M.TECH.
POWER ELECTRONICS AND DRIVES

Curriculum

NATIONAL INSTITUTE OF
TECHNICAL TEACHERS TRAINING AND RESEARCH CHENNAI
Deemed to be University under Distinct Category – A Centrally Funded Technical Institute
CSIR Road, Taramani, Chennai-600113

Regulations 2024

NATIONAL INSTITUTE OF TECHNICAL TEACHERS TRAINING AND RESEARCH CHENNAI

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M. Tech. POWER ELECTRONICS AND DRIVES

REGULATIONS 2024

The Master of Technology Programme in Power Electronics and Drives contributes to the provision of a current and dynamic course in Power Electronics and Drives and their applications. This concentration blends cutting-edge technologies with traditional ones, such as power semiconductor devices, electronics, electromagnetics, digital signal processors, control theory, EMC, and energy technology. The Power Electronics and Drives topics offer you an in-depth grasp of the technologies and scientific disciplines involved in electric energy conversion via power electronic converters and electric machines.

Program Education Objectives (PEOs)

Graduates will demonstrate ability:

- **PEO 1:** To Equip students with the skills and knowledge for a successful career in the power electronics industry, research, and academia.
- **PEO 2:** To Develop the ability to analyze, design, and innovate power electronic converters and drive systems.
- **PEO 3:** To Foster lifelong learning, professional ethics, and adherence to industry standards.
- **PEO 4:** To encourage students to engage in interdisciplinary research and emerging technological fields.

Program Outcomes (POs)

Our graduates by the time of graduation will be able to

- **PO 1:** Demonstrate the ability to independently conduct research, investigations, and development to solve real-world challenges.
- **PO 2:** Exhibit proficiency in writing and presenting comprehensive technical reports and documents.
- **PO 3**: Attain a high level of expertise in the chosen specialization, exceeding the competencies required at the undergraduate level.

- **PO 4**: Apply fundamental science and engineering principles to the design and testing of power electronic systems and drives.
- **PO 5**: Engage with industry professionally and ethically to address societal needs and contribute to sustainable development.
- **PO 6**: Develop and implement cost-effective, advanced technologies in power electronics and drive systems.

Programme Credit Requirement

		PG Certificate	PG Diploma	PG Degree
PCC (Theory)	Credit	6	12	12
	Course	2	4	4
PCC (Lab)	Credit	4	8	8
	Course	2	4	4
PEC / OEC	Credit	9	9	18
	Course	3	3	6
FC	Credit		3	3
	Course		1	1
MC	Credit	3	3	3
	Course	1	1	1
Audit Course	Credit	0	0	0
	Course	2	2	2
IIP	Credit	0	0	8
	Course	0	0	2
PD	Credit	0	5	28
	Course	0	1	2

Minimum Credit Requirement to obtain
PG Certificate – 20 Credits; PG Diploma – 40 Credits; PG Degree – 80 Credits

PCC	Professional Core Courses
PEC	Professional Elective Courses
OEC	Open Elective
FC	Foundation Course
MC	Mandatory Course
AC	Audit Course
IIC	Industrial Integrated Courses
PD	Project Dissertation

Course Structure and Details

PROFESSIONAL CORE COURSES (Theory)			
S. No	Course Code	Course Title	Credits
1	PD24P11	Power Semiconductor Devices	3
2	PD24P12	Special Electrical Machines	3
3	PD24P13	Analysis of Power Converters	3
4	PD24P14	Electric Vehicle Technology	3
PROFESSIONAL CORE COURSES (Laboratory)			
1	PD24P21	Power Converters Laboratory	2
2	PD24P22	Power Electronics and Drives Laboratory	2
3	PD24P23	Analog and Digital Controllers for PE Converters Laboratory	2
4	PD24P24	Design Laboratory for Power Electronics Systems	2
FOUNDATION COURSE			
1	MA24M16	Applied Mathematics for Power Electronics Engineers	3
MANDATORY COURSE			
1	RM24K11	Research Methodology and IPR	3
INDUSTRY ORIENTED COURSE			
1	PD24G11	Internet of Things and Cloud	4
2	PD24G12	Modern Automation Systems	4
3	PD24G13	Automotive Electronics	4
INDUSTRIAL TRAINING			
1	PD24G21	Internship Programme	4
PROJECT DISSERTATION			
1	PD24T21	Project Phase 1	12
2	PD24T22	Project Phase II	16

PROFESSIONAL ELECTIVE COURSE – POWER ELECTRONICS			
S. No	Course Code	Course Title	Credits
1	PD24A11	Modeling of Electrical Machines	3
2	PD24A12	Modern Rectifiers and Resonant Converters	3
3	PD24A13	Control of Power Electronics Circuits	3
4	PD24A14	Advanced Power Converter	3
5	PD24A15	Analysis of Electrical Drives	3

6	PD24A16	Applications in Power Electronics Engineering	3
PROFESSIONAL ELECTIVE COURSE – EMBEDDED SYSTEMS and CONTROL			
1	PD24B11	Embedded controllers in VLSI	3
2	PD24B12	DSP-based System Design	3
3	PD24B13	Systems Theory	3
4	PD24B14	Analog And Digital Controllers for PE Systems	3
5	PD24B15	Intelligent Controllers	3
PROFESSIONAL ELECTIVE COURSE – ARTIFICIAL INTELLIGENCE AND IOT			
1	PD24C11	Python Programming for Machine Learning	3
2	PD24C12	Machine Learning and Deep Learning	3
3	PD24C13	IoT for Smart Systems	3
4	PD24C14	Soft Computing Techniques	3
5	PD24C15	IOT Architecture and Protocols	3
PROFESSIONAL ELECTIVE COURSE – ELECTRIC VEHICLE TECHNOLOGY and UAV			
1	PD24D11	Electric Vehicles and Power Management	3
2	PD24D12	Electric Vehicle Charging Infrastructure	3
3	PD24D13	UAV for Engineering Applications	3
4	PD24D14	Energy Storage Systems for EV	3
5	PD24D15	EV Motor Drives and Control	3
PROFESSIONAL ELECTIVE COURSE – SMART GRID AND RENEWABLE ENERGY			
1	PD24E11	Renewable Technology	3
2	PD24E12	Smart Grid	3
3	PD24E13	Distributed Generation and Micro Grid	3
4	PD24E14	Power Electronics for Renewable Energy Systems	3
5	PD24E15	Wind Energy Conversion System	3
OPEN ELECTIVE COURSE			
1	OE24W11	Design Thinking for Educators	3
2	OE24W12	Blue Economy and Entrepreneurship	3

3	OE24W13	Swachhata Campus: Clean, Green, and Sustainable Energy	3
4	OE24W14	Integration of AI Educational Practices	3
5	OE24W15	Extended Reality Technologies	3
AUDIT COURSE			
1	AC24H11	English For Research Paper Writing	0
2	AC24H12	Indian Knowledge System	0

- ✓ **Theory: 1 Credit = 15 hours;**
- ✓ **Practical: 1 Credit = 30 hours;**
- ✓ **Experiential learning including relevant experience and proficiency/ professional levels acquired 1 Credit – 40 -45 hours**.

- **The guidelines for attendance and assessment as stipulated in the PG regulations.**

Detailed Syllabus

I. PROFESSIONAL CORE COURSES (Theory)

PD24P11	POWER SEMICONDUCTOR DEVICES	3 Credits

Course Description:

The "Power Semiconductor Devices" course provides a comprehensive understanding of the principles and applications of power semiconductor devices. It covers the characteristics, structure, and functionality of various power devices, including diodes, transistors, and thyristors. Students will learn about key parameters such as forward voltage drop, reverse recovery time, switching speed, and thermal resistance.

Course Content:

Unit I: INTRODUCTION

Power switching devices overview – Attributes of an ideal switch, application requirements, circuit symbols; Power handling capability – (SOA); Power diodes – Types, forward and reverse characteristics, switching characteristics – rating. Features and Brief History of Silicon Carbide- Promise and Demonstration of SiC Power Devices- Physical Properties of Silicon Carbide devices Unipolar and Bipolar Diodes- GaN Technology Overview.

Unit II: CURRENT CONTROLLED DEVICES

BJT's – Construction, static characteristics, switching characteristics; Negative temperature coefficient and second breakdown; - Thyristors – Construction, working, static and transient characteristics, types, series and parallel operation; comparison of BJT and Thyristor – steady state and dynamic models of BJT &Thyristor- Basics of GTO, SiC based Bipolar devices- Applications- Building a GaN Transistor –GaN Transistor Electrical Characteristics.

Unit III: VOLTAGE CONTROLLED DEVICES

Power MOSFETs and IGBTs – Principle of voltage-controlled devices, construction, types, static and switching characteristics, steady state and dynamic models of MOSFET and IGBTs – and IGCT. New semiconductor materials for devices – Intelligent power modules - study of modules like APTGT100TL170G, MSCSM70TAM05TPAG. Integrated gate commutated thyristor (IGCT) - SiC based unipolar devices-applications.

Unit IV: DEVICE SELECTION, DRIVING AND PROTECTING CIRCUITS

Device selection strategy – On-state and switching losses – EMI due to switching. Necessity of isolation, pulse transformer, optocoupler – Gate drive integrated circuit: Study of Driver IC – IRS2110/2113. SCR, MOSFET, IGBTs and base driving for power BJT. – Over voltage, over current and gate protections; Design of snubbers.

Unit V: THERMAL PROTECTION

Heat transfer – conduction, convection and radiation; Cooling – liquid cooling, vapour – phase cooling; Guidance for hear sink selection – Thermal resistance and impedance –Electrical analogy of thermal components, heat sink types and design – Mounting types- switching loss calculation for power device.

Course Outcomes:

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

CO1: Identification of a suitable device for the application.

CO2: Know the advantages of Silicon Carbide and Gallium Nitride devices.

CO3: Understand the principles and characteristics of Silicon, Silicon Carbide and Gallium Nitride devices.

CO4: Design proper driving circuits and protection circuits.

CO5: Construct a proper thermal protective device for power semiconductor devices.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	1	1
CO2	3	1	3	2	3	1
CO3	1	1	2	3	3	1
CO4	3	3	2	3	1	1
CO5	1	2	3	1	2	3

References:

1. Rashid M.H., “Power Electronics Circuits, Devices and Applications “, Pearson, 4th Edition, 10thImpression 2021.
2. Mohan, Undeland and Robins, “Power Electronics: Converters Applications and Design, MediaEnhanced 3rd Edition, Wiley, 2007
3. Tsunenobu Kimoto and James A. Cooper, Fundamentals of Silicon Carbide Technology: Growth, Characterization, Devices, and Applications, First Edition., 2014 John Wiley & Sons Singapore Pte Ltd
4. Alex Lidow, Johan Strydom, Michael de Rooij, David Reusch, GaN Transistors for efficient powerconversion, Second Edition, Wiley, 2015
5. Biswanath Paul, Power Electronics, Universities Press 2019

PD24P12	SPECIAL ELECTRICAL MACHINES	3 Credits

Course Description:

The Special Electrical Machines course delves into the advanced principles and applications of unique electrical machines, including permanent magnet synchronous motors, brushless DC motors, switched reluctance motors, and stepper motors. It covers the construction, operation, and performance characteristics of these machines, along with their control techniques and applications in various industries.

Course Content:

Unit I: PERMANENT MAGNET BRUSHLESS DC MOTORS

Fundamentals of Permanent Magnets- Types- Principle of operation- Magnetic circuit analysis EMF and Torque equations- Characteristics- Controller Design-Transfer function –Machine, Load and Inverter- Current and Speed Controller.

Unit II: SWITCHED RELUCTANCE MOTORS

Torque equation – Converter circuits - Control of SRM drive - Speed control – Current Control – Sensor less operation of SRM - Applications.

Unit III: STEPPER MOTORS

Stepper Motor – Classification – Modes of Excitation – Static and Dynamic Characteristics – Static Torque Production – Motor Driver and Suppressor Circuits - Input Controller – Need for Closed-loop Control – Concept of lead angle.

Unit IV: PERMANENT MAGNET SYNCHROUNOUS MOTORS

Permanent Magnet ac Machines, Machine Configurations, PMSM - Principle of operation – EMF and Torque equations - Phasor diagram - Torque speed characteristics – Modeling and small signal equations- evaluation of control characteristics- design of current and speed controllers- Constructional features, operating principle and characteristics of synchronous reluctance motor.

Unit V: OTHER SPECIAL MACHINES

Principle of operation and characteristics of Hysteresis motor – AC series motors – Linear motor – Applications.

Course Outcomes:

After the completion of this course, students will be able to

CO1: Know the concepts related to permanent magnet brushless DC motors.

CO2: Understand the working and various characteristics of switched reluctance machines.

CO3: Study the working principle and characteristics of Stepper motors.

CO4: Know the construction, working principles, and characteristics of permanent magnet synchronous motor and synchronous reluctance motor.

CO5: Understand the features of Hysteresis Motor and AC Series Motor.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	3	2	1
CO2	2	3	3	2	1	1
CO3	2	3	3	1	1	2
CO4	1	1	3	2	1	3
CO5	1	1	3	1	1	3

References:

1. Jacek F. Gieras, Dr. Rong-Jie Wang, Professor Maarten J. Kamper - Axial Flux Permanent Magnet Brushless Machines-Springer Netherlands (2008)
2. Bilgin, Berker_ Emadi, Ali_ Jiang, James Weisheng - Switched reluctance motor drives: fundamentals to applications-CRC (2019)
3. Ramu Krishnan - Permanent Magnet Synchronous and Brushless DC Motor Drives -CRC Press, Marcel Applications -CRC Press (2001)
4. T. Kenjo, 'Stepping motors and their microprocessor controls', Oxford University press, New Delhi, 2000 Dekker (2009)
5. T.J.E. Miller, 'Brushless magnet and Reluctance motor drives', Clarendon press, London, 1989
6. R. Krishnan - Switched Reluctance Motor Drives_ Modeling, Simulation, Analysis, Design, and Applications -CRC Press (2001)

PD24P13	ANALYSIS OF POWER CONVERTERS	3 Credits

Course Description:

The "Analysis of Power Converters" course provides an extensive study on the operation and characteristics of single-phase and three-phase AC-DC converters, single-phase and three-phase inverters, and modern multilevel inverters. The course covers the static characteristics of power diodes and SCRs, the principles of half and fully controlled converters, and the performance parameters like harmonics, ripple, distortion, and power factor. Students will explore the design, voltage control, and harmonic elimination techniques for inverters, including the application of multilevel inverters and current source inverters. Emphasis is given to understanding the impact of source impedance, overlap, and reactive power on converter performance.

Course Content:

UNIT I: SINGLE-PHASE AC-DC CONVERTER

Static Characteristics of power diode and SCR, half controlled and fully controlled converters with R-L, R-L-E loads and freewheeling diodes – continuous and discontinuous modes of operation - inverter operation –Sequence control of converters – performance parameters: harmonics, ripple, distortion, power factor – effect of source impedance and overlap-reactive power and power balance in converter circuits

UNIT II: THREE-PHASE AC-DC CONVERTER

Semi and fully controlled converter with R, R-L, R-L-E - loads and freewheeling diodes – inverter operation and its limit – performance parameters – effect of source impedance and overlap-12 pulse converter

UNIT III: SINGLE PHASE INVERTERS

Introduction to self-commutated switches: MOSFET and IGBT - Principle of operation of half and full bridge inverters – Performance parameters – Voltage control of single-phase inverters using various PWM techniques – various harmonic elimination techniques – Design of UPS-VSR operation

UNIT IV: THREE PHASE INVERTERS

180-degree and 120-degree conduction mode inverters with star and delta-connected loads – voltage control of three-phase inverters: single, multi-pulse, sinusoidal, space vector modulation techniques – VSR operation-Application to drive system – Current source inverters.

UNIT V: MODERN INVERTERS

Multilevel concept – diode clamped – flying capacitor – cascaded type multilevel inverters - Comparison of multilevel inverters - application of multilevel inverters – PWM techniques for MLI – Single phase &Three phase Impedance source inverters - Filters.

Course Outcomes:

On completion of the course, the student is expected to be able to

CO1: Acquire and apply knowledge of mathematics in power converter analysis.

CO2: Model, analyze, and understand power electronic systems and equipment.

CO3: Formulate, design, and simulate phase-controlled rectifiers for generic loads and for machine loads.

CO4: Formulate, design, and simulate switched mode inverters for generic loads and for machine loads.

CO5: Do device selection and calculation of performance parameters of power converters under various operating modes.

Articulation matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	2	2
CO2	3	1	3	2	1	2
CO3	3	1	3	2	1	2
CO4	2	2	3	2	1	2
CO5	1	1	3	2	1	3

References:

1. Rashid M.H., "Power Electronics Circuits, Devices and Applications ", Prentice Hall India, fourth Edition, New Delhi, 2014.
2. Jai P. Agrawal, "Power Electronics Systems", Pearson Education, Second Edition, 2002.
3. Bimal.K.Bose "Modern Power Electronics and AC Drives", Pearson Education, Second Edition, 2003.
4. Ned Mohan, T.M.Undeland and W.P.Robbins, "Power Electronics: converters, Application and design" John Wiley and sons. Wiley India edition, 2006.
5. Philip T. krein, "Elements of Power Electronics" Oxford University Press-1998.
6. P.S. Bimbhra, "Power Electronics", Khanna Publishers, Eleventh Edition, 2003.

PD24P14	ELECTRIC VEHICLE TECHNOLOGY	3 Credits

Course Description:

The "Electric Vehicles" course covers the history, need, and social/environmental importance of electric and hybrid vehicles. It explores electric vehicle types, performance, energy consumption, and architecture, including series and parallel hybrids. The course also delves into energy storage technologies, electric drives, control, and design aspects, with case studies on popular electric vehicles.

Course Content:

Unit I: NEED FOR ELECTRIC VEHICLES

History and need for electric and hybrid vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drivetrains on energy supplies, comparison of diesel, petrol, electric and hybrid vehicles, limitations, technical challenges

Unit II: ELECTRIC VEHICLE ARCHITECHTURE:

Electric vehicle types, layout and power delivery, performance – traction motor characteristics, tractive effort, transmission requirements, vehicle performance, energy consumption, Concepts of hybrid electric drive train, architecture of series and parallel hybrid electric drive train, merits and demerits, mild and full hybrids, plug-in hybrid electric vehicles and range extended hybrid electric vehicles, Fuel cell vehicles.

Unit III: ENERGY STORAGE

Batteries – types – lead acid batteries, nickel-based batteries, and lithium-based batteries, electrochemical reactions, thermodynamic voltage, specific energy, specific power, energy efficiency, Battery modeling and equivalent circuit, battery charging and types, battery cooling, Ultra-capacitors, Flywheel technology, Hydrogen fuel cell, Thermal Management of the PEM fuel cell.

Unit IV: ELECTRIC DRIVES AND CONTROL

Types of electric motors – working principle of AC and DC motors, advantages and limitations, DC motor drives and control, Induction motor drives and control, PMSM and brushless DC motor - drives and control, AC and Switch reluctance motor drives and control – Drive system efficiency – Inverters – DC and AC motor speed controllers.

Unit V: DESIGN OF ELECTRIC VEHICLES

Materials and types of production, Chassis skate board design, motor sizing, power pack sizing, component matching, Ideal gear box – Gear ratio, torque–speed characteristics, Dynamic equation of vehicle motion, Maximum tractive effort – Power train tractive effort Acceleration performance, rated vehicle velocity – maximum gradability, Brake performance, electronic control system, safety and challenges in electric vehicles. Case study of Nissan leaf, Toyota Prius, tesla model 3, and Renault Zoe cars.

Course Outcomes:

On completion of the course, the student is expected to be able to

CO1: Explain the need for electric vehicles and hybrid electric vehicles.

CO2: Describe the working and components of Electric Vehicle and Hybrid Electric Vehicle.

CO3: Explain the principles of power converters and electrical drives.

CO4: Illustrate the operation of storage systems such as battery and super capacitors.

CO5: Analyze the design of electric vehicles.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

References:

1. C.C Chan, K.T Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.
3. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel
4. Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.
5. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003

II. PROFESSIONAL CORE COURSES (Laboratory)

PD24P21	POWER CONVERTERS LABORATORY	3 Credits

Course Description:

The lab course includes experiments focused on the switching characteristics of Power MOSFETs and IGBTs, simulation of three-phase converters and inverters, PWM inverter spectrum analysis, and four-quadrant DC chopper operation. Students will generate gating pulses and simulate advanced inverters and converters, gaining practical skills in power electronics.

List of experiments:

1. Study of switching characteristics of Power MOSFET & IGBT.
2. Circuit Simulation of Three-phase semi-converter with R, RL& RLE load.
3. Circuit Simulation of Three-phase fully controlled converter with R, RL & RLE load.
4. Circuit Simulation of Three-phase Voltage Source Inverter in 180 and 120-degree mode of conduction.
5. Circuit simulation of Three-phase PWM inverter and study of spectrum analysis for various modulation indices.
6. Simulation of Four quadrant operation of DC Chopper.
7. Generation of Gating pulse using Arduino/Micro Controller/PIC microcontroller for a DC-DC converter and single-phase voltage source inverter.
8. Simulation of a single-phase Z-source inverter with R load.
9. Simulation of three-phase AC voltage Controller with R load.
10. Simulation of a five-level cascaded multilevel inverter with R load.
11. Simulation of a Flyback DC-DC converter.

Course Outcomes:

On completion of the course, the student is expected to be able to

CO1: Explain of the switching behavior of Power Electronic Switches.

CO2: Explain mathematical modeling of power electronic systems and ability to implement the same using simulation tools.

CO3: Use Arduino/microcontroller for power electronic applications.

CO4: Design and simulate various topologies of inverters and analyze their harmonic spectrum.

CO5: Design and fabricate the gate drive power converter circuits.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1		3	3	
CO2		2		3	3	
CO3		3	2			2
CO4	2		3			3
CO5	2	1		3	3	

PD24P22	POWER ELECTRONICS AND DRIVES LABORATORY	3 Credits

Course Description:

This lab course includes experiments focused on the control and simulation of various electric motors and drives. Students will explore closed-loop control, speed control, voltage source inverters, V/f control, microcontroller-based systems, DSP-based control, and voltage regulation. These hands-on activities provide practical skills in electric motor and drive technologies.

List of experiments:

1. Simulation of closed loop control of Converter fed DC drive.
2. Speed control of Converter fed DC motor.
3. Speed control of Chopper fed DC motor.
4. Simulation of VSI fed three phase Induction motor drive.
5. V/f control of Three-Phase Induction motor.

6. Microcontroller-based speed control of Stepper motor.
7. Speed control of BLDC motor.
8. DSP-based speed control of SRM motor.
9. Simulation of Four quadrant operation of three-phase induction motor.
10. Voltage Regulation of three-phase Synchronous Generator.
11. AC voltage Controller-based speed control of induction motor.

Course outcomes:

CO1: Ability to construct the simulation circuit for the closed loop control of drive systems.

CO2: Ability to formulate, design the speed controller for DC motor-based drive system.

CO3: Ability to conduct load tests in an electrical drive system.

CO4: Ability to formulate, design the speed controller for AC motor-based drive system.

CO5: Ability to design the control algorithm for the control of an electrical drive using Microcontrollerand Digital signal processor.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1		3	3	
CO2		2		3	3	
CO3		3	2			2
CO4	2		3			3
CO5		2		2		

References:

1. Ned Mohan, T.M. Undeland and W.P Robbin, “Power Electronics: converters, Application and design” John Wiley and sons. Wiley India edition, 2006
2. Rashid M.H., “Power Electronics Circuits, Devices and Applications ", Prentice Hal India, New Delhi, 1995.
3. Bimal K Bose “Modern Power Electronics and AC Drives” Pearson Education, Second Edition,2003.
4. Bin Wu, Mehdi Narimani, “High Power Converters and AC Drives, Wiley Publishers, Second Edition,2017.

PD24P23	ANALOG AND DIGITAL CONTROLLERS FOR PE CONVERTERS LABORATORY	3 Credits

Course Description:

This lab course includes experiments on designing and verifying amplifiers, filters, and ON/OFF controllers using Opamps, as well as driver circuits with IR2110. Students will generate PWM gate pulses, control duty cycles, create Sine-PWM pulses, and interface sensors with microcontrollers. Additionally, closed-loop P, I, and PI controllers will be designed and tested.

List of experiments:

1. Amplifiers and buffer design and verification by using Opamp.
2. Filter design and verification by using Opamp.
3. ON/OFF controller design and verification by using analog circuits.
4. Design of Driver Circuit using IR2110.
5. Waveform generation by using look up table.
6. Generation of PWM gate pulses with duty cycle control using PWM. peripheral of microcontroller (TI-C2000 family/ PIC18).
7. Duty cycle control from IDE.
8. Duty Cycle control using a POT connected to ADC peripheral in a standalone mode.
9. Generation of Sine-PWM pulses for a single and three phase Voltage Source. Inverter with control of modulation index using PWM peripheral of microcontroller (TI C2000 family/PIC 18).
10. Design and testing of signal conditioning circuit to interface voltage/current sensor with microcontroller (TI-C2000 family/ PIC18).
11. Interface Hall effect voltage and current sensor with microcontroller and display the current waveform in the IDE and validate with actual waveform in DSO.
12. Design of closed loop P, I and PI controllers using OP-AMP.
13. Design of closed loop P, I and PI controllers using TI-C2000 family/ PIC18.

Course outcomes:

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

CO1: Understand the concepts related with analog and digital controllers.

CO2: Design and understand the op-amp circuits and microcontroller circuits for power electronics.

CO3: Design the driving circuits, sensing circuits, protection circuits for power converters.

CO4: Design and select the appropriate digital controller for power converters along with control strategy.

CO5: Analyze and validate the performance of analog and digital control circuits for power electronics applications using simulation and hardware tools.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	2	2
CO2	3	2	3	2	2	2
CO3	3	2	3	2	2	2
CO4	3	2	3	2	3	2
CO5	3	3	3	3	3	2

PD24P24	DESIGN LABORATORY FOR POWER ELECTRONICS SYSTEMS	3 Credits

Course Description:

This lab course includes the selection and design of essential components like inductors, capacitors, transformers, and devices for power converters. Students will design and test both isolated and non-isolated converters (100 W). Additionally, the course features a mini project demonstration, providing practical application experience in power converter design.

List of experiments:

1. Selection and Design of components (Inductor, Capacitor, transformers and devices) for power converters
2. Design and testing of Isolated converter design and verification (100 W)
3. Design and testing of non-isolated converter design and verification (100 W)
4. Mini Project Demonstration with applications

Course Outcomes:

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

- CO1: Ability to independently carryout research and development work in power converters
- CO2: Ability to demonstrate a degree of mastery over the design and fabrication of switching regulators.
- CO3: Ability to apply conceptual basis required for design and testing of various
- CO4: Ability to interact with industry to take up problem of societal importance as mini project designed.
- CO5: Ability to compare different possible solution to the same practical problem

III. FOUNDATION COURSE

MA24M16	**APPLIED MATHEMATICS FOR POWER ELECTRONICS ENGINEERS**	**3 Credits**

Course Description:

The main objective of this course is to demonstrate various analytical skills in applied mathematics and extensive experience with the tactics of problem solving and logical thinking applicable for the students of electrical engineering. This course also will help the students to identify formulate, abstract, and solve problems in electrical engineering using mathematical tools from a variety of mathematical areas, including matrix theory, calculus of variations, probability, linear programming and Fourier series.

Course Content:

Unit I: MATRIX THEORY

The Cholesky decomposition - Generalized Eigenvectors - Canonical basis - QR factorization - Singular value decomposition - Pseudo inverses - Least square approximation.

Unit II: CALCULUS OF VARIATIONS

Concept of variations and its properties - Euler's theorem - Functional dependent on first and higher order of derivatives - Functionals dependent on functions of several independent variables - Variational problems with moving boundaries - Isoperimetric problems - Direct methods: Rayleigh Ritz method and Kantorovich problems.

Unit III: LAPLACE TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS

Definitions - Properties - Transform error function - Bessel's function - Dirac Delta function -Unit step function - Convolution theorem - Inverse Laplace transform - Complex inversion formula - Solutions to partial differential equations: Heat and Wave equations.

Unit IV: Z -TRANSFORM TECNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS

Z-transforms - Elementary properties – Convergence of Z-transforms - Initial and final value theorems - Inverse Z - transform (using partial fraction and residues) - Convolution theorem - Formation of difference equations – Solution of difference equations using Z - transforms.

Unit V: FOURIER SERIES

Fourier Trigonometric series: Periodic function as power signals - Convergence of series - Even and odd functions: Cosine and sine series - Non periodic function - Extension to other intervals - Power signals: Exponential Fourier series - Parseval's theorem and power spectrum - Eigenvalue problems and orthogonal functions - Regular Sturm –Liouville systems - Generalized Fourier series.

Course Outcomes:

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

CO1: Apply the concepts of matrix theory in Electrical Engineering problems.
CO2: Solve boundary value problems associated with engineering applications.
CO3: Solve problems using Laplace transform associated with engineering applications.
CO4: Use the effective mathematical tools for the solutions of partial differential equations by using Z transform techniques for discrete time systems.
CO5: Solve problems using Fourier series associated with engineering applications.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	1	1	1	1
CO2	1	2	1	2	1	1
CO3	2	3	2	1	2	1
CO4	1	2	1	2	1	1
CO5	2	3	1	2	1	1

References:

1. Richard Bronson, MATRIX OPERATION, Schaum's outline series, Second Edition, McGraw Hill, New Delhi, 2011.
2. Elsgolc. L.D., " CALCULUS OF VARIATIONS “, Dover Publications Inc., New York, 2007.
3. Sankara Rao. K, INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS, Prentice Hall of India Pvt. Ltd, New Delhi, 1997.
4. Grewal.B.S., “Higher Engineering Mathematics”, Khanna Publishers, New Delhi, 44^{th} Edition, 2018.
5. Andrews. L.C, and Phillips. R.L, MATHEMATICAL TECHNIQUES FOR ENGINEERS AND SCIENTISTS, Prentice Hall, New Delhi, 2005.

IV. MANDATORY COURSE

RM24K11	RESEARCH METHODOLOGY AND IPR	3 Credits

Refer to the syllabus of the MOOC course

V. INDUSTRY ORIENTED COURSE

PD24G11	INTERNET OF THINGS AND CLOUD	4 Credits

Course Description:

The "Internet of Things (IoT)" course introduces IoT fundamentals, including architecture, enabling technologies, and challenges. It covers IoT protocols, hardware platforms like Arduino and Raspberry Pi, and various industrial applications such as smart cities and healthcare.

The course also explores cloud computing concepts, platforms like AWS and Azure, and the integration of IoT with cloud services, emphasizing security and data management.

Course Content:

UNIT I: FUNDAMENTALS OF IoT

Introduction to IoT – IoT definition – Characteristics – IoT Complete Architectural Stack – IoT enabling Technologies – IoT Challenges. Sensors and Hardware for IoT – Hardware Platforms – Arduino, Raspberry Pi, Node MCU. A Case study with any one of the boards and data acquisition from sensors.

UNIT II: PROTOCOLS FOR IoT

Infrastructure protocol (IPV4/V6/RPL), Identification (URIs), Transport (Wifi, Lifi, BLE), Discovery, Data Protocols, Device Management Protocols. – A Case Study with MQTT/CoAP usage-IoT privacy, security and vulnerability solutions.

UNIT III: CASE STUDIES/INDUSTRIAL APPLICATIONS

Case studies with architectural analysis: IoT applications – Smart City – Smart Water – Smart Agriculture – Smart Energy – Smart Healthcare – Smart Transportation – Smart Retail – Smart waste management.

UNIT IV: CLOUD COMPUTING INTRODUCTION

Introduction to Cloud Computing - Service Model – Deployment Model- Virtualization Concepts – Cloud Platforms – Amazon AWS – Microsoft Azure – Google APIs.

UNIT V: IoT AND CLOUD

IoT and the Cloud - Role of Cloud Computing in IoT - AWS Components - S3 – Lambda - AWS IoT Core - Connecting a web application to AWS IoT using MQTT- AWS IoT Examples. Security Concerns, Risk Issues, and Legal Aspects of Cloud Computing- Cloud Data Security

Course Outcomes:

At the end of this course, the students should be able to:

CO1: Understand the various concept of the IoT and their technologies.

CO2: Develop IoT application using different hardware platforms.

CO3: Implement the various IoT Protocols.

CO4: Understand the basic principles of cloud computing.

CO5: Develop and deploy the IoT application into cloud environment.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2

References:

1. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman, CRC Press, 2017
2. Adrian McEwen, Designing the Internet of Things, Wiley,2013.
3. EMC Education Services, “Data Science and Big Data Analytics: Discovering, Analyzing, Visualizing and Presenting Data”, Wiley publishers, 2015.
4. Simon Walkowiak, “Big Data Analytics with R” PackT Publishers, 2016
5. Bart Baesens, “Analytics in a Big Data World: The Essential Guide to Data Science and its Applications”, Wiley Publishers, 2015.

PD24G12	MODERN AUTOMATION SYSTEMS	4 Credits

Course Description:

The "Automation and Industrial IoT" course covers fundamentals of automation, including sensing, communication, and cyber-physical systems, as well as AI and 5G technologies. It explores PLC hardware and programming, DCS and SCADA systems, and virtual instrumentation techniques. The course also delves into Industrial IoT, big data analytics, security, and cloud computing, with case studies on real-world applications.

Course Content:

Unit I: INTRODUCTION TO AUTOMATION

Sensing and actuation, Communication – Globalization and emerging issues – Cyber Physical systems - Cyber security - Challenges and prospective of AI and 5G enabled technologies – Effect of integrated IT systems on enterprise competitiveness - requirement for automation – Automation system controllers, Industry 4.0 and 5.0 standards and implementation – Robotics 4.0.

Unit II: PLC

PLC — Hardware – Internal architecture – Ladder and functional block programming – IL, SFC and ST programming methods - Communication Networks for PLC – Case study.

Unit III: DCS AND SCADA

Distributed Control System – Functional components- Diagnostics & IOS – Controllers – Workstation – Features of Distributed Control System – Functional Safety – SCADA – RTU – Communication technologies – Operator Interface – Case study.

Unit IV: VIRTUAL INSTRUMENTATION

Virtual Instrumentation (VI) – Architecture – Programming Techniques – Front Panel and Block diagram – Data flow programming – G programming concepts – Creating and saving VIs – Wiring, Editing and Debugging of Vis – Creating Sub Vis – Control structures – Nodes – Arrays – Cluster controls and indicators – Error handling – String controls – File I/O VIs and functions – Augmented Reality – Case Study.

Unit V: INDUSTRIAL INTERNET OF THINGS: INDUSTRIAL INTERNET OF THINGS

Introduction – Architecture – Sensing, communication – Big data analytics – Security and Fog computing, cloud computing- Internet for energy – Case Study.

Course Outcomes:

At the end of this course, the students should be able to:

CO1: Able to gain the knowledge on fundamentals of automation.

CO2: Able to understand the concepts of PLC, DCS and SCADA.

CO3: Able to understand Virtual Instrumentation for engineering processes.

CO4: Able to gain the knowledge on Industrial Internet of Things.

CO5: Able to apply the concepts and develop automation for different systems.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	3	1	2	1	3

References:

1. Lamb, Frank, “Industrial Automation: Hands-On”, 1st Edition, New York: McGraw-Hill Education, 2013.
2. Mehta B.R and Reddy Y.J, “Industrial Process Automation Systems: Design and Implementation”, Waltham MA: Butterworth-Heinemann, 2015.
3. Giacomo Veneri, Antonio Capasso, “Hands on Industrial Internet of things”, Packt, 2018
4. LabVIEW-based Advanced Instrumentation systems, S. Sumathi & P. Surekha, Springer Publications, 2018 Edition
5. Dag H. Hanssen, Programmable Logic Controllers, A Practical Approach to IEC 61131-3 using CODESYS, John Wiley & Sons Ltd., 2015
6. David Bailey & Edwin Wright, “Practical SCADA for Industry’’, Elsevier 2010er, Sep 2003

PD24G13	AUTOMOTIVE ELECTRONICS	4 Credits

Course Description:

The "Automotive Electronic Systems" course offers an in-depth study of electronic engine management components, modern sensors, charging systems, and automotive transmission control systems. It covers current trends in automotive electronics, including electromagnetic interference suppression, onboard diagnostics, and infotainment. Students will learn modern control strategies, sensor applications, and electronic systems through practical case studies in various fields.

Course Content:

Unit I: FUNDAMENTALS

Components for electronic engine management system, open and closed loop control strategies, PID control, Look up tables, introduction to modern control strategies like Fuzzy logic and adaptive control. Switches, active resistors, Transistors, Current mirrors/amplifiers, Voltage and current references, Comparator, Multiplier. Amplifier, filters, A/D and D/A converters.

Unit II: MODERN SENSORS

Film sensors, micro-scale sensors, Particle measuring systems, Vibration Sensors, SMART sensors, Machine Vision, Multi-sensor systems Applications of Sensors: Applications and case studies of Sensors in Automobile Engineering, Aeronautics, Machine tools and Manufacturing processes.

Unit III: CHARGING SYSTEM

Generation of Direct Current- Shunt Generator Characteristics- Armature Reaction- Third Brush Regulation- Cutout. Voltage and Current Regulators- Compensated Voltage Regulator Alternators Principle and Constructional Aspects and Bridge Rectifiers- New Developments.

Unit IV: AUTOMOTIVE TRANSMISSION CONTROL SYSTEMS

Transmission control - Cruise control – Braking control – Traction control –Suspension control – Steering control – Stability control – Integrated engine control.

Unit V: ELECTRONICS SYSTEMS

S Current Trends in Automotive Electronic Engine Management System- Types of EMS Electromagnetic interference Suppression- Electromagnetic Compatibility- Electronic Dashboard Instruments- Onboard Diagnostic System- Security - Warning System infotainment and Telematics.

Course Outcomes:

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

CO1: Explain the fundamentals, operation, function of various sensors and actuators in engine management systems.

CO2: Explain the Automotive Transmission Control Systems.

CO3: Enumerate the principles, application, construction and specification of different sensors and actuators usable in typical automobile by suitable testing.

CO4: List out the principles and characteristics of charging system components and demonstrate them working with suitable tools.

CO5: Describe the principles and architecture of electronics systems and its components present. in an automobile related to instrumentation, control, security and warning systems.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	3	2	2	2

References:

1. 1. Allan Bonnick, "Automotive Computer Controlled Systems", Butterworth-Heinemann, Elsevier, Indian Edition, 2011.
2. 2. Eric Chowanietz, "Automobile Electronics" by SAE Publications, 1995
3. 3. Tom Weather Jr and Cland C. Hunter, "Automotive Computers and Control System" Prentice Hall Inc.,1984 New Jersey.
4. 4. R.K. Jurgen, "Automotive Electronics Handbook", McGraw Hill 2nd Edition,1995.
5. 5. William B Ribbens, "understanding automotive electronics", 5th edition - Butter worth Heinemann Woburn, 1998.

VI. PROFESSIONAL ELECTIVE COURSES

Cluster A: POWER ELECTRONICS

PD24A11	MODELING OF ELECTRICAL MACHINES	3 Credits

Course Description:

This course covers the principles of electromagnetic energy conversion and its application in electrical machines. Topics include magnetic circuits, DC machines, and reference frame theory, along with a detailed analysis of induction and synchronous machines. Students will study machine dynamics, voltage and torque equations, and dynamic performance under load torque variations. The course also includes computer simulation techniques for analyzing permanent magnets, shunt DC motors, and multiphase machines.

Course Content:

Unit-I: PRINCIPLES OF ELECTROMAGNETIC ENERGY CONVERSION

Magnetic circuits, permanent magnet, stored magnetic energy, co-energy - force and torque in singly and doubly excited systems – machine windings and air gap mmf– determination of winding resistances and inductances of machine windings – determination of friction coefficient and moment of inertia of electrical machines.

Unit-II: DC MACHINES

Elementary DC machine and analysis of steady state operation - Voltage and torque equations – dynamic characteristics of permanent magnet and shunt DC motors – electrical and mechanical time constants - Time domain block diagrams –transfer function of DC motor-responses – digital computer simulation of permanent magnet and shunt DC machines.

Unit-III: REFERENCE FRAME THEORY

Historical background of Clarke and Park transformations – power invariance and phase transformation and commutator transformation – transformation of variables from stationary to arbitrary reference frame - variables observed from several frames of reference.

Unit-IV: INDUCTION MACHINES

Three phase induction machine, equivalent circuit and analysis of steady state operation –free acceleration characteristics – voltage and torque equations in machine variables and arbitrary reference frame variables – analysis of dynamic performance for load torque variations – modeling of multiphase machines - digital computer simulation of three phase induction machines.

Unit-V: SYNCHRONOUS MACHINES

Three phase synchronous machine and analysis of steady state operation - voltage and torque equations in machine variables and rotor reference frame variables (Park's equations) – analysis of dynamic performance for load torque variations – digital computer simulation of synchronous machines.

Course Outcomes:

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

CO1: Understand the principles of electromechanical energy conversion and characteristics of DC motors.

CO2: Know the concepts related with AC machines and modeling of 'n' phase machines

CO3: Interpret the concepts of reference frame theory.

CO4: Apply procedures to develop induction machine model in both machine variable form and reference variable forms.

CO5: Follow the procedures to develop synchronous machine model in machine variables form and reference variable form.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	1	1	2
CO2	1	1	3	2	1	3
CO3	1	1	2	1	1	1
CO4	1	2	2	1	1	2
CO5	1	1	2	1	1	1

References:

1. Stephen D. Umans, "Fitzgerald & Kingsley's Electric Machinery", Tata McGraw Hill, 7th Edition,2020.
2. Bogdan M. Wilamowski, J. David Irwin, The Industrial Electronics Handbook, Second Edition,Power Electronics and Motor Drives, CRC Press, 2011.
3. Paul C. Krause, Oleg Wasynczuk, Scott D. Sudhoff, Steven D. Pekarek, "Analysis of ElectricMachinery and Drive Systems", 3rd Edition, Wiley-IEEE Press, 2013.
4. R. Krishnan, Electric Motor & Drives: Modeling, Analysis and Control, Pearson Education, 1stImprint, 2015.
5. R. Ramanujam, Modeling and Analysis of Electrical Machines, I.k. International Publishing HousePvt.Ltd,2018.
6. P S Bimbhra, "Generalized Theory of Electrical Machines", Khanna Publishers, 2008.

PD24A12	MODERN RECTIFIERS AND RESONANT CONVERTERS	3 Credits

Course Description:

This course focuses on advanced power electronics concepts, covering topics such as power system harmonics, line-commutated rectifiers, and pulse-width modulated rectifiers. Students will learn about resonant converters, dynamic analysis of switching converters, and control techniques for PWM rectifiers. Key areas include harmonic mitigation, soft switching, state-space modeling, and various PWM control schemes. The course emphasizes practical design of efficient power conversion systems, with applications in voltage regulation and current shaping.

Course Content:

Unit I: POWER SYSTEM HARMONICS & LINE COMMUTATED RECTIFIERS

Average power-RMS value of an AC Waveform-Power factor-AC line current harmonic standards IEC 1000-IEEE 519- The Single-phase full wave Rectifier-Continuous Conduction Mode- Discontinuous Conduction Mode-Single Phase Rectifier's behavior for large value of Capacitance – Minimizing THD for small value of Capacitance- Three phase rectifiers- Continuous Conduction Mode-Discontinuous Conduction Mode- Introduction to Harmonic trap filters.

Unit II: PULSE WIDTH MODULATED RECTIFIERS

Properties of Ideal Rectifiers-Realization of non-ideal Rectifier-Single phase converter system incorporating ideal Rectifiers-Modeling losses and efficiency in CCM – high quality Rectifiers-Boost rectifier-expression for controller duty cycle-expression for DC load current-solution for converter Efficiency.

Unit III: **RESONANT CONVERTERS**

Review on Parallel and Series Resonant Switches-Soft Switching- Zero Current Switching – Zero Voltage Switching –Classification of Quasi Resonant Switches-Zero Current and Zero Voltage Switching of Quasi Resonant Buck converter- Zero Current and Zero Voltage Switching of Quasi Resonant Boost converter: Steady State analysis.

Unit IV: DYNAMIC ANALYSIS OF SWITCHING CONVERTERS

Review of linear system Analysis-State Space Averaging-Basic State Space Average Model- State Space Averaged model for Buck Converter, Boost Converter, Buck Boost Converter and Cuk Converter.

Unit V: CONTROL OF PWM RECTIFIRS

Pulse Width Modulation-Voltage Mode PWM Scheme-Current Mode PWM Scheme- Average current Control-Current programmed Control- Hysteresis control- Nonlinear carrier control –Design of Controllers: PI Controller, Variable Structure Controller for source current shaping of PWM rectifiers.

Course Outcomes:

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

CO1: To understand the standards for supply current harmonics and its significance.

CO2: To design power factor correction rectifiers for UPS applications.

CO3: To analyze and design the resonant converters.

CO4: To derive the state space model of basic and derived DC-DC converters.

CO5: To design an appropriate controller for PWM rectifiers.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References:

1. John G. Kassakian, Martin F. Schlecht, George C. Verghese, “Principles of Power Electronics”, Pearson, India, New Delhi, 2010
2. Philip T Krein, “Elements of Power Electronics”, Oxford University Press,1998 3.
3. Ned Mohan, “Power Electronics: A first course”, John Wiley,2011
4. Issa Batarseh, Ahmad Harb, “Power Electronics- Circuit Analysis and Design, Second edition,2018.

PD24A13	CONTROL OF POWER ELECTRONIC CIRCUITS	3 Credits

Course Description:

This course covers advanced controller design techniques for DC-DC and AC-DC converters. Topics include feedback control methods in voltage-mode, peak-current mode, and DCM, along with pole placement and observer design. It also explores sliding mode control and flatness-based control, emphasizing their applications in power converters. Students will gain practical insights into designing efficient control systems for various converter types, improving performance and stability in power electronics.

Course Content:

Unit-I: CONTROLLER DESIGN FOR BASIC DC-DC CONVERTERS- PART I

Introduction, Review of Linear Control Theory, Linearization of Various Transfer Function Blocks, Feedback Controller Design in Voltage-Mode Control, Peak-Current Mode Control, Feedback Controller Design in DCM

Unit-II: CONTROLLER DESIGN FOR BASIC DC-DC CONVERTERS- PART II

Introduction, Linear Feedback Control- Pole Placement by Full State Feedback, Pole Placement Based on Observer Design, Reduced Order Observers, Generalized Proportional Integral Controllers- Hamiltonian Systems Viewpoint - Application to power converters.

Unit-III: CONTROLLER DESIGN FOR BASIC AC-DC CONVERTER CIRCUITS

Introduction, Operating Principle of Single-Phase PFCs, Control of PFCs, Designing the Inner Average-Current-Control Loop, Designing the Outer Voltage-Control Loop, Example of Single-Phase PFC Systems.

Unit-IV: SLIDING MODE CONTROL

Introduction, Variable Structure Systems, Control of Single Switch Regulated Systems, Sliding Surfaces, Equivalent Control and the Ideal Sliding Dynamics, Accessibility of the Sliding Surface, Invariance Conditions for Matched Perturbations- Application to power converters.

Unit-V: FLATNESS BASED CONTROL

Flatness, the use of the differential flatness property, Controller development using flatness- Application to power converters.

Course Outcomes:

On completion of the course, the student is expected to be able to

CO1: Design controller for front-end power factor corrector circuits.

CO2: Design controllers for UPS application.

CO3: Design controllers for AC-DC converters.

CO4: Design sliding mode control for power converters.

CO5: Design flatness-based control for power converters.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	1	3	2	1	2

References:

1. Farzin Asadi and Kei Eguchi, Morgan &Claypool," Dynamics and Control of DC-DC Converters", 2018
2. Andre Kislovski, "Dynamic Analysis of Switching-Mode DC/DC Converters", Springer 1991
3. Azar, Ahmad Taher, Zhu, Quannmin," Advances and Applications in sliding mode control systems" Springer, 2015
4. Levine, Jean, "Analysis and control of Non-linear Systems A flatness-based approach" Springer, 2009

PD24A14	ADVANCED POWER CONVERTER	3 Credits

Course Description:

This course explores advanced DC-DC converter technologies, focusing on voltage-lift and super-lift converters, including Cuk, Luo, and SEPIC converters. It covers ultra-lift converters, multiple-quadrant operating Luo converters, and bidirectional dual active bridge (DAB) converters. Additionally, students will study impedance source converters, including voltage-fed and current-fed Z-source inverters, their modulation methods, and real-world applications. The course emphasizes performance analysis and practical implementation of these converters.

Course Content:

Unit I: VOLTAGE-LIFT CONVERTERS

Introduction- Self-lift and reverse self-lift circuits- Cuk converter, Luo converter and SEPIC converter-continuous and discontinuous conduction mode-Applications.

Unit II: POSITIVE OUTPUT & NEGATIVE OUTPUT SUPER-LIFT LUO CONVERTERS

Main series, -Elementary Circuit, Re-Lift Circuit, Triple-Lift Circuit, Higher-Order Lift Circuit-. Continuous and discontinuous conduction modes- Applications.

Unit III: ULTRA LIFT CONVERTERS AND MULTIPLE QUADRANT OPERATING LUO-CONVERTERS

Ultra-Lift Luo- Converter- Operation – Continuous and discontinuous conduction Modes of Ultra- Lift Luo-Converter-Instantaneous Values- Multiple quadrant operating Luo Converters- Circuit Explanations-Modes of operation- Applications.

Unit IV: BIDIRECTIONAL DUAL ACTIVE BRIDGE DC–DC CONVERTERS

Application of Bidirectional DC–DC Converter-Classification of Bidirectional DC–DC Converter – Working Principle of Hybrid-Bridge-Based Dual active bridge (DAB) converter- Performance- Voltage mode control- Principle of Dual-Transformer based DAB converter- Three-Level bidirectional DC–DC converter- Applications.

Unit V: IMPEDANCE SOURCE CONVERTER

Voltage-Fed Z-source inverters –Topologies –Steady state and dynamic model- Current fed Z- source inverter –Topology –Modification and operational principles. Modulation Methods- Sine PWM- SVPWM and Pulse Width Amplitude Modulation- Applications.

Course Outcomes:

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

CO1: Ability to understand the working of voltage life circuits.

CO2: Ability to design super lift converters.

CO3: Ability to design ultra-lift converters.

CO4: Ability to understand the working and design of bi-directional DC-DC converters.

CO5: Ability to understand the concepts related with impedance source converter.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	1	1	2
CO2	3	2	3	2	2	2
CO3	2	3	3	1	3	2
CO4	3	2	3	2	3	2
CO5	1	1	3	2	3	2

References:

1. Raj Kumar Buyya , James Broberg, andrzejGoscinski, “Cloud Computing:”, Wiley 2013
2. Dave shackleford, “Virtualization Security”, SYBEX a wiley Brand 2013
3. Mather, Kumaraswamy and Latif, “Cloud Security and Privacy”, OREILLY 2011
4. Mastering Cloud Computing Foundations and Applications Programming RajkumarBuyya, Christian Vechhiola, S. ThamaraiSelvi.
5. "Security for the Internet of Things: A Reference Book for Practitioners" by Dr. Reiner Kriesten.
6. "Internet of Things Security: Fundamentals, Techniques and Applications" by Shancang Li, Li Da Xu, and Liming Chen.

PD24A15	ANALYSIS OF ELECTRICAL DRIVES	3 Credits

Course Description:

This course covers DC motor fundamentals, speed control techniques, and mechanical system characteristics. Topics include converter and chopper control, closed-loop control systems with P, PI, and PID controllers, and modeling drive elements. It also explores VSI and CSI fed induction motor control, including PWM techniques, and rotor-controlled induction motor drives, such as static and modified Scherbius drives. Students will gain practical skills through simulation of motor drives and control systems.

Course Content:

UNIT I: DC MOTORS FUNDAMENTALS AND MECHANICAL SYSTEMS

DC motor- Types, induced emf, speed-torque relations; Speed control – Armature and field speed control; Ward Leonard control – Constant torque and constant horse power operation -Introduction to high-speed drives and modern drives. Characteristics of mechanical system – dynamic equations, components of torque, types of loads; Requirements of drives characteristics - stability of drives–multi-quadrant operation; Drive elements, types of motor duty and selection of motor rating.

UNIT II: CONVERTER AND CHOPPER CONTROL

Principle of phase control – Fundamental relations; Analysis of series and separately excited DC motor with single-phase and three-phase converters –performance parameters, performance characteristics. Introduction to time ratio control and frequency modulation; chopper-controlled DC motor – performance analysis, multi-quadrant control - Chopper based implementation of braking schemes; Related problems.

UNIT III: CLOSED LOOP CONTROL

Modeling of drive elements – Equivalent circuit, transfer function of self, separately excited DC motors; Linear Transfer function model of power converters; Sensing and feeds back elements - Closed loop speed control – current and speed loops, P, PI and PID controllers – response comparison. Simulation of converter and chopper fed DC drive.

UNIT IV: VSI AND CSI FED STATOR CONTROLLED INDUCTION MOTOR CONTROL

AC voltage controller – six step inverter voltage control-closed loop variable frequency PWM inverter fed induction motor (IM) with braking - CSI fed IM variable frequency motor drives – pulse width modulation techniques – simulation of closed loop operation of stator-controlled induction motor drives.

UNIT V: ROTOR CONTROLLED INDUCTION MOTOR DRIVES

Static rotor resistance control - injection of voltage in the rotor circuit – static scherbius drives – static and modified Kramer drives – sub-synchronous and super-synchronous speed operation of induction machines – simulation of closed loop operation of rotor-controlled induction motor drives

Course Outcomes:

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

CO1: Ability to acquire and apply knowledge of mathematics and converter/machine dynamics in Electrical engineering

CO2: Ability to formulate, design, simulate power supplies for generic load and for machine loads.

CO3: Ability to analyze, comprehend, design and simulate direct current motor based adjustable speed drives.

CO4: Ability to analyze, comprehend, design, and simulate induction motor-based adjustable speed drives.

CO5: Ability to design a closed-loop motor drive system with controllers for the current and speed control operations.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	1	3	1
CO2	2	3	2	2	3	1
CO3	2	3	1	3	3	1
CO4	2	2	3	2	3	1
CO5	1	2	2	2	2	3

References:

1. Gopal K Dubey, "Power Semiconductor controlled Drives", Prentice Hall Inc., New Yersy, 1989.
2. R.Krishnan, "Electric Motor Drives – Modeling, Analysis and Control", Prentice-Hall of India Pvt. Ltd., New Delhi,2010.
3. Bimal K Bose, "Modern Power Electronics and AC Drives", Pearson Education Asia 2002.
4. Gopal K.Dubey, "Fundamentals of Electrical Drives", Narosal Publishing House, New Delhi, Second Edition, 2009.
5. Vedam Subramanyam, "Electric Drives – Concepts and Applications", Tata McGrawHill publishing company Ltd., New Delhi, 2002.
6. P.C Sen "Thyristor DC Drives", John wiely and sons, New York, 1981.

Cluster B: EMBEDDED SYSTEMS and CONTROL

PD24B11	EMBEDDED CONTROLLERS IN VLSI	3 Credits

Course Description:

This course covers the architecture and programming of PIC and ARM microcontrollers. It includes topics on RISC vs. CISC architectures, assembly language programming, and various interfacing techniques. Students will learn timer, counter, serial port, and interrupt programming for PIC, as well as ARM instruction sets and programming. Practical applications include ADC/DAC interfacing, motor control, sensor integration, and LCD/keypad interfacing, providing hands-on experience in embedded systems design.

Course Content:

Unit I: PIC MICROCONTROLLER – ARCHITECTURE

RISC Vs CISC Architectures – PIC Architecture and Assembly Language Programming - Program Memory Organization- Branch, Call and Time Delay Loop - PIC I/O Port Programming - Arithmetic and Logic Instructions and Programs - PIC Bank Switching, Table Processing, Macros and Modules PIC Configuration Registers-PIC Hardware Connection-ROM Loaders.

Unit II: PIC INTERFACING

PIC Timer / Counter Programming - Timers 0 And 1- Programming Timers 2 and 3 -Serial Port Programming -Interrupt Programming -Flash / EEPROM Programming - Standard and Enhanced CCP Modules -Compare Mode Programming - Capture Mode Programming- PWM Programming- ECCP Programming.

Unit III: ARM ARCHITECTURE

Introduction to ARM Processor families – Pipeline- ARM7TDMI Programmers Model- Processor Modes- Program Status Registers - Vector Table- Assembler Rules and Directives - Predefined Register Names – Macros – Assembler – Operators – Literals - Load and Store Instructions - Operand Addressing – Endianness - Arm Rotation Scheme - Loading Constants and Addresses into Registers.

Unit IV: ARM PROGRAMMING

ARM Instruction Set - Data Processing Instructions – Branch Instructions -– Load Store Instructions – Software Interrupt Instruction – Program Status Register Instructions – Conditional Execution - Thumb Instruction Set-Thumb Programmers Model-Thumb Branch Instructions- Thumb Data Processing Instructions-Thumb Single Register Data Transfer- Thumb Multiple Register Data Transfer Instructions - Thumb Implementation.

Unit V: EMBEDDED APPLICATIONS

ADC, DAC and Sensor Interfacing –LCD and Keyboard Interfacing -Calculator with Keypad – Relays and Opto-isolators - Stepper Motor Interfacing - DC Motor Interfacing - PWM Motor Control with CCPDC - Motor Control With ECCP.

Course Outcomes:

On completion of the course, the student is expected to be

CO1: Understand the architecture of a PIC microcontroller.

CO2: Program using PIC microcontrollers.

CO3: Develop Program using ARM processors.

CO4: Design interfacing circuits with PIC microcontrollers.

CO5: Design embedded applications to solve real world problems.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

References:

1. Muhammad Ali Mazidi, "PIC Microcontrollers and Embedded Systems using Assembly and C for PIC18 ", Pearson Education, 2016.
2. William Hohl, "ARM Assembly Language", CRC Press, Second Edition, 2015.
3. John B. Peatman, "Design with PIC Microcontrollers", Pearson Education, Singapore –1998
4. Andrew Sloss, Dominic Symes, and Chris Wright, "ARM System Developer's Guide Designing and Optimizing System", The Morgan Kaufmann Series, 2004.
5. Steve Furber, "ARM System-on-Chip Architecture", Addison- Wesley Professional; ll Edition 2000.

PD24B12	DSP BASED SYSTEM DESIGN	3 Credits

Course Description:

This course explores the principles and architectures of Digital Signal Processing (DSP) systems. Topics include DSP algorithms (convolution, FFT, filters), system architecture, and computational techniques like parallelism and pipelining. Students will study DSP hardware architectures, including VLIW and FPGA, and their applications in real-time systems. The course also covers interfacing techniques such as ADC, CODEC, and synchronous serial interfaces for multi-core and multi-GPU systems.

Course Content:

Unit I: REPRESENTATION OF DSP SYSTEM

Single Core and Multicore, Architectural requirement of DSPs - high throughput, low cost, low power, small code size, embedded applications. Representation of digital signal processing systems - block diagrams, signal flow graphs, data-flow graphs, dependence graphs. Techniques for enhancing computational throughput - parallelism and pipelining.

Unit II: DSP ALGORITHMS

DSP algorithms - Convolution, Correlation, FIR/IIR filters, FFT, adaptive filters, sampling rate converters, DCT, Decimator, Expander and Filter Banks. DSP applications. Computational characteristics of DSP algorithms and applications, Numerical representation of signals-word length effect and its impact, Carry free adders, Multiplier.

Unit III: SYSTEM ARCHITECTURE

Introduction, Basic Architectural Features, DSP Computational Building Blocks, Bus Architecture and Memory, Data Addressing Capabilities, Address Generation Unit, Programmability and Program Execution, Features for External Interfacing. VLIW architecture. Basic performance issue in pipelining, Simple implementation of MIPS, Instruction Level Parallelism, Dynamic Scheduling, Dynamic Hardware Prediction, Memory hierarchy. Study of Fixed point and floating-point DSP architectures

Unit IV: ARCHITECTURE ANALYSIS ON PROGRAMMABLE HARDWARE

Analysis of basic DSP Architectures on programmable hardware. Algorithms for FIR, IIR, Lattice filter structures, architectures for real and complex fast Fourier transforms, 1D/2D Convolutions, Winograd minimal filtering algorithm. FPGA: Architecture, different sub-systems, design flow for DSP system design, mapping of DSP algorithms onto FPGA.

Unit V: SYSTEM INTERFACING

Examples of digital signal processing algorithms suitable for parallel architectures such as GPUs and multiGPUs. Interfacing: Introduction, Synchronous Serial Interface CODE, A CODEC Interface Circuit, ADC interface.

Course Outcomes:

At the end of this course, the students will have the ability in

CO 1: Evaluate the DSP system using various methods.

CO 2: Design algorithm suitable for different DSP applications.

CO 3: Explain various architectures of DSP system.

CO 4: Implement DSP system in programmable hardware.

CO 5: Build interfacing of DSP system with various peripherals.

Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	1	1	3
CO2	2	2	3	1	2	3
CO3	2	2	3	2	2	2
CO4	2	2	3	1	2	1
CO5	2	2	3	2	3	2

References

1. 1. Sen M Kuo, Woon Seng S Gan, Digital Signal Processors
2. Digital Signal Processing and Application with C6713 and C6416 DSK, Rulph Chassaing, Worcester Polytechnic Institute, A Wiley Interscience Publication
3. Architectures for Digital Signal Processing, Peter Pirsch John Weily, 2007
4. DSP Processor and Fundamentals: Architecture and Features. Phil Lapsley, JBier, AmitSohan, Edward A Lee; Wiley IEEE Press
5. K. K. Parhi - VLSI Digital Signal Processing Systems - Wiley – 1999.
6. Rulph Chassaing, Digital signal processing and applications with C6713 and C6416 DSK, Wiley, 2005
7. Keshab K Parhi, VLSI Digital Signal Processing Systems: Design and Implementation, student Edition, Wiley, 1999.
8. Nasser Kehtarnavaz, Digital Signal Processing System Design: LabVIEW-Based Hybrid Programming, Academic Press, 2008

PD24B13	SYSTEM THEORY	3 Credits

Course Description:

This course covers state-space analysis and stability of dynamic systems. Topics include state-variable representation, solution of state equations, controllability, observability, and system properties. Students will explore nonlinearities, phase plane analysis, Lyapunov stability, and modal analysis for both SISO and MIMO systems. The course also addresses state feedback, pole placement, and observer design for system performance enhancement.

Course Content:

Unit I: STATE VARIABLE REPRESENTATION

Introduction-Concept of State-Space equations for Dynamic Systems –Time invariance and linearity-Non uniqueness of state model- Physical Systems and State Assignment – free and forced responses-State Diagrams.

Unit II: SOLUTION OF STATE EQUATIONS:

Existence and uniqueness of solutions to Continuous-time state equations – Solution of Nonlinear and Linear Time Varying State equations – State transition matrix and its properties – Evaluation of matrix exponential- System modes- Role of Eigen values and Eigen vectors.

Unit III: PROPERTIES OF THE CONTROL SYSTEM:

Controllability and Observability-Stabilizability and Detectability-Test for Continuous Time Systems-Time varying and Time invariant Case-Output Controllability-Reducibility-System Realizations.

Unit IV: NON-LINEARITIES AND STABILITY ANALYSIS:

Equilibrium Points-Stability in the sense of Lyapunov-BIBO Stability-Stability of LTI Systems-Types of nonlinearities – Phase plane analysis – Singular points – Limit cycles – Construction of phase trajectories – Describing function method – Derivation of describing functions. Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems – Direct Method of Lyapunov and the Linear Continuous-Time Autonomous Systems- Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems-Krasovskii and Variable-Gradiant Method.

Unit V: MODAL ANALYSIS:

Controllable and Observable Companion Forms – SISO and MIMO Systems – Effect of State Feedback on Controllability and Observability-Pole Placement by State Feedback for both SISO and MIMO Systems-Full Order and Reduced Order Observers.

Course Outcomes:

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

CO1: Understand the concept of State-State representation for Dynamic Systems.

CO2: Explain the solution techniques of state equations.

CO3: Realize the properties of control systems in state space form.

CO4: Identify non-linearities and evaluate the stability of the system using Lyapnov notion.

CO5: Perform Modal analysis and design controller and observer in state space form.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	2	1	3	2	1	2

References:

1. M. Gopal, “Modern Control System Theory”, New Age International, 2005.
2. Z. Bubnicki,” Modern Control Theory”, Springer, 2005
3. K. Ogatta, “Modern Control Engineering”, PHI, 2002
4. John S. Bay, “Fundamentals of Linear State Space Systems”, McGraw-Hill, 1999
5. D. Roy Choudhury, “Modern Control Systems”, New Age International, 2005
6. John J. D’Azzo, C. H. Houpis and S. N. Sheldon, “Linear Control System Analysis and Design with MATLAB”, Taylor Francis, 2003
7. M. Vidyasagar, “Nonlinear Systems Analysis’, 2nd edition, Prentice Hall, Englewood Cliffs, New Jersey, 2002

PD24B14	ANALOG AND DIGITAL CONTROLLERS FOR PE SYSTEMS	3 Credits

Course Description:

This course focuses on control schemes for power converters and motor control using various microcontrollers. Topics include firing circuits for choppers, inverters, and AC-DC converters, as well as voltage and current feedback integration. Students will explore 8051, PIC, and Arduino-based control schemes, with hands-on exercises in programming, speed control of stepper motors, and monitoring electrical/non-electrical parameters using sensors.

Couse Content:

Unit-I: FIRING SCHEMES OF VARIOUS CONVERTERS

Firing circuits for choppers/ Switching Mode Power Converters using 555 timer / OPAMP circuits – Firing circuits for single/ three phase voltage/ current source inverters – Firing circuit for SCR based AC to DC converters: need for Synchronizing to the mains using ZCD circuits – PLL based frequency multiplier circuits and Ring counter based triggering circuit for three phase converters – Considering unbalance in the AC mains – Impact of superimposed voltage spikes in the input AC mains voltages in the operation of firing scheme.

Unit-II: INTEGRATION OF VOLTAGE AND CURRENT SENSORS FOR FEEDBACK

Current and voltage sensor-based feedback schemes – speed feedback: analog and digital tachometers – Transducers for Feed-back of other parameters: temperature, illumination, Measurement of harmonics – Role of LDRs for 2-axis solar tracking – Analog and digital implementation of P and PI controllers.

Unit-III: 8051 BASED CONTROL SCHEMES

8051 instruction set & simple programming exercises revision – Usage of Look-up Tables (referring to the LUTs in code memory and in the external memory) – 8051 based firing schemes for choppers. Inverters and converters – speed control of stepper motor – monitoring and display of measured / sensed electrical/ non-electrical parameters.

Unit-IV: PIC MICRO-CONTROLLER BASED CONTROL SCHEMES

PIC instruction set & simple programming exercises revision – Usage of Look-up Tables (referring to the LUTs in code memory and in the data memory) – Introduction to MPLAB IDE - PIC based firing schemes for choppers. Inverters and converters – speed control of stepper motor – monitoring and display of measured / sensed electrical/ non-electrical parameters.

Unit-V: ARDUINO MICRO-CONTROLLER BASED CONTROL SCHEMES

Arduino micro-controller based simple programming exercises revision – Comparison of feature of Arduino based boards available: Nano, Uno and Atmega - Arduino based firing schemes for choppers. Inverters and converters – speed control of stepper motor – monitoring and display of measured / sensed electrical/ non-electrical parameters.

Course Outcomes:

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

- CO1: Identify suitable analog controller for the Power Electronic Converter
- CO2: Understand the need for synchronization in AC-DC converter firing circuits.
- CO3: Understand the need for signal conditioning circuits while interfacing the feedback sensors.
- CO4: Analyze critically and select various controllers with strategies for design.
- CO5: Implement analog and digital controllers for real-time PE systems.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	3	2
CO2	3	2	3	2	2	2
CO3	3	2	3	2	3	2
CO4	3	2	3	2	3	2
CO5	3	3	2	2	3	3

References:

1. John B Peatman Designing with PIC micro-controllers, Pearson Education, 2005.
2. Kenneth Ayala, The 8051 micro-controller, fourth Edition, Thomson India Edition, 2014.
3. Neerparaj Rai, Arduino projects for Engineers, BPB publications, 2016.
4. G K Dubey, Doradla, Sinha, Introduction to power electronics,
5. Ned Mohan, Undeland and, Power Electronics: Devices, converters, and applications.
6. M H Rashid, Power Electronics

PD24B15	INTELLIGENT CONTROLLERS	3 Credits

Course Description

This course explores the fundamentals of Artificial Neural Networks (ANN) and Fuzzy Logic, focusing on their application in modeling and control systems. Topics include supervised and unsupervised learning, backpropagation, fuzzy set theory, and fuzzy control systems. Students will also study Genetic Algorithms for optimization and hybrid control schemes combining ANN and Fuzzy Logic. Practical case studies and toolbox familiarization enhance the learning experience.

Course Content:

Unit-I: OVERVIEW OF ARTIFICIAL NEURAL NETWORKS (ANN) & FUZZY LOGIC

Review of fundamentals - Biological neuron, Artificial neuron, Activation function, Supervised learning network- Single Layer Perceptron – Multi Layer Perceptron – Back propagation algorithm (BPA) – Unsupervised learning network – Maxnet – Mexican Hat net ; Fuzzy set theory – Fuzzy sets – Operation on Fuzzy sets - Scalar cardinality, fuzzy cardinality, union and intersection, complement (yager and sugeno), equilibrium points, aggregation, projection, composition, fuzzy relation – Fuzzy membership functions.

Unit-II: NEURAL NETWORKS FOR MODELLING AND CONTROL

Generation of training data - optimal architecture – Model validation- Control of non-linear system using ANN- Direct and Indirect neuro control schemes- Adaptive neuro controller – Case study - Familiarization of Neural Network Control Toolbox.

Unit-III: FUZZY LOGIC FOR MODELLING AND CONTROL

Modeling of nonlinear systems using fuzzy models (Mamdani and Sugeno) –TSK model - Fuzzy Logic controller – Fuzzification – Knowledge base – Decision making logic – Defuzzification- Examples of Fuzzy control system design - Adaptive fuzzy systems - Case study -Familiarization of Fuzzy Logic Toolbox.

Unit-IV: GENETIC ALGORITHM

Basic concept of Genetic algorithm and detail algorithmic steps, adjustment of free parameters. Solution of typical control problems using genetic algorithm. Concept on some other search techniques Firefly algorithm, Differential Evolution and Particle Swarm Optimization.

Unit-V: HYBRID CONTROL SCHEMES:

Fuzzification and rule base using ANN–Neuro fuzzy systems-ANFIS –Optimization of membership function and rule base using Genetic Algorithm and Particle Swarm Optimization - Case study – Familiarization of ANFIS Toolbox.

Course Outcomes:

CO1: Understand the basic architectures of NN and Fuzzy sets
CO2: Design and implement ANN architectures, algorithms and know their limitations.
CO3: Identify and work with different operations on the fuzzy sets.
CO4: Develop ANN and fuzzy logic-based models and control schemes for nonlinear systems.
CO5: Understand and explore hybrid control schemes and PSO

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	2	3	1	1	2	3

References:

1. LaureneV.Fausett, “Fundamentals of Neural Networks, Architecture, Algorithms, and Applications”, Pearson Education, 2008.
2. Timothy J Ross, “Fuzzy Logic with Engineering Applications” VISIONIAS, Third Edition,2020.
3. David E.Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Pearson Education, 2009.
4. W.T. Miller, R.S.Sutton and P.J.Webrose, “Neural Networks for Control”, MIT Press, 1996
5. George J.Klir and Bo Yuan, “Fuzzy Sets & Fuzzy Logic Theory And Applications” VISIONIAS, 2020.

Cluster C: ARTIFICIAL INTELLIGENCE AND IOT

PD24C11	PYTHON PROGRAMMING FOR MACHINE LEARNING	3 Credits

Course Description:

This course provides a comprehensive introduction to Machine Learning using Python, covering key topics such as data preprocessing, regression, classification, clustering, and neural networks. Students will explore Python's syntax, functions, and packages like NumPy, SciPy, and scikit-learn for implementing machine learning algorithms. The course also introduces TensorFlow, Keras, and TinyML for embedded systems, with practical applications using datasets like MNIST and Iris.

Course Content:

Unit I: MACHINE INTRODUCTION TO MACHINE LEARNING

Significance, Advantage and Applications – Categories of Machine Learning – Basic Steps in Machine Learning: Raw Data Collection, Pre-processing, Training a Model, Evaluation of Model, Performance Improvement. Introduction to Python and its significance – Difference between C, C++ and Python Languages; Compiler and Interpreters – Python3 Installation & Running – Basics of Python Programming Syntax: Variable Types, Basic Operators, Reading Input from User – Arrays/List, Dictionary and Set – Conditional Statements – Control Flow and loop control statements.

Unit II: PYTHON FUNCTIONS AND PACKAGES

File Handling: Reading and Writing Data – Errors and Exceptions Handling – Functions & Modules Package Handling in Python – Pip Installation & Exploring Functions in python package – Installing the Numpy Library and exploring various operations on Arrays: Indexing, Slicing, Multi- Dimensional Arrays, Joining Numpy Arrays, Array intersection and Difference, Saving and Loading Numpy Arrays – Introduction to SciPy Package & its functions - Introduction to Object Oriented Programming with Python.

Unit III: IMPLEMENTATION OF MACHINE LEARNING USING PYTHON

Description of Standard Datasets: Coco, ImageNet, MNIST (Handwritten Digits) Dataset, Boston Housing Dataset – Introducing the concepts of Regression – Linear, Polynomial & Logistic Regression with analytical understanding - Introduction to SciPy Package & its functions – Python Application of Linear Regression and Polynomial Regression using SciPy – Interpolation, Overfitting and Underfitting concepts & examples using SciPy.

Unit IV: INTRODUCTION TO NEURAL NETWORKS AND EMBEDDED MACHINE LEARNING

Introduction to ML Concepts of Clustering and Classification – Types of Classification Algorithms – Support Vector Machines (SVM) - Decision Tree - Random Forest – Introduction to ML using scikit- learn – Using scikit-learn, Loading a sample dataset, Learning & prediction, interpolation & fitting, Multiclass fitting - Implementation of SVM using Blood Cancer Dataset, Decision Tree using data from csv.

Types of Clustering Algorithms & Techniques – K-means Algorithm, Mean Shift Algorithm & Hierarchical Clustering Algorithm – Introduction to Python Visualization using Matplotlib: Plotting 2- dimensional, 3-dimensional graphs; formatting axis values; plotting multiple rows of data in same graph – Implementation of K-means Algorithm and Mean Shift Algorithm using Python.

Unit V: INTRODUCTION TO NEURAL NETWORKS AND EMBEDDED MACHINE LEARNING

Introduction to Neural Networks & Significance – Neural Network Architecture – Single Layer Perceptron & Multi-Layer Perceptron (MLP) – Commonly Used Activation Functions - Forward Propagation, Back Propagation, and Epochs – Gradient Descent – Introduction to Tensorflow and Keras ML Python packages – Implementation of MLP Neural Network on Iris Dataset – Introduction to Convolution Neural Networks – Implementation of Digit Classification using MNIST Dataset ML for Embedded Systems: Comparison with conventional ML – Challenges & Methods for Overcoming – TinyML and Tensorflow Lite for Microcontrollers – on-Board AI – ML Edge Devices: Arduino Nano BLE Sense, Google Edge TPU and Intel Movidius.

Course Outcome:

At the end of this course, the students will have the ability to

CO1: Develop skill in system administration and network programming by learning Python.

CO2: Demonstrating understanding in concepts of Machine Learning and its implementation using Python.

CO3: Relate to use Python’s highly powerful processing capabilities for primitives, modelling etc

CO4: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design.

CO5: Apply the concepts acquired over the advanced research/employability skills.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	2	1	1	2	1	1

References:

1. Mohan Mathur, R., Rajiv. K. Varma, “Thyristor – Based Facts Controllers forElectrical Transmission Systems”, IEEE press and John Wiley & Sons, Inc.
2. K.R.Padiyar, “FACTS Controllers in Power Transmission and Distribution”, New AgeInternational(P) Ltd., Publishers, New Delhi, Reprint 2008.
3. K.R.Padiyar, “HVDC Power Transmission Systems”, New Age International (P) Ltd., New Delhi, 2002.
4. J.Arrillaga, “High VoltageDirect Current Transmission”, Peter Pregrinus, London,1983.
5. V.K.Sood, “HVDC and FACTS controllers- Applications of Static Converters in Power System”, Kluwer Academic Publishers 2004.

PD24C12	MACHINE LEARNING AND DEEP LEARNING	3 Credits

Course Description:

This course covers key aspects of machine learning and deep learning, including supervised, semi-supervised, and unsupervised algorithms. It explores neural network architectures, training algorithms, and optimization techniques like backpropagation and gradient descent. Students will learn about classification metrics, feature selection, and classifiers such as SVM and decision trees. The course also delves into CNNs, RNNs, autoencoders, and GANs for advanced machine learning and AI applications.

Course Content:

Unit I: LEARNING PROBLEMS AND ALGORITHMS

Various paradigms of learning problems, Supervised, Semi-supervised and Unsupervised algorithms.

Unit II: NEURAL NETWORKS:

Differences between Biological and Artificial Neural Networks - Typical Architecture, Common Activation Functions, Multi-layer neural network, Linear Separability, Hebb Net, Perceptron, Adaline, Standard Back Propagation Training Algorithms for Pattern Association - Hebb rule and Delta rule, Hetero associative, Auto associative, Kohonen Self Organising Maps, Examples of Feature Maps, Learning Vector Quantization, Gradient descent, Boltzmann Machine Learning.

Unit III: MACHINE LEARNING – FUNDAMENTALS & FEATURE SELECTIONS&CLASSIFICATIONS

Classifying Samples: The confusion matrix, Accuracy, Precision, Recall, F1- Score, the curse of dimensionality, training, testing, validation, cross validation, overfitting, under-fitting the data, early stopping, regularization, bias and variance. Feature Selection, normalization, dimensionality reduction, Classifiers: KNN, SVM, Decision trees, Naïve Bayes, Binary classification, multi class classification, clustering.

Unit IV: DEEP LEARNING: CONVOLUTIONAL NEURAL NETWORKS

Feed forward networks, Activation functions, back propagation in CNN, optimizers, batch normalization, convolution layers, pooling layers, fully connected layers, dropout, Examples of CNNs.

Unit V: DEEP LEARNING: RNNS, AUTOENCODERS AND GANS

State, Structure of RNN Cell, LSTM and GRU, Time distributed layers, Generating Text, Autoencoders: Convolutional Autoencoders, Denoising autoencoders, Variational autoencoders, GANs: The discriminator, generator, DCGANs.

Course Outcome:

After successful completion of this course, the students will be able to

- CO1: Illustrate the categorization of machine learning algorithms.
- CO2: Compare and contrast the types of neural network architectures, activation functions.
- CO3: Acquaint with the pattern association using neural networks.
- CO4: Elaborate various terminologies related with pattern recognition and architectures of convolutional neural networks.
- CO5: Construct different feature selection and classification techniques and advanced neural network architectures such as RNN, Autoencoders, and GANs.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2

References:

1. J. S. R. Jang, C. T. Sun, E. Mizutani, Neuro Fuzzy and Soft Computing - A Computational Approach to Learning and Machine Intelligence, 2012, PHI learning
2. Deep Learning, Ian Good fellow, YoshuaBengio and Aaron Courville, MIT Press, ISBN: 9780262035613, 2016.
3. The Elements of Statistical Learning. Trevor Hastie, Robert Tibshirani and Jerome Friedman. Second Edition. 2009.
4. Pattern Recognition and Machine Learning. Christopher Bishop. Springer. 2006.
5. Understanding Machine Learning. Shai Shalev-Shwartz and Shai Ben-David. Cambridge University Press.

PD24C13	IoT FOR SMART SYSTEMS	3 Credits

Course Description:

This course explores the fundamentals of the Internet of Things (IoT), covering hardware and software requirements, sensor-actuator roles, and technology/business drivers. Topics include IoT architecture, communication protocols, wireless technologies, and IoT processors like Raspberry Pi and Arduino. Students will delve into big data analytics, security, and case studies on smart cities, industrial IoT, and applications in agriculture, defense, and more. Practical hands-on experience is included.

Course Content:

Unit I: INTRODUCTION TO INTERNET OF THINGS

Overview, Hardware and software requirements for IOT, Sensor and actuators, Technology drivers, Business drivers, Typical IoT applications, Trends and implications.

Unit II: IOT ARCHITECTURE

IoT reference model and architecture -Node Structure - Sensing, Processing, Communication, Powering, Networking - Topologies, Layer/Stack architecture, IoT standards, Cloud computing for IoT, Bluetooth, Bluetooth Low Energy beacons.

Unit III: PROTOCOLS AND WIRELESS TECHNOLOGY FOR IOT

Fundamentals of structural dynamics - Modal analysis and vibration testing - Vibration-based damage detection methods - Time-frequency analysis techniques - Static and Vibration based SHM.

Unit IV: IOT PROCESSORS: CONVOLUTIONAL NEURAL NETWORKS

Services/Attributes: Big-Data Analytics for IOT, Dependability, Interoperability, Security, Maintainability. Embedded processors for IOT: Introduction to Python programming -Building IOT with RASPERRY PI and Arduino.

Unit V: CASE STUDIES

Industrial IoT, Home Automation, smart cities, Smart Grid, connected vehicles, electric vehicle charging, Environment, Agriculture, Productivity Applications, IOT Defense.

Course Outcome:

At the end of this course, the students will have the ability to

- CO1: Analyze the concepts of IoT and its present developments.
- CO2: Compare and contrast different platforms and infrastructures available for IoT.
- CO3: Explain different protocols and communication technologies used in IoT.
- CO4: Analyze the big data analytic and programming of IoT.
- CO5: Implement IoT solutions for smart applications.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	1	1	2	1	3	1

References:

1. ArshdeepBahga and VijaiMadisetti : A Hands-on Approach "Internet of Things",Universities Press 2015.
2. Oliver Hersent, David Boswarthick and Omar Elloumi " The Internet of Things", Wiley,2016.
3. Samuel Greengard, "The Internet of Things", The MIT press, 2015.
4. Adrian McEwen and Hakim Cassimally"Designing the Internet of Things "Wiley,2014.
5. Jean- Philippe Vasseur, Adam Dunkels, "Interconnecting Smart Objects with IP: The Next Internet" Morgan Kuffmann Publishers, 2010.
6. Adrian McEwen and Hakim Cassimally, "Designing the Internet of Things", John Wiley and sons, 2014.
7. Lingyang Song/DusitNiyato/ Zhu Han/ Ekram Hossain," WirelesDevice-to-Device Communications and Networks, CAMBRIDGE UNIVERSITY PRESS,2015.
8. OvidiuVermesan and Peter Friess (Editors), "Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers Series in Communication, 2013.
9. Vijay Madisetti , ArshdeepBahga, "Internet of Things (A Hands on-Approach)", 2014.
10. Zach Shelby, Carsten Bormann, "6LoWPAN: The Wireless Embedded Internet", John Wiley and sons, 2009.
11. Lars T.Berger and Krzysztof Iniewski, "Smart Grid applications, communications and security", Wiley, 2015.
12. Janaka Ekanayake, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama and Nick Jenkins, "Smart Grid Technology and Applications", Wiley, 2015.

PD24C14	**SOFT COMPUTING TECHNIQUES**	**3 Credits**

Course Description:

This course covers the fundamentals of intelligent systems, focusing on artificial neural networks (ANN), fuzzy logic, genetic algorithms, and hybrid control schemes. Topics include soft computing techniques, the properties of swarm intelligence, neural network architectures (e.g., Perceptron, Adaline, Backpropagation), associative memory, and fuzzy logic modeling. The course explores genetic algorithms for optimization, and hybrid approaches like neuro-fuzzy systems and particle swarm optimization. Applications in real-world problems are emphasized with hands-on learning of relevant toolboxes.

Course Content:

Unit I: INTRODUCTION AND ARTIFICIAL NEURAL NETWORKS

Introduction to intelligent systems- Soft computing techniques- Conventional Computing versus Swarm Computing - Classification of meta-heuristic techniques - Properties of Swarm intelligent Systems - Application domain - Discrete and continuous problems - Single objective and multi-objective problems -Neuron- Nerve structure and synapse- Artificial Neuron and its model- activation functions- Neural network architecture- single layer and multilayer feed forward networks- Mc Culloch Pitts neuron model- perceptron model- Adaline and Madaline- multilayer perception model- back propagation learning methods- effect of learning rule coefficient -back propagation algorithm- factors affecting back propagation training- applications.

Unit II: ARTIFICIAL NEURAL NETWORKS AND ASSOCIATIVE MEMORY

Counter propagation network- architecture- functioning & characteristics of counter Propagation network- Hopfield/ Recurrent network configuration - stability constraints associative memory and characteristics- limitations and applications- Hopfield v/s Boltzman machine- Adaptive Resonance Theory- Architecture- classifications- Implementation and training - Associative Memory.

Unit III: FUZZY LOGIC SYSTEM

Introduction to crisp sets and fuzzy sets- basic fuzzy set operation and approximate reasoning. Introduction to fuzzy logic modeling and control- Fuzzification inferencing and defuzzification-Fuzzy knowledge and rule bases -Fuzzy modeling and control schemes for nonlinear systems. Self-organizing fuzzy logic control- Fuzzy logic control for nonlinear time delay system.

Unit IV: GENETIC ALGORITHM

Evolutionary programs – Genetic algorithms, genetic programming and evolutionary programming - Genetic Algorithm versus Conventional Optimization Techniques - Genetic representations and selection mechanisms; Genetic operators- different types of crossover and mutation operators - Optimization problems using GA-discrete and continuous - Single objective and multi-objective problems - Procedures in evolutionary programming.

Unit V: HYBRID CONTROL SCHEMES

Fuzzification and rule base using ANN–Neuro fuzzy systems-ANFIS – Fuzzy Neuron - Optimization of membership function and rule base using Genetic Algorithm –Introduction to Support Vector Machine-Evolutionary Programming-Particle Swarm Optimization - Case study – Familiarization of NN, FLC and ANFIS Toolbox.

Course Outcome:

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

CO1: Understand the basic architectures of NN and Fuzzy sets.

CO2: Design and implement ANN architectures, and algorithms and know their limitations.

CO3: Identify and work with different operations on the fuzzy sets.

CO4: Develop ANN and fuzzy logic-based models and control schemes for non-linear systems.

CO5: Understand and explore hybrid control schemes and PSO.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	2	2	3	2	3	1

References:

1. Laurene V. Fausett, “Fundamentals of Neural Networks: Architectures, Algorithms and Applications”, Pearson Education.
2. Timothy J. Ross, “Fuzzy Logic with Engineering Applications” Wiley India, 2008.
3. Zimmermann H.J. "Fuzzy set theory and its applications" Springer international edition, 2011.
4. David E. Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Pearson Education, 2009.
5. W.T. Miller, R.S. Sutton and P.J. Web rose, “Neural Networks for Control” MIT Press”, 1996.
6. T. Ross, “Fuzzy Logic with Engineering Applications”, Tata McGraw Hill, New Delhi, 1995.
7. EthemAlpaydin, “Introduction to Machine Learning (Adaptive Computation and Machine Learning Series)”, MIT Press, 2004.
8. Corinna Cortes and V. Vapnik, " Support - Vector Networks, Machine Learning” 1995.

PD24C15	IOT ARCHITECTURE AND PROTOCOLS	3 Credits

Course Description:

This course provides a comprehensive overview of IoT architecture, including design principles, capabilities, and standards considerations. It covers the fundamentals of M2M and IoT technology, including devices, gateways, networking, data management, and analytics. Topics also include IoT reference models, data link and network layer protocols (e.g., Zigbee, Bluetooth), transport/session layer protocols (e.g., TCP, MQTT), service layer protocols, and security considerations for IoT applications.

Course Content:

Unit I OVERVIEW

IoT-An Architectural Overview– Building an architecture, Main design principles and needed capabilities, An IoT architecture outline, standards considerations. M2M and IoT Technology Fundamentals- Devices and gateways, Local and wide area networking, Data management, Business processes in IoT, Everything as a Service (XaaS), M2M and IoT Analytics, Knowledge Management

Unit II: REFERENCE ARCHITECTURE

IoT Architecture-State of the Art – Introduction, State of the art, Reference Model and architecture, IoT reference Model - IoT Reference Architecture- Introduction, Functional View, Information View, Deployment and Operational View, Other Relevant architectural views. Real-World Design Constraints- Introduction, Technical Design constraints-hardware is popular again, Data representation and visualization, Interaction and remote control.

Unit III: IOT DATA LINK LAYER & NETWORK LAYER PROTOCOLS

PHY/MAC Layer (3GPP MTC, IEEE 802.11, IEEE 802.15), Wireless HART, Z-Wave, Bluetooth Low Energy, Zigbee Smart Energy, DASH7 - Network Layer-IPv4, IPv6, 6LoWPAN, 6TiSCH, ND, DHCP, ICMP, RPL, CORPL, CARP.

Unit IV: TRANSPORT & SESSION LAYER PROTOCOLS:

Transport Layer (TCP, MPTCP, UDP, DCCP, SCTP)-(TLS, DTLS) – Session Layer- HTTP, CoAP, XMPP, AMQP, MQTT.

Unit V: SERVICE LAYER PROTOCOLS & SECURITY

Service Layer -oneM2M, ETSI M2M, OMA, BBF – Security in IoT Protocols – MAC 802.15.4, 6LoWPAN, RPL, Application Layer.

Course Outcome:

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

CO1: Comprehend the essentials of IoT and its applications.

CO2: Understand the concepts of IoT Architecture Reference model and IoT reference architecture.

CO3: Analyze various IoT Application layer Protocols.

CO4: Apply IP based protocols and Authentication Protocols for IoT.

CO5: Design IoT-based systems for real-world problems.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	1	2	3	2	2
CO3	2	1	2	2	1	2
CO4	3	2	2	3	1	3
CO5	3	3	1	2	3	3

References:

1. Jan Holler, VlasiosTsiatsis, Catherine Mulligan, Stefan Avesand, StamatisKarnouskos, David Boyle, **"**From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence**",** 1st Edition, Academic Press, 2014.
2. Peter Waher**, "**Learning Internet of Things", PACKT publishing, BIRMINGHAM – MUMBAI
3. Bernd Scholz-Reiter, Florian Michahelles, "Architecting the Internet of Things", ISBN 978-3-642-19156-5 e-ISBN 978-3-642-19157-2, Springer
4. Daniel Minoli, "Building the Internet of Things with IPv6 and MIPv6: The Evolving World of M2M Communications", ISBN: 978-1-118-47347-4, Willy Publications
5. Vijay Madisetti and ArshdeepBahga, **"**Internet of Things (A Hands-on- Approach)**",** 1st Edition, VPT, 2014.
6. http://www.cse.wustl.edu/~jain/cse570-15/ftp/iot_prot/index.html

Cluster D: ELECTRIC VEHICLE TECHNOLOGY and UAV

PD24D11	ELECTRIC VEHICLES AND POWER MANAGEMENT	3 Credits

Course Description:

This course covers the fundamentals of Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs), comparing them with internal combustion engine vehicles. It explores EV architecture, powertrain components, and sizing, including gears, clutches, and transmission systems. The course also delves into power electronics, motor drives, and battery energy storage systems, including battery types, modeling, and life impacts. Additionally, it introduces alternative energy systems, such as fuel cells, hydrogen storage, and supercapacitors for transportation.

Course Content:

Unit I: ELECTRIC VEHICLES AND VEHICLE MECHANICS

Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Engine ratings- Comparisons of EV with internal combustion Engine vehicles- Fundamentals of vehicle mechanics.

Unit II: ARCHITECTURE OF EV's AND POWER TRAIN COMPONENTS

Architecture of EV's and HEVs – Plug-n Hybrid Electric Vehicles (PHEV)- Power train components and sizing, Gears, Clutches, Transmission and Brakes.

Unit III: POWER ELECTRONICS AND MOTOR DRIVES

Components – Power electronic switches- four quadrant operation of DC drives – Induction motor and permanent magnet synchronous motor-based vector control operation – Switched reluctance motor (SRM) drives- EV motor sizing.

Unit IV: BATTERY ENERGY STORAGE SYSTEM

Battery Basics- Different Types- Battery Parameters- Battery life & Safety Impacts -Battery Modeling-Design of battery for large vehicles.

Unit V: ALTERNATIVE ENERGY STORAGE SYSTEMS

Introduction to fuel cell – Types, Operation, and characteristics- proton exchange membrane (PEM) fuel cell for E-mobility– hydrogen storage systems –Supercapacitors for transportation applications.

Course Outcomes:

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

CO1: Understand the concept of electric vehicle and energy storage systems.

CO2: Describe the working and components of Electric Vehicle and Hybrid Electric Vehicle

CO3: Know the principles of power converters and electrical drives.

CO4: Illustrate the operation of storage systems such as battery and super capacitors

CO5: Analyze the various energy storage systems based on fuel cells and hydrogen storage.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	3	2	1
CO2	1	2	3	3	1	1
CO3	3	2	1	3	1	1
CO4	2	1	1	2	3	3
CO5	1	2	2	1	3	2

References:

1. Iqbal Hussain, “Electric and Hybrid Vehicles: Design Fundamentals, Second Edition” CRC Press, Taylor & Francis Group, Second Edition (2011).
2. Ali Emadi, Mehrdad Ehsani, John M.Miller, “Vehicular Electric Power Systems”, Special Indian Edition, Marcel dekker, Inc 2010.
3. Mehrdad Ehsani, YiminGao, Sebastian E. Gay, Ali Emadi, 'Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design', CRC Press, 2004.
4. C.C. Chan and K.T. Chau, 'Modern Electric Vehicle Technology', OXFORD University Press, 2001.
5. Wie Liu, “Hybrid Electric Vehicle System Modeling and Control”, Second Edition, John Wiley & Sons, 2017.

PD24D12	ELECTRIC VEHICLE CHARGING INFRASTRUCTURE	3 Credits

Course Description:

This course explores electric vehicle (EV) systems, focusing on charging infrastructure, including charging modes, EVSE components, and various charger types (AC/DC). It covers battery charging standards (IEC 61851), plugs, connectors, and challenges in infrastructure. Additionally, it addresses business models, tariff structures, and fast charging distribution systems. The course delves into power quality issues, EMI/EMC considerations, and energy storage systems, particularly renewable energy integration and microgrids for efficient charging solutions.

Course Content:

Unit I: INTRODUCTION

Introduction to EV Systems: Benefits of EV – Battery Charging Modes - Electric Vehicle Supply Equipment (EVSE) and its components – Classification of chargers based on charging levels : AC Slow Charger, DC Fast Charger - AC-DC Converter and DC-DC Converter for EV Charger: Types and Working Principles - Modes of charging based on IEC 61851 - Plugs and connectors - Cables: without thermal management, with thermal management - Standards related to Connectors and Communication – Challenges in Charging Infrastructure - Battery Swapping

Unit II: BUSINESS MODEL AND ELECTRICITY TARIFF STRUCTURE

Introduction - integrated business model - independent business model - tariff structure.

Unit III: ELECTRIC DISTRIBUTION SYSTEM FOR FAST CHARGING INFRASTRUCTURE

Single line diagram of fast charging infrastructure - Major components of fast charging infrastructure - Single point of failure - Configuration of electric distribution considering redundancy - Other configurations.

Unit IV: POWER QUALITY AND EMI/EMC CONSIDERATIONS

Power Quality: Impact of poor power quality from Power grid on EVSE - Impact of poor power quality from EVSE on power grid – EMI/EMC: Sources of EMI, Differential Mode Noise, Common Mode Noise, LISN, Measuring of EMI/EMC Spectrum, Design of DM filters, CM filters.

Unit V: ENERGY STORAGE SYSTEMS

Need for Energy Storage Systems for charging infrastructure - Renewable Energy Resources and ESS for Fast Charging Infrastructure - Modes of operation - Microgrids for Charging Infrastructure.

Course Outcomes:

Upon the successful completion of the course, students will be able to:

CO1: Design and select AC and DC chargers.

CO2: Understand and create awareness about power purchase and its tariff policy and its regulations.

CO3: Design a fast-charging infrastructure in a distribution network.

CO4: Understand the consequences of power quality issues and EMI/EMC in power grid

CO5: Analyze the need for ESS in EVSE and ESS integrated to the microgrid.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	1	2
CO2	2	2	3	2	2	2
CO3	2	1	3	2	1	2
CO4	3	2	3	2	1	2
CO5	3	3	2	2	3	3

References:

1. 1.Sivaraman P, Sharmeela C, Sanjeevikumar P, “Fast Charging Infrastructure for Electric and Hybrid Electric Vehicles”, First Edition, Wiley, 2023.
2. Sulab sachan, Sanjeevikumar P, Sanchari Deb, “Smart Charging Solutions for Electric and Hybrid Vehicles”, First Edition, Scrivener Publishing LLC, 2022.
3. Iqbal Husain, “Electric and Hybrid Vehicles”, Third Edition, CRC press, 2021.
4. L.Ashok Kumar, S.Albert Alexander, ”Power converters for Electric Vehicles”, First edition, CRC Press,2021.
5. Mehrdad Ehsani, Yimin Gao, Stefano Longo. Kambiz Ebrahimi,” Modern Electric, Hybrid Electric, and Fuel cell vehicles”, Third Edition, CRC Press,2019.

PD24D13	UAV FOR ENGINEERING APPLICATIONS	3 Credits

Refer SWAYAM – MOOC Syllabus.

PD24D14	ENERGY STORAGE SYSTEMS FOR EV	3 Credits

Course Description:

This course covers the fundamentals of electric vehicles (EVs), exploring types like battery electric vehicles, hybrids, and solar-powered vehicles. It delves into battery parameters, including voltage, capacity, energy efficiency, and self-discharge rates. Students will study various battery types (e.g., lead-acid, lithium, nickel-based) and charging techniques. Additionally, the course introduces alternative energy sources such as solar, wind, hydrogen fuel cells, flywheels, and supercapacitors for EV applications and future energy storage solutions.

Course Content:

Unit I: TYPES OF ELECTRIC VEHICLE

Battery electric vehicles, The IC engine/electric hybrid vehicle, fueled electric vehicles, Electric vehicles using supply lines, Solar powered vehicles, Electric vehicles which use flywheels or super capacitors, Electric Vehicles for the Future.

Unit II: BATTERY PARAMETERS

Electrochemical Batteries, Cell and battery voltages, Charge (or Amp hour) capacity, Energy stored, Specific energy, Energy density, Specific power, Amp hour (or charge) efficiency, Energy efficiency. Self-discharge rates, Battery geometry, Battery temperature, Battery life and number of deep cycles

Unit III: TYPES OF BATTERIES

Lead Acid Batteries, Nickel-based Batteries: Introduction, Nickel cadmium, Nickel metal hydride batteries, Sodium-based Batteries, Lithium Batteries, Metal Air Batteries,

Unit IV: BATTERY CHARGING AND MODELLING

Battery Charging, Battery chargers, Charge equalization, The Designer's Choice of Battery, Use of Batteries in Hybrid Vehicles, Internal combustion/battery electric hybrids, Battery/battery electric hybrids, Combinations using flywheels, Complex hybrids, Battery Modelling, the purpose of battery modelling, Battery equivalent circuit, Modelling battery capacity, Simulation a battery at a set power, Calculating the Peukert Coefficient, Approximate battery sizing.

Unit V: ALTERNATIVE AND NOVEL ENERGY SOURCES AND STORES

Introduction, Solar Photovoltaic, Wind Power, Flywheels, Ultra capacitors, Super Capacitors, Supply Rails, Hydrogen Fuel Cells: Basic Principles, Hydrogen Storage I: Storage as Hydrogen, Hydrogen Storage II: Chemical Methods

Course Outcomes:

At the end of this course, the students should be able to:

C01: Identify various types of electric vehicles and their performance parameters.

CO2: Analyze the battery parameters and their variations during charge and discharge cycles.

CO3: List different types of batteries and analyze their performance parameters.

CO4: Examine the battery charging requirements and develop the complete battery model.

CO5: Identify novel and alternate energy sources which could be used in EVs.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	1	3	2
CO2	2	2	3	1	2	2
CO3	2	2	3	2	2	1
CO4	3	2	3	2	2	1
CO5	3	3	2	2	2	1

References:

1. James Larminie Oxford Brookes University, Oxford, UK John Lowry Acenti Designs Ltd., UK,Electric Vehicle Technology Explained
2. M. Barak (Ed.), T. Dickinson, U. Falk, J.L. Sudworth, H.R. Thirsk, F.L. Tye, “Electrochemical Power Sources: Primary & Secondary Batteries”, IEE Energy Series 1, A. Wheaton &Co,Exeter, 1980.
3. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2004.

PD24D15	EV MOTOR DRIVES AND CONTROL	3 Credits

Course Description:

This course explores the dynamics and control of electric motors used in electric vehicles (EVs), focusing on EV motor characteristics, power conversion techniques, and motor control strategies. Topics include DC motor dynamics, induction motor modeling and speed control, pulse width modulation (PWM), and isolated converters like PMSM and BLDC. Additionally, it covers sensor technologies, sensor less control methods, and dynamic modeling of various motors. The course also addresses practical control system design and optimization techniques for efficient motor performance in EV applications.

Course Content:

Unit I: EV MOTORS CHARACTERISTICS

Requirement of EV motors, Comparison of EV motors. Introduction to power conversion: Converting power with resistors, Converting power with switches, the duty cycle factory, buck converter, boost converter, buck-boost Converter, Input filtering, RLC filter.

Unit II: DC MOTOR DYNAMICS & CONTROL

Current Loop Control, Speed Control Loop. Dynamical system control: Gain & Phase Margins, PD Controller, PI Controller, Selecting PI Gain for Speed Controller, PI Controller Design, PI Controller with Reference model, Comparison of conventional PI Controller with PI controller with Reference Model, 2 DOF Controller with Internal Model Control, Load Torque Observer, Feedback Linearization, Simplified Modeling of Practical Current Loop.

Unit III: INDUCTION MOTOR

Rotating Magnetic Field, Basics of Induction motor, Speed-Torque Curve Leakage inductance, circle diagram, current displacement (double cage rotor), line starting, Dynamic modelling of Induction motor. Induction motor speed control: Rotor Field oriented control, Stator Field Oriented Control, Field Weakening Control, Variable Voltage Variable Frequency Control. PWM and inverter: Sinusoidal PWM, Injection of third order harmonics, Space Vector Modulation, Dead time & compensation.

Unit IV: ISOLATED CONVERTERS

PMSM and BLDC, PMSM dynamic modelling, PMSM torque equations, PMSM control methods, machine sizing, current, voltage and speed limits, extending constant power speed range, current control methods.

Unit V: POSITION & CURRENT SENSORS: Encoders, Resolvers, R/D Converters, Hall current sensors and current sampling. Sensor less control of ac motors: Voltage Model Estimator, Current Model Estimator, Closed-loop MRAS observer, PMSM sensor less control.

Course Outcomes:

At the end of the course student will be able to

CO1: Describe the characteristics of the motors use in EV.

CO2: Analyze dynamics of DC motor and different controllers used in their control

CO3: Describe the speed control and PWM techniques used in the control of Induction motor

CO4: Analyze the operation and control of permanent magnet ac motors.

C05: Analyze sensor-less control of 3-phase ac motors.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	2	2
CO2	2	3	3	2	2	2
CO3	2	2	3	2	2	2
CO4	3	3	3	2	2	2
CO5	3	3	3	3	3	2

References:

1. K Wang Hee Nam: AC Motor Control & Electrical Vehicle Application, CR Press, Taylor & Francis Group, 2019
2. C.C Chan, K.T Chau: Modern Electric Vehicle Technology, Oxford University Press Inc., New York 2001
3. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2003.

Cluster E: SMART GRID RENEWABLE ENERGY

PD24E11	RENEWABLE TECHNOLOGY	3 Credits

Course Description:

This course provides an in-depth understanding of renewable energy systems, focusing on solar photovoltaics, wind energy, and other renewable sources. It covers energy classification, CO2 emissions, and the importance of renewable energy in reducing environmental impacts. Topics include solar radiation, PV cell characteristics, wind turbine aerodynamics, and system design. Students will explore various energy sources like ocean, biomass, hydrogen, and geothermal, as well as their environmental and practical applications in modern energy systems.

Course Content:

Unit I: INTRODUCTION

Classification of energy sources – Co2 Emission - Features of Renewable energy - Renewable energy scenario in India -Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment Per Capital Consumption - CO2 Emission - importance of renewable energy sources, Potentials – Achievements– Applications.

Unit II: SOLAR PHOTOVOLTAICS

Solar Energy: Sun and Earth-Basic Characteristics of solar radiation- angle of sunrays on solar collector-Estimating Solar Radiation Empirically - Equivalent circuit of PV Cell- Photovoltaic cell-characteristics: P-V and I-V curve of cell-Impact of Temperature and Insolation on I-V Characteristics-Shading Impacts on I-V Characteristics-Bypass diode -Blocking diode.

Unit III: PHOTOVOLTAIC SYSTEM DESIGN

Block diagram of solar photo voltaic system: Line commutated converters (inversion mode) - Boost and buck-boost converters - selection of inverter, battery sizing, array sizing - PV systems classification- standalone PV systems - Grid tied and grid interactive inverters- grid connection issues.

Unit IV: WIND ENERGY CONVERSION SYSTEMS

Origin of Winds: Global and Local Winds- Aerodynamics of Wind turbine-Derivation of Betz's limit-Power available in wind-Classification of wind turbine: Horizontal Axis wind turbine and Vertical axis wind turbine- Aerodynamic Efficiency-Tip Speed-Tip Speed Ratio-Solidity-Blade Count-Power curve of wind turbine - Configurations of wind energy conversion systems: Type A, Type B, Type C and Type D Configurations- Grid connection Issues - Grid integrated SCIG and PMSG based WECS.

Unit V: OTHER RENEWABLE ENERGY SOURCES

Qualitative study of different renewable energy resources: Ocean, Biomass, Hydrogen energy systems, Fuel cells, Ocean Thermal Energy Conversion (OTEC), Tidal and wave energy, Geothermal Energy Resources.

Course outcomes:

After completion of this course, the student will be able to

CO1: Demonstrate the need for renewable energy sources.

CO2: Develop a stand-alone photo voltaic system and implement a maximum power point tracking in the PV system.

CO3: Design a stand-alone and Grid connected PV system.

CO4: Analyze the different configurations of the wind energy conversion systems.

CO5: Realize the basic of various available renewable energy sources.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2
C05	3	1	2	1	2	3

References:

1. 1. S.N. Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009.
2. Rai. G.D, “Non-conventional energy sources”, Khanna publishes, 1993.
3. Rai. G.D,” Solar energy utilization”, Khanna publishes, 1993.
4. Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals,Technologies and Applications”, PHI Learning Private Limited, 2012.
5. John Twideu and Tony Weir, “Renewal Energy Resources” BSP Publications, 2006
6. Gray, L. Johnson, “Wind energy system”, prentice hall of India, 1995.
7. B.H.Khan, " Non-conventional Energy sources", , McGraw-hill, 2nd Edition, 2009.
8. Fang Lin Luo Hong Ye, " Renewable Energy systems", Taylor & Francis Group,2013.

PD24E12	SMART GRID	3 Credits

Course Description:

This course offers an in-depth exploration of Smart Grid technologies, focusing on their evolution, components, and impact on modern power systems. Topics include smart grid drivers, technologies such as smart meters, substations, and high-efficiency transformers, and power quality management. Students will also learn about demand-side management, metering infrastructure, and the role of high-performance computing and cybersecurity in smart grid applications.

Course Content:

Unit I: NTRODUCTION TO SMART GRID

Evolution of Electric Grid, Concept, Definitions and Need for Smart Grid, Smart grid drivers, functions, opportunities, challenges and benefits, Difference between conventional & Smart Grid, Comparison of Micro grid and Smart grid, Present development & International policies in Smart Grid, Smart Grid Initiative for Power Distribution Utility in India – Case Study.

Unit II: SMART GRID TECHNOLOGIES

Technology Drivers, Smart Integration of energy resources, Smart substations, Substation Automation, Feeder Automation, Transmission systems: EMS, FACTS and HVDC, Wide area monitoring, Protection and control, Distribution systems: DMS, Volt/Var control, Fault Detection, Isolation and service restoration, Outage management, High-Efficiency Distribution Transformers, Phase Shifting Transformers, Plug in Hybrid Electric Vehicles (PHEV) – Grid to Vehicle and Vehicle to Grid charging concepts.

Unit III: SMART METERS AND ADVANCED METERING INFRASTRUCTURE

Introduction to Smart Meters, Advanced Metering infrastructure (AMI) drivers and benefits, AMI protocols, standards and initiatives, AMI needs in the smart grid, Phasor Measurement Unit (PMU) & their application for monitoring & protection. Demand side management and demand response programs, Demand pricing and Time of Use, Real Time Pricing, Peak Time Pricing.

Unit IV: POWER QUALITY MANAGEMENT IN SMART GRID

Power Quality & EMC in Smart Grid, Power Quality issues of Grid connected Renewable Energy Sources, Power Quality Conditioners for Smart Grid, Web based Power Quality monitoring, Power Quality Audit.

Unit V: HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATION

Architecture and Standards -Local Area Network (LAN), House Area Network (HAN), Wide Area Network (WAN), Broadband over Power line (BPL), PLC, Zigbee, GSM, IP based Protocols, Basics of Web Service and CLOUD Computing, Cyber Security for Smart Grid.

Course outcomes:

After completion of this course, the student will be able to

CO1: Relate with the smart resources, smart meters and other smart devices.

CO2: Explain the function of Smart Grid.

CO3: Experiment the issues of Power Quality in Smart Grid.

CO4: Analyze the performance of Smart Grid.

CO5: Recommend suitable communication networks for smart grid applications.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	3	3	2	2

References:

1. Stuart Borlase ‘Smart Grid: Infrastructure, Technology and Solutions’, CRC Press 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu, Akihiko Yokoyama, ‘Smart Grid: Technology and Applications’, Wiley, 2012.
3. Mini S. Thomas, John D McDonald, ‘Power System SCADA and Smart Grids’, CRC Press, 2015
4. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, ‘Communication Networks for SmartGrids’, Springer, 2014
5. SMART GRID Fundamentals of Design and Analysis, James Momoh, IEEE press, A John Wiley& Sons, Inc., Publication.

PD24E13	DISTRIBUTED GENERATION AND MICRO GRID	3 Credits

Course Description:

This course provides a comprehensive overview of Distributed Generation (DG) and Microgrid technologies. Topics include DG definitions, its integration with the distribution system, and the impacts on technical, environmental, and economic factors. It explores renewable energy sources such as wind, solar, and CHP systems, DG planning and protection, microgrid modeling, and their role in the energy market. Emphasis is placed on hands-on learning and real-world applications.

Course Content:

Unit I: INTRODUCTION TO DISTRIBUTED GENERATION

DG definition - Reasons for distributed Generation-Benefits of integration - Distributed generation and the distribution system - Technical, Environmental and Economic impacts of distributed generation on the distribution system - Impact of distributed generation on the transmission system-Impact of distributed generation on central generation

Unit II: DISTRIBUTED ENERGY RESOURCES

Combined heat and power (CHP) Systems-Wind energy conversion systems (WECS)- Solar photovoltaic (PV) systems-Small-scale hydroelectric power generation-Other renewable energy sources-Storage Devices-Inverter interfaces.

Unit III: DG PLANNING AND PROTECTION

Generation capacity adequacy in conventional thermal generation Systems-Impact of distributed Generation-Impact of distributed generation on network Design-Protection of distributed generation-Protection of the generation equipment from internal Faults-Protection of the faulted distribution network from fault currents supplied by the distributed generator-Impact of distributed generation on existing distribution system protection.

Unit IV: CONCEPT OF MICROGRID

Microgrid Definition-A typical Microgrid configuration- Functions of Micro source controller and central controller- Energy Management Module (EMM) and Protection Co-ordination Module (PCM)- Modes of Operation- Grid connected and islanded modes- Modelling of Microgrid- Microturbine Model- PV Solar Cell Model- Wind Turbine Model-Role of Microgrid in power market competition.

Unit V: IMPACTS OF MICROGRID

Technical and economic advantages of Microgrid-Challenges and disadvantages of Microgrid Development-Management and operational issues of a Microgrid- Impact on heat utilization-Impact on process optimization-Impact on market-Impact on environment-Impact on distribution system- Impact on communication standards and protocols. Microgrid economics-Main issues of Microgrid economics-Micrograms and traditional power system economics-Emerging economic issues in Microgrids-Economic issues between Microgrids and bulk power systems-Potential benefits of Microgrid economics.

Course outcomes:

After completion of this course, the student will be able to

CO1: Understand the concepts of Distributed Generation and Microgrids.

CO2: Gain Knowledge about the various DG resources.

CO3: Familiarize with the planning and protection schemes of Distributed Generation.

CO4: Learn the concept of Microgrid and its mode of operation.

CO5: Acquire knowledge on the impacts of Microgrid.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	2	2	2	3

References:

1. Nick Jenkins, JanakaEkanayake , GoranStrbac , “Distributed Generation”, Institution of Engineering and Technology, London, UK,2010.
2. S. Chowdhury, S.P. Chowdhury and P. Crossley, “Microgrids and Active Distribution Networks”, The Institution of Engineering and Technology, London, United Kingdom, 2009.
3. Math H. Bollen , Fainan Hassan, “Integration of Distributed Generation in the Power System”, John Wiley &Sons, New Jersey, 2011.

4. Magdi S. Mahmoud, Fouad M. AL-Sunni, “Control and Optimization of Distributed Generation Systems”, Springer International Publishing, Switzerland, 2015.
5. NadarajahMithulananthan, Duong Quoc Hung, Kwang Y. Lee, “Intelligent Network Integration of Distributed Renewable Generation”, Springer International Publishing, Switzerland, 2017.
6. Ali K., M.N. Marwali, Min Dai, “Integration of Green and Renewable Energy in Electric Power Systems”, Wiley and sons, New Jersey, 2010.

PD24E14	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	3 Credits

Course Description:

This course explores renewable energy systems, focusing on solar, wind, biomass, ocean, and hydrogen energy sources. Topics include electrical machines for wind energy conversion, power converters for solar and wind systems, and analysis of grid-connected and stand-alone systems. The course also covers hybrid renewable energy systems, including Diesel-PV, Wind-PV, and Biomass-Diesel systems, with a focus on Maximum Power Point Tracking (MPPT).

Course Content:

Unit I: INTRODUCTION TO RENEWABLE ENERGY SYSTEMS

Classification of Energy Sources – Importance of Non-conventional energy sources – Advantages and disadvantages of conventional energy sources – Environmental aspects of energy – Impacts of renewable energy generation on the environment – Qualitative study of renewable energy resources: Ocean energy, Biomass energy, Hydrogen energy, - Solar Photovoltaic (PV), Fuel cells: Operating principles and characteristics, Wind Energy: Nature of wind, Types, control strategy, operating area

Unit II: ELECTRICAL MACHINES FOR WIND ENERGY CONVERSION SYSTEMS (WECS)

Review of reference theory fundamentals –Construction, Principle of operation and analysis: Squirrel Cage Induction Generator (SCIG), Doubly Fed Induction Generator (DFIG) – Permanent Magnet Synchronous Generator (PMSG).

Unit III: POWER CONVERTERS AND ANALYSIS OF SOLAR PV SYSTEMS

Power Converters: Line commutated converters (inversion-mode) – Boost and buck-boost converters-selection of inverter, battery sizing, array sizing.

Analysis: Block diagram of the solar PV systems – Types of Solar PV systems: Stand-alone PV systems, Grid integrated solar PV Systems – Grid connection Issues

Unit IV: POWER CONVERTERS AND ANALYSIS OF WIND SYSTEMS

Power Converters: Three-phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid-Interactive Inverters – Matrix converter.

Analysis: Stand-alone operation of fixed and variable speed WECS-Grid integrated SCIG and PMSG based WECS

Unit V: HYBRID RENEWABLE ENERGY SYSTEMS

Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Diesel-PV, Wind- PV, Micro-hydel-PV, Biomass-Diesel systems – Maximum Power Point Tracking (MPPT).

Course outcomes:

After completion of this course, the student will be able to

CO1: Analyze the impacts of renewable energy technologies on the environment and demonstrate them to harness electrical power.

CO2: Select a suitable Electrical machine for Wind Energy Conversion Systems.

CO3: Design the power converters such as AC-DC, DC-DC, and AC-AC converters for Solar energy systems.

CO4: Design the power converters such as AC-DC, DC-DC, and AC-AC converters for Wind energy systems.

CO5: Interpret the stand-alone, grid-connected, and hybrid renewable energy systems with MPPT.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2
CO5	2	1	3	2	2	2

References:

1. S.N.Bhadra, D. Kastha, & S. Banerjee "Wind Electrical Systems", Oxford University Press,2009
2. Rashid.M. H "Power electronics Hand book", Academic press,2nd Edition, 2006.
3. Rai. G.D, "Non-conventional energy sources", Khanna publishers, 2010.
4. Rai. G.D," Solar energy utilization", Khanna publishers, 5th Edition, 2008.
5. Gray, L. Johnson, "Wind energy system", prentice hall of india, 1995.
6. B.H.Khan "Non-conventional Energy sources ",Tata McGraw-hill Publishing Company, NewDelhi, 2017.

PD24E15	**WIND ENERGY CONVERSION SYSTEM**	**3 Credits**

Course Description:

This course covers the principles and technologies of Wind Energy Conversion Systems (WECS). Topics include the components of WECS, wind turbine types (HAWT, VAWT), power extraction, and rotor design. It explores fixed and variable speed systems, including synchronous generators, DFIG, PMSG, and grid-connected systems. Students will study the modelling of wind turbines, stability analysis, LVRT, and power regulation techniques.

Course Content:

Unit I: INTRODUCTION

Components of WECS-WECS Schemes-Power obtained from wind-simple momentum theory- Power coefficient-Sabinin's Theory-Aerodynamics of Wind turbine.

Unit II: WIND TURBINES

HAWT-VAWT-Power Developed-Thrust-Efficiency-Rotor Selection-Rotor design considerations- Tip Speed Ratio-No. Of Blades-Blade Profile-Power Regulation-yaw control- Pitch angle control- stall Control-Schemes for maximum power extraction.

Unit III: FIXED SPEED SYSTEMS

Generating Systems- Constant speed constant frequency systems –Choice of Generators- Deciding Factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor – Drive Train model- Generator model for Steady state and Transient stability analysis.

Unit IV: VARIABLE SPEED SYSTEMS

Need of variable speed Systems-Power-wind speed Characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG –Variable speed generators 53odeling – Variable speed variable frequency schemes.

Unit V: GRID CONNECTED SYSTEMS

Wind interconnection requirements, low-voltage ride through (LVRT), ramp rate limitations, and supply of ancillary services for frequency and voltage control, current practices and industry trends wind interconnection impact on steady-state and dynamic performance of the power system including modeling issue.

Course outcomes:

After completion of this course, the student will be able to

CO1: Attain knowledge on the basic concepts of Wind energy conversion system.

CO2: Attain the knowledge of the mathematical modeling and control of the Wind turbine.

CO3: Develop more understanding on the design of Fixed speed system.

CO4: Study about the need of Variable speed system and its modeling.

CO5: Learn about Grid integration issues and current practices of wind interconnections with power system.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	2	2
CO2	3	2	3	2	2	2
CO3	2	1	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	2	2	2	3

References :

1. L.L.Freris “Wind Energy conversion Systems”, Prentice Hall,1990
2. S.N.Bhadra, D.Kastha,S.Banerjee, ”Wind Electrical Systems”, Oxford University Press,2010.
3. Ion Boldea, “Variable speed generators”, Taylor & Francis group,2006.
4. E.W.Golding “The generation of Electricity by wind power”, Redwood burn Ltd., Trowbridge,1976.
5. N. Jenkins,” Wind Energy Technology” John Wiley &Sons,1997
6. S.Heir “Grid Integration of WECS”, Wiley1998in Electric Power Systems”, Wiley and sons, New Jersey, 2010.

VII. AUDIT COURSE: (0 credit)

Refer to Swayam – MOOC Syllabus

VIII. OPEN ELECTIVE: (3 credits)

Refer SWAYAM – MOOC Syllabus.

IX. INTERNSHIP PROGRAMME: (4 credits)

Refer to PG Regulations 2024.

X. PROJECT DISSERTATION:

i. Project Phase I (12 credits)

ii. Project Phase II (16 credits)

Refer to PG Regulations 2024.