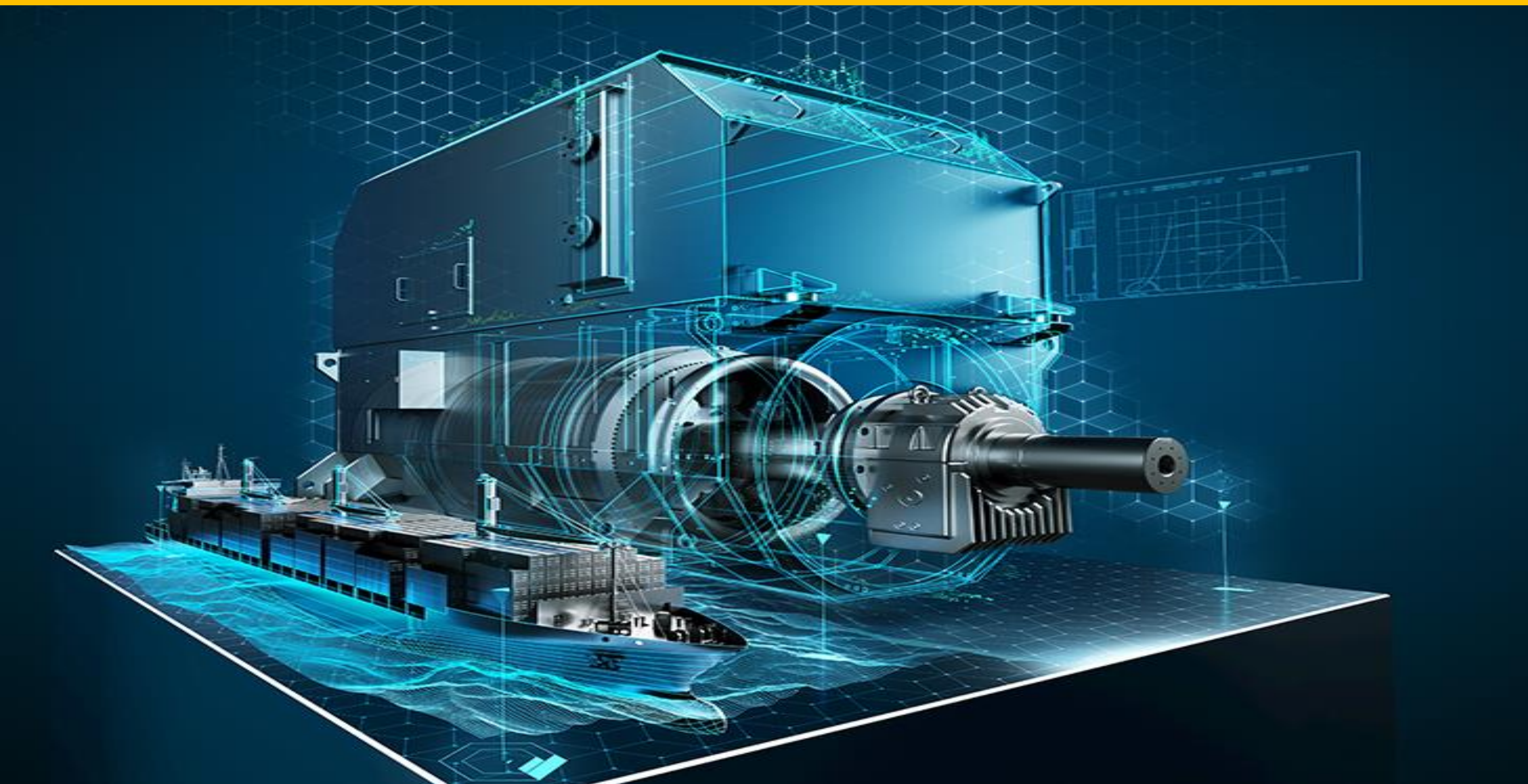
M.I.E.T. ENGINEERING COLLEGE

(Autonomous)

Curriculum & Syllabus

(Regulations 2024)



M.E. Power Electronics and Drives

M.I.E.T. ENGINEERING COLLEGE

(AUTONOMOUS)

(Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai)
Accredited by NBA (CIVIL, CSE, ECE, EEE & MECH)
Accredited with 'A+' grade by NAAC
(An ISO 9001:2015 Certified Institution)
(Recognized by UGC under section 2(f) & 12(B) of UGC Act, 1956)
TRICHY - PUDUKKOTTAI MAIN ROAD, TRICHY - 620 007

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CURRICULUM AND SYLLABUS

M.E. POWER ELECTRONICS AND DRIVES

(Regulations 2024)

Vision

To be recognized as a centre of excellence in Electrical and Electronics Engineering, contribution to the needs of stakeholders.

Mission

- To impart Quality Education through comprehensive exposure, value additions and effective teaching learning process.
- To facilitate learning environment in view of challenges in the field of Electrical andElectronics Engineering.
- To provide platform for students to update the contemporary knowledge with professional quality and commitment to lifelong learning.

Program Outcomes (POs)

1. An ability to independently carry out research/investigation and development work to solve practical problems.
2. An ability to write and present a substantial technical report/document.
3. Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
4. Apply knowledge of basic science and engineering in design and testing of power electronic systems and drives.
5. Interact with Industry in a professional and ethical manner to meet the requirementsof societal needs and to contribute sustainable development of the society.
6. Implement cost effective and cutting-edge technologies in power electronics and drives system.

Program Educational Objectives (PEO)

1. To prepare the students for successful career in power electronic industry, research and teaching institutions.
2. To analyze, design and develop the power electronic converters/drives.
3. To promote student awareness for the lifelong learning in the field of power electronics and drives.

PO-PEO Mapping

Program Educational Objectives	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
PEO1	3	3	3	3	2	3
PEO2	3	3	3	2	2	3
PEO3	3	3	3	2	3	2

1 - Low, 2 - Medium, 3 – High

CHOICE BASED CREDIT SYSTEM

I TO IV SEMESTERS (REGULAR) CURRICULUM AND SYLLABUS

SEMESTER I

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
THEORY								
1.	24PE1101	Analysis of Power Converters	PCC	3	1	0	4	4
2.	24PE1102	Analysis of Electrical Machines	PCC	3	1	0	4	4
3.	24PE1103	Renewable Energy Technologies	PCC	3	0	2	5	4
4.	24PE1104	Modeling of SMPS & UPS	PCC	3	0	2	5	4
5.	24RE1101	Research Methodology and IPR	RMC	2	0	0	2	2
6.	-	Professional Elective I	PEC	3	0	0	3	3
PRACTICAL								
7.	24PE1201	Seminar	EEC	0	0	2	2	1
							Total	**22**

SEMESTER II

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
THEORY								
1.	24PE2101	Industrial Electrical Drives	PCC	3	0	0	3	3
2.	24PE2102	Advanced Processors for Power Converters	PCC	3	0	0	3	3
3.	24PE2103	Electric Vehicles and Power Management	PCC	3	0	0	3	3
4.	-	Professional Elective II	PEC	3	0	0	3	3
5.	-	Professional Elective III	PEC	3	0	0	3	3
6.	24RE2101	Scientific Report Writing	RMC	2	0	0	2	2
PRACTICAL								
7.	24PE2201	Industrial Electrical Drives Laboratory	PCC	0	0	4	4	2
8.	24PE2202	Advanced Processors for Power Converters laboratory	PCC	0	0	4	4	2
							Total	**21**

SEMESTER III

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK L	T	P	TOTAL CONTACT PERIODS PER WEEK	CREDITS
THEORY								
1.	-	Professional Elective IV	PEC	3	0	0	3	3
2.	-	Professional Elective V	PEC	3	0	0	3	3
3.	-	Open Elective	OEC	3	0	0	3	3
PRACTICAL								
4.	24RE3201	Research Article Review	RMC	0	0	4	2	2
5.	24PE3501	Project Work Phase I	EEC	0	0	12	12	6
							Total	**17**

SEMESTER IV

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK L	T	P	TOTAL CONTACT PERIODS PER WEEK	CREDITS
PRACTICAL								
1.	24PE4501	Project Work Phase II	EEC	0	0	24	24	12
							Total	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE = 72

PROFESSIONAL CORE COURSES (PCC)

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK L	T	P	TOTAL CONTACT PERIODS PER WEEK	CREDITS
1.	24PE1101	Analysis of Power Converters	PCC	3	1	0	4	4
2.	24PE1102	Analysis of Electrical Machines	PCC	3	1	0	4	4
3.	24PE1103	Renewable Energy Technologies	PCC	3	0	2	5	4
4.	24PE1104	Modeling of SMPS & UPS	PCC	3	0	2	5	4
5.	24PE2101	Industrial Electrical Drives	PCC	3	1	0	4	4
6.	24PE2102	Advanced Processors for Power Converters	PCC	3	0	0	3	3
7.	24PE2103	Electric Vehicles and Power Management	PCC	3	0	0	3	3
8.	24PE2201	Industrial Electrical Drives Laboratory	PCC	0	0	4	4	2

9.	24PE2202	Advanced Processors for Power Converters Laboratory	PCC	0	0	4	2	2
							Total	**30**

PROFESSIONAL ELECTIVES COURSES (PEC)

SEMESTER I & II, PROFESSIONAL ELECTIVE I & II

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24PE1301	Smart Grid Technologies	PEC	3	0	0	3	3
2.	24PE1302	Electrical Systems in Wind Energy	PEC	3	0	0	3	3
3.	24PE1303	Power System Restructuring & Deregulation	PEC	3	0	0	3	3
4.	24PE1304	Distributed Generation and Micro-Grids	PEC	3	0	0	3	3
5.	24PE1305	Flexible AC Transmission System	PEC	3	0	0	3	3
6.	24PE1306	High Voltage DC Transmission	PEC	3	0	0	3	3

SEMESTER II & III, PROFESSIONAL ELECTIVE III & IV

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24PE1307	Energy Storage Systems	PEC	3	0	0	3	3
2.	24PE1308	Power Electronics for Renewable Energy Systems	PEC	3	0	0	3	3
3.	24PE1309	Advanced Power Converters	PEC	3	0	0	3	3
4.	24PE1310	Wind Energy Conversion System	PEC	3	0	0	3	3
5.	24PE1311	Grid Integration of Renewable Energy Sources	PEC	3	0	0	3	3
6.	24PE1312	Microcontroller Applications in Power Converters	PEC	3	0	0	3	3

SEMESTER III, PROFESSIONAL ELECTIVE V

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24PE1313	Fuzzy Systems	PEC	3	0	0	3	3
2.	24PE1314	Python Programming for Machine Learning	PEC	3	0	0	3	3
3.	24PE1315	Optimization Techniques	PEC	3	0	0	3	3
4.	24PE1316	IoT for Smart Systems	PEC	3	0	0	3	3
5.	24PE1317	Intelligent Control	PEC	3	0	0	3	3
6.	24PE1318	Embedded Systems Design for Power Electronic Applications	PEC	3	0	0	3	3

RESEARCH METHODOLOGY AND IPR COURSES (RMC)

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24RM1101	Research Methodology and IPR	RMC	2	0	0	2	2
2.	24RM2101	Scientific Report Writing	RMC	2	0	0	2	2
3.	24RM3101	Research Article Review	RMC	0	0	4	2	2

EMPLOYABILITY ENHANCEMENT COURSES (ECC)

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24PE1201	Seminar	EEC	0	0	2	2	1
2.	24PE3501	Project Work Phase I	EEC	0	0	12	12	6
3.	24PE4501	Project Work Phase II	EEC	0	0	24	24	12

24PE1101 ANALYSIS OF POWER CONVERTERS

	L	T	P	C
24PE1101 ANALYSIS OF POWER CONVERTERS	3	1	0	4

COURSE OBJECTIVES

- To provide the mathematical fundamentals necessary for deep understanding of power converter operating modes.
- To introduce the electrical circuit concepts behind the different working modes of power converters so as to enable deep understanding of their operation.
- To impart required skills to formulate and design inverters for generic load and for machine loads.

UNIT I SINGLE PHASE AC- DC CONVERTER 9+3

Static Characteristics of power diode, SCR and GTO, half controlled and fully controlled converters with R-L, R-L-E loads and freewheeling diodes–continuous and discontinuous modes of operation inverter operation and its limit –Sequence control of converters–performance parameters –effect of source impedance and overlap-reactive power and power balance in converter circuit.

UNIT II THREE PHASE AC-DC CONVERTER 9+3

Half controlled and fully controlled converters with R, R-L, R-L-E loads and freewheeling diodes-inverter operation and its limit–performance parameters–effect to source impedance and overlap 12 pulse converter–Applications-Excitation system, DC drive system.

UNIT III SINGLE PHASE INVERTERS 9+3

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 9+3

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 – Induction heating, AC drive system – Current source inverters.

UNIT V MODERN INVERTERS 9+3

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

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

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

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

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

CO4: Design and simulate switched mode inverters for generic load and for machine loads.

CO5: Select device and calculate performance parameters of power converters.

TEXT BOOKS

1. Jai P. Agrawal, "Power Electronics System Theory and Design", Pearson Education,First Edition, 2015.
2. Bin Wu, Mehdi Narimani, "High-Power Converters and AC Drives", Wiley, 2^{nd} Edition,2017.
3. Ned Mohan, T.M.Undeland and W.P.Robbins, "Power Electronics :converters, Application and design",3^{rd} edition Wiley, 2007.

REFERENCE BOOKS

1. Rashid M.H., "Power Electronics Circuits, Devices and Applications", Pearson, fourthEdition, 10^{th} Impression 2021.
2. Bimal.K.Bose" Modern Power Electronics and AC Drives", Pearson Education, Second Edition, 2003.
3. Philip T.Krein, "Elements of Power Electronics" Indian edition Oxford University Press-2017.
4. P.C.Sen,"ModernPowerElectronics",S.ChandPublishing2005.
5. BinWu, Mehdi Narimani, "High-Power Converters and AC Drives", Wiley, 2^{nd} Edition,2017.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	-	3	3	2	2
CO2	3	-	3	3	2	2
CO3	3	-	3	3	2	2
CO4	3	-	3	3	2	2
CO5	3	-	3	3	2	2
AVG	3	-	3	3	2	2

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE1102 ANALYSIS OF ELECTRICAL MACHINES L T P C

3 1 0 4

COURSE OBJECTIVES

- To providing knowledge about the principles of magnetic circuits as well as the energy, force, and torque of multi-excited systems, the conversion of three phase variables into two phase variables.
- To use mathematical modelling and computer simulation to examine the DC machine's steady state and dynamic state operations.
- To analyze the steady state and dynamic state operation of three-phase induction machines using transformation theory based mathematical modelling and digital computer simulation.

UNIT I ELECTROMECHANICAL ENERGY CONVERSIO **9+3**

Magnetic circuits, permanent magnet, stored magnetic energy, co-energy - force and torque in singly and multiple excited systems – machine windings and air gap mmf - winding inductances and voltage equations.

UNIT II DC MACHINES **9+3**

Fundamental DC machine and analysis of steady state operation - Voltage and torque equations – dynamic characteristics of permanent magnet and shunt DC motors – Time domain block diagrams - solution of dynamic characteristic by Laplace transformation – simulation of shunt DC machines.

UNIT III REFERENCE FRAME THEORY **9+3**

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 **9+3**

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 – Transformation theory for 'n' phase induction machine.

UNIT V SYNCHRONOUS MACHINES **9+3**

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 –Krons primitive machine.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Understand the fundamentals of electromechanical energy conversion and DC motor properties.

CO2: Know the concepts related with dc machines and their dynamic characteristics.

CO3: Understand the different types of reference frame theories.

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

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

TEXT BOOKS

1. R. Krishnan, Electric Motor & Drives: Modeling, Analysis and Control, Pearson Education, 1st Imprint, 2015.
2. R.Ramanujam, Modeling and Analysis of Electrical Machines, I.k. International Publishing House Pvt.Ltd,2018.
3. Stephen D. Umans, "Fitzgerald & Kingsley's Electric Machinery", Tata McGraw Hill, 7th Edition, 2020.

REFERENCE BOOKS

1. Stephen D. Umans, “Fitzgerald & Kingsley’s Electric Machinery”, Tata McGraw Hill, 7th Edition, 2020.
2. 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 Electric Machinery and Drive Systems”, 3rd Edition, Wiley-IEEE Press, 2013.
4. Arthur R Bergen and Vijay Vittal, “Power System Analysis”, 2nd Edition, Pearson, 2009.
5. Prabha Kundur, “Power System Stability and Control”, TMH, 2010.

Mapping of COs and POs

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

1 - Low, 2 - Medium, 3 – High

24PE1103	RENEWABLE ENERGY TECHNOLOGIES	L T P C
		3 0 2 4

COURSE OBJECTIVES

- To impart knowledge on the various concepts and working principles of renewable energy sources.
- To understand fundamental theory governing solar PV and the aerodynamic principle of turbine blade design.
- To design and analyze power conditions of solar PV system, different types of renewable energy technologies.

UNIT I INTRODUCTION 6

Classification of energy sources -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 - CO_2 Emission importance of renewable energy sources-Applications

UNIT II SOLAR PHOTOVOLTAICS 6

Solar cell array system analysis and performance prediction, Shadow analysis: Reliability, Solar cell array design concepts, PV system design, Design process and optimization: Detailed array design, Voltage regulation, Maximum tracking, Quick sizing method, Array protection.

UNIT III PHOTOVOLTAIC SYSTEM DESIGN AND ADVANCED TECHNOLOGIES 6

PV systems classification- standalone PV systems - Photovoltaic industries in India and World. International certification of solar panels and Indian scenario. Block diagram of Centralized and decentralized SPV systems, Stand alone, Grid-tied and grid interactive inverters- grid connection issues. Array design, inverter types and characteristics, Power conditioning system: design of standalone, hybrid and grid interactive plants, commissioning of solar PV plant.

UNIT IV WIND ENERGY CONVERSION SYSTEMS 6

Energy content in wind, Energy Conversion at the Blade -Rotor Blades, Gearboxes, Synchronous or Asynchronous Generators, Towers, Miscellaneous components, Turbine Selection- Derivation of Betz's limit-Classification of wind turbine: Horizontal Axis wind turbine and Vertical axis wind turbine- Aerodynamic Efficiency-Tip Speed Ratio- Solidity-Blade Count-Power curve of wind turbine - Grid connection Issues - Gridintegrated SCIG and PMSG based WECS.

UNIT V QUALITATIVE STUDY OF OTHER RENEWABLE ENERGY RESOURCES 6

A qualitative study of different renewable energy resources: Ocean, Biomass, Hydrogen energy systems, Fuel cells, Ocean Thermal Energy Conversion (OTEC), Tidal and wave energy, and Geothermal Energy Magneto-hydro-dynamic (MHD) energy conversion, Fuel Cells, Waste to Energy Conversion, Hydrogen Energy Resources.

TOTAL: 30 PERIODS

LIST OF EXPERIMENTS

1. Simulation on modelling of Solar PV System V-I Characteristics.
2. Simulation of self- excited Induction Generator.
3. Simulation of DFIG/ PMSG based Wind turbine.
4. Simulation of intelligent controllers for hybrid energy systems.
5. Simulation on Grid integration of RES.
6. Simulation study on Hydel Power.

TOTAL: 30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Realize the need for renewable energy systems.
CO2: Understand the working principle of solar photovoltaic cells.
CO3: Design a stand-alone and Grid connected PV system.
CO4: Analyse the different configurations of the wind energy conversion systems.
CO5: Identify the working principle of different resources of energy sources.

TEXT BOOKS

1. S.N.Bhadra, D. Kastha, & S. Banerjee “Wind Electrical Systems”, Oxford University Press, 2009.
2. Gray, L. Johnson, “Wind energy system”, prentice hall of India, 1995.
3. Chetan Singh Solanki, “Solar Photovoltaics: Fundamentals, Technologies and Applications”, PHI Learning Private Limited, 2012.

REFERENCE BOOKS

1. Rai. G.D, “Non-conventional energy sources”, Khanna publishes, 1993.
2. Rai. G.D,” Solar energy utilization”, Khanna publishes, 1993.
3. John Twideu and Tony Weir, “Renewal Energy Resources” BSP Publications, 2006
4. B.H.Khan, " Non-conventional Energy sources", , McGraw-hill, 2nd Edition, 2009.
5. "Renewable Energy: Fundamentals and Applications" by Ramesh K. Gupta,2014.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	2	2	1
CO2	3	-	2	3	3	3
CO3	3	-	2	3	3	3
CO4	3	-	2	3	3	2
CO5	3	-	2	2	2	2
AVG	3	-	2	2.6	2.6	2.2

1 - Low, 2 - Medium, 3 – High, ‘ –’ No correlation

24PE1104 MODELLING OF SMPS & UPS

L T P C
3 0 0 3

COURSE OBJECTIVES

- To inculcate knowledge on the steady state analysis of both non-isolated and isolated DC-DC converters.
- To educate on the various dynamics of DC-DC converters and their operational principles.
- To understand how to design controllers for DC-DC converters and describe theoperation of power conditioners, UPS, and filters.

UNIT I ANALYSIS OF NON-ISOLATED DC-DC CONVERTERS 6

Buck, Boost, Buck- Boost, and Cuk converters: Principles of operation – Continuous conduction mode and discontinuous conduction mode. –Concepts of Inductor Volt-Second Balance, Capacitor Charge Balance– Analysis and design based on steady- state relationships -SEPIC topologies – design examples.

UNIT II ANALYSIS OF ISOLATED DC-DC CONVERTERS 6

Introduction-classification- Forward converter, flyback converter, Push Pull, half bridge and full bridge converter, Isolated version of cuck converter and their analysis and design.

UNIT III CONVERTERS DYNAMIC ANALYSIS 6

AC equivalent circuit analysis – State space averaging – Circuit averaging – Averaged switchmodeling – Transfer function model for buck, boost, buck-boost and cuk converters – Input filters.

UNIT IV CONTROLLER DESIGN 6

Review of P, PI, and PID control concepts – gain margin and phase margin – Bode plot based analysis – Design of controller for buck, boost, buck-boost and cuk converters.

UNIT V POWER CONDITIONERS, UPS & FILTERS 6

Introduction- Power line disturbances- Power conditioners –UPS: offline UPS, Online UPS, Applications – Filters: Voltage filters, Series-parallel resonant filters, filter without series capacitors, filter for PWM VSI, current filter, DC filters – Design of inductor and transformerfor PE applications – Selection of capacitors.

TOTAL: 30 PERIODS

LIST OF EXPERIMENTS

1. Simulation of Basic converters.
2. Simulation of bidirectional DC-DC converter (both non-isolated and isolated).
3. Battery operated vehicle, PV system as an example application.
4. Simulation of basic topologies using state space model derived and Comparison withthe circuit model.
5. Simulation study of controller design for basic topologies.
6. Simulation of battery charger for EV applications.

TOTAL: 30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Analyze and design Non-Isolated DC-DC converter.
CO2: Analyze and design Isolated DC-DC converter.
CO3: Derive transfer function of different converters.
CO4: Design controllers for DC-DC converters.
CO5: Comprehend the concepts of power conditioners, UPS & filters.

TEXT BOOKS

1. "Switched-Mode Power Supplies: Modeling, Design, and Simulation" by D. S. K. H.N. Rao Year: 2015.
2. "Power Electronics: Converters, Applications, and Design" by N. Mohan, T. Undeland, and W. Robbins Year: 2006 (while this book is co-authored by an Indian author, it's widely used in India).
3. "Modeling and Control of Power Electronics Converters" by S. K. Gupta year: 2017.

REFERENCE BOOKS

1. Robert W. Erickson & Dragon Maksimovic, " Fundamentals of Power Electronics", Third Edition, 2020.
2. Ned Mohan," Power Electronics: A First Course", Johnwiley, 2013.
3. Power Electronic Converters, Teuvo Suntio, Tuomas Messo, Joonas Puukko, First Edition 2017.
4. V. Ramanarayanan, "Course material on Switched mode power conversion", 2008.
5. M.H. Rashid – "Power Electronics circuits, devices and applications"-Third edition- Prentice Hall of India New Delhi, 2007.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	2	3	3	3	3
CO2	3	2	-	2	2	3
CO3	3	-	2	2	-	2
CO4	2	-	1	-	-	3
CO5	1	2	2	2	2	2
AVG	2	2	2	2.25	2.33	2.6

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24RE1101 RESEARCH METHODOLOGY AND IPR

L	T	P	C
2	0	0	2

COURSE OBJECTIVES

- To acknowledge the importance of intellectual property and teach students the fundamental concepts of Intellectual Property Rights (IPR).
- To highlight the significance of understanding the practices and procedures for obtaining patents, copyrights, trademarks, and industrial designs.
- To simplify the statutory provisions of various forms of IPR and empower students toeffectively maintain and manage their intellectual property rights.

UNIT I RESEARCH DESIGN **6**

Overview of research process and design, Use of Secondary and exploratory data to answer the research question, Qualitative research, Observation studies, Experiments and Surveys, Research problem formulation, Research gap identification, Formulation of materials and methods.

UNIT II DATA COLLECTION AND SOURCES **6**

Measurements, Measurement Scales, Questionnaires and Instruments, Sampling and methods. Data - Preparing, Exploring, examining and displaying, Advanced tools and techniques.

UNIT III DATA ANALYIS AND REPORTING 6

Overview of Multivariate analysis, Hypotheses testing and Measures of Association- Presenting Insights and findings using written reports and oral presentation, Computer aided Research – Simulation – Case study.

UNIT IV INTELLCTUAL PROPERTY RIGHTS 6

Intellectual Property - The concept of IPR, Evolution and development of concept of IPR, IPR development process, Trade secrets, utility Models, IPR & Biodiversity, Role of WIPOand WTO in IPR establishments, Right of Property, Common rules of IPR practices, Types and Features of IPR Agreement, Trademark, Functions of UNESCO in IPR maintenance.

UNIT V PATENTS 6

Patents — objectives and benefits of patent, Concept, features of patent, Inventive step, Specification, Types of patent application, process E-filling, Examination of patent, Grant of patent, Revocation, Equitable Assignments, Licenses, Licensing of related patents, patent agents, Registration of patent agents.

TOTAL: 30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Differentiate and describe various types of intellectual property rights (IPRs).

CO2: Determine how to classify one's own intellectual work under specific forms of IPRs.

CO3: Apply legal provisions to safeguard particular forms of IPRs.

CO4: Examine the rights and responsibilities associated with patents, copyrights, trademarks, industrial designs, and other IPRs.

CO5: Identify the procedures for protecting different forms of IPRs at both national and international levels.

TEXT BOOKS

1. "Research Methodology: Concepts and Cases" by Deepak Chawla and Neena SondhiYear: 2011.
2. "Research Methodology: A Step-by-Step Guide for Beginners" by Ranjit Kumar Year:2019.
3. "Intellectual Property Rights: Unleashing the Knowledge Economy" by Prabha Shukla Year: 2018.

REFERENCE BOOKS

1. Cooper Donald R, Schindler Pamela S and Sharma JK, "Business Research Methods", Tata McGraw Hill Education, 11e (2012).
2. Catherine J. Holland, "Intellectual property: Patents, Trademarks, Copyrights, TradeSecrets", Entrepreneur Press, 2007.

3. Daniel Riordan - Technical Report Writing Today (1998).
4. Darla-Jean Weatherford - Technical Writing for Engineering Professionals (2016)Penwell Publishers.
5. "Intellectual Property Rights: A Global Vision" by R. P. Singh Year: 2016.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	2	1	2
CO2	3	3	3	2	1	2
CO3	2	3	2	2	1	2
CO4	3	3	3	2	1	2
CO5	2	3	2	2	1	2
AVG	2.2	3	2.2	2	1	2

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE1201 **SEMINAR** **L T P C**
0 0 2 1

COURSE OBJECTIVES

- To encourage the students to study advanced engineering developments.
- To prepare and present technical reports.
- To encourage the students to use various teaching aids such as overhead projectors,power point presentation and demonstrative models.

METHOD OF EVALUATION

During the seminar session each student is expected to prepare and present a topic on engineering/technology, for duration of about 8 to 10 minutes. In a session of three periods per week, 15 students are expected to present the seminar. Each student is expected to present atleast twice during the semester and the student is evaluated based on that. At the end of the semester, he / she can submit a report on his / her topic of seminar and marks are given based on the report. A Faculty guide is to be allotted and he / she will guide and monitor the progress of the student and maintain attendance also. Evaluation is 100% internal.

TOTAL: 30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Review, prepare and present technological developments.
CO2: Face the placement interviews.
CO3: Develop presentation skills.
CO4: Develop report writing.
CO5: Present ideas in conferences.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	1	1	2	2
CO2	2	1	1	1	2	2
CO3	-	-	-	-	-	-
CO4	-	-	-	-	-	-
CO5	-	-	-	-	-	-
AVG	2	1	1	1	2	2

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE2101 INDUSTRIAL ELECTRICAL DRIVES L T P C
3 1 0 4

COURSE OBJECTIVES

- To introduce basic concepts of load and drive interaction.
- To control speed of AC and DC drives.
- To analyze and design the speed reversal, regenerative braking aspects, methodologyfor the drive system.

UNIT I DRIVE DYNAMICS AND POWER RATINGS 9+3

Dynamics of Electric Drives: Multi quadrant operation, Moment of inertia, Torque and power for rotational and linear motion loads; Selection of motor power rating: Classes of duty, thermal model heating and cooling; Selection of power converters: Direct converters, converters with intermediate circuit, Converter rating from motor specification, Factors for drive selection, Overload capacity, Control range, Derating factor, Efficiency.

UNIT II CONTROL OF DC MOTOR DRIVE 9+3

Factors governing speed and torque of DC motors, Controlled rectifier-based speed control: Single quadrant, Two quadrant and four quadrant-controlled DC motor drive; Chopper fed speed control: Four quadrant operations; Closed loop control.

UNIT III CONTROL OF INDUCTION MOTOR DRIVE 9+3

Stator side control: Characteristics and equivalent circuit of poly-phase induction motor; Speed control techniques: Stator voltage control, variable frequency control, V/f control; Soft starting methods, braking methods; Rotor side control: static rotor resistance control, Kramer's drive, Scherbius drive, doubly fed induction motor drive.

UNIT IV VECTOR CONTROL OF INDUCTION MOTOR DRIVE 9+3

Principle of vector control, types of vector control, direct vector control, indirect vector control, rotor flux-oriented control, stator flux-oriented control, air gap flux-oriented control, decoupling circuits speed sensor less control, Concept of space vectors, DTC control strategy of induction motor.

UNIT V CONTROL OF SYNCHRONOUS MACHINE DRIVES 9+3

Steady-state equivalent circuits and dynamic model of synchronous machine; Zero d-axis current control, maximum torque per ampere control, direct torque control, and power factor control

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Develop the capability to understand and apply mathematical principles and converter / machine dynamics in electrical engineering.

CO2: Formulate, design, and simulate power supplies for both general and machine-specific loads.

CO3: Analyze, understand, design, and simulate adjustable speed drives based on direct current motors.

CO4: Analyze, understand, design, and simulate adjustable speed drives based on induction motors.

CO5: Design a closed-loop motor drive system incorporating controllers for current and speed control operations.

TEXT BOOKS

1. R. Raja Singh, Energy Conservation Strategies for Asynchronous Machine Drives, Lap Lambert Academic Publishing, Germany, 2021.
2. Bimal K Bose, "Modern Power Electronics and AC Drives", Pearson Education Asia, 2012.
3. R. Krishnan, Electric Motor Drives: Modelling, Analysis, and Control, 2015, Second edition, Pearson Education India.

REFERENCE BOOKS

1. Gopal K Dubey, "Fundamentals of Electrical Drives", CRC Press, Second Edition, 2015. Peter vas, Vector control of AC Machines –Oxford university press, 1990.
2. "Electric Motor Drives: Modeling, Analysis, and Control" by R. Krishnan Publisher: Prentice Hall Year: 2001.
3. "Electric Drives: An Integrative Approach" by C. V. Jones Publisher: Prentice Hall Year: 2002.
4. "Fundamentals of Electric Drives" by G. B. Gharehpetian and A. R. D. K. Zare Publisher: Cengage Learning Year: 2010.
5. "Control of Electric Drives" by W. Leonhard Publisher: Springer Year: 2001.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	3	1
CO2	3	3	3	3	3	2
CO3	2	3	3	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2
AVG	2.8	3	2.8	2.8	3	1.8

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE2102 ADVANCED PROCESSORS FOR POWER CONVERTERS L T P C
3 0 0 3

COURSE OBJECTIVES

- To introduce ARM Processor and DSP controller.
- To analyze the resources available in ARM Processor and DSP-controller which will be used to generate pulses.
- To overview of programming frame work, software building blocks and Interrupt structures, event manager, and compare unit in processors.

UNIT I ARM PROCESSORS 9

Arm processor architecture and pipelining; Programmer's model; Data paths and instruction decoding; Advanced Microcontroller Bus architecture; ARM instruction set; Addressing modes; General Purpose Input and Output (GPIO); Analog to Digital Converter; Digital to Analog Converter; Simple programming.

UNIT II TIMERS AND PWM 9

Different modes of operation of Timers; Match Registers; Generation of PWM using Compare registers; Capture Control; Single and Double Edge Controlled PWM; programming to generate triggering pulses for power converters.

UNIT III COMPONENT INTERFACING AND NETWORKS 9

System Control; RTC, Watch Dog Timer, USB 2.0 Full-Speed device controller with DMA, Communication interface; UART, I2C Bus Serial Interface, SPI, SSP Serial Interfaces.

UNIT IV EXCEPTION AND INTERRUPT HANDLING 9

Exception Handling Overview; Interrupts; Interrupt Handling Schemes; External Interrupt, Timer Interrupt, PWM Interrupt, ADC Interrupt; Utility Of Interrupts In Closed Loop Control Of A Real Time System; Programming.

UNIT V DIGITAL SIGNAL PROCESSING WITH ARM **9**

Representing a Digital Signal; Introduction to DSP on the ARM; Industry needs from the digital implementation perspective on the processors.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

- CO1: Understand the Arm processor architecture.
- CO2: Use the Timers and PWM to generate triggering pulses for power electronic circuits.
- CO3: Experiment with the exceptions of ARM processor to vary the triggering pulses for power electronic circuits.
- CO4: Apply digital signal processing in ARM processor.
- CO5: Experiment with the peripherals of DSP processor for power electronics applications.

TEXT BOOKS

1. "Power Electronics" by A. K. Singh and B. M. Gupta Publisher: PHI Learning, 2016.
2. "Advanced Power Electronics Converters" by M. S. J. M. K. Ranjan Publisher: Springer Year: 2021.
3. "Power Electronics: Essentials and Applications" by D. S. Kumar and S. S. Gupta Publisher: Wiley Year: 2015.

REFERENCE BOOKS

1. Andrew N.Sloss, Dominic Symes, Chris Wright, "ARM System Developer'sGuide Designing and Optimizing System Software" Morgan Kaufmann Publishers, 2011.
2. Hamid A. Toliyat, Steven Campbell, "DSP based electromechanical motion control", CRC press, New York, Washington Dc, 2012.
3. William Hohl, Christopher Hinds "ARM Assembly Language – Fundamentals and Techniques" Second Edition, CRC Press Taylor & Francis Group 2015.
4. Ata Elahi, Trevor Arjeski "ARM Assembly Language with Hardware Experiments", Springer 2015.
5. "Control of Power Converters" by B. G. Fernandes and K. R. K. R. Rao Publisher: CRC Press Year: 2020.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	-	2	3	2	1
CO2	2	-	2	3	2	1
CO3	2	-	2	3	2	1
CO4	2	-	2	3	2	1
CO5	2	-	2	3	2	1
AVG	2	-	2	3	2	1

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE2103 ELECTRIC VEHICLES AND POWER MANAGEMENT **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To understand the concept and operations of electric and hybrid electric vehicles (EVs and HEVs), including their architecture.
- To explore the need for energy storage in hybrid vehicles and the technologies available for energy storage.
- To provide an overview of various energy storage technologies applicable to electric vehicles.

UNIT I ELECTRIC VEHICLES AND VEHICLE MECHANICS **9**

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 **9**

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

UNIT III POWER ELECTRONICS AND MOTOR DRIVES **9**

Electric drive 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 **9**

Battery Basics- Different types- Battery Parameters-Battery life & safety impacts -Battery modeling-Design of battery for large vehicles.

UNIT V ALTERNATIVE ENERGY STORAGE SYSTEMS **9**

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

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student 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.

TEXT BOOKS

1. "Electric Vehicles: Technology, Policy, and Business" by A. K. Jain and A. B. Shukla Publisher: PHI Learning Year: 2020.
2. "Electric and Hybrid Vehicles: Design Fundamentals" by J. K. Gupta and R. P. Gupta Publisher: New Age International Year: 2015.
3. "Electric Vehicles: An Overview" by K. R. Rao and S. K. Jain Publisher: Wiley Year:2018.

REFERENCE BOOKS

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, Yimin Gao, 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. "Electric Vehicle Technology Explained" by H. M. Tiwari and S. S. Jain
6. Publisher: Tata McGraw-Hill Year: 2017.

Mapping of COs and POs

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

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24RE2101 SCIENTIFIC REPORT WRITING L T P C
2 0 0 2

COURSE OBJECTIVES

- To understand the essentials of project writing and the structure of technical and project reports.
- To recognize the differences between general writing and technical writing.
- To assimilate the fundamental features of report writing and its unique characteristics.

UNIT I WRITING SKILL 6

Writing Skills – Essential Grammar and Vocabulary – Passive Voice, Reported Speech, Concord, Signpost words, Cohesive Devices – Paragraph writing - Technical Writing vs. General Writing.

UNIT II PROJECT REPORT 6

Project Report – Definition, Structure, Types of Reports, Purpose – Intended Audience – Plagiarism – Report Writing in STEM fields – Experiment – Statistical Analysis.

UNIT III STRUCTURE OF PROJECT REPORT 6

Structure of the Project Report: Framing a Title – Content – Acknowledgement – Funding Details -Abstract – Introduction – Aim of the Study – Background - Writing the research question –Need of the Study/Project Significance, Relevance – Determining the feasibility – Theoretical Framework.

UNIT IV REPORT WRITING 6

Literature Review, Research Design, Methods of Data Collection - Tools and Procedures - Data Analysis - Interpretation - Findings –Limitations -Recommendations – Conclusion – Bibliography.

UNIT V PROOF READNG 6

Proof reading a report – Avoiding Typographical Errors – Bibliography in required Format – Font –Spacing – Checking Tables and Illustrations – Presenting a Report Orally – Techniques.

TOTAL: 30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Write effective project reports.
CO2: Use statistical tools with confidence.
CO3: Explain the purpose and intension of the proposed project coherently and with clarity.
CO4: Create writing texts to suit achieve the intended purpose.
CO5: Master the art of writing winning proposals and projects.

TEXT BOOKS

1. "Scientific Writing and Communication in Agriculture and Natural Resources" by R.C. Choudhury Publisher: New India Publishing Agency Year: 2018.
2. "Technical Writing: A Practical Guide for Engineers and Scientists" by Phillip A. Laplante (with contributions from Indian authors) Publisher: Wiley Year: 2016.
3. "Effective Technical Communication" by M. Ashraf Rizvi Publisher: Tata McGraw- Hill Year: 2008.

REFERENCE BOOKS

1. Gerson and Gerson - Technical Communication: Process and Product, 7th Edition, Prentice Hall (2012).
2. Virendra K. Pamecha - Guide to Project Reports, Project Appraisals and Project Finance (2012).
3. Daniel Riordan - Technical Report Writing Today (1998).
4. Darla-Jean Weatherford - Technical Writing for Engineering Professionals (2016) Penwell Publishers.
5. "Writing Scientific Research Articles: Strategy and Steps" by S. R. K. Rao Publisher: Springer Year: 2019.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	-	-	1	-
CO2	3	3	-	-	1	-
CO3	3	3	-	-	1	-
CO4	3	3	-	-	1	-
CO5	3	3	-	-	1	-
AVG	3	3	-	-	1	-

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE2201 INDUSTRIAL ELECTRICAL DRIVES LABORATORY **L T P C**
0 0 4 2

COURSE OBJECTIVES

- To understand the performance of electrical drives experimentally under various operating conditions and improve knowledge of power electronic drive applications.
- To regulate the speed of DC motor-based drive systems and manage stepper and BLDC motor-based drive systems.
- To implement various speed control strategies for electric drives.

LIST OF EXPERIMENTS

1. Design and speed control of AC to DC converter fed DC motor drive.
2. Design and speed control of DC to DC converter fed DC motor drive.
3. Speed control of induction motor drive using V/f control.

4. Simulation of Speed control of induction motor drive using field-oriented control.
5. Design and control of induction motor drive under four quadrants.
6. Micro controller based speed control of Stepper motor.
7. Simulation of Speed control of BLDC motor.
8. Simulation of Speed control of induction motor drive using flux sensor less control.
9. Simulation of Speed control of slip ring induction motor using static rotor resistance control.
10. Simulation of Speed control of permanent magnet synchronous motor (PMSM) drive.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Build simulation circuits for closed-loop control of drive systems.

CO2: Capability to design and develop speed controllers for DC motor-based drive systems.

CO3: Proficiency in performing load tests on electrical drive systems.

CO4: Design and implement speed controllers for AC motor-based drive systems.

CO5: Creating control algorithms for electrical drive systems using microcontrollers and digital signal processors.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE2202 ADVANCED PROCESSORS FOR POWER CONVERTERS LABORATORY **L T P C 0 0 4 2**

COURSE OBJECTIVES

- To utilize ARM and DSP controllers to generate and optimize control signals for power converters.
- To apply the resources of ARM and DSP controllers to enhance control signal precision.
- To integrate ARM and DSP controller capabilities to improve the performance of power converters.

LIST OF EXPERIMENTS

1. Single phase single quadrant DC-DC converter and its control.
2. Control of a single phase single quadrant bridge type AC-DC converter.
3. Single phase two quadrant AC-DC converter controlled through ARM processor.
4. Control of a High power two quadrant bridge type AC-DC converter.
5. ARM processor based control of a residential UPS.
6. Single phase step down cycloconverter and its control.
7. PWM control of single quadrant DC chopper.
8. DSP based implementation of PWM techniques to control an inverter.
9. Control of single phase half controlled converter using DSP processor.
10. Control of chopper circuit in TRC and variable frequency method.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Build simulation circuits for timers and PWM to generate triggering pulses for power electronic circuits.

CO2: Capability to experiment with the functionalities of ARM processors to vary the triggering pulses for power electronic circuits.

CO3: Proficiency in utilizing DSP processors for various power electronics applications.

CO4: Design speed controllers for drive systems.

CO5: Implementing and testing the performance of speed controllers in drive systems.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	2	2	-	-
CO2	3	3	2	2	-	-
CO3	3	3	3	3	-	-
CO4	3	3	3	3	-	-
CO5	-	-	-	-	-	-
AVG	3	3	2.5	2.5	-	-

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24RE3201 RESEARCH ARTICLE REVIEW L T P C
0 0 4 2

COURSE OBJECTIVES

- To gain knowledge on collecting the research articles.
- To read and understand the various literatures related to the research.
- To write the review article for publication

STAGES OF REVIEW

Stage 1	Collection of latest Research articles
Stage-2	Read the entire article and take a note in his/her own words.
Stage-3	Summarize the literature in his/her own words.
Stage-4	Classify and arrange the literatures with template
Stage 5	Preparation of review article
Stage 6	Plagiarism checked by the department and it must be less than 10%
Stage 7	Article must be communicated to the journal.

The students must do the above work individually by the guidance of faculty members and one coordinator is required to monitor the work progress. The evaluation will be done based on the following

a) Review of work after stage 3 10%
b) Review of work after stage 5 20%
c) Review of work after stage 7 20%
d) Final examination 50%

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Understand the technique to collect the literatures from various resources.
CO2: Apply the knowledge for collecting the required research data from the articles.
CO3: Formulate the research problem.
CO4: Analyze the research gap from various researchers work.
CO5: Create the new article to publish in the research journals.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	-	-	2	-
CO2	2	2	-	-	-	-
CO3	2	2	-	-	-	-
CO4	2	2	-	-	2	-
CO5	2	2	-	-	2	-
AVG	2	2	-	-	2	-

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PF3501 **PROJECT WORK PHASE I** **L T P C**
0 0 12 6

COURSE OBJECTIVES

- To develop knowledge to formulate a real-world problem.
- To use different tools and techniques to arrive at a solution.
- To prepare a report and give a presentation.

Project Guidelines and Evaluation

- **Selection of a project topic:** It is a crucial and involves a literature survey and creative input, guided by a project supervisor. The topic should allow skill development in design, fabrication, analysis, testing, and research.
- **Literature survey**: Which helps to identify gaps and build on existing research. Initial project work should be completed during Dissertation I to lay the groundwork for further research.
- **Completed project work phase-I:** will be evaluated by internal and external examiners based on an oral presentation and the project report, which is submitted at the end of Dissertation-I. The evaluation follows the institution's credit system regulations.

ESSENTIALS

1. **ZEROTH REVIEW:** Confirmed project title, Print out of base paper, abstract, with minimum of **6 slides** of Power Point Presentation.

2. **FIRST REVIEW:** Reply for queries (if any) given in **ZEROTH REVIEW**, clear idea about existing and collection of clear literature survey (Minimum of 20 articles) from the reputed journals, with minimum of 15 slides. 25% of work should be completed.

3. **SECOND REVIEW:** Reply for queries (if any) given in **FIRST REVIEW,** collect and prepare the literatures (Minimum of 50 articles) with Literature template, minimum of **30 slides. 50%** of work should be completed.

4. **THIRD REVIEW:** Reply for queries (if any) given in **SECOND REVIEW, 90%** of work completion including Research Gap, Problem statement, Project Workflow Chart, Study of proposed work comparing with existing literatures Example: Calculation, Simulations, Analysis, optimization with minimum of **45 slides.**

TOTAL: 180 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Design and analyze, an identified problem using scientific tools.
CO2: Simulation/ Theoretical analysis of a physical system.
CO3: Integrate various domain knowledge for a sustainable solution.
CO4: Set Goals, Targets, timeline, plan and execute activities of the project.
CO5: Disseminate work both in oral and written format.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	3	-	-
CO2	2	2	3	3	-	-
CO3	2	2	3	3	-	-
CO4	2	2	3	3	-	-
CO5	2	2	3	3	-	-
AVG	2	2	3	3	-	-

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE4501 **PROJECT WORK PHASE II** **L T P C**
0 0 24 12

COURSE OBJECTIVES

- To define the problem of the proposed research work.
- To enable students to apply any piece of theory and experiments which they have learned to a specific problem related to industry / research.
- To demonstrate and validate the results of the design concept

ESSENTIALS:

1. **ZEROTH REVIEW:** Confirmed project title, Print out of base paper, abstract, with minimum of **6 slides** of Power Point Presentation.

2. **FIRST REVIEW:** Reply for queries (if any) given in **ZEROTH REVIEW**, clear idea about existing and proposed project work, clear literature survey, with minimum of **15 slides**.

3. **SECOND REVIEW:** Reply for queries (if any) given in **FIRST REVIEW,** nearly **30%** of work completion including Project Workflow Chart, Design, Calculation with minimum of **20 slides.**

4. **THIRD REVIEW:** Reply for queries (if any) given in **SECOND REVIEW, 50%** of work completion including Project Workflow Chart, Design, Calculation, simulations, Fabrication, with minimum of **25 slides.**

TOTAL: 360 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Identify and formulate research problem.
CO2: Design and develop solution to the problem.
CO3: Analyze and solve the complex problems.

CO4: Plan, implement and execute the project.
CO5: Write effective technical report and demonstrate through presentation.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	-	-
CO2	2	2	3	3	-	-
CO3	2	2	3	3	-	-
CO4	2	2	3	3	-	-
CO5	2	2	3	3	-	-
AVG	2	2	3	3	-	-

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE1301 SMART GRID TECHNOLOGIES L T P C
3 0 0 3

COURSE OBJECTIVES

- To study about Smart Grid technologies, different smart meters and advanced metering infrastructure.
- To familiarize the power quality management issues in Smart Grid.
- To familiarize the high–performance computing for Smart Grid application.

UNIT I INTRODUCTION TO SMART GRID 9

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 9

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 9

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 9

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 9

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.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Relate with the smart resources, smart meters and other smart devices.
CO2: Describe the functions of the Smart Grid.
CO3: Investigate the power quality issues within the Smart Grid.
CO4: Evaluate the performance of the Smart Grid.
CO5: Suggest appropriate communication networks for Smart Grid.

TEXT BOOKS

1. Stuart Borlase 'Smart Grid: Infrastructure, Technology and Solutions', CRC Press 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu, Akihiko Yokoyama, 'Smart Grid: Technology and Applications', Wiley, 2012.
3. D. Kirschen and G. Strbac, Fundamentals of Power System economics, John Wiley & Sons Ltd,2019, 2nd Edition.

REFERENCE BOOKS

1. Mini S. Thomas, John D McDonald, 'Power System SCADA and Smart Grids', CRC Press, 2015.
2. Kenneth C.Budka, Jayant G. Deshpande, Marina Thottan, 'Communication Networks for Smart Grids', Springer, 2014.
3. SMART GRID Fundamentals of Design and Analysis, James Momoh, IEEE press, A John Wiley & Sons, Inc., Publication.
4. Vehbi C. Güngör, Dilan Sahin, Taskin Kocak, Salih Ergüt, Concettina Buccella, Carlo Cecati and Gerhard P. Hancke, 'Smart Grid Technologies: Communication Technologies and Standards', IEEE Transactions on Industrial Informatics, Vol. 7, No. 4, November 2011.
5. Lars T.Berger and Krzysztof Iniewski, "Smart Grid applications, communications and security", Wiley, 2015.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	3	3	3
CO2	3	2	-	2	2	2
CO3	3	-	2	2	-	2
CO4	2	-	1	-	-	3
CO5	1	2	2	2	2	2
AVG	2	2	2	2.25	2.33	2.4

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE1302 ELECTRICAL SYSTEMS IN WIND ENERGY **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To understand the basic scientific principles, design components, and efficiency computation theories of wind turbines.
- To learn the design, control principles, and concepts of both fixed and variable speed wind energy conversion systems.
- To analyze grid integration of wind turbines and identify related challenges andissues.

UNIT I WIND POWER BASICS **9**

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

UNIT II WIND TURBINE **9**

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 TECHNOLOGY OF WIND ENERGY CONVERSION SYSTEM **9**

Fixed speed and variable speed systems. Electrical machines for wind energy systems, synchronous and asynchronous generators and power electronics. Integration of wind energy systems to electrical networks, converters, inverters, directly connected, wind energy storage solutions.

UNIT IV CONTROL SYSTEMS **9**

Requirements, components and strategies. Small wind turbines special considerations and designs, testing, noise issues, Off-shore turbines.

UNIT V GRIDCONNECTED SYSTEMS **9**

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.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

- CO1: Gain an understanding of the fundamental concepts of wind energy conversion systems.
- CO2: Acquire knowledge in the mathematical modeling and control of wind turbines.
- CO3: Deepen understanding of the design principles for fixed-speed systems.
- CO4: Explore the necessity and modeling of variable-speed systems.
- CO5: Learn about grid integration challenges and current practices for connecting wind energy to power systems.

TEXT BOOKS

1. Joshua Earnest Wind Power Technology, PHI Learning Pvt. Ltd., 2014.
2. S. N. Bhadra, D. Kastha, and S. Banerjee Wind Electrical Systems, Oxford University Press, 2005.
3. S. S. Rao and B. B. Parekh, Wind Energy: Theory and Practice, PHI Learning Pvt. Ltd., 2018.

REFERENCE BOOKS

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. B. H. Khan, Non-Conventional Energy Resources, McGraw Hill Education, 2017.

Mapping of COs and POs

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

1 - Low, 2 - Medium, 3 – High, ‘-’ No correlation

24PE1303 POWER SYSTEM RESTRUCTURING & DEREGULATION **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To impart knowledge about the restructuring and deregulation of power sector.
- To introduce the fundamental concepts relevant to congestion management.
- To enable the students to understand the factors related with deregulation of power industry in different countries.

UNIT I INTRODUCTION **9**

Basic concept and definitions, privatization, restructuring, transmission open access, wheeling, deregulation, components of deregulated system, advantages of competitive system. Power System Restructuring: An overview of the restructured power system, Difference between integrated power system and restructured power system, Explanation with suitable practical examples.

UNIT II DEREGULATION OF POWER SECTOR **9**

Separation of owner ship and operation, Deregulated models, pool model, pool and bilateral trades model, multilateral trade model. Competitive electricity market: Independent System Operator activities in pool market, Wholesale electricity market characteristics, central auction, single auction power pool, double auction power pool, market clearing and pricing, Market Power and its Mitigation Techniques, Bilateral trading, Ancillary services.

UNIT III TRANSMISSION PRICING **9**

Marginal pricing of electricity, nodal pricing, zonal pricing, embedded cost, Postage stamp method, Contract Path method, Boundary flow method, MW-mile method, MVA-mile method, Comparison of different methods.

UNIT IV CONGESTION MANAGEMENT **9**

Congestion management in normal operation, explanation with suitable example, Total Transfer Capability (TTC), Available Transfer Capability (ATC), Transmission Reliability Margin (TRM), Capacity Benefit Margin (CBM), Existing Transmission Commitments (ETC).

UNIT V CASE STUDY **9**

Different Experiences in deregulation: England and Wales, Norway, China, California, New Zealand and Indian power system.

TOTAL:45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Identify various concepts of restructuring and deregulation of power sector.

CO2: Describe important concepts related with deregulation like models, market power, OASIS, congestion management etc.

CO3: Apply different transmission pricing concepts to real-world scenarios.

CO4: Apply different congestion management techniques to case studies and practical examples to address congestion issues.

CO5: Analyze case studies of deregulation in various countries and assess their outcomes and impacts on the power sector.

TEXT BOOKS

1. Loi Lei Lai, Power System Restructuring and Deregulation: Trading, Performance and Information Technology, Wiley India Pvt. Ltd., 2001.
2. K. Bhattacharya, M. H. J. Bollen, and J. E. Daalder, Operation of Restructured Power Systems, Springer India, 2012.
3. S. A. Khaparde and A. R. Abhyankar, Restructured Power Systems, Narosa Publishing House, 2019.

REFERENCE BOOKS

1. Power System Restructuring and Deregulation by Loi Lei Lai, John Wiley & Sons Ltd.
2. Understanding Electric Utilities and Deregulation by Lorrin Philipson and H. Lee Willis, Marcel Dekker Inc, New York, CRC Press.
3. Power System Restructuring Engineering & Economics by Marija llic by Francisco Galiana and Lestor Fink, Kulwer Academic Publisher, USA.
4. Ashikur Bhuiya: Power System Deregulation: Loss Sharing in Bilateral Contracts and Generator Profit Maximization, VDM Verlag Publisher, 2008.
5. S. Hunt,, Making competition work in electricity, John Wiley & Sons, Inc., 2002, 1st Edition.

Mapping of COs and POs

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

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE1304 DISTRIBUTED GENERATION AND MICRO GRID **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To explain the concept of distributed generation, explore its various topologies, and evaluate the effects of its integration with the grid.
- To study concept of Microgrid and its configuration.
- To understand various modes of operation and control of micro grid.

UNIT I INTRODUCTION TO DISTRIBUTED GENERATION 9

Need for Distributed generation, renewable sources in distributed generation, current scenario in Distributed Generation, Planning of DGs – Siting and sizing of DGs – optimal placement of DG sources in distribution systems.

UNIT II GRID INTEGRATION OF DISTRIBUTED GENERATION 9

Different types of interfaces - Inverter based DGs and rotating machine based interfaces - Aggregation of multiple DG units. Energy storage elements: Batteries, ultra capacitors, flywheels.

UNIT III TECHNICAL IMPACTS OF DISTRIBUTED GENERATION 9

Transmission systems, Distribution systems, De-regulation – Impact of DGs upon protective relaying – Impact of DGs upon transient and dynamic stability of existing distribution systems.

UNIT IV ECONOMIC AND CONTROL ASPECTS OF DISTRIBUTED GENERATION 9

Market facts, issues and challenges - Limitations of DGs. Voltage control techniques, Reactive power control, Harmonics, Power quality issues. Reliability of DG based systems – Steady-state and Dynamic analysis.

UNIT V INTRODUCTION TO MICRO-GRIDS 9

Types of micro-grids – autonomous and non-autonomous grids – Sizing of micro-grids-modeling & analysis- Micro-grids with multiple DGs – Micro- grids with power electronic interfacing units. Transients in micro-grids - Protection of micro-grids – Case studies.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Comprehend the concepts of Distributed Generation and Microgrids.
CO2: Learn about the different Distributed Generation (DG) resources.
CO3: Become familiar with the planning and protection strategies for Distributed Generation.
CO4: Understand the concept of Microgrids and their operational modes.
CO5: Associate different types of micro-grids and analyse the transients and protection related issues in micro-grids.

TEXT BOOKS

1. S. N. Singh, Electric Power Generation, Transmission, and Distribution: Distributed Generation and Microgrid, PHI Learning Pvt. Ltd., 2011.
2. R. C. Bansal, Distributed Generation and Microgrids, CRC Press India, 2017.
3. S. Chowdhury, P. Crossley, and S. P. Chowdhury, Microgrids and Active Distribution Networks, IET India, 2009.

REFERENCE BOOKS

1. Nick Jenkins, Janaka Ekanayake , Goran Strbac , “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. Nadarajah Mithulananthan, Duong Quoc Hung, Kwang Y. Lee, “Intelligent Network Integration of Distributed Renewable Generation”, Springer International Publishing, Switzerland, 2017.

Mapping of COs and POs

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

1 - Low, 2 - Medium, 3 – High, ‘-’ No correlation

24PE1305 FLEXIBLE AC TRANSMISSION SYSTEMS **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To explore Smart Grid technologies, including smart meters and advanced metering infrastructure.
- To understand the functions of the Smart Grid and power quality management challenges.
- To gain knowledge of high-performance computing and communication networks used in Smart Grid applications.

UNIT I FACTS CONCEPTS **9**

Transmission interconnections power flow in an AC system, loading capability limits, Dynamic stability considerations, importance of controllable parameters, basic types of FACTS controllers, benefits from FACTS controllers.

UNIT II VOLTAGE SOURCE CONVERTERS 9

Single Phase Three Phase Full Wave Bridge Converter Transformer Connections for 12 Pulse 24 And 48 Pulse Operation. Three Level Voltage Source Converter, Pulse Width Modulation Converter, Basic Concept of Current Source Converters, and Comparison of Current Source Converters with Voltage Source Converters.

UNIT III STATIC SHUNT COMPENSATION 9

Objectives of Shunt Compensation, Midpoint Voltage Regulation Voltage Instability Prevention, Improvement of Transient Stability, Power Oscillation Damping, Methods of controllable VAR Generation, Variable Impedance Type Static VAR Generators Switching Converter Type VAR Generators Hybrid VAR Generators.

UNIT IV SVC AND STATCOM 9

The Regulation and Slope Transfer Function, Dynamic Performance, Transient Stability Enhancement and Power Oscillation Damping, Operating Point Control and Summary of Compensator Control.

UNIT V STATIC SERIES COMPENSATORS 9

Concept of Series Capacitive Compensation, Improvement of Transient Stability, Power Oscillation Damping, Subsynchronous Oscillation Damping. Functional Requirements of GTO Thyristor Controlled Series Capacitor (GCSC), Thyristor Switched Series Capacitor (TSSC), And Thyristor Controlled Series Capacitor (TCSC) Control Schemes for GCSC, TSSC and TCSC.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

- CO1: Understand various types of power controllers in transmission lines.
- CO2: Familiarize the high-performance computing for Smart Grid applications
- CO3: Understand the static VAR compensator and its applications.
- CO4: Understand the TCSC controller and its applications.
- CO5: Understand the transient stability and modeling of STATCOM.

TEXT BOOKS

1. NarainG. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, Wiley India Pvt. Ltd., 2011.
2. S.Rao, EHV-AC, HVDC Transmission & Distribution Engineering, Khanna Publishers, 2011.
3. D. P. Kothari and I. J. Nagrath, Modern Power System Analysis, McGraw Hill Education, 2013.

REFERENCE BOOKS

1. R.Mohan Mathur, Rajiv K.Varma, "Thyristor – Based Facts Controllers for Electrical Transmission Systems", IEEE press and John Wiley & Sons, Inc, 2002.
2. Narain G. Hingorani, "Understanding FACTS -Concepts and Technology of Flexible AC Transmission Systems", Standard Publishers Distributors, Delhi- 110 006, 2011.
3. K.R.Padiyar," FACTS Controllers in Power Transmission and Distribution", New Age International (P) Limited, Publishers, New Delhi, 2008.
4. N. G. Hingorani, L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, Wiley, 2000.
5. Suman Bhowmick, Flexible AC Transmission Systems (FACTS), CRC Press, 2023, First Edition.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	-	1	1
CO2	3	1	3	-	1	1
CO3	3	3	3	-	1	1
CO4	3	3	3	-	1	1
CO5	3	3	3	-	1	1
AVG	3	2.2	3	-	1	1

1 - Low, 2 - Medium, 3 - High, '-' No correlation

24PE1306 HIGH VOLTAGE DC TRANSMISSION L T P C
3 0 0 3

COURSE OBJECTIVES

- To emphasize the need for HVDC transmission and understand the characteristics, applications, and modeling of HVDC controllers.
- To analyze the interaction of different HVDC controllers and perform control coordination.
- To gain knowledge on the operation, modeling, and control of HVDC links, including steady-state analysis of AC/DC systems.

UNIT I DC POWER TRANSMISSION TECHNOLOGY 9

Introduction, Comparison of HVAC and HVDC transmission system, Applications of DC transmission, Description of DC transmission system, Configurations, Modern trends in DC transmission. Pulse number, Choice of converter configuration, Simplified analysis of Graetz circuit, Converter bridge characteristics, Characteristics of a twelve-pulse converter.

UNIT II CONVERTER AND HVDC SYSTEM CONTROL 9

General, Principles of DC link control, Converter control characteristics, System control hierarchy, Firing angle control, Current and extinction angle control, Starting and stopping of DC link, Power control, Higher level controllers.

UNIT III POWER FLOW ANALYSIS **9**

DC system model for load flow studies, Load flow study of AC-DC system sequential method, simultaneous method. Reactive power requirements in steady state, conventional control strategies, alternate control strategies, equipment for reactive power.

UNIT IV FAULTS AND PROTECTION **9**

Short circuit ratio, Effective short circuit ratio, dynamic over voltages, power modulation, commutation failure, disturbances on AC side, disturbances on DC side, Characteristic harmonics, derivation of relevant equations for 12 pulse converter. AC filters single tuned, doubled tuned filters, brief introduction to DC circuit breakers.

UNIT V MULTI TERMINAL DC TRANSMISSION **9**

Introduction, potential applications of MTDC systems, Types of MTDC systems, control and protection.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Choose intelligently AC and DC transmission systems for the dedicate applications.
CO2: Identify the suitable two-level/multilevel configuration for high power converters.
CO3: Select the suitable protection method for various converter faults.
CO4: Identify suitable reactive power compensation method.
CO5: Decide the configuration for harmonic mitigation on both AC and DC sides.

TEXT BOOKS

1. K. R. Padiyar, HVDC Power Transmission Systems: Technology and System Interactions New Age International Publishers, 2011.
2. S. Kamakshaiah and V. Kamaraju, HVDC Transmission, McGraw Hill Education, 2011.
3. J. Arrillaga and B. S. R. Murthy,High Voltage Direct Current Transmission, IET India, 2015.

REFERENCE BOOKS

1. Arrillaga, J., HVDC Transmission, IEE Press (2007).
2. Edwart, K., Direct Current Transmission (Vol. 1), John Wiley and Sons (2008).
3. Padiyar, K.R., HVDC Power Transmission System, New Age International (P) Limited, Publishers (2008).
4. Arrillaga, J. and Smith, B.C., AC to DC Power System Analysis, IEE Press (2008).

5. Turan Gonen, Electric Power Transmission System Engineering Analysis and Design, CRC Press, 2014, Third Edition.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	2	2
CO2	3	3	2	2	3	2
CO3	3	3	2	2	3	3
CO4	3	3	2	3	3	3
CO5	3	3	2	3	3	3
AVG	3	3	2	2.4	2.8	2.6

1 - Low, 2 - Medium, 3 – High

24PE1307 ENERGY STORAGE SYSTEMS L T P C
3 0 0 3

COURSE OBJECTIVES

- To understand different types of energy storages.
- To analyze different battery storage technologies and thermodynamics of Fuel Cell.
- To study the various applications of energy storage system.

UNIT I ENERGY STORAGE 9

Necessity and types of energy storage, Mechanical, electrical and chemical energy storage systems and its application; Available energy; Energy analysis: Second law efficiency; Helmholtz & Gibb's function; Recent trends in energy storage systems.

UNIT II STORAGE SYSTEMS 9

Fundamental concept of batteries – Measuring of battery performance: charging and discharging of battery, storage density, energy density and safety issues; Modeling of batteries; Zinc-air, Nickel hydride, Lithium battery; State of charge; Technology challenges.

UNIT III SUPER CAPACITORS 9

Super capacitors; Types of electrodes and electrolytes; Electrode materials: high surface area activated carbons, metal oxide and conducting polymers; Electrolyte: aqueous or organic, disadvantages and advantages of super capacitors; Modeling of super capacitors; Application of super capacitors.

UNIT IV FUEL CELLS 9

Fuel Cell – History of Fuel cell, Principles of Electrochemical storage – Types: Hydrogen oxygen cells, Hydrogen air cell, Hydrocarbon air cell, Alkaline fuel cell - Modeling of Fuel Cells, maximum intrinsic efficiency of an electrochemical converter; Physical interpretation; Carnot efficiency factor in electrochemical energy converters; – Advantages and disadvantages –Fuel Cell Thermodynamics.

UNIT V ENERGY STORAGE APPLICATIONS **9**

Application of Power Electronics Converters in Energy Storage Systems; Standalone photovoltaic systems; Grid connected systems; Power smoothing, grid ancillary services, energy management case studies and simulation.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Understand the concept of energy storage system.
CO2: Understand the physics of energy storage.
CO3: Model the different energy technologies.
CO4: Recognize the applications of various techniques.
CO5: Design and analyze the energy storage technologies.

TEXT BOOKS

1. Andrei G. Ter-Gazarian, "Energy storage systems for Power systems", Second edition, IET 2011.
2. James Larmini 1. Yves Brunet, "Energy Storage", Wiley-ISTE, 1st Edition, 2010. M.TECH (C&A).
3. Andrei G. Ter-Gazarian, "Energy storage systems for Power systems", Second edition, IET 2011.

REFERENCE BOOKS

1. R M. Dell, D.A.J. Rand, "Understanding Batteries" RSC Publications, 1st edition, 2012.
2. Tetsuya Osaka, Madhav Datta, "Energy Storage Systems in Electronics-New Trends in Electrochemical Technology", CRC Press, 2000.
3. James Larminie and Andrew Dicks, 'Fuel cell systems Explained', Wiley publications, 2003.
4. LunardiniV.J, "Heat Transfer in Cold Climates", John Wiley and Sons 1981.
5. Jiujun Zhang (Editor), Lei Zhang (Editor), Hansan Liu (Editor), Andy Sun (Editor), Ru-Shi Liu (Editor), "Electrochemical technologies for energy storage and conversion", Two Volume Set, Wiley publications, 2012.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	1	-	-	2	-
CO2	2	1	2	-	3	-
CO3	2	2	2	-	3	-
CO4	3	2	3	-	3	2
CO5	2	2	2	2	2	3
AVG	2.25	1.6	2.25	2	2.6	2.5

1 - Low, 2 - Medium, 3 – High, ' -' No correlation

24PE1308 POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS **L T P C 3 0 0 3**

COURSE OBJECTIVES

- To analyze various electrical Generators used for the Wind Energy Conversion Systems and various maximum power point tracking algorithms.
- To design a power converter used in renewable energy systems such as AC-DC, DC-DC, and AC-AC converters.
- To understand the importance of standalone, grid-connected, and hybrid operation in renewable energy systems.

UNIT I INTRODUCTION TO RENEWABLE ENERGY SYSTEM 9

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 9

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 &ANALYSIS OF SOLAR PV SYSTEMS 9

Introduction to PV-Cells, Array, Solar power extraction using PV-Cells, I-V Characteristics. Line commutated converters (inversion-mode) – Boost and buck-boost converters- selection of inverter, battery sizing, array sizing. 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 9

Three-phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid-Interactive Inverters – Matrix converter. Stand-alone operation of fixed and variable speed WECS-Grid integrated SCIG and PMSG based WECS.

UNIT V HYBRID RENEWABLE ENERGY SYSTEMS 9

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).

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful 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: Analyze the hybrid renewable energy system.

TEXT BOOKS

1. N.Bhadra, D. Kastha, & S. Banerjee "Wind Electrical Systems", Oxford University Press, 2009.
2. Rashid .M. H "Power electronics Hand book", Academic press, Second Edition, 2006.
3. Rai. G.D, "Non-conventional energy sources", Khanna publishers, 2010.

REFERENCE BOOKS

1. Rai. G.D," Solar energy utilization", Khanna publishers, 5th Edition, 2008.
2. Gray, L. Johnson, "Wind energy system", prentice hall of India, 1995.
3. B.H.Khan "Non-conventional Energy sources ", Tata McGraw-hill Publishing Company, New Delhi, 2017.
4. Suleiman M. Sharkh, Mohammad A. Abu-Sara, Georgios I. Orfanoudakis, Babar Hussain, "Power Electronic Converters for Microgrids" Wiley-IEEE Press, April 2014.
5. Chakraborty, William E. Kramer, "Power Electronics for Renewable and Distributed Energy Systems" Springer 2013.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	2	3	2
CO2	2	1	3	2	2	2
CO3	2	1	3	2	2	2
CO4	1	1	3	2	2	2
CO5	1	1	3	2	2	2
AVG	1.4	1	3	2	2.2	2

1 - Low, 2 - Medium, 3 – High, ‘ -’ No correlation

24PE1309 ADVANCED POWER CONVERTERS **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To learn the operation of ultra-lift converters and multiple quadrant converters.
- To provide knowledge on the principle of bidirectional dual active bridge converters.
- To educate on the working principle of Impedance source converter, voltage lift circuits, super lift circuits.

UNIT I VOLTAGE-LIFT CONVERTERS **9**

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 CONVERTER **9**

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 **9**

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 **9**

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 **9**

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.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Understand the working of voltage lift circuits.

CO2: Design the super lift converters.

CO3: Understand the working and applications of ultra-lift converters.

CO4: Acquire knowledge on working and design of bi-directional DC-DC converters.

CO5: Understand the concepts related with impedance source converter.

TEXT BOOKS

1. Ned Mohan, Tore M.Undeland and William P. Robbins, "Power Electronics – Converters, Applications and Design", John Willey & sons, Inc., 3rd ed., 2003.
2. Muhammad H. Rashid, "Power Electronics - Circuits, Devices and Applications", Prentice Hall of India, 3rd ed., 2009.
3. Derek A. Paice "Power Electronic Converter Harmonics – Multi pulse Methods for Clean Power", IEEE Press, 1996.

REFERENCE BOOKS

1. Muhammad H. Rashid , "Power Electronics Handbook", Elsevier, 3rd ed., 2011.
2. P.C.Sen, "Modern Power Electronics ", S. Chand and Co. Ltd., New Delhi, 2000.
3. Vijay K. Sood, "HVDC and FACTS Controllers Applications of Static Converters in Power Systems", Kluwer Academic Publishers, Boston, 2004.
4. L. Umanand, "Power Electronics Essentials and Applications", Wiley India Ltd., 2009 Recent Literature.
5. Dubey G.K. "Power Semiconductor Controlled Drives", PRENTICE- -Hall of India Pvt, New Jersey, 2002.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	2	3	2	1
CO2	2	-	2	3	2	1
CO3	2	-	2	3	2	1
CO4	2	-	2	3	2	1
CO5	2	-	2	3	2	1
AVG	2	-	2	3	3	1

1 - Low, 2 - Medium, 3 – High, ‘ -’ No correlation

24PE1310 WIND ENERGY CONVERSION SYSTEM **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To learn about the basic concepts of wind energy conversion system and design and control principles of Wind turbine.
- To understand the concepts of fixed speed wind energy conversion and Variable speed wind energy conversion systems.
- To model the grid integration.

UNIT I FUNDAMENTALS OF WIND ENERGY GENERATION SYSTEM 9

Components of WECS-WECS schemes-Power obtained from wind-simple momentum theory- Power coefficient - Sabinin's theory-Aerodynamics of Wind turbine-wind resources worldwide and in India, wind energy forecast.

UNIT II WIND TURBINES 9

Types and characteristics of wind turbine-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 9

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 9

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 9

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.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

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

CO2: Attain 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.

TEXT BOOKS

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, Second Edition, 2006.
3. Rai. G.D, "Non-conventional energy sources", Khanna publishers, 2010.

REFERENCE BOOKS

1. Rai. G.D," Solar energy utilization", Khanna publishers, Fifth Edition, 2008.
2. Gray, L. Johnson, "Wind energy system", prentice hall of India, 1995.
3. B.H.Khan, "Non-conventional Energy sources", Tata McGraw Hill Publishing Company, New Delhi, 2017.
4. Earnest Joshua, "Wind Power Technology", Second edition, PHI Learning Pvt. Ltd., New Delhi, 2015.
5. Johnson G. L., "Wind Energy Systems", Prentice Hall, 1994.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	3	2	3	1
CO2	3	1	3	2	3	1
CO3	3	1	3	2	3	1
CO4	3	1	3	2	3	1
CO5	3	1	3	2	3	1
AVG	2.6	1	3	2	3	1

1 - Low, 2 - Medium, 3 – High, ' -' No correlation

24PE1311 GRID INTEGRATION OF RENEWABLE ENERGY SOURCES L T P C

3 0 0 3

COURSE OBJECTIVES

- To understand the concepts and techniques in power systems and renewable energy sources.
- To analyse various equipments used for grid integration.
- To get knowledge about power quality management and grid connected and standalone PV system.

UNIT I INTRODUCTION 9

Various techniques of utilizing power from renewable energy sources, concept of nano/micro/mini grid. Need of integrating large renewable energy sources, issues related to integration of large renewable energy sources, rooftop plants.

UNIT II POWER SYSTEM EQUIPMENTS FOR GRID INTEGRATION 9

Synchronous generator: synchronization/integration to existing grid, load sharing during parallel operation, stability (swing equation and solution). Induction Generator: working principle, classification, stability due to variable speed and counter measures. Power Electronics: need of power electronic equipments in grid integration, converter, inverter, chopper, ac regulator and cycloconverters for AC/DC conversion.

UNIT III POWER QUALITY MANAGEMENT 9

THD, voltage sag, voltage swell, frequency change and its effects, network voltage management, frequency management, system protection, grid codes. Influence of WECS on system transient response - Interconnection standards and grid code requirements for integration.

UNIT IV STAND ALONE AND GRID CONNECTED PV SYSTEM 9

Solar modules – storage systems – Basics of batteries – Batteries for PV Systems – Charge Controllers – MPPT and Inverters – Power Conditioning and Regulation – protection – Types of Solar PV systems - standalone PV systems design – sizing – PV systems in buildings – design issues for central power stations – safety – Economic aspect – efficiency and performance – International PV program.

UNIT V INTEGRATION OF ALTERNATE SOURCES OF ENERGY 9

Introduction, principles of power injection: converting technologies, power flow; instantaneous active and reactive power control approach; integrating multiple renewable energy sources; DC link integration; AC link integration; HFAC link integration; islanding and interconnection.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Know about the techniques for integration of various renewable energy sources into the grid.

CO2: Analyze various equipment for grid integration.

CO3: Analyze the power quality management.

CO4: Analyze and compare stand alone and PV system.

CO5: Understand the different integration techniques.

TEXT BOOKS

1. S.P. Sukhatme, 'Solar Energy', Tata McGraw Hill, 1987. 7. Chetan Singh Solanki, 'Solar Photovoltaic Technology and Systems' – A Manual for Technicians, Trainees and Engineers, PHI, 2014.
2. Majid Jamil, M. Rizwan, D.P.Kothari," Grid integration of solar photovoltaic systems", CRC Press (Taylor & Francis group), 2017.

3. Allen J. Wood, Bruce F. Wollenberg, Gerald B," Power Generation, Operation, and Control", John Wiley & Sons, New York, 2013.

REFERENCE BOOKS

1. Stuart R.Wenham, Martin A. Green, Muriel E. Watt and Richard Corkish, 'Applied Photovoltaics', Earthscan, UK, 2007.
2. Joshua Earnest, 'Wind power technology', II Edition, PHI, 2015.
3. Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright and Mike Hughes, 'Wind generation Modelling and Control', A John Wiley and Sons, Ltd., Publication, 2009.
4. Brenden Fox, Damian Flynn and Leslie Bryans, 'Wind Power Integration Connection and system operational aspects', Published by The Institute of Engineering and Technology, London, United Kingdom, 2007.
5. Frank S. Barnes & Jonah G.Levine, 'Large Energy Storage Systems Handbook', CRC Press, 2011.

Mapping of COs and POs

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

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE1312 MICROCONTROLLER APPLICATIONS IN POWER CONVERTERS **L T P C 3 0 0 3**

COURSE OBJECTIVES

- To analyze the internal structure and operations of the 8051 and PIC16F876 microcontrollers.
- To develop proficiency in assembly language programming for generating firing and control signals with these microcontrollers.
- To explore digital controllers and power electronics, while mastering microcontroller programming using MPLAB.

UNIT I 8051 MICROCONTROLLER **9**

8051 microcontroller – Architecture – Addressing modes – I/O ports - Instruction sets – Simple assembly language programming.

UNIT II PULSE GENERATION TECHNIQUES **9**

Use of microcontrollers for pulse generation in power converters - Overview of Zero-Crossing Detectors – typical firing/gate-drive circuits – Firing/gate pulses for typical single phase and three phase power converters - PIC16F876 Micro-controller – Device overview – Pin diagrams.

UNIT III PIC16F876 MICRO CONTROLLER **9**

PIC16F876 micro-controller memory organization – Special Function Registers - I/O ports – Timers – Capture/ Compare/ PWM modules (CCP).

UNIT IV MICROCONTROLLER PROGRAMMING **9**

Analog to Digital Converter module – Instruction set – Instruction description – Introduction to PIC microcontroller programming – Oscillator selection – Reset – Interrupts – Watch dog timer.

UNIT V MICROCONTROLLER PROGRAMMING USING MPLAB **9**

Introduction to MPLAB IDE and PICSTART plus – Device Programming using MPLAB and PICSTART plus – Generation of firing / gating pulses for typical power converters.

COURSE OUTCOMES

On successful completion of this course, the student will be able to

- CO1: Understand the architecture of 8051 microcontroller.
- CO2: Understand the architecture of PIC16F876 microcontroller.
- CO3: Develop assembly language programs employing 8051 microcontroller.
- CO4: Develop assembly language programs employing 16F876 microcontroller.
- CO5: Analyze the microcontroller programming using MPLAB and develop typical programs for power converter applications.

TEXT BOOKS

1. Ramesh S. Chandra,"Microcontrollers in Power Electronics", Laxmi Publications, 2013.
2. A. K. Gupta," Microcontroller Based Projects", Prentice Hall India,2014.
3. Mohan, Undeland, and Robbins "Power Electronics: Converters, Applications, and Design,Wiley India, 2015.

REFERENCE BOOKS

1. PIC16F87X Datasheet 28/40–pin 8 bit CMOS flash Microcontrollers, Microchip technology Inc., 2001 and MPLAB IDE Quick start guide, Microchip technology Inc., 2007.
2. John B. Peatman, 'Design with PIC Microcontrollers', Prentice Hall, 2003.
3. MykePredko, 'Programming and customizing the PIC Microcontroller', Tata McGraw-Hill, 3 rd Edition, 2008.
4. M.A. Mazidi, J.G. Mazidi and R.D. McKinlay, 'The 8051 microcontroller and embedded systems', Prentice Hall India, 2nd Edition, New Delhi, 2007.

5. James K. P. S. Gupta, "Embedded Systems: A Contemporary Design Tool", Cengage Learning, 2012.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	1	1	2
CO2	2	-	2	2	1	3
CO3	1	2	3	1	1	3
CO4	2	-	2	2	1	1
CO5	3	2	2	3	1	1
AVG	1.8	2	2.4	1.8	1	2

1 - Low, 2 - Medium, 3 – High, '-' No correlation

24PE1313 FUZZY SYSTEMS L T P C
3 0 0 3

COURSE OBJECTIVES

- To understand the theory and principles of fuzzy logic and fuzzy set theory, and explore real-world applications across various domains.
- To apply fuzzy logic concepts to design and analyze fuzzy systems, including the design of components for fuzzy systems development.
- To implement fuzzy systems using relevant software tools to enhance practical understanding and application of fuzzy logic principles.

UNIT I INTRODUCTION TO FUZZY LOGIC 9

Introduction to Fuzzy Logic: Fuzzy Controllers- Preliminaries – Fuzzy sets and Basic notions – Fuzzy relation calculations – Fuzzy members – Indices of Fuzziness – comparison of Fuzzy quantities – Methods of determination of membership functions-Fundamentals of fuzzy logic systems, Fuzzy Sets, operations, relations.

UNIT II FUZZY LOGIC SYSTEM 9

Fuzzy Sets-Fuzzy Rules - Fuzzy reasoning Introduction-Basis definitions and terminology-Set, theoretic operations-MF formulation and parameterization- More on fuzzy union-Intersection and Complement- Extension principal and fuzzy relations.

UNIT III FUZZY INFERENCE SYSTEMS (FIS) 9

Fuzzy interference System- fuzzy logic,-fuzzy control - other considerations- Neuro- fuzzy Networks,- Artificial Neural Network: Supervised Learning Neural Network-Preceptron-Adaline multi-layer neural network- Fuzzy If- Then rules, fuzzy reasoning.

UNIT IV CLASSICAL SETS AND FUZZY SETS 9

Different faces of imprecision – Inexactness-Ambiguity-Undecidability-Fuzziness and certainty- Probability and fuzzy logic, Intelligent systems-Fuzzy sets and crisp sets - Intersections of Fuzzy sets-Union of Fuzzy sets.

UNIT V FUZZY LOGIC APPLICATION TO ENGINEERING 9

The complement of Fuzzy sets- Fuzzy reasoning - Linguistic variables-Fuzzy propositions-Fuzzy compositional rules of inference-Methods of decompositions- Defuzzification-Methodology of fuzzy design - Direct & Indirect methods with single and multiple experts, Adaptive fuzzy control, Rule base design using dynamic response-Fuzzy logic applications to engineering-Fuzzy decision making, Neuro-Fuzzy systems, Fuzzy Genetic Algorithms.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

- CO1: Understanding Fuzzy Logic Concepts.
- CO2: Design and Implementation of Fuzzy Systems.
- CO3: Develop fuzzy logic based controllers.
- CO4: Design fuzzy system to Integrate with Other Systems.
- CO5: CO5: Apply and analyze fuzzy sets for existing systems.

TEXT BOOKS

1. H. J. Zimmels, "Fuzzy Set Theory and its Applications", Springer India, 2008.
2. Rajasekaran, S. & Pai, G. A. V, "Fuzzy Logic and Neural Networks: A Practical", Prentice Hall India, 2005.
3. Timothy J. Ross, "Fuzzy Logic with Engineering Applications", Wiley India, 2010.

REFERENCE BOOKS

1. Zimmermann H. J., ‘Fuzzy set theory and its applications’, Allied publishers limited, Madras, Fourth Edition, 2001.
2. Klir G. J. and Folger T., ‘Fuzzy sets, uncertainty and information’, Prentice Hall of India, New Delhi, 1991.
3. EarlCox, ‘The Fuzzy Systems Handbook’, AP professional Cambridge, 1999.
4. Karray, Fakhreddine O, and Clarence W. De Silva. Soft computing and intelligent systems design: theory, tools, and applications. Pearson Education, 2004.
5. M. Negnevitsky, Artificial Intelligence, A Guide to Intelligent Systems, Pearson Publishing, 2006.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	1	1	2
CO2	2	-	2	2	1	3
CO3	1	2	3	1	1	3
CO4	2	-	2	2	1	1
CO5	3	2	2	3	1	1
AVG	1.8	2	2.4	1.8	1	2

1 - Low, 2 - Medium, 3 – High, ‘ -’ No correlation

24PE1314 PYTHON PROGRAMMING FOR MACHINE LEARNING L T P C
3 0 0 3

COURSE OBJECTIVES

- To understand fundamental programming principles, including data types, variables, conditionals, loops, recursion, and function calls.
- To Gain proficiency in basic data structures such as lists and dictionaries, and develop skills in manipulating text files and images.
- To familiarize students with machine learning concepts and techniques, enabling them to effectively approach and implement machine learning problems using Python.

UNIT I INTRODUCTION TO MACHINE LEARNING AND PYTHON 9

Introduction to Machine Learning: Significance, Advantage and Applications – Categories of Machine Learning – Basic Steps in Machine Learning: Raw Data Collection, Pre-processing, 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 9

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

UNIT III IMPLEMENTATION OF MACHINE LEARNING USING PYTHON 9

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 – Python Application of Linear Regression and Polynomial Regression using SciPy – Interpolation, Overfitting and Underfitting concepts & examples using SciPy.

UNIT IV CLASSIFICATION AND CLUSTERING CONCEPTS OF ML 9

Introduction to ML Concepts of Clustering and Classification – Types of Classification Algorithms – Support Vector Machines (SVM) - Decision Tree - Random Forest – Introduction to ML using scikitlearn – 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 9

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 – on-Board AI – ML Edge Devices: Arduino Nano BLE Sense, Google Edge TPU and Intel Movidius.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

- CO1: Develop skill in system administration and network programming by learning Python.
- CO2: Relate to use Python's highly powerful processing capabilities for primitives modeling etc.
- CO3: Improved Employability and entrepreneurship capacity due to knowledge up gradation on recent trends in embedded systems design.
- CO4: Demonstrating understanding in concepts of Machine Learning and its implementation using Python.
- CO5: Apply and analyze python for existing systems.

TEXT BOOKS

1. Sebastian Raschka & Vahid Mirjalili, "Python Machine Learning", Packet Publishing, 2019.
2. Mark E. Fenner, "Machine Learning with Python for Everyone", Pearson, 2018.
3. Wes McKinney, "Python for Data Analysis", O'Reilly Media publication, 2018.

REFERENCE BOOKS

1. Mark Lutz, "Learning Python, Powerful OOPs", O'reilly, 2011.
2. Zelle, John "M. Python Programming: An Introduction to Computer Science", Franklin Beedle & Associates, 2003.

3. Andreas C. Müller, Sarah Guido, “Introduction to Machine Learning with Python”, O'Reilly, 2016.
4. Sebastian Raschka, Vahid Mirjalili, “Python Machine Learning - Third Edition”, Packet, December 2019.
5. Paolo Perrotta, “Programming Machine Learning" Pragmatic Bookshelf, 2020.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	1	1	2
CO2	2	-	2	2	1	3
CO3	1	2	3	1	1	3
CO4	2	-	2	2	1	1
CO5	3	2	2	3	1	1
AVG	1.8	2	2.4	1.8	5	5

1 - Low, 2 - Medium, 3 – High, ‘ -’ No correlation

24PE1315 OPTIMIZATION TECHNIQUES L T P C
3 0 0 3

COURSE OBJECTIVES

- To understand and analyze intermediate languages and program structures.
- To learn and apply optimization techniques.
- To explore inter procedural optimizations and improve resource utilization.

UNIT I INTRODUCTION 9

Definition, Classification of optimization problems, Classical Optimization Techniques, Single and Multiple Optimization with and without inequality constraints.

UNIT II LINEAR PROGRAMMING 9

Simplex method of solving LPP, revised simplex method, duality, Constrained optimization, Theorems and procedure, Linear programming, mathematical model, solution technique, duality.

UNIT III NON LINEAR PROGRAMMING 9

Steepest descent method, conjugates gradient method, Newton’s Method, Sequential quadratic programming, Penalty function method, augmented Lagrange multiplier method.

UNIT IV DYNAMIC PROGRAMMING 9

Multistage decision processes, concept of sub-optimization and principle of optimality, Recursive relations, Integer Linear programming, Branch and bound algorithm.

UNIT V GENETIC ALGORITHM **9**

Introduction to genetic Algorithm, working principle, coding of variables, fitness function, GA operators; Similarities and differences between Gas and traditional methods; Unconstrained and constrained optimization using genetic Algorithm, real coded gas, Advanced Gas, global optimization using GA, Applications to power system.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Explore various classifications of optimization problems and techniques.

CO2: Acquire knowledge of linear programming concepts.

CO3: Understand the application of non-linear programming within optimization techniques.

CO4: Grasp the fundamental concepts of dynamic programming.

CO5: Learn about genetic algorithms and their application in power system optimization.

TEXT BOOKS

1. S.S. Rao, "Optimization Theory and Applications", Wiley Eastern publication, Second edition, 2009.
2. Singiresu S. Rao, "Engineering Optimization: Theory and Practice", Wiley publications, Fifth edition,2019.
3. Jorge Nocedal and Stephen J. Wright, "Numerical Optimization", Springer, Second edition, 2006.

REFERENCE BOOKS

1. S.S. Rao, "Engineering Optimization – Theory and Practice", John Wiley & Sons, Inc., 2009.
2. Hamdy A. Taha, Operations Research: An Introduction, 10th Edition, Pearson, 2016.
3. David G. Luenberger, "Introduction to Linear and Nonlinear Programming", Addison- Wesley, 1973.
4. E. Polak, "Computational methods in Optimization", Academic Press, 1971.
5. Pierre D.A., "Optimization Theory with Applications", Wiley Publications, 1969.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	-	3	-	-	1
CO2	3	-	3	-	-	1
CO3	3	-	3	-	-	1
CO4	3	-	3	-	-	1
CO5	3	-	3	-	3	1
AVG	3	-	3	-	3	1

1 - Low, 2 - Medium, 3 – High, ‘ -’ No correlation

24PE1316 IoT FOR SMART SYSTEMS L T P C
3 0 0 3

COURSE OBJECTIVES

- To study Internet of Things (IoT) technologies and their real-time applications.
- To introduce the necessary infrastructure, accessories, and communication techniques for IoT.
- To provide insights on embedded processors, sensors, and IoT platforms.

UNIT I INTRODUCTION TO INTERNET OF THINGS 9

Introduction to IoT-Sensing- Actuation-Basics of Networking-Communication Protocols-Sensor Networks- Machine-to-Machine Communications -Interoperability in IoT-Technology drivers - Typical IoT applications, Trends and implications.

UNIT II INTRODUCTION TO ARDUINO 9

Introduction to Arduino Programming-types of sensors and actutators- Integration of Sensors and Actuators with Arduino- Introduction to Raspberry Pi – programming using raspberrypi-Implementation of IoT with Raspberry Pi- Interfacing sensors with microcontrollers Arduino, Raspberry Pi)- Integration of Sensors and Actuators with Raspberry Pi- comparison of Arduino and Raspberry Pi.

UNIT III IoT CLOUD COMPUTATION AND APPLICATIONS 9

Introduction to SDN-SDN for IoT-Data Handling and Analytics-Cloud Computing - Sensor Cloud-Fog Computing-Role of ML and AI in IoT-Data analysis techniques (statistical analysis, machine learning)- Cloud platforms for IoT (AWS IoT, Azure IoT, Google Cloud IoT).

UNIT IV PROTOCOLS AND WIRELESS TECHNOLOGIES FOR IOT 9

PROTOCOLS: RFID, GSM, GPRS- Wireless technologies for IoT: WiFi (IEEE 802.11)-Bluetooth- Smart ZigBee-Smart UWB (IEEE 802.15.4)- LoWPAN- Proprietary systems and Recent trends- Embedded processors for IoT: Introduction to Python programming -Building IOT with RASPERRY PI and Arduino.

UNIT V CASE STUDIES **9**

Smart Cities- Smart Homes- Connected Vehicles- Smart Grid- Agriculture- Healthcare- Activity Monitoring-Industrial IoT- IoT Defense.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Understand and evaluate the characteristics of smart home appliances.

CO2: Understand the behaviour of IoT and their applications.

CO3: Manage smart communication systems with multiple sensors and protocols.

CO4: Design and simulate smart homes and smart cities with IoTs and cloud computing.

CO5: Design embedded processors using sensors and IoT.

TEXT BOOKS

1. Peter Waher, 'Learning Internet of Things', Packet Publishing, 2015 3. Editors Ovidiu Vermesan.
2. Peter Friess, 'Internet of Things – From Research and Innovation to Market Deployment', River Publishers, 2014.
3. Internet of Things - A Hands-on Approach, Arshdeep Bahga and Vijay Madisetti, Universities Press, 2015, ISBN: 9788173719547.

REFERENCE BOOKS

1. Getting Started with Raspberry Pi, Matt Richardson & Shawn Wallace, O'Reilly (SPD), 2014, ISBN: 9789350239759.
2. Raspberry Pi Cookbook, Software and Hardware Problems and solutions, Simon Monk, O'Reilly (SPD), 2016, ISBN 7989352133895.
3. Pethuru Raj and Anupama C. Raman, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press publications, 2017.
4. Adrian McEwen and Hakim Cassimally, “Designing the Internet of Things", Wiley publications, 2013.
5. Simone Cirani, Gianluigi Ferrari, Marco Picone, Luca Veltri "Internet of Things: Architectures, Protocols and Standards", Wiley publications, 2018.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	1	1	2
CO2	2	-	2	2	1	3
CO3	1	2	3	1	1	3
CO4	2	-	2	2	1	1
CO5	-	-	-	-	-	-
AVG	1.5	2	2.5	1.5	1	2.25

1 - Low, 2 - Medium, 3 – High, ‘ -’ No correlation

24PE1317 INTELLIGENT CONTROL

L	T	P	C
3	0	0	3

COURSE OBJECTIVES

- To understand and implement intelligent control strategies.
- To design, develop, and evaluate controllers.
- To analyze and optimize intelligent control systems.

UNIT I NEURAL NETWORKS **9**

Introduction – biological neurons – Artificial neurons – activation function – learning rules – feed forward networks – supervised learning – perception networks – adaline – madaline – back propagation networks – learning factors – linear separability – Hopfield network – discrete Hopfield networks.

UNIT II ARCHITECTURE **9**

Types: Recurrent auto association memory, bidirectional associative memory– temporal associative memory - Boltzmann machine Hamming networks Self organizing feature maps adaptive resonance theory network Instar Outsar model counter propagation network – radial basis function networks.

UNIT III FUZZY SETS AND SYSTEMS **9**

Crisp set – vaguness – uncertainty and imprecision – fuzzy set – fuzzy operation- properties crisp versus fuzzy relations fuzzy relation cardinality operations, properties – fuzzy Cartesian composition non interactive fuzzy sets tolerance equivalence relations – fuzzy ordering relations – fuzzy morphism – composition of fuzzy relations.

UNIT IV FUZZY LOGIC CONTROLLER **9**

Fuzzy to crisp conversion – Lambda cuts for fuzzy sets and relations – definition methods – structure of fuzzy logic controller – database –rule Base Inference engine.

UNIT V APPLICATION AND DESIGN **9**

Applications of Neural network and Fuzzy system for single phase fully controlled converter, single phase ac voltage controller, DC Drive and AC Drive, Designing of controllers using Simulation Software Fuzzy Logic Toolbox Modeling of DC Machines using Simulation Software and Simulink Toolbox.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Understand Intelligent Systems Concepts.

CO2: Apply AI Techniques in various applications.

CO3: Design and Development of Intelligent Controllers.

CO4: Integration of Intelligent Systems in Practical Applications.

CO5: Apply Neural Network Techniques in various applications.

TEXT BOOKS

1. "Intelligent Control Systems with an Introduction to System of Systems Engineering" by H. K. Khalil, second edition,1992.
2. "Introduction to Intelligent Control: Concepts, Methods, and Applications" by S. K. Gupta and K. V. A. V. Rao, Third Edition, 2002.
3. "Neural Networks for Control" by W. S. Levine (Editor), Foruth Edition,2000.

REFERENCE BOOKS

1. Lawrence Fausatt, "Fundamentals of neural networks", Prentice Hall of India, New Delhi, 1994.
2. Timothy J. Ross, "Fuzzy Logic with Engineering Applications", McGraw Hill Interna tional Edition, USA, 1997.
3. Bart kosko, "Neural Networks and Fuzzy Systems", Prentice Hall of India, New Delhi, 1994.
4. Mo Jamshidi, "Intelligent Control Systems with an Introduction to System of Systems CRC Press Publication, 2009.
5. Guoqing Zhang, "Fuzzy Control: Theory and Applications", Springer Publication, 2018.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	2	3	1	1	2
CO2	2	-	2	2	1	3
CO3	1	2	3	1	1	3
CO4	2	-	2	2	1	1
CO5	2	-	2	2	1	1
AVG	1.6	2	2.4	1.6	1	2

1 - Low, 2 - Medium, 3 – High, ‘ -’ No correlation

24PE1318	**EMBEDDED SYSTEMS DESIGN FOR POWER ELECTRONIC APPLICATIONS**	**L T P C** **3 0 0 3**

COURSE OBJECTIVES

- To impart a comprehensive understanding of control concepts and strategies for power electronics devices and electrical drives, emphasizing the integration of embedded systems in these applications.
- To explore and analyze various embedded system-based control strategies for electrical drives, focusing on their effectiveness and practicality in real-world scenarios.
- To introduce and discuss optimization and machine learning techniques, as well as high-performance computing methodologies, that enhance the performance and efficiency of electrical drives.

UNIT I INTRODUCTION TO EMBEDDED COMPUTING **9**

Embedded systems Overview, Characteristics of embedded computing applications, Design Challenges, Common Design Metrics, Processor Technology, IC Technology, Trade-offs. The Process of Embedded System Development: The development process, Requirements, Specification, Architecture Design, Designing Hardware and Software components, system Integration and testing.

UNIT II HARDWARE PLATFORMS **9**

Types of Hardware Platforms, Single board computers, PC Add-oncards, custom-built hardware platforms, ARM Processor, CPU performance, CPU power consumption, Bus-based computer systems, Memory devices, I/O devices, component interfacing, Designing with microprocessors, system level performance analysis.

UNIT III PROGRAM DESIGN AND ANALYSIS **9**

components for Embedded programs, Models of programs, Assembly, Linking, and loading, basic compilation techniques, software performance optimization, program level energy and Power analysis, Program validation and Testing.

UNIT IV REAL-TIME OPERATING SYSTEMS **9**

Architecture of the kernel, Tasks and Task Scheduler, Scheduling algorithms, Interrupt Service Routines, Semaphores, Mutex, Mailboxes, Message queues, Event Registers, Pipes, Signals, Timers, Memory management, Priority Inversion problem. Overview of off-the shelf operating systems.

UNIT V EMBEDDED SYSTEMS FOR POWER ELECTRONICS **9**

Power Devices: Power Diodes, BJT, Thyristor, Power MOSFET, IGBT- Line Commutated Converters: Three phase semi controlled & fully controlled converter, Dual converters, Voltage/Current Source Inverters: Voltage source inverters single/multiple-pulse/ SPWM/ modified SPWM methods- multilevel converters.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

- CO1: Apply embedded systems in power electronics.
- CO2: Understand the System Modeling and Simulation.
- CO3: Apply Embedded System Programming in power electronics.
- CO4: Analyze the performance of embedded systems in power electronic applications.
- CO5: Apply control theory concepts to design effective control algorithms for various power electronic converters and drives.

TEXT BOOKS

1. Vedam Subramanyam, “Electric Drives – Concepts and Applications”, Tata McGraw- Hill publishing company Ltd., New Delhi, 2002, Second Edition.
2. K.Venkataratnam, Special Electrical Machines, Universities Press, 2014, First Edition.

3. Steve Furber, 'ARM system on chip architecture', Addision Wesley, Second Edition, 2015.

REFERENCE BOOKS

1. Ron Sass and Anderew G.Schmidt, "Embedded System design with platform FPGAs: Principles and Practices", Elsevier, 2010, First Edition.
2. Tim Wescott , Applied Control Theory for Embedded Systems , Elsevier, 2006, First Edition.
3. David E-Simon: An Embedded software Primer, Pearson Education, 2007. 3.
4. K.V.K.K. Prasad Real-Time Systems: Concepts Design and Programming, Dreamtech Press, 2005.
5. R.Krishnan, "Electric Motor Drives – Modeling, Analysis and Control", Prentice-Hall of India Pvt. Ltd., New Delhi, 2010, First Edition.
6. James K. Peckol, "Embedded Systems: A Contemporary Design Tool", Wiley Publication, 2016.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	3	1	1	2
CO2	2	-	2	2	1	3
CO3	1	2	3	1	1	3
CO4	2	-	2	2	1	1
CO5	3	2	2	3	1	1
AVG	1.8	2	2.4	1.8	1	2

1 - Low, 2 - Medium, 3 – High, '-' No correlation

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