization strategies for advanced energy management and optimization in hybrid systems. (PI 11.2.2)</i> <i>LO6.6 Source and comprehend technical literature on power electronics coordination and AI-based control algorithms to implement suitable energy management strategies. (PI 11.3.1)</i>	
	Course Conclusion Upon completion of this course, learners will have developed the capability to design, evaluate, and integrate multiple renewable energy technologies into practical and sustainable energy systems. They will be able to apply engineering fundamentals and analytical methods to optimize system performance under real-world conditions. By engaging with emerging technologies, sustainability considerations, energy storage strategies, and hybrid system architectures. The course builds a strong foundation for advanced study, research, and professional practice in renewable energy engineering.	01
Total		45

Performance Indicators:

P.I. No. P.I. Statement

- 1.1.2 Apply advanced mathematical techniques to model and solve electrical engineering problems
- 1.3.1 Apply fundamental engineering concepts to solve engineering problems
- 1.4.1 Apply Mechanical engineering concepts to solve engineering problems.
- 2.1.2 Identify engineering systems, variables, and parameters to solve the problems.
- 2.3.1 Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
- 2.4.3 Identify sources of error in the solution process, and limitations of the solution.
- 2.4.4 Extract desired understanding and conclusions consistent with objectives and limitations of the analysis.
- 3.1.6 Determine design objectives, functional requirements and arrive at specifications.
- 3.2.1 Apply formal idea generation tools to develop multiple engineering design solutions.
- 3.3.1 Apply formal decision-making tools to select optimal engineering design solutions for further development.
- 3.4.1 Refine a conceptual design into a detailed design within the existing constraints (of the resources)
- 4.1.2 Examine the relevant methods, tools and techniques of experiment design, system calibration, data acquisition, analysis and presentation.
- 4.1.3 Apply appropriate instrumentation and/or software tools to make measurements of physical quantities.
- 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.
- 6.3.2 Understand the relationship between the technical, socio-economic and environmental dimensions of sustainability.
- 6.3.4 Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline.
- 11.2.2 Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field.
- 11.3.1 Source and comprehend technical literature and other credible sources of information.

Course Outcomes:

A learner will be able to -

1. Apply engineering fundamentals to estimate loads, analyse site-specific renewable resource data, and derive design specifications using standard datasets. (LO1.1, LO1.2, LO1.3, LO1.4)
2. Design and analyse solar photovoltaic and thermal systems. (LO2.1, LO2.2, LO2.3, LO2.4, LO2.5, LO2.6, LO2.7, LO2.8)
3. Design and analyse wind energy conversion systems. (LO3.1, LO3.2, LO3.3, LO3.4, LO3.5, LO3.6, LO3.7, LO3.8)
4. Specify the design requirements and technical feasibility of Hydro, Biomass, and Geothermal systems. (LO4.1, LO4.2, LO4.3, LO4.4, LO4.5)
5. Design and integration of Energy Storage devices in renewable energy systems. (LO5.1, LO5.2, LO5.3, LO5.4, LO5.5, LO5.6)
6. Design hybrid renewable energy architectures and apply energy management strategies for optimal multi-source coordination. (LO6.1, LO6.2, LO6.3, LO6.4, LO6.5, LO6.6)

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCRE703.1	3	3									
HMCRE703.2	3	3	3	3		3					3
HMCRE703.3	3	3	3	3							
HMCRE703.4	3		3			3					
HMCRE703.5	3	3	3								
HMCRE703.6		3	3								3
Average	3	3	3	3		3					3

Text Books:

1. B. H. Khan, *Renewable Energy Resources and Emerging Technologies*, 3rd ed. New Delhi, India: McGraw-Hill, 2018.
2. S. P. Sukhatme and J. K. Nayak, *Solar Energy: Principles of Thermal Collection and Storage*, 3rd ed. New Delhi, India: Tata McGraw-Hill, 2017.
3. C. S. Solanki, *Solar Photovoltaics: Fundamentals, Technologies and Applications*, 3rd ed. New Delhi, India: PHI Learning, 2020.
4. J. F. Manwell, J. G. McGowan, and A. L. Rogers, *Wind Energy Explained: Theory, Design and Application*, 2nd ed. Hoboken, NJ, USA: Wiley, 2010.
5. N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*, 3rd ed. Hoboken, NJ, USA: Wiley, 2003.
6. R. A. Huggins, *Energy Storage: Fundamentals, Materials and Applications*, 2nd ed. Cham, Switzerland: Springer, 2016.

Reference Books:

1. V. V. N. Kishore, *Renewable Energy Engineering and Technology: A Knowledge Compendium*, New Delhi, India: TERI Press, 2011.
2. L. Rodriguez and T. Gonzalez, *Small Hydropower Systems Design*, Boca Raton, FL, USA: CRC Press, 2018.
3. H. A. Joshi, *Energy Storage Systems and Power Conversion Electronics*, Boca Raton, FL, USA: CRC Press, 2020.
4. S. Chowdhury, P. Crossley, and S. Chowdhury, *Microgrids and Active Distribution Networks*, London, U.K.: IET, 2009.
5. M. H. Rashid, *Electric Renewable Energy Systems*, Burlington, MA, USA: Academic Press, 2015.

Other Resources:

1. C. S. Solanki, "Solar Photovoltaics," NPTEL Online Course, Indian Institute of Technology Bombay, 2020.
2. IIT Bombay, "Fundamentals of Solar Thermal," NPTEL Online Course, 2018.
3. S. Chakravarty, "Wind Energy Engineering," NPTEL Online Course, Indian Institute of Technology Madras, 2021.
4. IIT Roorkee, "Renewable Energy Engineering," NPTEL Online Course, 2019.
5. N. M. S. Hassan, "Energy Storage Systems," NPTEL Online Course, Indian Institute of Science Bangalore, 2022.
6. G. Narayanan, "Power Electronics," NPTEL Online Course, Indian Institute of Science Bangalore, 2019.
7. IITs, "Artificial Intelligence for Energy Systems," NPTEL Online Course, 2023.

IN-SEMESTER ASSESSMENT (75 MARKS)

1. Continuous Assessment - Theory- (20 Marks)

Assignment on live problems/ case studies, wherein problems are given prior.	:10 Marks
Students are expected to research and collect required resources. They can use the resources and solve the problem on assigned date and time in Institute premises in presence of faculty member.	
Open book test/ Open notes 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
HML	HMLRE701	Renewable Energy Laboratory	2

Examination Scheme		
Continuous Assessment	Practical /Oral	Total
50	-	50

Pre-requisite:

1. HMCRE501- Solar Energy System
2. HMCRE602 - Wind Energy System

Program Outcomes addressed:

1. PO2: Problem analysis
2. PO5: Modern Tool Usage
3. PO8: Individual and team work
4. PO9: Communication
5. PO11: Life-long learning

Course Objectives:

1. To impart the knowledge on various components /sub-systems of renewable energy sources and subsystems with the testing of their functionalities and performance.
2. To impart the knowledge to characterize, evaluate and select/size various renewable energy sources and energy storage elements for a given applications.
3. To impart the knowledge on the analysis and implementation of RE plant design using suitable software tools.

Module	Details	Hrs
	Course Introduction This lab course in renewable energy offers insight and hands-on in use of various renewable energy sources, their characterization, testing, along with their power electronics interfaces. It also includes exploration of plant design for a real life implementation of the RES systems.	
01.	Renewable Energy Sources- Characterization Learning Objective: <i>To acquire the knowledge of various components /sub-systems of renewable energy sources and systems with their functionalities/ performance.</i> Theme for conducting experiment: 1. To characterize solar cell/ module/ panel using actual components / emulator and compare the results with relevant data sheets. Learning Outcomes: <i>A learner will be able to</i> <i>LO 1.1: Identify, assemble, test and analyse the characteristics of various components/sub-systems of RE Sources and compare the results with datasheet. (PI-2.2.2, 2.2.3, PI. 8.2.1,.8.3.1, 11.3.1)</i> Theme for conducting experiments/ simulation: 2. To characterize a wind energy system using actual components / emulator and compare the results with relevant data sheets. Learning Outcomes: <i>A learner will be able to</i> <i>LO 1.2: Use any experimental setup /simulation tool to model wind Energy System, analyze the performance, and assess operation of EV powertrain (PI 2.1.2, 2.2.2, 5.2.1, 5.2.2, 8.2.1,.8.3.1, 11.3.1)</i> Theme for conducting experiments/ simulation: 3. Experimental / Simulation based verification of Fuel cell (FC)/Battery/Ultra-capacitor (UC) characteristics. Learning Outcomes: <i>A learner will be able to</i>	08

	<i>LO 1.3: verify and evaluate the operation of the various energy storage elements with suitable experimental setups or simulation tool (PI 2.1.2, 2.2.2, 5.2.1, 5.2.2, 8.2.1, 8.3.1, 11.3.1)</i>	
02	Power Electronic Interfaces for RE sources Learning Objective: To acquire skill to characterize, evaluate and select/size various renewable energy sources and ES with their power electronic interfaces for a given applications Theme for conducting experiment: 4. To test and characterize PE interfaces for Solar panels / Wind Energy power extraction and optimization. Learning Outcomes: A learner will be able to LO 2.1: Test, characterize and assess the suitability of various types battery cell/modules/pack EV applications. (P.I.-2.2.2, 2.2.3, 4.3.1, 11.2.2, 11.3.1) Theme for conducting experiment: 5. To test and characterize PE interfaces ultra-capacitor cells/modules. 6. To test and characterize PE interfaces for battery cells/pack of different chemistry. 7. To test and characterize PE interfaces for Fuel cells/emulator of different chemistry. Learning Outcomes: A learner will be able to LO 2.2: Test, characterize and assess the performance of PE interfaces for Energy Storage (ES) elements and means to create hybrid ES for a given application. (P.I.-2.2.2, 2.2.3, 4.3.1, 11.2.2, 11.3.1) Theme for conducting experiment/simulation: 8. To test and characterize the PE interfaces for Hybrid Energy Storage (HES) source using battery and ultra-capacitor. Learning Outcomes: A learner will be able to LO 2.3: evaluate the performance of HES source for Power Generation applications. (P.I.-2.2.2, 2.2.3, 4.3.1, 5.2.1, 5.2.2, 11.2.2, 11.3.1)	12
03.	Renewable Energy Plant design Learning Objective: To acquire knowledge on design, and Techno-economic analysis of on-grid and off-grid RE plants. Theme for conducting experiment/simulation: 9. Design the off-grid Solar PV plant size (1kW- 10kW capacity) using suitable software tools. 10. Design the on-grid Solar PV plant size (10kW- 100kW capacity) using suitable software tools. 11. Design the off-grid hybrid RE (SPV/Wind/FC/Micro-hydro/Energy Storage) plant size (1kW- 10kW capacity) using suitable software tools. Learning Outcomes: A learner will be able to LO 3.1: Design and select the RE sources and a balance of system components for off-grid and on-grid plant with the help of suitable software / AI tool. Estimate the performance of the designed plant to match it with real life application. (PI 2.2.2, 2.2.3, 4.3.1, 5.2.1, 5.2.2, 11.3.1)	08
04.	Visit to RE source manufacturing or plant visit Learning Objective: To acquire knowledge of design, installation and commissioning of Renewable energy sources and power plant along with BoS components / systems and protocols.	08

	Theme for visit EV manufacturing / EV charging infra facility: 12. Visit to a facility / industry / research institute carrying out work in the domain of renewable energy 13. Visit to a facility / installation large (>50kW) renewable energy plant (report based on actual field Visit) Learning Outcomes: <i>A learner will be able to</i> <i>LO 4.1: Demonstrate effective communication as individual and present reports as a team for an Industrial visit (PI. 8.2.1, 8.3.1, 11.2.2, 11.3.1)</i>	
	Minimum 2 experiments/simulations from Modules 1 to 3 , two Industrial visit and a Course Project based on Module 3	

Performance Indicators:

P.I. No. P.I. Statement

- | | |
|--------|---|
| 2.1.2 | Identify engineering systems, variables, and parameters to solve the problems |
| 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 |
| 4.1.1 | Define a problem, its scope and importance for purposes of investigation |
| 4.3.1 | Use appropriate procedures, tools and techniques to conduct experiments and collect data |
| 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 |
| 5.2.1 | Identify the strengths and limitations of tools for modeling and simulating engineering designs. |
| 5.2.2 | Demonstrate proficiency in using discipline-specific tools |
| 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 |
| 6.2.1 | Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public |
| 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 |
| 11.2.2 | Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field |
| 11.3.1 | Source and comprehend technical literature and other credible sources of information |

Course Outcomes:

Learner will be able to

- Identify and analyse the functioning of various RE Sources and components/ sub-systems (*LO1.1, LO1.2, LO1.3*).
- Test, characterize and evaluate the performance of PE interfaces for RE / ES sources (*LO2.1, LO2.2, LO2.3, LO4.1*)
- Design and analyse RE System design using software /AI tools to match real world practices (*LO2.1, LO2.2, LO2.3, LO 3.1, LO4.1*).

CO-PO mapping table with correlation level:

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMLRE701.1		3			3			3			3
HMLRE701.2		3		3	3						3
HMLRE701.3		3		3				3			3
Average		3		3	3			3			3

Other Resources: Virtual Lab Website

1. <https://www.vlab.co.in/broad-area-mechanical-engineering> - Energy Storage Labs, Solar Energy lab, Wind Energy Lab
2. <http://vlab.co.in/broad-area-electrical-engineering>

CONTINUOUS ASSESSMENT (50 Marks)*Suggested breakup of distribution*

- Laboratory Exercises: **20 Marks**
- Course Project: **20 Marks**
As a part of Internal Assessment, students will do course mini project as a team to inculcate teamwork.
Students will be tasked with design /develop a small-scale EV sub-system using suitable H/W, Software, Simulation or Emulation platform. This project-based assessment will require students to apply their knowledge and skills gained throughout the course to design and implement a functional system.
Course Project Rules:
 1. Group Size: Groups of 2 to 4 members allowed.
 2. Project Proposal: Detailed proposal with scope, objectives.
 3. Presentation:
 - Present project features, challenges faced, and solutions.
 - Q&A session for evaluation.
 4. Evaluation Criteria:
 - Adherence to requirements and objectives.
 - Effective presentation and Q&A skills.
- Industrial Visit: Students' visit to be arranged to the nearby facility industry involved in design/ manufacturing/ processing. in the EV domain All students shall submit visit report in appropriate format as a part of the submission: **05 Marks**
- Regularity and active participation: **05 Marks**

Course Type	Course Code	Course Name	Credits
Honours	HMCRE804	Grid Integration of Renewable 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. Power Electronics
2. Solar Energy System,
3. Wind Energy System

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 about methodologies, technical requirements, regulatory standards, and safety considerations involved in grid-interfaced renewable energy systems
2. To Introduce case studies and real-life examples that reflect current industry practices, standards, and technologies, helping students connect theoretical concepts to practical applications.
3. To Equip students to contribute to climate change solutions and sustainability, while also encouraging innovation and entrepreneurship in the renewable energy sector.

Module	Details	Hrs
	Course Introduction This course imparts knowledge about the methodologies, technical requirements, regulatory standards, and safety considerations of grid interfaced renewable energy systems. Case studies and real life examples that reflect current industry practices, standards, and technologies are included. Students can connect the course content to how it applies to real-world situations. Equips students to contribute to solutions for climate change and sustainability and encourages entrepreneurship.	01
01.	Introduction <i>Learning Objective/s:</i> To equip students with foundational knowledge of renewable energy integration into the grid, with emphasis on the Indian context, standards, and safety practices. Contents Centralized and Distributed generation, Distributed generation with renewable energy sources, Indian scenario of grid-renewable energy integration, Grid integration requirements, Grid codes and standards like IEEE 1547, IEC 61727, German standards etc, Safety issues, Energy storage options. <i>Self-Learning Topics:</i> India's renewable energy targets and grid modernization efforts. <i>Learning Outcomes:</i> A learner will be able to	03-04

	<i>LO 1.1: Apply electrical engineering concepts to understand the differences between centralized and distributed generation and their roles in modern power systems (PI-1.4.1)</i> <i>LO 1.2: Identify and interpret grid integration requirements, including voltage/frequency regulation, fault ride-through, and reactive power support. (PI- 2.1.2)</i> <i>LO 1.3: Compare and contrast various energy storage options (e.g., batteries, pumped hydro) and their role in balancing renewable energy variability. (PI-2.2.4)</i> <i>LO 1.4: Extract engineering requirements from IEEE and IEC standards to assess and ensure reliable grid integration of renewable energy systems.(PI- 3.1.4)</i>	
02.	Grid Interfaced PV Technologies and its Control Learning Objective: To learn the principles and requirements of grid-connected PV systems and its operational aspects. Contents: Grid connection principle, Requirements of PV-Grid interface, types of interface-double stage and single stage power conversion systems, transformer-less grid interface, DC-DC converters in grid interfaced PV systems, Inverters in grid interfaced PV systems Classification of Inverter arrangement, Grounding issues, Islanding issues. Block diagram of control for PV-Grid interface, MPPT control, Grid Synchronization techniques, Current control strategies and its comparison, Anti-islanding methods. Self-Learning Topics: Learning Outcomes: A learner will be able to <i>LO 2.1: Apply electrical engineering concepts to identify the fundamental requirements for connecting a PV system to an electrical grid, including synchronization of voltage, frequency, and phase. (PI 2.1.3)</i> <i>LO 2.2: Apply fundamentals of preventive engineering to synthesize the requirements for a safe, sustainable grid tied PV system. (PI- 6.3.4, PI-3.1.5)</i> <i>LO 2.3: Combine the scientific principles of power electronics and the engineering concepts of cascaded control to formulate a model for both single-stage and double-stage power conversion architectures and compare in terms of efficiency, cost-per-watt, and transient stability. (PI- 2.3.1)</i> <i>LO 2.4: Articulate specific engineering systems (control loops), variables (current, voltage), and parameters (gains, frequencies) pertaining to different types of grid tied inverter for specific application.(PI: 2.1.1)</i>	08-09
03.	Grid Interfaced Wind Energy Technologies Learning Objective: To equip students with knowledge of wind power plant grid integration, including connection requirements, operational challenges, standards, power quality, and environmental considerations. Contents: Grid integration of wind power plants: Grid connection requirements of WPPs , types of WPP and wind farm grid connections, integration issues, operational issues and challenges in grid integration, wind power grid integration standards, power system stability, power quality management, environmental aspects, introduction to super grid strategy Learning Outcomes: A learner will be able to <i>LO 3.1: Apply the electrical engineering concepts to identify the functional requirements of integrating wind power plants (WPPs) into the grid. (PI- 2.1.3)</i> <i>LO 3.2: Determine the functional requirements, operational issues, standards, and strategies for effective and sustainable wind energy integration (PI 3.1.6, 6.3.4)</i>	05-06

	<i>LO 3.3: Interpret and identify the relevant legislation, grid codes that mandate strict limits on power quality and system stability for protection of public and uninterrupted supply. (PI 2.1.3, 6.2.1)</i>	
04.	IoT Applications in Grid Interfaced PV Systems Learning Objective: <i>To design, implement, and evaluate a comprehensive Internet of Things (IoT) solution for the real-time monitoring, visualization, and control of Photovoltaic (PV) system performance.</i> Contents: Review of basics of IoT architecture (sensors, microcontrollers, communication protocols) ,Real-time monitoring of PV system parameters (voltage, current, temperature, irradiance), Smart meters and energy data logging , Remote diagnostics and predictive maintenance , Communication protocols and their integration with cloud platforms (e.g., Thing Speak, AWS IoT, Blynk). Self-Learning Topics: Nil Learning Outcomes: <i>A learner will be able to</i> <i>LO 4.1: Identify IoT technologies for real-time monitoring of PV system parameters such as voltage, current, temperature, and irradiance. (PI- 2.1.2, 11.2.2)</i> <i>LO 4.2: Identify the engineering knowledge and the relevant computational knowledge required to successfully interface PV system hardware with cloud platforms for real-time data visualization and control. (PI- 2.1.3, 11.2.1)</i>	09-10
05.	Power Quality Issues and Ancillary Services Learning Objective: <i>To examine power quality issues and evaluate the role of ancillary services in ensuring reliable and stable grid integration of renewable energy systems.</i> Contents: Power Quality issues such as Voltage fluctuations, Harmonic distortion, Frequency deviation, DC injection in to the grid. Ancillary services such as Active and Reactive power support, Harmonic compensation by PV inverters, Low voltage ride through capability. Self-Learning Topics: Nil Learning Outcomes: <i>A learner will be able to</i> <i>LO 5.1: Identify the electrical engineering knowledge of power electronics, control theory, and the relevant standards knowledge to mitigate power quality issues such as voltage fluctuations, harmonic distortion, frequency deviation, and DC injection in grid-connected renewable systems. (PI-2.1.3).</i> <i>LO 5.2: Compare and contrast alternative control strategies to achieve ancillary service functions—namely active/reactive power support, harmonic compensation, and low voltage ride-through capability—and select the best process based on trade-offs in performance (speed, accuracy), cost, and control complexity.(PI- 2.2.4)</i>	07-08
06.	Case studies and Real life examples Learning Objective/s: <i>To enable students to apply the principles, components, and design methodologies of grid-connected solar and wind energy systems for residential and utility-scale applications.</i> Contents: Design of on grid PV-grid system for residential application including protection aspects, Design of grid interfaced solar power plants, Design of grid interfaced wind energy systems. Integration of IOT. Case Studies Learning Outcomes:	06-07

	<i>A learner will be able to</i> <i>LO 6.1: Determine design objectives and requirements for grid-connected solar PV systems considering current trends like IOT integration. (PI 3.1.6,11.2.2)</i> <i>LO 6.2: Source and comprehend technical literature and other credible sources of information to design residential and utility-scale renewable energy systems with appropriate protection mechanisms. (PI-11.3.1, 6.2.1)</i> <i>LO 6.3: Determine design objectives and requirements for grid-connected wind energy systems.(PI 3.1.6)</i>	
	Course Conclusion This course has equipped students with comprehensive knowledge of integrating renewable energy systems—such as solar and wind—into the electrical grid. It covered technical requirements, control strategies, grid codes, safety considerations, and emerging technologies like IoT and energy storage. Through case studies and real-life examples, learners are prepared to contribute to sustainable energy solutions and grid modernization efforts in India and globally.	01
Total		45

Performance Indicators:

P.I. P.I. Statement No.

- 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
- 2.1.3 Identify the mathematical, engineering and other relevant knowledge that applies to a given problem
- 2.2.4 Compare and contrast alternative solution processes to select the best process.
- 2.3.1 Combine scientific principles and engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
- 3.1.4 Extract engineering requirements from relevant engineering Codes and Standards such as IEEE, IEC, CEA.
- 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
- 6.2.1 Interpret legislation, regulations, codes, and standards relevant to your discipline and explain its contribution to the protection of the public
- 6.3.4 Apply principles of preventive engineering and sustainable development to an engineering activity or product relevant to the discipline
- 11.2.2 Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field
- 11.3.1 Source and comprehend technical literature and other credible sources of information

Course Outcomes:

Learner will be able to

1. Apply electrical engineering concepts to analyze modern power systems by comparing generation models, grid integration needs, energy storage options and India's renewable energy scenario (*LO 1.1, LO 1.2, LO 1.3*).
2. Design and analyze grid-connected PV systems with respect to synchronization, grid codes, power conversion, and inverter control strategies. (*LO 1.4, LO 2.1, LO 2.2, LO 2.3, LO 2.4, LO 6.1, LO 6.2*).
3. Design and analyse wind power systems and their grid integration by analyzing functional requirements and challenges related to power quality and stability (*LO 1.4, LO 3.1, LO 3.2, LO 3.3, LO 6.3*).

4. Apply IoT and communication technologies for real-time monitoring, cloud integration, and control of photovoltaic systems. (LO 4.1, LO 4.2, LO 6.1).
5. Assess power quality and ancillary services for reliable grid integration of renewable energy systems. (LO 5.1, LO 5.2)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCRE804.1	2	3									
HMCRE 804.2		3	3			3					3
HMCRE 804.3		3	3			3					
HMCRE E804.4		3									3
HMCRE 804.5		3									
Average	2	3	3			3					3

Text Books :

1. S. Heier. Grid integration of wind energy conversion systems. 3rd Ed. John Wiley & Sons: W. Sussex, England, 2014. ISBN: 978-1-119-96294-6.
2. Qing-Chang Zhong; Tomas Hornik, Control of Power Inverters in Renewable Energy and Smart Grid Integration, Wiley-IEEE Press
3. Antonio Moreno-Muñoz- Large Scale Grid Integration of Renewable Energy Sources: Solutions and technologies , 2nd Edition
4. Pallavi Verma, Rachana Garg, and Priya Mahajan-Grid Integration of Renewable Energy Systems
5. M. Kathiresh, A. Mahaboob Subahani, G.R. Kanagachidambaresan Integration of Renewable Energy Sources with Smart Grid, ISBN:9781119750420 © 2021 Scrivener Publishing LLC
6. Dilan Jayaweera -Smart Power Systems and Renewable Energy System Integration

Reference Books :

1. Remus Teodorescu, Marco Liserre, Pedro Rodriguez- Grid Converters for Photovoltaic and Wind Power Systems, Wiley-IEEE Press, Print ISBN: 9780470057513
2. Anuradha Tomar, B Rajanarayan Prusty, Neeraj Gupta - Renewable Energy Integration to the Grid: A Probabilistic Perspective
3. Siegfried Heier Grid Integration of Wind Energy: Onshore and Offshore Conversion Systems, ISBN:9781119962946, Copyright © 2014 John Wiley & Sons, Ltd
4. Majid Jamil, M Rizwan, D P Kothari Grid Integration of Solar Photovoltaic Systems, ISBN 9781498798327, CRC Press

Other Resources :

1. NPTEL Course: Introduction to Smart Grid, Prof. N. P. Padhy, Prof. Premalata Jena, IIT Roorkee

IN-SEMESTER ASSESSMENT (50 MARKS)

Suggested breakup of distribution

1. Continuous Assessment (20 Marks)
 - Assignments: 10 Marks
 - Presentation: 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
HMP	HMPXX801	Honours/Minor Mini Project	02

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: Modern Tool Usage
6. PO6: The Engineer & World
7. PO7: Ethics
8. PO8: Individual & team work
9. PO9: Communication
10. PO10: Project Management & Finance
11. PO11: Life-long learning

Course Objectives

1. To guide students in identifying specialization-domain problems
- 2.. To explore advanced solutions using emerging technologies and specialized tools.
3. To develop research aptitude, innovation mindset, entrepreneurship potential, and lifelong learning skills.
- 4.. To foster self-directed learning, domain-specific competency, and collaboration.

Course Outcomes

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

CO1: Identify and articulate a domain-relevant societal, industrial, or research problem using literature review and analysis.

CO2: Apply engineering principles and specialized tools to design innovative and feasible technical solutions.

CO3: Conduct investigations, simulations, or experiments to validate the proposed solution using appropriate methods.

CO4: Evaluate the solution considering sustainability, ethics, feasibility, and potential for commercialization or IP.

CO5: Demonstrate teamwork, project management, and professional technical communication through reports and presentations.

CO6: Engage in self-directed learning and continuous improvement to enhance domain expertise and professional growth.

Guidelines for the Mini Project

- Projects should align with the Honors/Minor specialization domain
- Mini project may be carried out in one or more form of following:

Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc. • Students must form groups of 3 to 4 members. • Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty. • An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted. • Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor. • Faculty input should emphasize guiding by faculty and self-learning by group members. • Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model. • The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report. • With the focus on self-learning, innovation, research orientation, addressing societal and industry challenges, and developing entrepreneurship qualities among students, the Mini Project should reflect appropriate depth, technical sophistication, specialization-domain relevance, and quality. Students are encouraged to adopt an innovative approach, explore emerging technologies, and demonstrate prototype development, domain-specific research outputs, or commercialization potential, rather than limiting to basic model implementation.
In-Semester Continuous Assessment and End-Semester Examination Guidelines • The coordinating Head of the Department will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations in a semester. • Assessment will be based on individual contributions, understanding, and responses to questions asked. • Continuous Assessment marks distribution (50 marks): ○ 20 marks for the Topic Approval Presentation in front of the progress monitoring committee ○ 20 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee ○ 10 marks for regularity & active participation The review/progress monitoring committee will assess projects based on the following criteria. • Theoretical solution completion, including component/system selection/design of software solution and cost analysis. • Two reviews will occur: ○ The first review will focus on finalizing the problem statement (topic approval). ○ Second review will assess the progress of building a working prototype. (Mid Semester Presentation)

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. Quality of survey and need identification aligned with specialization or societal/industry relevance.
2. Clarity and innovativeness in problem definition and solution Clarity, originality, and innovativeness in problem definition, solution approach, and use of advanced tools/techniques.
3. Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.
4. Completeness and full functioning of the working model.
5. Effective use of skill sets and engineering norms.
6. Verification & validation of the solutions/test cases.
7. Individual contributions to the group.
8. Clarity in written and oral communication.
9. Participation in research paper presentation, domain-specific competitions, hackathons, demonstrations, start-up pitching, or innovation challenges.

End-Semester Examination (50 marks):

1. Presentation and demonstration to internal and external examiners: 20 marks.
2. Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.

Syllabi
Honours/Minor:
Power electronics and Drives
-Track

Curriculum Structure – Honours/Minor: Power electronics and Drives-Track

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		L	P	T	L	P	T	Total
HMCPD501	Special Electric Machines & Drives	3	--	--	3	--	-	3
HMCPD602	Industrial Drives	3	--	--	3	--	--	3
HMCPD703	Power Converters and Control for Drives	4	--	--	4	--	--	4
HMLPD701	Advance Drives Laboratory	--	4	--	--	2	--	2
HMCPD804	Design of Electrical Drives	4	--	--	4	--	--	4
HMPPD801	Mini Project	--	6	--	--	2	--	2
Total		14	10	--	14	4	--	18

Examination Scheme – Honour/Minor

Course Code	Course Name	Examination Scheme					Total
		In-Semester Assessment		End Sem Exam (ESE)	Exam Duration for Theory (in Hrs)		
		Continuous Assessment	Mid-Sem Exam		Mid-Sem	End-Sem	
HMCPD501	Special Electric Machines & Drives	20	30	50	1.5	2	100
HMCPD602	Industrial Drives	20	30	50	1.5	2	100
HMCPD703	Power Converters and Control for Drives	20	30	50	1.5	2	100
HMLPD701	Advance Drives Laboratory	50	--	--	--	--	50
HMCPD804	Design of Electrical Drives	20	30	50	1.5	2	100
HMPPD801	Mini Project	50	--	50	--	--	100
Total		180	120	250	--	--	550

Course Type	Course Code	Course Name	Credits
HMC	HMCPD501	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
5. PO11: Life-long learning

Course Objectives: To impart knowledge on

1. Comprehend the constructional details of special electrical machines.
2. Impart knowledge on the performance characteristics of special electrical machines.
3. Study applications of different special electrical machines.
4. Impart knowledge 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)	10
	Learning Objective: <i>Apply fundamental concepts of BLDC motors and identify its applications for specific engineering problems.</i>	

	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.	
	Learning Outcomes: A learner will be able to <i>LO 1.1: Apply fundamental concepts of DC and AC motor to understand construction of BLDC motors. (P.I.1.3.1)</i> <i>LO 1.2: Apply fundamental concepts of microcontroller in control techniques of BLDC motors. (P.I. 1.4.1)</i> <i>LO 1.3: Identify suitable rating of BLDC motor in EV applications. (P.I.2.1.2)</i> <i>LO 1.4: Identify existing BLDC motors used in different applications and their ratings. (P.I.2.2.3)</i> <i>LO 1.5: List different BLDC motors used in Electric vehicles in the manufacturer's website, and identify their ratings. (P.I. 11.3.1)</i> <i>LO 1.6: Demonstrate legislation, regulations, codes, and standards followed by the industry to manufacture BLDC motors. (P.I. 6.1.1) (P.I.6.2.1)</i> <i>LO 1.7: Comprehend information and instructions based on practical insights of induction motor observed in manufacturing industry and produce clear, well-constructed, and well-supported report. (P.I.9.1.2) (P.I.9.2.1)</i>	
02.	Permanent Magnet Synchronous Motor (PMSM)	09
	Learning Objective: To comprehend performance of PMSM motors and identify its applications for specific engineering problems.	
	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.	
	Learning Outcomes: A learner will be able to <i>LO 2.1: Apply basic mathematical techniques to drive EMF and torque equation of PMSM motors. (P.I.1.1.1)</i> <i>LO 2.2: Apply fundamental concepts phasors to draw phasor diagram of PMSM motors. (P.I. 1.4.1)</i> <i>LO 2.3: Identify different parameters and determine their ratings in EV applications. (P.I.2.1.2)</i> <i>LO 2.4: Compare control techniques of PMSM motors and select best technique for specific application. (P.I. 2.2.4)</i> <i>LO 2.5: List different PMSM motors used in Electric vehicles in the manufacturer's website, and identify their ratings. (P.I. 11.3.1)</i>	
03	Switched Reluctance Motors (SRM)	08

	Learning Objective: <i>Use characteristics of Switched reluctance motors to select in different industrial applications.</i> Content: 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: <i>Learner will be able to</i> LO 3.1: <i>Apply basic mathematical techniques to drive EMF and torque equation of SRM motors. (P.I.1.1.1)</i> LO 3.2: <i>Apply fundamental concepts phasors to draw phasor diagram of SRM motors. (P.I. 1.4.1)</i> LO 3.3: <i>Identify objective of Rotor position sensors and analyze different schemes (P.I.2.1.1)</i> LO 3.4: <i>Compare different power converter circuits and select suitable one for engineering applications. (P.I. 2.2.4)</i>	
04.	Stepper Motors Learning Objective: <i>Compare different types of Stepper motors and select suitable one for industrial applications.</i> 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: <i>Apply basic mathematical techniques to drive torque equation of Stepper motors. (P.I.1.1.1)</i> LO 4.2: <i>Apply fundamental concepts electrical engineering to analyze characteristics of stepper motors. (P.I. 1.4.1)</i> LO 4.3: <i>Compare different types of Stepper motors and their characteristics to select suitable motor for given application. (P.I. 2.2.4)</i> LO 4.4: <i>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)</i>	07
05.	Synchronous Reluctance Motors (SyRM) Learning Objective: <i>Analyze performance of SyRM and select in suitable engineering applications.</i> Content: Construction, working principle, phasor diagram, torque equation, Introduction to control of SyRM, advantages of SyRM, applications	05

	Learning Outcomes: <i>Learner will be able to</i> <i>LO 5.1: Apply basic mathematical techniques to drive torque equation of SyRM. (P.I.1.1.1)</i> <i>LO 5.2: Apply fundamental concepts of phasors and draw phasor diagram of SyRM. (P.I. 1.4.1)</i> <i>LO 5.3: Identify engineering systems in which SyRM motors are used and find their ratings. (P.I. 2.1.2)</i> <i>LO 5.4: Extract desired understanding and conclusions consistent with objective of control technique used in SyRM. (P.I.2.4.4)</i>	
06.	Linear Induction Motors <i>Learning Objective/s:</i> <i>Analyze basic working principle of Linear Induction motors and identify its applications.</i> Content: Construction, Thrust equation of Linear Induction motors, Goodness factor, equivalent circuit of LIM, characteristics of LIM, design aspects, applications. <i>Learning Outcomes:</i> <i>A learner will be able to</i> <i>LO 6.1: Apply basic mathematical techniques to drive thrust equation and Goodness factor of Linear Induction motors. (P.I.1.1.1)</i> <i>LO 6.2: Apply fundamental knowledge of Linear Induction motors to draw its equivalent circuit. (P.I. 1.4.1)</i> <i>LO 6.3: Select Linear Induction Motor and apply design concepts to get different parameters. (P.I. 2.1.1)</i> <i>LO 6.4: Identify engineering systems in which LIM motors are used and find their ratings. (P.I. 2.1.2)</i>	04
	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.

Course Outcomes: Learner will be able to

1. Identify the suitability of BLDC motors for various industrial/ automotive applications and produce a clear, well-structured, and well-supported report based on observations and technical insights gained during an industrial visit. (LO 1.1, LO 1.2, LO 1.3, LO 1.4, LO 1.5, LO 1.6, LO 1.7)
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, LO 2.5)
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 ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCPD501.1	3	3				3			3		3
HMCPD501.2	3	3									3
HMCPD501.3	3	3									
HMCPD501.4	3	3									
HMCPD501.5	3	3									
HMCPD501.6	3	3									
Average	3	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

An industrial visit is to be arranged as part of the course.

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 Team Work
6. PO11: Life long 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 <i>Learning Objective: To comprehend basic concepts of electrical drives in particular application.</i>	5
	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)	7
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)	6

	<i>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)</i> <i>LO 3.4: Determine key design objectives and functional requirements for motor applications. (PI-3.1.6)</i> <i>LO 3.5: Identify suitable evaluation criteria for comparing different motor designs. (PI-3.2.3)</i>	
04.	DC/AC Drives Learning Objectives: To impart knowledge on basic concepts of DC/AC motor drives and their applications in Industry. 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: <i>Regenerative braking and energy recovery systems.</i> Learning Outcomes: A learner will be able to <i>LO 4.1: Apply fundamental concepts of DC/AC motor and drives to solve engineering problems. (PI-1.3.1).</i> <i>LO 4.2: Apply Electrical Engineering concepts to analyze operation of different drive systems for given engineering problem. (PI-1.4.1)</i> <i>LO 4.3: To identify control method for DC/AC drive application. (PI-2.2.3)</i> <i>LO 4.4: Identify and select the best control technique in DC/AC drives for given engineering problem. (PI-2.2.4)</i>	10
05.	Special Purpose Drives Learning Objective/s: To impart knowledge on basic concepts of special motor drives and their applications in Industry. 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: <i>Electric and Hybrid Electric Vehicles.</i> Learning Outcomes : A learner will be able to <i>LO 5.1: Apply fundamental concepts of special purpose drives to solve engineering problems. (PI-1.3.1)</i> <i>LO 5.2: Apply Electrical Engineering concepts to analyze operation of different special purpose drive systems for given engineering problem. (PI-1.4.1)</i> <i>LO 5.3: Identify suitable special purpose motor drive for particular application. (PI-2.1.2)</i>	8

	<i>LO 5.4: Identify and select suitable special purpose drives for given engineering problem. (PI-2.2.4)</i>	
06.	Energy Efficiency and Drive Applications <i>Learning Objective/s: To impart knowledge on energy efficient practices in Industrial drive applications.</i> Contents: Energy-efficient drive systems and techniques. Case studies of industrial applications: Conveyor systems, rolling mills, electric traction, electric vehicles, robotics. Drive selection for energy-saving applications. <i>Self-Learning Topics: Case Studies on Industrial Applications.</i> Learning Outcomes: A learner will be able to <i>LO 6.1: Apply fundamental concepts of energy efficient drive systems and techniques to solve engineering problems. (PI-1.3.1)</i> <i>LO 6.2: Apply Electrical Engineering concepts to analyze energy efficient technologies in drives for given engineering problem. (PI-1.4.1)</i> <i>LO 6.3: Identify energy efficient solution for a specific Industrial Drive application. (PI-2.1.2)</i> <i>LO 6.4: Identify and select the suitable energy efficient technique in electrical drives for given engineering problem. (PI-2.2.4)</i> <i>LO 6.5: Describe energy efficient techniques and their management in Industrial Drive applications. (PI-6.3.3)</i> <i>LO 6.6: Apply principles of preventive engineering and sustainable development to an electrical engineering product/system design. (PI. -6.3.4)</i> <i>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)</i>	7
	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.

Course Type	Course Code	Course Name	Credits
HMC	HMCPD703	Power Converters and Control for 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. HMCPD501: Special Electric Machines & Drives
2. HMCPD602- Industrial drives

Program Outcomes addressed:

1. PO2: Problem analysis
2. PO3: Design/Development of Solutions
3. PO5: Engineering tool usage
4. PO8: Individual and team work:
5. PO11: Life-long learning

Course Objectives: To impart knowledge on

1. The role and operation of power converters for electric drives.
2. The control of DC drives using various DC–DC converter configurations.
3. Scalar and vector control strategies for induction motor drives.
4. Sensor-less and advanced control techniques for AC and synchronous machine drives.
5. Various drive solutions for industrial, electric-vehicle, and renewable-energy applications.

Module	Details	Hrs
	Course Introduction This course provides a comprehensive foundation in the power-electronic interfaces and control strategies that enable high-performance electric drive systems. It examines the operation, modelling, and control of DC–DC converters and inverter topologies that regulate torque, speed, and flux in DC motors, induction motors, and permanent magnet synchronous motors. The course integrates analytical methods, simulation-based evaluation, and application-oriented insights across industrial automation, electric mobility, and renewable-energy conversion	01
01.	Role of power converters in Drives. <i>Learning Objective:</i> Analyze working of different types of converters and identify their effective control strategies. Content: DC-DC Converters, buck-boost, bidirectional DC-DC Converters, effect of parasitic elements, performance analysis, controller design for DC-DC converters, Three Phase Inverter, Voltage Source Inverter and Current source inverter, PWM Techniques- Sine PWM, Space Vector PWM, Hysteresis Control, Comparison of PWM techniques.	06-08

	Learning Outcomes: <i>A learner will be able to</i> 1. Apply fundamental mathematical concepts to derive output equations of dc-dc converters. (P.I. 2.1.3) 2. Design and analysis of DC–DC converters, inverters and their controllers. (P.I. 2.2.3) 3. Interpret engineering standards for designing power electronic systems. (P.I. 3.1.4) 4. Define design objectives, functional requirements, and formulate specifications for the converters/inverters. (P.I.3.1.6)	
02.	DC Machine drives	07-09
	Learning Objective: <i>Analyze different solid-state converter configurations used for controlling DC drives.</i>	
	Content: Single phase fully controlled rectifier control of dc separately excited motor (Continuous conduction mode): One quadrant operation, two quadrant operation, four quadrant operation, chopper control of separately excited dc motor; One quadrant operation, two quadrant operation, four quadrant operation, machine control with voltage controlled dc-dc converter.	
	Learning Outcomes: <i>A learner will be able to</i> 1. Determine the electrical, mathematical, and machine-related principles required to analyze converter-fed DC drive systems. (PI 2.1.3) 2. Compare different converter topologies, quadrant modes, and control strategies and choose the most effective method for a given drive application. (PI 2.4.4) 3. Use modern engineering tool to check performance of dc drives and present result as a team. (PI 5.1.1., PI 8.3.1) 4. Demonstrate proficiency in using modern tools to compare performance of different dc drives and present them with effective communication implementing the norms of practice. (PI 5.2.2, PI 8.1.2)	
03	Control of Induction motor drives	08-10
	Learning Objective: <i>Analyze different control methods for induction motor drives and assess their performance.</i>	
	Content: Induction motor: dq model, small signal model, Scalar control: voltage fed inverter control- open loop Volts/Hz control, Energy conservation effect by variable frequency drive, speed control with slip regulation, speed control with torque and flux control, current controlled voltage fed inverter drive, Current-fed Inverter control, speed and flux control in current fed inverter drive.	
	Learning Outcomes: <i>Learner will be able to</i> 1. Identify and analyze different speed control methods of Induction motor and select suitable one for the given drives. (P.I. 2.2.3) 2. Analyze different control techniques of Induction motor drives and interpret objective and limitations of each analysis. (P.I.2.4.4) 3. Use modern engineering tool to analyze and evaluate Induction motor drives speed control techniques and present result as a team. (PI 5.1.1., PI 8.3.1) 4. Demonstrate proficiency in using modern tools to compare performance of different Induction motor drives speed control techniques and present them with effective	

	<i>communication implementing the norms of practice. (PI 5.2.2, PI 8.1.2)</i>	
04.	Sensor-less control of Induction motor	06-08
	Learning Objective: <i>Identify different sensor less speed control techniques of Induction motor and analyze their performance,</i>	
	Content: Speed estimation methods, slip calculations, direct synthesis from state equations, model reference adaptive system (MRAS), speed adaptive flux observer (Luenberger Observer), extended Kalman filter (EKF).	
	Learning Outcomes: 1. <i>Identify different methods of speed estimations and slip calculations of 3 phase Induction motor.(P.I. 2.1.2)</i> 2. <i>Compare operation of different rotor speed calculation methods and interpret suitable one for an application. (P.I.2.2.4)</i>	
05.	Synchronous Machine Drives	06-08
	Learning Objective: <i>Identify different control strategies for synchronous machine drives and analyze their operating characteristics.</i>	
	Content: Sinusoidal SPM Machine drives- open loop Volts/ Hz control, self control model, absolute position encoder, optical encoder, analog resolver with encoder; Vector control.	
	Learning Outcomes: <i>Learner will be able to</i> 1. <i>Analyze working of different speed control techniques of Synchronous machine drives and identify effective method for a given application. (PI 2.2.4)</i> 2. <i>Compare different rotor position sensing devices and select suitable one for a given application. (P.I. 2.4.4)</i>	
06.	Case studies	04-06
	Learning Objective/s: <i>Explore real-world applications of power electronics and drive systems in industry, transportation, and renewable energy.</i>	
	Content: • Industrial Applications of Drives • Drives in Electric Vehicles and Hybrid Electric Vehicles • Power Electronics in Renewable Energy Systems	
	Learning Outcomes: <i>A learner will be able to</i> 1. <i>Identify different drives used in industries and choose suitable drive systems for different applications. (P.I. 2.1.2)</i> 2. <i>Select appropriate drive configurations for electric and hybrid vehicle applications. (P.I. 2.2.3)</i> 3. <i>Refer technical literature and credible sources for solving real life problems (Industrial Drives / EV & HEV / Renewable-energy drives), perform a detailed analysis of the power electronics/drives involved, and present findings as a team. (P.I. 8.3.1, P.I. 11.3.1)</i> 4. <i>Analyze technical and popular information for feasibility, viability, sustainability in</i>	

	<i>the given case studies and present findings with effective communication skills.(P.I. 8.2.1, P.I.11.3.2)</i>	
	Course Conclusion:	01
Total		45

Performance Indicators:

P.I. No. P.I. Statement

- 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.
- 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.
- 3.1.6 Determine design objectives, functional requirements and arrive at specifications.
- 5.1.1 Identify modern engineering tools such as computer-aided drafting, modeling and analysis; techniques and resources for engineering activities
- 5.2.2 Create/adapt/modify/extend tools and techniques to solve engineering problems.
- 8.1.2 Implement the norms of practice (e.g. rules, roles, charters, agendas, etc.) of effective team work, to accomplish a goal.
- 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. Use analytical and design methods to derive converter equations for power electronic systems used in different drives. (P.I.2.1.3, P.I. 2.2.3, P.I.3.1.4, P.I.3.1.6)
2. Analyze different DC-drive configurations using appropriate analytical principles and simulation tools, then select the most suitable one for given application. (P.I.2.1.3, P.I. 2.4.4, P.I. 5.1.1, P.I. 5.2.2, P.I. 8.1.2, P.I. 8.3.1)
3. Evaluate the suitability of different control strategies of induction motor for achieving the desired speed torque characteristics of the given application.(P.I. 2.2.3, P.I.2.4.4, P.I. 5.1.1, P.I. 5.2.2, P.I. 8.1.2, P.I. 8.3.1)
4. Identify various speed-estimation methods for induction motors and compare their performance to select the most suitable method for a given application.(P.I.2.1.2 ,P.I. 2.2.4)
5. Analyze various synchronous-machine speed-control techniques to determine the most suitable control approach for a given application.(P.I.2.2.4,P.I. 2.4.4)
6. Identify and select appropriate power electronic drive systems for industrial, EV/HEV, and renewable applications, supported by technical data, feasibility criteria, and sustainability considerations. (P.I.2.1.2, P.I. 2.2.3, P.I.8.2.1, P.I.8.3.1, P.I. 11.3.1, P.I.11.3.2)

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCPD703.1		3	3								
HMCPD703.2		3			3			3			
HMCPD703.3		3			3			3			
HMCPD703.4		3									
HMCPD703.5		3									
HMCPD703.6		3						3			3
Average		3	3		3			3			3

Text Books :

1. Modern Power Electronics and AC Drives by Bimal K. Bose, Upper Saddle River, NJ, USA: Prentice Hall, 2002.
2. Analysis of Electric Machinery and Drive Systems by Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven D. Pekarek John Wiley & Sons, 22 May 2013
3. Power Electronics: Converters, Applications, and Design by N. Mohan, T. M. Undeland, and W. P. Robbins, 3rd ed. Hoboken, NJ, USA: Wiley, 2003

Reference Books :

1. Sensorless Vector and Direct Torque Control by P. Vas, New York, NY, USA: Oxford Univ. Press, 1998.
2. Fundamentals of Electrical Drives by G. K. Dubey, Narosa Publication
3. Electric Motor Drives: Modelling, Analysis and Control by Krishnan R, PHI

IN-SEMESTER ASSESSMENT (50 MARKS)

1. Continuous Assessment (20 Marks)

Suggested breakup of distribution

Assignment on live problems/ case studies: 10 Marks

Article reading & summarization: 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
HML	HMLPD701	ADVANCED DRIVES LABORATORY	01
Continuous Assessment		Total	
50		50	

Pre-requisite:

1. HMCPD501: Special Electric Machines & Drives
2. HMCPD602: Industrial Drives
3. HMCPD703: Power Converters and Control for Drives

Program Outcomes addressed:

1. PO2: Problem analysis
2. PO4: Conduct investigations of complex problems
3. PO5: Engineering tool usage
4. PO8: Individual and Collaborative Team work
5. PO11: Life-long learning

Course Objectives: To impart knowledge on

1. Various subsystems of electrical drives.
2. Steady state and transient analysis of electrical drives.
3. Simulation, analysis and implementation aspects of electrical drives.

Module	Details	Hrs
	Course Introduction The Advanced Drives Laboratory focuses on modern electrical drive systems and control techniques, including vector control of induction motors, control of permanent magnet synchronous and brushless DC motors, and adaptive control strategies. By engaging in practical experiments, students gain hands-on experience in implementing and tuning drive systems used in applications such as electric vehicles, robotics, and industrial automation.	
01.	Learning Objective: <i>To acquire skill on simulation, analysis and implementation of power modulator of a drive.</i> Simulations: 1. Modeling, Simulation, and Performance Analysis of DC Motors using MATLAB. 2. Modeling, Simulation, and Performance Analysis of Three Phase Induction Motors using MATLAB. Learning Outcome: <i>A learner will be able to</i> <i>LO1.1: Use any simulation tool to model DC / three-phase induction motors, analyze its performance, and assess transient operations (PI 2.1.2, 2.2.2, 5.2.1, 5.2.2)</i> Simulation/Experiments: 3. Modeling and Performance Analysis of a PWM Inverter-Fed Induction Motor Drive using MATLAB 4. Experimental Analysis of Components, Functions, and Performance of a PWM Inverter-Fed Induction Motor Drive Learning Outcomes: <i>LO1.2: Analyze the operation and performance of PWM inverter fed induction motor by simulations/experiments. (PI 2.2.1, 2.2.3, 8.2.1, 8.2.3)</i> Simulation/Experiments:	07

	5. Modeling and Performance Analysis of a Chopper controlled DC Drive using MATLAB 6. Experimental Analysis of Components, Functions, and Performance of a Chopper controlled DC Drive Learning Outcomes: A learner will be able to LO1.3: Analyze the operation and performance of chopper fed separately excited DC motor by experiments/simulations. (PI 2.2.2, 2.4.4, 4.1.4, 4.3.3)	
02.	Learning Objective: To acquire knowledge on simulation, analysis and implementation of speed control schemes of induction motor. Simulation/Experiments: 7. Simulation and Performance Analysis of Closed-Loop V/f Control for a Three-Phase Induction Motor 8. Experimental Analysis of Components, Functions, and Performance of a Variable Frequency Drive (VFD) Learning Outcomes: A learner will be able to LO2.1: Analyze the operation and performance of V/f control of three-phase induction motor by simulation. (PI 2.2.2, 2.2.3, 5.2.1, 5.2.2) LO2.2: Examine the various components of a variable frequency induction motor drive and analyze its performance characteristics through experimental observation. (PI 2.2.1, 2.2.3, 8.2.1, 8.2.3) Simulation: 9. Simulation and Performance Analysis of Vector Control (Field-Oriented Control) of Induction Motor Learning Outcomes: A learner will be able to LO2.3: Analyze the operation and performance of vector control of three-phase induction motor by simulation. (PI 2.2.2, 2.2.3, 5.2.1, 5.2.2) Simulation: 10. Simulation and Performance Analysis of Direct Torque Control (DTC) of Induction Motor Learning Outcomes: A learner will be able to LO2.4: Analyze the operation and performance of direct torque control of three-phase induction motor by simulation. (PI 2.2.2, 2.2.3, 5.2.1, 5.2.2)	08
03.	Learning Objective: To acquire knowledge on simulation, analysis and implementation of speed control schemes of PMSM/BLDC motor. Simulation: 11. Speed Control of Permanent Magnet Synchronous Motor (PMSM) Learning Outcomes: A learner will be able to LO3.1: Analyze the operation and performance of speed control of permanent magnet synchronous motor by simulations/experiments. (PI 2.2.2, 2.2.3, 5.2.1, 5.2.2) Experiment: 12. Speed Control of brushless DC (BLDC) Motor. Learning Outcomes: A learner will be able to LO3.2: Analyze the operation and performance of speed control of brushless DC motor by experiments/ simulations. (PI 2.2.2, 2.2.3, 8.2.1, 8.2.3)	07

04.	Learning Objective: <i>To acquire knowledge on adaptive control algorithms in drives application and how to implement simple control algorithms using a microcontroller/digital signal processor (DSP).</i>	08
	Simulation: 13. Simulation and Performance Evaluation of Adaptive Fuzzy Logic Control in Induction Motor Drives 14. Simulation and Performance Evaluation of Model Reference Adaptive Scheme (MRAS) for Speed Estimation of an Induction Motor	
	Learning Outcomes: <i>A learner will be able to</i> <i>LO4.1: Simulate and analyze simple adaptive control scheme in drives application / speed estimation process for sensorless control of an induction motor. (PI 2.2.2, 2.2.3, 5.2.1, 5.2.2)</i>	
	Experiments: 15. Implementation of PWM Control Algorithms for Drive Applications using Microcontroller/DSP	
	Learning Outcomes: <i>A learner will be able to</i> <i>LO4.2: Implement PWM control algorithms in drives application using digital signal processors. (PI 5.2.1, 5.2.2, 11.2.2, 11.3.1)</i>	
	Experiments: 16. Implementation of V/f Control Algorithm for Induction Motor using Microcontroller/DSP.	
	Learning Outcomes: <i>A learner will be able to</i> <i>LO4.3: Implement V/f control algorithms of induction motor using a microcontroller/DSP. (PI 5.2.1, 5.2.2, 11.2.2, 11.3.1)</i>	
	Minimum 2 experiments from each module, and total at least 10 experiments	30

Performance Indicators:

P.I. No. P.I. Statement

- 2.1.2 Identify engineering systems, variables, and parameters to solve the problems
- 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
- 4.1.4 Establish a relationship between measured data and underlying physical principles.
- 4.3.3 Represent data (in tabular and/or graphical forms) so as to facilitate analysis and explanation of the data, and drawing of conclusions
- 5.2.1 Identify the strengths and limitations of tools for (i) acquiring information, (ii) modeling and simulating, (iii) monitoring system performance, and (iv) creating engineering designs.
- 5.2.2 Demonstrate proficiency in using discipline specific tools
- 8.2.1 Demonstrate effective communication, problem solving, conflict resolution and leadership skills
- 8.2.3 Listen to other members
- 11.2.2 Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field
- 11.3.1 Source and comprehend technical literature and other credible sources of information

Course Outcomes:

Learner will be able to

1. Analyze the characteristics of different components of electrical drives under different operating conditions (LO1.1, LO1.2, LO1.3).
2. Simulate electrical drive systems using software tool and analyze the simulation results to assess the performance of the drive systems (LO2.1, LO2.3, LO3.1).
3. Analyze various control techniques used in electrical drives such as scalar control, vector control, direct torque control and adaptive control (LO2.1, LO2.3, LO2.4, LO3.2, LO4.1).
4. Implement simple control algorithms in drives application using microcontroller/digital signal processor (LO2.2, LO4.2, LO4.3).

Text Books:

1. Modern Power Electronics and AC Drives by B. K. Bose, Prentice Hall PTR
2. Advanced Electric Drives: Analysis, Control, and Modeling using MATLAB/Simulink by Ned Mohan, Wiley.
3. Fundamentals of Electrical Drives by G. K. Dubey, Narosa Publication
4. A First Course on Electrical Drives by S. K. Pillai, New Age International.

Reference Books:

1. Electric Motor Drives: Modelling, Analysis and Control by Krishnan R, PHI
2. Power Electronics by Muhammad H. Rashid, Pearson
3. Dynamics and Control of Electrical Drives by Piotr Wach, Springer
4. High Performance AC Drives Modelling Analysis and Control by Mukhtar Ahmad, Springer.

Other Resources :

1. NPTEL Course: Fundamentals of Electric Drives, IIT Kanpur by Prof. Shyama Prasad Das
<https://nptel.ac.in/courses/108/104/108104140/>
2. NPTEL Course: Industrial Drives - Power Electronics, IISc Bangalore by Prof. K. Gopakumar.
<https://nptel.ac.in/courses/108/108/108108077/>
3. NPTEL Course: Industrial Drives, IIT Delhi by Dr. K.R. Rajagopal
<https://nptel.ac.in/courses/108/102/108102046/>
4. Application reports for the implementation of V/f control and indirect vector control of IM, provided by Texas Instruments, Infineon Technologies etc.

CONTINUOUS ASSESSMENT (50 Marks)

Suggested breakup of distribution

- Practical Exercises - 25 Marks
(Each practical can be evaluated for 10 Marks with the following rubrics)
Rubrics for Assessment:
Readiness to perform experiment (02Marks)
Active participation in performance (02 Marks)
Report writing (02 Marks)
Interpretation of result (02 Marks)
Regularity in Submission (02 Marks)
- Mini Project (As part of the Internal Assessment, students will work in teams to carry out a mini project focused on developing various subsystems of electrical drives) - 20 Marks
- Regularity and active participation - 05 Marks

Course Type	Course Code	Course Name	Credits
HMC	HMCPD804	DESIGN OF ELECTRICAL DRIVES	04

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 Electrical Machines And Drives
2. HMCPD602: Industrial Drives

Program Outcomes addressed:

1. PO1: Engineering knowledge
2. PO2: Problem analysis and interpretation of system behaviour
3. PO3 :Design/development of solutions for engineering problems
4. PO4 :Investigation of complex problems (experiments, simulations, analysis)
5. PO5 :Use of modern engineering and IT tools for modelling/analysis
6. PO8: Individual and team work in technical/engineering tasks
7. PO11:Life-long learning and adaptability to modern technologies

Course Objectives:

1. To develop a in controlled strong foundation rectification and closed-loop control for variable speed drives.
2. To apply PWM techniques and inverter topologies, including multilevel inverters, for efficient drive control.
3. To model, simulate, and design control strategies for DC and induction motor drives using modern engineering tools.
4. To enhance problem-solving, design skills, and lifelong learning abilities for modern power electronics and drive system applications.

Module	Details	Hrs.
	Course Introduction Electric drives and power electronics focuses on developing a strong foundation in controlled rectification, AC–DC conversion, motor modeling and closed-loop control for variable-speed applications. It emphasizes understanding pulse width modulation (PWM) techniques and inverter topologies, including multilevel inverters, to achieve efficient and precise drive control. Through modeling, simulation and design of DC and induction motor drives using modern tools and gain practical insights into real-world applications of drive systems and their performance optimization.	01
01.	Controlled Rectification & AC–DC Converters <i>Learning Objective:</i>	07

	- Comprehend the operation of single-phase and three-phase controlled rectifiers for motor drives. - Analyze the effects of firing angle, load types, and supply variations on rectifier performance. - Design of rectifier circuits suitable for variable speed DC drive applications.	
	Contents: Single-phase and three-phase controlled rectifiers, firing angle control, R/RL/motor load, freewheeling diode, performance analysis, power factor and harmonics.	
	Self-Learning Topics: Advantages and disadvantages of controlled rectifiers, effect of firing angle variation, freewheeling diode application, performance parameters such as ripple factor and efficiency.	
	Learning Outcomes: A learner will be able to - LO 1.1: Apply basic electrical engineering techniques to govern the role of controlled rectifiers (PI 1.1.2) - LO 1.2: With fundamental engineering concepts to interpret operation and analyze waveform of controlled rectifiers (PI 1.3.1) - LO 1.3: Identify source and load variation effects and improve rectifier performance. (PI 2.1.2, 11.2.2) - LO 1.4: Compare and contrast rectifier performance under power factor and harmonics. (PI 2.2.4) - LO 1.5: Identify assumptions (mathematical and physical) necessary to allow modeling of controlled rectifier circuits for specific drive applications. (PI 2.3.2, 11.3.2)	
02.	DC Motor Modelling & Closed Loop Control Learning Objective: - Derive mathematical models of DC motors under different operating conditions. - Design for closed-loop controllers for speed and current regulation in DC motor drives. - Evaluate stability and dynamic performance of DC motor drives. Contents: DC motor modeling, transfer function development, open-loop vs closed-loop systems, PI/PID control, speed and current control strategies, stability analysis. Self-Learning Topics: Electrical and mechanical time constants of DC motors, armature and field control, effect of load disturbances, tuning of PI/PID controllers. Learning Outcomes: A learner will be able to - LO2.1: Using fundamental engineering concepts, develop mathematical models for DC motor speed and torque characteristics. (PI 1.3.1) - LO2.2: Apply laws of natural science to models for DC motor speed and torque characteristics. (PI 1.2.1) - LO2.3: Identify existing methods for solving transfer function development including assumptions (PI 2.2.3) - LO2.4: Compare and contrast alternative solution processes to select open-loop vs closed-loop systems with and without PI/PID control (PI 2.2.4) - LO2.5: Apply formal decision-making tools to select and simulate the closed-loop speed and current controllers for motor using modern engineering tool. (PI 3.1.1, 5.2.1) - LO2.6: Refine a conceptual design into a detailed design within of closed-loop performance in terms of stability and dynamic response. using modern engineering tool (PI 3.1.4, 5.2.1)	09
03.	PWM Techniques for Drives	09

	Learning Objective: • Compare various PWM modulation techniques and their performance. • Design and implementation of PWM strategies for inverter-fed drives. • Analyze harmonic reduction and performance improvement with PWM control. Contents: Sine-triangle PWM, current hysteresis control, space vector PWM, harmonic analysis, modulation index, dynamic performance and implementation issues. Self-Learning Topics: Comparison of PWM schemes for different inverter types, effect of switching frequency on harmonics, digital implementation of PWM strategies. Learning Outcomes: A learner will be able to LO3.1: Combine suitable performance features of sine-triangle, hysteresis and space vector for PWM as per drive requirement. (PI 2.3.1) LO3.2: Apply fundamental electrical engineering concepts to solve PWM technique dynamic performance. (PI 1.3.1) LO3.3: Apply electrical engineering concepts to solve PWM different modulation techniques. (PI 1.4.1) LO3.4: Combine scientific principles and engineering concepts to formulate and develop PWM techniques for various drive applications. (PI 2.3.1, 11.3.1) LO3.5: Identify existing processes for solving the problem and get dynamic PWM technique for drives. (PI 2.2.3, 11.3.1)	
04.	Inverters & Multilevel Inverters Learning Objectives: • Determine working principles and characteristics of VSI, CSI, and multilevel inverters. • Design of inverter topology for medium and high-power applications. • Evaluate inverter performance in terms of efficiency and harmonic reduction. Contents: Voltage source inverter (VSI), current source inverter (CSI), multilevel inverter topologies (diode-clamped, flying capacitor, cascaded H-bridge), switching strategies, harmonics, efficiency. Self-Learning Topics: Advantages/disadvantages of VSI, CSI, and multilevel inverters; selection criteria for inverter topologies; practical examples of inverter application in motor drives. Learning Outcomes: A learner will be able to LO4.1: Apply fundamental engineering concepts to determine VSI, CSI and multilevel inverter operations and characteristics. (PI 1.3.1) LO4.2: Apply electrical engineering concepts to compute parameters of inverter topologies for traction and drive applications. (PI 1.4.1) LO4.3: Apply engineering mathematics and computations to evaluate inverter performance for efficiency. (PI 2.4.1) LO4.4: Apply engineering mathematics and computations to evaluate inverter performance for harmonic reduction. (PI 2.4.1)	06
05.	Induction Motor Modeling Learning Objective/s: • Develop mathematical models of induction motors using d–q transformation. • Design and simulation of induction motor models for various load conditions. • Interpret motor performance from simulations and experimental results. Contents: Dynamic modeling of induction motors, equivalent circuit, d–q transformation, torque-speed characteristics, balanced/unbalanced supply modeling, performance analysis. Self-Learning Topics: Interpretation of induction motor equivalent circuit parameters, modeling using MATLAB/Simulink, effect of rotor parameters on performance.	07

	Learning Outcomes: A learner will be able to LO5.1: Apply laws of natural science to motor models for practical applications. (PI 1.2.1) LO5.2: Apply electrical engineering concepts to get experimental results for induction motors. (PI 1.4.1) LO5.3: Identify engineering systems, variables, and parameters to solve motor equivalent circuit. (PI 2.1.2) LO5.4: Identify assumptions necessary to model for induction motors under balanced and unbalanced supply. (PI 2.3.2) LO5.5 Apply formal decision-making tools to select optimal engineering design solutions for motor models for performance analysis. (PI 3.3.1,8.2.1) LO5.6: Refine a conceptual design into a detailed design within the existing constraints to interpret and simulate for induction motors. (PI 3.4.1,8.2.1)	
06.	Design and Control of Variable Frequency Induction Motor Learning Objective/s: • Elucidate scalar (V/f) control principles and limitations. • Design using a case study in variable frequency control schemes for high-performance induction motor drives. • Compare scalar and vector control in efficiency and dynamic performance. Contents: Design for induction motor drive using scalar control (V/f), vector control principle, direct and indirect field-oriented control, inverter-based implementation, performance comparison, control tuning methods. Self-Learning Topics: Comparison of scalar and vector control, implementation of field-oriented control, tuning strategies, practical examples of induction motor control in EV/industrial drives. Learning Outcomes: A learner will be able to LO6.1: Apply decision making to solve scalar control and vector control schemes for induction motor drives. (PI 1.3.1) LO6.2: Apply electrical engineering concepts to elucidate direct and indirect field-oriented control. (PI 1.4.1,11.2.2) LO6.3: Apply formal decision-making tools to select optimal engineering design solutions for inverter-based implementation, performance comparison and control tuning methods. (PI 3.3.1,11.3.2)	06
	Course Conclusion Base of power electronic converters, motor control methods and simulation tools enables engineers to design high-performance, reliable, and intelligent drive systems. These skills strengthen analytical and design abilities while promoting innovation, adaptability and lifelong learning essential for advancing modern electric drive and sustainable energy technologies.	01
Total		45

Performance Indicators:

P.I. No.

P.I. Statement

- | | |
|-------|--|
| 1.1.2 | Apply advanced mathematical techniques to model and solve electrical engineering problems |
| 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 Mechanical 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 engineering concepts to formulate model/s (mathematical or otherwise) of a system or process that is appropriate in terms of applicability and required accuracy.
- 2.3.2 Identify assumptions (mathematical and physical) necessary to allow modeling of a system at the level of accuracy required.
- 2.4.1 Apply engineering mathematics and computations to solve mathematical models
- 3.1.1 Recognize that need analysis is key to good problem definition
- 3.1.4 Extract engineering requirements from relevant engineering Codes and Standards
- 3.3.1 Apply formal decision-making tools to select optimal engineering design solutions for further development
- 3.3.1 Apply formal decision-making tools to select optimal engineering design solutions for further development
- 3.4.1 Refine a conceptual design into a detailed design within the existing constraints (of the resources)
- 5.2.1 Identify the strengths and limitations of tools for (i) acquiring information, (ii) modeling and simulating, (iii) monitoring system performance, and (iv) creating engineering designs.
- 8.2.1 Demonstrate effective communication, problem-solving, conflict resolution and leadership skills
- 11.3.1 Source and comprehend technical literature and other credible sources of information
- 11.2.2 Recognize the need and be able to clearly explain why it is vitally important to keep current regarding new developments in your field
- 11.3.2 Analyze sourced technical and popular information for feasibility, viability, sustainability, etc.

Course Outcomes:

A learner will be able to -

1. Apply mathematical and analytical principles to model and analyze electrical drive systems, including controlled rectifiers, AC–DC converters, and DC motor drives. *(LO1.1, LO1.2, LO2.1, LO3.1, LO4.1 and LO5.1).*
2. Design and develop electrical drive solutions, including closed-loop DC motor controllers, PWM strategies, and inverter topologies, using formal design tools and modeling techniques. *(LO1.3, LO2.2, LO3.2, LO4.2 and LO5.2).*
3. Conduct investigations and analyze performance of motor drives under various operating conditions, including harmonics, torque-speed characteristics, and vector control. *(LO1.4, LO2.3, LO3.3, LO4.3, LO5.3 and LO5.4).*
4. Work effectively in teams and apply engineering tools for modeling, design, and control of variable-speed drive systems, integrating multi-disciplinary knowledge. *(LO3.4, LO4.2, LO6.1)*
5. Involve in life-long learning and develop sustainable drive solutions by applying knowledge, analysis, and modelling to evolving technologies and practical applications. *(LO4.2, LO4.3, LO5.5, LO5.6, LO6.3).*

CO-PO Mapping Table with Correlation Level

CO ID	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
HMCPD804.1	3	3									3
HMCPD804.2	3	3			3						
HMCPD804.3	3	3						3			3
HMCPD804.4			3		3			3			

HMCPD804.5			3							3
Average	3	3	3		3			3		3

Text Books :

1. Marcel Jufer, *Electric Drives: Design Methodology*, Wiley-ISTE, 2009.
2. T.H. Liu (Ed.), *Design and Control of Electrical Motor Drives*, MDPI, 2022.
3. K.T. Chau, C.C. Chan, S.N. Hui, *Electric Vehicle Machines and Drives: Design, Analysis, and Application*, Wiley-IEEE Press, 2015.
4. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, Ali Emadi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design*, CRC Press, 2005.

Reference Books :

1. Kai Borgeest, *EMC and Functional Safety of Automotive Electronics*, IET, 2018.
2. R. Krishnan, *Electric Motor Drives: Modeling, Analysis, and Control*, Pearson, 2010.
3. Vedam Subrahmanyam, *Electric Drives: Concepts and Applications*, McGraw-Hill Education, 2012.

Other Resources :

1. NPTEL Course: Fundamentals of Electric Drives
2. NPTEL Course: EV - Vehicle Dynamics and Electric Motor Drives

IN-SEMESTER ASSESSMENT (75 MARKS)

1. Continuous Assessment - Theory-(20 Marks)

Suggested breakup of distribution

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
HMP	HMPXX801	Honours/Minor Mini Project	02

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: Modern Tool Usage
6. PO6: The Engineer & World
7. PO7: Ethics
8. PO8: Individual & team work
9. PO9: Communication
10. PO10: Project Management & Finance
11. PO11: Life-long learning

Course Objectives

1. To guide students in identifying specialization-domain problems
- 2.. To explore advanced solutions using emerging technologies and specialized tools.
3. To develop research aptitude, innovation mindset, entrepreneurship potential, and lifelong learning skills.
- 4.. To foster self-directed learning, domain-specific competency, and collaboration.

Course Outcomes

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

CO1: Identify and articulate a domain-relevant societal, industrial, or research problem using literature review and analysis.

CO2: Apply engineering principles and specialized tools to design innovative and feasible technical solutions.

CO3: Conduct investigations, simulations, or experiments to validate the proposed solution using appropriate methods.

CO4: Evaluate the solution considering sustainability, ethics, feasibility, and potential for commercialization or IP.

CO5: Demonstrate teamwork, project management, and professional technical communication through reports and presentations.

CO6: Engage in self-directed learning and continuous improvement to enhance domain expertise and professional growth.

Guidelines for the Mini Project

- Projects should align with the Honors/Minor specialization domain
- Mini project may be carried out in one or more form of following:

Product preparations, prototype development model, fabrication of set-ups, laboratory experiment development, process modification/development, simulation, software development, integration of software (frontend-backend) and hardware, statistical data analysis, creating awareness in society/environment etc. • Students must form groups of 3 to 4 members. • Groups should conduct surveys to identify needs and develop problem statements in consultation with faculty. • An implementation plan in Gantt/PERT/CPM chart format covering weekly activities must be submitted. • Each group must maintain a logbook to record weekly progress, to be verified by the faculty supervisor. • Faculty input should emphasize guiding by faculty and self-learning by group members. • Groups should propose multiple solutions, select the best one in consultation with the supervisor, and develop a working model. • The solution to be validated with proper justification and report to be compiled in standard format of the Institute. Software requirement specification (SRS) documents, research papers, competition certificates may be submitted as part of annexure to the report. • With the focus on self-learning, innovation, research orientation, addressing societal and industry challenges, and developing entrepreneurship qualities among students, the Mini Project should reflect appropriate depth, technical sophistication, specialization-domain relevance, and quality. Students are encouraged to adopt an innovative approach, explore emerging technologies, and demonstrate prototype development, domain-specific research outputs, or commercialization potential, rather than limiting to basic model implementation.
In-Semester Continuous Assessment and End-Semester Examination Guidelines • The coordinating Head of the Department will assign a guide to each of the mini-projects and shall form a progress monitoring committee. The guide will carry out weekly monitoring of the project's progress. The committee shall carry out in-semester project evaluation based on presentations with a minimum of two evaluations in a semester. • Assessment will be based on individual contributions, understanding, and responses to questions asked. • Continuous Assessment marks distribution (50 marks): ○ 20 marks for the Topic Approval Presentation in front of the progress monitoring committee ○ 20 marks for the Mid-Semester Progress Presentation in front of the progress monitoring committee ○ 10 marks for regularity & active participation The review/progress monitoring committee will assess projects based on the following criteria. • Theoretical solution completion, including component/system selection/design of software solution and cost analysis. • Two reviews will occur: ○ The first review will focus on finalizing the problem statement (topic approval). ○ Second review will assess the progress of building a working prototype. (Mid Semester Presentation)

In addition to above mentioned points, the following performance criteria shall be included during in-semester continuous assessment:

1. Quality of survey and need identification aligned with specialization or societal/industry relevance.
2. Clarity and innovativeness in problem definition and solution Clarity, originality, and innovativeness in problem definition, solution approach, and use of advanced tools/techniques.
3. Requirement gathering via SRS/feasibility study, cost-effectiveness, and societal impact of proposed solutions.
4. Completeness and full functioning of the working model.
5. Effective use of skill sets and engineering norms.
6. Verification & validation of the solutions/test cases.
7. Individual contributions to the group.
8. Clarity in written and oral communication.
9. Participation in research paper presentation, domain-specific competitions, hackathons, demonstrations, start-up pitching, or innovation challenges.

End-Semester Examination (50 marks):

1. Presentation and demonstration to internal and external examiners: 20 marks.
2. Emphasis on problem clarity, innovativeness, societal impact, functioning of the model, skill utilization, and communication clarity: 30 marks.